



# **Secure Interoperable Open Smart Grid Demonstration Project**

## **Final Technical Report**

**Award Number: DE-OE0000197**

**Project Type: Regional Demonstration**

**Principal Investigator: Thomas Magee, General Manager,  
Smart Grid Implementation Group**

**Recipient:**

**Consolidated Edison Company of New York, Inc.**

Consolidated Edison Company of New York, Inc.  
Taxpayer ID Number: 13-5009340  
Organizational DUNS: 00-698-2359  
4 Irving Place  
New York, NY 10003

December 28, 2014 - Revised

## Disclaimer

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government or Consolidated Edison Company of New York, Inc., its affiliates or employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by Consolidated Edison Company of New York, Inc., the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of Consolidated Edison Company of New York, Inc., the United States Government or any agency thereof.

## Acknowledgment

This material is based upon work supported by the Department of Energy under Award Number DE-OE-0000197.

## Table of Contents

|                                                       |           |
|-------------------------------------------------------|-----------|
| <b>1. Executive Summary .....</b>                     | <b>1</b>  |
| <b>2. Project Overview .....</b>                      | <b>6</b>  |
| 2.1 Project Context .....                             | 6         |
| 2.2 Objectives .....                                  | 10        |
| 2.3 Project Team .....                                | 11        |
| 2.4 Sub-projects .....                                | 15        |
| 2.5 Demonstration Timeline .....                      | 16        |
| <b>3. Technical Approach.....</b>                     | <b>17</b> |
| 3.1 Secure Systems Integration.....                   | 18        |
| 3.2 DR and DER Connectivity .....                     | 19        |
| 3.3 Optimization and Control .....                    | 20        |
| <b>4. Methodology.....</b>                            | <b>22</b> |
| 4-A. Secure Systems Integration .....                 | 22        |
| 4-A.1. DERMS .....                                    | 24        |
| 4-A.2. DRMS .....                                     | 27        |
| 4-A.3. ISM and Control Algorithms.....                | 28        |
| 4-A.4. Wireless Communication and MDM .....           | 32        |
| 4-B. DR and DG Connectivity .....                     | 33        |
| 4-B.1. DR and BMS Integration .....                   | 33        |
| 4-B.2. SSGUs.....                                     | 35        |
| 4-B.3. DRCC .....                                     | 37        |
| 4-B.4. PV, Battery Storage, and BMS Integration ..... | 38        |
| 4-B.5. Streamlined PV Design and Build.....           | 39        |
| 4-C. Optimization and Control .....                   | 40        |
| 4-C.1. SGDM .....                                     | 40        |
| 4-C.2. Energy Optimizer Controller and ISM.....       | 42        |
| 4-C.3. DTC and LSOC.....                              | 43        |
| 4-C.4. IDSM Potential Model .....                     | 43        |
| <b>5. Conclusions.....</b>                            | <b>45</b> |
| 5.1 Major Accomplishments .....                       | 45        |
| 5.2 Project Benefits .....                            | 51        |
| 5.3 Key Takeaways .....                               | 53        |
| 5.3.1 Overall Project .....                           | 53        |
| 5.3.2 Sub-project Specific.....                       | 55        |
| 5.4 Implications for the Future.....                  | 58        |
| 5.4.1 Future Commercialization and Scalability .....  | 59        |



5.4.2 Alignment with New York State REV Process..... 60

**Appendix A. Final Technical Reports .....A-1**

## List of Figures and Tables

### *Figures:*

|                                                                                 |    |
|---------------------------------------------------------------------------------|----|
| Figure 1-1. SGDP System Overview Diagram .....                                  | 3  |
| Figure 2-1. Manhattan Skyline: Con Edison Service Territory .....               | 6  |
| Figure 2-2. Con Edison Service Territory within New York State .....            | 7  |
| Figure 2-3. Graphical Depiction of Con Edison Distribution System.....          | 8  |
| Figure 2-4. Projections for Con Edison DG Installed Capacity .....              | 9  |
| Figure 2-5 Annual Load Duration Curve for Con Edison (2013) .....               | 10 |
| Figure 3-1. SGDP System Overview Diagram .....                                  | 18 |
| Figure 4-1. The SGAM.....                                                       | 23 |
| Figure 4-2. DERMS Architecture Diagram.....                                     | 25 |
| Figure 4-3. Visualization of Grid-Connected DR Resources.....                   | 26 |
| Figure 4-4. Diagram of the DRMS System .....                                    | 27 |
| Figure 4-5. O&R ISM Architecture Diagram.....                                   | 30 |
| Figure 4-6. Diagram of Viridity's VPower Implementation .....                   | 33 |
| Figure 4-7. Diagram of an EDN .....                                             | 36 |
| Figure 4-8. Diagram of DRCC Configuration.....                                  | 38 |
| Figure 4-9. PV Installation on Con Edison's Headquarters .....                  | 39 |
| Figure 4-10. Clip-on Sensor with Three-phase Disturbance Monitor Traces .....   | 40 |
| Figure 4-11. Diagram of the Energy Optimizer Controller Built by CALM.....      | 42 |
| Figure 5-1. Increased Visibility of DR and DG through Systems Integration ..... | 46 |
| Figure 5-2. Commercialization of Viridity Energy DR Resources .....             | 59 |

### *Tables:*

|                                                                         |    |
|-------------------------------------------------------------------------|----|
| Table 1-1. SGDP Sub-project and Project Partner Overview .....          | 2  |
| Table 2-1. Con Edison Service Territory Characteristics .....           | 7  |
| Table 2-2. Sub-project and Project Partner Overview .....               | 15 |
| Table 2-3. SGDP Demonstrations .....                                    | 16 |
| Table 4-1. DR Resources Integrated Using Viridity's System.....         | 35 |
| Table 5-1. Completion and Demonstration of the Project Objectives.....  | 48 |
| Table 5-2. Summary of Project Benefits .....                            | 52 |
| Table 5-3. Potential Enhancements to Con Edison's DR Capabilities ..... | 55 |
| Table 5-4. Challenges and Lessons Learned by Sub-project .....          | 56 |

## List of Abbreviations

| <u>Abbreviation</u> | <u>Description</u>                                                 |
|---------------------|--------------------------------------------------------------------|
| AABE .....          | American Association for Blacks in Engineering                     |
| AC .....            | Alternating Current                                                |
| AHJ .....           | Authority Having Jurisdiction                                      |
| AMI .....           | Advanced Metering Infrastructure                                   |
| ARRA .....          | American Recovery and Reinvestment Act                             |
| ASC .....           | Adaptive Stochastic Controller                                     |
| BAT .....           | Brooklyn Army Terminal                                             |
| BAU .....           | Business as Usual                                                  |
| BMS .....           | Building Management System                                         |
| C&I .....           | Commercial and Industrial                                          |
| CALM .....          | CALM Energy, Inc. (also, Computer Aided Lean Management)           |
| CBL .....           | Customer Baseline Load                                             |
| CCLS .....          | Center for Computational Learning Systems (at Columbia University) |
| CHP .....           | Combined Heat and Power                                            |
| CIM .....           | Common Information Model                                           |
| Con Edison .....    | Consolidated Edison Company of New York                            |
| DB .....            | Database                                                           |
| DC .....            | Direct Current                                                     |
| DCC .....           | Distribution Control Center                                        |
| DER .....           | Distributed Energy Resource                                        |
| DERMS .....         | Distributed Energy Resource Management System                      |
| DEW .....           | Distributed Engineering Workstation                                |
| DG .....            | Distributed Generation                                             |
| DO .....            | Distribution Control Center Operators                              |
| DOE .....           | Department of Energy                                               |
| DR .....            | Demand Response                                                    |
| DRCC .....          | Demand Response Command Center                                     |
| DRMS .....          | Demand Response Management System                                  |
| DSCADA .....        | Distribution Supervisory Control and Data Acquisition              |
| DSM .....           | Demand-Side Management                                             |



|             |                                                   |
|-------------|---------------------------------------------------|
| DSP.....    | Distributed System Platform                       |
| DTC.....    | Dynamic Treatment Controller                      |
| E3.....     | Energy and Environmental Economics                |
| ECC.....    | Energy Control Center                             |
| EDD.....    | Electrical Distribution Design                    |
| EDN.....    | Energy Delivery Network                           |
| EE.....     | Energy Efficiency                                 |
| EEL.....    | Edison Electric Institute                         |
| EUCI.....   | Electric Utility Consultants, Inc.                |
| EV.....     | Electric Vehicle                                  |
| GCN.....    | Green Charge Networks                             |
| GHG.....    | Greenhouse Gas                                    |
| HAN.....    | Home Area Network                                 |
| HTM.....    | High-Tension Monitoring                           |
| HVAC.....   | Heating, Ventilating, and Air Conditioning        |
| ICCP.....   | Inter-Control Center Communications Protocol      |
| IDSM.....   | Integrated Demand-Side Management                 |
| IEC.....    | International Electrotechnical Commission         |
| IEE.....    | Institute for Electric Efficiency                 |
| IEEE.....   | Institute of Electrical and Electronics Engineers |
| ISM.....    | Integrated Systems Model                          |
| ISO.....    | Independent System Operator                       |
| IT.....     | Information Technology                            |
| kW.....     | Kilowatt                                          |
| kWh.....    | Kilowatt-hour                                     |
| LIC.....    | Long Island City                                  |
| LSOC.....   | Load Source Optimization Controller               |
| MACRUC..... | Mid-Atlantic Conference for Regulatory Utilities  |
| MDM.....    | Meter Data Management                             |
| MDMS.....   | Meter Data Management System                      |
| MPLS.....   | Multiprotocol Label Switching                     |
| MW.....     | Megawatts                                         |
| NIST.....   | National Institute of Standards and Technology    |
| NOC.....    | Network Operations Center                         |



|              |                                                   |
|--------------|---------------------------------------------------|
| NYC .....    | New York City                                     |
| NYCEDC ..... | New York City Economic Development Corporation    |
| NYISO .....  | New York Independent System Operator              |
| NYPSC .....  | New York Public Service Commission                |
| O&R .....    | Orange and Rockland Utilities, Inc.               |
| OMS .....    | Outage Management System                          |
| PACE-D ..... | Partnership to Advance Clean Energy – Development |
| PMU .....    | Phasor Measurement Unit                           |
| PV .....     | Photovoltaic                                      |
| RDSI .....   | Renewable and Distributed Systems Integration     |
| REV .....    | Reforming Energy Vision                           |
| RFI .....    | Request for Information                           |
| RFP .....    | Request for Proposal                              |
| RTO .....    | Regional Transmission Organization                |
| SG .....     | Smart Grid                                        |
| SGAM .....   | Smart Grid Architecture Model                     |
| SGDM .....   | Smart Grid Disturbance Monitor                    |
| SGDP .....   | Smart Grid Demonstration Project                  |
| SGIG .....   | Smart Grid Investment Grant                       |
| SME .....    | Subject Matter Expert                             |
| SSGU .....   | Smart Storage and Generation Unit                 |
| T&D .....    | Transmission and Distribution                     |
| TDSM .....   | Targeted Demand-Side Management                   |
| TIBCO .....  | TIBCO Software                                    |
| TIS .....    | Target Information Sensor                         |
| UPS .....    | United Parcel Service of North America, Inc.      |
| US .....     | United States                                     |
| var .....    | Volt-amps reactive                                |
| VirG .....   | Virtual Generator                                 |
| VVC .....    | Volt-var control                                  |
| XML .....    | Extensible Markup Language                        |
| YMCA .....   | Young Men’s Christian Association                 |

## 1. Executive Summary

The Consolidated Edison, Inc., of New York (Con Edison) Secure Interoperable Open Smart Grid Demonstration Project (SGDP), sponsored by the United States (US) Department of Energy (DOE), demonstrated that the reliability, efficiency, and flexibility of the grid can be improved through a combination of enhanced monitoring and control capabilities using systems and resources that interoperate within a secure services framework. The project demonstrated the capability to shift, balance, and reduce load where and when needed in response to system contingencies or emergencies by leveraging controllable field assets. The range of field assets includes curtailable customer loads, distributed generation (DG), battery storage, electric vehicle (EV) charging stations, building management systems (BMS), home area networks (HANs), high-voltage monitoring, and advanced metering infrastructure (AMI). The SGDP enables the seamless integration and control of these field assets through a common, cyber-secure, interoperable control platform, which integrates a number of existing legacy control and data systems, as well as new smart grid (SG) systems and applications. By integrating advanced technologies for monitoring and control, the SGDP helps target and reduce peak load growth, improves the reliability and efficiency of Con Edison's grid, and increases the ability to accommodate the growing use of distributed resources.

Con Edison is dedicated to lowering costs, improving reliability and customer service, and reducing its impact on the environment for its customers. These objectives also align with the policy objectives of New York State as a whole. To help meet these objectives, Con Edison's long-term vision for the distribution grid relies on the successful integration and control of a growing penetration of distributed resources, including demand response (DR) resources, battery storage units, and DG. For example, Con Edison is expecting significant long-term growth of DG. The SGDP enables the efficient, flexible integration of these disparate resources and lays the architectural foundations for future scalability.

Con Edison assembled an SGDP team of more than 16 different project partners, including technology vendors, and participating organizations, and the Con Edison team provided overall guidance and project management. Project team members are listed in Table 1-1.

**Table 1-1. SGDP Sub-project and Project Partner Overview**

|                               | Sub-project Description                                                                | Project Partner                                                                  |
|-------------------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| A. Secure Systems Integration | A.1. Distributed Energy Resource (DER) Management System (DERMS)                       | Siemens and TIBCO                                                                |
|                               | A.2. Demand Response Management System (DRMS)                                          | Alstom Grid (Alstom)                                                             |
|                               | A.3. Integrated Systems Model (ISM) and Control Algorithms                             | Orange & Rockland Utilities, Inc. (O&R) and Electrical Distribution Design (EDD) |
|                               | A.4. Wireless Communication and Meter Data Management (MDM)                            | Digi and Ambient                                                                 |
| B. DR and DER Connectivity    | B.1. DR and BMS Integration                                                            | Viridity                                                                         |
|                               | B.2. Smart Storage and Generation Units (SSGU)                                         | Green Charge Networks (GCN)                                                      |
|                               | B.3. Demand Response Command Center (DRCC)                                             | Innoventive                                                                      |
|                               | B.4. Photovoltaic (PV), Battery Storage, and BMS Integration                           | New York City (NYC) Economic Development Corporation (NYCEDC)                    |
|                               | B.5. Streamlined PV Design and Build                                                   | Gehrlicher Solar                                                                 |
| C. Optimization and Control   | C.1. Smart Grid Disturbance Monitor (SGDM)                                             | Softstuf                                                                         |
|                               | C.2. Energy Optimizer Controller                                                       | CALM Energy, Inc. (CALM)                                                         |
|                               | C.3. Dynamic Treatment Controller (DTC) and Load-Source Optimization Controller (LSOC) | Columbia University                                                              |
|                               | C.4. Integrated Demand-Side Management (IDSM) Potential Model                          | Energy & Environmental Economics (E3) and Navigant Consulting, Inc. (Navigant)   |

Together, the project team executed 13 individual sub-projects, which were implemented across Con Edison's and O&R's<sup>1</sup> service territories. Conceptually, these sub-projects can be organized into three broad categories, also shown Table 1-1 and described below.

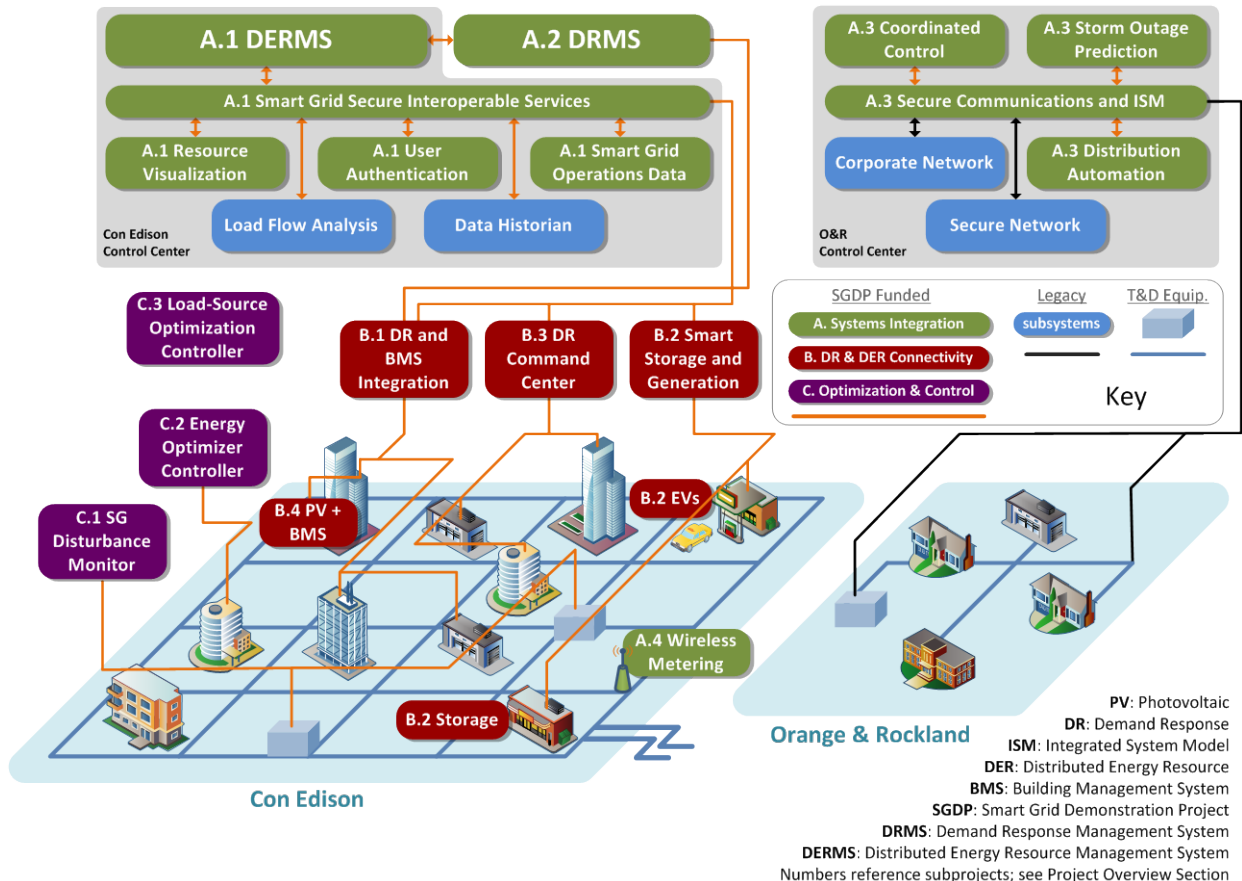
- A. **Secure Systems Integration:** Includes the DRMS, DERMS, secure communications for distribution automation, and wireless metering deployed through this demonstration project, which are the core systems integration components supporting the project's new SG functionality, legacy systems, and interconnectivity to external resources.
- B. **DR and DER Connectivity:** Includes the connection of DR, storage, and DG resources to enhance efficiency, reliability, and economic savings for the utility and end users alike.

<sup>1</sup> O&R is a wholly owned subsidiary of Con Edison.

- C. **Optimization and Control:** Includes the optimization and control of these interconnected systems and resources.

Figure 1-1 provides a high-level illustration of how these components fit together to achieve an integrated system.

**Figure 1-1. SGDP System Overview Diagram**



*Note: Con Edison also completed an IDSMP Potential Model as part of the SGDP.*

Over the course of six demonstrations to the DOE, the SGDP successfully accomplished targeted load reductions, grid management, and grid reliability improvements through the secure integration of the enhanced monitoring and control capabilities and intelligent analysis tools. As a result of the SGDP, Con Edison is now capable of monitoring and communicating with a wide range of DR and DER assets in near real-time from a common, cyber-secure, interoperable platform. Accomplishment of all project objectives was demonstrated through the six iterative and cumulative demonstrations performed over the course of the SGDP.

A significant outcome of the SGDP was development of the DERMS visualization platform, which provides DOs with a wide-area situational view of the interconnected SG DRs and their availability to relieve specific grid load constraints. Other notable project accomplishments include the following:



- Deployment of approximately 500 Digi and 15 Ambient nodes to enhance communications between difficult-to-access meters and Con Edison's MV-90 and Meter Data Management Systems (MDMS).
- Development and implementation of protocols for integrating project-related resources and applications in an industry standard and cyber-secure manner

Over the course of the SGDP, the project team identified and leveraged opportunities to expand the original scope in ways which enhanced the overall outcome, such as:

- Viridity Energy expanded their scope from the integration of five buildings to 23 buildings, due to their early success in the project.
- The DRMS sub-project, provided by Alstom, was added in order to provide DR program management and customer visibility.
- Con Edison added an IDSM Potential Study, which will serve as a comprehensive platform to expand Con Edison's TDSM program, improve capital decision-making, support ongoing efforts to further build DR capability, and establish a set of new programs to maximize both system and customer benefits by network, segment, and building type.
- The wireless communications and MDM project was added as an essential element for success of DRMS project.
- Additional GCN battery storage units were added at Walgreens and United Parcel Service (UPS).
- A 40-kilowatt solar panel installation was added at 4 Irving Place which was not part of the original scope.
- DR and DG resources were mapped and integrated with the DERMS system across the entire Con Edison service area.

While the SGDP started on a limited portion of Con Edison's service area (two boroughs and two networks), the platform is extremely flexible and scalable, and is currently being expanded to encompass the entire Con Edison service area (five boroughs, Westchester County and 64 networks), which will enable the growth expected for DER and DR across Con Edison's territory.

In addition to enabling the increased integration of DR and DER, the results of the SGDP also allow Con Edison to more effectively and efficiently respond to regulatory directives and initiatives such as the proceeding announced by the New York Public Service Commission (NYPSC) in April 2014, known as "Reforming the Energy Vision" (REV).<sup>2</sup> REV will reform New York State's energy industry and regulatory practices to meet the future challenges related to more efficient use of energy, deeper penetration of renewable energy resources (e.g., wind and solar), and wider deployment of DERs (e.g., micro-grids, on-site power supplies, and storage). Overall, the approach and results of the SGDP are consistent with the NYPSC's and Con Edison's shared objectives for increasing the reliability of Con

---

<sup>2</sup> Information on REV can be found at <http://www3.dps.ny.gov/W/PSCWeb.nsf/All/26BE8A93967E604785257CC40066B91A?OpenDocument>



Edison's distribution services at improved costs, while leveraging DERs to complement and even offset the need for additional capacity from large, centralized generation plants.

## 2. Project Overview

The Con Edison Secure Interoperable Open SGDP, sponsored by the US DOE, has demonstrated that the reliability, efficiency, and flexibility of the grid can be improved through a combination of enhanced monitoring and control capabilities using systems and resources that interoperate within a secure services framework. The project has demonstrated the capability to shift, balance, and reduce load where and when needed in response to system contingencies or emergencies by leveraging controllable field assets. The range of field assets includes curtailable customer loads, DG, battery storage, EV charging stations, BMS, HANs, high-voltage monitoring, and AMI. The SGDP enables the seamless integration and control of these field assets through a common, cyber secure, interoperable control platform, which integrates a number of existing legacy control and data systems, as well as new SG systems and applications. By integrating advanced technologies for monitoring and control, the SGDP helps target and reduce peak load growth, improves the reliability and efficiency of Con Edison's grid, and increases the ability to accommodate the growing use of distributed resources.

### 2.1 Project Context

Con Edison owns and operates one of the most complex, yet most reliable, electric delivery systems in the world. Its service territory covers NYC and surrounding areas, including some of the densest electric distribution networks in North America. Figure 2-1 shows a section of the Manhattan skyline, a widely recognized portion of the Con Edison service area.

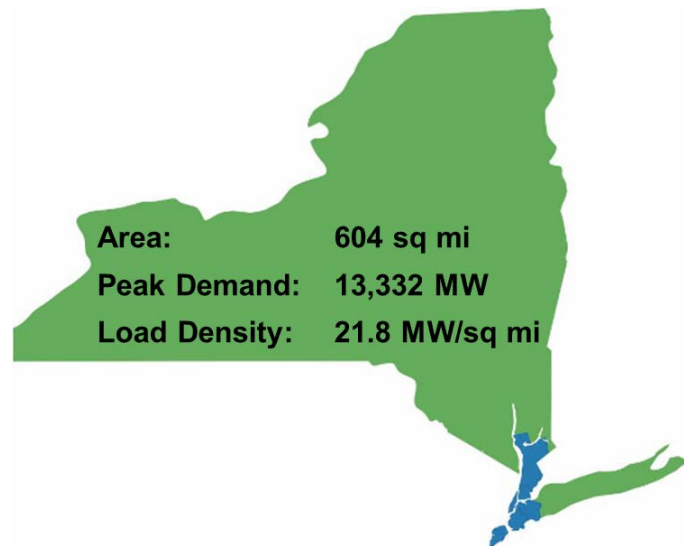
**Figure 2-1. Manhattan Skyline: Con Edison Service Territory**



The service area covers over 600 square miles at the southeast corner of New York State, as shown in Figure 2-2. Con Edison serves about 3.3 million residential, commercial, and industrial customers, operates more than 700 megawatts (MW) of electric generation, and manages an electric distribution

system of more than 90,000 miles of underground cables and over 30,000 miles of overhead wire. These statistics are shown in Table 2-1.

**Figure 2-2. Con Edison Service Territory within New York State**



Con Edison's electric service territory includes a mix of high-density urban loads, such as those found in midtown Manhattan, and moderate-density urban and suburban loads found in other boroughs and surrounding counties.

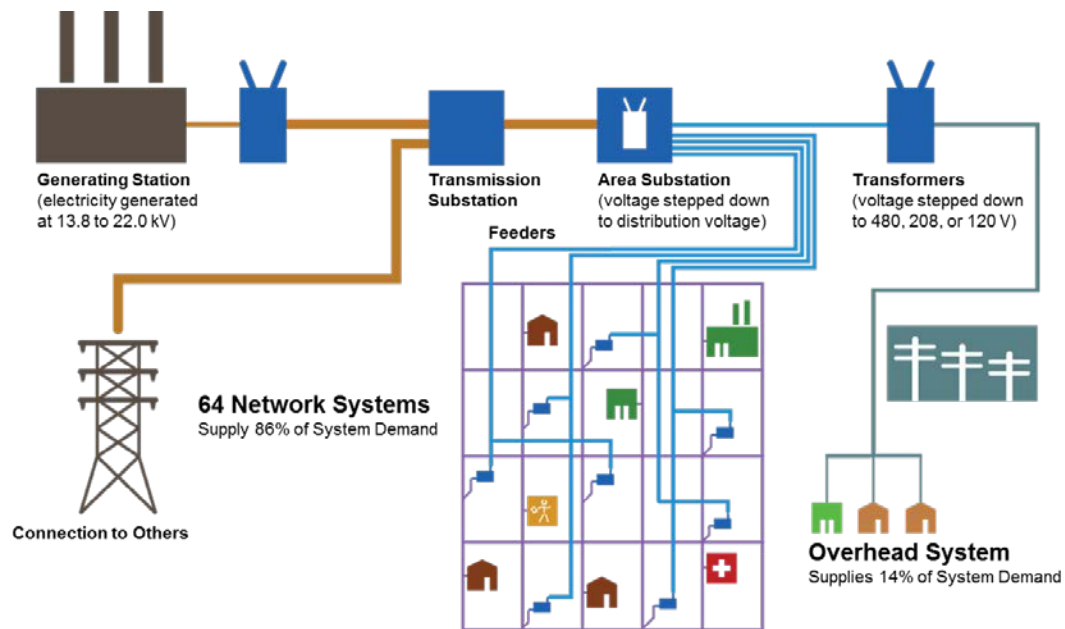
**Table 2-1. Con Edison Service Territory Characteristics**

| Number of Customers                                       | Con Edison       | O&R            | Total            |
|-----------------------------------------------------------|------------------|----------------|------------------|
| Residential                                               | 2,832,764        | 260,547        | 3,093,311        |
| Commercial and Industrial (C&I)                           | 494,817          | 40,562         | 535,379          |
| Other                                                     | 4,726            | 630            | 5,356            |
| <b>Total</b>                                              | <b>3,332,307</b> | <b>301,739</b> | <b>3,634,046</b> |
| <b>Electrical Transmission and Distribution (T&amp;D)</b> |                  |                |                  |
| Underground (cable miles)                                 | 96,661           | 1,772          | 98,433           |
| Overhead (wire miles)                                     | 36,818           | -              | 36,818           |
| Overhead distribution (circuit miles)                     | -                | 3,779          | 3,779            |
| <b>Total</b>                                              | <b>133,479</b>   | <b>5,551</b>   | <b>139,030</b>   |

*Source: Con Edison documentation*

Con Edison operates a highly complex distribution system. Approximately 86% of the distribution system demand is met through underground networks, which use a highly reliable design including redundancy of critical components. Con Edison has a dedicated team of employees with a breadth of experience and knowledge in the design and operation of the control systems and equipment for this complex distribution system. Components of the distribution system, including both underground network systems and overhead systems, are graphically illustrated in Figure 2-3.

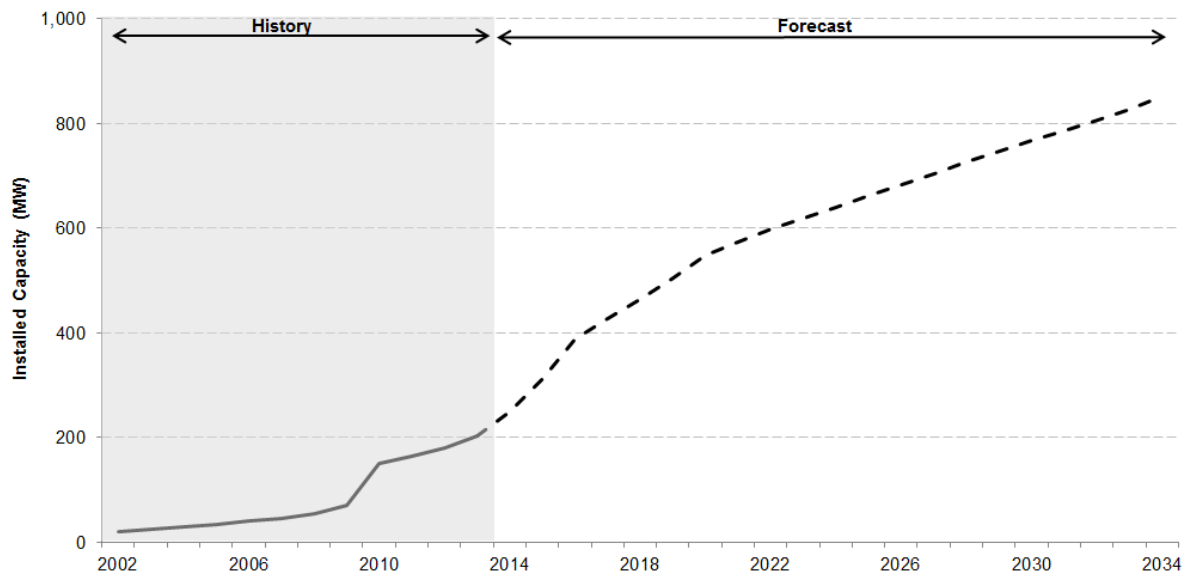
Figure 2-3. Graphical Depiction of Con Edison Distribution System



Source: Con Edison documentation

Use of distributed resources is growing within the service area, including DR resources, battery storage units, and DG. These resources can help Con Edison lower costs, improve reliability and customer service, and reduce its impact on the environment if they are managed properly. In just the past year (from 2013 to 2014), program enrollment in Con Edison's commercial DR program has increased by 14%, and as Figure 2-4 shows, Con Edison is also expecting significant long-term growth of DG. The growth of these distributed resources, as well as combined heat and power (CHP), is expected to continue.

**Figure 2-4. Projections for Con Edison DG Installed Capacity**

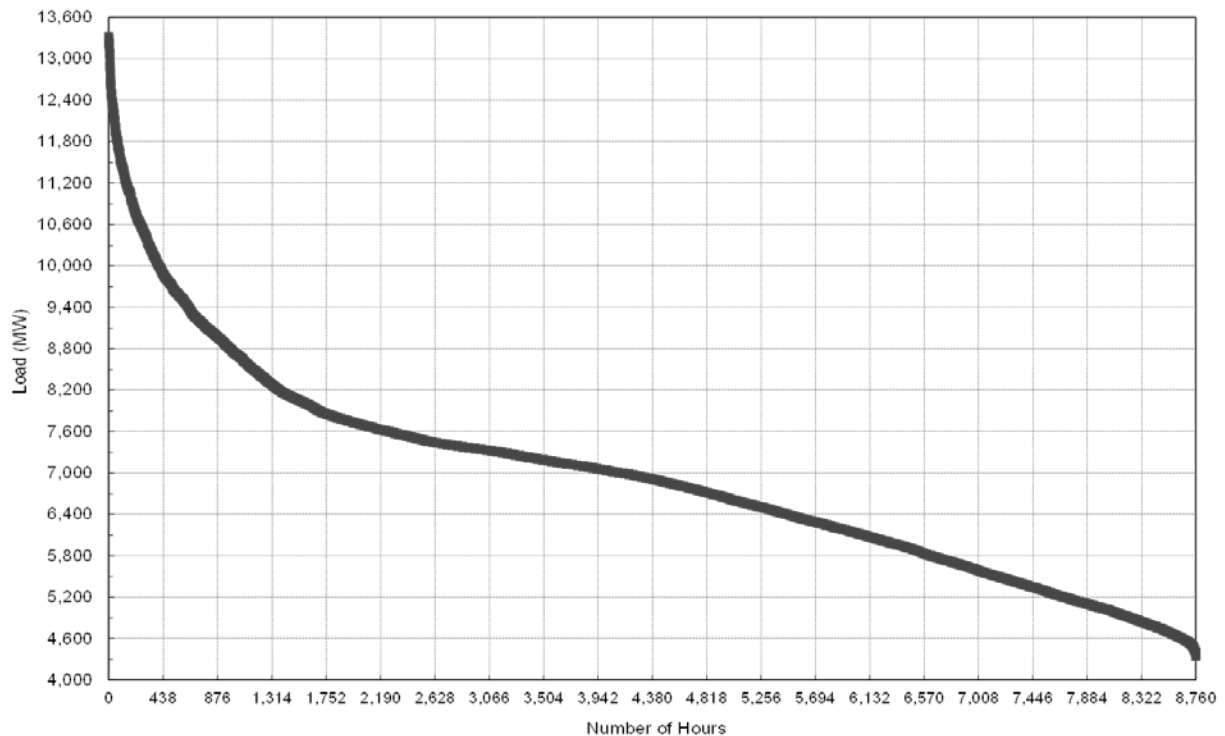


**Source: CECONY Distribution Engineering, Strategic Planning.**

To reliably and efficiently accommodate the growing penetration of DERs, Con Edison has been working on SG technology that can improve the management of the distribution grid through a combination of enhanced monitoring and control capabilities, along with intelligent analytical tools. Successfully integrating these advanced technologies with distributed resources is a key objective of the SGDP.

In particular, Con Edison is interested in managing peak loads and peak load growth with these resources. As illustrated in Figure 2-5, the peak capacity of the system is only required for very few hours per year. The integration of DR, renewables, and DG enabled by this SGDP will reduce peak capacity requirements and ultimately help defer infrastructure investments.

Figure 2-5 Annual Load Duration Curve for Con Edison (2013)



Source: Con Edison documentation

Con Edison will use the lessons learned through this project to effectively control, dispatch, and potentially monetize a wide range of distribution-level resources. The SGDP also enables several features that may be beneficial for a Distributed System Platform (DSP) model in the future, including DERMS and DRMS integration with DER components, integration with Control Center operations, communication and secure messaging options, and enhanced DR processes.

Finally, results of the SGDP will help Con Edison achieve these goals, while also enabling Con Edison to more effectively and efficiently respond to regulatory directives and initiatives such as the previously mentioned REV proceeding. REV will reform New York State's energy industry and regulatory practices to meet the future challenges related to more efficient use of energy, deeper penetration of renewable energy resources (e.g., wind and solar), and wider deployment of DERs (e.g., micro-grids, on-site power supplies, and storage). It will also promote greater use of advanced energy management products to enhance demand elasticity and efficiencies. These changes, in turn, will empower customers by allowing them more choice in how they manage and consume electric energy. The potential for alignment between the SGDP and REV is discussed in more detail in Section 5.4.

## 2.2 Objectives

The primary goal of the SGDP was to demonstrate that the secure integration of enhanced monitoring and control capabilities with intelligent analytical tools can improve the management of the distribution grid and enable greater deployment of renewable energy resources and SG technologies. To accomplish this goal, Con Edison integrated existing legacy control and data systems along with new SG



applications in a common, cyber-secure, interoperable control platform. This has enabled Con Edison to demonstrate seamless integration and control of renewable energy resources and SG technologies, such as EV charging stations, DG, and BMS.

The following list presents the project objectives which were used to guide the project team in accomplishing the project goals. The first five objectives come directly from the original Statement of Project Objectives, and the remaining items are additional objectives that the project team identified in later stages of the project.

1. Improve control capabilities for existing grid assets
2. Determine how to best apply newly developing technologies
3. Minimize peak load growth
4. Improve grid reliability
5. Provide customers with greater visibility, flexibility, and value
6. Leverage controllable field assets that can reduce load where and when needed
7. Provide grid operators and designers with improved, enhanced decision aids
8. Integrate legacy applications, sensor data, and decision aids into the middleware
9. Integrate data from system sensors and control functionality with the middleware

Further discussion on how the SGDP achieved each objective is included in Section 5.1

### ***2.3 Project Team***

Con Edison was responsible for recruiting and providing overall project management of the project team. Ultimately, more than 16 different project partners, vendors, and organizations played a role in the SGDP. Provided below are brief descriptions of the primary members of the project team.

#### **Consolidated Edison, Inc.**

Con Edison is one of the nation's largest investor-owned energy-delivery companies. The company provides a wide range of energy-related products and services to its customers, primarily through its two regulated utility subsidiaries, Con Edison and O&R, and its three competitive businesses. Con Edison was the prime recipient of the SGDP award.

To support this project, Con Edison maintained schedules and budgets, dictated communications - protocols, tracked risks and issues, and established and maintained change control procedures. The project management team was responsible for managing the integration and implementation of the various monitoring, control, and decision support initiatives required to interface with other project participants to achieve the goals and objectives of this project. These responsibilities included defining the configuration management, software development, and test and evaluation plans for the software products deployed at Con Edison.

Con Edison was also responsible for planning, scheduling, and hosting six demonstrations of the project's capabilities. Con Edison provided ongoing coordination of the installation of servers,



workstations, and software applications at their 4 Irving Place Headquarters Data Center, which supports the Manhattan Distribution Control Center (DCC). These equipment and applications supported the demonstrations that enabled integrated functions in service territories supported by the Manhattan DCC, the Energy Control Center (ECC), and the Brooklyn/Queens Control Center.

### **Siemens**

Siemens SG Enterprise Architecture Solutions (SOL) group executed the Con Edison SGDP integration project. The SOL business unit deploys commercial product solutions for the electric utility industry including Substation Automation, Metering, Energy Management Systems, Distribution Management Systems, Energy Market Management applications, DRMS, Common Model Management Systems, and Enterprise Integration.

As part of the SGDP, Siemens partnered with TIBCO (see below) to integrate and interconnect existing applications, new SG applications, and external service connections in a secure and industry-standard compliant design. The project leverages Siemens' expertise in Utility Real-Time Operations domains and information technology (IT), in tandem with TIBCO's service-oriented middleware architecture, to bridge functional silos, collect data from heterogeneous applications, and establish secure, reliable communication connections between them. Siemens' platform additionally enables Con Edison users to visualize and monitor integrated data from a range of sources and take informed actions.

### **TIBCO Software**

TIBCO is a technology leader in providing commercial products for interoperable secure services to real-time systems.

As discussed above, TIBCO partnered with Siemens to integrate and interconnect existing applications, new SG applications, and external service connections as part of the SGDP. TIBCO was deployed for secure services interoperability within the control center and to external customer sites, directly and through third-party providers. TIBCO's application suite utilizes centrally defined policies for security, auditing, logging, and service-level agreements. The software is a standards-based service creation, orchestration, and integration product, enabling exposure of existing systems as services and the creation of new services to internal legacy systems as well as interoperability with external systems.

### **Alstom Grid**

Alstom Grid, a division of Alstom, designs, manufactures, installs, and services power T&D system technologies.

For the SGDP, Alstom Grid developed a DRMS that supports many of the DR management functions, including enrollment, reporting and DR settlement. This system interoperates with Con Edison's information systems, streamlines a number of business processes, and enables Con Edison to measure customer performance using automated baseline calculations.

### **Orange and Rockland Utilities, Inc.**

O&R, a wholly owned subsidiary of Con Edison is an electric and gas utility headquartered in Pearl River, New York. O&R and its two utility subsidiaries, Rockland Electric Company and Pike County Light & Power Co., serve a population of approximately 750,000 in seven counties in New York, northern New Jersey, and northeastern Pennsylvania. Its system features more than 4,000 miles of



overhead electric wires and approximately 2,000 miles of underground cable to accommodate a suburban and agricultural customer base.

As part of this project, O&R worked collaboratively with TIBCO and Siemens to install a middleware solution, which enabled the integration of various Control Center applications into a common platform. EDD provided modeling software for this project. O&R supported the integration activities and provided subject matter experts (SMEs) for each of the systems they integrated.

#### **Digi International and Ambient Corporation**

Digi International has expertise in machine-to-machine communications, combining products and services as end-to-end solutions to drive business efficiencies.

Ambient's software platform enables utilities to deploy and integrate multiple SG applications and technologies, in parallel on a single communications infrastructure, supporting Smart Metering, Distribution Automation, Distribution Management, DR, DG, and more.

Con Edison brought Digi International and Ambient Corporation to the project to support the enhancement of communications between interval meters and Con Edison's MV-90 and MDMS. Digi and Ambient were selected due to their expertise and product offerings around wireless communication nodes.

#### **Viridity Energy**

Viridity Energy provides its clients, primarily university and C&I customers, with intelligent decision tools that increase energy savings while creating new revenue streams obtained by participating in various utility and regional transmission organization (RTO)/independent system operator (ISO) energy markets. Viridity's VPower™ platform enables customers to dynamically shift, shave, and balance energy load; integrate advanced energy technologies; and convert existing energy investments into new revenue streams through integration with power markets.

Viridity Energy established interfaces to customer BMSs across the Con Edison service territory. Data provided through VPower by the BMSs, DG, and battery systems includes capacity, amount of stored energy, and capability rate for discharge of batteries. This information enables distribution system operators to make informed decisions about customer curtailment and deployment of energy storage.

#### **Green Charge Networks**

GCN is a company that specializes in energy storage solutions that enable the use of electrical equipment while limiting high energy consumption peaks. GCN's systems accommodate local demand for electricity under existing generation and storage capacity restraints. GCN works directly with utility companies and public- and private- sector organizations.

With a special focus on EV charging, GCN built and deployed customer-sited SSGUs for this project to reduce customer energy spending and achieve increased efficiency.

#### **Innoventive**

Innoventive manages load curtailment and DG programs for large commercial firms and large residential facilities. As part of the SGDP, Innoventive integrated a previously developed software



system, known as the DRCC, with Con Edison's DERMS platform. The DRCC (developed under DE-FC26-08NT02869) allows the remote dispatch of 23 facilities, representing a total of 20 MW.

#### **New York City Economic Development Corporation**

NYCEDC is NYC's primary agent for economic development. Acting under annual contracts with the City of New York, NYCEDC serves as the catalyst for promoting economic development and business growth. NYCEDC was a sub-awardee in the Con Edison SGDP and installed a PV and battery storage system at their Brooklyn Army Terminal (BAT) site.

#### **Gehrlicher Solar**

Gehrlicher Solar is an internationally operating PV company. Gehrlicher participated in the SGDP by installing a 40-kilowatt (kW) solar installation at Con Edison's 4 Irving Place headquarters.

#### **Softstuf, Inc.**

Softstuf specializes in the design of advanced analysis systems for measuring performance of large electrical power systems during fault and disturbance conditions. Softstuf's contribution to the SGDP included the instrumentation of relay protection circuits associated with 11 345-kilovolt (kV) circuit breakers with Target Information Sensors (TIS), as well as global positioning system clocks to synchronize these measurements. In addition, approximately 4,000 sensors, including those associated with the 11 breakers, were integrated into a user interface that can be used by engineers and technical personnel to conduct remote analysis.

#### **CALM Energy**

CALM develops and deploys Computer-Aided Lean Management (CALM) to help optimize grid operations. CALM developed an ISM Decision Aid platform. In addition, CALM built a building smart node energy optimization controller, which was used to securely communicate with the utility's platform for energy monitoring and DR.

#### **Columbia University's Center for Computational Learning Systems (CCLS)**

Columbia University's CCLS dedicated research resources to develop the Adaptive Stochastic Controller (ASC) and a LSOC for equipment failure prediction, day-ahead load and price forecasts, and optimization of the real options for maximizing energy efficiency (EE) and minimizing costs within the SG.

#### **Energy and Environmental Economics**

E3 is a consulting firm specializing in solving business and regulatory issues related to the electricity industry. With assistance from Navigant, E3 designed and built the IDSM Potential Model to help Con Edison determine how to optimally deploy Targeted Demand-Side Management (TDSDM) strategies on specific capacity-constrained feeders and networks.



### Navigant Consulting, Inc.

Navigant's EE and Demand-Side Management (DSM) division has expertise in assessing markets, developing market intervention strategies, designing and implementing EE programs, and evaluating the effectiveness of those programs. Navigant worked with E3 to develop data inputs for the IDSM Potential Model discussed above.

## 2.4 Sub-projects

To accomplish the objectives outlined in the preceding section, Con Edison and the project partners organized the work into 13 individual sub-projects, which were implemented across Con Edison's and O&R's service territories. Conceptually, the sub-projects can be organized into three broad categories, as shown on the left side of Table 2-2.

- A. Secure Systems Integration
- B. DR and DER Connectivity
- C. Optimization and Control

These three categories, and their subprojects, are described in more detail in Section 3.

**Table 2-2. Sub-project and Project Partner Overview**

|                               | Subproject Description                        | Project Partner     |
|-------------------------------|-----------------------------------------------|---------------------|
| A. Secure Systems Integration | A.1. DERMS                                    | Siemens and TIBCO   |
|                               | A.2. DRMS                                     | Alstom Grid         |
|                               | A.3. ISM and Control Algorithms               | O&R and EDD         |
|                               | A.4. Wireless Communication and MDM           | Digi and Ambient    |
| B. DR and DER Connectivity    | B.1. DR and BMS Integration                   | Viridity Energy     |
|                               | B.2. SSGUs                                    | GCN                 |
|                               | B.3. DRCC                                     | Innovative Power    |
|                               | B.4. PV, Battery Storage, and BMS Integration | NYCEDC              |
|                               | B.5. Streamlined PV Design and Build          | Gehrlicher Solar    |
| C. Optimization and Control   | C.1. SGDM                                     | Softstuf            |
|                               | C.2. Energy Optimizer Controller              | CALM                |
|                               | C.3. DTC and LSOC                             | Columbia University |
|                               | C.4. IDSM Potential Model                     | E3 and Navigant     |

Sub-project accomplishments and results are also presented in the relevant sections of the document below, and additional details are provided in Appendix A.



## 2.5 Demonstration Timeline

The project officially began on January 4, 2010, when Con Edison entered into a cooperative agreement with the DOE. Con Edison demonstrated successful completion of the project objectives by developing and hosting a series of six demonstrations (Table 2-3).

**Table 2-3. SGDP Demonstrations**

| Demonstration Name |                                                                                         | Demonstration Purpose                                                                                                                                 | Demonstration Date                                       |
|--------------------|-----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------|
| 1                  | Long Island City 1 (LIC)                                                                | Demonstration of Situational Awareness and targeted DR                                                                                                | March 27, 2012                                           |
| 2                  | O&R                                                                                     | Demonstration of message communication between environments at Con Edison.                                                                            | September 28, 2012                                       |
| 3                  | LIC 2                                                                                   | Demonstration of additional sites for situational awareness and targeted DR.                                                                          | October 19, 2012                                         |
| 4                  | Demonstration of integrated system with Con Edison's ECC Systems                        | Demonstration of demand-side resources (DR and DG) integrated with substation status. Demonstration of situational awareness across full energy grid. | Preliminary walk through with operators on June 20, 2013 |
| 5                  | Demonstration of integrated system with Con Edison's Bowling Green distribution network | Demonstration of additional sites in Bowling Green for situational awareness and targeted DR.                                                         | October 19, 2012                                         |
| 6                  | Capstone – demonstration of integrated system                                           | Demonstration of previous phases combined.                                                                                                            | July 15, 2013                                            |

These demonstrations showed how data from disparate systems can be securely communicated, integrated, and displayed to the operator, and how that information can be analyzed in legacy power flow applications to identify the location of curtailable loads that can be leveraged to mitigate overloaded grid components. Additional discussion on the accomplishments of each demonstration and how those accomplishments relate to the project objectives can be found in Section 5.1

### 3. Technical Approach

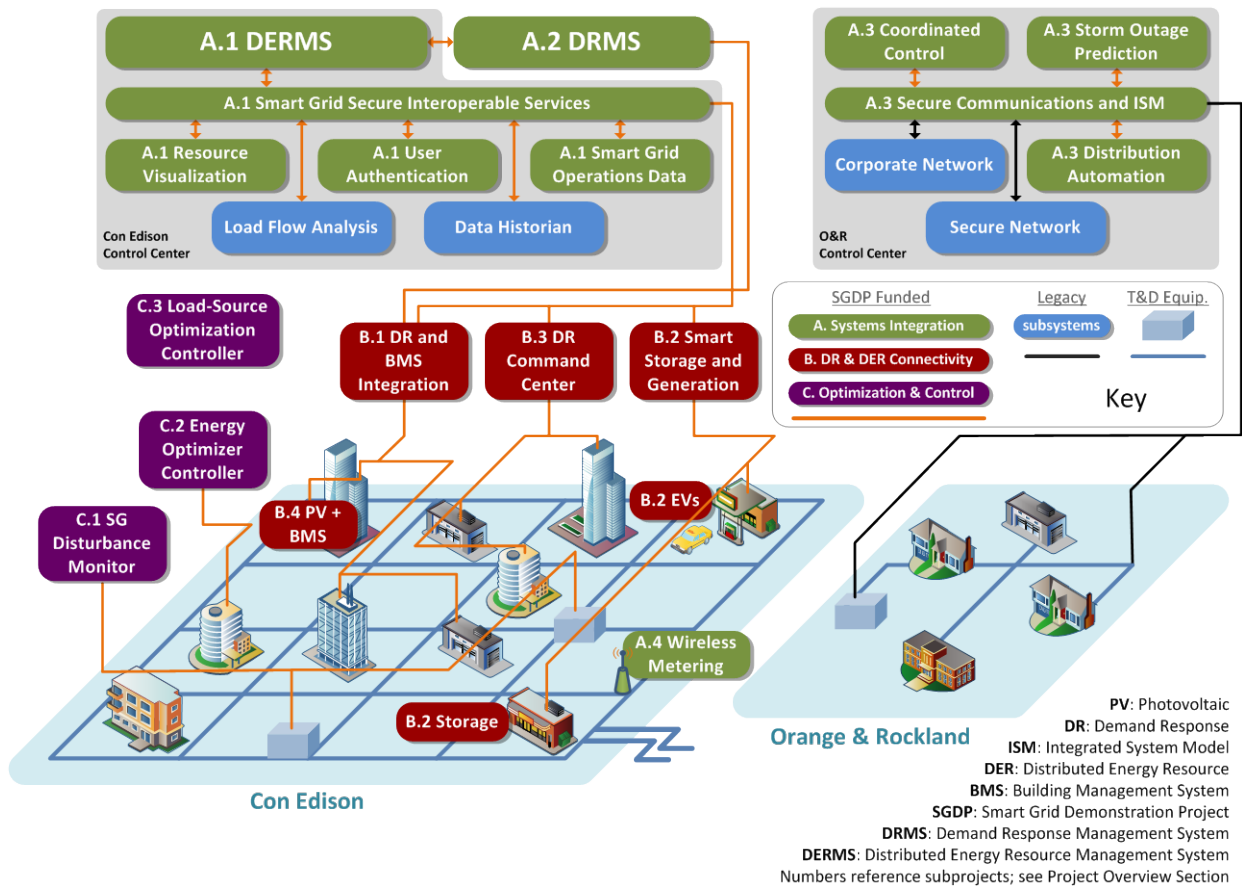
As part of the SGDP, Con Edison demonstrated how a variety of disparate systems can work together to optimize demand-side resource utilization in response to system operational events, environmental and equipment conditions, and market conditions, while using the latest industry standards for cyber-security. The SGDP provides the ability to link different internal and external data sources and legacy applications. The SGDP enables existing tools to identify DER and could relieve overloaded distribution system components. Furthermore, the SGDP platform optimizes the application of controllable field assets in both normal and contingency operations for increased energy delivery, reliability, and security.

This section provides an overview of sub-projects within the SGDP. The sub-projects that link these systems and data can be grouped into three broad categories (as also described in Section 2.3), with illustration of how these components fit together shown in Figure 3-1.

- A. **Secure Systems Integration:** Includes the DRMS, DERMS, secure communications for distribution automation, and wireless metering deployed through this demonstration project, which are the core systems integration components supporting the project's new SG functionality, legacy systems, and interconnectivity to external resources.
- B. **DR and DER Connectivity:** Includes the connection of DR, storage, and DG resources to enhance efficiency, reliability, and economic savings for the utility and end users alike.
- C. **Optimization and Control:** Includes the optimization and control of interconnected systems and resources.

The remainder of this section describes the integration of the sub-projects and Con Edison's systems in the context of these categories. Appendix A provides more detailed descriptions of each of the sub-projects.

Figure 3-1. SGDP System Overview Diagram



Note: Con Edison also completed an IDSM Potential Model as part of the SGDP. This model is not pictured here, but is described below under Optimization and Control.

### 3.1 Secure Systems Integration

The core systems integration components deployed through this demonstration project include DRMS, DERMS, secure communications for distribution automation, and wireless metering.

**A.1 DERMS:** The DERMS is a command and control center for a DR network. Siemens and TIBCO designed this system to visualize and optimize the use of DR, DG, and energy storage. DERMS has been deployed on a service architecture to interface to internal Con Edison systems and external customer sites. Key features of the platform include the ability to model and visualize DR and DER on existing Con Edison distribution system displays. The services also support receiving the near real-time status of these resources for distribution system impact analysis.

**A.2 DRMS:** The Alstom Grid DRMS is an information management system (IMS) that is expected to efficiently manage and optimize Con Edison's growing DR portfolio and streamline DR-related business processes. The DRMS moves DR-related data to and from Con Edison's back-office systems including: Customer Information System, MDMS, PI (OSIsoft), and load forecasting systems. This system supports multiple DR-related functions, including DR program enrollment, event notification, customer



performance calculation, settlement calculation, and reporting. Con Edison may also use this system in the future to control resources via the OpenADR 2.0 protocol and dispatch DR resources on an economic or targeted basis.

**A.3 Distribution Automation and Secure Communications:** The O&R sub-project also focused on systems integration, but in contrast to the Con Edison DERMS/DRMS sub-projects that focused on resource integration, O&R leveraged some of the same secure infrastructure to further automate their distribution system. O&R accomplished this by developing model-centric, coordinated volt-var control (VCC), auto restoration control, and a storm prediction model, which will be integrated into the utility's real-time systems and data stream.

**A.4 Wireless Communication and MDM:** The MDMS feeds near real-time customer interval meter data into the DERMS and DRMS platforms described above. Reliable transmission of interval metering data from some customer premises (e.g., where land lines have failed or do not exist) to the MV-90xi system that feeds the MDMS is an ongoing challenge for Con Edison. The goals of this sub-project were to install additional hardware to enhance communication to those premises and to improve the necessary systems and hardware required to support increased throughput of 15-minute-interval meter data collection. This near real-time visibility of customer response during DR events greatly improves the effectiveness of targeted demand-side strategies and allows integration with the DRMS for customer baseline calculation and settlement purposes.

### ***3.2 DR and DER Connectivity***

The integration of the systems described above enabled the connection of DR, storage, and DG resources to enhance efficiency, reliability, and economic savings for the utility and end users alike. The sub-projects demonstrating these capabilities included the following:

**B.1 DR and BMS Integration:** This project, led by Viridity, enabled proactive customer involvement in the markets by the integration of customers' BMS systems into its Network Operations Center (NOC) and the DERMS. To do so, this project coupled real-time information and insight into the electricity market with advanced communication protocols. This information enables operators to make informed decisions about customer curtailment and deployment of energy storage. The VPower system, a web-based software platform with customer-facing portal, optimizes building system operations for the customer while giving system operators access to curtailable load. Customers will gain greater visibility of their energy needs, consumption, and costs, which they can use to develop strategies to improve efficiency. This project illustrates the value of load management to individual participating customers, the local utility, and the system as a whole.

**B.2 SSGUs:** The primary accomplishment of this project, led by GCN, was the development of a behind-the-meter energy storage system. These systems were outfitted with the equipment and controls necessary to charge EVs, accept energy from local PV installations, and participate in utility DR incentive programs. These SSGUs are intended to reduce the monthly demand charges assessed on commercial ratepayers. This project was unique in its focus on providing power (kilowatt [kW]) from the storage units, rather than energy (kilowatt-hour [kWh]) arbitrage.



**B.3 DRCC:** Innoventive worked with Con Edison to integrate the DRCC, which was developed as part of Con Edison's Renewable and Distributed Systems Integration (RDSI) project, with the DERMS. The DRCC allows the remote activation of DG resources that are owned and maintained by an independent third party (telecommunication provider). This DRCC allows Con Edison to access, through a secure, Internet-based communication path, 20 MW of diesel generation, which can be deployed for DR events. The DRCC is also designed to allow the DR resource owners to simultaneously participate in the New York Independent System Operator's (NYISO) DR program.

**B.4 PV, Battery Storage, and BMS:** The NYCEDC developed a demonstration project at their BAT in Sunset Park that integrates three main components: 1) a 100-kW solar PV array, 2) a BMS, and 3) a 720-kWh battery for on-site energy storage capable of delivering 100 kW for four hours. The project set out to demonstrate the benefits of on-site renewable energy generation coupled with energy storage and management systems to reduce demand on the grid, offset energy costs, and advance the City's PlaNYC sustainability objectives by reducing greenhouse gas (GHG) emissions associated with energy generation and use.

**B.5 Streamlined PV Design and Build:** In cooperation with Gehrlicher Solar, Con Edison also undertook a sub-project to demonstrate DG connectivity by installing a 40-kW PV system on their Irving Place headquarters. This allowed them to gain firsthand knowledge of the challenges of a behind-the-meter solar installation, the complexities and logistical challenges of installing solar on a high-rise building in NYC, the process for meeting landmarks certification, and to provide a test bed for connecting behind-the-meter solar.

### ***3.3 Optimization and Control***

In addition to securely integrating systems and connecting several types of DER, this demonstration project also included several sub-projects aimed at optimizing and controlling interconnected systems and resources.

**C.1 SGDM:** The SGDM sub-project, executed by Softstuf, integrated sensor data from 4,000 sensors to a single data repository and developed automated analysis tools. These analysis tools leveraged a new type of TIS which can be deployed on electro-mechanical relays without necessitating interruptions of service or upgrade to costly digital relays. Integration of these sensors enabled Con Edison and Softstuf to develop algorithms to enable fault current modeling and sequence-of-events reports, which typically would not have been possible using legacy equipment.

**C.2 Energy Optimizer Controller:** Also in the realm of optimization and control, CALM developed and demonstrated a low-cost building Energy Optimization controller for small and mid-sized commercial buildings that was able to communicate directly with Con Edison's DERMS. These communications included low-cost thermostatic control of multiple optimization capabilities to reduce peak loads and reduce energy usage in commercial buildings.

**C.3 LSOC:** Columbia University's CCLS was responsible for developing ASCs, including a DTC, to assist distribution system operations in optimizing decisions about maintenance actions and an LSOC for optimizing the dispatch of SG resources. The ASCs used sophisticated sets of algorithms to determine the optimal actions to be taken. These algorithms incorporate disparate data, such as pricing



information, system loads, weather, and the impact of proposed actions on future flexibility to respond to system conditions.

**C.4 IDSM Potential Model:** Con Edison is also developing an IDSM Potential Model as part of the SGDP. E3, with assistance from Navigant, is developing the model, which is expected to be completed in September 2014. The model will aid in evaluating the market potential for technologies that are commercially available now or within the next three to five years, including EE, DR, energy storage, and customer-sited DG technologies. This effort also includes the development of an integrated set of models and decision tools to conduct integrated DR analyses. The technology assessment and requisite decision tools will serve as a comprehensive platform to expand Con Edison's TDSM program, improve capital decision-making, support ongoing efforts to further build DR capability, and establish a set of new programs to maximize both system and customer benefits by network, segment, and building type.

## 4. Methodology

This section summarizes the methods used in the various sub-projects to achieve the goals of the overall project. Individual project partner inputs to the Final Technical Report, which discuss the objectives, methods, and accomplishments of each sub-project in more detail, can be found in Appendix A.

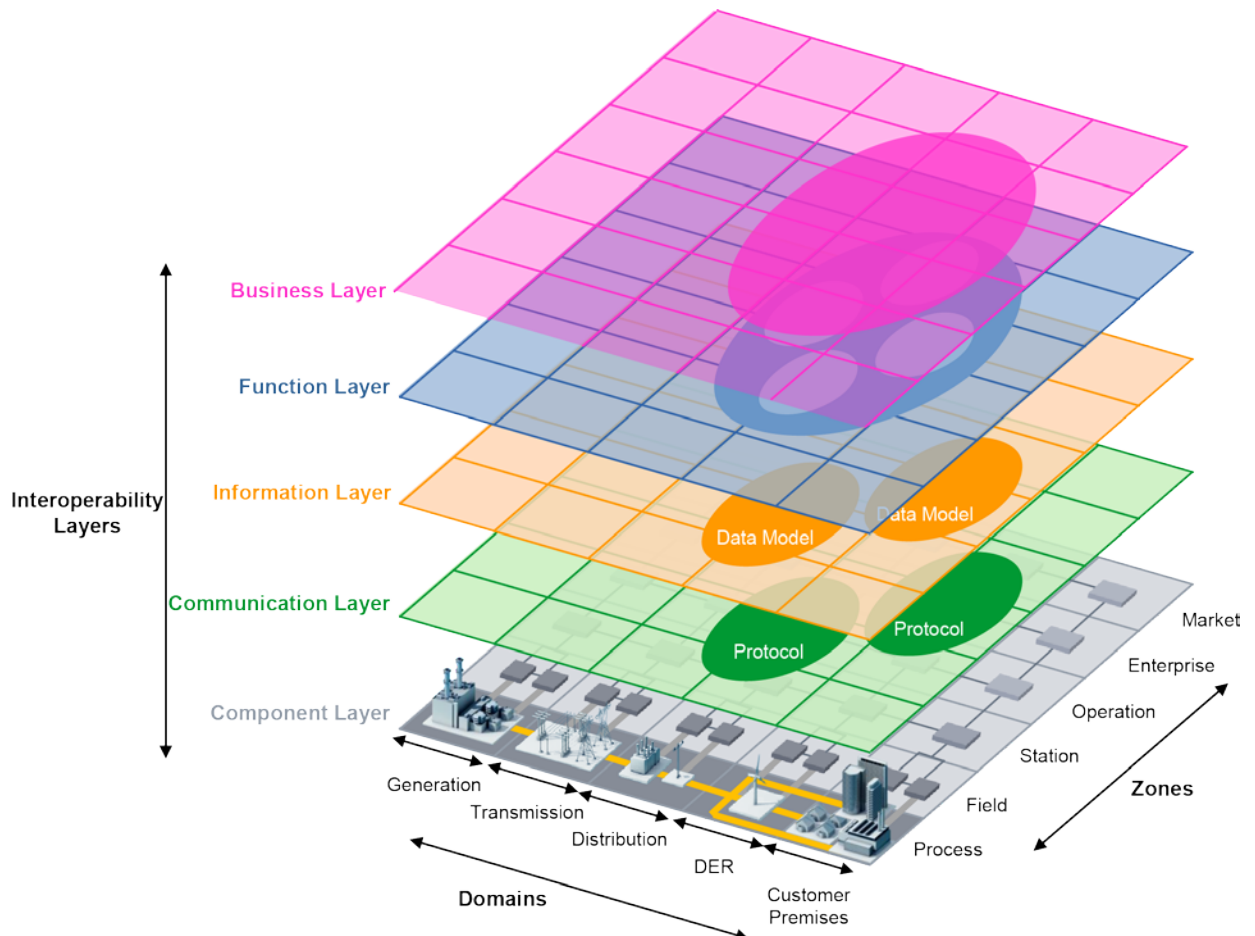
### *4-A. Secure Systems Integration*

The systems integration design focused on establishing a secure interoperable service bus that supports industry-standard service architecture with new SG functionality and legacy systems, as well as interconnectivity to external resources. The design also supports virtualization of new SG applications where possible and integrating legacy systems on the service bus to enable a service framework.

The Secure Services Platform at Con Edison was designed to interface up to 10,000 DR sites for the SGDP. The architecture design started with SGDP use cases derived from the project objectives. Stakeholders drove the services architecture and technical and functional requirements. The process aligned the architecture with the National Institute of Standards and Technology (NIST) 1108 conceptual framework and International Electrotechnical Commission (IEC) SG roadmap to identify domains, actors, and services within the SG domains. The SGDP interoperability requirements were aligned with NIST 7628 and IEC specifications. Cyber-security requirements were driven in part by NIST 7628 Guidelines for Smart Grid Cyber Security and the NIST 800-30 risk management guide.

This process resulted in a SGDP Architecture, Interoperability, and Cyber-Security framework that was shared, reviewed, and updated by Con Edison technology departments, the project partners, NIST, and the DOE. The Smart Grid Architecture Model (SGAM) is a comprehensive “all-in-one” SG toolbox. The SGAM divides the energy industry into five domains, six zones of information management, and five layers of interoperability. Siemens leveraged the reference architecture model in Figure 4-1 to design and implement the interoperability platform used by DERMS and the other projects in this section. While the SGDP does not span all the zones and domains shown in the figure below, the Siemens platform does allow flexibility and scalability to incorporate all of them as part of Con Edison’s roadmap.

Figure 4-1. The SGAM



Source: European SG Coordination Group; based on NIST SG 1108 and 7628

The SGDP team focused on developing an architecture design based on open-services architecture to support interconnectivity between legacy systems and new SG applications, and interoperability with external DR resources. As noted above, the approach for achieving interoperability and cyber-security was based on aligning the SGDP applications, functions, services and interfaces with the NIST and IEC reference architectures to develop SGDP reference architecture. This process identified SG functions, common services, and data flows in alignment with the reference architectures so that available standards could be identified and applied.

The SGDP architecture design was based upon open-services architecture to support interconnectivity between systems and services. The implementation required a SG Secure Interoperable Service bus to support standard service interoperability between SG systems. As noted above, the approach for achieving interoperability and cyber-security was based on aligning the SGDP applications, services, and interfaces with the NIST and IEC reference architecture. This process identified SG functions, common services, and data flows in alignment with the reference architectures so that available standards could be identified and applied.



The goal of such standards-compliant services is to help integrate legacy control center applications, new SG applications, external IT applications, and other external participating entities. As these services are well defined and standards compliant, other applications who wish to use them are free to implement them. The following four sub-projects all utilized these standards-compliant services and open architecture to achieve their integration.

#### **4-A.1. DERMS**

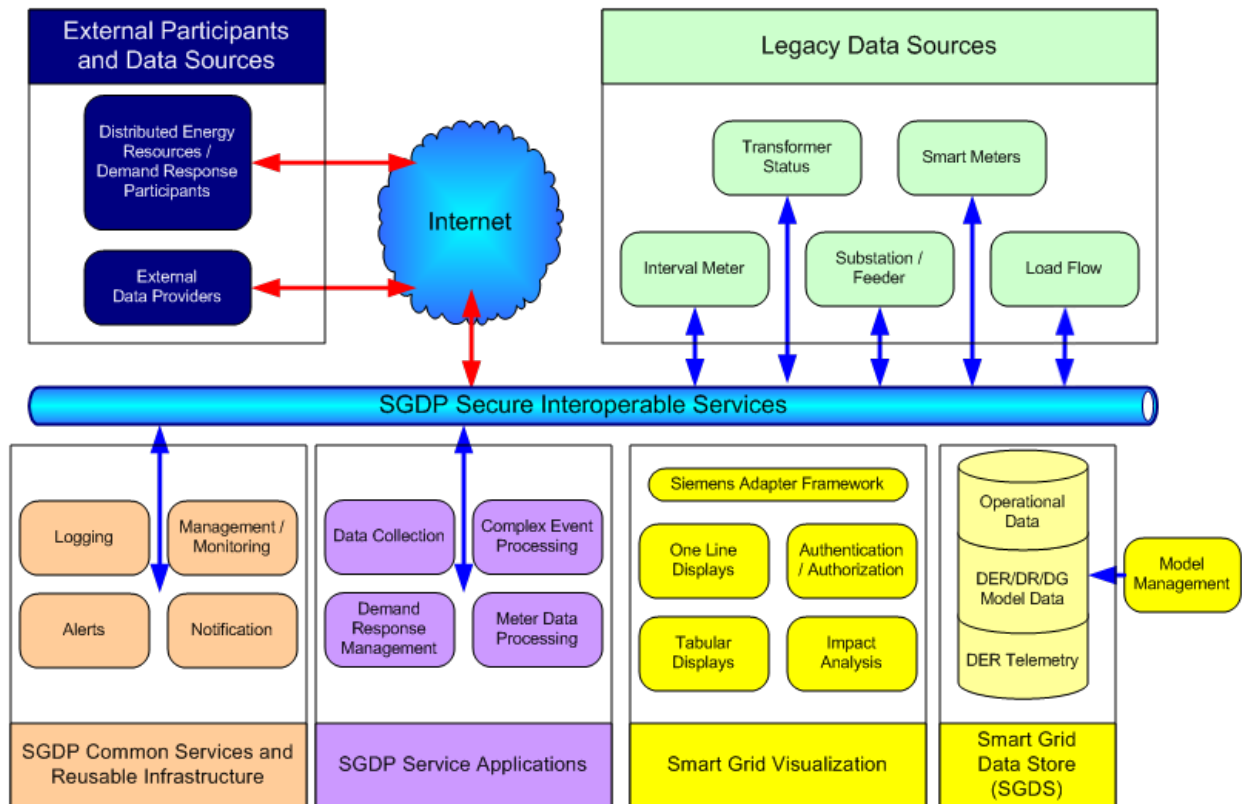
Siemens, its subcontractor TIBCO, and other partners were selected by Con Edison to deploy SG technologies to illustrate the impact of integrated and optimized DER on system efficiency and reliability, translating to improvements to the utility's business processes and underlying applications, as well as cost savings for the company and its customers.

Siemens designed DERMS to easily incorporate new technologies and standards while still integrating with legacy applications, with no replacement or redesign required. The solution is scalable and flexible, allowing Con Edison to implement both its mid-term and long-term SG roadmap, while efficiently navigating and managing any changes that may occur in the future.

The DERMS incorporates existing, off-the-shelf commercial products from both Siemens and TIBCO, alongside existing Con Edison legacy applications. The solution adheres to accepted industry standards (e.g., IEC and NIST) and architectural best practices proven across other large-scale utility projects. The use of standards and adapters within this Service-Oriented Architecture encourages reuse of libraries across multiple applications subject to integration, an especially critical distinction when integrating with external partners.

DERMS was designed from the outset to provide a means of integrating various existing software packages using a cyber-secure means of communication and to provide a means to visualize the state of the grid and the various assets of interest. The integration occurs using a commercial off-the-shelf Enterprise Service Bus from TIBCO. The data that is passed between these software packages is based on the IEC Common Information Model (CIM) standard and uses extensible markup language (XML) based messages. The software packages range from providing functionality to analyzing conditions on the grid to calling DR programs that communicate with loads and to controlling generation, all using web services and XML messages. This integration mechanism means that existing software packages and the investment in their development, configuration, maintenance, and know-how can be leveraged and used in the changing grid, while allowing the addition of newer software that adds value to the reliable and secure operation of the grid. A diagram of the software and systems integration architecture is provided in Figure 4-2.

Figure 4-2. DERMS Architecture Diagram



Using this standards-based, secure integration mechanism, DERMS provides the monitoring and control of a variety of DERs and DR resources, including solar, backup generation, DR aggregators, and others, from a variety of vendors.

The controls to and the responses from the various resources are collected by DERMS and are presented to the operator for visualization and to monitor conditions on the grid. The data is also used by software packages such as Load Flow Analysis to give operators the means to operate the grid more efficiently and to select what resources may be candidates for enrollment into the DR programs.

The DERMS architecture prioritizes security, taking into account existing Con Edison security layers and incorporating security standards and best practices that interface with non-Con Edison distributed energy and load resources, and DR providers, enabling the integration of new applications, existing legacy applications, and other third-party services.

The following are the primary objectives of the DERMS project:

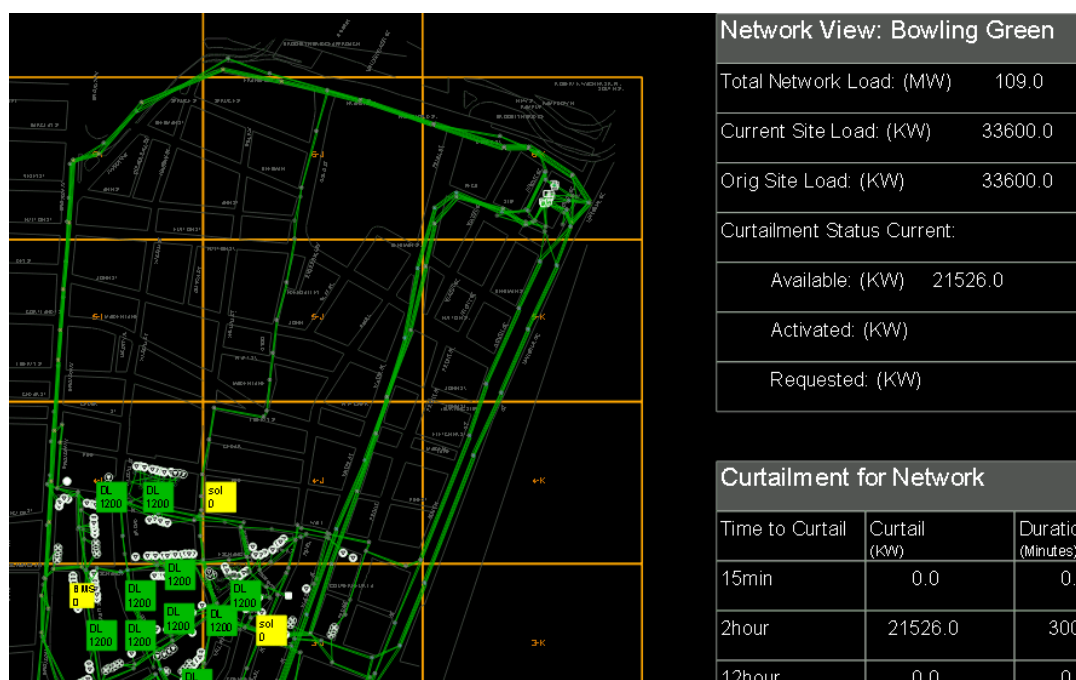
- Improve control capabilities of existing grid assets
- Minimize peak load growth and maximize EE savings throughout the electrical grid
- Provide world-class cyber-security for SG systems

- Demonstrate open standards and interoperability with vendors with commercially available products

Siemens' Model Driven Integration approach leverages the IEC CIM model as the Data/Domain Model within the Information layer to map and model data interface requirements. These requirements are driven by Functional Use Cases within the Function Layer, which in turn is influenced by Con Edison's Business Objectives and Processes within the Business Layer. Ultimately, the interfaces are implemented within the Communication Layer or the middleware, enabling interoperability between the various zones.

DERMS is an advanced software application that optimizes resource utilization in response to system operational events, environmental conditions, and equipment feedback. The platform provides visibility of and the capability to control a diverse portfolio of resources – for example, solar, wind, storage, and EVs – to address local complications, while flexibly addressing system-wide concerns. Visualization of the available resources allows the operator to simultaneously view the dynamic statuses of the resources and distribution grid components. A screenshot of the resource visualization interface is shown in Figure 4-3.

**Figure 4-3. Visualization of Grid-Connected DR Resources**



The conceptual purpose of a DERMS is to manage diverse DERs, to understand the unique status and capabilities of each, and present these capabilities to the Distribution Control Center Operator (DO) and other applications in a more useful and manageable way. This means aggregating the capabilities of individual devices, and transforming their settings and effects so that they become attributes at the circuit, feeder, or segment level.

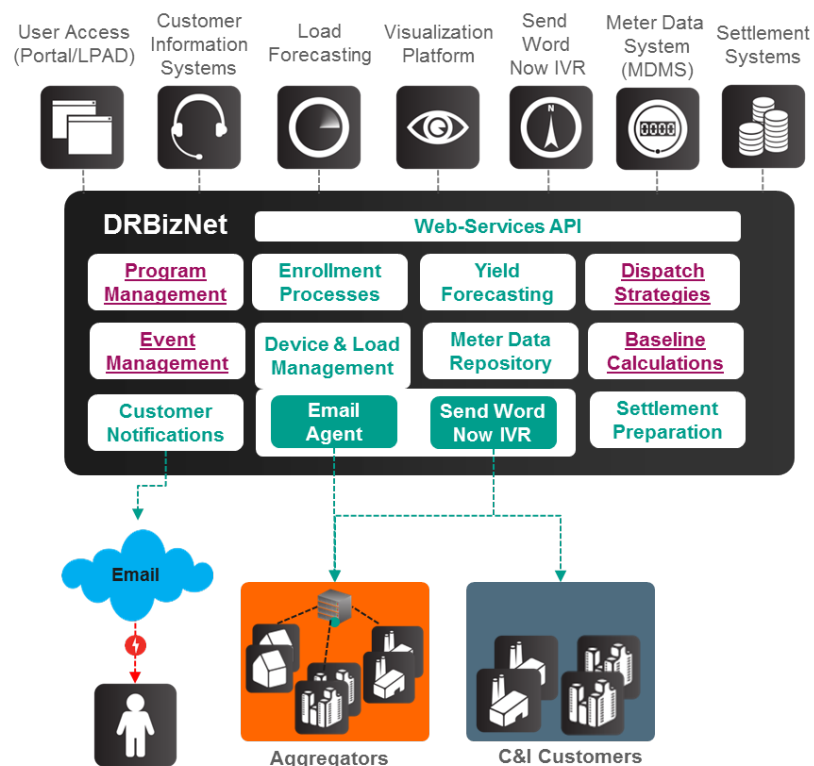
DERMS communicates with each DER controller to determine the operating status of each DER and to issue energy management control commands to reliably manage the stable integration of DER with the larger scale grid.

#### 4-A.2. DRMS

The DRMS is a proven software technology platform that enables market operators and utilities to manage and implement the DR program through a single integrated management system. It can help reduce the imbalance between energy supply and demand. The DRMS software generally enables utilities to offer highly customized programs for its customers and to review real-time and historical outcome of DR programs to assess their effectiveness.

Alstom Grid's DRMS (see Figure 4-4) is a system that integrates commercial and industrial DR programs. The DRMS forecasts available load curtailment capacity and has been deployed at other utilities with the capability to send signals for automatic load control to aggregators or directly to devices such as air conditioners or water heaters, thus optimizing the use of electricity. It then calculates customers' normal electricity usage as a baseline, and then compares actual reduced usage to measure performance.

**Figure 4-4. Diagram of the DRMS System**



The DRMS is intended to be the system that manages all activities and data related to demand-side load resources for Con Edison's current and future programs. The DRMS can serve as the following:

- Single system of record for supporting DR Program Management and Operations
- A point of enrollment/registration for all DR programs including residential and C&I programs
- A command and control event management system
- Notification to DR customers of start of event
- Calculation engine to measure customer performance and calculate settlements using automated baseline calculations
- The system of record for all data and transactions related to DR programs and events

The scope of the DRMS project also included the following:

- Analyzing existing DR programs and business processes
- Gathering requirements for streamlining programs, processes, and DR performance measurement and calculations
- Configuring and implementing the DRMS
- Customizing baseline calculation options and control methods
- Migrating the existing DR programs, customers, resources, and related data to the new DRMS

#### **4-A.3. ISM and Control Algorithms**

The objective of the real-time control systems work performed at O&R was to demonstrate that a single, detailed, reusable model of the electric distribution system can be used in a secure, interoperable environment for multiple objectives, creating “model-centric”-type systems that can be used in real time for control applications such as fault isolation and restoration to improve system reliability, and to coordinate VVC to reduce system losses and energy consumption.

The second major objective was to develop and integrate a system into the interoperable environment that monitors weather conditions and the receipt of outage calls in real time to detect the beginning of storm events causing electric system outages and predicts the total number of outages that will be received, looking one hour and three hours ahead using a real-time feed-forward loop. Knowing the number of outage incidents that a storm will generate early in the storm allows the utility to right-size the restoration resource sooner, which reduces time to full restoration.

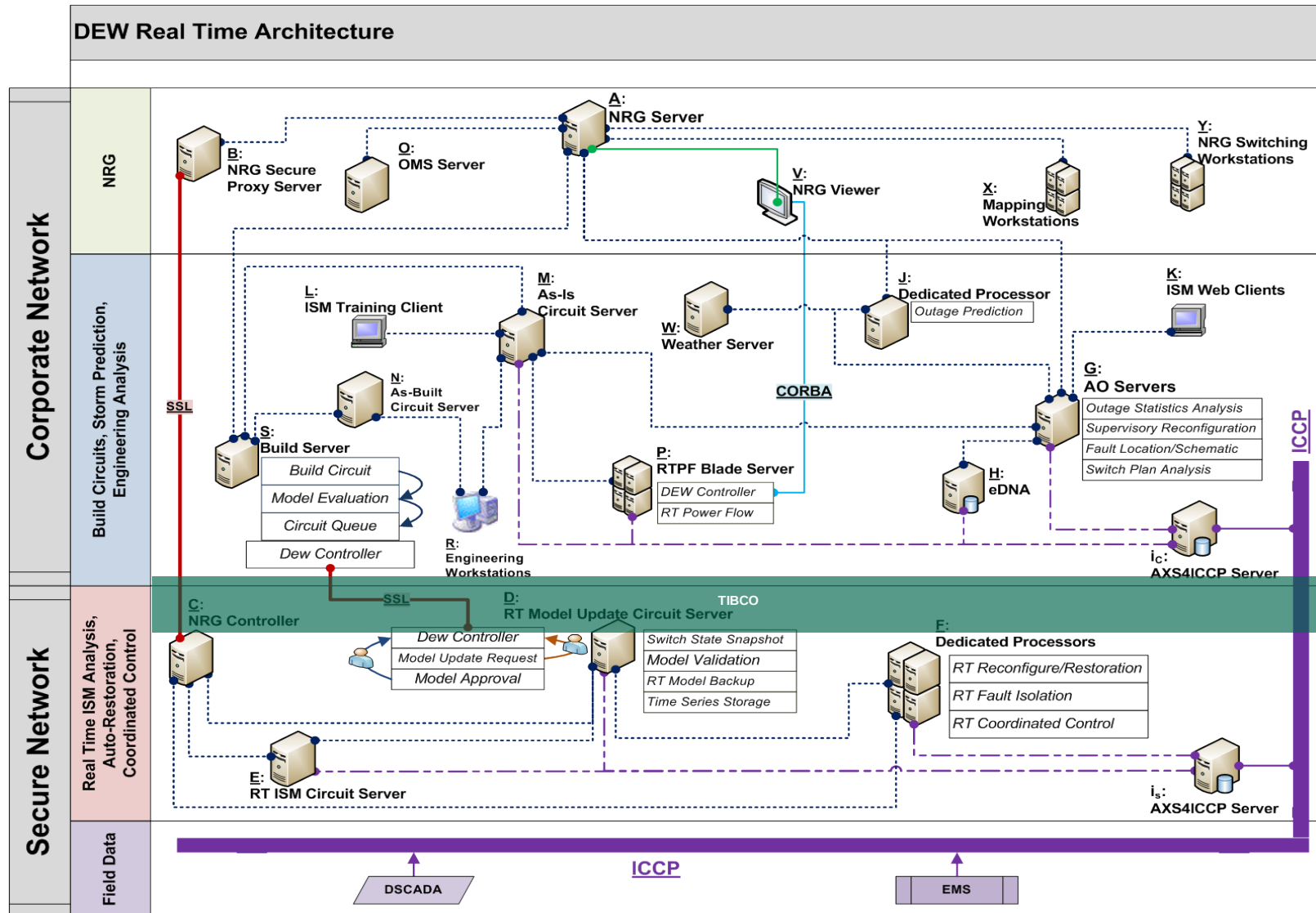
Prior to this project, O&R's system incorporated field devices such as reclosers and automated switches. The drawback to the previous configuration was that those devices could only respond automatically to preprogrammed scenarios; events outside those parameters could cause those devices to shut down. O&R's model-centric approach, built and tested on one circuit as part of this SGDP, provides real-time data from many points on the circuit, allowing more accurate depiction of power flows. This approach provides greater accuracy in understanding what is happening on the grid and allows more flexibility in adapting to non-normal operating conditions.

The work performed under this project integrated automated control systems with a detailed model of the electric distribution system known as the ISM and a fast, robust power flow analysis program known as Distributed Engineering Workstation (DEW) with a real-time Distribution Supervisory Control and



Data Acquisition (DSCADA) system to allow the fully integrated system to make and execute decisions in real time based on monitored and calculated electrical parameters and actual system conditions. Figure 4-5 shows how the ISM and control systems were integrated.

Figure 4-5. O&R ISM Architecture Diagram



New technology and equipment can easily be added to the ISM and controlled by the model-centric system through DSCADA. This allows for use of off-the-shelf equipment that does not require customization, is not limited by any proprietary protocols, and is not specific to any vendor, providing maximum flexibility.

Additionally, expansion of a model-centric control system requires minimal effort. Once the new equipment is installed in the field and communications with DSCADA have been established, setup of the control system requires only that the new device be added to the ISM. There is no scenario programming, thus simplifying the expansion process.

#### ***4-A.3.1. Auto Restoration Model-Centric Control System Demonstration***

A demonstration of the auto restoration model-centric control system in a laboratory environment using ISM, DEW power flow analysis, DSCADA, and the auto restoration model-centric control system was performed. Actual recloser control hardware was set up in the lab in a configuration matching an actual open-loop distribution circuit. The fast fault isolation and customer restoration functions of the system were demonstrated on the laboratory arrangement. Two circuits configured in auto loop configuration with midpoint and tie reclosers for automatic fault clearing, and, with SCADA operable switches between the substation breakers and midpoint reclosers and between the midpoint reclosers and the tie reclosers, were represented. The demonstration used all of the production systems, such as the production DSCADA system, actual 220-megahertz radio communications between the controls set up in the lab and a production master radio site for the DSCADA system, as well as the production back-haul communications to the DSCADA servers.

#### ***4-A.3.2. Model-Centric VVC System***

The ISM is also used as part of a model-centric dynamic VVC system. The control system reduces energy consumption through continuous dynamic optimization of voltage levels and minimizes losses through dynamic var injection. This is done by real-time coordination of voltage-regulating devices, such as the substation Load Tap Changer and distribution line voltage regulators, with var injection equipment, such as switched shunt capacitors. Using the ISM, DEW runs power flows on the system as monitored voltage and currents change in real time. This provides voltage and var requirements across the entire system. The control system then uses these real-time and calculated system parameters to optimize var injections while maintaining acceptable voltage levels as close to minimally acceptable levels as possible to enable conservation voltage reduction. It then sends control commands to DSCADA to switch and adjust the appropriate devices. The system maintains voltage at the minimal acceptable levels while supplying the necessary vars, so that efficiency through loss reduction and energy reduction through conservation voltage reduction can both be realized.

#### ***4-A.3.3. Storm Outage Detection and Prediction System***

In addition to the real-time auto restoration and coordinated VVC systems, a Storm Outage Detection and Prediction application was developed and tested. The system is designed to determine, in real time, when a storm hits the service area by monitoring weather conditions and the receipt of outages in the



Outage Management System (OMS). It then uses this information to statistically predict the number of outage incidents that will be received, looking one hour ahead and three hours ahead.

The system continuously monitors OMS in real time and adjusts its predictions, which are then visualized on a web page. Quickly being able to understand how many outage incidents will be received allows the utility to right-size its restoration effort sooner, which can significantly reduce the time to completion. This is particularly useful for storms that have no specific track, such as severe afternoon summer thunderstorms that pop up over a geographical area.

#### **4-A.4. Wireless Communication and MDM**

In 2011, Con Edison's Itron MV-90xi system's hardware and software were upgraded for fast polling in support of DR data collection requirements. Even with this upgrade, the MV-90xi implementation was not capable of gathering the interval data from the meters fast enough for the DR program requirements.

Analysis done in December 2012 to evaluate MV-90xi system capabilities showed an inconsistent and limited rate of interval meter data collection and processing of 3,000 meters/hr. maximum. This rate would result in the system only being able to support reading about 700 meters every 15 minutes. Con Edison's current DR customer base includes a total of about 1,200 meters, which is far more than the current throughput capability. For this system to support the current 1,200 meters included in the DR program, it would need to be capable of consistently collecting and then exporting the data at a rate of no less than 4,800 meters/hr. (approximately 1,200 meters every 15 minutes). Any growth in the DR program would require even higher throughput rates.

To enhance the MV-90xi system, the plan and key tasks included the following:

- Rebalancing processing across workstations to increase workstation utilization and throughput
- Rebalancing modems across communications workstations to increase workstation utilization and throughput
- Reviewing the current population of meters and ensuring the right number and type of modems match the meter population
- Implementing a line-sharing function in support of daisy-chained meters and Selcom devices to prevent collisions in calling meters managed by these devices
- Implementing XML multi-threaded file transfers between MV-90xi and the MDM to increase throughput

The MDMS project exceeded the initial goals of the project. The MDMS project did the following:

- Converted from an Oracle database (DB) to SQL server
- Completed a version upgrade of Itron's MDMS software from V 7.0 to v 8.1, allowing the MDMS to benefit from using a 64- rather than 32-bit operating system and DB.
- Upgraded the hardware configuration, increasing the DB processing capability by 500% and memory by 400%. In addition, solid-state, rather than spinning drives, were used for temporary file processing,



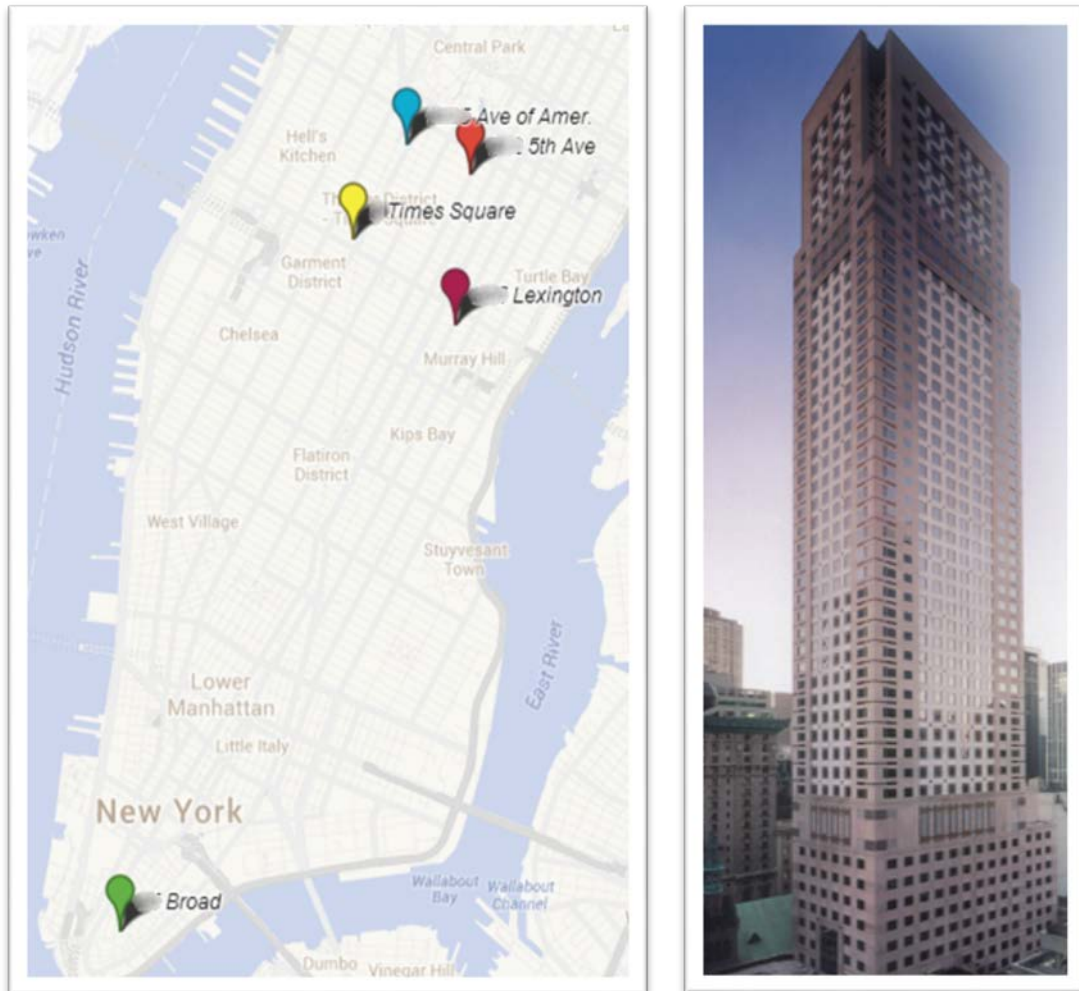


The VPower™ optimizer determines an operating schedule which minimizes costs and maximizes revenue for optimal economic operational value. The VPower™ model is validated by comparing the business-as-usual (BAU) customer baseline load (CBL) produced by the model to the metered load from the building(s) for a historical period of time, typically 30 days. The model parameters are tuned to produce a best match between the BAU CBL and the building's/buildings' metered load. The best match is obtained when the average value of the absolute value of the BAU CBL relative error for the entire validation timeframe is minimized.

Table 4-1 lists resources that were selected for inclusion in a demonstration based on the relative size of controllable, curtailable loads and their general location on the Con Edison distribution network.

**Table 4-1. DR Resources Integrated Using Viridity's System**

| Building               | Vintage                | Floors | Area (sq. ft.) |
|------------------------|------------------------|--------|----------------|
| Avenue of Americas     | 1989                   | 35     | 898,743        |
| 5 <sup>th</sup> Avenue | 1990                   | 53     | 574,857        |
| Broad Street           | 1968 (renovated: 1995) | 30     | 400,000        |
| Times Square           | 2001                   | 32     | 855,000        |
| Lexington              | 1959                   | 22     | 232,000        |



*Above: A map showing building locations and a photo of the 5<sup>th</sup> Avenue building.*

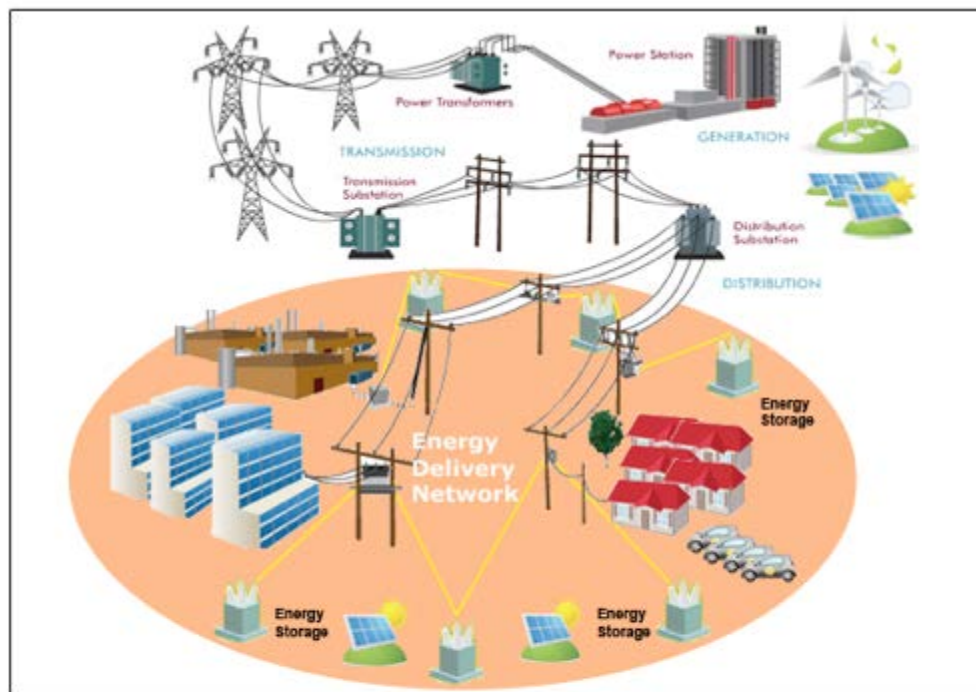
#### 4-B.2. SSGUs

Current distribution systems typically have limited ability to absorb renewable energy. Increasing EV adoption and battery capacity will further stress distribution grids. A comprehensive, distributed system of “on-the-edge” generation and energy storage will help to ensure robust reliability as the grid grows larger, greener, and more complex. This on-the-edge system consists of multiple smart energy storage

devices that are coupled with DG to augment normal grid power in an Energy Delivery Network (EDN) using SSGUs. Figure 4-7 provides schematic context for an EDN. Key features of EDNs include the following:

1. They can address isolated load pocket reliability-related issues while applying most of their capacity to peak shaving needs.
2. They can optimize DER potential in the distribution grid by modulating the intermittency of PV, effectively time-shifting supply to match peak demand. Instead of individual storage units acting in isolation, potentially increasing instability, EDNs can assist in coordinating all energy sources across the distribution grid.
3. EDNs have inherent real-time knowledge of the distribution-level energy mix which can enable shifting of discretionary load to match renewable energy supply.

**Figure 4-7. Diagram of an EDN**



**Renewable Energy, Price and Reliability Optimization Engine**

Provides:

1. Energy Storage on Edges Capacity and Command and Control
2. Balances System Needs for Reliability, Renewable Energy and Price
3. Incorporates required capability from Load Pocket management System

The SSGUs, which enable the key functionality of an EDN, are relatively small (each providing anywhere between 27 and 300 kW). Their small footprint enables rapid site approvals and installations. SSGUs consist of four main components:

- EV charging system
- energy storage system



- PV system
- System controller

These four components and their interconnection are discussed in greater detail in Appendix A.

While distributed battery storage is beneficial in and of itself, this part sub-project strove to demonstrate that SSGUs connected in an intelligent EDN can provide additional value. GCN demonstrated that a network of SSGUs can operate in unison and respond to the utility in times of need. One example of this is the ability to curtail EV charging during DR events. GCN demonstrated that distributed energy storage can be centrally controlled by the utility, enabling targeted response to dynamic grid conditions.

#### **4-B.3. DRCC**

The objective of the DRCC sub-project was to develop and demonstrate methodologies to enhance the ability of customer-sited DR resources to integrate with electric delivery companies and RTOs.

This project was composed of the following two discrete components:

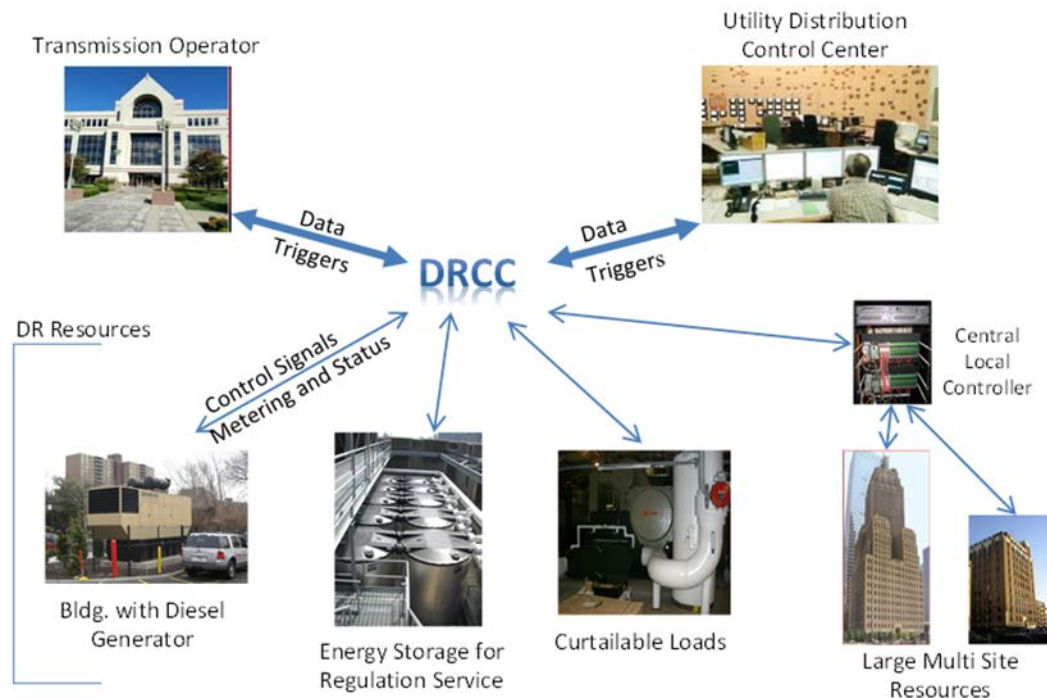
##### **DRCC**

The DRCC is designed to aggregate DR resources for activation in response to various conditions of the electric grid. This software was developed as part of an RDSI project, but a secure communications interface to the NOC was developed as part of the SGDP. This interface allowed DG to be integrated into the platform, and the functionality was tested many times throughout the project, demonstrating its technical effectiveness and ability to integrate with the broader platform. It will be utilized in a production environment to enable automatic DR for project resources. A total of 23 facilities and 20 MW of generation have been integrated into the DRCC. Figure 4-8 shows how the DRCC is positioned relative to the other grid components.

##### **Virtual Generator (VirG)**

A VirG is created by activating an aggregation of DR resources by the DRCC. This aggregated set of resources is able to supply virtual generation. A VirG is able to solve a capacity shortage on the transmission system as well as address system contingencies in electric distribution networks. Figure 4-8 illustrates the type of DR resources which may be dispatched by the DRCC. Backup power provided by standby generators is an excellent candidate to provide targeted, persistent load reduction to address network events by responding to dispatch signals from a grid operator within five minutes. In fact, the NYISO has included the concept of the VirG in its Reliability Needs Assessment as a potential solution to anticipated regional shortages of capacity.

Figure 4-8. Diagram of DRCC Configuration



#### 4-B.4. PV, Battery Storage, and BMS Integration

The NYCEDC completed construction of a SG system at their BAT site, which integrated three main components: 1) a 100-kW solar PV array, 2) a BMS, and 3) a 720-kWh battery for on-site energy storage capable of delivering 100 kW for four hours. The project demonstrated the benefits of on-site renewable energy generation coupled with energy storage and management systems to reduce demand on the grid, offset energy costs, and advance the City's PlaNYC<sup>3</sup> sustainability objectives by reducing GHG emissions associated with energy generation and use. Additionally, the project findings will benefit the industry as a whole by sharing lessons learned and best practices to support acceleration across New York City.

Construction at the BAT began in January 2013. In addition to the installation of the PV and battery systems, a battery room was constructed to house the battery cells. The battery room was designed to meet fire code and building code requirements, provide structurally sufficient flooring, and to accommodate the valve-regulated lead-acid battery technology. The room features a Heating, Ventilating, and Air Conditioning (HVAC) system, hydrogen gas detection and alarm system linked to an outside exhaust system, fire-rated walls, structural improvements to the battery room floor, acid-resistant flooring, a pre-activated dry sprinkler system, and a tempered safety shower and eye bath. An on-site controller allows for direct control and programming of the battery inverter, which is also controlled through the BMS, located on the first floor in the building's operational offices. The solar PV

<sup>3</sup> PlaNYC is the NYC Office of Long-Term Planning and Sustainability's blueprint for resiliency and sustainability within NYC. For more information, see: <http://www.nyc.gov/html/planyc/html/home/home.shtml>

system was commissioned in August 2013, and has produced over 61 megawatt-hours of electricity through April 2014, averaging approximately 6.8 megawatt-hours per month. The integrated battery and BMS system was commissioned in October 2013.

#### 4-B.5. Streamlined PV Design and Build

In 2013, Con Edison contracted Gehrlicher Solar to install a 40-kW alternating current (AC) solar PV installation at Con Edison's 4 Irving Place headquarters (Figure 4-9). Con Edison believes that by integrating this installation into the project, we gain hands-on experience with the process of installing equipment on NYC commercial building rooftops. This project was unique in that this behind-the-meter solar installation was completed atop a 19th-story roof of a NYC landmark building

**Figure 4-9. PV Installation on Con Edison's Headquarters**



The installation began in November of 2013 and was completed in January 2014. The main challenges included logistics and the weather. This building has a highly utilized loading dock. Extensive planning was necessary to reserve the loading dock, find adequate staging areas needed for the work location, and to plan the work to limit the amount of noise affecting building tenants. The harsh weather that NYC faced that year also added to the length of the project. Given those challenges, Con Edison believes that this was representative of a worst-case situation and yet, was still a successful installation.

- All permits and approvals were received from local authorities having jurisdiction (AHJs) including NYC Department of Buildings, Environmental Control Board (for electrical review)

and inspection), Landmarks Preservation Commission, and Con Edison's DG department for utility interconnection.

- The PV system was successfully installed, inspected, and commissioned. It is currently operating at its full capacity.

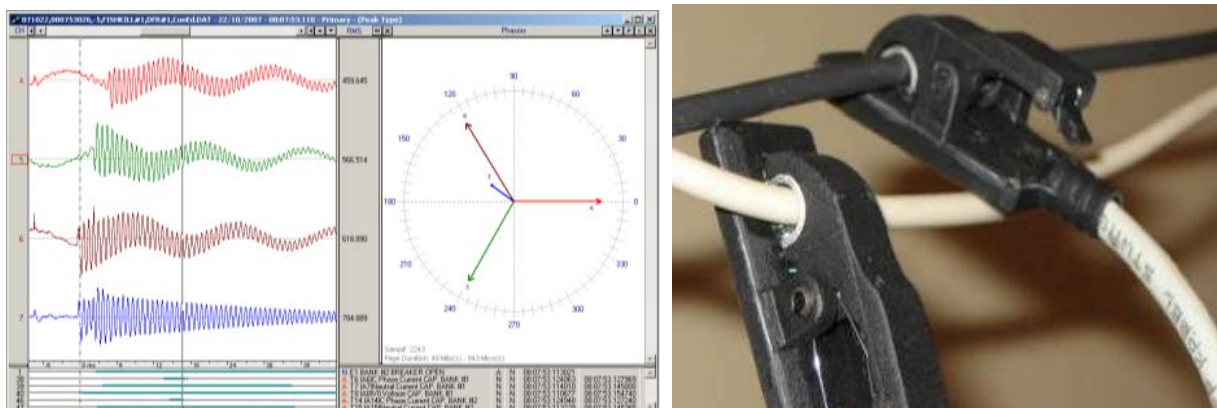
## 4-C. Optimization and Control

### 4-C.1. SGDM

Traditional power system disturbance monitors are effective but are costly to deploy (in and especially beyond the substation environment). The main reason is that traditional monitors are not deployable on live circuits. Utilities have to plan and schedule outages prior to deployment. To eliminate the need for such outages, a Con Edison, Softstuf collaborative effort resulted in the invention of low- cost, patent-protected monitoring technology that is just as effective as traditional methods but that can also be deployed on live circuits. The new technology uses small, non-intrusive sensors that clip on electrical circuits without disrupting equipment, which provides the added benefit of rapid deployment, thus allowing utilities to achieve timely compliance with regulatory requirements. A picture of sensor (right) and its output (left) is shown in Figure 4-10.

Furthermore, legacy protection relay systems do not provide sufficient data for fault analysis because they are mainly composed of analog devices (electro-mechanical). The lack of sufficient data limits the utility's ability to determine root causes and mitigate risks of pending or actual failures. Most of the U.S. power grid, especially nuclear power plants, continues to be based on analog devices though a SG demands digital input for quick analysis and diagnosis. Utilities are therefore forced to replace their legacy relays with modern digital relays (even if the legacy relays still have useful life and do not require replacement). The new sensors offer an alternative solution that allows legacy relays to stay in place, while providing the additional monitoring capability featured in the latest digital relays. Supplementing legacy infrastructure with new, non-intrusive sensors can make legacy substations similar to modern substations with digital relays. The sensors help increase grid reliability and extend the lifetime of critical assets. Utilities may use these sensors to tune protection systems, extend maintenance and testing cycles, expose faulty wiring, and identify good/bad relay operations. The net balance is a more reliable grid at a lower operational cost.

**Figure 4-10. Clip-on Sensor with Three-phase Disturbance Monitor Traces**



The DOE SG funding through Con Edison supported the Softstuf task of producing and delivering a SGDM based on the new sensors technology. The SGDM is composed of over 4,000 sensors, a small array of concentrators powerful enough to process high-speed data (microsecond rate) from all of the sensors simultaneously, and an expert system smart enough to rank and report upon discovery of pending or incipient failures. Con Edison undertook the task of deployment of the SGDM at a major 345-kV substation to monitor performance of critical equipment under power system fault and disturbance conditions (such as transformers, breakers, and protective relay systems). Data from the deployed sensors is collected by the concentrators and analyzed at a central server using the expert system software. The performance of the SGDM during a number of real-life power system disturbances successfully demonstrated its effectiveness in discovery of events and cataloging of fault signatures based on targets, fault magnitude, and duration. The disturbances included reporting on a major 345-kV transformer event, a phase angle regulator fire, and Hurricane Sandy.

The project activities were multifold and proceeded in parallel. The main focus was on building the simulator, delivering the sensors and supporting hardware, and installing the SGDM software on the central server.

#### ***4-C.1.1. Simulator***

The simulator, representing a substation with three feeders, was designed and assembled at the Softstuf Lab at 333 Bainbridge Street in Philadelphia. The feeders are a ring bus mimic two analog schemes (electromechanical protection) and one digital scheme (numeric relay). The simulator is equipped with a state-of-the-art, three-phase current/voltage injection test set and includes sensors, concentrators, a server with the SGDM software, and a breaker simulator mounted in a panel to mimic a substation control board.

The simulator and test set were used for application of various types of fault and disturbance conditions including balanced and unbalanced faults (phase-to-phase and phase-to-ground faults) designed to challenge both the sensors and the developed software. The simulator and test set were invaluable in demonstrating the features of the SGDM, which are not easily done on service equipment because fault occurrences are unpredictable by nature.

#### ***4-C.1.2. Sensors and Infrastructure***

Sensors were produced and delivered to Con Edison within the first three months of the project start. The required infrastructure was also procured and delivered along with the sensors. The required infrastructure included 100 sampling units, 40 network switches, four data concentrators, and other supporting components such as cables, connectors, and power supplies.

The sensors connect to the sampling units, which broadcast their measurements through the switches to the data concentrators. The data concentrators process the incoming measurements at the microsecond level and generate waveform captures of any detected fault or disturbance signatures. The captures include both pre- and post-fault measurements and are transmitted to the central server upon occurrence (report by exception).

#### 4-C.1.3. Central Server

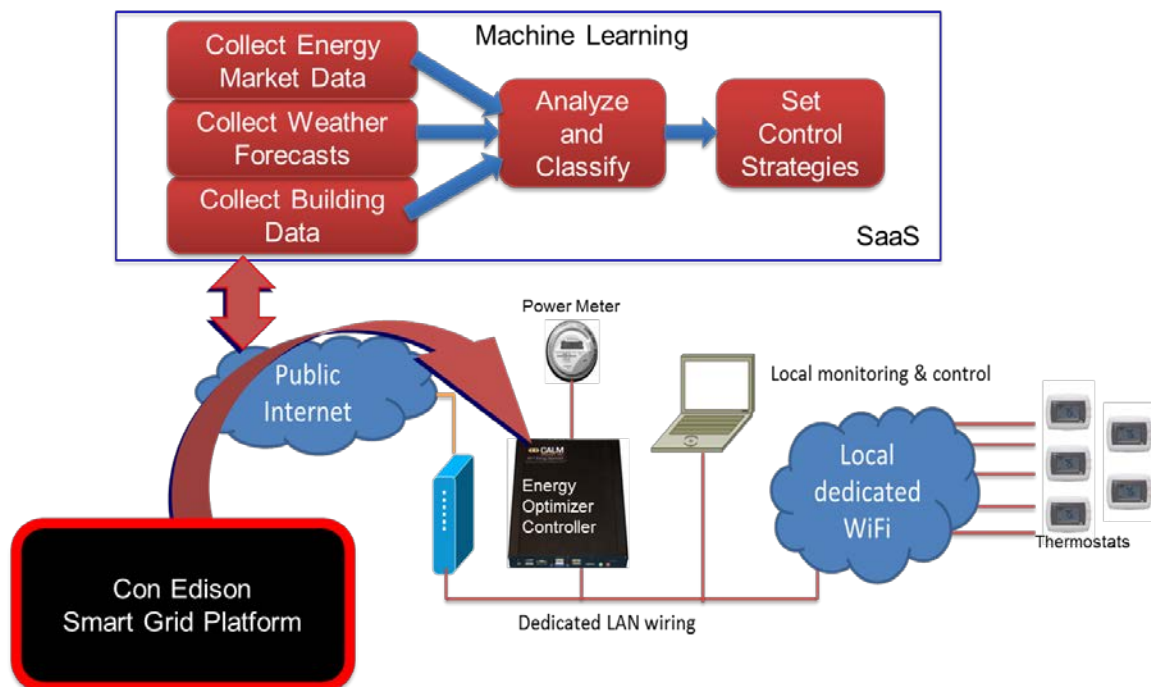
The server was provided by Con Edison and Softstuf was given secure access to remotely deploy, monitor, and refine the performance of the software. The software was successfully deployed, the performance was monitored for an extended period, and the software was then refined accordingly. The software receives sensor data captures from the concentrators in the field and includes an expert module designed to organize the sensor data based on monitored circuits and time of fault occurrence. The software also includes an adaptive engine that processes and ranks the data captures based on fault magnitude, duration, and targets. A number of additional interfaces are also provided for manual diagnostics and visual purposes, including sequence-of-events reports and three-phase metering displays.

#### 4-C.2. Energy Optimizer Controller and ISM

The business case for deployment of the CALM ISM Decision Aid platform was to help prevent cascading area station or sub-transmission feeder incidents. The ISM Decision Aid supports this incident prevention by predicting in advance vulnerabilities of overloaded equipment and providing recommended preemptive, targeted actions to take, like DR, to mitigate the potential incident.

The specific goal for the CALM sub-project was to develop and demonstrate the ISM decision aid platform. The objective was to then validate its value in a real-world electric grid operational environment. The ISM Decision Aid platform was not connected to the Con Edison SG DERMS platform. It was successfully developed and demonstrated using offline data.

**Figure 4-11. Diagram of the Energy Optimizer Controller Built by CALM**



CALM's demonstrated technology included the following:



- ISM Decision Aid platform for use by T&D control center operators
- Building smart node energy optimization controller

#### **4-C.3. DTC and LSOC**

CCLS was responsible for developing ASCs to assist distribution system operations in optimizing decisions about maintenance actions. The ASC used a sophisticated set of algorithms to determine the optimal action.

An alpha version of the DTC was developed to provide recommendations for which operator actions should be implemented. For example, actions on the secondary grid to improve reliability could include repair of open mains or closure of network protector switches. Colombia also developed various visualization tools to inform operators of recommended actions.

The LSOC was intended to provide real-time recommendations for curtailing load when the grid is stressed in order to drive the SG to fewer failures and more efficient delivery of power. Additionally, feedback would be provided to the LSOC of constantly changing grid conditions so that the LSOC could continually simulate multiple future variants and select optimal recommendations to the operator. These algorithms incorporate disparate data, such as pricing information, system loads, weather, and the impact of proposed actions on future flexibility to respond to system conditions.

The LSOC was an approach to recommending curtailable loads to DOs. It aimed to achieve more precise, targeted curtailment of customers considering most likely events and not just worst events. It does so by optimizing a load balancing objective function across hundreds of possible future situations (with their power flows) whose possibilities are delineated by the uncertainties in load and feeder failure rates 19 hours into the future. The curtailment policy (set of customers to be curtailed) it suggests is robust in that it attempts to cover many possible situations with its prioritization of customers to curtail.

The LSOC optimizes the curtailment recommendations given to the operator. It optimizes these recommendations based on a future looking 19 hours ahead considering what might happen in the network based on load being driven by weather forecast, and also based on forecast on the feeder failure rates. It displays these recommendations sorted (descending) by curtailable amount and highlighted along with all the possible curtailable customers in the network to the DO and gives the operator the choice to select those or entertain other possible selections. The DO is presented with charts that describe the performance of the choices compared to a simple selection of all possible curtailable loads (baseline). Auxiliary screens present details of cable sections and transformers that are overloaded. A demonstration of the LSOC was conducted in March, 2012.

#### **4-C.4. IDSM Potential Model**

Since 2004, Con Edison has operated the TDSM program focused on deploying customer sided EE for demand reductions in constrained electric networks. With a focus on system and cost management, along with the growth in EE and DSM technology and associated customer strategies, Con Edison recognized the need for increased visibility into customer and technology potential and economics on the demand side. To address this need, Con Edison, along with E3 and Navigant, have created the IDSM



Potential Model, a dynamic, geographically specific, and technology-integrated analysis tool to assess the market potential and economics of EE and DSM for cost-effective deferral or avoidance of capital expenditures required to meet growing customer demand.

The IDSM model was developed to evaluate Con Edison electric networks for demand-side market potential and economics. The model can evaluate individual electric networks, groups of networks, whole boroughs/counties, and the entire system, depending on the needs of the company. The initial model contains eight of Con Edison's 82 networks/load areas, and will be scaled up to include all networks over time (starting with the most near-term constrained networks). Flexibility and usability have been built into the model via standardized input data templates, which will enable easy updates as new customer, technology, and market data are developed or gathered. The model will allow for better and more detailed customer engagement by outputting EE and DSM potential at the technology and customer segment level, specific to the geographic areas in question. Model outputs also include cost-effectiveness testing based on user selections to ensure solution cost-effectiveness. The model outputs will be evaluated by EE and DSM staff to assess the feasibility of deploying TDSM to defer specific capital infrastructure needs and inform go-to-market strategies (e.g., evaluation of vendor proposals via competitive Requests for Information [RFIs] and Requests for Proposals [RFPs]). Con Edison will be using the project model immediately following its completion (September 2014) to evaluate market-proposed TDSM solutions aimed at relieving electric constraints in Brooklyn and Queens.

## 5. Conclusions

The Con Edison SGDP provides the fundamental building blocks for Con Edison to efficiently and flexibly respond to current and future reliability, environmental, and regulatory drivers. This section summarizes the major accomplishments of the project, the key takeaways, and the implications that the project's learnings and accomplishments have for future operations of Con Edison's system, as well as other electricity delivery systems across the country.

### 5.1 Major Accomplishments

The SGDP successfully demonstrated that the secure integration of enhanced monitoring and control capabilities with intelligent analytical tools can improve the management of the distribution grid and enable greater deployment of renewable energy resources and SG technologies.

In this project, Con Edison worked on SG technology that can improve the management of the Distribution Grid through a combination of enhanced monitoring and control capabilities along with intelligent analytical tools. Con Edison demonstrated that it can integrate a number of existing legacy control and data systems along with new SG applications in a common, cyber-secure, interoperable control platform. This enabled Con Edison to demonstrate seamless integration and control of renewable energy resources and SG technologies, such as EV charging stations, DG, and BMS.

The successful integration of the underlying technologies was verified through a series of live demonstrations conducted by Con Edison and its partners. A DERMS was developed which includes a visualization platform that provides DOs with a wide-area situational view of the interconnected SG distributed resources and displays available resources within a network that can be utilized to relieve specific grid load constraints. The DERMS platform was integrated with third-party control centers.

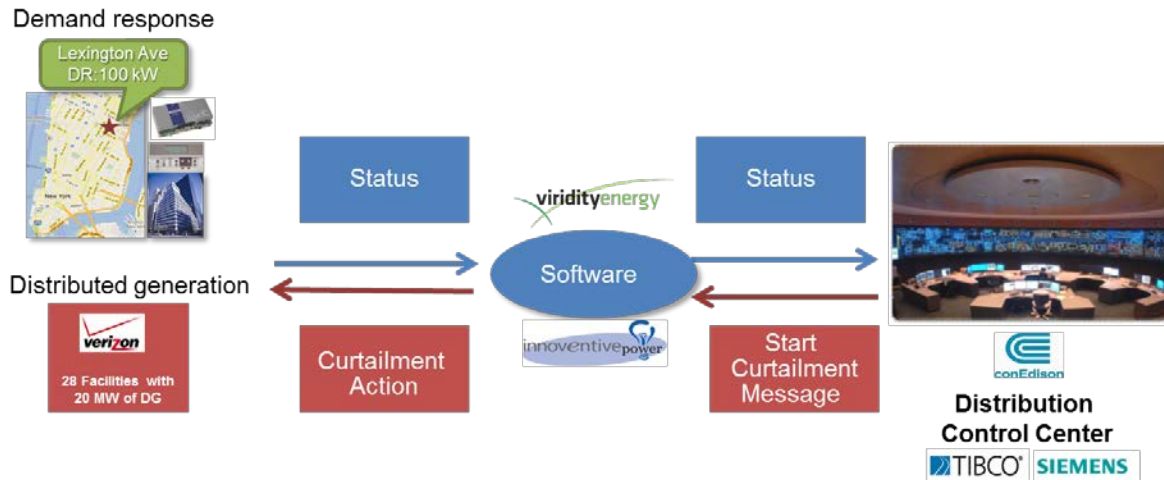
These third-party control systems have the ability to manage specified customer equipment, allowing for things such as load reduction using existing BMS or starting customer-sited DG to relieve localized system needs. From the DERMS platform, operators have the capability of visualizing near real-time customer load information associated and curtailment capacity available from customer-sited distributed and DR resources. The platform was developed with an integrated decision aid tool that can make recommendations as to which demand resources can meet the need of a specific constraint. The tool also enables the DO to see the near real-time impact of a DR resource once it has been activated. The integration of the decision aid tools enables targeted DR.

Targeted DR allows DO to alleviate a particular distribution feeder overload condition by calling upon the distributed resources that can effectively reduce the overload, thus improving overall grid reliability.

In addition to the DERMS platform, a DRMS was implemented as part of the project to more efficiently manage the enrollment, event notification, settlement, and reporting processes associated with Con Edison's DR programs. The DRMS will automate many of these processes, enabling them to be completed more efficiently and at lower cost.

The DERMS and DRMS platforms are two parts of the SGDP that will help Con Edison manage the integration of DR resources.

**Figure 5-1. Increased Visibility of DR and DG through Systems Integration**



**Integration of SG Applications and Resources:** As a result of the SGDP, Con Edison is now capable of monitoring and communicating with a variety of SG resources, including the following:

- BMS
- DG
- EV Charging Stations
- Aggregator Network Operation Centers

The DERMS visualization platform also provides DOs with a wide-area situational view of the interconnected SG distributed resources and their availability to relieve specific grid load constraints. To date, the following have been mapped to the visualization platform:

- All 64 networks in Con Edison's service territory
- All 774 enrolled distribution load relief DR program sites and an additional 400 SG DER sites (including solar sites)
- Ongoing effort to include additional DR sites and EV charging sites

Additionally, approximately 500 Digi and 15 Ambient nodes were deployed to support the enhancement of communications between interval meters and Con Edison's MV-90 and MDMS.

The project team developed and implemented protocols for integrating project-related resources and applications in a cyber-secure manner. This approach will be replicated when integrating resources and applications in the future.



**Additions to Project Scope:** Over the course of the project and with appropriate approval from the DOE, Con Edison took advantage of opportunities to enhance or improve upon the original scope of the project in the following ways:

- Viridity expanded their scope from the integration of five buildings to 23 buildings, due to their early success in the project.
- The DRMS sub-project, provided by Alstom Grid, was added in order to provide DR program management and customer visibility.
- Con Edison added an IDSMP Potential Study which will serve as a comprehensive platform to expand Con Edison's TDSMP program, improve capital decision-making, support ongoing efforts to further build DR capability, and establish a set of new programs to maximize both system and customer benefits by network, segment, and building type.
- The Wireless Communications and MDM project was added as an essential element for success of the DRMS project.
- Additional GCN battery storage units at Walgreens and UPS
- 40-kW solar panel installation at 4 Irving Place
- Mapping and integration of DR and DG resources across entire distribution network with the DERMS system

**Realization of Project Objectives:** The SGDP accomplished each of the project objectives outlined in Section 2.2 and demonstrated these capabilities through six iterative and cumulative demonstrations performed over the course of the SGDP. These six demonstrations built upon the learnings of the previous demonstrations to ultimately accomplish all project objectives, and culminated in a final capstone demonstration performed by Con Edison for the DOE on July 15, 2013.

Table 5-1 gives examples of how each project objective was realized, by which sub-project and which demonstration.

**Table 5-1. Completion and Demonstration of the Project Objectives**

| Project Objective                                                                     |                                                                                              | Objective Achieved by: |   |   |   |   |   | Demonstration |     |     |     | Sub-project |     |     |     |     |     |     |     |     |  |
|---------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|------------------------|---|---|---|---|---|---------------|-----|-----|-----|-------------|-----|-----|-----|-----|-----|-----|-----|-----|--|
|                                                                                       |                                                                                              | 1                      | 2 | 3 | 4 | 5 | 6 | A.1           | A.2 | A.3 | A.4 | B.1         | B.2 | B.3 | B.4 | B.5 | C.1 | C.2 | C.3 | C.4 |  |
| 1. Improve control capabilities for existing grid assets                              | DERMS visualization functionality                                                            | x                      |   | x | x | x | x | x             | x   | x   |     | x           |     | x   |     |     | x   | x   | x   |     |  |
| 2. Determine how to best apply newly developing technologies                          | Architecture, technology, and systems integration in conjunction with industry standards     | x                      | x | x |   | x | x | x             | x   |     | x   | x           |     | x   |     | x   | x   |     |     | x   |  |
| 3. Minimize peak load growth                                                          | DERMS visualization, customer site system monitoring, and third-party service provider NOCs  | x                      |   | x |   | x | x | x             | x   |     |     | x           |     | x   |     |     |     |     |     | x   |  |
| 4. Improve grid reliability                                                           | DERMS interoperability between distribution system operations and DERs                       | x                      | x | x | x | x | x | x             |     |     | x   | x           |     | x   |     |     | x   | x   | x   | x   |  |
| 5. Provide customers with greater visibility, flexibility, and value                  | Third-party service providers                                                                | x                      |   | x |   | x | x |               |     |     |     | x           |     | x   |     |     |     |     |     |     |  |
| 6. Leverage controllable field assets that provide targeted load reductions, such as: | Third-party service providers                                                                | x                      |   | x | x | x | x |               | x   |     |     | x           |     | x   |     |     |     |     |     |     |  |
| <i>curtailable customers</i>                                                          | SGDP curtailment functions, third-party service NOC, customer sites                          | x                      |   | x | x | x | x | x             | x   |     |     | x           |     | x   |     |     |     |     |     |     |  |
| <i>customer-owned switches</i>                                                        | Third-party service providers and control interfacing                                        |                        | x |   |   |   | x |               |     |     |     |             |     | x   |     |     |     |     |     |     |  |
| <i>DG</i>                                                                             | SGDP technology services framework, visualization, engineering analysis, load flow extension |                        |   | x | x | x | x |               |     |     |     |             |     | x   |     |     |     |     |     |     |  |
| <i>battery storage</i>                                                                | Customer battery storage monitoring                                                          | x                      |   | x | x | x | x |               |     |     |     |             | x   |     | x   |     |     |     |     |     |  |
| <i>EV charging stations</i>                                                           | Third-party service providers and control interfacing                                        | x                      |   | x | x | x | x |               |     |     |     |             |     | x   |     |     |     |     |     |     |  |

| Project Objective                                                                   | Objective Achieved by:                                      | Demonstration |   |   |   | Sub-project |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
|-------------------------------------------------------------------------------------|-------------------------------------------------------------|---------------|---|---|---|-------------|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| <i>BMS</i>                                                                          | Third-party service providers and control interfacing       | x             | x | x | x |             |   |     |     | x   |     |     |     |     |     |     |     |     |     |     |
| <i>HANs</i>                                                                         | Third-party service providers and control interfacing       | x             | x |   | x | x           |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| <i>high-voltage monitoring</i>                                                      | SGDP integration with high-voltage meters                   |               | x |   | x | x           |   |     |     |     |     |     |     |     |     |     |     |     |     |     |
| <i>AMI</i>                                                                          | SGDP Services and improve MDMS                              | x             |   |   | x | x           |   | x   |     |     |     |     |     |     |     |     |     |     |     |     |
| 7. Decision Aids                                                                    | Modeling and control decision aides and DERMS visualization | x             |   | x |   | x           | x |     | x   |     |     |     |     | x   | x   | x   | x   |     |     |     |
| 8. Integrate legacy applications, sensory data, and decision aids to the middleware | DERMS and TIBCO middleware                                  | x             | x | x | x | x           | x | x   | x   |     |     |     |     |     |     |     |     |     |     |     |
| 9. Integrate data from system sensors and control functionality with the middleware | DERMS and TIBCO middleware                                  | x             | x | x | x | x           | x | x   | x   |     | x   | x   |     |     |     |     |     |     |     |     |
| 10. Conduct an Operational Readiness Review prior to each demonstration             | <i>completed prior to each demonstration</i>                | x             | x | x | x | x           | x |     |     |     |     |     |     |     |     |     |     |     |     |     |
|                                                                                     |                                                             | 1             | 2 | 3 | 4 | 5           | 6 | A.1 | A.2 | A.3 | A.4 | B.1 | B.2 | B.3 | B.4 | B.5 | C.1 | C.2 | C.3 | C.4 |



**Public Outreach:** Con Edison leveraged the SGDP as a platform for raising public awareness of the SG and its implications for utility customers. Con Edison's Public Affairs department worked with the Smart Grid Implementation Group to create public awareness of SG in Con Edison's service area through broadly disseminated communications and messaging, as well as targeted communications to the communities most affected by visible installations. Con Edison's outreach efforts are cited and linked below:

### Community Engagement

- Developed a clean-tech curriculum as part of a Solar1 initiative that includes SG technologies. (Independent of the SGDP)
- Young Men's Christian Association (YMCA) presentation by R&D – SG model for high school students
- Video of Solar Project at 4 Irving Place- and press releases
- SG animation on YouTube (more than 20,000 views) [https://www.youtube.com/watch?v=QPWCCz\\_OTGU](https://www.youtube.com/watch?v=QPWCCz_OTGU)

### Press Releases

- Con Edison Releases SG Animation: <http://www.coned.com/newsroom/news/pr20100701.asp>
- Additional \$45 Million in SG Stimulus Funding: [http://www.coned.com/newsroom/news/pr20091124\\_2.asp](http://www.coned.com/newsroom/news/pr20091124_2.asp)
- \$136 Million in SG Stimulus Funding <http://www.coned.com/newsroom/news/pr20091027.asp>
- Senator Gillibrand Pushes For SG Funding: <http://www.gillibrand.senate.gov/newsroom/press/release/gillibrand-pushes-for-smart-electric-grid-funding-for-new-york-federal-dollars-would-lower-energy-costs-in-hudson-valley>
- NYISO Press Release – Phasor Measurement Unit (PMU) Project attended by P. Hoffman October 2012
- Con Edison Installs PV Panels on Historic NYC

Headquarters <http://www.coned.com/newsroom/news/pr20140421.asp>

- Con Edison SG Initiative <http://www.coned.com/publicissues/smartgrid.asp>

### Media Coverage

- US Electricity blackouts skyrocketing <http://www.cnn.com/2010/TECH/innovation/08/09/smart.grid/index.html>
- "They'll rays the roof in B'klyn" <http://nypost.com/2010/11/22/theyll-rays-the-roof-in-bklyn/>
- SG Illuminates New York's Underground <http://www.smartplanet.com/blog/intelligent-energy/smart-grid-illuminates-new-yorks-underground/>
- Con Ed Tests a SG in Queens <http://cityroom.blogs.nytimes.com/2009/08/05/con-ed-tests-a-smart-grid-in-queens/>
- Con Ed testing a \$6 million pilot SG program in Queens neighborhoods hit by blackout <http://www.nydailynews.com/new-york/ed-testing-6-million-pilot-smart-grid-program-queens-neighborhoods-hit-blackout-article-1.394171>

### Professional Conferences and Events

- Con Edison recognized at the 4th Annual Network Grid Event as being among the top 10 Distribution Automation projects in the country
- Presentations at GridWeek in 2011 and 2012

- Presentation on Demonstration and Investment Grant Projects at Distributech 2012
  - Institute for Electric Efficiency (IEE) – March 2011- SG Model Display and Smart Grid Investment Grant (SGIG)/ Demonstration Project Overview (SG-Powering the People Innovations)
  - American Association for Blacks in Engineering (AABE) conference in Jersey City –April 2011 -SG Model Display and SGIG/Demonstration Project Overview
  - Mid-Atlantic Conference for Regulatory Utilities (MACRUC) - Utility Commissioner event – SG Model Display and Project Overview Hershey Penn- June 2011
  - Edison Electric Institute (EEI) Board Meeting at Waldorf Astoria Conference (Sept. 6 – Sept. 8, 2011)
- Institute of Electrical and Electronics Engineers (IEEE) Presentation (2-25-2012, Washington, DC)
- SG Peer Review (6-8-2012, San Diego, CA)
  - Electric Utility Consultants, Inc. (EUCI) Conference (9-19-2012 – Philadelphia, PA)
  - SICA (Atlanta, GA Spring 2013)
  - Technically Speaking Seminar Presentations August 2011 and August 2013. Continuing Education Credits received by attendees.
  - Stevens Institute/ Burns & Roe employee Presentation – SGIG and Demonstration Projects - March 2014 for Continuing Education Credits
  - EEI Building Integration Conference – Presentation on SGIG projects and Demonstration Projects (June 2013)
  - Advanced Energy Conference April SG Projects (April 2013 and May 2014)
  - DOE Demonstrations attended by the DOE (March 27, 2012 and July 15, 2013)
  - Partnership to Advance Clean Energy – Development (PACE-D) delegation from India (1-21-2014 – Con Edison Headquarters)
  - IEEE Presentation with Hank Kenchington (Feb. 2014, Washington, DC)
  - DR National Forum Presentation on DERMS/DRMS (May 2014)
  - DERMS/DRMS Project presentation – Public Service Commission (Albany, NY - May 2014)
  - REV at Public Service Commission (5-28-2014 – Albany, NY)

## 5.2 Project Benefits

Table 5-2 summarizes the overall benefits realized by Con Edison through the SGDP, as a result of the project's accomplishments described above. These benefits were demonstrated throughout the project performance period and, more importantly, will continue to develop in the future as Con Edison capitalizes on the groundwork developed through the SGDP.

**Table 5-2. Summary of Project Benefits**

| Benefit                                                                                                                              | Category    | Subcategory                  | Description of Benefit Achievement                                                                                                                                                                                                                                                                                                         |
|--------------------------------------------------------------------------------------------------------------------------------------|-------------|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Capacity, Arbitrage, and Ancillary Service Revenue                                                                                   | Economic    | Market Revenue               | Viridity estimates that \$1.1 million and Innoventive estimates that \$3.7 million in additional annual income may be available to market participants as a result of the DR resources deployed through this project. Additional market revenues will likely be possible in the future as a result of this project.                        |
| Optimized Generator Operation, Deferred Generation Capacity Investments, Reduced Ancillary Service Cost, and Reduced Congestion Cost | Economic    | Improved Asset Utilization   | Although the DR and DG systems that were installed as part of this project have a relatively small impact on system generation optimization, capacity investments, and congestion costs, the supporting platforms developed during this project will ultimately enable integration of additional DERs that will improve asset utilization. |
| Deferred T&D Capacity Investments                                                                                                    | Economic    | Distribution Capital Savings | Integration of DR and DG resources and the associated control and visualization systems will allow Con Edison to defer distribution capacity investments.                                                                                                                                                                                  |
| Reduced Equipment Failures                                                                                                           | Economic    | Distribution Capital Savings | Through load reduction using targeted DR and advanced equipment failure monitoring, Con Edison can minimize potential failures and damage associated with transformer and feeder overloads.                                                                                                                                                |
| Reduced Meter-Reading Costs                                                                                                          | Economic    | Distribution O&M Savings     | The wireless metering project has improved communication for meter reading on over 1,000 meters, resulting in approximately \$2 million dollars per year of operational savings.                                                                                                                                                           |
| Reduced Electricity Losses                                                                                                           | Economic    | Energy Efficiency            | Integration of DERs using the DERMS and DRMS platforms has reduced line losses, resulting in energy savings.                                                                                                                                                                                                                               |
| Reduced Electricity Cost                                                                                                             | Economic    | Electricity Cost Savings     | Customer-sited generation and storage units reduced customer peak capacity payments.                                                                                                                                                                                                                                                       |
| Reduced Sustained Outages                                                                                                            | Reliability | Power Interruptions          | Enabling DR and DG using DERMS will lead to fewer sustained outages.                                                                                                                                                                                                                                                                       |

| Benefit                                                                             | Category      | Subcategory         | Description of Benefit Achievement                                                                                                                                                                  |
|-------------------------------------------------------------------------------------|---------------|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Reduced Major Outages                                                               | Reliability   | Power Interruptions | The enhanced O&R distribution equipment controls will reduce the number and frequency of major outages.                                                                                             |
| Reduced Restoration Cost                                                            | Reliability   | Power Interruptions | Root cause and equipment failure analysis systems implemented by Softstuf will reduce overall restoration costs.                                                                                    |
| Reduced CO <sub>2</sub> , SO <sub>x</sub> , NO <sub>x</sub> , and PM -2.5 Emissions | Environmental | Air Emissions       | Enabling renewables, reducing reliance on emissions-intense peaking generators, and reducing the number of truck rolls and labor for meter reading all have reduced emissions.                      |
| Reduced Oil Usage                                                                   | Environmental | Security            | The immediate impact of this project on oil usage has been minimal, but the platforms developed and implemented will ultimately allow for increased renewables integration and oil usage reduction. |

### 5.3 Key Takeaways

The SGDP has provided a number of key takeaways that can be leveraged to the benefit of future projects as some of the technologies and approaches move towards commercialization and broader deployment. The key takeaways come in the form of *challenges* encountered and *lessons learned*. Some of these takeaways pertain to the entire project, while others are specific to sub-projects. Thus, they have been organized into overall project and sub-project specific sections below.

#### 5.3.1 Overall Project

Overall project takeaways rise to the level of importance across the entire project, spanning all sub-projects, and thus can be thought of as the “meta-lessons” from the overall SGDP. These takeaways fall into the areas of project management, technical, and customer engagement.

**Project Management:** SG projects by definition involve a complex set of technologies, functions, and stakeholders. The complex planning and interplay between the parties leads to project management challenges.

- *Challenge:* Establishing and maintaining a focused strategy with achievable and measurable goals, is a complex undertaking that should not be underestimated.
  - *Lesson Learned:* Detailed scope of work and requirements are critical to successful integration projects. This may seem obvious, but it cannot be emphasized enough.
- *Challenge:* Keeping the project on track despite the replacement of the proposed middleware provider/system integrator. The middleware provider/system integrator did not start work until August 2011, approximately 20 months following project kick-off.

- *Lesson Learned:* Unexpected events or changes can and will affect project schedules and outcomes, and a project management approach must be in place to deal with the unexpected.
- *Challenge:* Enforcing compliance with technical standards that are constantly evolving can be difficult and cause ripple effects across project components.
  - *Lesson Learned:* Project plans should allow for monitoring of key standards and should build in flexibility to accommodate evolving standards.

**Technical:** Integrating disparate technologies, both new and legacy, creates multiple challenges that must be overcome. It also presented certain opportunities.

- *Challenge:* Integrating equipment into Con Edison's operations required a great deal of flexibility. Despite vendors' claims, their equipment and software do not always work exactly as described.
  - *Lesson Learned:* Laboratory testing of vendors' products is critical to the success of the project. On-site laboratory testing has found and eliminated a number of undisclosed issues that would have prevented successful operations.
- *Challenge:* Identifying and integrating data from multiple systems and sources within the enterprise is complicated. In most cases, data resides within silos and bringing these silos together requires a clear understanding of the data as well as the purpose for integrating the data.
  - *Lesson Learned:* Integrating this disparate data requires access to SMEs of the disparate system and an overarching understanding of how to bring this data together to present in a unified manner.
- *Opportunity:* As a demonstration project, the objectives included learning about the barriers that private-sector project developers would face in leveraging new technologies. In particular, integrating storage was a key goal.
  - *Lesson Learned:* Among those identified is that particular battery chemistries do not yet have local permitting guidelines, so project developers must consider both performance and regulatory readiness in selecting technologies.
  - *Lesson Learned:* Existing power system design specifications do not readily allow battery generation. For example, integrating battery storage required the use of a reverse power relay for safe operation, which was not anticipated initially.

**Business:** Business and financial challenges continue to exist, even though the American Recovery and Reinvestment Act of 2009 (ARRA) funding provided a significant boost in these areas.

- *Challenge:* The cost and overhead required for project compliance was significant, and should not be underestimated. Significant cost-share commitments often hamstringing small businesses.
  - *Lessons Learned:* Fortune 500 companies are interested in reducing energy costs and GHGs. 7-Eleven, Avis, and Whole Foods all committed significant money (\$250,000+ each), time, and resources to partner with GCN on this ARRA project. These companies are interested in being on the forefront of the energy revolution.

- *Challenge:* Existing DR programs do not readily measure the impact response, as well as other limitations.
  - *Lessons Learned:* DR programs can be significantly enhanced through application of new SG technologies, as illustrated in Table 5-3.

**Table 5-3. Potential Enhancements to Con Edison's DR Capabilities**

|                                            | <b>Current Demand Response</b> | <b>Demonstration</b>                      |
|--------------------------------------------|--------------------------------|-------------------------------------------|
| <b>Visibility into location on network</b> | • Limited                      | • High                                    |
| <b>Magnitude</b>                           | • Discounted for uncertainty   | • Higher real-time availability           |
| <b>Timing</b>                              | • Two hours to day-ahead       | • Close to real-time (under five minutes) |
| <b>Security</b>                            | • Not applicable               | • Added layer of cyber security           |
| <b>Customer experience</b>                 | • Manual intervention          | • Automated and seamless                  |

The takeaways above will be leveraged in the continued SG development efforts by Con Edison, and should be leveraged by other utilities and SG technology providers as inputs into SG project planning efforts.

### 5.3.2 Sub-project Specific

Individual subprojects also encountered challenges and developed key learnings during the process of developing their specific, agreed deliverables. The challenge areas and lessons learned, in addition to the overall SGDP lessons above, can be instrumental in informing future work that leverages and builds on the work performed as part of this project. Table 5-4 reviews these key challenges and lessons learned for selected sub-projects whose lessons learned were specific to the activities of that sub-project.

**Table 5-4. Challenges and Lessons Learned by Sub-project**

| Sub-project                       | Deliverable                                            | Challenges                                                                                                                                                     | Lessons Learned                                                                                                                                                                                                                                                          |
|-----------------------------------|--------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>A1. DERMs (Siemens, TIBCO)</b> | Meeting the demonstration timeline and scheduled dates | Communicating with project partners to achieve objectives across multiple participants                                                                         | Documentation, communication, and up-front scope agreement are critical to timely success.                                                                                                                                                                               |
|                                   | Data integration of legacy and SG systems              | Accessing subject matter experts, presenting data in unified manner, and leveraging data residing within silos – must facilitate bringing these silos together | Must understand technical capabilities of diverse group of partners during system integration activities                                                                                                                                                                 |
|                                   | Cyber-security implementation                          | Integrating legacy systems that weren't necessarily designed with cyber-security in mind                                                                       | Utility and Third Party systems have cyber- security challenges that require advance planning and careful implementation.                                                                                                                                                |
| <b>A.3 ISM (O&amp;R)</b>          | Developing a cyber-secure & interoperable system       | Integrating <i>real-time</i> command and control systems that reside on cyber-secure network with corporate network systems                                    | Solve problems in laboratory environment before trying to solve in the field                                                                                                                                                                                             |
|                                   |                                                        | Data communications (inter-control center communications protocol (ICCP), OPC, Secure Sockets)—getting these communications to work in realistic environment   | Use real-time logic simulator with production software and actual communications during the testing process                                                                                                                                                              |
|                                   |                                                        | Managing last-mile radio communications                                                                                                                        | End-to-end system testing using production systems, actual data communication systems, last-mile radio communication, and field hardware setup in a laboratory environment identified problems that would not have been discovered until the system failed in the field. |
|                                   | Developing ISM                                         | Micro Corba software used for control room displays, Open Platform Communications client software used for DSCADA interfaces                                   | ISM approach can identify/provide solutions to problems that were not envisioned at beginning.                                                                                                                                                                           |
|                                   |                                                        | Identifying start of storm                                                                                                                                     | Identified need and is providing                                                                                                                                                                                                                                         |

| Sub-project                                  | Deliverable                     | Challenges                                                                                              | Lessons Learned                                                                                                        |
|----------------------------------------------|---------------------------------|---------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|
|                                              |                                 | from weather and incoming outage data                                                                   | solution for radio bandwidth management issues                                                                         |
| <b>B.1 DR and BMS Integration (Viridity)</b> | Building and resource models    | Buildings not yielding meaningful DR                                                                    | Developed screening methods to target high-potential sites                                                             |
|                                              |                                 | NYC commercial building culture and configuration presented a learning curve.                           | Must refine approach to targeting and acquiring sites                                                                  |
|                                              |                                 | Scope dependent on actual site acquisition (sales of a sort) leading to some missed expectations        | Target, but not commit to, specific sites unless contracts are in place – use risk-based planning                      |
|                                              | Con Edison interface            | Middleware provider established 20 months into project                                                  | Develop requirements and design to greatest extent possible, as done with the Con Edison – VPower™ messaging interface |
|                                              | NYISO interface                 | First operational exposure to NYISO market rules                                                        | Trained the NOC resources appropriately and adjusted strategy                                                          |
|                                              |                                 | NYISO price forecasting tools somewhat unreliable                                                       | Augmented with an external pricing feed                                                                                |
|                                              | Other                           | Hurricane Sandy flooded several sites which remain inactive.                                            | Consider risk in site-assessment and equipment location                                                                |
| <b>B.2 SSGU (GCN)</b>                        | Installing energy storage units | Department of Transportation, safety, and space concerns must be addressed for mobile energy storage.   | Mobile energy storage may not yet be ready for full-scale deployment.                                                  |
|                                              | Integrating software            | Integration of battery storage, PV, and EV storage at small commercial customer sites has no precedent. | The control software is the key behind effective customer side of the meter energy storage.                            |

| Sub-project                                   | Deliverable           | Challenges                                                                                                                                                                                                                                              | Lessons Learned                                                             |
|-----------------------------------------------|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| <b>B.3 DRCC (Innovative)</b>                  | Software developments | Integration of many moving parts developed by various teams is a management challenge. In this project, software was developed by four different organizations with requirements driven by three different entities.                                    | Precise management of requirements and schedules is required upfront.       |
|                                               | DRCC                  | Technology changes rapidly and designs must be able to accommodate these changes (DRCC, Metering, Frame relay vs. Multiprotocol Label Switching [MPLS]).                                                                                                | Must remain flexible                                                        |
|                                               | Program participation | Market rules and regulations must be carefully monitored and influenced, if possible, to get the most value out of the software (NYISO Direct Communications, Demand-Side Ancillary Service Program Aggregation, and Distribution Load Relief Program). | Do not underestimate the effort needed to change or create new markets      |
|                                               | Continuity            | Hurricane Sandy                                                                                                                                                                                                                                         | Redesigning and rethinking can be essential to project success.             |
|                                               | Development of SGDM   | Synchronizing data files                                                                                                                                                                                                                                | Utilize a simulator for testing/verification prior to field deployment      |
| <b>C.2 Energy Optimizer Controller (CALM)</b> | Software development  | Retrieving data for design and testing can be challenging.                                                                                                                                                                                              | Must maintain a flexible and innovative design process                      |
|                                               | Administrative        | Reporting and documentation requirements                                                                                                                                                                                                                | Administrative functions can be exhaustive for a small government contract. |
|                                               | Other                 | Managing large number of data files                                                                                                                                                                                                                     | Large data files require additional effort.                                 |

### 5.4 Implications for the Future

Con Edison is dedicated to lowering costs, improving reliability and customer service, and reducing its impact on the environment for its customers. These objectives also align with the policy objectives of New York State, as a whole. As part of this strategy, Con Edison's long-term vision for the distribution grid relies on the successful integration and control of a growing penetration of distributed resources, including DR resources, battery storage units, DG, and EV charging stations. For example, as shown

previously in Figure 2-4, Con Edison is expecting significant long-term growth of DG. The SGDP enables the seamless integration of these disparate resources and lays the architectural foundations for future scalability.

#### 5.4.1 Future Commercialization and Scalability

The SGDP began as a demonstration project for the DOE with two boroughs, two distribution networks, and one substation, as well as O&R. The platform is extremely flexible and scalable, and has been expanded to encompass the entire Con Edison distribution network (five boroughs, Westchester County and 64 networks), which will enable the growth expected for DER and DR across Con Edison's territory. Currently, the SGDP platform includes all enrolled (774) distribution load relief program sites and an additional 400 SG DER sites (including solar sites). The effort is ongoing to include additional DR sites and EV charging sites.

With the DERMS visualization layering capability, it is possible to include as many sites as required for monitoring the availability and accessing the condition of the distribution network.

In addition to the DERMS platform, a DRMS was implemented to more efficiently manage the enrollment, event notification, settlement, and reporting processes associated with Con Edison's DR programs. The DRMS automates many of these processes, enabling them to be completed more efficiently and at lower cost.

Over the course of the project, Viridity Energy commercialized a total of 31 SGDP-related sites by operating them in both NYISO and Con Edison DR (capacity) programs in parallel to project participation. Leveraging the project investment in ongoing commercialization, Viridity entered 2014 summer program operations representing 32.85 MW at \$8.7M estimated economic value (revenue from NYISO/Con Edison), as shown in Figure 5-2. These results and the implied benefit to economic and environmental sustainability are directly attributable to Viridity's partnership with Con Edison, made possible by the DOE project funding.

**Figure 5-2. Commercialization of Viridity Energy DR Resources**

| Grant Related Commercialization Progression                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                  |             |                    |                    |                    |                    | Capture Improvement |             |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|-------------|--------------------|--------------------|--------------------|--------------------|---------------------|-------------|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | MW Value         | Grant Sites | Last Reported      | Current            | Extension          | Combined           | Value               | %           |
| <b>Site Count</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                  | <b>23</b>   | <b>5</b>           | <b>16</b>          | <b>15</b>          | <b>31</b>          | <b>26</b>           | <b>520%</b> |
| Curtailable Load (SCR) MW                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | ---              | ---         | 5.154              | 7.45               | 3.90               | 11.35              | 6.20                | 120%        |
| Curtailable Load (DLRP) MW                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | ---              | ---         | 3.402              | 7.05               | 3.90               | 10.95              | 7.55                | 222%        |
| Curtailable Load (CSRP) MW                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | ---              | ---         | 3.894              | 7.05               | 3.50               | 10.55              | 6.66                | 171%        |
| <b>Total Curtailable Load</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | ---              | ---         | <b>12.45</b>       | <b>21.55</b>       | <b>11.30</b>       | <b>32.85</b>       | <b>20.40</b>        | <b>164%</b> |
| <b>Est. Economic Annual Value</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <b>\$265,100</b> | ---         | <b>\$3,300,495</b> | <b>\$5,712,905</b> | <b>\$2,995,630</b> | <b>\$8,708,535</b> | <b>\$5,408,040</b>  | <b>164%</b> |
| <div>  <div> <div>Conservative average annual value of 1 MW of curtailable load across these non-exclusive DR programs</div> <div>Total number of sites that participated in the program / grant with Viridity</div> <div>Initially commercialized with 5 of 23 sites as reported in the 2013 technical review in WV</div> <div>Improved commercialization to 16 of 23 sites participating in program</div> <div>Extended commercial terms to 15 additional sites of real estate portfolio managers benefitting from program / grant</div> <div>Total sites commercialized as direct result of program / grant</div> </div> <div>Realized improvement in commercialization in the past 12 months stemming from program / grant, related NYSEDA programs, ConEdison DR incentives, and Viridity Market Strategy</div> </div> |                  |             |                    |                    |                    |                    |                     |             |

The DOE SG funding through Con Edison also supported the Softstuf task of producing and delivering a SGDM based on a new sensor technology. Softstuf is actively working to make SGDMs commercially available in whole and in part by packaging, advertising, and soliciting investment capital. The ongoing process of commercialization was initiated by Softstuf during the project.

#### 5.4.2 Alignment with New York State REV Process

In December of 2013, the NYPSC announced that it would comprehensively consider how the regulatory paradigm and retail and wholesale market designs effectuate or impede progress toward achieving the policy objectives underlying system benefits programs and regulation of electric distribution utilities. As of April 24, 2014, the NYPSC outlined these objectives in its strategic report, “REV”.<sup>4</sup> Today these policy objectives are stated as follows:

- Enhanced customer knowledge and tools to manage the energy bill
- Market animation and leveraging customer contributions
- System-wide efficiency
- Fuel and resource diversity
- System reliability and resiliency
- Reduction of carbon emissions

Con Edison recognizes that significant investment will be needed to: (1) meet these new policy objectives, (2) provide customers with the level of service they desire, and (3) compensate the customers in partnership for the level of service they may also provide to the system. Future investments in generation, transmission, and distribution facilities will be more effectively coordinated with demand-side resources, IT, and communication infrastructure, some of which will enable and integrate customer and third-party investment in DERs. The policy objectives actively promote EE and renewable generation to further reduce customer GHG emissions. Energy produced by customer-sited renewables offsets procured energy, thereby reducing the overall level of non-renewable energy consumed.

The SGDP lays the groundwork for implementing several of the policy objectives laid out by the NYPSC in the REV proceeding. Additional investments will be necessary to meet the requirements of the DSP. This project has deployed technologies that will improve system visibility, enhance control, and support analytics that can help achieve objectives described in REV. Specifically, the DERMS and DRMS deployed through this project will facilitate integration with DER components and control center operations, provide communication options and secure messaging, and enhance the overall DR implementation process. This will allow Con Edison to align with REV in the following ways:

- Engage, educate, and empower customers through increased options for customer-sited solutions and energy management tools
- Better enable DR and DER penetration through enhanced visibility and control of these distributed resources to do the following:
  - o Increase system-wide efficiency
  - o Reshape the load curve
  - o Provide greater reliability and resiliency
  - o Provide fuel and resource diversity, while reducing carbon emissions

---

<sup>4</sup> [Reforming the Energy Vision](#), NYS Department of Public Service Staff Report and Proposal, April 24, 2014.



Overall, the approach and results of the SGDP are consistent with the NYPSC's and Con Edison's shared objectives for increasing the reliability of Con Edison's distribution services at improved costs, while leveraging DER to complement centralized generation plants.



## Appendix A. Final Technical Reports

[Please see separate attachment]



# **Secure Interoperable Open Smart Grid Demonstration Project**

## **Final Technical Report**

### **Appendices**

**Award Number: DE-OE0000197**

**Project Type: Regional Demonstration**

**Principle Investigator: Thomas Magee, General Manager,  
Smart Grid Implementation Group**

**Recipient:**

**Consolidated Edison Company of New York, Inc.**

Consolidated Edison Company of New York, Inc.

Taxpayer ID Number: 13-5009340

Organizational DUNS: 00-698-2359

4 Irving Place

New York, NY 10003

December 28, 2014

## Table of Contents

|                   |                                                                        |            |
|-------------------|------------------------------------------------------------------------|------------|
| <b>Appendix A</b> | <b>Reports Submitted by Project Partners</b>                           | <b>A-6</b> |
| A.1               | Siemens / TIBCO: Distributed Energy Resource Management System (DERMS) | A-6        |
| A.2               | Alstom Grid: Demand Response Management System (DRMS)                  | A-14       |
| A.3               | O&R / EDD: Integrated Systems Model (ISM) and Control Algorithms       | A-19       |
| A.4               | Digi / Ambient: Wireless Communication and Meter Data Management (MDM) | A-77       |
| A.5               | Viridity: DR and BMS Integration                                       | A-84       |
| A.6               | GCN: Smart Storage and Generation Units (SSGUs)                        | A-96       |
| A.7               | Innoventive: Demand Response Command Center (DRCC)                     | A-124      |
| A.8               | NYCEDC: PV, Battery Storage and BMS Integration                        | A-128      |
| A.9               | Gehrlicher: Streamlined PV Design and Installation                     | A-136      |
| A.10              | Softstuf: Smart Grid Disturbance Monitor (SGDM)                        | A-138      |
| A.11              | CALM: ISM and Decision Aid                                             | A-148      |

## List of Abbreviations

| <u>Abbreviation</u> | <u>Description</u>                            |
|---------------------|-----------------------------------------------|
| AC .....            | Alternating Current                           |
| AES .....           | Advanced Encryption Standard                  |
| AHJ .....           | Authority Having Jurisdiction                 |
| AMI .....           | Advanced Metering Infrastructure              |
| ASME .....          | American Society of Mechanical Engineers      |
| BAT .....           | Brooklyn Army Terminal                        |
| BAU .....           | Business as Usual                             |
| BMS .....           | Building Management System                    |
| BNL .....           | Brookhaven National Lab                       |
| BRKE .....          | Business Rules Knowledge Engine               |
| CBL .....           | Customer Baseline Load                        |
| CHAdemo .....       | Charge de Move                                |
| CIM .....           | Common Information Model                      |
| CIP .....           | Critical Infrastructure Protection            |
| CLE .....           | Common Logging Engine                         |
| COTS .....          | Commercial Off-the-Shelf                      |
| CR .....            | Counting Recloser                             |
| CSRP .....          | Commercial System Relief Program              |
| CSV .....           | Comma Separated Values                        |
| CT .....            | Current Transformer                           |
| CVR .....           | Conservation Voltage Reduction                |
| DC .....            | Direct Current                                |
| DCC .....           | Distribution Control Center                   |
| DER .....           | Distributed Energy Resource                   |
| DERMS .....         | Distributed Energy Resource Management System |
| DEW .....           | Distribution Engineering Workstation          |
| DG .....            | Distributed Generation                        |
| DLRP .....          | Distribution Load Relief Program              |
| DMS .....           | Distribution Management System                |
| DNP3 .....          | Distributed Network Protocol                  |
| DOB .....           | Department of Buildings                       |



|              |                                                       |
|--------------|-------------------------------------------------------|
| DOE .....    | Department of Energy                                  |
| DOT .....    | Department of Transportation                          |
| DR .....     | Demand Response                                       |
| DRCC.....    | Demand Response Command Center                        |
| DRMS.....    | Demand Response Management System                     |
| DSCADA ..... | Distribution Supervisory Control and Data Acquisition |
| EDD.....     | Electrical Distribution Design                        |
| EDN .....    | Energy Delivery Network                               |
| EMS.....     | Energy Management System                              |
| EO.....      | Energy Optimizer                                      |
| EV .....     | Electric Vehicle                                      |
| EVSE .....   | Electric Vehicle Service Equipment                    |
| FAT .....    | Factor Acceptance Testing                             |
| FB .....     | Feeder Breaker                                        |
| FDNY .....   | Fire Department of New York                           |
| FTR.....     | Final Technical Report                                |
| GCN .....    | Green Charge Networks, LLC                            |
| GIS.....     | Geographic Information System                         |
| GPS.....     | Global Positioning System                             |
| GRC.....     | Governance, Risk, and Compliance                      |
| GSNI .....   | Grid Synergy Network Integrator                       |
| GSNOC.....   | Grid Synergy Network Operations Center                |
| HTTP(S)..... | Hyper Text Transfer Protocol (Secure)                 |
| HVAC .....   | Heating, Ventilating, and Air Conditioning            |
| IBCU .....   | Incremental Building Control Unit                     |
| ICCP.....    | Inter-Control Center Communications Protocol          |
| IEC.....     | International Electrotechnical Commission             |
| IP .....     | Internet Protocol                                     |
| IRIG.....    | Inter-Range Instrument Group                          |
| IRR .....    | Internal Rate of Return                               |
| ISM.....     | Integrated Systems Model                              |
| IT .....     | Information Technology                                |
| IVR .....    | Interactive Voice Response                            |
| JACE .....   | Java Applet Control Engine                            |
| JMS.....     | Java Messaging Service                                |



|              |                                                                      |
|--------------|----------------------------------------------------------------------|
| kW .....     | Kilowatt                                                             |
| kWh.....     | Kilowatt-Hours                                                       |
| LPDS .....   | Load Profile Data System                                             |
| LSR.....     | Line Side Reset                                                      |
| LTE.....     | Long Term Evolution                                                  |
| MDM.....     | Meter Data Management                                                |
| MDMS .....   | Meter Data Management System                                         |
| MHP .....    | Mandatory Hourly Pricing                                             |
| MHz .....    | Megahertz                                                            |
| MR.....      | Midpoint Recloser                                                    |
| MW .....     | Megawatts                                                            |
| NAESB.....   | North American Energy Standards Board                                |
| NEC.....     | National Electric Code                                               |
| NERC.....    | North American Electric Reliability Corporation                      |
| NIST .....   | National Institute of Standards and Technology                       |
| NOC.....     | Network Operations Center                                            |
| NYC .....    | New York City                                                        |
| NYCEDC.....  | New York City Economic Development Corporation                       |
| NYISO.....   | New York Independent System Operator                                 |
| NYPSC.....   | New York Public Service Commission                                   |
| NYSERDA..... | New York State Energy Research and Development Authority             |
| O&R .....    | Orange and Rockland                                                  |
| OASIS .....  | Organization for the Advancement of Structured Information Standards |
| OLE .....    | Object Linking and Embedding                                         |
| OMS .....    | Outage Management System                                             |
| OPC.....     | OLE for Process Control                                              |
| OPDS .....   | Open Data Source                                                     |
| OpenADR..... | Open Automated Demand Response                                       |
| PID .....    | Proportional-Integral-Derivative                                     |
| POTS.....    | Plain Old Telephone Service                                          |
| PPS .....    | Pulse per Second                                                     |
| PV .....     | Photovoltaic                                                         |
| PVL .....    | Poly-Voltage Load-flow                                               |
| QA .....     | Quality Assurance                                                    |
| RFP.....     | Request for Proposal                                                 |



|              |                                          |
|--------------|------------------------------------------|
| ROI.....     | Return on Investment                     |
| RTU .....    | Remote Terminal Unit                     |
| SAT .....    | Site Acceptance Testing                  |
| SCADA .....  | Supervisory Control and Data Acquisition |
| SCR.....     | Special Case Resource                    |
| SG .....     | Smart Grid                               |
| SGAM .....   | Smart Grid Architecture Model            |
| SGDM .....   | Smart Grid Disturbance Monitor           |
| SGDP.....    | Smart Grid Demonstration Project         |
| SHPO .....   | State Historic Preservation Office       |
| SLA .....    | Service Level Agreement                  |
| SOA.....     | Service Oriented Architecture            |
| SOAP .....   | Simple Object Access Protocol            |
| SOE .....    | Sequence of Events                       |
| SPM.....     | Service Performance Manager              |
| SQL .....    | Structured Query Language                |
| SR .....     | Sectionalizing Recloser                  |
| SSGU .....   | Smart Storage and Generation Unit        |
| TR.....      | Tie Recloser                             |
| TRUC .....   | Transient Recorders Users Council        |
| TSP .....    | Thermal Storage Plant                    |
| UL.....      | Underwriters Laboratory                  |
| UML.....     | Unified Modeling Language                |
| UN.....      | United Nations                           |
| UPS.....     | United Parcel Service                    |
| VIS.....     | Visualization                            |
| VPN.....     | Virtual Private Network                  |
| VRLA .....   | Valve Regulated Lead Acid                |
| VVC.....     | Volt-var control                         |
| WSDL.....    | Web Services Description Language        |
| WS-SEC ..... | Web Services Security                    |
| XML .....    | Extensible Markup Language               |

## Appendix A Reports Submitted by Project Partners

These subproject reports were written by the project partners and Con Edison to provide more detail and background on the individual subprojects. They have been provided here for completeness.

### ***A.1 Siemens / TIBCO: Distributed Energy Resource Management System (DERMS)***

The Siemens/TIBCO team developed a summary of Smart Grid Demonstration Project (SGDP) activities as part of the input to the Final Technical Report (FTR). Results and information below has been used to develop the overall takeaways and lessons learned in the FTR.

#### **A.1.1 Executive Summary**

The Con Edison DERMS project, sponsored by the United States Department of Energy (DOE), integrates multiple sources of operations and logistical information to visualize delivery grid condition and manage available Distributed Energy Resources (DERs), both demand and generation, to enable energy delivery reliability and security.

The project leverages Siemens' expertise in Utility Real-Time Operations domains and information technology (IT) in tandem with TIBCO's service-oriented middleware architecture to bridge functional silos, collecting data from heterogeneous applications and establishing secure, reliable communication connections between them. Siemens' platform additionally enables Con Edison users to visualize and monitor integrated data from a range of sources and take informed actions. Internal users of SGDP do not require installation of client as the system is enabled with Microsoft virtual application (Microsoft App-V) and can be used and run by any workstation that was authorized to run the DERMS virtual application.

#### **A.1.2 Project Goals and Accomplishments**

Understanding the stated project goals is essential to accurately evaluating the DERMS's tactical accomplishments. The following section depicts Siemens' major objectives and the technological achievements that resulted.

##### ***A.1.2.1 Project Objectives***

- **Objective:** Improve control capabilities of existing grid assets  
**Description:** Siemens developed and integrated a wide-area visualization platform to manage, monitor and control a distribution system utilizing secured web services. Siemens provided near-real-time status of distributed energy resources onto existing network real-time displays, integrated-load flow analysis and decision aid capability during peak load conditions, enabled impact analysis of distributed energy and load resources and implemented targeted Demand Response (DR) on electric distribution systems. The integrated package establishes wide-area situational awareness for electrical distribution operators.
- **Objective:** Minimize peak load growth and maximize energy efficiency savings throughout the electrical grid  
**Description:** Siemens platform in coordination with DR providers allows, identification of DER that correlate with Con Edison distribution network components with the potential for relieving

overloads on specific feeders or transformers by placing targeted DR requests. This opens the possibility for capacity deferrals in system infrastructure plans.

- **Objective:** Provide world-class cyber security for smart grid (SG) systems  
**Description:** Siemens employed secure web services to request the reduction of load or additional generation, and securely queried status of availability and curtailment capacity using industry standards. The communication platform supports multiple secure technology standards such as, message level security and transport level security. In addition Siemens implemented security controls in the area of user authentication and role based access control.
- **Objective:** Demonstration of open standards and interoperability with vendors with commercially available products  
**Description:** Siemens leveraged open standards and integrated newly developed technologies while simultaneously interfacing to legacy applications. Messages used for communication with third party vendors comply with existing standards and any extensions will be proposed for inclusion in future standard revisions.
- **Objective:** Maintenance of electrical delivery system reliability and increased utilization of existing equipment  
**Description:** Siemens platform enables distribution system operators to visualize and remotely manage various distributed resources in the Con Edison distribution network including available Distributed Generation (DG) and controllable demand. The ability to manipulate these resources extends the equipment life and utilization, avoids potential equipment damage, and should improve the general feeder equipment condition reducing overall maintenance requirements and improving reliability.

#### *A.1.2.2 Other Project Accomplishments*

During the course of the project Siemens also provided:

- Modeling of DG and DR sites and resources utilizing and/or extending existing Common Information Model (CIM) standard.
- Support for grouping multiple sites (each with multiple resources) which, for example, could be used for support of microgrid interoperability
- Support for mobile generation resources – for dynamic connection, analysis, and monitoring
- Modeling and monitoring support for generation (solar sites, diesel, and gas generation).
- Interoperability with existing legacy models and tools
- Support for interoperability of site/resource model and dynamic data with existing and future Electric Distribution Systems – Load Flow, Pocket Analysis, Microgrid tools, etc.
- Support for impact measurement of DERs and load variations on the Distribution system components
- Support for simulation of DER sites and resources to identify critical sites with greatest potential benefit on the grid for DR
- Integration of the existing Con Edison Load Flow analysis program which can prioritize DR sites and provide decision aid to operators for targeted DR

- Support for identification and monitoring of critical infrastructure sites for grid component operator alerts

#### A.1.2.3 *Challenges and Lessons Learned*

**Table A-1. Challenges and Lessons Learned**

| Deliverable                               | Challenges                                                                                                                                                                                                              | Lessons Learned                                                                                                                                                                        |
|-------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Meeting scheduled demonstration dates     | <ul style="list-style-type: none"> <li>• Communication w/ project partners</li> </ul>                                                                                                                                   | <ul style="list-style-type: none"> <li>• Documentation, communication and scope agreement are critical to timely success</li> </ul>                                                    |
| Data Integration of legacy and SG systems | <ul style="list-style-type: none"> <li>• Timely access to subject matter experts</li> <li>• Presenting data in unified manner</li> <li>• Data resides within silos, facilitate bringing these silos together</li> </ul> | <ul style="list-style-type: none"> <li>• Must understand technical capabilities of diverse group of partners during system integration activities</li> </ul>                           |
| Cyber Security                            | <ul style="list-style-type: none"> <li>• Coordination with multiple DR providers</li> </ul>                                                                                                                             | <ul style="list-style-type: none"> <li>• Utility and Third Party legacy systems have cyber- security challenges that require advance planning &amp; careful implementation.</li> </ul> |

#### A.1.2.4 *Commercialization – Configurability and Scalability*

The DERMS project started as a demonstration project for the DOE with two boroughs, two distribution primary networks, and one substation in Con Edison’s service territory. The project has been evaluated by Con Edison teams during the period of multiple demonstrations to the DOE and has been extended for the Con Edison production system. The platform is extremely flexible and scalable and currently represents Con Edison’s six boroughs and 64 networks. It has been extended to encompass the entire Con Edison service area.

With the visualization layering capability, it is possible to include as many sites as required for monitoring the availability and accessing the condition of the distribution network. It is also possible to transfer an existing SG site to a DR site and vice versa based on Con Edison tariff for load relief programs or future potential tariffs for targeted DR.

### A.1.3 **Project Activities**

#### A.1.3.1 *Approach*

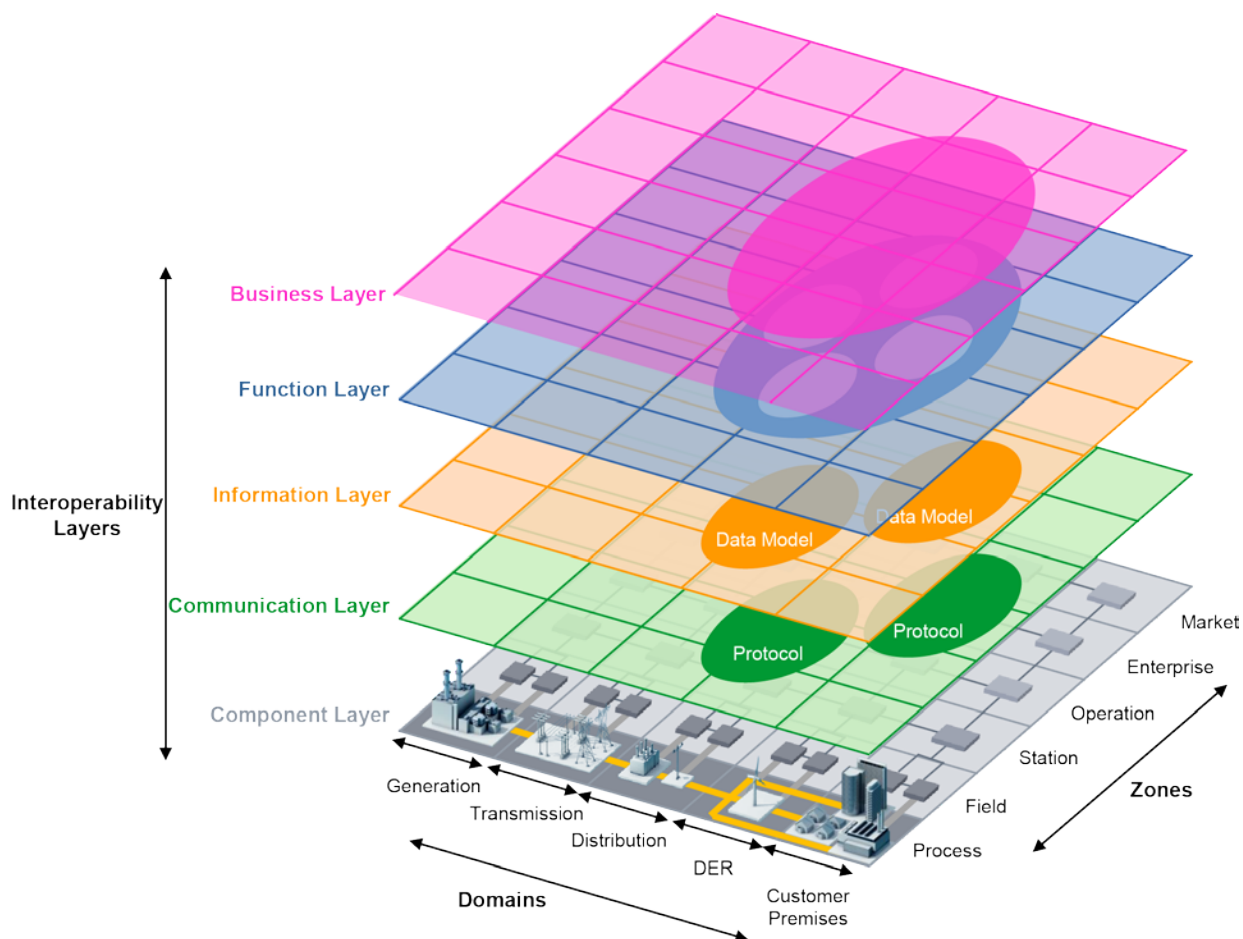
The SGDP teamed Con Edison with Siemens and TIBCO in an effort to implement an interoperable information exchange platform to integrate information from multiple utility domains, capitalizing on Siemens’ SG expertise and TIBCO’s middleware products.

### Applying the SG Reference Architecture

The Smart Grid Architecture Model (SGAM) is a comprehensive “all-in-one” SG toolbox. The SGAM divides the energy industry into five domains, six zones of information management and five layers of interoperability. Siemens leveraged the below reference architecture model to design and implement the DERMS visualization and interoperable platform specified by Con Edison. While the DERMS does not span all the zones and domains shown in the figure below, the Siemens platform does allow flexibility and scalability in support of Con Edison’s roadmap.

Siemens’ Model Driven Integration approach leverages the International Electrotechnical Commission (IEC) CIM model as the Data/Domain Model within the Information layer to map and model data interface requirements. These requirements are driven by Functional Use Cases within the Function Layer, which in turn is influenced by Con Edison’s Business Objectives and Processes within the Business Layer. Ultimately the interfaces are implemented within the Communication Layer or the middleware, enabling interoperability between the various zones.

**Figure A-1. Siemens Smart Grid Architecture Model**

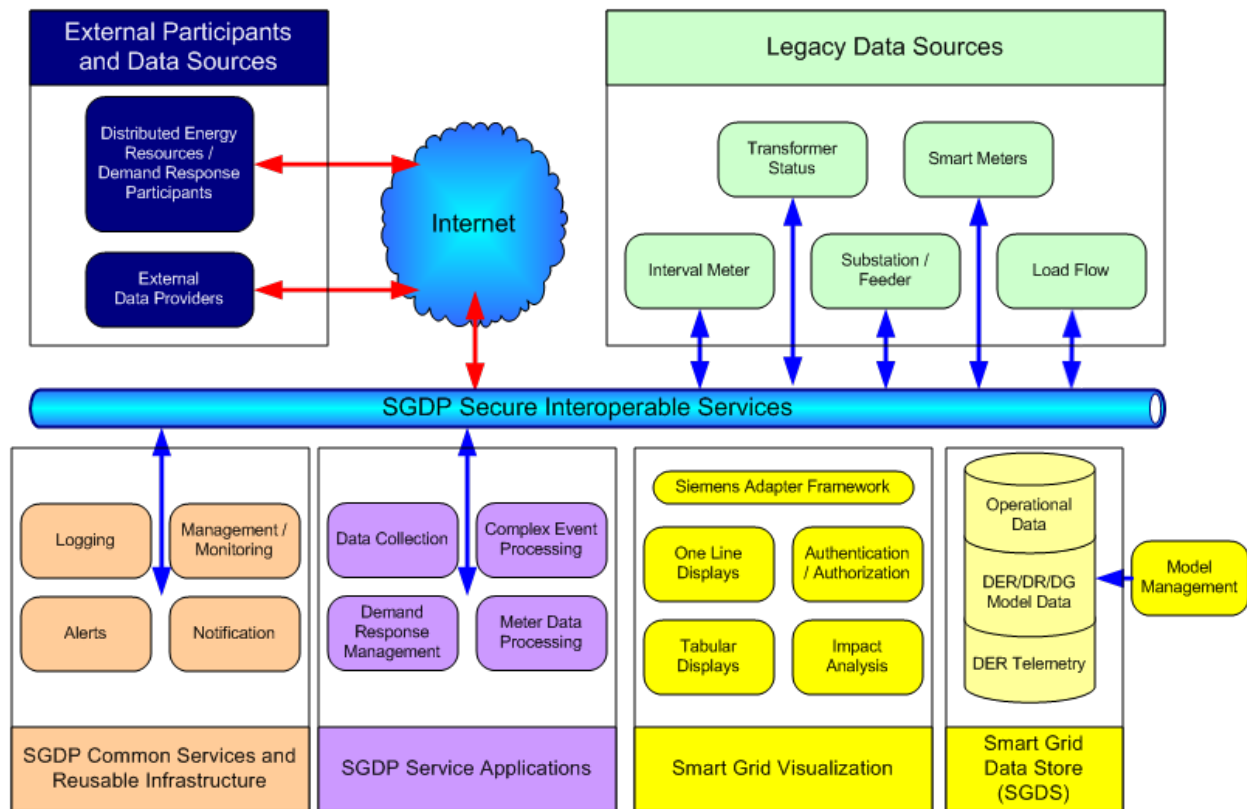


Source: European Smart Grid Coordination Group; based on National Institute of Standards and Technology (NIST) Smart Grid 1108 and 7628

### SGDP Secure Interoperable Architecture

The SGDP Secure Interoperable Architecture, depicted below, implements standardized data models and protocols to integrate multiple functions across various applications, within and external to Con Edison. The TIBCO middleware enables dynamic data exchanges between various functions within SGDP while the Operational Data Store (OPDS) maintains data for archiving, reporting, and analysis purposes. Each of the rounded rectangles represents actors (i.e., the services, programs, or entities) that exchange information or requests.

**Figure A-2. SGDP Secure Interoperable Architecture**



SGDP leverages Web Services to enable dynamic data exchanges between various functions. These Web Services leverage industry standards such as Simple Object Access Protocol (SOAP), Extensible Markup Language (XML), Web Services Description Language (WSDL), etc. These web services carry XML payloads which Siemens has designed from the IEC CIM Unified Modeling Language (UML) model. Siemens has created CIM extensions for DR attributes which did not exist within the CIM UML model and mapped to existing CIM attributes where available. These Web Services have been implemented and deployed within the TIBCO middleware and leverage the Hyper Text Transfer Protocol (HTTP[S]) and Java Messaging Service (JMS) protocols for transport.

#### A.1.3.2 Common and Reusable Infrastructure

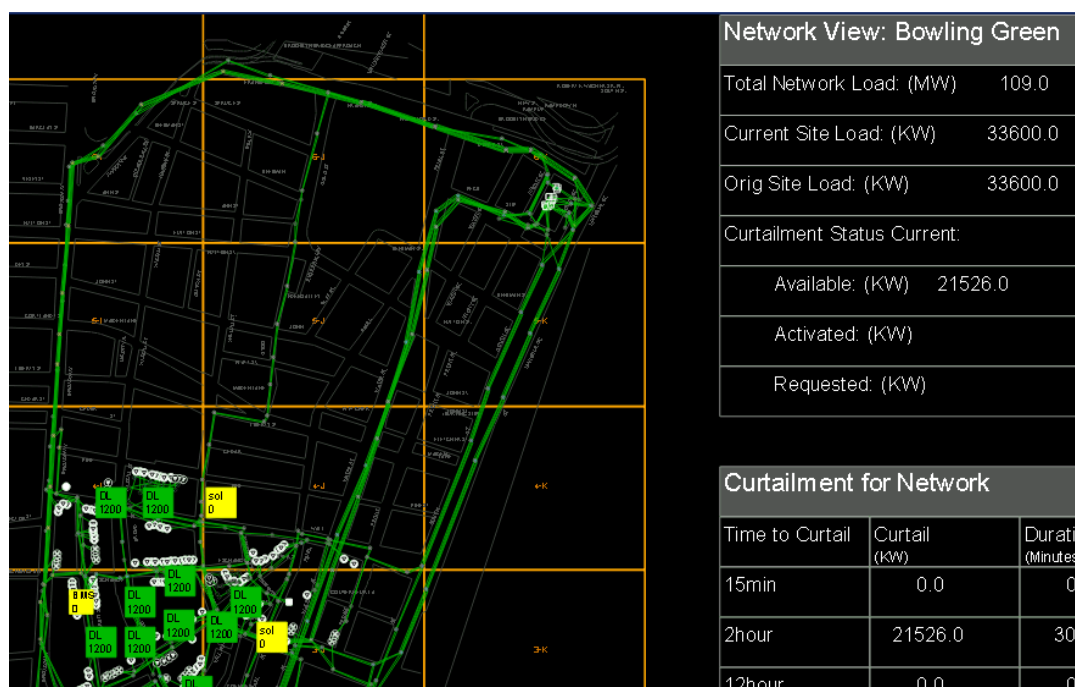
SGDP leverages an Service Oriented Architecture (SOA) based enterprise architecture which brings integration best practices such as component reuse, monitoring, security, and standards.

### A Convergent Visualization Platform

The Siemens Visualization (VIS) solution overlays data from newly implemented applications on top of Con Edison's existing geographic maps related information from legacy systems. VIS provides a consistent display of information without regard to the data source and plays a major role in situational awareness.

VIS pushes dynamic updates to clients as the OPDS changes. Users on the VIS client directly trigger CIM-compliant messages to the DERMS Common Integration.

**Figure A-3. SGDP Visualization Display**



The DERMS visualization display example above depicts VIS one-lines automatically converted from Con Edison's existing one-line displays. Configuration-driven display building allows Con Edison to quickly create and deploy tabular and other displays.

### Reusable Service Infrastructure

DERMS applies a common framework and employs a standardized design for all new TIBCO Business Works applications, an architecture that supports fast demonstrations of meta-applications like Complex Event Processing. DERMS applications also implement a set of reusable services supporting the use of applications developed outside of the DERMS solution: Any authorized system can use the CIM-compliant messages to partially or fully integrate into SGDP.

Siemens and TIBCO Commercial Off-the-Shelf (COTS) products have been utilized in the development of the following services:



- **Notification Service** is a simple re-use component that allows SGDP Applications to send e-mail notifications to other systems.
- **Alerts Service** is a listening service that collects CIM-compliant alert messages and aggregates them in the Operational Data Store and Visualization.
- **Common Logging Engine (CLE)** receives debug, informational and critical logs from all SGDP Applications. Administrators analyze these logs to determine root causes for service issues in SGDP.
- **TIBCO HAWK** and **Hardware Management/Monitoring** provide low-level hardware monitoring for SGDP Administrators. The Alert and Notification systems support initial visibility to administrators and supervisors, and TIBCO Service Performance Manager (SPM) provides Service Level Agreement (SLA) monitoring.

#### *A.1.3.3 Data Integration*

The quality and consistency of DERMS data underlines the venture's success. The DERMS brings together numerous functional areas to forge a single OPDS. The functional areas fall into two categories: legacy system integration and new system integration.

##### **Legacy System Integration via Internal Services**

The DERMS retrieves information from a host of existing Con Edison data sources, a strategy enabling the utility to onboard new data sources with greater accuracy and speed. Siemens deployed well-defined web services against existing Con Edison applications to abstract internal functional details and standardize interfaces, simplifying maintenance and enabling monitoring.

The following Con Edison existing legacy applications have been integrated as part of the DERMS.

- **Load Profile Data System (LPDS)** provides Interval Meter data and High Voltage Vault Meter data from the ITRON MV-90xi.
- **Advanced Metering Infrastructure (AMI)** provides Smart Meter data from UtilityIQ.
- **Data Acquisition** provides Feeder Status, Substation Status and Network data.
- **Model Data** provides SG Distributed DR Energy Resources connectivity points.
- **Load Flow** provides Decision Aid data.

##### **New Integration via External Services**

The SGDP also enables new Con Edison information access and functionality. Secure Web Services ensure protected interactions with DR-participant companies, supported by a CIM-compliant message structure. New CIM extensions for these use cases were created as necessary. New external data providers were connected to the SGDP as well.

The following external Con Edison partners and data services have been integrated as part of the DERMS.

- **External DR Participants** provide DERMS with options for load relief at their systems. DERMS DR IEC CIM compliant messaging allows Con Edison to securely request Status and Demand Curtailment over the Internet to these participants. When Con Edison is ready to return to normal operations, the utility can request DR Participant to Stop Curtailment. All requests are



sent with Transport Level and Message Level security compliant to Organization for the Advancement of Structured Information Standards (OASIS) Web Services Security (WS-SEC) standards.

- **Solar** (external data provider) delivers near real-time photovoltaic (PV) resources information across the area covered by DERMS.
- **Deep Thunder** (external data provider) delivers customized weather forecast data.



## **A.2 *Alstom Grid: Demand Response Management System (DRMS)***

The Alstom team developed the following summary of SGDP activities as part of the input to the FTR. Results and information below has been used to develop the overall takeaways and lessons learned in the FTR.

### **A.2.1 Executive Summary**

Con Edison utilizes DR programs to incent customers to reduce their energy use during times of distribution system constraint and peak demand. The primary drivers for utilizing DR resources are to manage Emergency Capacity Reserves and Peak Load Reduction. The primary business functions and processes associated with Con Edison's DR program, such as enrollment, notification and settlement, are largely manual today.

Operating two types of commercial DR programs – Contingency and Peak Shaving – Con Edison seeks to maximize electric distribution system opportunities through effective DR program execution from May 1 through October 31 each year. Con Edison's contingency programs are initiated at short notice in response to engineering conditions on the electric distribution system (feeder outages, voltage reduction) and are available across the whole service territory. The Peak Shaving programs are initiated when the Day Ahead System Forecast is at 96% or higher of the forecasted system's summer peak level. The Peak Shaving program is only applicable to New York Independent System Operator (NYISO) Zone J (the five boroughs of New York City [NYC]).

In 2013 there were about 750 unique customers enrolled in Con Edison's Commercial DR programs, the majority of whom were represented by one of 12 DR aggregators/curtailment services providers. These customers/aggregators accounted for approximately 1,100 meters. The potential exists that the programs could increase fivefold in customer and meter size over the next few years and any management system needs to be scalable.

As part of the SGDP, Consolidated Edison has an objective of implementing technology to help alleviate the constraints caused by the manual processes currently utilized to manage their DR programs. The technical solution to address this requirement is the implementation of a DRMS. Alstom Grid was selected by Con Edison to deploy their DRBizNet software solution and to assist in managing the deployment of the DRMS system.

### **A.2.2 Project Scope**

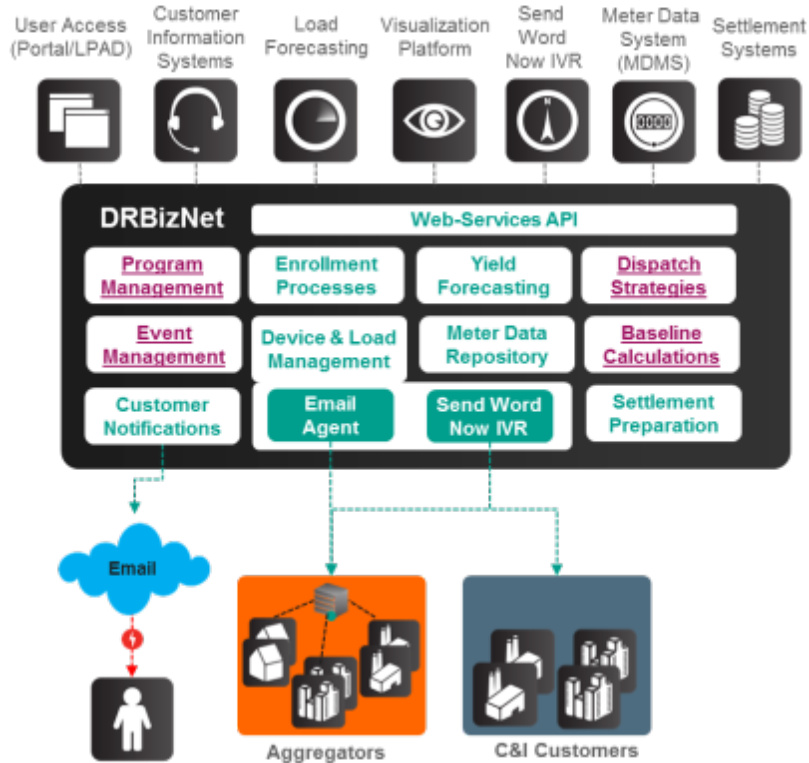
SGDP demonstrated monitoring and control capabilities, leveraging controllable field assets (curtailable customers, switches, DG, battery storage, electric vehicle (EV) charging stations, building management systems (BMSs), home area networks, high tension monitoring, and AMI) to shift, balance, or reduce load in response to system contingencies or emergencies in a way that reduced load where and when needed.

### **A.2.3 Deliverables**

Con Edison selected the e-terraDRBizNet solution from Alstom Grid as the preferred DRMS. DRBizNet is designed to enable advanced load management for Retail electric distribution operators. The system has a

robust suite of functionality built upon a modular architecture that can be adapted to address the unique needs of each customer.

**Figure A-4. Diagram of DRMS Components offered by Alstom**

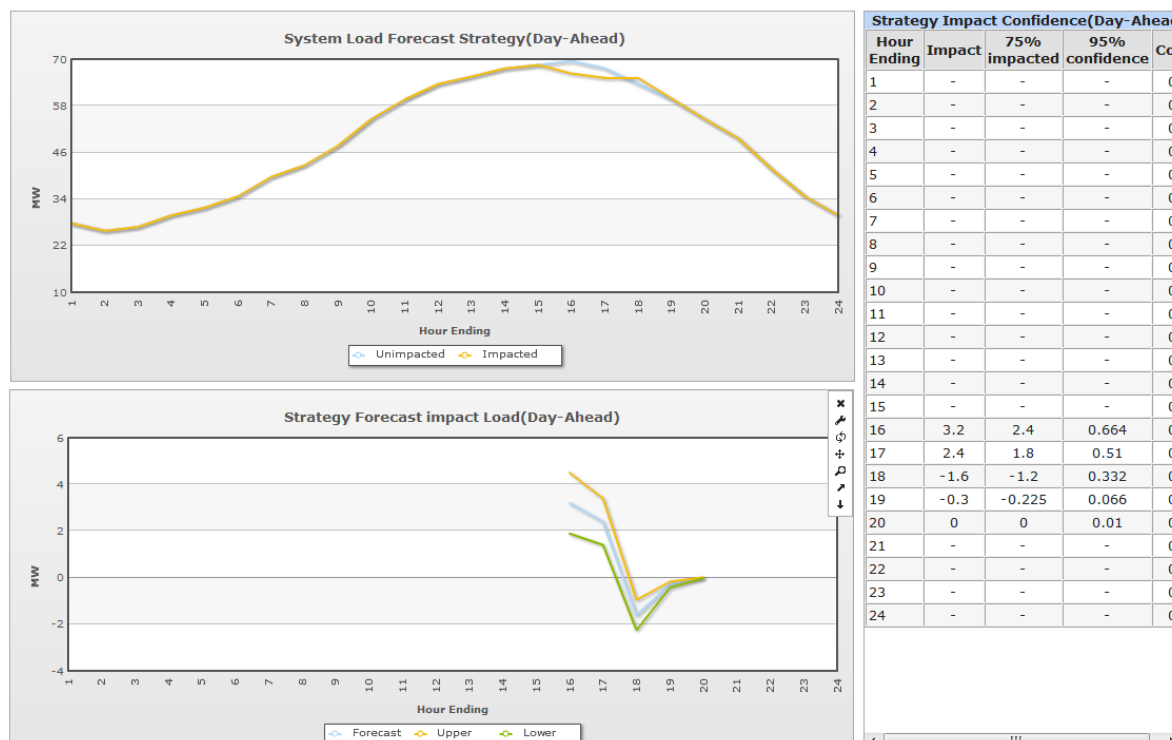


**DRBizNet at Consolidated Edison**

For Con Edison, Alstom Grid is delivering the entire suite of DRMS functionality including:

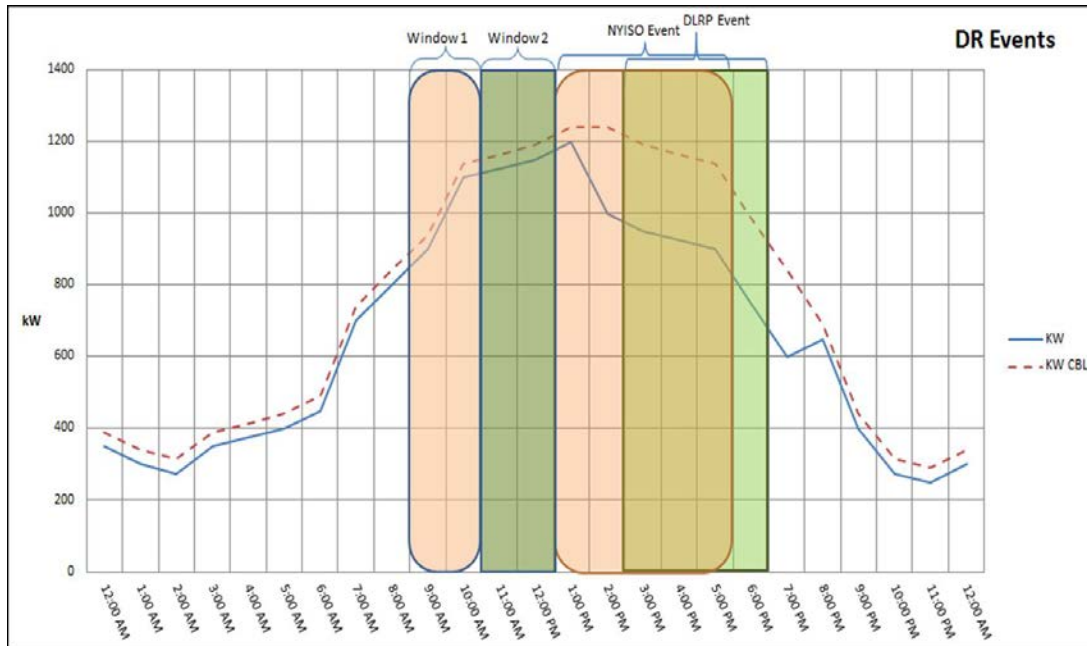
- **Program Management:** allows for simple and rapid creation of Retail customer programs that Con Edison will offer to its customer base. This functionality can apply to Commercial, Industrial and Residential-type DR programs.
- **Customer Registration:** tracks customer locations and manages the processes for enrollment in programs and limits enrollment when prohibited by program rules.
- **Forecasting:** provides available DR forecasting that accommodates program constraints such as device availability, weather, and profile including decay and snapback, as well as real-time feedback of opt outs, and confidence levels of forecast capabilities. e-terraDRBizNet can forecast available DR according to location/zone and/or network model including the substation, feeder bank, and feeder/circuit (see Figure A-5).

Figure A-5. Example of Load Forecasting Capability



- **Optimization:** includes DR resource optimization with multiple objective functions such as reducing peak load during high cost energy periods, or maximizing profit based upon market forecasted prices.
- **Event Management:** provides dispatch operators with a way to construct event dispatch schedules, which could range from simple single resource group quick dispatches, to multi-leg events for longer events. These dispatch methods can be saved as templates and easily recalled and launched by adding start time and end time or event duration.
- **Notification Management:** notifies devices using supported protocols such as Open Automated Demand Response (OpenADR) and/or people of event dispatch schedules through email. For this project, Send Word Now Interactive Voice Response (IVR) is being deployed.
- **Local Control and Event Overrides:** supports customer overrides when participating in an event while capturing and tracking the number of overrides per customer.
- **Meter Data Integration:** provides two methods to upload meter data for performance calculations – standard Application Programming Interface (API) and comma separated values (CSV) files (i.e., spreadsheets).
- **Performance and Settlements:** follows North American Energy Standards Board (NAESB) standard baseline methodologies to calculate performance per customer event.

Figure A-6. DR Event Performance Review Display



- **Dashboard/Reporting:** provides a dashboard for charts and reports of program operating data such as Marketing Campaign performance, device installation work order summary, installation status, device population status, service request summary, customer defection, forecast of available DR per program, amount of DR called to date by program and others.

Figure A-7. Example of DR Reporting Dashboard





- **Portal Access:** provides customer portal APIs and provides existing customer-facing solution giving access to DR data while allowing customers to update authorized information.
- **Integration:** Alstom is providing the DRMS APIs and integration design and support to move DR related data to and from Con Edison's back office systems including: Customer Information System, Meter Data Management System (MDMS), load forecasting, legacy load management systems, customer portal, new load management systems, settlements and billing systems.

#### **A.2.4 Project Methodology**

Alstom Grid is providing the domain expertise to manage the DRMS requirements gathering, software configuration, implementation, support of integration to back office systems, and DRMS testing.

Alstom Grid also provided the Business Analysts to review the Con Edison programs, processes, data flows, integrations, user roles, and key functionality requirements.

Alstom Grid will configure the DRMS and provide custom software development and support as needed.

#### **A.2.5 Project Schedule**

- The contract was signed and a purchase order received on February 25th, 2014.
- Factory Acceptance Testing (FAT) was completed at the end of July 2014.
- The system is currently undergoing Site Acceptance Testing (SAT).
- The system is scheduled to be deployed and operational in a production environment by December 2014.

### ***A.3 O&R / EDD: Integrated Systems Model (ISM) and Control Algorithms***

The Orange and Rockland (O&R) and Electrical Distribution Design (EDD) team developed the following summary of SGDP activities as part of the input to the FTR. Results and information below has been used to develop the overall takeaways and lessons learned in the FTR.

#### **A.3.1 Executive Summary**

##### ***A.3.1.1 Goals, Objectives, and Accomplishments***

The objective of the real-time control systems work was to demonstrate that a single, detailed, reusable model of the electric distribution system can be used in a secure, interoperable environment for multiple objectives. A model-centric approach was used wherein the complete distribution system is modeled and updated in real-time. Model-centric systems, due to their comprehensive understanding of the system, can be used for control applications such as fault isolation and restoration to improve system reliability. In addition, a prime objective of the system was to coordinate volt-var control (VVC) to reduce system losses and energy consumption.

The second major objective was to develop and integrate a system into the interoperable environment that monitors weather conditions and the receipt of outage calls in real time to detect the beginning of storm events causing electric system outages and predicts the total number of outages that will be received looking one hour and three hours ahead using a real-time feed forward loop. Knowing the number of outage incidents that a storm will generate early in the storm allows the utility to right-size the restoration resource sooner, which reduces time to full restoration.

Listed below in Table A-2 are the high-level goals/objectives and the associated accomplishments of the work performed under this project.

**Table A-2. High-Level Project Goals/Objectives and Related Accomplishments**

| Goals/Objectives                                                    | Accomplishments                                                                                                                                                                                   |
|---------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Develop Model-Centric Auto Restoration System                       | Developed and demonstrated a model-centric auto restoration capability based on peer-reviewed journal papers on Graph Trace Analysis reconfiguration for restoration algorithm                    |
| Develop Model-Centric Coordinated VVC System                        | Developed and demonstrated a model-centric coordinated VVC system based on peer-reviewed journal and conference papers on Graph Trace Analysis coordinated control algorithms                     |
| Develop Model-Centric Storm Detection and Outage Prediction System  | Developed and demonstrated a model-centric outage prediction system that accurately predicted the number of outages for control samples of historical storms based on peer-reviewed journal paper |
| Develop a cyber-secure environment for the model-centric approach   | A cyber-secure, high-value network architecture was designed and mapped to NIST's standards and documented in this report.                                                                        |
| Develop an interoperable environment for the model-centric approach | Interoperability was demonstrated using TIBCO middleware.                                                                                                                                         |

#### **A.3.1.2 Control System Development**

This integration permits higher penetration of automation within the electric power grid so that enhanced system reliability, deferred capital investment, energy conservation, and improved overall efficiency benefits can be realized.

This open architecture system can simplify the adoption and control of renewable resources and energy storage devices, and can facilitate the integration of new and emerging technologies such as microgrids.

Development, use, and maintenance of an ISM, and application of fast analytical processing of real-time data streams by electronic software applications, provide the analytical backbone that enables this model-centric approach to command and control the system. This approach also enables efficient and effective expansion of proof-of-concept and pilot projects to full-scale utility deployment.

Present distribution automation systems rely on equipment that uses voltage and/or current sensing at the device as inputs to their local electronic controls. The equipment knows nothing about what is taking place on the rest of the system and cannot react to optimize system conditions. These controls use set-points to determine when and how the equipment should operate. When sensing indicates that specific electrical parameters venture out of user-specified bandwidths around the setpoint, the equipment reacts to it automatically. This limits localized automatic control logic to a single reaction for a locally sensed condition. This type of automation operates without remote monitoring and without remote control, and is the most prevalent type of distribution automation currently in service. The operating scenario must be predetermined by an engineer and setpoint values calculated for the device. Careful coordination of



setpoints between devices and the addition of timers to the device's electronics has allowed the devices to be used to provide single-function, non-optimal automatic control.

Some vendors have developed proprietary systems that use peer-to-peer communications between automation devices in the field to determine what is happening elsewhere on the system. These devices work together and can adjust for changing conditions. For the system to be effective, each and every possible normal and contingency operating scenario must be identified and programmed into all of the devices. Should a scenario occur that has not been identified and programmed, the system will either react in an unintentional manner or may totally shut down and not operate. Should this occur during storm conditions or other emergency conditions, the results would be problematic. While these systems can and do work well in very small deployments, O&R feels they are too restrictive and complex for full-scale utility deployment.

The next step up from automatic local control is a combination of automatic local control and Distribution Supervisory Control and Data Acquisition (DSCADA) systems. DSCADA systems have been installed to monitor and remotely control automation and remote operable equipment. After the device has operated via its automatic localized control logic, a Distribution System Operator can change the condition of the device to help accommodate conditions elsewhere on the system. The limitation of operator control is the speed at which an operator can understand and react to changing conditions and the onslaught of data that he is subjected to. If conditions change too rapidly, as during emergency events and storm conditions, it can take a substantial amount of time for an operator to analyze the incoming data to determine what has transpired, identify a course of action, and to adjust the system to accommodate the situation.

### **Model-Centric Control Systems**

The model-centric control system is the next evolution in distribution system control. In this type of control system, the distribution system is fully modeled in detail in an ISM where circuit topology changes are updated in real time for automatic devices under Supervisory Control and Data Acquisition (SCADA) control such as line reclosers and SCADA operable switches, and in near real time for manually operated switching devices, such as hook-stick-operated disconnect switches and manually operated, grouped interrupter switches. Real-time data from substation circuit breakers and distribution automation devices is attached to the model via SCADA. Fast analytical software then runs power flows on the model each time a real-time value within the model changes. As a result, real-time or calculated values of system electrical parameters are known for each section of wire and piece of equipment within the model. This information is then used by the control system algorithms to determine the optimal solution to changing system conditions. The control system is interfaced to the DSCADA system so that once the best course of action is determined by the control system; it is automatically executed through the interconnection to the DSCADA system.

Model-centric control has knowledge of electrical parameters and circuit topology across the entire system through the ISM and can rapidly make and execute decisions on how best to react to changing system conditions in real time. Having system electrical parameters in real time, either actual or calculated, for each section of wire and piece of equipment, allows the control system to vary solutions based on time varying loading. Thus, the ISM control solutions are not singular. They continuously optimize the response and vary depending on system parameters at the time of the response.



The model-centric control system rapidly responds to changing conditions and can handle multiple system contingencies, which singular function, automatic operation cannot do, and which automatic operation under operator control takes a significant amount of time to do. Additionally, because model-centric control is open architecture, as long as a device can be communicated with via DSCADA, it can be added to the control system by adding it to the ISM. Line reclosers, SCADA operable switches, switched shunt capacitor banks, voltage regulators, power quality nodes, faulted circuit indicators, and voltage and current sensors are examples of some of the present-day equipment that can be included in the system.

A direct connection to DSCADA allows solutions to be executed once they have been determined by the model-centric control system. This relieves the Distribution Operator from having to cope with the onslaught of data during system emergencies and storm conditions and from having to analyze the data to determine solutions, thus speeding restoration. Instead of having to focus on solving individual restoration problems, the operator can monitor and focus on the big picture and communications with field crews.

The ISM is interfaced to the distribution DSCADA system so automatic operation of distribution automation devices updates circuit topology in real time. In the future, the ISM will be interfaced to O&R's Geographic Information System (GISs) switch order system, which will provide near real-time topology updates from manual switching, and changes to topology and assets resulting from completed construction projects. This will fully automate the upkeep of the ISM, insuring that the circuit topology remains as accurate as possible by updating it in as close to real time as possible.

#### **Auto Restoration Model-Centric Control System Demonstration**

A demonstration of the Auto Restoration model-centric control system in a laboratory environment using ISM, Distribution Engineering Workstation (DEW) power flow analysis, DSCADA, and the auto restoration model-centric control system was performed. In the lab, faults were simulated using geo-synched relay power supplies controlled via scenario programming of the power supplies. A simulated fault was entered between devices in the system. The fault clearing device reacted automatically with its local control logic to clear the fault. When the model-centric control system received a change in state from the fault clearing device via the DSCADA system, it read the information sent from all of the other devices on the circuit. Information such as status, fault indication, voltage, and fault current were returned. Using the information returned from SCADA, the model-centric control determined the location of the fault and calculated an optimal solution that maximizes the number of customers restored without violating any constraints such as minimum voltage or maximum conductor and equipment loadings. Determination of the solution required less than 300 milliseconds and was fed directly into the DSCADA system. The DSCADA system then executed the commands, operating SCADA operable devices to further isolate the fault and restore out-of-service customers. The entire operation takes under one minute.

#### **VVC Model-Centric System Demonstration**

A demonstration of the model-centric VVC system in a laboratory environment using ISM, DEW power flow analysis, DSCADA, and the Volt VAR model-centric control system was performed. Actual regulator and capacitor bank control hardware was set up in the lab in a configuration matching an actual distribution circuit. The demonstration used all of the production systems, such as the production DSCADA system, actual 220 MHz radio communications between the controls set up in the lab, and a

production master radio site for the DSCADA system, as well as the production backhaul communications to the DSCADA servers. Varying substation loadings were injected manually into the model and the VVC system reacted by turning on or off switched capacitor banks to meet var requirements and adjusted voltages to be adequate, but at the minimally adequate level so energy reduction from conservation voltage reduction (CVR) could be realized.

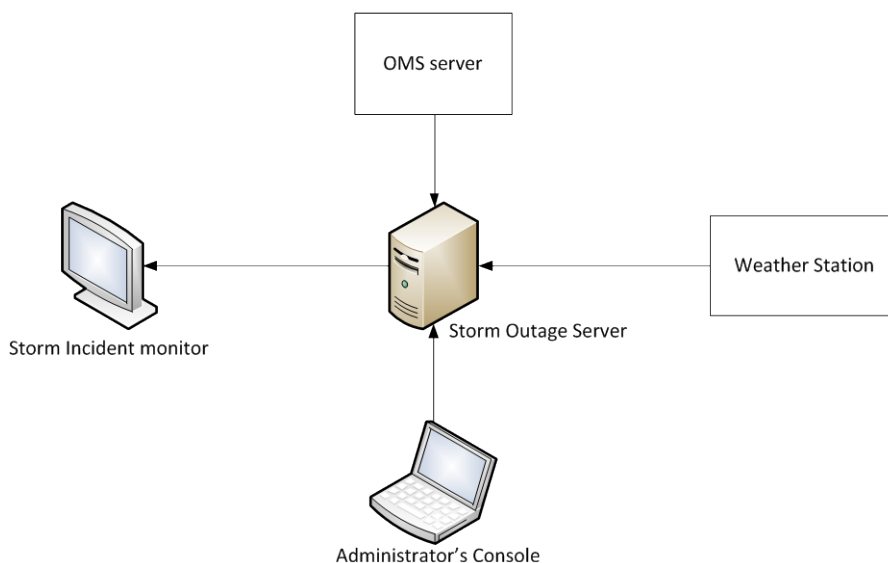
#### A.3.1.3 Storm Outage Detection and Prediction System

*The Storm Outage Detection and Prediction system was also described in section 4-A.3 of the main report.*

##### System Architecture

Storm Outage Detection and Prediction interfaces with the existing Outage Management System (OMS) and real-time weather information to detect or predict outages caused by storms. The program runs continuously on the Storm Outage Server, shown in Figure A-8, automatically selecting the appropriate mode (i.e., Detection or Prediction) based on the relevant data and control settings. Applicable run parameters and control settings are input from the Administrator's console.

**Figure A-8. Storm Outage Relationship Diagram**



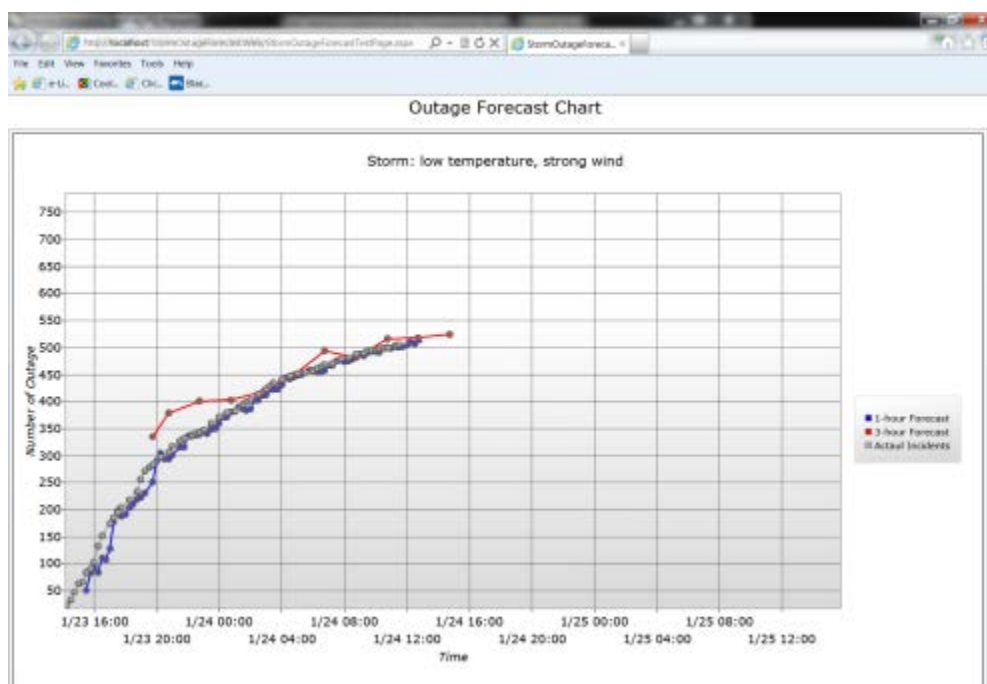
##### Detection Mode

In Detection mode, the program monitors the number of incidents received from the OMS server. If the number of incidents or changes in the number of incidents meets specified detection criteria, the program generates a storm warning based on the current weather condition from the weather station and switches into the Prediction mode. In the Prediction mode the program uses the reported outages to project the accumulated total of expected incidents for the next hour, with updates every 15 minutes. It also gives an hourly update of the total projected incidents that will be accumulated over the next three hours. When the defined prediction period is over, the program returns to the Detection mode and continues to monitor the number of incidents.

## Results Visualization

The predictions and the actual number of incidents are presented in a line chart on a webpage, an example of which is given below. This output can be viewed with a web browser from any computer with access to the Storm Outage Server.

**Figure A-9. Webpage Example**



## Storm Detection Process

In the Detection mode the program polls the number of incidents every 10 minutes from OMS. If the number of incidents is greater than the detection threshold, then a storm warning is generated. Otherwise, the number of incidents is put into a queue. Once the number of data points reaches the observation window length and the first number in the queue is larger than the trend line threshold, the program calculates a trend line from the queue. If the trend line gradient exceeds the defined slope value, then a storm warning is generated. The initial/default values of the detection criteria are:

|                           |     |
|---------------------------|-----|
| Trend line threshold      | 7   |
| Observation window length | 4   |
| Slope value               | 0.5 |
| Detection threshold       | 40  |

## Storm Outage Prediction Process

In the Prediction mode, the program polls the number of incidents every 15 minutes and feeds the number into a computational observer. The observer utilizes this data and the empirical model applicable for current storm with error compensation, to predict the number of incidents for the next 15 minutes, which is later used in a regression algorithm to generate the predicted number of incidents for the next hour and the next three hours. The empirical model is a statistical model derived from historical data that



describes the outage pattern for each storm type. More information about the empirical model and the observer is available in the footnoted article.<sup>1</sup>

### Demonstration

To demonstrate this application, storm outages from O&R's storm outage database were used along with historical weather data. This historical data was fed into the system to simulate real-time receipt of the data and the output was visualized on the web page. Storm prediction was only 80% accurate, so clearly additional work is needed to determine when a storm has arrived and when the system should switch from determination to prediction mode. Brookhaven National Laboratory (BNL) has recently been awarded a New York State Energy Research and Development Authority (NYSERDA) grant to study the use of Doppler Weather Radar for storm outage prediction O&R will be working collaboratively with BNL on this project along with EDD, the developers of this software for O&R. This study has the potential for providing the means to significantly improve the accuracy of the storm detection portion of the software.

Once the software detects a storm it switches to prediction mode. In the demonstration, the real-time observer adjusted the prediction curve, making it more accurate as time advanced. This allowed the total number of outages to be known long before all of the customer outages were received.

### Conclusions and Lessons Learned from the Demonstration

Table A-3 lists conclusions and lessons learned associated with each conclusion.

**Table A-3. Conclusions and Lessons Learned**

| Conclusions                                                                                                                                                                                                              | Lessons Learned                                                                                                                                                                       |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| While not demonstrated completely in the project, the model-centric approach provides a seamless approach from design to evaluation of alternatives to economic justification to real-time analysis to real-time control | The model-centric approach provides flexibility that is not available in systems that are designed from a functional perspective.                                                     |
| SG devices and algorithms need to be tested in a laboratory environment prior to field-testing to minimize field troubleshooting and repair.                                                                             | Manufacturer's documentation is not always clear on how devices respond in a real-world environment. Lab testing is required to assure that device controls respond as needed.        |
| Testing should involve production communication protocols and systems.                                                                                                                                                   | To reduce communication traffic, during events devices should only communicate data needed by control and decision systems. SCADA systems need the ability to suppress unneeded data. |
| Hardware-in-a-simulation loop environment provides an effective testing environment                                                                                                                                      | Many issues that would have resulted in problems in the field were able to be identified and corrected in the lab.                                                                    |

<sup>1</sup> Zhu, D., Cheng, D., Broadwater, R., & Scirbona, C. (2007). Storm modeling for prediction of power distribution system outages. *Electric Power Systems Research*, volume 77, issue 8, 973 - 979.

| Conclusions                                                                                                                                                                                              | Lessons Learned                                                                                                                                                                  |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A very detailed system model can be used in real-time calculations for control.                                                                                                                          | This provides an alternative to programming for each scenario that a control system needs to respond to.                                                                         |
| Once a type of storm is successfully classified, the number of outages can be accurately predicted as a storm progresses using feed forward statistical models and feedback from actual measured outages | Empirical storm-outage models need to be developed and continually maintained. It is preferable that the model maintenance be automated as new storm and outage data is obtained |

### A.3.2 Software Development and Testing

#### A.3.2.1 O&R

O&R worked with Siemens, TIBCO and EDD to integrate a number of corporate applications with control center applications. Working with EDD O&R developed two real time control and one real time storm outage prediction applications. A key component of O&R's Demonstration Project is demonstration of system interoperability and cyber security.

#### A.3.2.2 Scope of Work and Schedule

O&R's work was incorporated into a sub-award agreement that was executed in April 2011 and amended in May 2012.

O&R's scope of work focused on demonstrating that the reliability of the grid can be improved through a combination of enhanced monitoring and control capabilities along with intelligent analysis tools in the following areas:

- Intelligent Storm Impact Analysis
- System Interoperability
- Cyber Security
- Integration of field device information into Distribution SCADA to perform automated control via intelligent, model-centric control systems.

#### A.3.2.3 Software Requirements Development Process

The software development for this project built upon existing engineering applications by modifying and re-tasking existing algorithms and software applications to provide intelligent real time command and control.

The process included building upon previously funded DOE work and incorporates recent technical findings from third party, peer reviewed technical publications into the system. A list of applicable technical publications is provided in Appendix E.

The requirements for the software included the capability for taking real time system data from substations and field installed devices into a very detailed ISM, consisting of approximately 365,000

multi-phase components. This translates into approximately 1,000,000 node voltage values. A real-time power flow application is run on the ISM each time a change in a real-time value exceeds a threshold. The real-time power flow application, developed prior to this project, processes the ISM sufficiently fast for real-time analysis (i.e., on the order of a few seconds). The results of the power flow are used by other processes and systems to make control decisions. The other processes and systems execute the decisions through a real-time interconnection to an Energy Management System (EMS) and a DSCADA system. The interface to the EMS system is for control of substation load tap changers and feeder breakers. The interface to the DSCADA system is for control of all distribution automation devices.

The requirements development process was based on providing the vendor with the details of the system architecture, details of the cyber-security requirements, as well as the communications protocols, and a description of what the system was to accomplish.

Cyber security requirements were mapped to NIST requirements and appropriate measures were put in place to secure vulnerabilities and permit sharing of data between the systems on the corporate network and those on the high-value, cyber-secure network where the real time systems reside. See Appendix D for cyber-security details.

#### ***A.3.2.4 Software Specification Development Process***

The specifications were iteratively developed around the concept of a model-centric implementation. The specifications were developed with low-cost flexibility and extendibility in mind. O&R specifications for the software were:

1. The model-centric control system must work with off-the-shelf, distribution automation equipment communicating with the SCADA systems.
2. All real-time analysis and control functions must use the same real time ISM model.
3. The power flow application must solve the ISM model from the O&R transmission system through to each individual customer load. (Developed under earlier project)
4. The same analysis functions that are used in planning analysis must be reused in real time analysis for the control systems.
5. The power flow application must be distributable and able to solve the ISM in a few seconds. (Developed under earlier project)
6. Real-time power flow results must be able to drive hundreds of real-time interfaces. (Developed under earlier project)
7. ISM model updates must occur in near real time. (Developed under earlier project)
8. The ISM model updates must have a model Quality Assurance (QA) process. (Currently under development outside of the DOE project)
9. Storm identification must use a set of time series values of outages coupled with weather measurements to identify the presence and type of storm.
10. Storm prediction must use a sampled interval of outages coupled with weather measurements to predict outage volumes.
11. Load estimation must take into account weather measurements provided from substations.

12. Auto reconfiguration must execute within 300 milliseconds.
13. Coordinated control must be able to work with ganged control devices, individual phase control devices, and multi-step devices, including multi-step capacitor banks.
14. Coordinated control, in CVR mode, must maintain customer level voltages at the primaries of distribution transformers above a user specified value.
15. Coordinated control, in either CVR or feeder efficiency modes, must switch to Maximum Capacity mode if low voltages or equipment overloads are detected.
16. The real-time applications must be easily extendable to work with solar generation, wind generation, storage devices, and EVs.
17. The auto-restoration application must operate correctly in the presence of islands.
18. All real-time functions must work seamlessly with selected middleware and within specified architectural design.

#### ***A.3.2.5 Software Development Process***

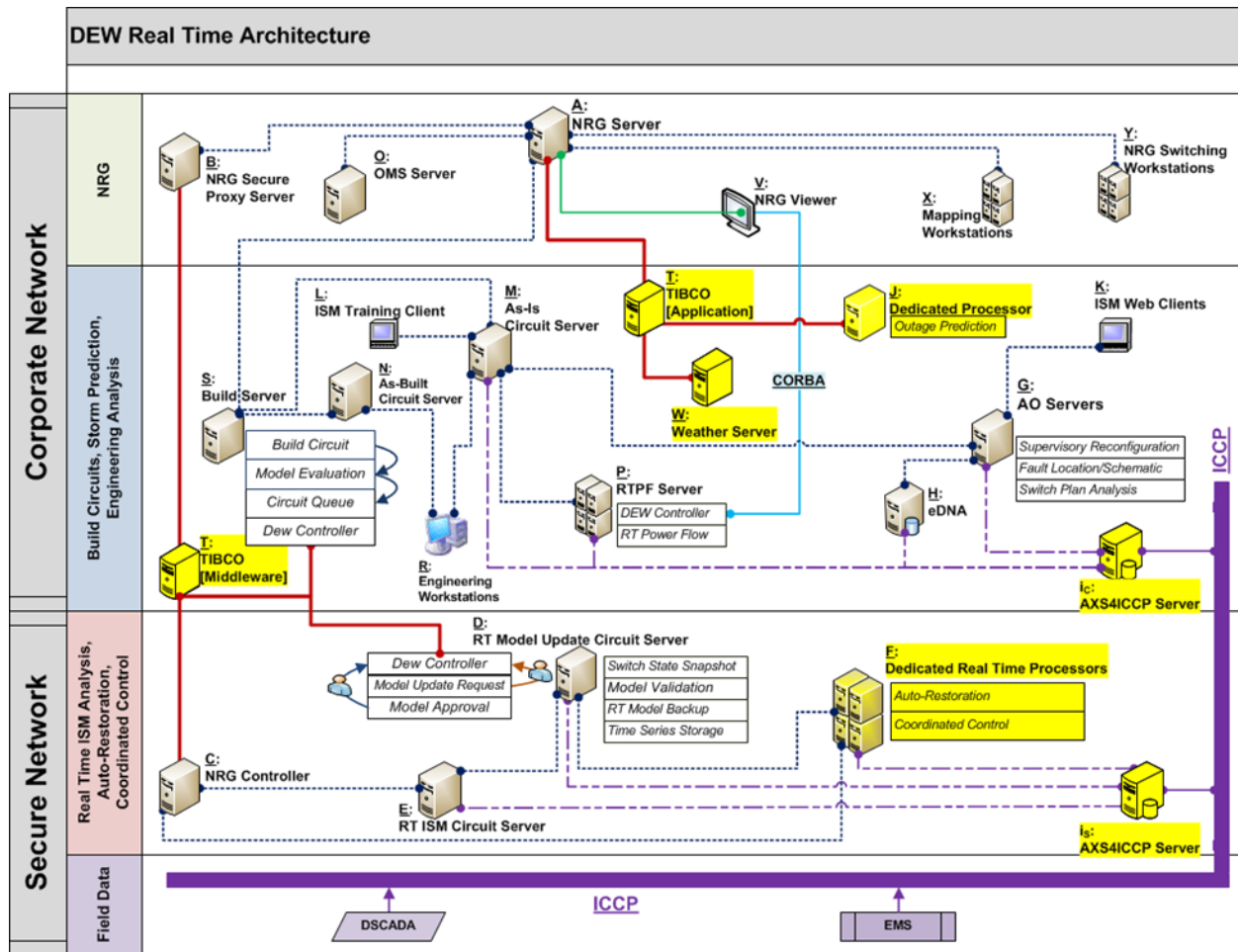
##### **History**

The software developed in this DOE project leverages previous efforts and is part of the development of O&R's Distribution Management System (DMS).

##### **Development Process**

The architecture for the real-time analysis and control hardware and software was established. This architecture defined the framework for the real time applications. The architecture defined the interfaces for each real time application. For communications between the secure network and the corporate network Inter-Control Center Communications Protocol (ICCP) communications was selected. For real time analysis and control application interfaces to EMS and DSCADA, Object Linking and Embedding (OLE) for Process Control (OPC) was selected. For interfaces to operator displays, Mico Corba was selected. TIBCO middleware was selected to simplify interoperability and enhance cyber security among systems. Figure A-10 illustrates the overall hardware/software architecture. The servers highlighted in yellow and communication paths shown in red are all part of this DOE project.

Figure A-10. O&R DMS Hardware/Software Architecture



Each software application was developed using an incremental, test driven process. O&R provided initial requirement specifications listed in Section 4 of this report. A prototype of the software was developed, tested by the software developers, and then tested by personnel independent of the developers. O&R personnel then reviewed the software, provided feedback on the software features, and a second phase of the software development was performed. This incremental, agile development process was continued until O&R was satisfied with the software features and operability.

To meet the O&R specifications, the following real time software capabilities were identified and developed:

1. EMS and DSCADA interfaces to ISM circuit server.
2. Instantiation of measurement driven, auto-restoration event process, where the planning reconfiguration for restoration application was encapsulated as a real-time application.
3. Coordinated control as measurement driven, continuous process, where the planning coordinated control application was encapsulated as a real-time application.
4. Storm identification as a measurement-driven application.

5. Outage volume prediction as a measurement-driven application with memory.
6. Real-time testing simulator that will be transitioned to a training simulator after the DOE project.

### **A.3.3 Testing Process**

#### ***A.3.3.1 Control Systems Testing***

A real-time simulator was developed for use in testing the auto-restoration and the coordinated control real time applications. The simulator uses the same communication interfaces as used in the production system. Thus, software that is successfully tested in this simulator environment can be directly moved into the production environment with no changes.

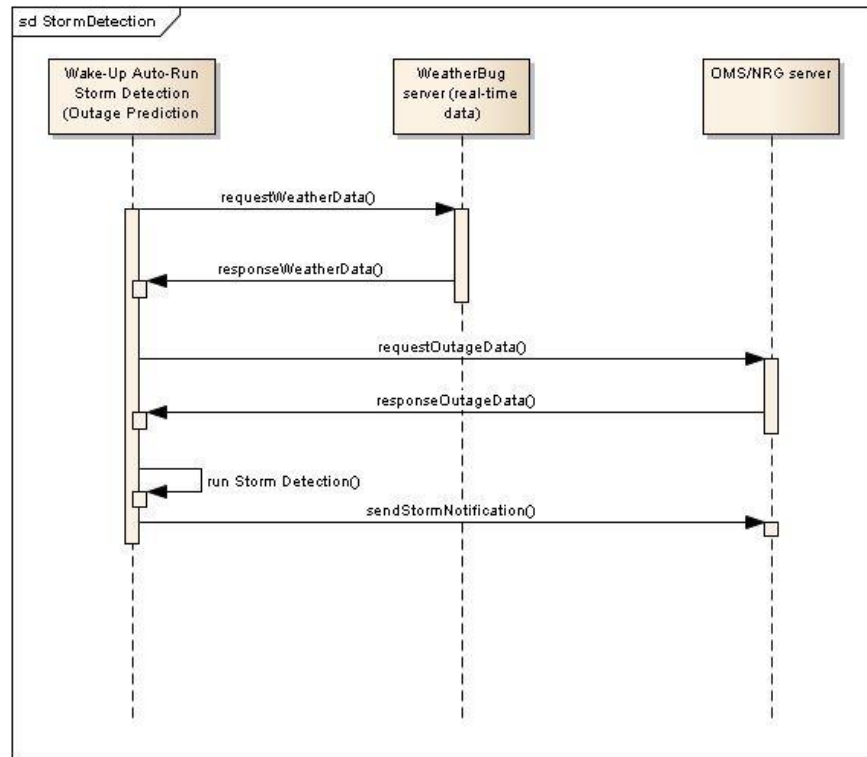
The following process was used for testing of the real-time analysis and control software developed for O&R.

1. Control Algorithm Implementation and Testing.
  - a. Implement algorithm in a real-time simulator framework.
  - b. Test real-time implementation using O&R pilot circuit models running in simulator.
2. Utility Real-Time Simulator and Lab Testing.
  - a. Test control applications using pilot circuits running in real time simulator framework.
  - b. Test production software in O&R SG Lab with end-to-end, hardware-in-the-loop simulation using production DSCADA system and production communication systems.
3. Utility Field Test (to be implemented): Test real-time control running on O&R's electric distribution system.

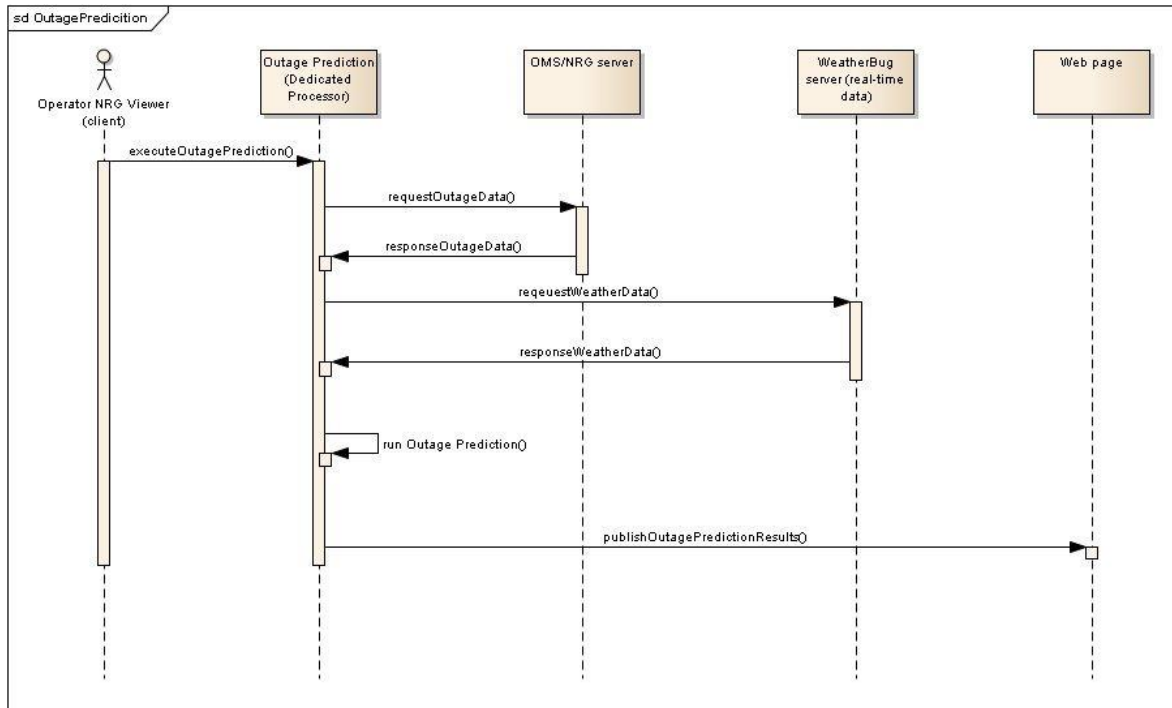
#### ***A.3.3.2 Storm Identification/Prediction Testing***

A testing driver was set up to test the storm identification/prediction application. Figure A-11 and Figure A-12 show the software messages/interactions that were tested for the storm identification and storm outage prediction, respectively. Actual data for two storms was selected from the O&R historical storm database. One storm was a high-temperature storm whose outage data matched the expected high temperature storm model fairly well. The other storm, a high temperature-strong wind storm, was abnormal in that its outage data did not match well with the expected high-temperature-strong wind-storm model.

**Figure A-11. Message Interaction for Storm Identification**



**Figure A-12. Message Interactions for Storm Outage Prediction**



#### **A.3.3.3 Testing Status**

The testing status is as follows:

1. The GIS integration to power flow modeling has been completed and tested (see TIBCO report for software development and testing).
2. The OMS interface to the storm prediction module is in the final iteration of testing. The storm prediction module is complete but is being modified to run as a Web service integrated with the TIBCO Middleware.
3. The DSCADA and EMS systems have been tied through ICCC interfaces to DEW control systems. These interfaces have been tested and have been reviewed by cyber security consultants for compliance with North American Electric Reliability Corporation (NERC) Critical Infrastructure Protection (CIP) requirements.
4. Cyber-security requirements have been fulfilled with a review of architecture and procedures performed by cyber security consultants.
5. The model-centric auto-restoration control system has been developed and tested on field hardware in a laboratory environment.
6. The model-centric coordinated VCC system has been developed and tested on the real-time simulator.
7. The coordinated VCC system will be tested in the O&R SG Lab with production software, production communication systems, and production DSCADA system in June 2013.

#### **A.3.4 Demonstrations**

##### **A.3.4.1 Auto-Restoration Control System**

The real time simulator will be used to demonstrate one or more complex restoration scenarios. Following the real-time simulator demonstration, the O&R SG Lab will be used to demonstrate one or more scenarios using actual automation hardware, communications, and production software. The lab demonstration setup and procedure are provided below.

##### **Lab Demonstration Setup**

1. Six control cabinets from distribution automation equipment are installed in O&R SG Lab.
2. Six geo-synched power supplies are setup and programmed to inject faults into the controls.
3. The controls are equipped with radios and RTUs and communicate with O&R's Spring Valley master radio site.
4. At the master radio site a gate-way communicates with O&R's SCADANET, a cyber-secure, private Internet Protocol (IP) system.
5. The data is back-hauled to concentrators in O&R's NERC CIP compliant, secure server room.
6. Within the O&R secure server room, Distributed Network Protocol (DNP3) over IP communications brings the data from the concentrators into O&R's EMS and DSCADA systems as appropriate.

7. ICCP connects the EMS/DSCADA data with the auto-restoration control system.

#### **Lab Procedure**

1. A fault is injected into the system by the geo-synched power supplies.
2. The automation equipment will clear the fault and communicate status and analog information to DSCADA.
3. The auto-restoration control system reads the change in status of the devices, checking downstream devices to determine the faulted line section.
4. The control system will isolate the fault by sending control signals to DSCADA operable devices to open.
5. The control system will restore customers on unfaulted line sections by sending control signals to the appropriate DSCADA operable devices to close.

#### **A.3.4.2 Coordinated VVC System**

The real time simulator will be used to demonstrate one or more complex coordinated VVC scenarios. Following the real time simulator demonstration, the O&R SG Lab will be used to demonstrate one or more scenarios using actual automation hardware, communications, and production software. Three modes of control will be demonstrated which are: 1-Conservation Voltage Reduction; 2-Optimum Feeder Efficiency; 3-Maximum Capacity.

The lab demonstration setup and procedure are provided below.

#### **Lab Demonstration Setup**

1. Controls for voltage regulating equipment and capacitor banks will be setup in the O&R SG Lab.
2. The controls are equipped with radios and Remote Terminal Units (RTUs) and communicate with O&R's Spring Valley master radio site.
3. At the master radio site a gate-way communicates with O&R's SCADANET, a cyber-secure, private IP system.
4. The data is back-hauled to concentrators in O&R's NERC CIP compliant, secure server room.
5. Within the O&R secure server room, DNP3 over IP communications brings the data from the concentrators into O&R's EMS and DSCADA systems as appropriate.
6. ICCP connects the EMS/DSCADA data with the coordinated control system.

#### **Lab Procedure**

1. The CVR control mode is selected.
2. Voltages and currents are injected as appropriate at the substation controller, the voltage regulator controller, and the capacitor bank controller.
3. The coordinated VVC system minimizes feeder voltage levels without creating any low customer voltages.

4. The Optimum Feeder Efficiency control mode is selected.
5. Voltages and currents are injected as appropriate at the substation controller, the voltage regulator controller, and the capacitor bank controller.
6. The coordinated VVC system adjusts feeder voltage levels to minimize feeder losses without violating any operating constraints.
7. The Maximum Capacity control mode is selected.
8. Voltages and currents are injected as appropriate at the substation controller, the voltage regulator controller, and the capacitor bank controller, where one of the voltages leads to a low customer voltage.
9. The coordinated VVC system adjusts feeder voltage levels to eliminate the low customer voltage.

#### ***A.3.4.3 Storm Identification/Outage Prediction System***

The storm identification/outage prediction system was demonstrated using the software developed for testing the system. Storm data from an actual, high temperature-strong wind storm was used in the demonstration.

Using outage volume measurements and weather measurements, the storm identification algorithm may identify the onset of the storm and the type of storm.

As noted in section A3.1.3, to demonstrate this application, storm outages from O&R's storm outage database were used along with historical weather data. This historical data was fed into the system to simulate real-time receipt of the data and the output was visualized on the web page. Storm prediction was only 80% accurate, so clearly additional work is needed to determine when a storm has arrived and when the system should switch from determination to prediction mode. BNL was awarded a NYSERDA grant to study the use of Doppler Weather Radar for storm outage prediction. O&R will be working collaboratively with BNL on this project along with EDD, the developers of this software for O&R. This study has the potential for providing the means to significantly improve the accuracy of the storm detection portion of the software.

#### **A.3.5 Supporting Documentation**

O&R ISM design documentation, which includes:

- Use Cases
- Architecture
- Process Definitions

Storm identification/outage prediction documentation, which includes:

- Overview
- Process Descriptions
- Program Interfaces
- Data Storage

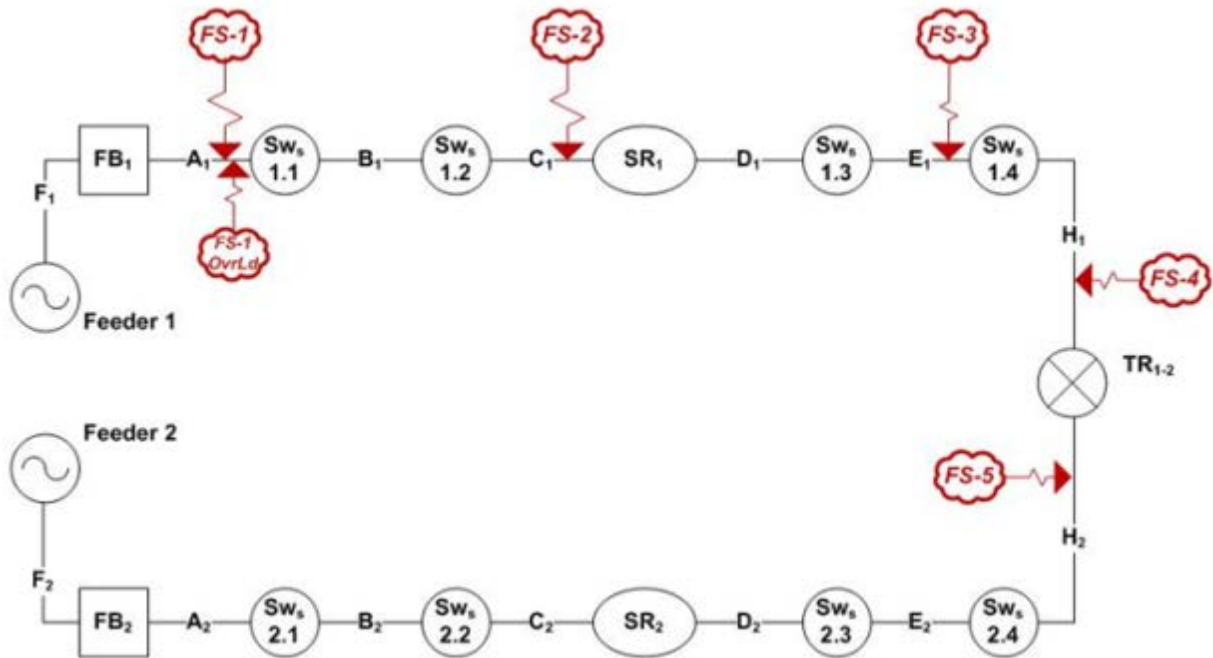
- Deployment Instructions

### A.3.6 Auto-Restoration Scenarios

#### A.3.6.1 Real-Time Simulator Testing

Figure A-13 shows a schematic that is referred to by the scenarios presented in this appendix.

**Figure A-13. Schematic Used in Auto-Restoration Scenarios**



#### FS-1: Fault in Segment A<sub>1</sub>, No Overload

**Initial State:** Circuit in normal operation, TR1-2 open, No faults, Reconfiguration control model fault, and switch operation flags cleared.

**Table A-4. FS-1 Sequence of Events**

| Distribution System                           | ICCP Status & Control Signals | Reconfiguration Controller                                                                                                              |
|-----------------------------------------------|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| Fault occurs in line segment A <sub>1</sub> . |                               | Watch for Feeder Breaker (FB) open signals<br>Watch for fault indicator signals<br><b>Note:</b> FB do not send fault indicator signals. |

| Distribution System                                                                                                                                           | ICCP Status & Control Signals       | Reconfiguration Controller                                                    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|-------------------------------------------------------------------------------|
| FB <sub>1</sub> opens for fault<br>SR <sub>1</sub> senses loss of voltage,<br>starts LS timer<br>TR <sub>1-2</sub> senses loss of voltage,<br>starts LS timer | Status FB <sub>1</sub> – Open (1)   | Open FB <sub>1</sub> in model<br>Start FB <sub>1</sub> lockout timer (70 sec) |
| FB <sub>1</sub> recloses in ½ second<br>SR <sub>1</sub> loss of voltage timer<br>resets<br>TR <sub>1-2</sub> loss of voltage timer<br>resets                  | Status FB <sub>1</sub> – Closed (1) | Close FB <sub>1</sub> in model                                                |
| FB <sub>1</sub> opens<br>SR <sub>1</sub> senses loss of voltage,<br>starts LS timer<br>TR <sub>1-2</sub> senses loss of voltage,<br>starts LS timer           | Status FB <sub>1</sub> – Open (1)   | Open FB <sub>1</sub> in model                                                 |
| FB <sub>1</sub> recloses (15 sec typical)<br>SR <sub>1</sub> loss of voltage timer<br>resets<br>TR <sub>1-2</sub> loss of voltage timer<br>resets             | Status FB <sub>1</sub> – Closed (1) | Close FB <sub>1</sub> in model                                                |
| FB <sub>1</sub> opens<br>SR <sub>1</sub> senses loss of voltage,<br>starts LS timer<br>TR <sub>1-2</sub> senses loss of voltage,<br>starts LS timer           | Status FB <sub>1</sub> – Open (1)   | Open FB <sub>1</sub> in model                                                 |
| FB <sub>1</sub> recloses (30 sec typical)<br>SR <sub>1</sub> loss of voltage timer<br>resets<br>TR <sub>1-2</sub> loss of voltage timer<br>resets             | Status FB <sub>1</sub> – Closed (1) | Close FB <sub>1</sub> in model                                                |

| Distribution System                                                                                                                                               | ICCP Status & Control Signals                                                                                                            | Reconfiguration Controller                                                                                                                                                                                                                                                                                                                                                                                                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| FB <sub>1</sub> opens and locks out<br>SR <sub>1</sub> senses loss of voltage,<br>starts LS timer<br>TR <sub>1-2</sub> senses loss of voltage,<br>starts LS timer | Status FB <sub>1</sub> – Open (1)                                                                                                        | Open FB <sub>1</sub> in model<br>FB <sub>1</sub> watch timer times out<br>Deem FB <sub>1</sub> to be open & Trip to<br>Lockout<br>Set fault flags: FB <sub>1</sub><br>Run Radial Reconfiguration:<br>Generates switch operation list:<br>Open: (1) SW <sub>S1.1</sub> , (2) FB <sub>1</sub><br>Close: (3) TR <sub>1-2</sub><br>Block open:<br>Radial reconfiguration:<br>Sets switch operation flags<br>Clears fault flags |
|                                                                                                                                                                   |                                                                                                                                          | Generate control signals:<br>Open SW <sub>S1.1</sub> , FB <sub>1</sub><br>Close TR <sub>1-2</sub>                                                                                                                                                                                                                                                                                                                          |
|                                                                                                                                                                   | Control signal SW <sub>S1.1</sub> – Trip to<br>Lockout<br>Control signal FB <sub>1</sub> – Trip to<br>Lockout                            | Set App Inhibit on isolation<br>switches<br>App Inhibit FB <sub>1</sub> , SW <sub>S1.1</sub><br>Send isolation signals:<br>Trip to Lockout FB <sub>1</sub> (Note FB <sub>1</sub><br>already open)<br>Trip to Lockout SW <sub>S1.1</sub><br>Verify FB <sub>1</sub> open. If not received in<br>5 sec generate Dew alarm.<br>Watch for SW <sub>S1.1</sub> to open. If not<br>received in<br>5 sec generate Dew alarm.        |
| FB <sub>1</sub> remains open<br>SW <sub>S1.1</sub> opens                                                                                                          | Status FB <sub>1</sub> – Open (1)<br>Status SW <sub>S1.1</sub> – Recloser Open (1)<br>Status SW <sub>S1.1</sub> – Control Lockout<br>(1) | Open FB <sub>1</sub> in model<br>Open SW <sub>S1.1</sub> in model                                                                                                                                                                                                                                                                                                                                                          |
|                                                                                                                                                                   | Control signal TR <sub>1-2</sub> – Close                                                                                                 | Send restoration signals:<br>Close TR <sub>1-2</sub><br>Watch for TR <sub>1-2</sub> close. If not<br>received in<br>5 sec generate Dew alarm.                                                                                                                                                                                                                                                                              |
| TR <sub>1-2</sub> closes                                                                                                                                          | Status TR <sub>1-2</sub> – Recloser Closed (1)                                                                                           | Close TR <sub>1-2</sub> in model                                                                                                                                                                                                                                                                                                                                                                                           |
|                                                                                                                                                                   |                                                                                                                                          | Automated reconfiguration<br>complete                                                                                                                                                                                                                                                                                                                                                                                      |

### FS-1 Overload: Fault in Segment A<sub>1</sub>, With Overload on Segment A<sub>2</sub>

**Initial State:** Circuit in normal operation, TR<sub>1-2</sub> open, No faults, Reconfiguration control model fault, and switch operation flags cleared.

**Table A-5. FS-1 Overload Sequence of Events**

| Distribution System                                                                                                                                     | ICCP Status & Control Signals       | Reconfiguration Controller                                                                             |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|--------------------------------------------------------------------------------------------------------|
| Fault occurs in line segment A <sub>1</sub> .                                                                                                           |                                     | Watch for FB open signals                                                                              |
|                                                                                                                                                         |                                     | Watch for fault indicator signals<br><b>Note:</b> Feeder breakers do not send fault indicator signals. |
| FB <sub>1</sub> opens for fault<br>SR <sub>1</sub> senses loss of voltage, starts LS timer<br>TR <sub>1-2</sub> senses loss of voltage, starts LS timer | Status FB <sub>1</sub> – Open (1)   | Open FB <sub>1</sub> in model<br>Start FB <sub>1</sub> lockout timer ( 70 sec)                         |
| FB <sub>1</sub> recloses in ½ second<br>SR <sub>1</sub> loss of voltage timer resets<br>TR <sub>1-2</sub> loss of voltage timer resets                  | Status FB <sub>1</sub> – Closed (1) | Close FB <sub>1</sub> in model                                                                         |
| FB <sub>1</sub> opens<br>SR <sub>1</sub> senses loss of voltage, starts LS timer<br>TR <sub>1-2</sub> senses loss of voltage, starts LS timer           | Status FB <sub>1</sub> – Open (1)   | Open FB <sub>1</sub> in model                                                                          |
| FB <sub>1</sub> recloses (15 sec typical)<br>SR <sub>1</sub> loss of voltage timer resets<br>TR <sub>1-2</sub> loss of voltage timer resets             | Status FB <sub>1</sub> – Closed (1) | Close FB <sub>1</sub> in model                                                                         |
| FB <sub>1</sub> opens<br>SR <sub>1</sub> senses loss of voltage, starts LS timer<br>TR <sub>1-2</sub> senses loss of voltage, starts LS timer           | Status FB <sub>1</sub> – Open (1)   | Open FB <sub>1</sub> in model                                                                          |
| FB <sub>1</sub> recloses (30 sec typical)<br>SR <sub>1</sub> loss of voltage timer resets<br>TR <sub>1-2</sub> loss of voltage timer resets             | Status FB <sub>1</sub> – Closed (1) | Close FB <sub>1</sub> in model                                                                         |

| Distribution System                                                                                                                                         | ICCP Status & Control Signals                                                                                                                                                                                                              | Reconfiguration Controller                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| FB <sub>1</sub> opens and locks out<br>SR <sub>1</sub> senses loss of voltage, starts LS timer<br>TR <sub>1-2</sub> senses loss of voltage, starts LS timer | Status FB <sub>1</sub> – Open (1)                                                                                                                                                                                                          | Open FB <sub>1</sub> in model<br>FB <sub>1</sub> watch timer times out<br>Deem FB <sub>1</sub> to be open & Trip to Lockout<br>Set fault flags: FB <sub>1</sub><br>Run Radial Reconfiguration:<br>Generates switch operation list:<br>Open: (1) SW <sub>S1.1</sub> , (2) FB <sub>1</sub><br>Close:<br>Block open: (3) TR <sub>1-2</sub><br>Radial reconfiguration:<br>Sets switch operation flags<br>Clears fault flags<br>Generate control signals:<br>Open SW <sub>S1.1</sub> , FB <sub>1</sub><br>Block open TR <sub>1-2</sub> |
|                                                                                                                                                             | Control signal SW <sub>S1.1</sub> – Trip to Lockout<br>Control signal FB <sub>1</sub> – Trip to Lockout<br>Control signal TR <sub>1-2</sub> – Source I Disable<br>Control signal TR <sub>1-2</sub> – Source II Disable                     | Set App Inhibit on isolation switches<br>App Inhibit FB <sub>1</sub> , SW <sub>S1.1</sub><br>Send isolation signals:<br>Open SW <sub>S1.1</sub> , FB <sub>1</sub><br>Block open TR <sub>1-2</sub><br>Verify FB <sub>1</sub> open. If not received in 5 sec generate Dew alarm<br>Watch for SW <sub>S1.1</sub> to open. If not received in 5 sec generate Dew alarm.<br>Watch for TR <sub>1-2</sub> to block open. If not received in 5 sec generate Dew alarm.                                                                    |
| FB <sub>1</sub> remains open<br>SW <sub>S1.1</sub> opens<br>TR <sub>1-2</sub> blocked open                                                                  | Status FB <sub>1</sub> – Open (1)<br>Status SW <sub>S1.1</sub> - Recloser Open (1)<br>Status SW <sub>S1.1</sub> – Control Lockout (1)<br>Status TR <sub>1-2</sub> – Source I Status (0)<br>Status TR <sub>1-2</sub> – Source II Status (0) | Open FB <sub>1</sub> in model<br>Open SW <sub>S1.1</sub> in model<br>Open TR <sub>1-2</sub> in model                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Send restoration signals: None                                                                                                                              |                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

| Distribution System | ICCP Status & Control Signals | Reconfiguration Controller         |
|---------------------|-------------------------------|------------------------------------|
|                     |                               | Automated reconfiguration complete |

## FS-2: Fault in Segment C<sub>1</sub>, No Overload

**Initial State:** Circuit in normal operation, TR<sub>1-2</sub> open, No faults, Reconfiguration control model fault, and switch operation flags cleared.

**Table A-6. FS-2 Sequence of Events**

| Distribution System                                                                                                                                     | ICCP Status & Control Signals                                                                                                                                                                                                                                                                                                                                                           | Reconfiguration Controller                                                                                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| Fault occurs in line segment C <sub>1</sub> .                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                         | Watch for FB open signals<br>Watch for fault indicator signals<br><b>Note:</b> Feeder breakers do not send fault indicator signals. |
| FB <sub>1</sub> opens for fault<br>SR <sub>1</sub> senses loss of voltage, starts LS timer<br>TR <sub>1-2</sub> senses loss of voltage, starts LS timer | Status FB <sub>1</sub> – Open (1)<br>Status SWs <sub>1.1</sub> Phase A Fault Indicator (1)<br>Status SWs <sub>1.1</sub> Phase B Fault Indicator (1)<br>Status SWs <sub>1.1</sub> Phase C Fault Indicator (1)<br>Status SWs <sub>1.2</sub> Phase A Fault Indicator (1)<br>Status SWs <sub>1.2</sub> Phase B Fault Indicator (1)<br>Status SWs <sub>1.2</sub> Phase C Fault Indicator (1) | Open FB <sub>1</sub> in model<br>Start FB <sub>1</sub> lockout timer (70 sec)                                                       |
| FB <sub>1</sub> recloses in ½ second<br>SR <sub>1</sub> loss of voltage timer resets<br>TR <sub>1-2</sub> loss of voltage timer resets                  | Status FB <sub>1</sub> – Closed (1)                                                                                                                                                                                                                                                                                                                                                     | Close FB <sub>1</sub> in model                                                                                                      |
| FB <sub>1</sub> opens<br>SR <sub>1</sub> senses loss of voltage, starts LS timer<br>TR <sub>1-2</sub> senses loss of voltage, starts LS timer           | Status FB <sub>1</sub> – Open (1)                                                                                                                                                                                                                                                                                                                                                       | Open FB <sub>1</sub> in model                                                                                                       |
| FB <sub>1</sub> recloses (15 sec typical)<br>SR <sub>1</sub> loss of voltage timer resets<br>TR <sub>1-2</sub> loss of voltage timer resets             | Status FB <sub>1</sub> – Closed (1)                                                                                                                                                                                                                                                                                                                                                     | Close FB <sub>1</sub> in model                                                                                                      |

| Distribution System                                                                                                                                               | ICCP Status & Control Signals                                                                                 | Reconfiguration Controller                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| FB <sub>1</sub> opens<br>SR <sub>1</sub> senses loss of voltage,<br>starts LS timer<br>TR <sub>1-2</sub> senses loss of voltage,<br>starts LS timer               | Status FB <sub>1</sub> – Open (1)                                                                             | Open FB <sub>1</sub> in model                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| FB <sub>1</sub> recloses (30 sec typical)<br>SR <sub>1</sub> loss of voltage timer resets<br>TR <sub>1-2</sub> loss of voltage timer<br>resets                    | Status FB <sub>1</sub> – Closed (1)                                                                           | Close FB <sub>1</sub> in model                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| FB <sub>1</sub> opens and locks out<br>SR <sub>1</sub> senses loss of voltage,<br>starts LS timer<br>TR <sub>1-2</sub> senses loss of voltage,<br>starts LS timer | Status FB <sub>1</sub> – Open (1)                                                                             | Open FB <sub>1</sub> in model<br>FB <sub>1</sub> watch timer times out<br>Deem FB <sub>1</sub> to be open & locked<br>Set fault flags: FB <sub>1</sub> , SWs <sub>1.1</sub> , SWs <sub>1.2</sub><br>Run Radial Reconfiguration<br>Generates switch operation list:<br>Open: (1) SWs <sub>1.2</sub> , (2) SR <sub>1</sub><br>Close: (3) TR <sub>1-2</sub> (4) FB <sub>1</sub><br>Block open:<br>Radial reconfiguration:<br>Sets switch operation flags<br>Clears fault flags<br>Generate control signals:<br>Open SWs <sub>1.2</sub> , SR <sub>1</sub><br>Close TR <sub>1-2</sub> , FB <sub>1</sub><br>Clear switch operation flags |
|                                                                                                                                                                   | Control signal SWs <sub>1.1</sub> – Trip to<br>Lockout<br>Control signal SR <sub>1</sub> – Trip to<br>Lockout | Set App Inhibit on isolation switches<br>App Inhibit SWs <sub>1.2</sub> , SR <sub>1</sub><br>Send isolation signals:<br>Open SWs <sub>1.2</sub> , SR <sub>1</sub><br>Watch for SWs <sub>1.2</sub> to open. If not<br>received in<br>5 sec generate Dew alarm.<br>Watch for SR <sub>1</sub> to open. If not<br>received in<br>5 sec generate Dew alarm.                                                                                                                                                                                                                                                                             |

| Distribution System                               | ICCP Status & Control Signals                       | Reconfiguration Controller                                                         |
|---------------------------------------------------|-----------------------------------------------------|------------------------------------------------------------------------------------|
| SW <sub>S1.1</sub> Opens<br>SR <sub>1</sub> Opens | Status SW <sub>S1.1</sub> – Recloser Open (1)       |                                                                                    |
|                                                   | Status SW <sub>S1.1</sub> – Control Lockout (1)     | Open SW <sub>S1.1</sub> in model<br>Open SR <sub>1</sub> in model                  |
|                                                   | Status SR <sub>1</sub> – Recloser Open (1)          |                                                                                    |
|                                                   | Status SR <sub>1</sub> – Control Lockout (1)        |                                                                                    |
|                                                   |                                                     | Send restoration signals:<br>Close TR <sub>1-2</sub> , FB <sub>1</sub>             |
|                                                   |                                                     | Watch for TR <sub>1-2</sub> close. If not received in<br>5 sec generate Dew alarm  |
|                                                   |                                                     | Control signal TR <sub>1-2</sub> – Close<br>Control signal FB <sub>1</sub> – Close |
|                                                   |                                                     | Watch for FB <sub>1</sub> close. If not received in<br>5 sec generate Dew alarm    |
| TR <sub>1-2</sub> closes                          | Status TR <sub>1-2</sub> – Recloser Closed (1)      | Close TR <sub>1-2</sub> in model                                                   |
| FB <sub>1</sub> closes                            | Status FB <sub>1</sub> – Circuit Breaker Closed (1) | Close FB <sub>1</sub> in model                                                     |
| Automated reconfiguration complete                |                                                     |                                                                                    |

### FS-3: Fault in Segment E<sub>1</sub>, No Overload

**Initial State:** Circuit in normal operation, TR<sub>1-2</sub> open, No faults, Reconfiguration control model fault, and switch operation flags cleared.

**Table A-7. FS-3 Sequence of Events**

| Distribution System                           | ICCP Status & Control Signals | Dew Reconfiguration Controller/Model                              |
|-----------------------------------------------|-------------------------------|-------------------------------------------------------------------|
| Fault occurs in line segment E <sub>1</sub> . |                               | Watch for FB open signals<br>Watch for fault indicator signals    |
|                                               |                               | <b>Note:</b> Feeder breakers do not send fault indicator signals. |

| Distribution System                                                                                      | ICCP Status & Control Signals                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Dew Reconfiguration Controller/Model |
|----------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|
| SR <sub>1</sub> opens (overcurrent trip)<br>TR <sub>1-2</sub> senses loss of voltage,<br>starts LS timer | Status SR <sub>1</sub> – Recloser Open (1)<br>Status SR <sub>1</sub> Phase A Fault Trip (1)<br>Status SR <sub>1</sub> Phase B Fault Trip (1)<br>Status SR <sub>1</sub> Phase C Fault Trip (1)<br>Status SWs <sub>1.3</sub> Phase A Fault Indicator (1)<br>Status SWs <sub>1.3</sub> Phase B Fault Indicator (1)<br>Status SWs <sub>1.3</sub> Phase C Fault Indicator (1)<br>Status SWs <sub>1.2</sub> Phase A Fault Indicator (1)<br>Status SWs <sub>1.2</sub> Phase B Fault Indicator (1)<br>Status SWs <sub>1.2</sub> Phase C Fault Indicator (1)<br>Status SWs <sub>1.1</sub> Phase A Fault Indicator (1)<br>Status SWs <sub>1.1</sub> Phase B Fault Indicator (1)<br>Status SWs <sub>1.1</sub> Phase B Fault Indicator (1) | Open SR <sub>1</sub> in model        |
| SR <sub>1</sub> recloses in ½ second<br>TR <sub>1-2</sub> loss of voltage timer<br>resets                | Status SR <sub>1</sub> – Recloser Closed (1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Close SR <sub>1</sub> in model       |
| SR <sub>1</sub> opens<br>TR <sub>1-2</sub> senses loss of voltage,<br>starts LS timer                    | Status SR <sub>1</sub> – Recloser Open (1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Open SR <sub>1</sub> in model        |
| SR <sub>1</sub> recloses (17 sec typical)<br>TR <sub>1-2</sub> loss of voltage timer<br>resets           | Status SR <sub>1</sub> – Recloser Closed (1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Close SR <sub>1</sub> in model       |
| SR <sub>1</sub> opens<br>TR <sub>1-2</sub> senses loss of voltage,<br>starts LS timer                    | Status SR <sub>1</sub> – Recloser Open (1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Open SR <sub>1</sub> in model        |
| SR <sub>1</sub> recloses (32 sec typical)<br>TR <sub>1-2</sub> loss of voltage timer<br>resets           | Status SR <sub>1</sub> – Recloser Closed (1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Close SR <sub>1</sub> in model       |

| Distribution System                                                                                 | ICCP Status & Control Signals                                                                                                                                                                        | Dew Reconfiguration Controller/Model                                                                                                                                                                                                                                                                                                                                                                                       |
|-----------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SR <sub>1</sub> opens and locks out<br>TR <sub>1-2</sub> senses loss of voltage,<br>starts LS timer | Status SR <sub>1</sub> – Recloser Open (1)<br>Status SR <sub>1</sub> – Control Lockout (1)                                                                                                           | Open SR <sub>1</sub> in model<br>Set fault flags: SW <sub>S1.3</sub> , SR <sub>1</sub> ,<br>SW <sub>S1.2</sub> , SW <sub>S1.1</sub><br>Run Radial<br>Reconfiguration:<br>Generates switch<br>operation list:<br>Open: (1) SW <sub>S1.3</sub> , (2) SW <sub>S1.4</sub><br>Close: (3) TR <sub>1-2</sub> , (4) SR <sub>1</sub><br>Block open:<br>Radial reconfiguration:<br>Sets switch operation flags<br>Clears fault flags |
|                                                                                                     |                                                                                                                                                                                                      | Generate control signals:<br>Open SW <sub>S1.3</sub> , SW <sub>S1.4</sub><br>Close TR <sub>1-2</sub> , SR <sub>1</sub><br>Clear switch operation<br>flags                                                                                                                                                                                                                                                                  |
|                                                                                                     | Control signal SW <sub>S1.3</sub> – Trip to Lockout<br>Control signal SW <sub>S1.4</sub> – Trip to Lockout                                                                                           | Set App Inhibit on<br>isolation switches<br>Inhibit SW <sub>S1.3</sub> , SW <sub>S1.4</sub><br>Send isolation signals:<br>Open SW <sub>S1.3</sub> , SW <sub>S1.4</sub><br>Watch for SW <sub>S1.3</sub> to open.<br>If not received in<br>5 sec generate Dew alarm.<br>Watch for SW <sub>S1.4</sub> to open.<br>If not received in<br>5 sec generate Dew alarm.                                                             |
|                                                                                                     |                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                            |
| SW <sub>S1.3</sub> opens<br>SW <sub>S1.4</sub> opens                                                | Status SW <sub>S1.3</sub> – Recloser Open (1)<br>Status SW <sub>S1.3</sub> – Control Lockout (1)<br>Status SW <sub>S1.4</sub> – Recloser Open (1)<br>Status SW <sub>S1.4</sub> – Control Lockout (1) | Open SW <sub>S1.3</sub> in model<br>Open SW <sub>S1.4</sub> in model                                                                                                                                                                                                                                                                                                                                                       |
|                                                                                                     |                                                                                                                                                                                                      | Send restoration signals:<br>Close TR <sub>1-2</sub> ,SR <sub>1</sub>                                                                                                                                                                                                                                                                                                                                                      |

| Distribution System      | ICCP Status & Control Signals                  | Dew Reconfiguration Controller/Model                                                                                                                                   |
|--------------------------|------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                          | Control signal TR <sub>1-2</sub> – Close       | Watch for TR <sub>1-2</sub> to close. If not received in 5 sec generate Dew alarm.<br>Watch for SR <sub>1</sub> to close. If not received in 5 sec generate Dew alarm. |
| TR <sub>1-2</sub> closes | Status TR <sub>1-2</sub> – Recloser Closed (1) | Close TR <sub>1-2</sub> in model                                                                                                                                       |
| SR <sub>1</sub> closes   | Status SR <sub>1</sub> – Recloser Closed (1)   | Close SR <sub>1</sub> in model                                                                                                                                         |
|                          |                                                | Automated reconfiguration complete                                                                                                                                     |

#### FS-4: Fault in Segment H<sub>1</sub>, No Overload

**Initial State:** Circuit in normal operation. TR<sub>1-2</sub> open. No faults. Reconfiguration control set to let reclosers operate and lock.

Table A-8. FS-4 Sequence of Events

| Distribution System                                                                                   | ICCP Status & Control Signals                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Dew Reconfiguration Controller/Model                                                                                                |
|-------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| Fault occurs in line segment H <sub>1</sub>                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Watch for FB open signals<br>Watch for fault indicator signals<br><b>Note:</b> Feeder breakers do not send fault indicator signals. |
| SR <sub>1</sub> opens (overcurrent trip)<br>TR <sub>1-2</sub> senses loss of voltage, starts LS timer | Status SR <sub>1</sub> – Recloser Open (1)<br>Status SR <sub>1</sub> Phase A Fault Trip (1)<br>Status SR <sub>1</sub> Phase B Fault Trip (1)<br>Status SR <sub>1</sub> Phase C Fault Trip (1)<br>Status SWs <sub>1.4</sub> Phase A Fault Indicator (1)<br>Status SWs <sub>1.4</sub> Phase B Fault Indicator (1)<br>Status SWs <sub>1.4</sub> Phase C Fault Indicator (1)<br>Status SWs <sub>1.3</sub> Phase A Fault Indicator (1)<br>Status SWs <sub>1.3</sub> Phase B Fault Indicator (1)<br>Status SWs <sub>1.3</sub> Phase C Fault Indicator (1)<br>Status SWs <sub>1.2</sub> Phase A Fault Indicator (1)<br>Status SWs <sub>1.2</sub> Phase B Fault Indicator (1)<br>Status SWs <sub>1.2</sub> Phase C Fault Indicator (1)<br>Status SWs <sub>1.1</sub> Phase A Fault Indicator (1)<br>Status SWs <sub>1.1</sub> Phase B Fault Indicator (1)<br>Status SWs <sub>1.1</sub> Phase B Fault Indicator (1) | Open SR <sub>1</sub> in model                                                                                                       |
| SR <sub>1</sub> recloses in ½ second<br>TR <sub>1-2</sub> loss of voltage timer resets                | Status SR <sub>1</sub> – Recloser Closed (1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Close SR <sub>1</sub> in model                                                                                                      |
| SR <sub>1</sub> opens<br>TR <sub>1-2</sub> senses loss of voltage, starts LS timer                    | Status SR <sub>1</sub> – Recloser Open (1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Open SR <sub>1</sub> in model                                                                                                       |
| SR <sub>1</sub> recloses (17 sec typical)<br>TR <sub>1-2</sub> loss of voltage timer resets           | Status SR <sub>1</sub> – Recloser Closed (1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Close SR <sub>1</sub> in model                                                                                                      |
| SR <sub>1</sub> opens<br>TR <sub>1-2</sub> senses loss of voltage, starts LS timer                    | Status SR <sub>1</sub> – Recloser Open (1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Open SR <sub>1</sub> in model                                                                                                       |
| SR <sub>1</sub> recloses (32 sec typical)<br>TR <sub>1-2</sub> loss of voltage timer resets           | Status SR <sub>1</sub> – Recloser Closed (1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Close SR <sub>1</sub> in model                                                                                                      |

| Distribution System                                                                                 | ICCP Status & Control Signals                                                                                                                                                                         | Dew Reconfiguration Controller/Model                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|-----------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SR <sub>1</sub> opens and locks out<br>TR <sub>1-2</sub> senses loss of voltage,<br>starts LS timer | Status SR <sub>1</sub> – Recloser Open (1)<br>Status SR <sub>1</sub> – Control Lockout (1)                                                                                                            | Open SR <sub>1</sub> in model<br>Set fault flags: SW <sub>S1.4</sub> ,<br>SW <sub>S1.3</sub> , SR <sub>1</sub> , SW <sub>S1.2</sub> ,<br>SW <sub>S1.1</sub><br>Run Radial<br>Reconfiguration:<br>Radial reconfiguration<br>generates switch<br>operation list:<br>Open: (1) SW <sub>S1.4</sub> , (2) TR <sub>1-2</sub><br>Close: (3) SR <sub>1</sub><br>Block open:<br>Radial reconfiguration:<br>Sets switch operation flags<br>Clears fault flags<br><br>Generate control signals:<br>Open SW <sub>S1.4</sub><br>Block open TR <sub>1-2</sub><br>Clear switch operation<br>flags |
|                                                                                                     | Control signal SW <sub>S1.4</sub> – Trip to Lockout<br>Control signal TR <sub>1-2</sub> – Source I Disable<br>Control signal TR <sub>1-2</sub> – Source II Disable                                    | Set App Inhibit on<br>isolation switches<br>Inhibit SW <sub>S1.4</sub> , TR <sub>1-2</sub><br>Send isolation signals:<br>Open SW <sub>S1.4</sub> ,<br>Block open TR <sub>1-2</sub><br>Watch for SW <sub>S1.4</sub> to open.<br>If not received in<br>5 sec generate Dew alarm.<br>Watch for TR <sub>1-2</sub> to block<br>open. If not received<br>in 5 sec generate Dew<br>alarm.                                                                                                                                                                                                 |
| SW <sub>S1.4</sub> opens<br>TR <sub>1-2</sub> blocked open                                          | Status SW <sub>S1.4</sub> - Recloser Open (1)<br>Status SW <sub>S1.4</sub> – Control Lockout (1)<br>Status TR <sub>1-2</sub> – Source I Status (0)<br>Status TR <sub>1-2</sub> – Source II Status (0) | Open SW <sub>S1.4</sub> in model<br>Open TR <sub>1-2</sub> in model                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|                                                                                                     |                                                                                                                                                                                                       | Send restoration signals:<br>Close SR <sub>1</sub>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

| Distribution System    | ICCP Status & Control Signals                | Dew Reconfiguration Controller/Model                                             |
|------------------------|----------------------------------------------|----------------------------------------------------------------------------------|
|                        | Control signal SR <sub>1</sub> – Close       | Watch for SR <sub>1</sub> to close. If not received in 5 sec generate Dew alarm. |
| SR <sub>1</sub> closes | Status SR <sub>1</sub> – Recloser Closed (1) | Close SR <sub>1</sub> in model                                                   |
|                        |                                              | Automated reconfiguration complete                                               |

### FS-5: Fault in Segment H<sub>2</sub>, No Overload

**Initial State:** Circuit in normal operation, TR<sub>1-2</sub> open, No faults, Reconfiguration control model fault, and switch operation flags cleared.

**Table A-9. FS-5 Sequence of Events**

| Distribution System                                                                                   | ICCP Status & Control Signals                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Dew Reconfiguration Controller/Model                                                                                                |
|-------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| Fault occurs in line segment H <sub>2</sub>                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Watch for FB open signals<br>Watch for fault indicator signals<br><b>Note:</b> Feeder breakers do not send fault indicator signals. |
| SR <sub>2</sub> opens (overcurrent trip)<br>TR <sub>1-2</sub> senses loss of voltage, starts LS timer | Status SR <sub>2</sub> – Recloser Open (1)<br>Status SR <sub>2</sub> Phase A Fault Trip (1)<br>Status SR <sub>2</sub> Phase B Fault Trip (1)<br>Status SR <sub>2</sub> Phase C Fault Trip (1)<br>Status SWs <sub>2.4</sub> Phase A Fault Indicator (1)<br>Status SWs <sub>2.4</sub> Phase B Fault Indicator (1)<br>Status SWs <sub>2.4</sub> Phase C Fault Indicator (1)<br>Status SWs <sub>2.3</sub> Phase A Fault Indicator (1)<br>Status SWs <sub>2.3</sub> Phase B Fault Indicator (1)<br>Status SWs <sub>2.3</sub> Phase C Fault Indicator (1)<br>Status SWs <sub>2.2</sub> Phase A Fault Indicator (1)<br>Status SWs <sub>2.2</sub> Phase B Fault Indicator (1)<br>Status SWs <sub>2.2</sub> Phase C Fault Indicator (1)<br>Status SWs <sub>2.1</sub> Phase A Fault Indicator (1)<br>Status SWs <sub>2.1</sub> Phase B Fault Indicator (1)<br>Status SWs <sub>2.1</sub> Phase B Fault Indicator (1) | Open SR <sub>2</sub> in model                                                                                                       |
| SR <sub>2</sub> recloses in ½ second<br>TR <sub>1-2</sub> loss of voltage timer resets                | Status SR <sub>2</sub> – Recloser Closed (1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Close SR <sub>2</sub> in model                                                                                                      |
| SR <sub>2</sub> opens<br>TR <sub>1-2</sub> senses loss of voltage, starts LS timer                    | Status SR <sub>2</sub> – Recloser Open (1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Open SR <sub>2</sub> in model                                                                                                       |
| SR <sub>2</sub> recloses (17 sec typical)<br>TR <sub>1-2</sub> loss of voltage timer resets           | Status SR <sub>2</sub> – Recloser Closed (1)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Close SR <sub>2</sub> in model                                                                                                      |

| Distribution System                                                                              | ICCP Status & Control Signals                                                                                                                                                                         | Dew Reconfiguration Controller/Model                                                                                                                                                                                                                                                                                                                                                                     |
|--------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SR <sub>2</sub> opens<br>TR <sub>1-2</sub> senses loss of voltage, starts LS timer               | Status SR <sub>2</sub> – Recloser Open (1)                                                                                                                                                            | Open SR <sub>2</sub> in model                                                                                                                                                                                                                                                                                                                                                                            |
| SR <sub>2</sub> recloses (32 sec typical)<br>TR <sub>1-2</sub> loss of voltage timer resets      | Status SR <sub>2</sub> – Recloser Closed (1)                                                                                                                                                          | Close SR <sub>2</sub> in model                                                                                                                                                                                                                                                                                                                                                                           |
| SR <sub>2</sub> opens and locks out<br>TR <sub>1-2</sub> senses loss of voltage, starts LS timer | Status SR <sub>1</sub> – Recloser Open (1)<br>Status SR <sub>1</sub> – Control Lockout (1)                                                                                                            | Set SR <sub>2</sub> open<br>Set fault flags: SWs <sub>2,4</sub> , SWs <sub>2,3</sub> , SR <sub>2</sub> , SWs <sub>2,2</sub> , SWs <sub>2,1</sub><br>Run Radial Reconfiguration:<br>Generates switch operation list:<br>Open: (1) SWs <sub>2,4</sub> , (2) TR <sub>1-2</sub><br>Close: (2) SR <sub>2</sub><br>Block open:<br>Radial reconfiguration:<br>Sets switch operation flags<br>Clears fault flags |
|                                                                                                  |                                                                                                                                                                                                       | Generate control signals:<br>Open SWs <sub>2,4</sub><br>Block open TR <sub>1-2</sub><br>Clear switch operation flags                                                                                                                                                                                                                                                                                     |
|                                                                                                  | Control signal SWs <sub>2,4</sub> – Trip to Lockout<br>Control signal TR <sub>1-2</sub> – Source I Disable<br>Control signal TR <sub>1-2</sub> – Source II Disable                                    | Set App Inhibit on isolation switches<br>Inhibit SWs <sub>2,4</sub> , TR <sub>1-2</sub><br>Send isolation signals:<br>Open SWs <sub>2,4</sub><br>Block open TR <sub>1-2</sub><br>Watch for SWs <sub>2,4</sub> to open. If not received in 5 sec generate Dew alarm.<br>Watch for TR <sub>1-2</sub> block to open. If not received in 5 sec generate Dew alarm.                                           |
| SWs <sub>2,4</sub> opens<br>TR <sub>1-2</sub> blocked open                                       | Status SWs <sub>2,1</sub> – Recloser Open (1)<br>Status SWs <sub>1,1</sub> – Control Lockout (1)<br>Status TR <sub>1-2</sub> – Source I Status (0)<br>Status TR <sub>1-2</sub> – Source II Status (0) | Open SWs <sub>2,4</sub> in model<br>Open TR <sub>1-2</sub> in model                                                                                                                                                                                                                                                                                                                                      |
|                                                                                                  |                                                                                                                                                                                                       | Send restoration signals:<br>Close SR <sub>2</sub>                                                                                                                                                                                                                                                                                                                                                       |
|                                                                                                  | Control signal SR <sub>2</sub> – Close                                                                                                                                                                | Watch for SR <sub>2</sub> to close. If not received in 5 sec generate Dew alarm.                                                                                                                                                                                                                                                                                                                         |
| SR <sub>2</sub> closes                                                                           | Status SR <sub>2</sub> – Recloser Closed (1)                                                                                                                                                          | Close SR <sub>2</sub> in model                                                                                                                                                                                                                                                                                                                                                                           |

| Distribution System | ICCP Status & Control Signals | Dew Reconfiguration Controller/Model |
|---------------------|-------------------------------|--------------------------------------|
|                     |                               | Automated reconfiguration complete   |

#### A.3.6.2 Auto-Restoration O&R SG Lab Test Results

The Auto-Restoration test consists of six Reclosers in the lab environment which correlate with a Breaker and five Reclosers in a DEW model. This model represents a circuit in the O&R distribution system. These units communicate through DigitaLogic IGIN units and master radio to the DSCADA server. Specific status points are forwarded to the DEW simulation server by ICCP and OPC servers. Omicron test units are coordinated by Global Positioning System (GPS) synchronization and supply fault currents and appropriate states to each of the Recloser controllers.

The devices are connected in series from the breaker, Sectionalizing Recloser (SR1), Counting Recloser (CR1), Midpoint Recloser (MR1), , Sectionalizing Recloser (SR2), and Tie Recloser (TR1). All are initially closed, except for TR1, which is open and configured with Line Side Reset (LSR).

The tests consist of programmed plans in the Omicron test units to inject faults between each of the Reclosers. Switch status changes and Device Lock-Out flags are evaluated by DEW, an Auto-Restoration solution is calculated, and commands are systematically sent to the sectionalizing Devices, while switch status changes are monitored, and opened switches are flagged in the model for non-operation. The non-operational flags in the model ensure that DEW will not consider closing the switches for a next event until they are cleared by an operational close command. Table A-5 shows the results of the five lab tests.

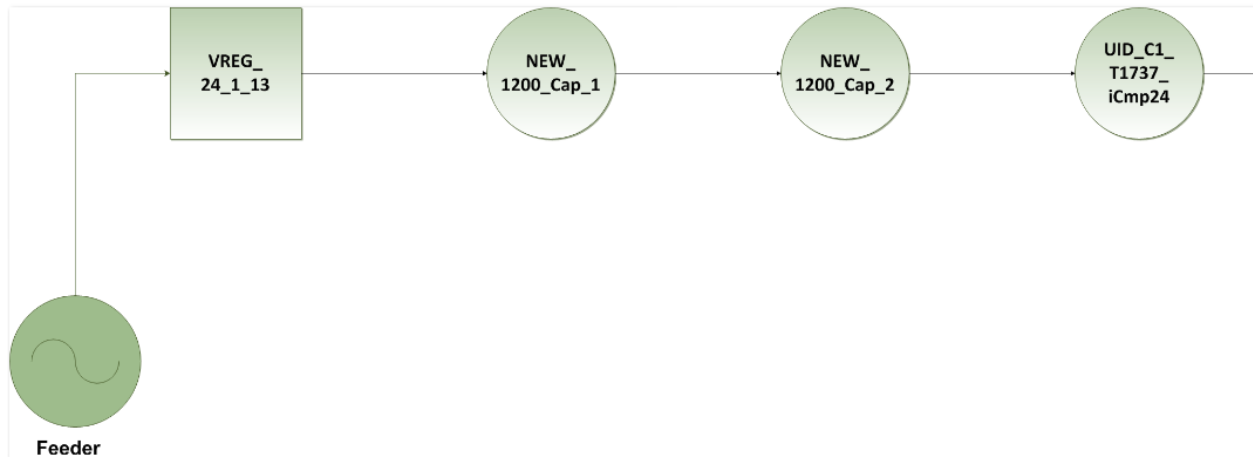
**Table A-10. Results of Auto-Restoration Tests in SG Lab**

| Fault Action                  | Expected Result                                                                                     | Result Pass / Fail |
|-------------------------------|-----------------------------------------------------------------------------------------------------|--------------------|
| Fault between breaker and SR1 | Breaker Open, Locked-Out ;<br>Commands: Open SR1; Close TR1                                         | Pass               |
| Fault between SR1 and CR1     | Breaker Trip/Reclose; SR1 Open<br>Locked-Out; Commands: Open CR1;<br>Close TR1                      | Pass               |
| Fault between CR1 and MR1     | Breaker Trip/Reclose; SR1 Open<br>Locked-Out; Commands: Open MR1<br>Open; CR1; Close SR1; Close TR1 | Pass               |
| Fault between MR1 and CR2     | Breaker Trip/Reclose; SR1 Open<br>Locked-Out; Commands: Open MR1;<br>Open CR2; Close SR1; Close TR1 | Pass               |
| Fault between CR2 and TR1     | Breaker Trip/Reclose; SR1 Open<br>Locked-Out; Commands: Open CR2;<br>Close SR1                      | Pass               |

### A.3.7 Coordinated VVC Test Scenarios

Figure A-14 shows a schematic that is referred to from the scenarios presented in this appendix.

**Figure A-14. Schematic Used in Coordinated Control Scenarios**



#### A.3.7.1 Scenario 1: Low Load Point

Date/Time: January 5, 2013, 2 a.m.

Feeder Amps: 24-1-13 Feeder settings at 170 Amps

Sub-Transformer Voltage: 24-1-13 at 120 Volts

Config File: Lower Limit 100%, Upper Limit 110%, Efficiency Mode

Iteration Steps:

1. New\_1200\_CAP\_2 Set to 1
2. Set Feeder to 175, NEW\_1200\_CAP\_1 Set to 1
3. Set Feeder to 170, UID\_C1\_T1737\_ICmp24 Set to 1
4. Set Feeder to 160, VREG\_24\_1\_13 Set to 1
5. Set Feeder to 170, VREG\_24\_1\_13 Set to 2
6. Set Feeder to 160, VREG\_24\_1\_13 Set to 3
7. Set Feeder to 170, VREG\_24\_1\_13 Set to 4
8. Set Feeder to 160, VREG\_24\_1\_13 Set to 5
9. Set Feeder to 170, VREG\_24\_1\_13 Set to 6
10. Set Feeder to 160, no violations to improve
11. Set Feeder to 170, no violations to improve

#### A.3.7.2 Scenario 2: Artificially Extreme Low Load Point

Date/Time: January 5, 2013, 2 a.m.

Feeder Amps: 24-1-13 Feeder settings at 15 Amps

Sub-Transformer Voltage: 24-1-13 at 120 Volts



Config File: Lower Limit 100%, Upper Limit 110%, Efficiency Mode  
Iteration Steps:

1. New\_1200\_CAP\_2 Set to 1
2. Set Feeder to 10 Amps, UID\_C1\_T1737\_ICmp24 Set to 1
3. Set Feeder to 5 Amps, VREG\_24\_1\_13 Set to 1
4. Set Feeder to 10 Amps, VREG\_24\_1\_13 Set to 2
5. Set Feeder to 5 Amps, VREG\_24\_1\_13 Set to 3
6. Set Feeder to 10 Amps, VREG\_24\_1\_13 Set to 4
7. Set Feeder to 5 Amps, VREG\_24\_1\_13 Set to 5
8. Set Feeder to 10 Amps, VREG\_24\_1-13 Set to 6

#### ***A.3.7.3 Scenario 3: High Load Point***

Date/Time: July 4, 2013, 5 p.m.

Feeder Amps: 24-1-13 Feeder settings at 170 Amps

Sub-Transformer Voltage: 24-1-13 at 120 Volts

Config File: Lower Limit 100%, Upper Limit 110%, Efficiency Mode

Iteration Steps:

1. New\_1200\_CAP\_2 Set to 1
2. Set Feeder to 180, NEW\_1200\_CAP\_1 Set to 1
3. Set Feeder to 190, UID\_C1\_T1737\_ICmp24 Set to 1
4. Set Feeder to 200, VREG\_24\_1\_13 Set to 1
5. Set Feeder to 210, VREG\_24\_1\_13 Set to 2
6. Set Feeder to 220, VREG\_24\_1\_13 Set to 3
7. Set Feeder to 230, VREG\_24\_1\_13 Set to 4
8. Set Feeder to 220, VREG\_24\_1\_13 Set to 5
9. Set Feeder to 230, VREG\_24\_1\_13 Set to 6
10. Set Feeder to 220, VREG\_24\_1\_13 Set to 7
11. Set Feeder to 230, VREG\_24\_1\_13 Set to 8
12. Set Feeder to 220, VREG\_24\_1\_13 Set to 9
13. Set Feeder to 230, VREG\_24\_1\_13 Set to 10
14. Set Feeder to 220, VREG\_24\_1\_13 Set to 11
15. Set Feeder to 230, VREG\_24\_1\_13 Set to 10
16. Set Feeder to 220, VREG\_24\_1\_13 Set to 11
17. Set Feeder to 230, VREG\_24\_1\_13 Set to 10

#### ***A.3.7.4 Scenario 4: High Load Point change to Low Load Point***

Date/Time: January 5, 2013, 2 a.m.

Feeder Amps: 24-1-13 Feeder settings at 150 Amps

Sub-Transformer Voltage: 24-1-13 at 120 Volts

Config File: Lower Limit 100%, Upper Limit 110%, Efficiency Mode

Caps: Cap\_1, CAP\_2 and ICMP24 all set to 1 initially.

Iteration Steps:

1. Set Feeder to 150, VREG\_24\_1\_13 Set to 1
2. Set Feeder to 170, VREG\_24\_1\_13 Set to 2
3. Set Feeder to 180, VREG\_24\_1\_13 Set to 3
4. Set Feeder to 170, VREG\_24\_1\_13 Set to 4
5. Set Feeder to 160, no update
6. Set Feeder to 150, no update
7. Set Feeder to 100, UID\_C1\_T1737\_ICMP24 Cap set to 0

#### ***A.3.7.5 Scenario 5: Customer Voltage Regulation Prioritized***

Date/Time: January 5, 2013, 2 a.m.

Feeder Amps: 24-1-13 Feeder settings at 150 Amps

Sub-Transformer Voltage: 24-1-13 at 120 Volts

Config File: Lower Limit 93%, Upper Limit 96%, Voltage Mode

Iteration Steps:

1. Set Feeder to 150, VREG\_24\_1\_13 Set to -1
2. Set Feeder to 160, VREG\_24\_1\_13 Set to -2
3. Set Feeder to 170, VREG\_24\_1\_13 Set to -3
4. Set Feeder to 180, VREG\_24\_1\_13 Set to -4
5. Set Feeder to 200, VREG\_24\_1\_13 Set to -5
6. Set Feeder to 220, UID\_C1\_T1737\_ICmp24 Cap set to 1
7. Set Feeder to 250, no update

### **A.3.8 NIST Cyber-Security Requirements**

NIST has outlined guidelines for SG Cyber Security. Each security requirement is allocated to one of three categories: governance, risk, and compliance (GRC), common technical or unique technical. The intent of the GRC requirements is to have them addressed at the organization level. It may be necessary to augment these organization-level requirements for specific logical interface categories and/or SG information systems. The common technical requirements are applicable to all of the logical interface categories. The unique technical requirements are allocated to one or more of the logical interface categories. The common and unique technical requirements should be allocated to each SG system and not necessarily to every component within a system, as the focus is on security at the system level.



Each organization must develop security architecture for each SG information system and allocate security requirements to components/devices. SG security policy can be included as part of the general information security policy for the organization. However, procedures can be developed for the security program in general and for a particular SG information system when required.

For the Logical Reference Model, NIST categorizes the SG into seven domains: Transmission, Distribution, Operations, Bulk Generation, Markets, Customers and Service Provider. A domain is a high-level grouping of actors with similar objectives relying on or participating in similar types of applications. Actors are devices, systems or programs that make decisions and exchange information necessary for executing applications within the SG. The interactions between different NIST actors are further defined by logical interfaces, which are grouped by category, based on common attributes for security requirements.

The following two tables extract the actors and logical interfaces defined by the NIST guidelines that are applicable for the O&R SG implementation with DEW. For example, the interaction between NRG and DEW corresponds with the NIST defined interaction between the GIS (actor-17) and the DMS (actor-27) utilizing the logical interface “U102”, found in logical interface category #2.

**Table A-11. Actor Descriptions for Logical Reference Model**

| Actor Number | Domain       | Actor                                                           | Abbreviation     | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|--------------|--------------|-----------------------------------------------------------------|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 15           | Distribution | Distribution Remote Terminal Unit/Intelligent Electronic Device | RTUs or IEDs     | Receive data from sensors and power equipment, and can issue control commands, such as tripping circuit breakers, if they sense voltage, current, or frequency anomalies, or raise/lower voltage levels in order to maintain the desired level.                                                                                                                                                                                                                   |
| 17           | Distribution | GIS                                                             | NRG              | A spatial asset management system that provides utilities with asset information and network connectivity for advanced applications.                                                                                                                                                                                                                                                                                                                              |
| 26           | Operations   | Distribution Engineering                                        | DEW (planning)   | <p>A technical function of planning or managing the design or upgrade of the distribution system. For example:</p> <ul style="list-style-type: none"> <li>• The addition of new customers</li> <li>• The build-out for new load</li> <li>• The configuration and/or capital investments for improving system reliability.</li> </ul>                                                                                                                              |
| 27           | Operations   | DMS                                                             | DEW (operations) | A suite of application software that supports electric system operations. Example applications include topology processor, online three-phase unbalanced distribution power flow, contingency analysis, study mode analysis, switch order management, short-circuit analysis, volt-var management, and loss analysis. These applications provide operations staff and engineering personnel additional information and tools to help accomplish their objectives. |
| 28           | Operations   | Distribution Operator                                           | DO               | Person operating the distribution system.                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 29           | Operations   | Distribution Supervisory Control and Data Acquisition           | DSCADA           | A type of control system that transmits individual device status, manages energy consumption by controlling compliant devices, and allows operators to directly control power system equipment.                                                                                                                                                                                                                                                                   |

| Actor Number | Domain     | Actor                    | Abbreviation | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|--------------|------------|--------------------------|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 30           | Operations | EMS                      | EMS          | <p>A system of computer-aided tools used by operators of electric utility grids to monitor, controls, and optimize the performance of the generation and/or transmission system. The monitor and control functions are known as SCADA; the optimization packages are often referred to as "advanced applications." (Note: Gas and water could be separate from or integrated within the EMS.)</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 36           | Operations | Outage Management System | OMS          | <p>An OMS is a computer system used by operators of electric distribution systems to assist in outage identification and restoration of power.</p> <p>Major functions usually found in an OMS include:</p> <ul style="list-style-type: none"> <li>• Listing all customers who have outages.</li> <li>• Prediction of location of fuse or breaker that opened upon failure.</li> <li>• Prioritizing restoration efforts and managing resources based upon criteria such as location of emergency facilities, size of outages, and duration of outages.</li> <li>• Providing information on extent of outages and number of customers impacted to management, media, and regulators.</li> <li>• Estimation of restoration time.</li> <li>• Management of crews assisting in restoration.</li> <li>• Calculation of crews required for restoration.</li> </ul> |

**Table A-12. Logical Interfaces by Category**

| LI Cat# | Logical Interface Category                                                                                                                                                                                                                                       | Logical Interfaces |
|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|
| 2       | Interface between control systems and equipment without high availability, but with compute and/or bandwidth constraints, for example: <ul style="list-style-type: none"> <li>Between NRG (NIST actor 17) and DEW (NIST actor 27)</li> </ul>                     | U102               |
| 4       | Interface between control systems and equipment without high availability, without compute nor bandwidth constraints, for example: <ul style="list-style-type: none"> <li>Between distribution SCADA (NIST actor 29) and RTUs or IEDs (NIST actor 15)</li> </ul> | U117               |
| 10      | Interface between control systems and non-control/corporate systems, for example: <ul style="list-style-type: none"> <li>Between NRG proxy and NRG Controller</li> </ul>                                                                                         | User defined       |

The following matrix outlines the Cyber Security processes utilized by O&R to protect logical interfaces U102, U117 and the user defined interface between NRG Proxy and the NRG Controller.

**Table A-13. O&R SG Cyber Security Compliance Matrix**

| SG Security Requirement | SG Requirement Name                            | O&R SG<br>Cyber Security processes to protect logical interfaces U102, U117 and the user defined interface between NRG Proxy and the NRG Controller.                                                                        |
|-------------------------|------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SG.AC                   | Access Control                                 | Active Directory to be utilized for domain authentication. Access determined by application protocols.                                                                                                                      |
| SG.AT                   | Awareness and Training                         | Yearly Cyber Security training required by corporate policy.                                                                                                                                                                |
| SG.AU                   | Audit and Accountability                       | Review of cyber security policies and procedure by corporate auditing.                                                                                                                                                      |
| SG.CA                   | Security Assessment and Authorization          | Compliance audits and incident reviews to gauge effectiveness of the security program.                                                                                                                                      |
| SG.CM                   | Configuration Management                       | Configuration Management software will document system configuration.<br>Tests, validates, and documents configuration changes (e.g., patches and updates) before installing them on the operational SG information system. |
| SG.CP                   | Continuity of Operations                       | Redundancy built in to the system to allow for continual operation.<br>Alternate control center to be utilized when primary control center is unavailable.                                                                  |
| SG.IA                   | Identification and Authentication              | Active Directory to be utilized for domain authentication. Access determined by application protocols.                                                                                                                      |
| SG.ID                   | Information and Document Management            | Corporate record and documentation management requirements.<br>Non- disclosure agreements utilized for transfer of sensitive information (CEII).                                                                            |
| SG.IR                   | Incident Response                              | Incident response plan in place to track and report incidents on the system.<br>Corporate disaster recovery procedure used as well.                                                                                         |
| SG.MA                   | Information System Development and Maintenance | Change management procedure used to implement and document changes and upgrades to the network.<br>Change control procedure utilized for assets.                                                                            |
| SG.MP                   | Media Protection                               | Corporate policy for media protection and disposal.                                                                                                                                                                         |

| SG Security Requirement | SG Requirement Name                             | O&R SG<br>Cyber Security processes to protect logical interfaces U102, U117 and the user defined interface between NRG Proxy and the NRG Controller.                                                      |
|-------------------------|-------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SG.PE                   | Physical and Environmental Security             | ECC access is restricted via corporate card access control in a CIP compliant environment. Utilize ECC access control procedures. Field devices are in locked cabinets with door alarms tied back to ECC. |
| SG.PL                   | Strategic Planning                              | Disaster recovery procedures in place to insure continuity of operation.                                                                                                                                  |
| SG.PM                   | Security Program Management                     | Corporate information system security policy and DOE Cyber Security plan outline overall CS framework.                                                                                                    |
| SG.PS                   | Personnel Security                              | Corporate security screening and background checks for critical staff positions and access control.                                                                                                       |
| SG.RA                   | Risk Management and Assessment                  | Risk identification and classification process is continually performed to monitor the SG information system's compliance status.                                                                         |
| SG.SA                   | Information System and Service Acquisitions     | Cyber Security compliance is part of the purchasing process. Vendors must certify compliance to be considered. Use of nondisclosure agreements with vendors to ensure confidentiality.                    |
| SG.SC                   | Information System and Communication Protection | Firewalls and 256 bit data encryption utilized to protect the system.                                                                                                                                     |
| SG.SI                   | Information System and Information Integrity    | Stealthwatch IDS continually monitors the network. Application protocols (IGIN, DEW) provide data validation and integrity checks.                                                                        |

The NIST defined guidelines that are outlined in the 'O&R SG Cyber Security Compliance Matrix' are described below.

#### ***A.3.8.1 Access Control (SG.AC)***

The focus of access control is ensuring that resources are accessed only by the appropriate personnel, and that personnel are correctly identified. Mechanisms need to be in place to monitor access, and report inappropriate activity.

#### ***A.3.8.2 Awareness and Training (SG.AT)***

SG information system security awareness is a critical part of SG information system incident prevention. Implementing a SG information system security program may change the way personnel access

computer programs and applications, so organizations need to design effective training programs based on individuals' roles and responsibilities.

#### ***A.3.8.3 Audit and Accountability (SG.AU)***

Periodic audits and logging of the SG information system need to be implemented to validate that the security mechanisms present during SG information system validation testing are still installed and operating correctly. These security audits review and examine a SG information system's records and activities to determine the adequacy of SG information system security requirements and to ensure compliance with established security policy and procedures. Audits also are used to detect breaches in security services through examination of SG information system logs.

#### ***A.3.8.4 Security Assessment and Authorization (SG.CA)***

Security assessments include monitoring and reviewing the performance of the SG information system. Internal checking methods, such as compliance audits and incident investigations, allow the organization to determine the effectiveness of the security program. Finally, through continuous monitoring, the organization regularly reviews compliance of the SG information systems. If deviations or nonconformance exist, it may be necessary to revisit the original assumptions and implement appropriate corrective actions.

#### ***A.3.8.5 Configuration Management (SG.CM)***

The organization's security program needs to implement policies and procedures that create a process by which the organization manages and documents all configuration changes to the SG information system. A comprehensive change management process needs to be implemented and used to ensure that only approved and tested changes are made to the SG information system configuration. SG information systems need to be configured properly to maintain optimal operation. Therefore, only tested and approved changes should be allowed on a SG information system. Vendor updates and patches need to be thoroughly tested on a non-production SG information system setup before being introduced into the production environment to ensure that no adverse effects occur.

#### ***A.3.8.6 Continuity of Operations (SG.CP)***

Continuity of operations addresses the capability to continue or resume operations of a SG information system in the event of disruption of normal system operation. The ability for the SG information system to function after an event is dependent on implementing continuity of operations policies, procedures, training, and resources. The security requirements recommended under the continuity of operations family provide policies and procedures for roles and responsibilities, training, testing, plan updates, alternate storage sites, alternate command and control methods, alternate control centers, recovery and reconstitution and fail-safe response.

#### ***A.3.8.7 Identification and Authentication (SG.IA)***

Identification and authentication is the process of verifying the identity of a user, process, or device, as a prerequisite for granting access to resources in a SG information system. The SG information system uniquely identifies and authenticates users. The authentication mechanisms must obscure feedback of authentication information during the authentication process to protect the information from possible exploitation/use by unauthorized individuals.

#### ***A.3.8.8 Information and Document Management (SG.ID)***

Information and document management is generally a part of the organization records retention and document management system. Digital and hardcopy information associated with the development and execution of a SG information system is important and sensitive, and need to be managed. SG information system design, operations data and procedures, risk analyses, business impact studies, risk tolerance profiles, etc., contain sensitive organization information and need to be protected. This information must be protected and verified that the appropriate versions are retained.

#### ***A.3.8.9 Incident Response (SG.IR)***

Incident response addresses the capability to continue or resume operations of a SG information system in the event of disruption of normal SG information system operation. Incident response entails the preparation, testing, and maintenance of specific policies and procedures to enable the organization to recover the SG information system's operational status after the occurrence of a disruption. Disruptions can come from natural disasters, such as earthquakes, tornados, floods, or from manmade events like riots, terrorism, or vandalism. The ability for the SG information system to function after such an event is directly dependent on implementing policies, procedures, training, and resources in place ahead of time using the organization's planning process. The security requirements recommended under the incident response family provide policies and procedures for incident response monitoring, handling, reporting, testing, training, recovery, and reconstitution of the SG information systems for an organization.

#### ***A.3.8.10 SG Information System Development and Maintenance (SG.MA)***

Security is most effective when it is designed into the SG information system and sustained, through effective maintenance, throughout the life cycle of the SG information system. Maintenance activities encompass appropriate policies and procedures for performing routine and preventive maintenance on the components of a SG information system. This includes the use of both local and remote maintenance tools and management of maintenance personnel. Maintenance records must be maintained showing date and time of maintenance, name of individual performing the maintenance, description of maintenance performed and list of equipment removed or replaced including identification numbers.

#### ***A.3.8.11 Media Protection (SG.MP)***

The security requirements under the media protection family provide policy and procedures for limiting access to media to authorized users. Security measures also exist for distribution and handling requirements as well as storage, transport, sanitization (removal of information from digital media), destruction, and disposal of the media. Media assets include compact discs; digital video discs; erasable, programmable read-only memory; tapes; printed reports; and documents.

#### ***A.3.8.12 Physical and Environmental Security (SG.PE)***

Physical and environmental security encompasses protection of physical assets from damage, misuse, or theft. Physical access control, physical boundaries, and surveillance are examples of security practices used to ensure that only authorized personnel are allowed to access SG information systems and components. Environmental security addresses the safety of assets from damage from environmental concerns. Physical and environmental security addresses protection from environmental threats.

#### ***A.3.8.13 Planning (SG.PL)***

The purpose of strategic planning is to maintain optimal operations and to prevent or recover from undesirable interruptions to SG information system operation. Interruptions may take the form of a natural disaster (hurricane, tornado, earthquake, flood, etc.), an unintentional manmade event (accidental equipment damage, fire or explosion, operator error, etc.), an intentional manmade event (attack by bomb, firearm or vandalism, hacker or malware, etc.), or an equipment failure. The types of planning considered are security planning to prevent undesirable interruptions, continuity of operations planning to maintain SG information system operation during and after an interruption, and planning to identify mitigation strategies.

#### ***A.3.8.14 Security Program Management (SG.PM)***

The security program lays the groundwork for securing the organization's enterprise and SG information system assets. Security procedures define how an organization implements the security program.

#### ***A.3.8.15 Personnel Security (SG.PS)***

Personnel security addresses security program roles and responsibilities implemented during all phases of staff employment, including staff recruitment and termination. The organization screens applicants for critical positions in the operation and maintenance of the SG information system. The organization may consider implementing a confidentiality or nondisclosure agreement that employees and third-party users of facilities must sign before being granted access to the SG information system. The organization also documents and implements a process to secure resources and revoke access privileges when personnel terminate.

#### ***A.3.8.16 Risk Management and Assessment (SG.RA)***

Risk management planning is a key aspect of ensuring that the processes and technical means of securing SG information systems have fully addressed the risks and vulnerabilities in the SG information system.

An organization identifies and classifies risks to develop appropriate security measures. Risk identification and classification involves security assessments of SG information systems and interconnections to identify critical components and any areas weak in security. The risk identification and classification process is continually performed to monitor the SG information system's compliance status.

#### ***A.3.8.17 SG Information System and Services Acquisition (SG.SA)***

SG information systems and services acquisition covers the contracting and acquiring of system components, software, firmware, and services from employees, contactors, and third parties. A policy with detailed procedures for reviewing acquisitions should reduce the introduction of additional or unknown vulnerabilities into the SG information system. The organization must consider the increased security risk associated with outsourcing as part of the decision-making process to determine what to outsource and what outsourcing party to select. The organization must consider confidentiality or nondisclosure agreements and intellectual property rights.

#### **A.3.8.18 SG Information System and Communication Protection (SG.SC)**

SG information system and communication protection consists of steps taken to protect the SG information system and the communication links between SG information system components from cyber intrusions. Although SG information system and communication protection might include both physical and cyber protection, SG.SC addresses only cyber protection. Physical protection is addressed in SG.PE, Physical and Environmental Security.

#### **A.3.8.19 SG Information System and Information Integrity (SG.SI)**

Maintaining a SG information system, including information integrity, increases assurance that sensitive data have neither been modified nor deleted in an unauthorized or undetected manner. The security requirements described under the SG information system and information integrity family provide policy and procedure for identifying, reporting, and correcting SG information system flaws. Requirements exist for malicious code detection. Also provided are requirements for receiving security alerts and advisories and the verification of security functions on the SG information system. In addition, requirements within this family detect and protect against unauthorized changes to software and data; restrict data input and output; check the accuracy, completeness, and validity of data; and handle error conditions.

**\*\*\*\* This document references the document NISTIR 7628 - Guidelines for SG Cyber Security: Vol. 1, SG Cyber Security Strategy, Architecture, and High-Level Requirements, August 2010.**

To facilitate review of the O&R implementation with the appropriate guidelines, the DEW Real Time Architecture drawings have been annotated with the corresponding actors and logical interface categories defined by the NIST Cyber Security guidelines. In the following illustrations, the overall and the process-specific architectures are presented with their NIST Logical Reference Model correlations:

**Figure A-15. NIST Legend**

**Legend: NIST Logical Reference Model**

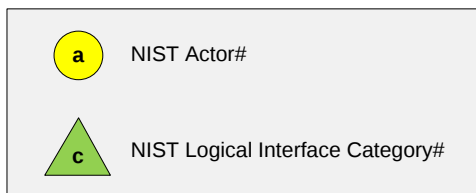


Figure A-16. DEW Real-Time Architecture

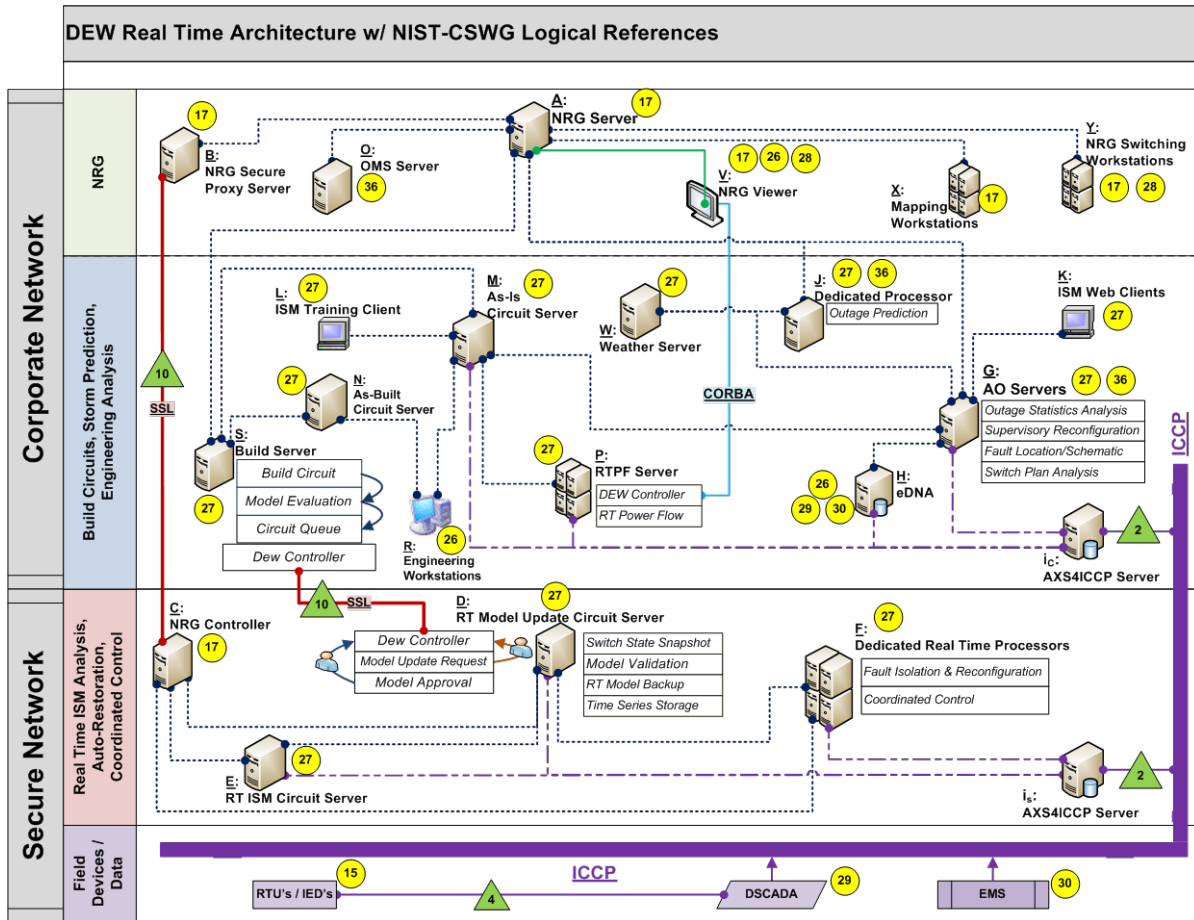


Figure A-17. Model Validation Architecture

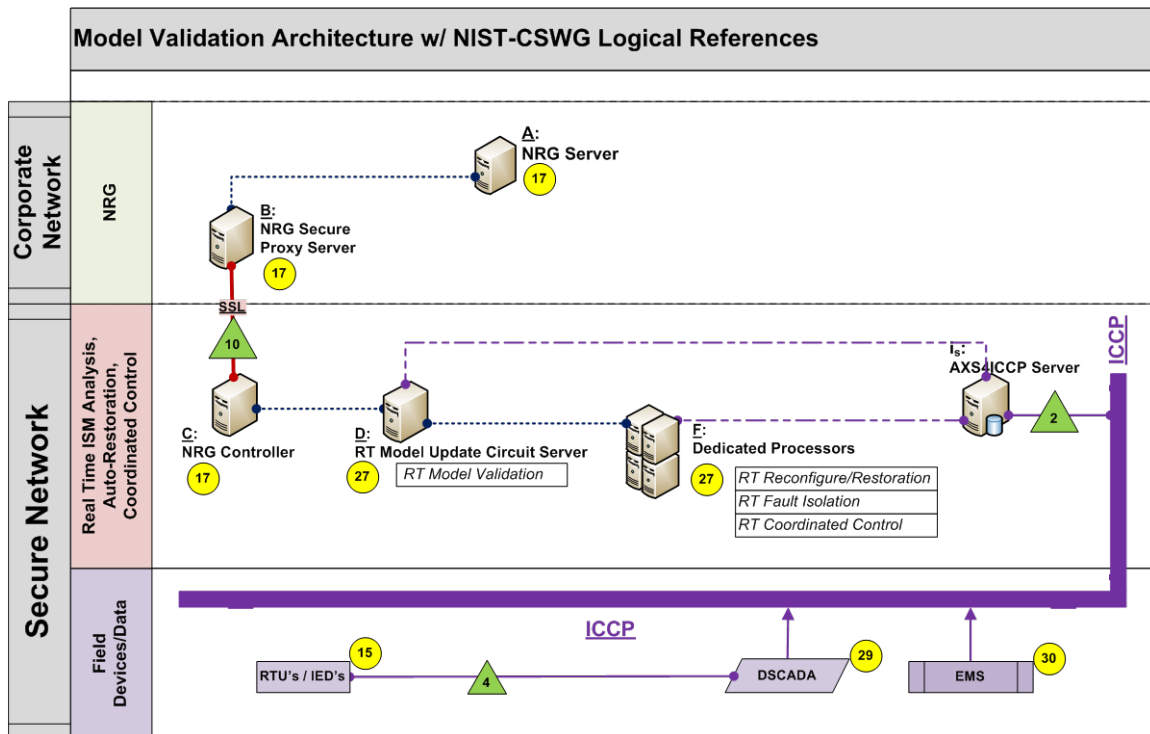


Figure A-18. Automatic Switching Operations Architecture

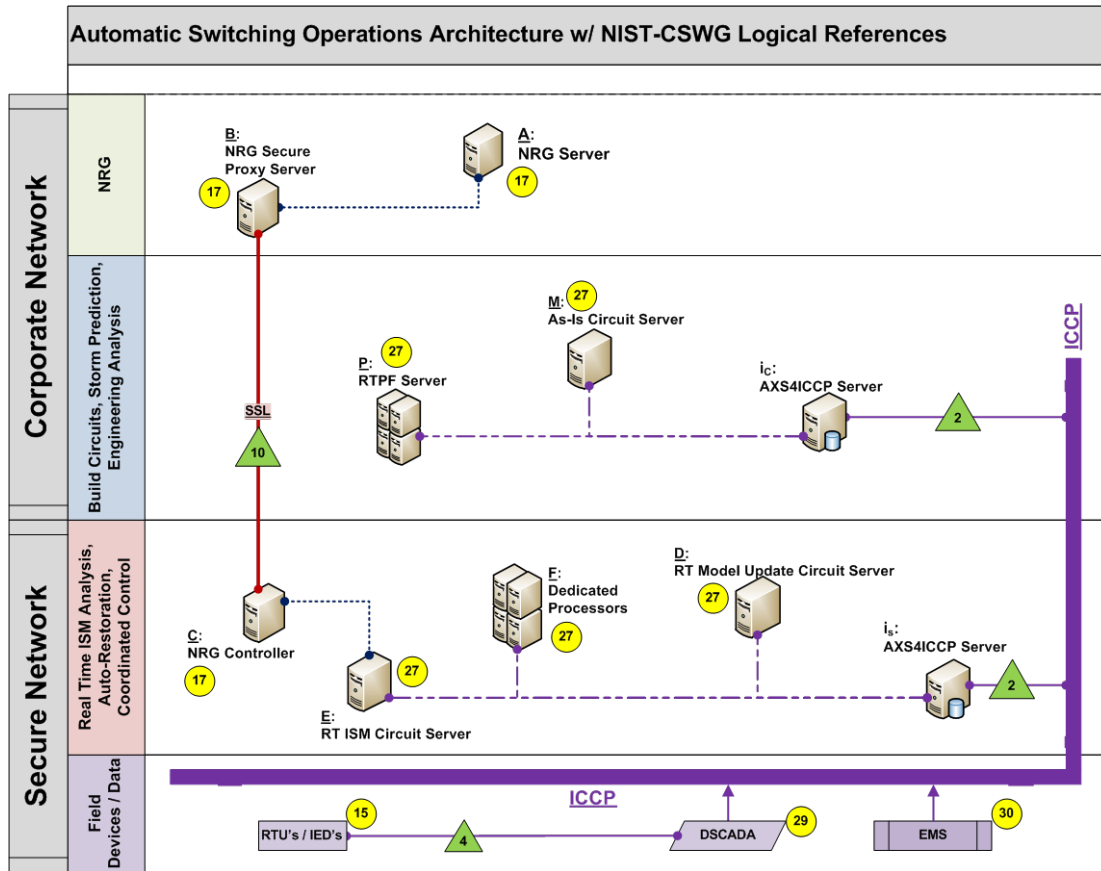


Figure A-19. Manual Switching Operations Architecture

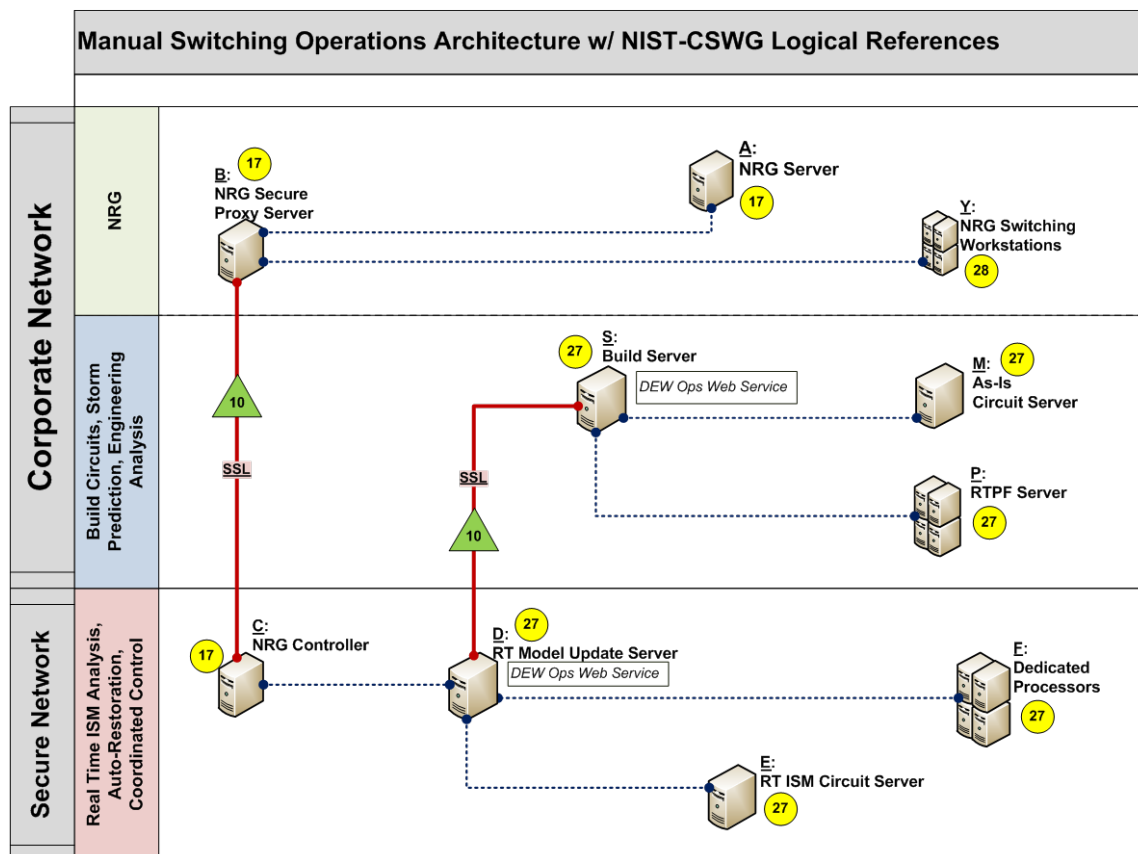


Figure A-20. RT Coordinated Control Network

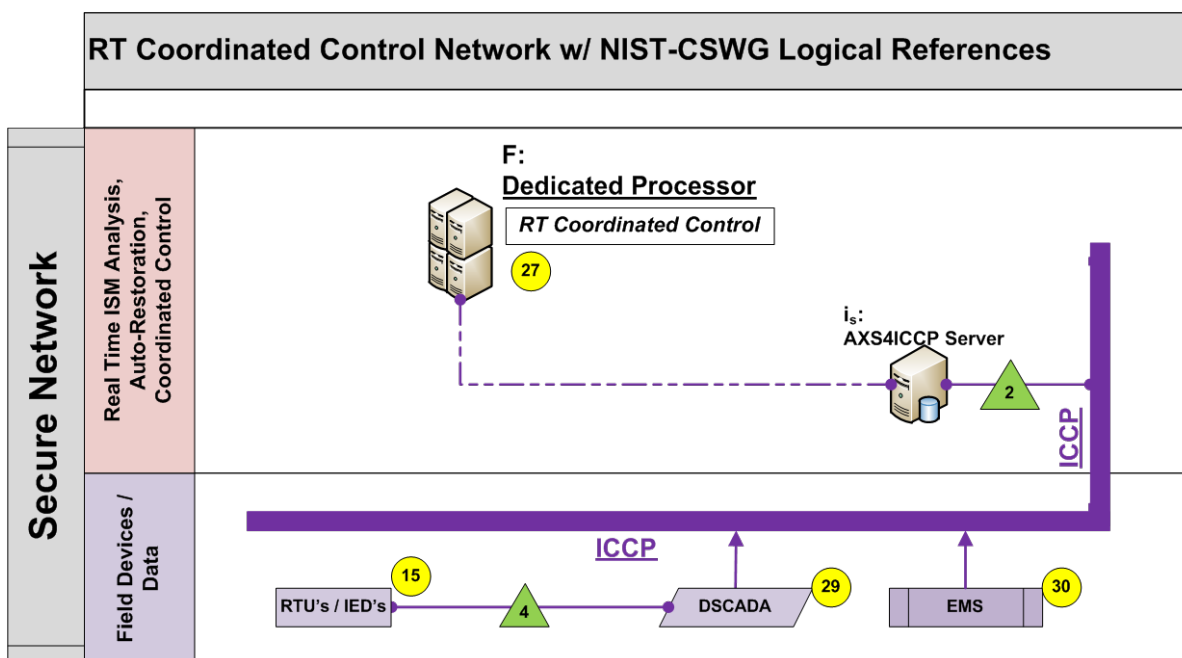


Figure A-21. Real-Time Fault Isolation Architecture

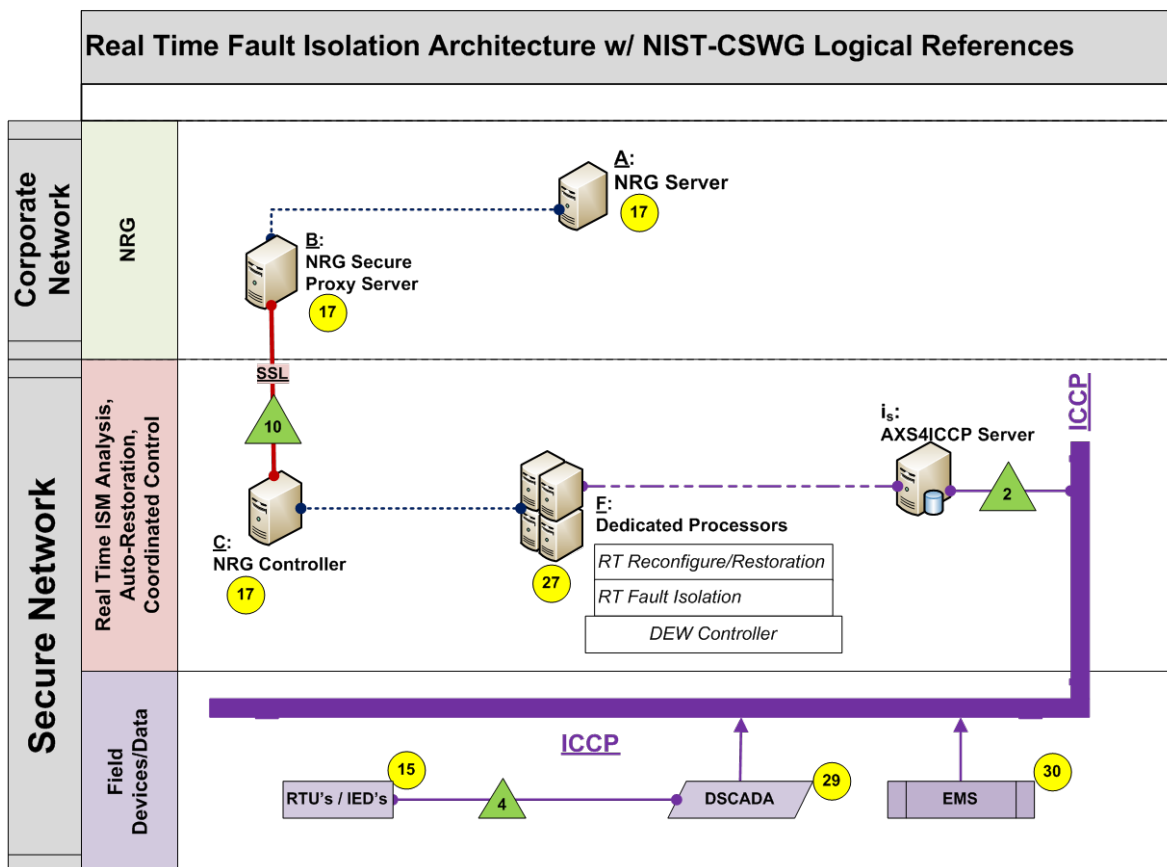


Figure A-22. Fault Location Architecture

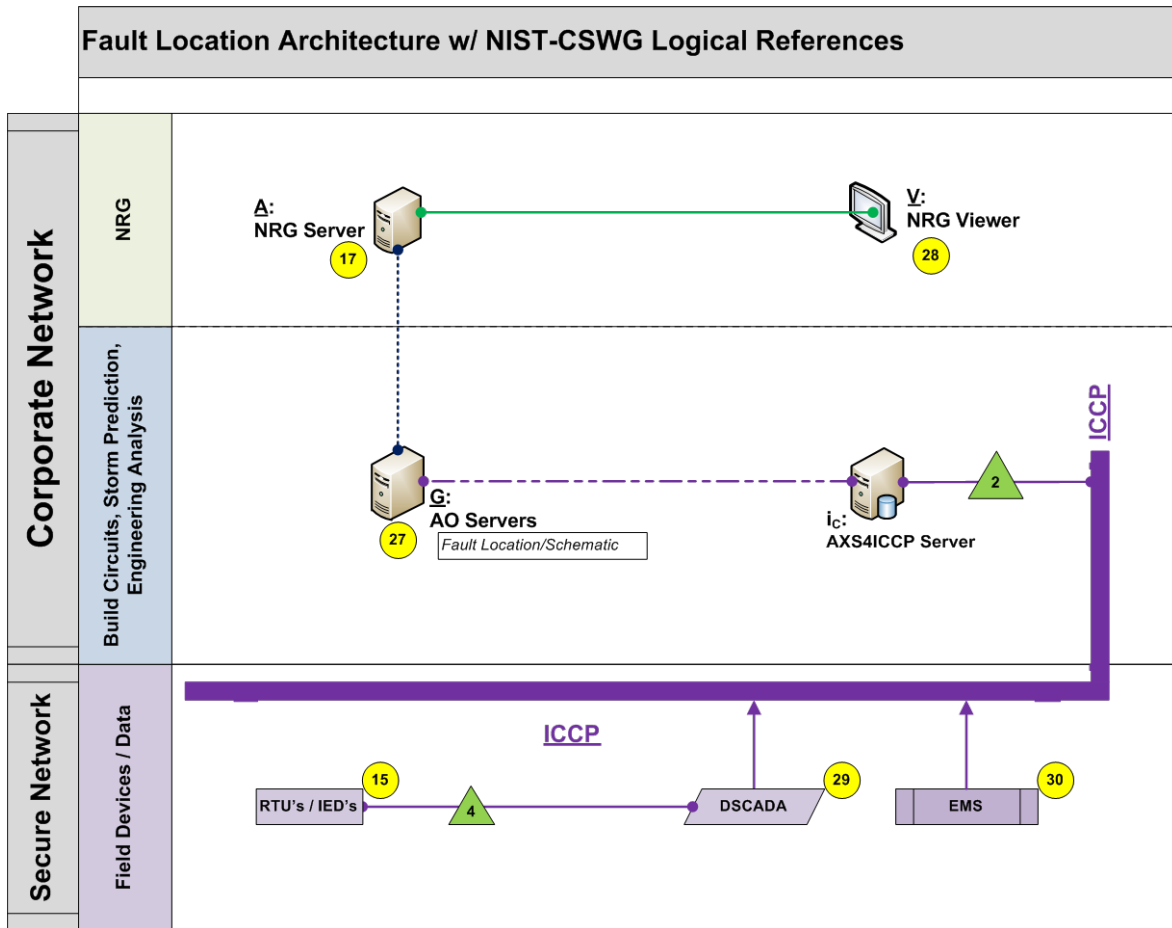


Figure A-23. Model Maintenance Architecture

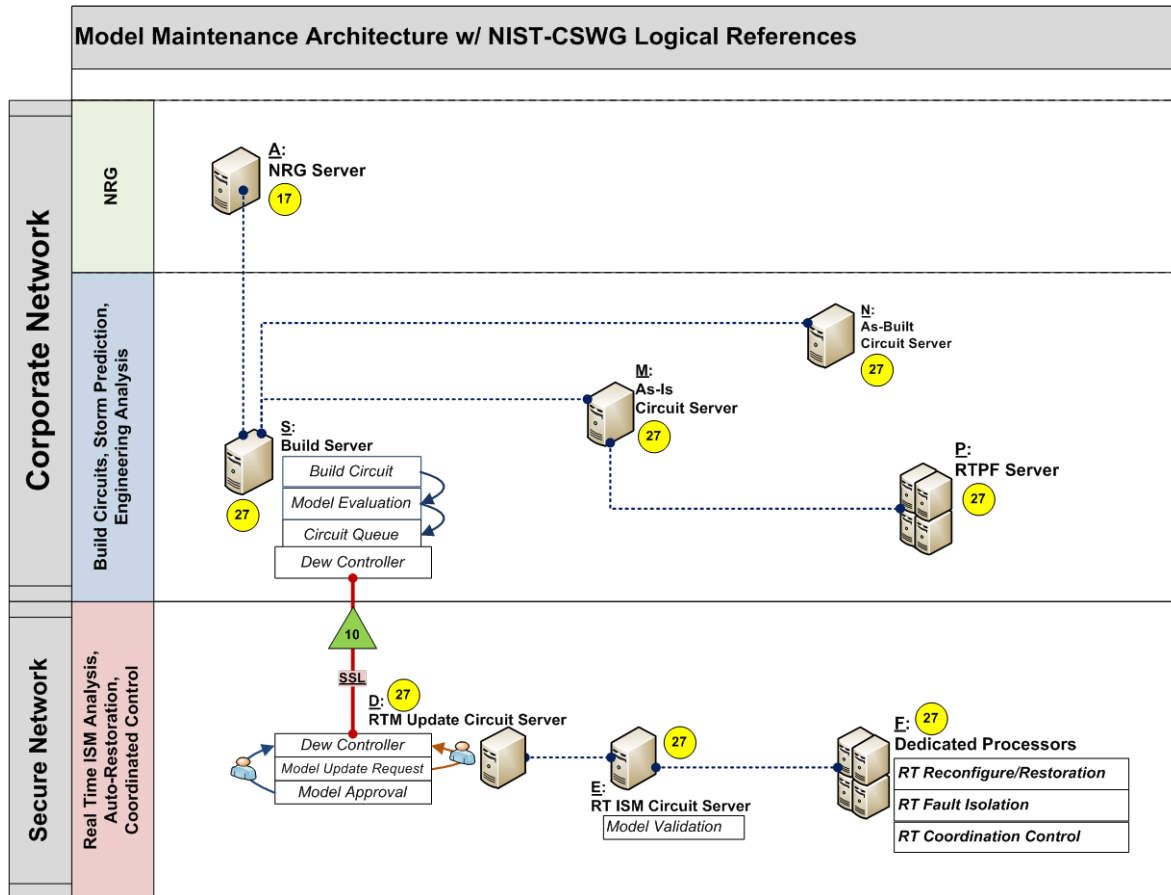


Figure A-24. Model Amendment Architecture

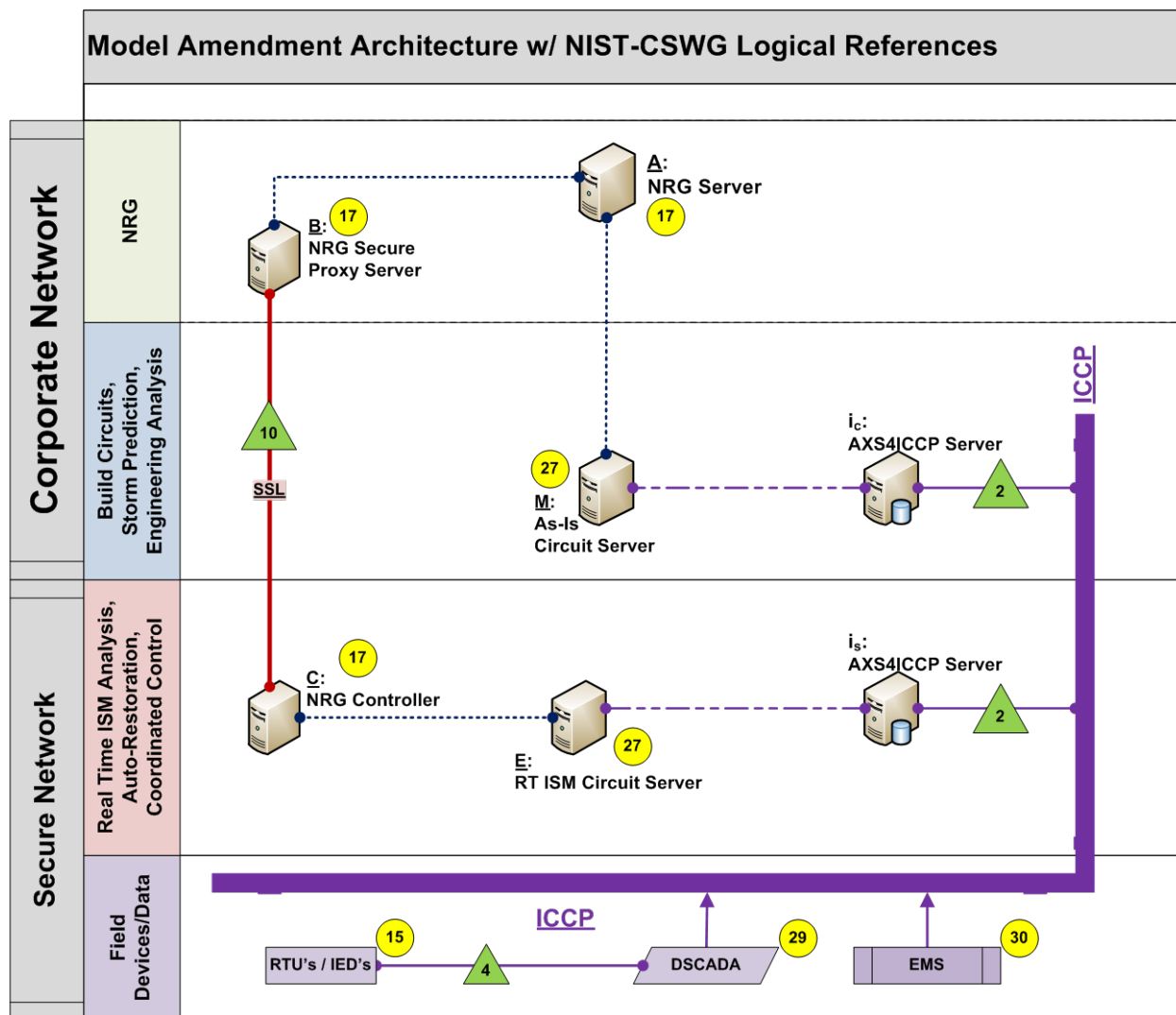


Figure A-25. Real-Time Power Flow Architecture

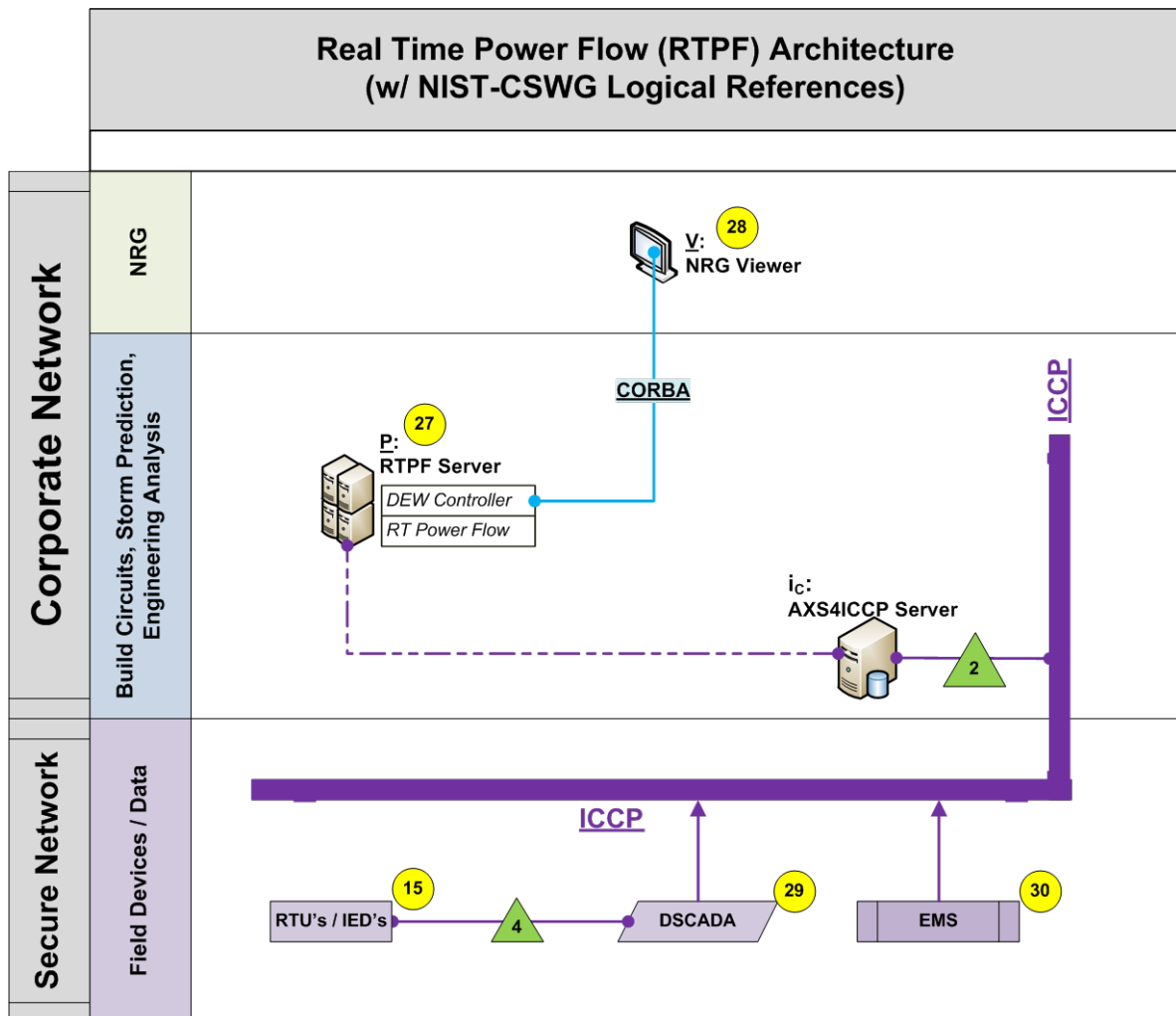


Figure A-26. Supervisory Reconfiguration Architecture

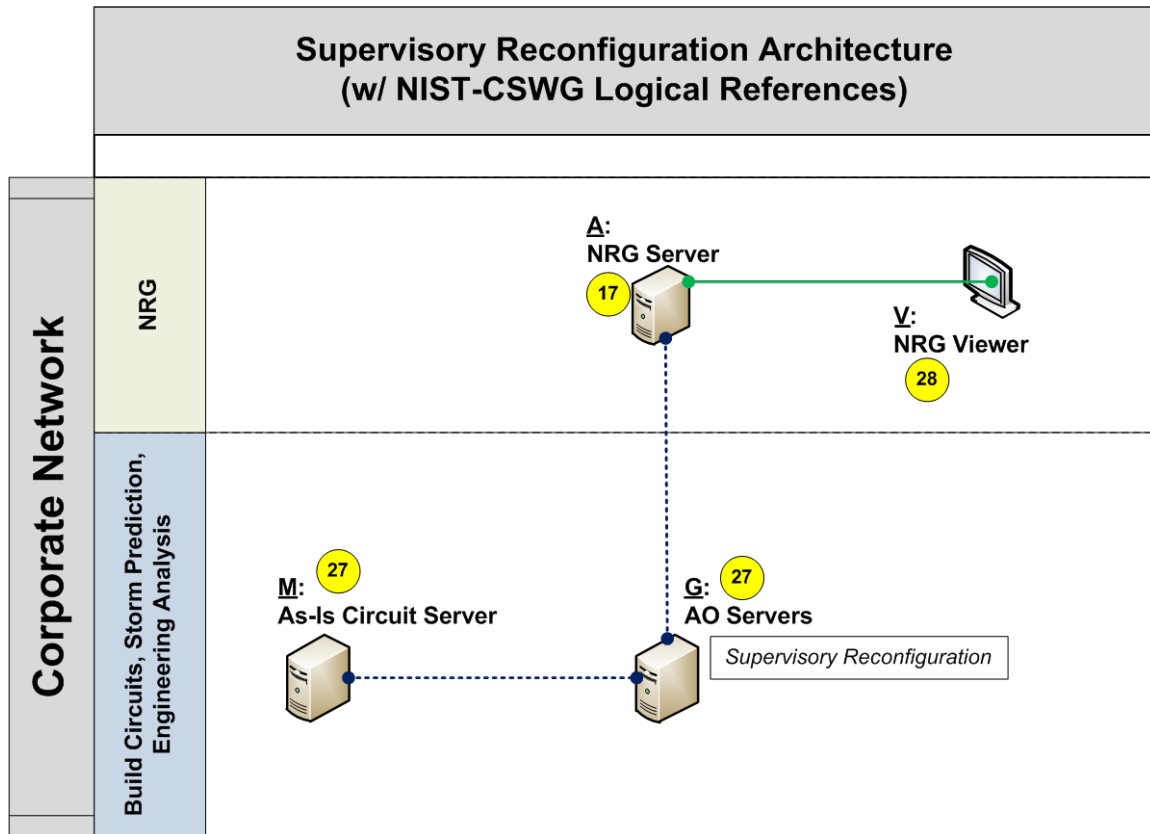


Figure A-27. Switch Plan Analysis Architecture

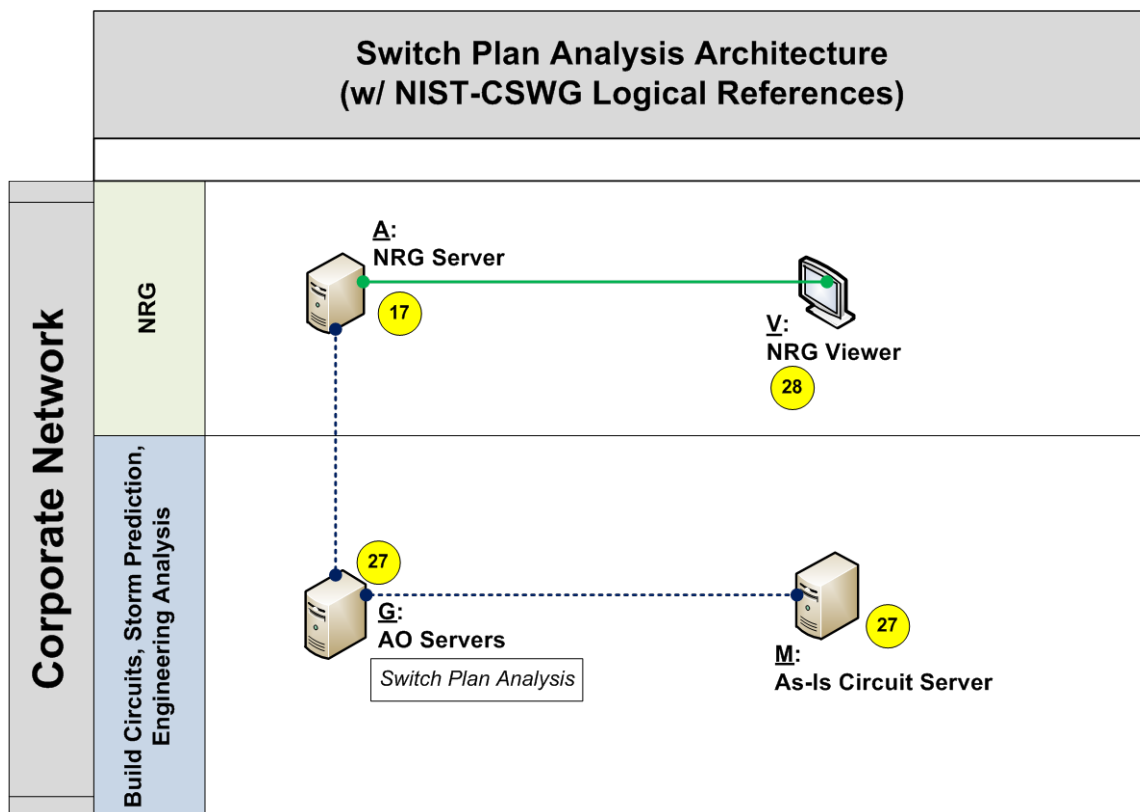
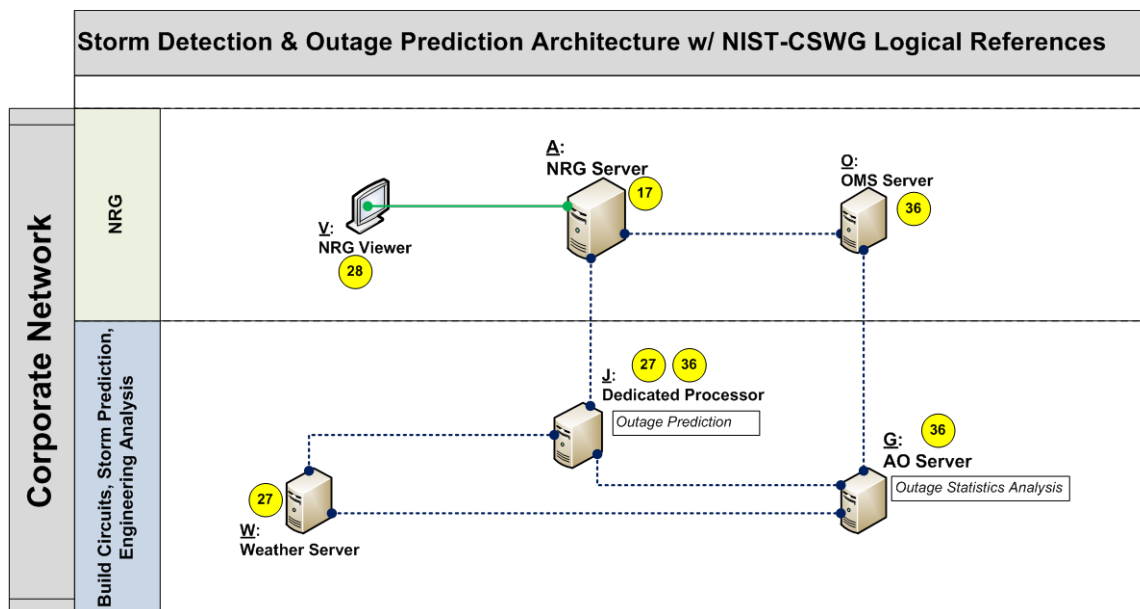


Figure A-28. Storm Detection and Outage Prediction Architecture



### A.3.9 Relevant Technical Publications

1. Ahmet Onen, Jeremy Woyak, Reza Arghandeh, Jaesung Jung, Charlie Scirbona, Robert P. Broadwater, "Time-varying Cost of Loss Evaluation in Distribution Networks Using Market Marginal Price," accepted for publication in International Journal of Electrical Power and Energy Systems.
2. Ahmet Onen, Jeremy Woyak, Reza Arghandeh, Jaesung Jung, Charlie Scirbona, Robert P. Broadwater, Danling Cheng, Ahmet Onen, Reza Arghandeh, Jaesung Jung, Robert Broadwater, Charlie Scirbona, "Model Centric Approach for Monte Carlo Assessment of Storm Restoration and Smart Grid Automation," Proceedings of the ASME 2014 Power Conference, July 28-31, 2014, Baltimore, MD.
3. Jaesung Jung, Ahmet Onen, Reza Arghandeh, Robert Broadwater, "Coordinated Control of Automated Devices and Photovoltaic Generators for Voltage Rise Mitigation in Power Distribution Circuits," Renewable Energy 66C (2014), pp. 532-540.
4. Ahmet Onen, Danling Cheng, Reza Arghandeh, Jaesung Jung, Jeremy Woyak, Murat Dilek, Robert P. Broadwater, "Model Based Coordinated Control Based on Feeder Losses, Energy Consumption, and Voltage Violations," Electric Power Component and Systems, Vol. 41, Issue 16, Oct. 23, 2013.
5. D. Kleppinger, R. Broadwater, and C. Scirbona, "Generic reconfiguration for Restoration," *Electric Power Systems Research*, Vol. 80, pp. 287-295, March 2010.
6. D. Zhu, D. Cheng, R. Broadwater, C. Scirbona, "Storm modeling for prediction of power distribution system outages", *Electric Power Systems Research*, June 2007.
7. "Configurable, Hierarchical, Model-based Control of Electrical Distribution Circuits," Josh Hambrick, Robert Broadwater, *IEEE Transactions on Power Systems*, Pages Volume:26, Number:3, August 2011, Pages 1072-1079.
8. "Advantages of Integrated System Model-Based Control for Electrical Distribution System Automation," Josh Hambrick, Robert Broadwater, *Proceedings of 18th IFAC World Congress*, Aug. 28 – Sept. 2, 2011, Milano, Italy.
9. "Real Time Control of Distributed Generation," R. P. Broadwater, M. Murat, *Electric Power Generation, Transmission, and Distribution*, Taylor & Francis Group, April 2007.
10. F. Li, and R. Broadwater., "Distributed Algorithms with Theoretic Scalability Analysis of Radial and Looped Load Flows for Power Distribution," *Electric Power Systems Research*, Vol. 65, 2003.
11. K. Russell, and R. Broadwater, "Graph Trace Analysis Based Interdependent System Recoverability Analysis Criteria, Constraints and Measures," *Naval Engineerins Journal*, Accepted for publication 2011.
12. D. Kleppinger, K. Russell, K. and R. Broadwater, "Graph Trace Analysis Based Shipboard HM&E System Priority Management and Recovery Analysis," *IEEE Electric Ship Technologies Symposium*, pp. 109-114, May 2007.
13. L. Feinauer, K. Russell, and R. Broadwater, "Graph Trace Analysis and Generic Algorithms for Interdependent Reconfigurable System Design and Control," *Naval Engineers Journal*, vol. 120, issue 1, pp. 29-40, March 2008.



14. "Object-Oriented Analysis of Distribution System Reconfiguration for Power Restoration," I. Drezga, R. Broadwater, A. Sugg, Proceedings of 2001 IEEE Power Engineering Society Summer Meeting, July 15-19, 2001, Vancouver, Canada.
15. "A Heuristic Nonlinear Constructive Method for Distribution System Reconfiguration," T. E. McDermott, R. Broadwater, IEEE Transactions on Power Systems, Vol. 14, No. 2, pp. 478-483, May 1999.

## **A.4 *Digi / Ambient: Wireless Communication and Meter Data Management (MDM)***

### **A.4.1 Executive Summary**

In order to provide a data feed into the visualization and decision aid platform (i.e., DERMS) that was developed as part of the SGDP, as well as in support of Con Edison's Demand Response reporting requirements, a near real-time feed of customer interval meter data was necessary. In late 2012 the focus was to investigate the necessary system/hardware changes required to support 15-minute interval meter data collection by MV-90 xi, and to modify the data connections to MDM, the visualization system, and Customer Care portal to make use of the more timely data.

The initial investigation found that the data was collected from the interval meters by the MV-90xi system and then passed into LPDS and the MDM. Also found were several system limitations that needed to be addressed:

1. The MDM system as implemented at Con Edison was on an aging hardware and software platform, and suffered from poor performance. In addition, this system is critical for calculating billing determinants and could not be taxed with any further requests for data.
2. LPDS (a Con Edison legacy system) did not suffer from performance issues; however, it is dependent on a feed from MV-90xi, which collects the data from interval meters in the field via phone, cellular, and other communication means.

### **A.4.2 Project Goals and Accomplishments**

An initial assessment determined that LPDS was capable of handling whatever additional load that would be required. Con Edison's Customer Operations group had a plan and funding to upgrade MDMS hardware and software. They worked with Itron, KEMA, and Information Resources on a Con Edison capital project that will enhance the throughput, processing, and storage capabilities of the MDMS. This effort could support the visualization platform by integrating billing meter data from our Distribution Load Relief Program (DLRP) customer's sites into the DERMS system, thus enhancing ability to visualize the DLRP customer load. This project is categorized as cost share for the SGDP.

The MDMS project exceeded the initial goals of the project. The MDMS project did the following:

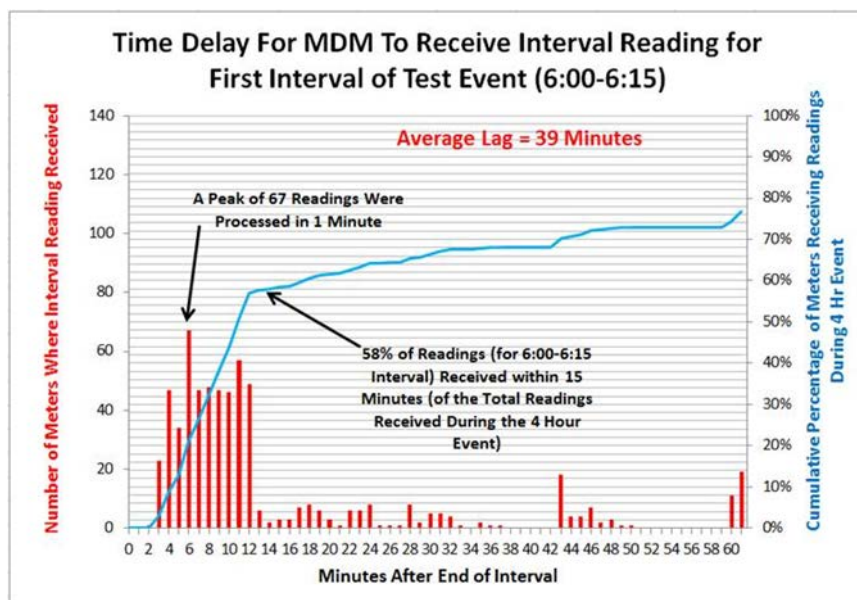
- Converted from an Oracle database to Structured Query Language (SQL) Server
- Completed a version upgrade of Itron's MDMS software from V 7.0 to v 8.1, allowing the MDMS to benefit from using a 64- rather than 32-bit operating system and database
- Upgraded the hardware configuration, increasing the database processing capability by 500% and memory by 400%. In addition, solid-state, rather than spinning drives, were used for temp file processing, which dramatically improved performance.

Figure A-29 and Figure A-30 shown below, the first from the 06/06/13 test and the second graph from the 2/26/14 test, depict the increase in throughput rate for interval meter data collected by MV-90xi and exported to the MDM for the same 1,160 meters. Although the scale of this test does not fully stress the new XML export function, this data, in conjunction with data from the daily billing runs, can be used to

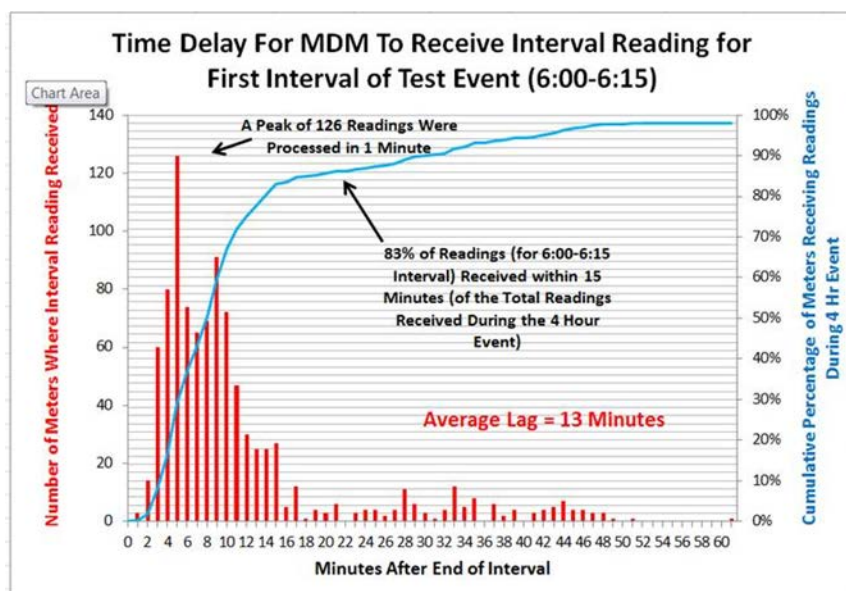
project an increase in the ability to support retrieval and display of 15-minute data from approximately 640 meters for a DR event to the ability to support approximately 910 meters for a DR event, nearly a 30% increase in throughput. There are ongoing issues still being investigated that will improve system performance.

The throughput improvement that has been made to date is depicted in the following graphs:

**Figure A-29. Example Peak Throughput prior to Improvements**



**Figure A-30. Example of Peak Throughput after Improvements**





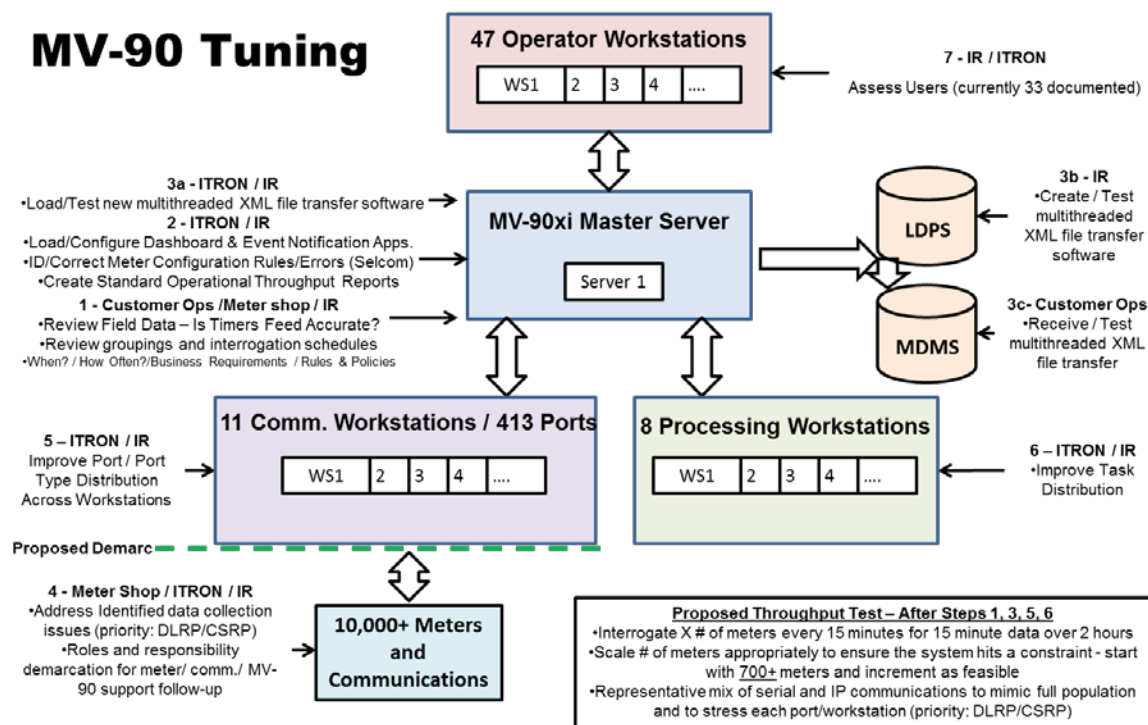
#### **A.4.3 Project Activities**

As the processing demands on MDMS continued to grow from increased numbers of billing and demand response accounts, it became more difficult to process all the required data requests in a timely manner. The MDMS hardware platform was outdated and the software needed to be upgraded. The server hardware was no longer supported by Hewlett Packard and the current version of the MDMS software was not supported under newer versions of Oracle. As a result of this data processing and obsolescence dilemma, in 2013 the MDM underwent a major overhaul. An effort was launched to convert the data in the existing Oracle database to SQL server. The migration required converting nearly five billion rows of data and 600 data tables from Oracle to SQL Server.

To get additional benefits and performance, Con Edison also performed a version upgrade of the MDMS software from v7.0 to v8.1. This upgrade allowed the MDMS to benefit from using a 64- rather than 32-bit operating system and database. This version upgrade was coupled with a new hardware configuration that increased the database processing capability by 500% and memory by 400%. In addition, solid-state, rather than spinning, drives were used for temp file processing, which also added to dramatically improved performance.

Finally, additional MDM modifications were needed to implement and test Green Button functionality for the MHP customer class and to better support fast polling that informs DR customers of their usage in near real time during an event. In the past, these DR customers would only be able to determine how they performed in an event the day after the event was called; fast polling allows them to see their usage each 15 minutes. This was achieved through MV-90 tuning, changing file exports to MDMS from single threading to multi-threading and through hardware and software upgrades to the MDMS that enabled high-speed data aggregation, which was essential when coupled with fast polling.

Figure A-31. MV-90 Tuning



**\* Expected Result – Doubling of system throughput to 6,000+ meters/hr \***

In addition to the system improvements described in section 4-A.4 of the main report, there were also many small operational improvements. One operational improvement was an increase to MV-90xi throughput via reorganization of the call groups and call group schedule. Two of the primary benefits of this reorganization include:

- Concentrated call schedules at two points of the day – 1a.m. and 1 p.m. This opens up time during the day for other maintenance tasks on the MV-90xi system such as backups and patches, so that these tasks do not affect throughput during meter interrogations.
- Moved meters with “problem communications” (meters that have not been successfully interrogated in over six months) to a separate call group called once per week. This reduced the number of failed MV-90xi meter interrogations by over 4,000/day, providing relief to system resources. These meters will be automatically returned to their appropriate call group once they begin to communicate.

#### A.4.4 Wireless Communication Project Update

Con Edison’s largest customers have their meter interval data collected via the Itron MV-90xi system. Data are collected through a variety of communication channels, including cellular, broadband IP and Plain, Old Telephone Service (POTS). Some of the meters are installed in underground vaults or building basements where a “typical” wireless or phone line solutions are not readily available which makes it challenging to communicate with them and hence, very difficult to collect timely billing data.

Funded partially by the DOE, the Wireless Communications project was established to repair approximately 1200 non-communicating interval meters. The primary accounts targeted in this project are approved DR program customers and high and low service-voltage customers who have interval meters that are not communicating. Below is a breakdown on the interval meters currently in the scope:

- 297 - DR meters
- 722 – Low and high service voltage meters
- 263 – High voltage railroad meters

Wireless communication nodes from two manufacturers, Digi International and Ambient Corporation, were utilized in this project. Both Ambient Corporation and Digi International agreed to offer cost share.

**Figure A-32. Digi International TransPort WR21**



**Figure A-33. Ambient MiniNode**



The communication equipment that was deployed utilized the latest and most advanced Verizon 4G Long Term Evolution (LTE) cellular network, with private IP addresses, Secure Shell (SSH) point-to-point password validation, and Advanced Encryption Standard (AES) data encryption for extra security. Con Edison also plans to further enhance cyber security by deploying Virtual Private Network (VPN) tunnels between Con Edison firewall and wireless nodes, as depicted in Figure A-34.

Figure A-34. Meter Remote Communication Diagram

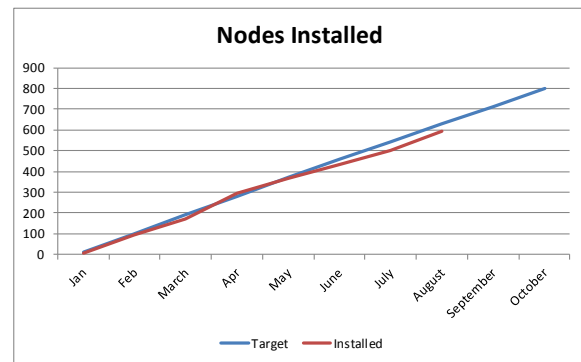
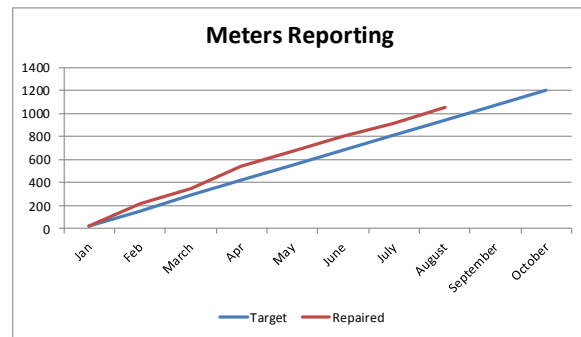


As the project progressed, Digi equipment displayed robust performance while the Ambient equipment had some technical issues that delayed deployment of their nodes. Ambient has been working proactively with Con Edison to address these issues.

As of August 27<sup>th</sup> 2014, the project team has made significant progress in repairing communication links, with a total of 1055 interval meters repaired and 595 wireless nodes installed, as depicted in Figure A-35. Of 595 installed nodes, 569 were provided by Digi International and 26 by Ambient Corporation. Currently the project is under budget and on schedule to complete implementation phase by October 31<sup>st</sup> 2014, repairing communication links with at least 1200 interval meters.

Figure A-35. Wireless Metering Communications Project Progress

| Total         |                  |             |                 |            |
|---------------|------------------|-------------|-----------------|------------|
|               | Meters Reporting |             | Nodes Installed |            |
|               | Target           | Repaired    | Target          | Installed  |
| <b>Totals</b> | <b>1200</b>      | <b>1055</b> | <b>800</b>      | <b>595</b> |
| Monthly       |                  |             |                 |            |
| Month         | Target           | Repaired    | Target          | Installed  |
| Jan           | 21               | 26          | 10              | 6          |
| Feb           | 135              | 194         | 90              | 89         |
| March         | 134              | 129         | 90              | 75         |
| Apr           | 130              | 189         | 90              | 124        |
| May           | 130              | 138         | 90              | 74         |
| June          | 130              | 122         | 90              | 67         |
| July          | 130              | 120         | 85              | 66         |
| August        | 130              | 137         | 85              | 94         |
| September     | 130              | 0           | 85              | 0          |
| October       | 130              | 0           | 85              | 0          |
| Cumulative    |                  |             |                 |            |
| Month         | Target           | Repaired    | Target          | Installed  |
| Jan           | 21               | 26          | 10              | 6          |
| Feb           | 156              | 220         | 100             | 95         |
| March         | 290              | 349         | 190             | 170        |
| Apr           | 420              | 538         | 280             | 294        |
| May           | 550              | 676         | 370             | 368        |
| June          | 680              | 798         | 460             | 435        |
| July          | 810              | 918         | 545             | 501        |
| August        | 940              | 1055        | 630             | 595        |
| September     | 1070             | 1055        | 715             | 595        |
| October       | 1200             | 1055        | 800             | 601        |





## A.5 Viridity: DR and BMS Integration

The Viridity team developed the following summary of SGDP activities as part of the input to the FTR. Results and information below has been used to develop the overall takeaways and lessons learned in the FTR.

### A.5.1 Executive Summary

Viridity Energy, among other partners, was selected by Con Edison to deploy SG technology within NYC and demonstrate the ability to integrate and optimize distributed energy resources to enhance efficiency, reliability, and economic savings for the utility and end users alike.

Viridity's contribution to the Con Edison SG Initiative, sponsored by the DOE, illustrates the value of the load management function to individual participating customers, the local utility, and to a smart city as a whole. The project couples real-time information and insight into the electricity market with advanced communication protocols to enable pro-active customer involvement in the markets.

In the aggregate, the project realized 5.4 MW in reliability benefits from Con Edison DLRP and NYISO DR program. The projected annual economic benefits associated with this integrated, controllable load follow.

|                                           |                    |
|-------------------------------------------|--------------------|
| NYISO Capacity Market Revenue             | \$ 481,194         |
| Con Edison Capacity Program Revenue       | \$ 259,200         |
| Distribution Demand Charge Savings        | \$ 365,402         |
| <b>Combined Value (Revenue + Savings)</b> | <b>\$1,105,796</b> |

Through this project, VPower™ was integrated with energy consuming and controlling resources at 23 buildings throughout NYC with an estimated 5.4 MW of curtailable load. Via additional integration with Con Edison, Viridity can support distribution system load relief through virtual power, which is realized through the VPower™ integration to end use customers.

Leveraging the project investment in ongoing commercialization, Viridity is now entering 2014 summer program operations representing 32.85 megawatts at \$8.7M estimated economic value (revenue from NYISO / Con Edison). These impressive results and the implied benefit to economic and environmental sustainability are directly attributable to Viridity's partnership with Con Edison made possible with the DOE project funding.

The approach and results are consistent with the tenets of the New York Public Service Commission's (NYPSC) recent strategic report<sup>2</sup> highlighting the need for increased reliability at improved costs

<sup>2</sup> [Reforming the Energy Vision](#), NYS DEPARTMENT OF PUBLIC SERVICE STAFF REPORT AND PROPOSAL, April 24, 2014.



leveraging distributed energy resources to complement and even offset large centralized generation plants.

### **A.5.2 Project Goals and Accomplishments**

Evaluating the tactical accomplishments within the sub-award component of the project can only be done with an understanding of the following stated project goals.

#### **Viridity Scope of Work**

- Establish interfaces to buildings and BMSs in NYC
- Provide data and control capabilities through Con Edison middleware platform
- Interface with NYISO
- Optimize building system operations for customers
- Validate building resource models

#### **Viridity Project Objectives**

- Improve Control Capabilities of Existing Grid Assets
- Minimize Peak Load Growth & Improve Grid Reliability
- Provide Customers with Greater Visibility, Flexibility and Value
- Promote Cyber Security

The following table demonstrates how Viridity's major deliverables (scope) map into the project objectives. In short, the original intent of the project investment has been met.

**Table A-14. Deliverables and Objectives**

| Deliverable                          | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Objective Mapping                                                                                                                                                                                                                                                                          |
|--------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| VPower™ Building and Resource Models | Viridity Energy’s scope includes establishing interfaces to 23 BMSs located throughout our service territory and using VPower™ platform to create a “virtual generation” capability via demand reductions. Each building has a unique curtailment strategy that has been modeled in VPower™. Viridity Energy’s platform is capable of creating optimal schedule for market participation and optimizes loads behind the meter and interfaces through its Network Operations Center (NOC) to the visualization platform in the Distribution Control Center (DCC). | <ul style="list-style-type: none"> <li>✓ Improve Control Capabilities of Existing Grid Assets</li> <li>✓ Minimize Peak Load Growth &amp; Improve Grid Reliability</li> <li>✓ Provide Customers with Greater Visibility, Flexibility and Value</li> <li>✓ Promote Cyber Security</li> </ul> |
| Con Edison Interface                 | Viridity developed and implemented an interface to the Siemens middleware platform that was validated during several tests and demonstrations. Through this secure communication, Con Edison can dispatch DR via VPower™ to assist in responding to distribution-level system contingencies, for instance, relieving overloads on specific feeders. In turn, VPower™ exercises load control strategies at specific buildings.                                                                                                                                    | <ul style="list-style-type: none"> <li>✓ Improve Control Capabilities of Existing Grid Assets</li> <li>✓ Minimize Peak Load Growth &amp; Improve Grid Reliability</li> <li>✓ Provide Customers with Greater Visibility, Flexibility and Value</li> <li>✓ Promote Cyber Security</li> </ul> |
| NYISO Interface                      | Viridity developed and tested a NYISO interface targeting price forecasting in VPower™. As a result Viridity has integrated NYISO Real Time price forecasts as part of the market participation process in VPower™.                                                                                                                                                                                                                                                                                                                                              | <ul style="list-style-type: none"> <li>✓ Improve Control Capabilities of Existing Grid Assets</li> <li>✓ Minimize Peak Load Growth &amp; Improve Grid Reliability</li> <li>✓ Provide Customers with Greater Visibility, Flexibility and Value</li> </ul>                                   |

#### **A.5.2.1 Other Project Accomplishments**

In the course of achieving the scope of work, Viridity completed other notable interim deliverables, including:

- Vetted VPower™ cyber security via NIST compliance assessments by two independent auditors
- Applied advanced modeling, forecasting, and adaptive control techniques such as Block Box modeling, Kalman Filtering, and proportional-integral-derivative (PID) loop control



- Provided monthly economic benefit reports reflecting potential demand savings and market participation revenue for each fully implemented building in the program
- Conducted integrated system demonstration and testing
- Continues to operate related project participants in Con Edison and NYISO curtailment programs
- Focused on commercialization of the approach to fully leverage the DOE project (below)

*Commercialization:* Commercialization is the process of contracting with a site to participate in a DR program. By the summer of 2013, Viridity Energy commercialized five (of 23) sites by operating them in both NYISO and Con Edison DR (capacity) programs in parallel to project participation. As of April 2014, Viridity increased the volume of commercialized sites to 16 (of 23). Through demonstrating the economic value of curtailment within the project and by emphasizing our business development work in NYC, Viridity enrolled an additional 15 sites with these same building owners/operators participating in the SGD, bringing the total to 31 SGD-related sites.

**Figure A-36. Commercialization**

| Grant Related Commercialization Progression                                         |                                                                                                      |                                                                              |                                                                                            |                                                                       |                                                                                                                     |                                                                | Capture Improvement                                                                                                                                                             |      |
|-------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
|                                                                                     | MW Value                                                                                             | Grant Sites                                                                  | Last Reported                                                                              | Current                                                               | Extension                                                                                                           | Combined                                                       | Value                                                                                                                                                                           | %    |
| Site Count                                                                          |                                                                                                      | 23                                                                           | 5                                                                                          | 16                                                                    | 15                                                                                                                  | 31                                                             | 26                                                                                                                                                                              | 520% |
| Curtailable Load (SCR) MW                                                           | ---                                                                                                  | ---                                                                          | 5.154                                                                                      | 7.45                                                                  | 3.90                                                                                                                | 11.35                                                          | 6.20                                                                                                                                                                            | 120% |
| Curtailable Load (DLRP) MW                                                          | ---                                                                                                  | ---                                                                          | 3.402                                                                                      | 7.05                                                                  | 3.90                                                                                                                | 10.95                                                          | 7.55                                                                                                                                                                            | 222% |
| Curtailable Load (CSRP) MW                                                          | ---                                                                                                  | ---                                                                          | 3.894                                                                                      | 7.05                                                                  | 3.50                                                                                                                | 10.55                                                          | 6.66                                                                                                                                                                            | 171% |
| Total Curtailable Load                                                              | ---                                                                                                  | ---                                                                          | 12.45                                                                                      | 21.55                                                                 | 11.30                                                                                                               | 32.85                                                          | 20.40                                                                                                                                                                           | 164% |
| Est. Economic Annual Value                                                          | \$265,100                                                                                            | ---                                                                          | \$3,300,495                                                                                | \$5,712,905                                                           | \$2,995,630                                                                                                         | \$8,708,535                                                    | \$5,408,040                                                                                                                                                                     | 164% |
|  | Conservative average annual value of 1 MW of curtailable load across these non-exclusive DR programs | Total number of sites that participated in the program / grant with Viridity | Initially commercialized with 5 of 23 sites as reported in the 2013 technical review in WV | Improved commercialization to 16 of 23 sites participating in program | Extended commercial terms to 15 additional sites of real estate portfolio managers benefitting from program / grant | Total sites commercialized as direct result of program / grant | Realized improvement in commercialization in the past 12 months stemming from program / grant, related NYISERDA programs, ConEdison DR incentives, and Viridity Market Strategy |      |
|                                                                                     |                                                                                                      |                                                                              |                                                                                            |                                                                       |                                                                                                                     |                                                                |                                                                                                                                                                                 |      |

### A.5.2.2 Challenges and Learning

As expected, the full project lifecycle was complex and completed with many challenges, shifts in approach, and opportunities to learn which went beyond the original intent of the project. The table below summarizes notable challenges by major deliverable and the related learning points.

| Deliverable                          | Challenges                                                                                                                                                                                                                                                                               | Lessons Learned                                                                                                                                                                                                                                                                     |
|--------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| VPower™ Building and Resource Models | <ul style="list-style-type: none"> <li>Buildings not yielding meaningful DR</li> <li>NYC commercial building culture &amp; configuration presented a learning curve</li> <li>Scope dependent on actual site acquisition (sales of a sort) leading to some missed expectations</li> </ul> | <ul style="list-style-type: none"> <li>Developed screening methods to target high potential sites</li> <li>Refined approach helped in targeting and acquiring sites</li> <li>Target but not commit to specific sites unless contracts are in place – risk based planning</li> </ul> |
| Con Edison Interface                 | <ul style="list-style-type: none"> <li>Middleware provider established 20 months into project</li> </ul>                                                                                                                                                                                 | <ul style="list-style-type: none"> <li>Develop requirements and design to greatest extent possible, as done with the Con Edison - VPower™ messaging interface</li> </ul>                                                                                                            |
| NYISO Interface                      | <ul style="list-style-type: none"> <li>First operational exposure to NYISO market rules</li> <li>NYISO price forecasting tools somewhat unreliable</li> </ul>                                                                                                                            | <ul style="list-style-type: none"> <li>Trained the NOC resources appropriately &amp; adjusted strategy</li> <li>Augmented with an external pricing feed</li> </ul>                                                                                                                  |
| Other                                | <ul style="list-style-type: none"> <li>Hurricane Sandy flooded several sites which remain inactive</li> </ul>                                                                                                                                                                            | <ul style="list-style-type: none"> <li>Consider risk in site-assessment and equipment location</li> </ul>                                                                                                                                                                           |

### A.5.3 Project Approach and Activities

During the Con Edison SGDP, Viridity Energy integrated with 23 separate buildings in NYC and with Con Edison to demonstrate the value of distributed and secure control of DR resources.

The DOE funding supported the purchase and integration of control related equipment at each commercial building site. Viridity designed a unique DR strategy for each site and programmed the related sequence of operations into each site's Building Automation System. As a result, Viridity is able to monitor the related building loads, trigger curtailment events in response to NYISO and Con Edison needs, and monitor real-time building curtailment responses in our NOC in Philadelphia, PA.

The project scope and related benefits were achieved by leveraging the following approach which, in practice was iterative and incrementally accomplished, moving from one site to the next. This outline ignores commercial aspects including customer contracting and Market settlement operations. Each is subsequently presented in more detail.

- Con Edison – VPower™ System Integration

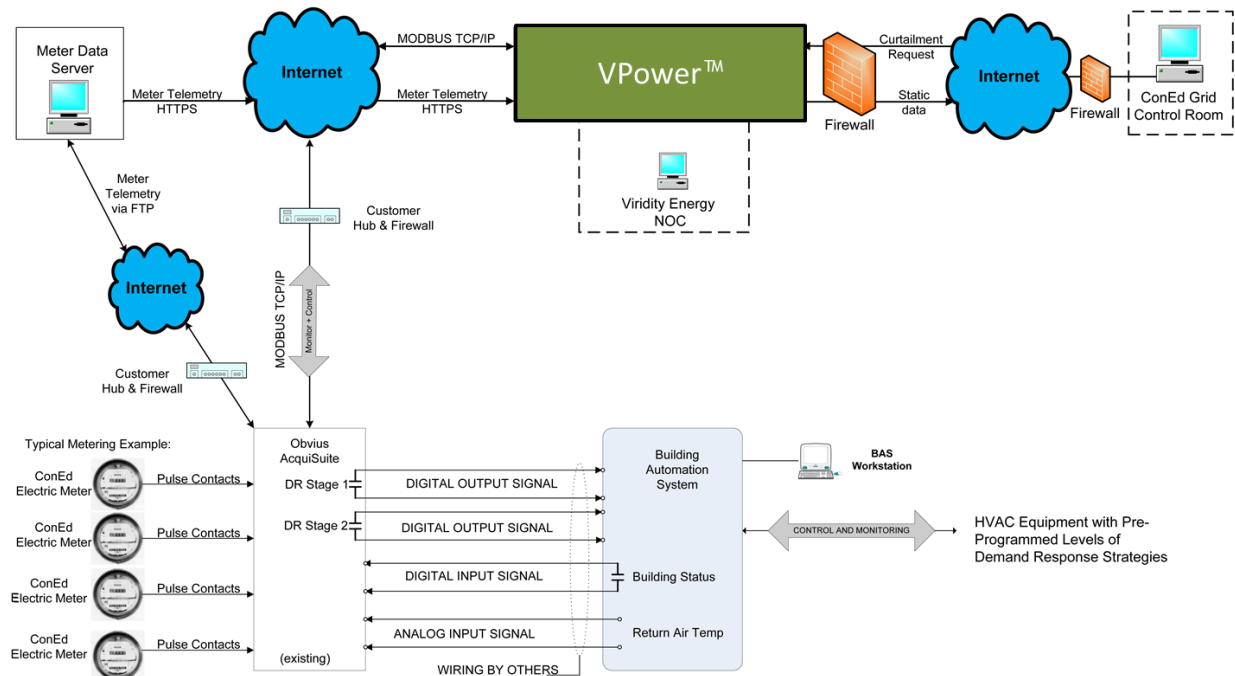
- Resource-Specific Integration & Control
- VPower™ Resource Modeling & Optimization
- VPower™ Resource Model Validation & Tuning
- Monthly Benefit Analysis & Reporting

#### A.5.3.1 Con Edison – VPower™ System Integration

In Figure A-37 below depicting the Con Edison – VPower™ system integration, a general sequence of operations is implied. The end-to-end system supports full data acquisition and control signaling with VPower™ brokering the exchange of information to and from the end use resources in this distributed model.

VPower™ communicates via XML messaging using a Java Applet Control Engine (JACE®) as a communication translator. Other approved gateway related infrastructure includes VPower SCADA, Obvius, and AquisSuite. The data acquisition and control is conducted over IP in a secure framework.

**Figure A-37. VPower™ System Integration**



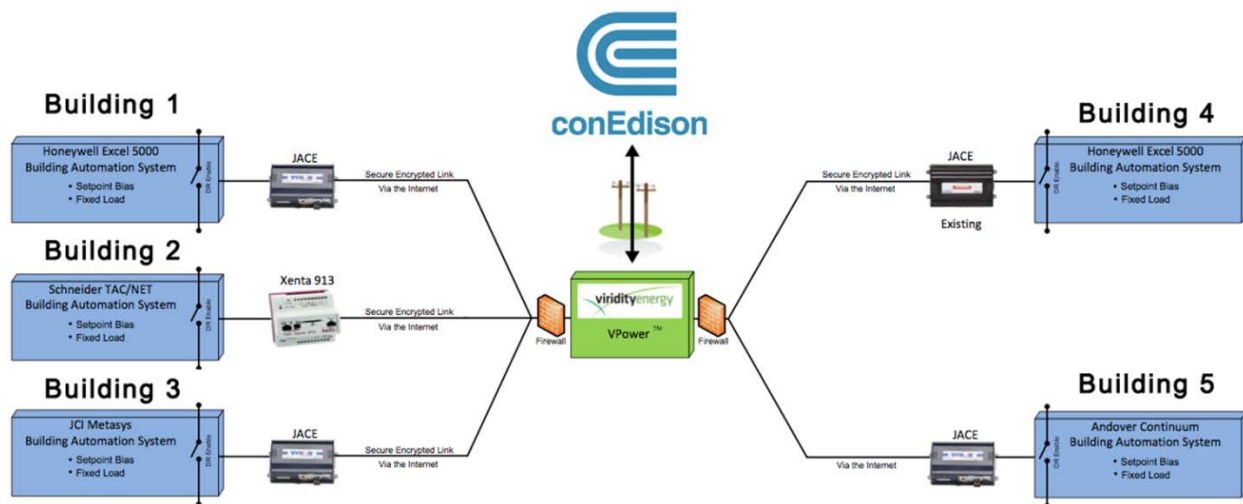
### A.5.3.2 Resource-Specific Integration and Control

The actual resource telemetry yielding performance to Con Edison and/or NYISO program participation is a result of a broader integration approach. Those steps are outlined below.

1. Site and Resource Assessment
2. Market/Curtailment Strategy
3. Communications and Control Strategy
4. VPower™ Resource Modeling
5. JACE® Programming
6. BMS Programming
7. System Communication and Resource Integration Testing
8. Training and Operational Knowledge Transfer
9. Ongoing Market/System Operations with VPower™

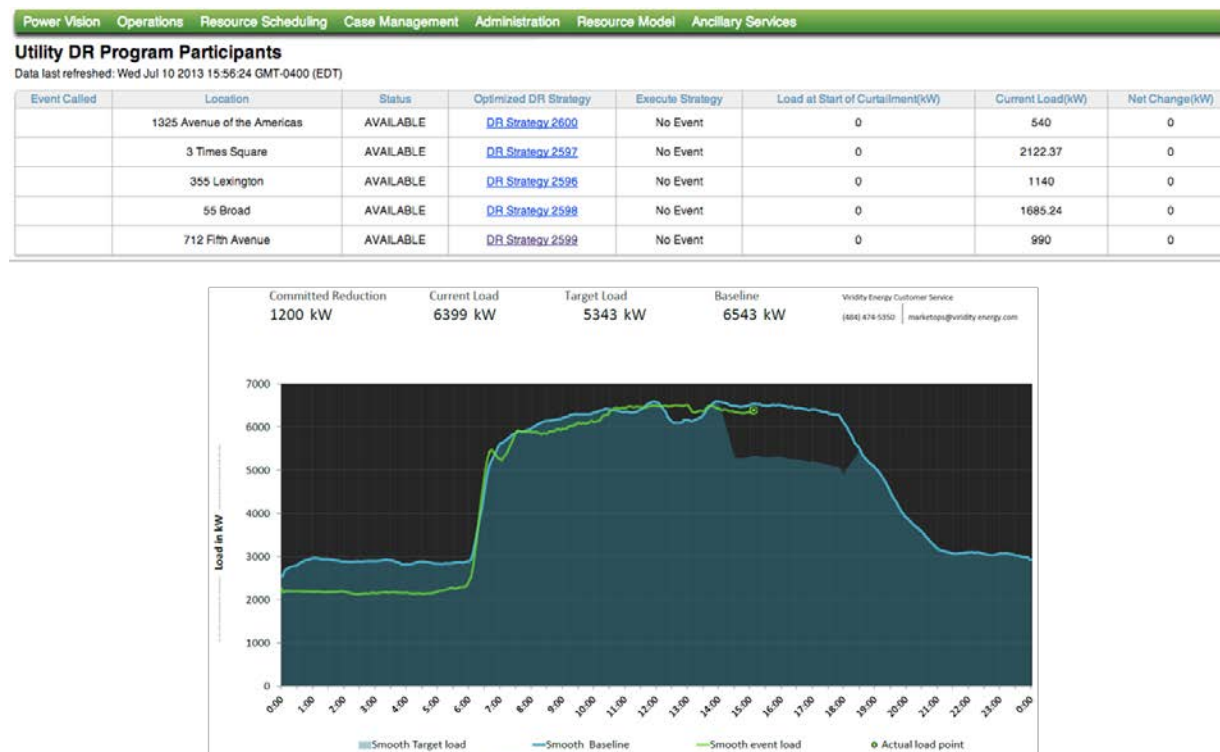
A simplified representation of the Con Edison – VPower™ – End-User integration is shown below.

**Figure A-38. VPower™ End-User Integration**



Through the exchange of information between VPower™ and Con Edison, there is a common understanding of resource availability and resource performance. This is supported by XML messaging with the Con Edison middleware structures. The VPower™ screen shot graphic below displays some of this messaging, along with a view of event performance.

**Figure A-39. VPower™ Screen Shot**



### A.5.3.3 VPower™ Resource Modeling and Optimization

A building resource is modeled in VPower™ with the following information:

- Specific DER - their key performance and operational characteristics
- Setpoint temperature at the building (occupied and unoccupied)
- Maximum occupancy
- Mass of building and overall heat transfer coefficient
- Black-box methods were deployed as well for lower cost/higher accuracy

VPower™ optimizer determines an operating schedule, which minimizes costs and maximizes revenue for optimal economic operational value. This may yield NYISO market bids or Con Edison program availability or other energy cost savings strategies for the end user such as demand charge mitigation.

- Model inputs: pricing forecast, weather forecasts, and building values
- Techniques applied: linear and non-linear programming relative to (Customer Baseline Load) CBL and other inputs

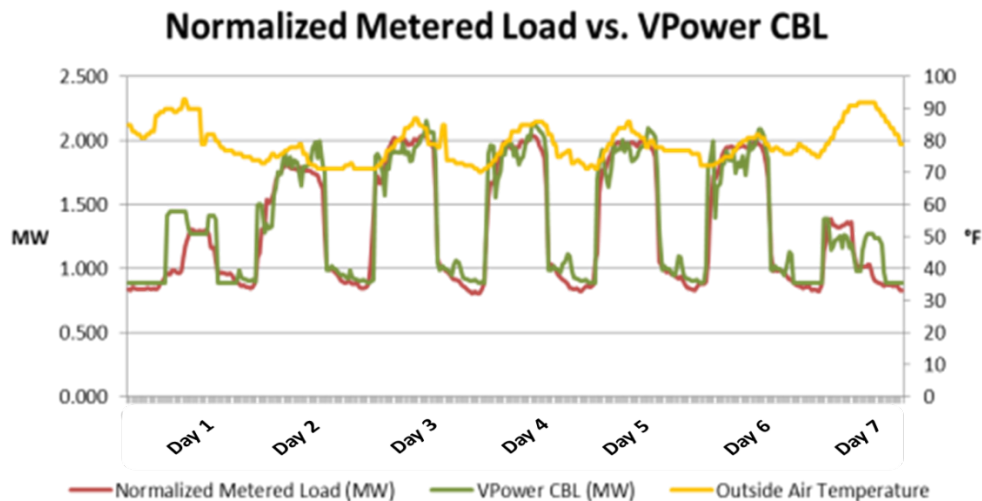
- Outputs: time series plans for market bidding and building/DER setpoints
- Operationally, a PID control loop was applied for dynamic variance correction.

#### A.5.3.4 VPower™ Resource Model Validation and Tuning

To assure that the resource models leveraged in VPower™ were effective, and that they offered an accurate view of resource load consumption variation, Viridity performed some statistical tests and tuned the models accordingly.

The CBL is a simulation of would-be customer load without planned curtailment action. This generally supports curtailment performance relative to “baseline” loads. The VPower™ model is validated by comparing the CBL produced by the model to the metered load from the building(s) for a historical period, typically 30 days.

**Figure A-40. Time Series Plot of Normalized Metered Load and VPower™ CBL**



The resource model parameters were tuned to produce a best match between the business as usual (BAU) CBL and the building(s) metered load. The best match is obtained when the average value of the absolute value of the BAU CBL relative error for the entire validation period is minimized.

#### A.5.3.5 Monthly Benefit Analysis and Reporting

In collaboration with Con Edison program staff, Viridity developed a method for determining/simulating the economic value of participation in NYISO and Con Edison curtailment programs. Once developed, Viridity executed these reports on a monthly basis and distributed them to Con Edison. These reports also helped us monitor actual event performance before developing similar capability in VPower™. The reports offered the additional value of supporting a commercialization discussion whereby project participants would enter commercial operations with Viridity and Con Edison and/or NYISO.



#### **A.5.1 Product Development and Technology Transfer**

The following documentation provides insight to the work completed, the demonstration results, and simulated economic benefits related to the SGDP.

1. Submitted to Con Edison separately is a performance view of the two buildings leveraged in the Capstone Demonstration on July 15, 2013. These reports, produced from a performance-monitoring feature in VPower™ 2.0, a new software platform developed independent of the project and related funding, are quite meaningful and serve as evidence of a successful demonstration. An example of the reports is shown in Figure A-41. The results show load curtailed in response to a simulated grid-based event solely for the purposes of the Capstone Demonstration. However, the system conditions were such that all curtailment was beneficial with extremely hot and humid conditions and peak loads across the system. Just as in real grid operations, the DR results varied by asset/site. In this case, the DR resources under Viridity control performed well.

Figure A-41. Example of Demonstration Report



2. The economic benefit reporting and analysis described earlier in this document helped to refine the approach, define good prospects, and ultimately to commercialize. This file was submitted to Con Edison separately.
3. Viridity generated the following “awareness” related to the SGDP:
  - a. 2009 press release on [Business Wire](#) resulting in the following placements:
    - i. [Smart Grid Observer](#)
    - ii. [Bloomberg](#)

- iii. [Pipeline & Gas Journal](#)
  - iv. [Consulting Engineer](#)
  - v. [Keystone Edge](#)
  - vi. [Philly Tech News](#)
- b. Viridity has also featured the Con Ed demonstration in a number of public presentations, including:
- i. [Emerging Issues Policy Forum](#)
  - ii. [Americans for Clean Energy Grid](#)
- c. Viridity created a “case study” (submitted separately) related to the project work with Con Edison, which leverages the document based on client/partner situational interest.
4. Viridity developed the VPower™ and VPower™ 2.0 software platforms independently of project funding. Energy resource models (not “computer models”) were configured within the VPower™ operating environment as a way to test certain curtailment strategies. An example of this resource modeling is show in Figure A-42.

**Figure A-42. Resource Modeling Example**

| Client: Rudin Management Location: 560 Lexington RTO: NYISO Weather Location: JFK Price Location: NY Zone J deterngottfried logout                                                                                                                 |            |             |                              |                        |                             |                             |                                 |                                       |                         |                        |      |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|-------------|------------------------------|------------------------|-----------------------------|-----------------------------|---------------------------------|---------------------------------------|-------------------------|------------------------|------|
|                                                                                                                                                                  |            |             |                              |                        |                             |                             |                                 |                                       |                         |                        |      |
| Power Vision Operations Resource Scheduling Case Management Administration Resource Model Ancillary Services                                                                                                                                       |            |             |                              |                        |                             |                             |                                 |                                       |                         |                        |      |
| Resource Model - HVACs                                                                                                                                                                                                                             |            |             |                              |                        |                             |                             |                                 |                                       |                         |                        |      |
| <div> <a href="#">HVACs</a> <a href="#">HVAC Defaults</a> <a href="#">Ventilators</a> <a href="#">Ventilator Defaults</a> <a href="#">Chillers</a> <a href="#">Chiller Defaults</a> <a href="#">Heaters</a> <a href="#">Heater Defaults</a> </div> |            |             |                              |                        |                             |                             |                                 |                                       |                         |                        |      |
| <div> <a href="#">Create New Ventilator</a> <a href="#">Show/Hide Columns</a> </div>                                                                                                                                                               |            |             |                              |                        |                             |                             |                                 |                                       |                         |                        |      |
| ID                                                                                                                                                                                                                                                 | Name       | Send Signal | Energy Consumption Rate (MW) | Efficiency Coefficient | Minimum Flow Rate (Mlbs/hr) | Maximum Flow Rate (Mlbs/hr) | OAX Maximum Flow Rate (Mlbs/hr) | OAX Maximum Electric Consumption (MW) | Pre Heat Capacity (Btu) | Pre Heat Cost (\$/Btu) | Mete |
| HVAC - HVAC                                                                                                                                                                                                                                        |            |             |                              |                        |                             |                             |                                 |                                       |                         |                        |      |
| 498                                                                                                                                                                                                                                                | HVAC AHU-A | false       | 0.284                        | 0.85                   | 0.000                       | 1.333                       | 1.333                           | 0.00000                               | 0.000                   | 0.00                   |      |

## **A.6 GCN: Smart Storage and Generation Units (SSGUs)**

The Green Charge Networks (GCN) team developed the following summary of SGDP activities as part of the input to the FTR. Results and information below has been used to develop the overall takeaways and lessons learned in the FTR.

### **A.6.1 Executive Summary**

Green Charge Networks LLC (Small Business Entity, 10 C.F.R. 600.325, App. A, FAR 52.227-23, 10 U.S.C. 784) is a SG technology company based on California with offices in New York. The main accomplishment for Green Charge Networks on this SGDP is the demonstration of a behind-the-meter energy storage system for the private sector. The paradigm shift is to gear away from energy (kWh) arbitrage, and focus on power (kW). These appliances called the SSGU, or GreenStation, are intended to reduce the monthly demand charges assessed on commercial ratepayers. When taking into account the value streams from demand charge reduction, infrastructure upgrade avoidance, and EV charging enablement, energy storage could become economical and can gain adoption by the private sector without significant public subsidies. The hardware demonstrated has proven to be robust, having survived hurricane Sandy, and the current software is stable, having been in 24/7 operations for more than two years. This platform may gain market adoption and open up a new market for Power Efficiency solutions (as opposed to Energy Efficiency solutions) in the private sector. It may directly enable the propagation of energy storage for commercial, behind-the-meter customers.

The GreenStation has taken root in California through a combination of state government support (California Energy Commission) and private-sector sales. A number of large-scale private sector customers have signed up for the offering, including Walgreens, UPS, Avis, Kaiser Permanente, and 7-Eleven.

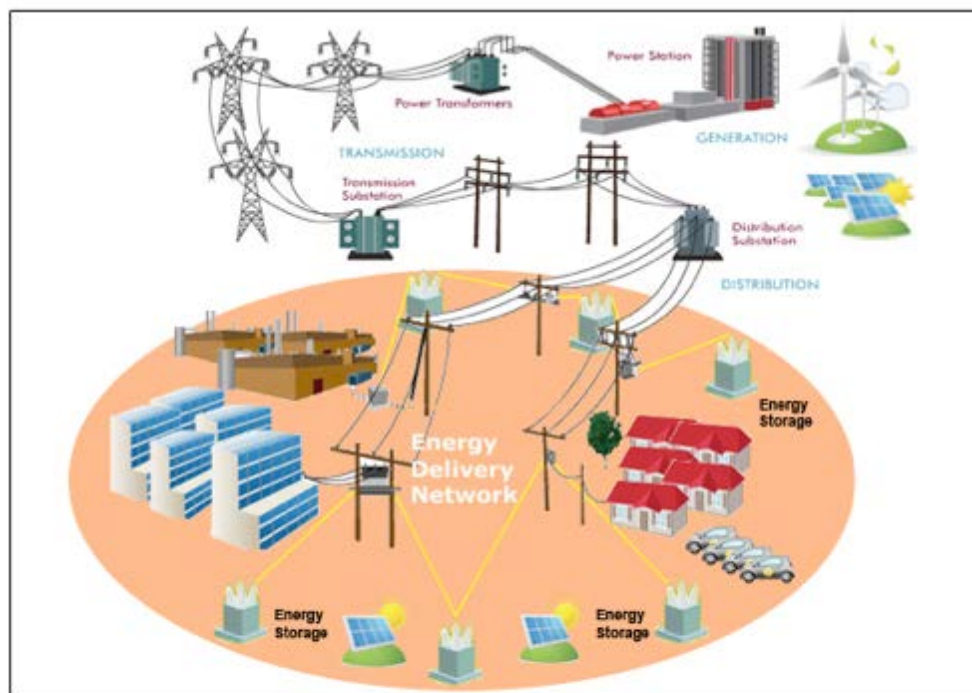
The second accomplishment of this project is to prove out the integration of energy storage with EV adoption and PV. Setting up EV chargers in electrically congested area can be difficult and costly, and energy storage is a viable path forward for deploying these high-powered devices. In fact, the technology from this program has already cross-pollinated to California, where the California Energy Commission awarded a project for GCN to install energy storage + EV charger in combination. The integration with PV proved that where PV is about kWh, energy storage complements existing PV projects by providing kW support. The two are entirely complementary, and provide two separate and distinct value streams to the host customer. Furthermore, in the case of the 7-Eleven installation, the savings have reached parity.

Finally, the integration with a premier utility like Con Edison is the third accomplishment that GCN is very proud of. It enhances the value for the entire electrical distribution chain, and becomes a win-win for all parties involved. The equipment deployed as part of this project enables targeted DR capability.

### **A.6.2 Background**

Current distribution systems typically have limited resilience to absorb renewable energy. The advent of EVs of 200-mile range (40 kWh) will further stress distribution grids as significant market penetration occurs.

**Figure A-43. Energy Delivery Network (EDN) Operating in the Distribution Grid**



**Renewable Energy, Price and Reliability Optimization Engine**

Provides:

1. Energy Storage on Edges Capacity and Command and Control
2. Balances System Needs for Reliability, Renewable Energy and Price
3. Incorporates required capability from Loan Pocket management System

With respect to relieving peak local energy congestion and demands, localized energy generation, storage, and curtailment offer a potentially economically attractive and environmentally responsible alternative to transmitting power from afar. The scope of the EDN project was to validate and demonstrate the feasibility of this assertion.

Multiple SSGUs were installed on Con Edison's distribution grid. SSGUs include renewable generation in the form of PV panels, energy storage in the form of battery banks, and both level II alternating current (AC) and Quick Charging EV Chargers. Distributed energy storage and generation units on the order of 27 kW to 300 kW are small enough that they can be sited in areas with existing electrical load congestion or future EV charging station locations.

EVs represent an opportunity to reduce dependence on foreign oil, CO<sub>2</sub> emissions, and fuel costs. Without the Smart Grid, electrification of automotive transportation at scale could require expensive infrastructure upgrades to reinforce existing distribution feeders.

Despite the fact that the local generation and storage is significantly smaller in magnitude than adjacent loads on the distribution grid, it has the potential ability to relieve local overloaded secondary distribution lines. For example, a typical 250,000 ft<sup>2</sup> office building with a peak demand of 1,500 kW vs. 1,100 kW average summer demand, a nearby 200 kW storage unit could supply half of the surge in peaking demand, thereby significantly reducing the strain on the grid and improving reliability.

Utilities are driven to reduce electric rates and looking for cost effective methods to avoid infrastructure investments. Rapid adoption of EVs will drive utilities to broaden adoption of systems that enable widespread charging of EVs that don't create large capital outlays for the utility and which tend to stabilize the demand on the local grid.

#### ***A.6.2.1 Energy Distribution Network Description***

A comprehensive, distributed system of “on the edge” generation and energy storage will help to ensure robust reliability as the grid grows larger, greener, and more complex. This “on the edge” system consists of multiple smart energy storage devices that are coupled with DG to augment normal grid power.

The EDN can help manage local loads. It is designed to optimize renewable energy usage and enable recharging of EVs even in areas of electrical congestion. It enables peak shaving. It can also accommodate combinations of the above. By sensing renewable energy availability, it can charge energy storage devices or flow renewable energy directly to discretionary and price sensitive loads during periods of high renewable energy availability.

Storing and generating energy in an EDN “on the edge” alleviates electrical congestion by surgically inserting power during periods of peak demand. The actual sized SSGUs that comprise the EDN are small enough (each providing anywhere between 27 kW to 300 kW) that the tiny footprint in theory should allow for rapid site approvals and installations, following the trajectory in the solar industry once interconnection procedures are standardized. The relatively low cost for each SSGU allows for a low-risk - gradual scale up vs. the step function normally associated with upgrading transmission capacity. The transformational concept behind GCN's new technology is not in the storage and generation products themselves, but in the interconnecting of these different nodes together to formulate a reliable EDN network. Key features of EDNs are:

1. Secure, reliable, and real-time communication between control center and distributed SSGU nodes
2. Remote monitoring of system state-of-health, charge/discharge state
3. Distributed intelligent agents enabling arbitrage opportunities between peak / off-peak etc.
4. Central command and control capability that can override local SSGU behavior in order to alleviate system-wide peak load or congestion
5. Advanced modeling and real-time decision aids to control SSGU clusters based on evolving needs
6. Distributed SSGUs

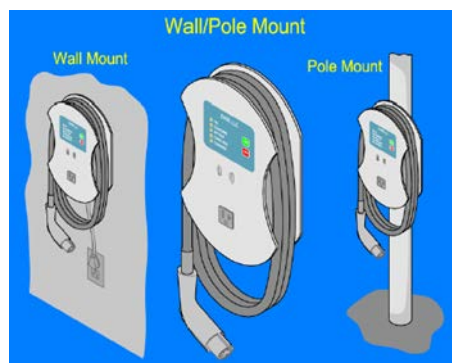
Data contained on the SSGUs are inherently distributed. Each local model represents knowledge learned from the local data source, but could lack *global* knowledge. SSGUs communicate by message passing over a wireless network, in order to keep track of the global information. Since the data stored in SSGUs is distributed – this model results in a large, *dynamic and distributed* environment storing data in different modalities. Such distributed environments with many data and computing resources require novel methodology for supporting efficient data retrieval and analysis.

#### A.6.2.2 SSGU Components

##### EV Charging System

SSGUs are, in part, designed to help alleviate the increased capacity requirements associated with increased EV charging, and as a result, need to have a smart EV charging system such as an level II Electric Vehicle Service Equipment (EVSE) capable of IP network communications via a CAT5 cable, Zigbee, WiFi, or cellular 3G. Due to safety concerns and insurance requirements, only Underwriters Laboratory (UL) certified equipment were installed in deployed SSGUs. There are multiple EVSE suppliers and selection was based on aesthetic appeal, cost, functional ability, and ease of use. Additionally, at SSGU7, GCN deployed a CHAdeMO (“Charge de Move”) based direct current (DC) Fast Charger that could charge a Nissan Leaf up to 80% state of charge under 30 minutes.

**Figure A-44. EV Charging System**



##### Energy Storage System

In order to smooth the peaks associated with EV charging and to participate in DR markets, SSGUs require a reliable energy storage system. Lithium-ion battery banks were selected for use in the EDN demonstration project. The batteries were sized based on number of site-specific conditions. Chemistries such as zinc-bromine flow batteries and sealed lead acid batteries were also considered, but failed to provide the same benefits as the lithium-ion battery. Safety, reliability, cost, energy density, and charge & discharge rate were the significant battery chemistry selection metrics. Lithium-ion batteries used in automotive applications lose the ability to hold a full charge over time, resulting in replacement. EDN provides a significant market for these used batteries, most of which are replaced when unable to hold less than 70% of original charge.

A battery management system ensures safe charging of the individual lithium ion cells, ensuring even distribution of heat and current. The battery management system interfaces with a bi-directional inverter system. This system consists of a series of inline inverters and transformers allowing for the charging and discharging of the battery system. All inverters used to discharge energy from the energy storage to the distribution grid must be UL1741 compliant, specifically regarding the IEEE1547 Anti-Islanding provisions.

Figure A-45. SSGU System Controller



### PV System

The PV system compliments the other components of the SSGU by providing a means for charging the EVs locally, when power is available, or storing excess solar energy until it is needed by the grid. Crystalline silicon modules were used in the EDN Demonstration due to their low cost, availability, and large number of suppliers. They are installed in rooftop applications. Panel supplier and models are selected based on price, availability, lead time, efficiency, and energy density. An in-line grid-tied inverter was used to convert the DC power generated by the panels into AC power to be consumed by the system. The PV inverter was equipped with a maximum power point-tracking system to optimize power output. Like the energy storage discharging inverters, PV inverters must also be UL1741/IEEE1547 compliant.

### Electrical Connection

Con Edison and NYC Department of Buildings (DOB) were operating under National Electric Code (NEC) 2005 version at the time of implementation. According to these codes, in commercial applications, the sum of the maximum current rating, in amps, of all circuit breakers supplying power to an electrical panel cannot exceed the maximum rated amperage of that panel. In residential applications, the sum of maximum ratings can be less than or equal to 120% of the panel rating. This allows for the installation of small power sources (i.e., energy storage or PV solar) in a residential panel without altering the main panel.

In typical commercial applications, a business owner has few practical options if she or he wants to install a power source such as an SSGU. Their first option is to de-rate the main disconnect breaker through which power from the utility is traditionally provided. This reduces the overall capacity of the location to consume power, which is typically undesirable to most commercial customers. A second option is to upgrade their main panel. This option is a costly and time-consuming. The main panel must be isolated, de-terminated, and upgraded. A new, higher rated panel must be purchased, installed, terminated, inspected, and activated. This process involves not only Con Edison, but also coordination with NYC



DOB and an electrical contractor. Depending on the customer, this option can be more or less attractive than the first. However, it is still a significant undertaking.

Fortunately, a third option exists that is commonly referred to as a 'line side tap' or a 'line side splice'. In this case, the new power source (i.e. battery or PV system) is connected upstream of a building's main panel. In order to take advantage of the power generated by PV systems, the connection is made downstream of the utility revenue meter. By connecting power sources between the meter and the panel, the building can consume the same amount of power while taking advantage of the revenue generated by PV systems. In addition, the distribution grid can take advantage of having energy storage which can be used to reduce the consumption of or supply all of an SSGU's building power. Most SSGU customers will probably prefer a line side tap installation.

### **System Controller**

In order for all of the above components to work collaboratively and integrate with the broader EDN, they need an intelligent controller. Each SSGU was subject to a constantly fluctuating energy environment. PV output fluctuated based on cloud cover. Building loading will change based on heating, ventilating, and air conditioning (HVAC), elevator, and other load usage. The system controller is the rules based local engine that monitors local energy conditions and dispatches the EVSE & battery accordingly.

The system controller has several sub-functions including electrical monitoring and interfacing with Con Edison's distribution grid operations control center through business rules knowledge engine (BRKE). In the event that Con Edison calls upon an SSGU to support the grid, the utility communicates can control energy storage and EVSE through the system controller.

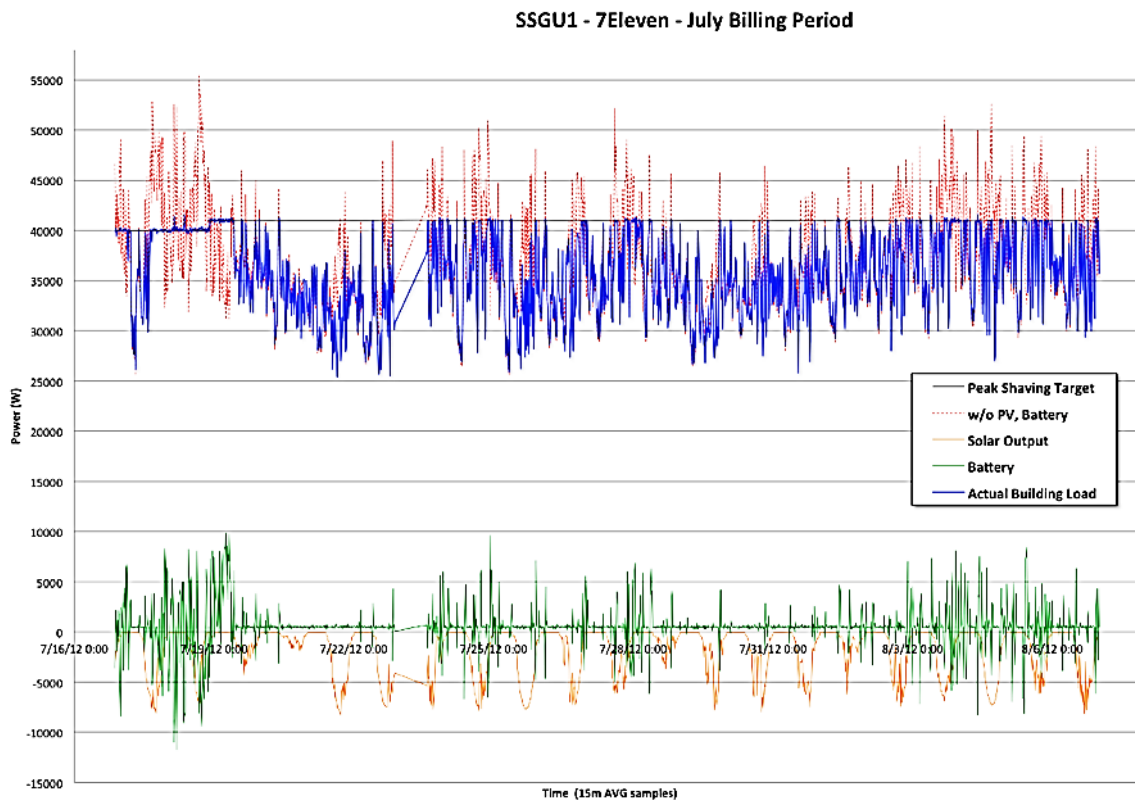
## **A.6.3 Project Goals and Accomplishments**

Below are the highlights of our actual accomplishments.

### ***A.6.3.1 Field Deployment of an EDN with Multiple SSGUs***

One of the project accomplishments was that the integration of PV, EV charging, and energy storage occurred very early in the program, with a significant amount of data captured. Below is a screenshot of a month's performance.

Figure A-46. SSGU1 Billing Period, July 2012



GCN accumulated more than two years of data on numerous installations on a second-by-second basis, inclusive of energy storage charge/discharge rate, temperature, state of charge, voltage, PV solar output, and EV usage. These systems have overcome summer heat waves, polar vortices, and even hurricane Sandy. The deployments covered four separate use cases of distributed energy storage:

1. **Reduce demand charge for the host customer.** GCN gathered two years of performance data, tracking predicted demand charge reduction vs. actual at the end of the billing period.
2. **Avoidance of utility service upgrades.** At Avis LaGuardia Airport, a utility service upgrade (transformer and underground cable) would have been necessary to support the installation of 21 level II EV chargers. The addition of SSGU to serve the local peak loading avoided the need for the service upgrade, saving Avis \$400,000 in construction cost.
3. **Forming an EDN (Multiple SSGUs working together).** In July 2013, GCN demonstrated three SSGU systems working in unison to dispatch energy upon command from Con Edison operator with seconds delay.
4. **Mobile SSGU.** GCN developed a mobile SSGU with the intention of being easily transportable, connected to PV, and also provide portable EV charging. However, Department of Transportation (DOT) regulations pertaining to lithium ion batteries proved to be a major hurdle that prevented the deployment of the mobile unit.

Photos of the various installations follow.

Figure A-47. SSGU1 – 7-Eleven Northern Blvd.

## SSGU1 – 7-Eleven Northern Blvd



GS NOC



Energy Storage



Solar



EV Charging Level 2 and Level 3

Figure A-48. SSGU2 – Avis LaGuardia

## SSGU2 – Avis LaGuardia



Figure A-49. SSGU3 – Mobile



Figure A-50. SSGU4 – 7-Eleven Francis Lewis

## SSGU4 – 7-Eleven Francis Lewis



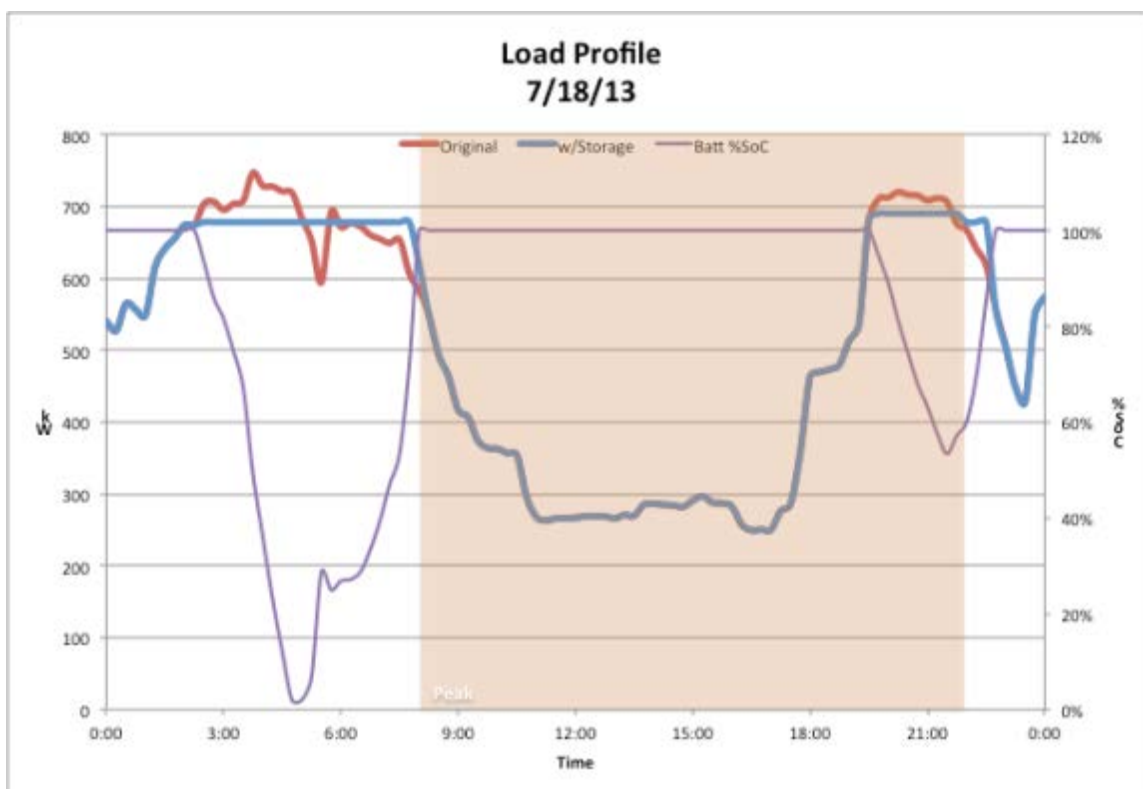
Figure A-51. SSGU5 - Walgreens



### A.6.3.2 Developed Business Case for Distributed Energy Storage System

GCN developed a business model for distributed, behind-the-meter energy storage system by tackling rising demand charges. GCN field-tested charge/discharge algorithms and models for quantifying the savings. Below is an example analysis from our UPS installation (scheduled for Sept 2014).

Figure A-52. UPS Installation Example



| Bill End        | Abs Origin al Max kW | Abs Reduced Max kW | Abs Demand Shaved kW | G&T Peak Max kW | SetPoint G&T Peak kW | Demand Shaved G&T Peak kW | \$/kW Tariff at G&T Peak | Primary Peak Max kW | SetPoint Primary Peak kW | Primary Demand Shaved kW | \$/kW Tariff at Primary Peak | Second. Peak Max kW | SetPoint Sec Peak kW | Demand Shaved Sec kW | \$/kW Tariff at Sec Peak | Monthly Savings        | Notes       |
|-----------------|----------------------|--------------------|----------------------|-----------------|----------------------|---------------------------|--------------------------|---------------------|--------------------------|--------------------------|------------------------------|---------------------|----------------------|----------------------|--------------------------|------------------------|-------------|
| 8/16/2013 0:00  | 746.9                | 690.2              | 56.6                 | 406.1           | 306.1                | 100.0                     | \$8.28                   | 745.0               | 690.2                    | 54.7                     | \$15.49                      | 746.9               | 678.1                | 68.8                 | \$16.62                  | \$2,818.59             |             |
| 9/17/2013 0:00  | 737.3                | 668.3              | 69.0                 | 467.5           | 367.5                | 100.0                     | \$8.28                   | 714.2               | 647.7                    | 66.6                     | \$15.49                      | 737.3               | 668.3                | 69.0                 | \$16.62                  | \$3,006.19             |             |
| 10/17/2013 0:00 | 687.4                | 625.3              | 62.1                 | 426.2           | 326.2                | 100.0                     | \$8.28                   | 670.1               | 620.0                    | 50.1                     | \$15.49                      | 687.4               | 625.3                | 62.1                 | \$16.62                  | \$2,635.52             |             |
| 11/5/2013 0:00  | 680.6                | 614.6              | 66.1                 | 383.0           | 348.4                | 34.7                      | \$0.00                   | 650.9               | 591.5                    | 59.3                     | \$11.42                      | 680.6               | 614.6                | 66.1                 | \$5.33                   | \$1,029.88             |             |
|                 | 0.0                  | 0.0                | 0.0                  |                 |                      | 0.0                       |                          |                     |                          | 0.0                      |                              |                     |                      | 0.0                  |                          | \$1,000.00             | estimate    |
|                 | 0.0                  | 0.0                | 0.0                  |                 |                      | 0.0                       |                          |                     |                          | 0.0                      |                              |                     |                      | 0.0                  |                          | \$1,000.00             | estimate    |
|                 | 0.0                  | 0.0                | 0.0                  |                 |                      | 0.0                       |                          |                     |                          | 0.0                      |                              |                     |                      | 0.0                  |                          | \$1,000.00             | estimate    |
|                 | 0.0                  | 0.0                | 0.0                  |                 |                      | 0.0                       |                          |                     |                          | 0.0                      |                              |                     |                      | 0.0                  |                          | \$1,000.00             | estimate    |
|                 | 0.0                  | 0.0                | 0.0                  |                 |                      | 0.0                       |                          |                     |                          | 0.0                      |                              |                     |                      | 0.0                  |                          | \$1,000.00             | estimate    |
|                 | 0.0                  | 0.0                | 0.0                  |                 |                      | 0.0                       |                          |                     |                          | 0.0                      |                              |                     |                      | 0.0                  |                          | \$1,000.00             | estimate    |
|                 | 0.0                  | 0.0                | 0.0                  |                 |                      | 0.0                       |                          |                     |                          | 0.0                      |                              |                     |                      | 0.0                  |                          | \$1,000.00             | estimate    |
|                 | 0.0                  | 0.0                | 0.0                  |                 |                      | 0.0                       |                          |                     |                          | 0.0                      |                              |                     |                      | 0.0                  |                          | \$1,000.00             | estimate    |
|                 | 0.0                  | 0.0                | 0.0                  |                 |                      | 0.0                       |                          |                     |                          | 0.0                      |                              |                     |                      | 0.0                  |                          | \$2,800.00             | estimate    |
|                 |                      |                    |                      |                 |                      |                           |                          |                     |                          |                          |                              |                     |                      |                      |                          | Past 12 Months Savings | \$19,290.18 |

A financial analysis for this UPS site is summarized below. After planning was already underway for this project, a new incentive in NYC, at \$2,100 per kW<sup>3</sup>, became available for energy storage. Accordingly, the two financial analyses below for each 96 kWh/100 kW SSGU system include an assessment without and with the incentive. At UPS, a total of three SSGUs were installed.

<sup>3</sup> Note that this is based on a four-hour rating.

|               | Equipment Cost | Installation Cost | Energy Storage Incentive | Final Cost    | Annual Savings | Payback   | Internal Rate of Return (IRR) (%) |
|---------------|----------------|-------------------|--------------------------|---------------|----------------|-----------|-----------------------------------|
|               | a              | b                 | c                        | d = a + b - c | -              | -         | -                                 |
| w/o Incentive | \$130,000      | \$133,000         | \$0                      | \$263,000     | \$19,291       | 9.6 years | 1.50%                             |
| w/ Incentive  | \$130,000      | \$133,000         | \$50,400                 | \$212,600     | \$19,291       | 9.0 years | 4.50%                             |

NOTE: Savings are escalated five percent per year based on historical increase in demand charges in Con Edison territory.

There are two important notes about this analysis. First is that the energy storage incentive can have a significant impact in determining whether a project is financially viable or otherwise. In this analysis, the energy storage incentive improves the project payback by 0.6 years and the IRR by 3%. Second, the installation costs of this project unexpectedly became a significant driver of costs, accounting for over half of the total project cost. Construction in Manhattan can be particularly expensive, nearly doubling the cost in the outer Boroughs. Lessons-learned from this project will help stakeholders better identify cost drivers for citing an energy storage system, better allowing systems to be installed while avoiding these significant installation costs.

#### ***A.6.3.3 Distributed Energy Storage Can be Used In Place of Utility Service Upgrade***

At Avis LaGuardia Airport, GCN was initially informed that 21 level II EVSEs would require a utility service upgrade. The customer transformer cannot handle the added load. Additionally, the customer-side power cables that run underneath the parking lot would need to be upsized. This upgrade would have cost \$400,000, including digging up the parking lot and interrupting business for several weeks. Instead, GCN worked with the electrical professional engineer and sized the SSGU to serve the peak load. As a result, the utility service upgrade was not required.

#### ***A.6.3.4 Intelligent Software is the Key to Making Energy Storage Economical***

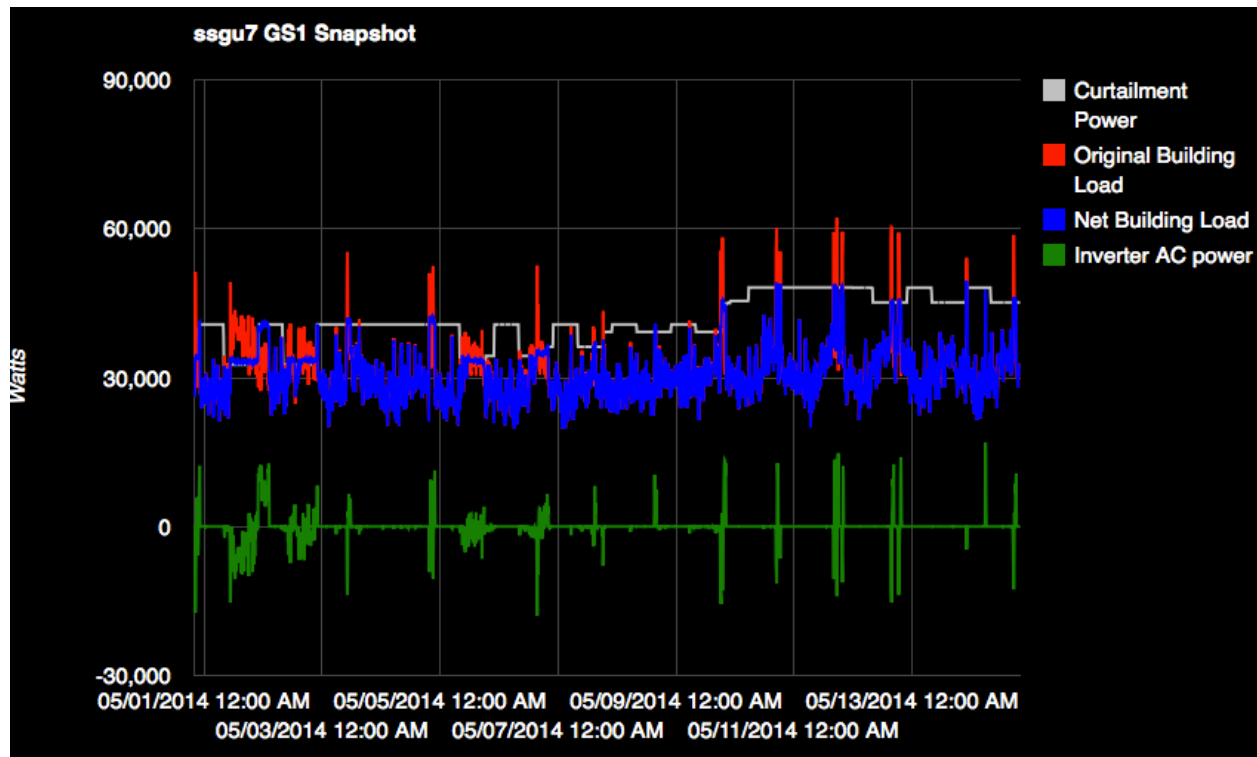
GCN demonstrated that intelligent software that is able to predict and reduce power demand is the key to shrinking the size of battery hardware needed, thereby improving the economics for mass adoption of distributed energy storage technology.

#### ***A.6.3.5 DC Fast Chargers for EVs Require Energy Storage for Mass Adoption***

A DC fast charger that can charge an EV in 30 minutes is a necessary component of the EV refueling infrastructure. Demand charges are prohibitively expensive, causing host customers to either not want it or require a separate meter paid by the EV charger operator. This adds a significant obstacle and cost to deployment.

Through this project, GCN has proven that DC fast chargers for EVs (>30kW) can be installed behind the meter under existing service/meter using intelligent software and energy storage. This paves the way for mass adoption and deployment. See below screenshot of a month's performance at the 7-Eleven test site.

Figure A-53. Month's Performance Example



#### A.6.3.6 EDN Benefits

GCN demonstrated that a network of SSGUs can in fact operate in unison and respond to the utility in times of need. GCN demonstrated that distributed energy storage can be centrally controlled by the utility, enabling “surgical curtailment”. This has multiple advantages when compared to the current crop of DR load relief technology:

- Generation assets without a single point of failure
- Surgical curtailment targeting feeders, individual utility transformers if needed
- Real-time, instantaneous response
- No humans in the loop; complete automation with performance guarantee
- No hassles or inconvenience for the end user

#### A.6.3.7 Mobile SSGU

Through this effort, GCN learned many important lessons relating to a portable micro-grid system, including the following:

1. Transportability of lithium ion batteries
2. Use cases for portable energy storage
3. Feasibility of providing portable EV charging

The Mobile Unit can accommodate up to 10 kW of PV as well as commercial, off-the-shelf level 2 EVSE chargers. The built-in grid-tied inverter will invert DC from PV or energy storage into AC if connected to a facility or building. The DC Fast Charger port is a special case. The commercial, off-the-shelf systems use 50kW of 480V AC power and rectify it into DC to power a vehicle. GCN applied its own independent research and development to power a DC fast charger using DC instead of AC to save the roundtrip conversion losses. The end result is a DC fast-charge controller that can power a Nissan Leaf or Mitsubishi iMiEV directly from a DC source.

GCN completed the development of one mobile SSGU unit that was demonstrated in July 2011 at a SG conference sponsored by Siemens in Raleigh Durham, NC. Subsequently, GCN discovered that there was significant costs associated with deploying a mobile lithium-ion based mobile storage unit, due to highway transportation regulations. The basis for the restrictions imposed by the federal DOT regulations is the classification of lithium ion as a DOT class 9 hazardous material. The United Nations (UN) has made specific recommendations to the DOT, titled UN Model Regulation 3480 and 3481. Getting through these regulations and tests required destructive testing on real-life equipment samples and was cost prohibitive. As a result, further mobile SSGU deployment was aborted.

**Figure A-54. Mobile SSGU Specifications**

#### Modular Features

- Complete Mobile Electric Vehicle (EV) Charge Station
- Outdoor-rated Weatherproof Secure Metal Enclosure
- Computer Controlled Power Management
- Removable Lithium Battery Powered (3 kWh capacity)
- 260 Amp Onboard Vehicle Charge System
- Dashboard Monitor Display (optional)
- Accessible User Control Panel with Emergency Shutdown and Status Lights

#### Level 2 Features

- SAE J1772 compliant
- Maximum 6kW Power Output
- Ground fault detection safety **shutoff**

#### DC Fast Charge Features

- Offboard Charging with direct DC connection
- 12 kW Rate DC Fast Charge

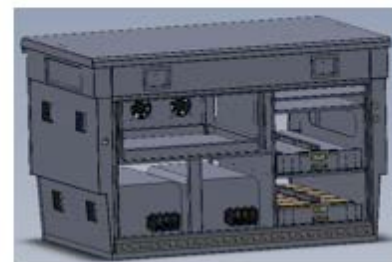


Figure A-55. Mobile SSGU in Use



SSGU3 is a proof-of-concept mobile energy storage and EV charging platform. Using it and its derivatives, including the truck-based mini-system, GCN explored the various use cases for mobile energy storage and EV charging, including the needs of utilities and commercial customers. GCN also explored commercial partnerships to bring such a system into the market. GCN learned that there are many situations that warrant such a system, including providing voltage support, DG, and EV charging for public gathering events.

#### *A.6.3.8 Comparison of Actual Results versus Original Goals*

The high-level objective of GCN's project was to use sophisticated software to meet rising power demands at a fraction of the cost of utility infrastructure upgrades. This is a paradigm shift from traditional energy efficiency initiatives, which have been about energy or kWh. GCN's project tackled power (kW) efficiency. The mechanism to quantify the savings on the customer's side of the meter is through demand charge reduction. Through this project, GCN aimed to provide a solution with an economic return on investment (ROI) of less than eight years that can be readily commercialized.

Below is the summary table of the goals/objectives and actual accomplishments.

**Table A-15. Summary of Goals and Results**

| Original                                                                                                                                                                                                                                       | Actual                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Lesson Learned                                                                                                                                                                      |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| BRKE – Distilling institutional knowledge from Con Edison expert operators, improved processing of repetitive and data-intensive activities, greater clarity and speed. Integration with Columbia stochastic controller.                       | BRKE – Early on in the implementation, Boeing and then Siemens Energy took over the utility operator expert knowledge engine and working with Con Edison operators and IR. The scope of work evolved to a rules engine for the local environment at the facility where the SSGU is installed. GCN implemented localized rules and predictive algorithms to anticipate changing power loading based on weather and historical usage.                                                                                                                                    | GCN designed a flexible platform that can accommodate the needs of utilities as well as down to the individual customer facility.                                                   |
| DSM – Visibility into secondary grid and connected assets, including distributed generators and curtailment. Bring DR programs into the control room; surgical curtailment of load at the feeder level.                                        | DSM – At the final demonstration in July 2013, GCN connected three SSGUs / GreenStations to the demonstration platform under Con Edison operator's control. The operator had real-time visibility into PV generation and EV charger consumption. Furthermore, a portion of the energy content of the SSGU was dedicated to the operator's control. At the press of a button, the operator triggered DG at all three sites, thereby reducing loads within seconds. The operator was able to pick and choose specific generators, thus providing "surgical" load relief. | Aggregation of DG assets is challenging due to cybersecurity and reliability concerns; however, if done correctly and repeatedly, such a network adds tremendous value to the grid. |
| EDN – Validate that distributed energy storage on the edge outperforms centralized energy storage, in terms of reliability, renewable integration, weather susceptibility, demand relief in light of EV chargers, and demand charge reduction. | GCN ran into numerous issues, including permits, interconnection, contracts, and costs, which limited the number of installations GCN could do. GNC installed a total of eight systems and successfully proved the value of distributed energy storage.                                                                                                                                                                                                                                                                                                                | Interconnection approval with the utility takes a tremendous amount of time and effort. Get this process started upfront at the beginning of a project.                             |

## A.6.4 Project Activities

### A.6.4.1 Original Hypotheses

The functional software requirements of the BRKE, Demand Side Manager (DSM), and EDN were developed with the following considerations:

#### BRKE

1. Store a collection of business rules to be evaluated when system overload indicators arise
2. Allow network operators to maintain the business rules through a user interface
3. Continuously process near real-time data of grid assets to identify potential trouble spots and overloaded assets



4. Utilize a decision aid algorithm to propose an optimized curtailment schedule to maximize relief on stressed equipment and incorporate business logic maintained by operators
5. Securely communicate to the utility to obtain updated grid conditions and send suggested curtailment schedules

#### DSM

1. Securely receive DR requests from the utility
2. Send automated notifications and requests to DR aggregators and smart storage devices connected to the secondary grid
3. Provide visibility to connected assets, including distributed generators, PV, and EVSE
4. Evaluate, measure, and verify curtailment requests sent

#### EDN

1. Provide real-time visibility into GCN's deployed assets to the utility
2. Interface with and control smart assets within the SSGU
3. Act upon a DR request and report curtailment statuses

#### ***A.6.4.2 Original Approaches***

GCN developed proof-of-concept BRKE and DSM web applications, incorporating the Bosch Visual Rules engine. Over time through the project development process, some of the requirements that were originally contemplated to be performed by GCN's BRKE and DSM were instead accomplished via the integration of Con Edison's existing poly-voltage load-flow (PVL) applications. The focus of GCN's software requirements evolved to be installation-site specific, balancing the power and energy flows of assets and devices at the customer site in a manner which would enable a reduction in peak demand.

The BRKE and DSM features are fully integrated within the Grid Synergy Network Operations Center (GSNOC). Secure messaging through a middleware and integration system will allow for the GSNOC to receive requests and data from systems within Con Edison. The EDN is made up of three of GCN's SSGUs tied together via a Grid Synergy Network Integrator (GSNI) communicating securely to the GSNOC. By the end of September 2014, GCN will have three additional systems online at UPS for the EDN network. Day-ahead weather prediction has been integrated into the load forecast in order to determine optimal state-of-charge of the energy storage systems going into the next day. Figure A-56 and Figure A-57 below show the high-level system diagrams of the BRKE system and the DSM/EDN diagrams, respectively.

Figure A-56. High-Level BRKE System Diagram

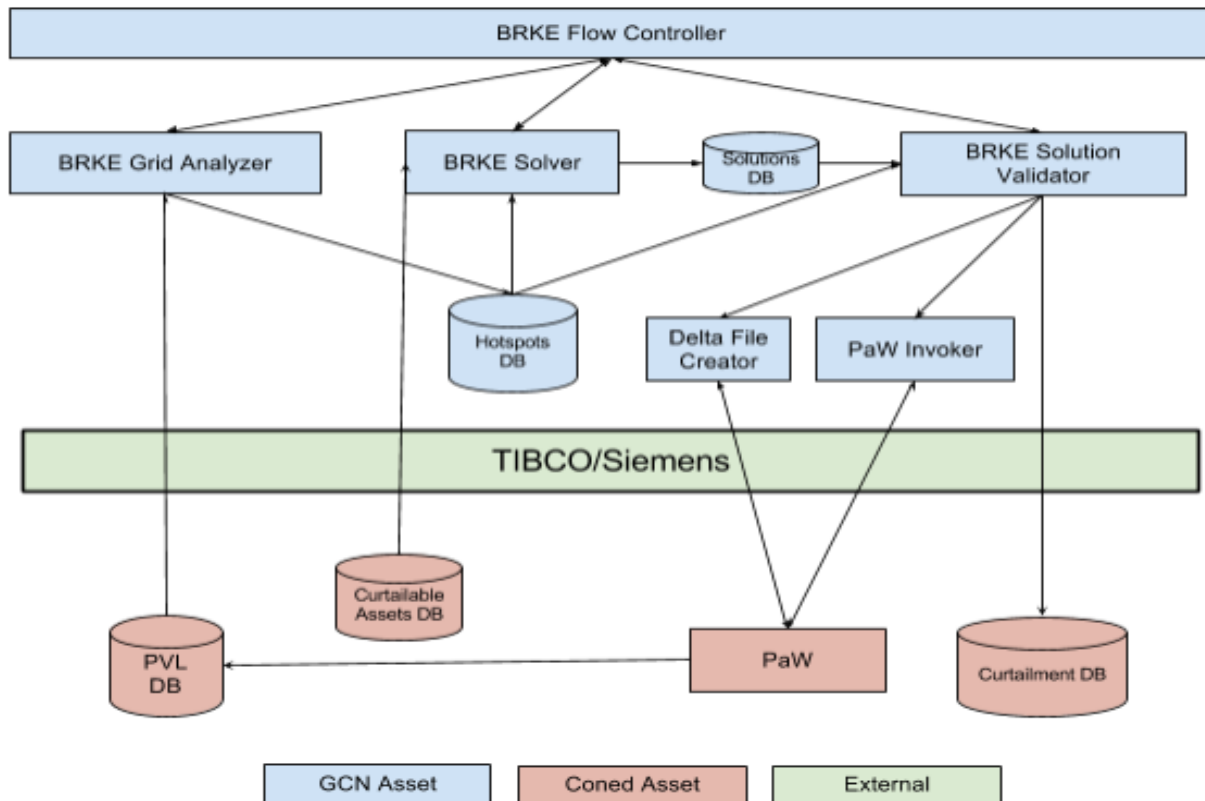
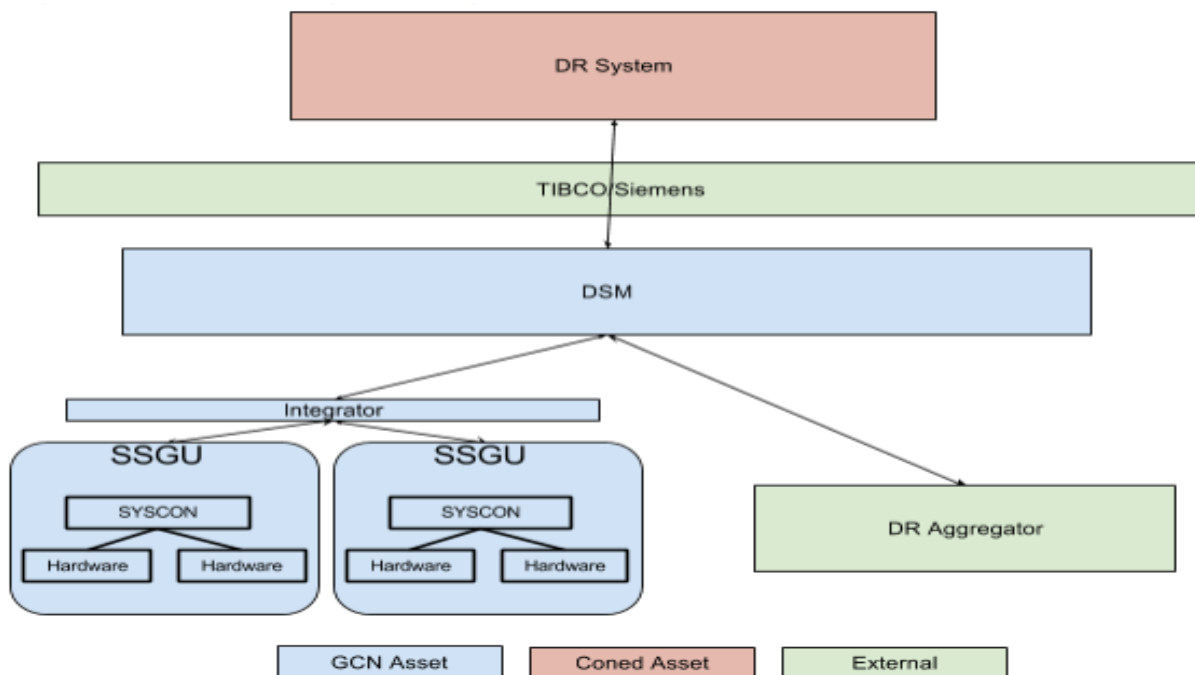


Figure A-57. High-Level DSM/EDN System Diagram





The GSNOC has been built using a SOA methodology. Using the Spring Web Service Framework, a discrete service and interface was created to handle DR requests from the utility, status requests from the utility, curtailment requests to the SSGUs, status requests to the SSGUs, and communication to a Java-based web application.

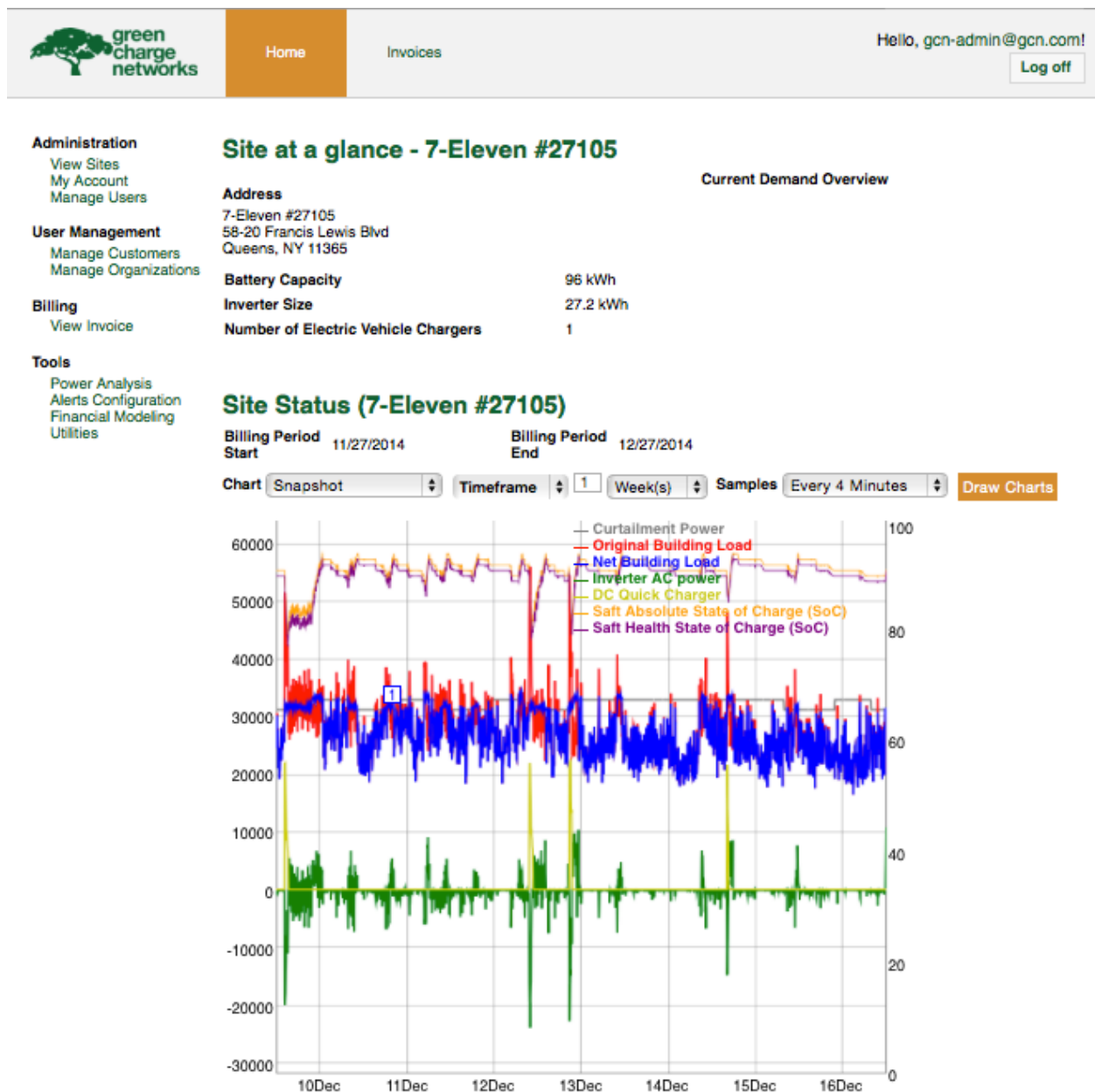
### **GSNOC**

The GSNOC is a customer portal and an administrative interface for GSNOC operators. The GSNOC has three core administrative responsibilities: communicate with the field assets, issue peak demand set-points, and monitor the health of the assets. GSNOC operators are able to remotely monitor and control GCN's field assets, and customers can view the status of their systems.

#### **Features:**

1. Cybersecurity to NIST 7628 standards for communicating with assets in the field and to the electric utility
2. Auditable records of commands and actions taken
3. Performance and acknowledgement of command/control back to the utility
4. Monitors field assets
5. Reports of system performance, savings through demand charge reduction
6. Customer interface portal
7. GCN super-user technical and financial savings analysis tools

Figure A-58. GSNOG Example



All communications to and from GSNOG are encrypted via AES-128 bit security. GSNOG implements a User Access Control system. Only users with proper permissions can access certain portions of GSNOG.

GSNOG also contains “super-user” features that allow a user to perform savings analysis. Screenshots of these features are shown below.

Figure A-59. GSNOG Super-User Features Example

#### Administration

Dashboard  
View Sites  
My Account

#### Billing

Create Invoice  
View Invoices

#### Customers

View  
Accounts  
Organizations

#### Tools

Power Analysis  
Financial Modeling  
Utilities

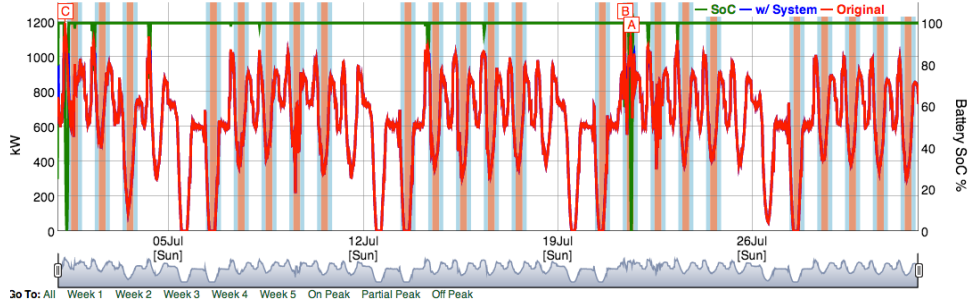
#### Santa Clara\_Berger\_180

File 2jurbdwu4l.SC Berger.Interval.Txt.txt  
Battery Size (kWh) 180 kWh  
Inverter Size (kW) 180 kW  
Period 12/1/2008 - 11/30/2009

Tariff PG&E - E-20  
Time Zone Pacific Standard Time  
Savings \$36,640.95  
Utility Classification Primary  
Error Logs Open

| Billing Start | Billing End | Abs Original Max kW | Abs Reduced Max kW | Abs Demand Shaved | Abs Peak Time       | Full Peak Max kW | Full Peak Max Time   | SetPoint Full Peak kW | Full Peak Shaved kW | S/kW Tariff at Full Peak | Part Peak Max kW | Part Peak Max Time    | SetPoint Part Peak kW | Part Peak Demand Shaved kW | S/kW Tariff at Part Peak | Off Peak Max kW | Off Peak Max Time   | SetPoint Off Peak kW | Demand Shaved Off Peak kW | S/kW Tariff at Off Peak |
|---------------|-------------|---------------------|--------------------|-------------------|---------------------|------------------|----------------------|-----------------------|---------------------|--------------------------|------------------|-----------------------|-----------------------|----------------------------|--------------------------|-----------------|---------------------|----------------------|---------------------------|-------------------------|
| 12/1/2008     | 8/1/2009    | 1195                | 1032               | 163               | 7/1/2009 6:45:00 AM | 1121             | 7/21/2009 3:15:00 PM | 941                   | 180                 | \$16.68                  | 1194             | 7/21/2009 10:00:00 AM | 1014                  | 180                        | \$3.49                   | 1195            | 7/1/2009 6:45:00 AM | 1032                 | 163                       | \$9.97                  |

7/1/2009 - 8/1/2009



#### Administration

Dashboard  
View Sites  
My Account

#### Billing

Create Invoice  
View Invoices

#### Customers

View  
Accounts  
Organizations

#### Tools

Power Analysis  
Financial Modeling  
Utilities

#### Santa Clara\_Berger\_180

File 2jurbdwu4l.SC Berger.Interval.Txt.txt  
Battery Size (kWh) 180 kWh  
Inverter Size (kW) 180 kW  
Period 12/1/2008 - 11/30/2009

Tariff PG&E - E-20  
Time Zone Pacific Standard Time  
Savings \$36,640.95  
Utility Classification Primary  
Error Logs Open

Create Financial Models  
View Financial Models

| Id   | Abs Original Max kW | Abs Reduced Max kW | Abs Demand Shaved | Abs Peak Time         | Full Peak Max kW | Full Peak Max Time    | SetPoint Full Peak kW | Full Peak Shaved kW | S/kW Tariff at Full Peak | Part Peak Max kW | Part Peak Max Time    | SetPoint Part Peak kW | Part Peak Demand Shaved kW | S/kW Tariff at Part Peak | Off Peak Max kW | Off Peak Max Time     | SetPoint Off Peak kW | Demand Shaved Off Peak kW | S/kW Tariff at Off Peak | Monthly Savings |       |
|------|---------------------|--------------------|-------------------|-----------------------|------------------|-----------------------|-----------------------|---------------------|--------------------------|------------------|-----------------------|-----------------------|----------------------------|--------------------------|-----------------|-----------------------|----------------------|---------------------------|-------------------------|-----------------|-------|
| 09   | 1060                | 987                | 73                | 12/4/2008 8:30:00 AM  |                  |                       |                       |                     |                          | 1060             | 12/4/2008 8:30:00 AM  | 987                   | 73                         | \$0.25                   | 1053            | 12/4/2008 7:45:00 AM  | 932                  | 121                       | \$9.97                  | \$746.06        | Graph |
| 09   | 1092                | 912                | 180               | 1/22/2009 6:00:00 PM  |                  |                       |                       |                     |                          | 1092             | 1/22/2009 6:00:00 PM  | 912                   | 180                        | \$0.25                   | 974             | 1/10/2009 6:45:00 AM  | 810                  | 164                       | \$9.97                  | \$1,839.80      | Graph |
| 09   | 1229                | 1049               | 180               | 2/13/2009 4:45:00 PM  |                  |                       |                       |                     |                          | 1229             | 2/13/2009 4:45:00 PM  | 1049                  | 180                        | \$0.25                   | 940             | 2/14/2009 5:30:00 PM  | 847                  | 93                        | \$9.97                  | \$1,839.80      | Graph |
| 09   | 999                 | 879                | 120               | 3/27/2009 6:30:00 AM  |                  |                       |                       |                     |                          | 992              | 3/11/2009 6:30:00 AM  | 879                   | 113                        | \$0.25                   | 999             | 3/27/2009 6:30:00 AM  | 875                  | 124                       | \$9.97                  | \$1,224.85      | Graph |
| 09   | 1073                | 918                | 155               | 4/8/2009 8:15:00 AM   |                  |                       |                       |                     |                          | 1007             | 4/24/2009 8:30:00 AM  | 844                   | 163                        | \$0.25                   | 1073            | 4/8/2009 8:15:00 AM   | 918                  | 155                       | \$9.97                  | \$1,586.10      | Graph |
| 09   | 1162                | 982                | 180               | 5/19/2009 7:15:00 AM  | 1036             | 5/5/2009 3:45:00 PM   | 892                   | 144                 | \$16.68                  | 1001             | 5/8/2009 8:30:00 AM   | 887                   | 114                        | \$3.49                   | 1162            | 5/19/2009 7:15:00 AM  | 982                  | 180                       | \$9.97                  | \$4,594.38      | Graph |
| 09   | 1202                | 1074               | 128               | 6/30/2009 7:15:00 AM  | 1087             | 6/23/2009 12:15:00 PM | 907                   | 180                 | \$16.68                  | 1155             | 6/9/2009 8:30:00 AM   | 1043                  | 112                        | \$3.49                   | 1202            | 6/30/2009 7:15:00 AM  | 1074                 | 128                       | \$9.97                  | \$4,669.44      | Graph |
| 09   | 1195                | 1032               | 163               | 7/1/2009 6:45:00 AM   | 1121             | 7/21/2009 3:15:00 PM  | 941                   | 180                 | \$16.68                  | 1194             | 7/21/2009 10:00:00 AM | 1014                  | 180                        | \$3.49                   | 1195            | 7/1/2009 6:45:00 AM   | 1032                 | 163                       | \$9.97                  | \$5,255.71      | Graph |
| 09   | 1192                | 1056               | 136               | 8/18/2009 7:15:00 AM  | 819              | 8/28/2009 5:45:00 PM  | 645                   | 174                 | \$16.68                  | 1085             | 8/18/2009 8:30:00 AM  | 1005                  | 80                         | \$3.49                   | 1192            | 8/18/2009 7:15:00 AM  | 1056                 | 136                       | \$9.97                  | \$4,537.44      | Graph |
| 09   | 1318                | 1148               | 170               | 9/15/2009 6:30:00 AM  | 1074             | 9/10/2009 2:45:00 PM  | 894                   | 180                 | \$16.68                  | 1176             | 9/18/2009 8:30:00 AM  | 996                   | 180                        | \$3.49                   | 1318            | 9/15/2009 6:30:00 AM  | 1148                 | 170                       | \$9.97                  | \$5,325.50      | Graph |
| 09   | 1118                | 1041               | 77                | 10/6/2009 8:15:00 AM  | 1010             | 10/28/2009 4:45:00 PM | 890                   | 120                 | \$16.68                  | 1084             | 10/1/2009 9:00:00 AM  | 904                   | 180                        | \$3.49                   | 1118            | 10/6/2009 8:15:00 AM  | 1041                 | 77                        | \$9.97                  | \$3,397.49      | Graph |
| 2009 | 1151                | 992                | 159               | 11/19/2009 4:15:00 PM |                  |                       |                       |                     |                          | 1151             | 11/19/2009 4:15:00 PM | 992                   | 159                        | \$0.25                   | 1090            | 11/11/2009 5:30:00 PM | 956                  | 134                       | \$9.97                  | \$1,624.98      | Graph |

## GSNI

Primary purpose:

- Data acquisition and storage

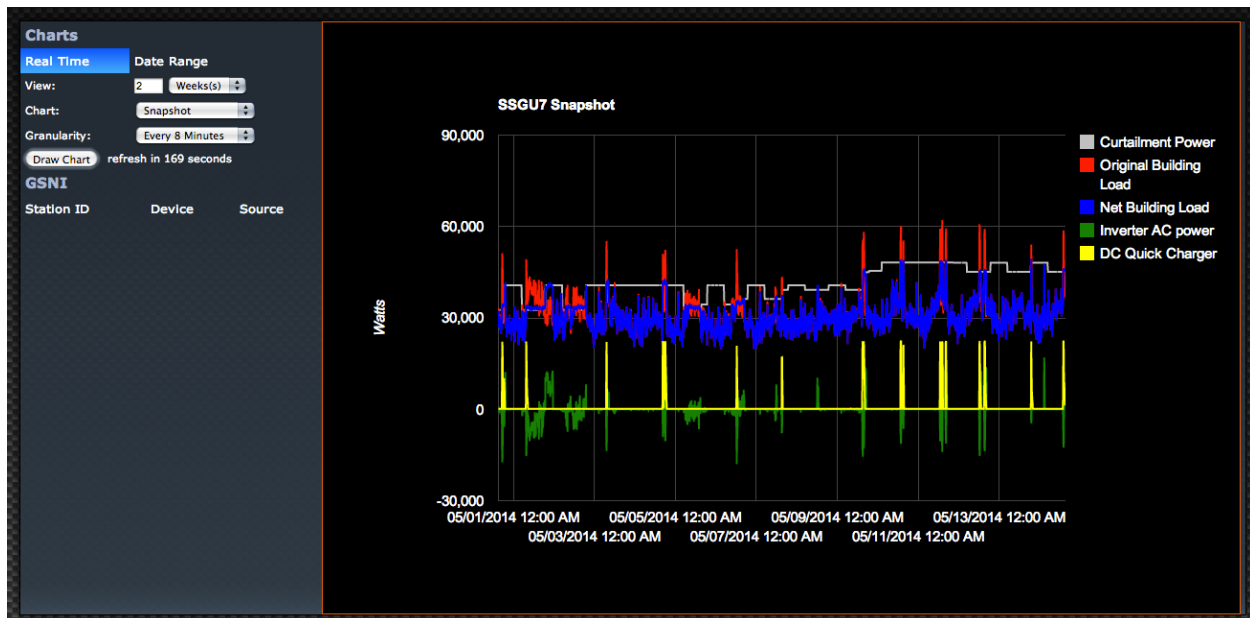
Goals:

- No data loss
- Fast performance (very fast inserts, fast queries)

- Non-blocking, high throughput (SSGUs will be posted frequently, data will be queried frequently)
- Security (authentication, privacy)
- Simplicity: insert and read only (no interpretation or editing)
- Eventual scalability

GSNI also provides an admin interface for GCN operations and monitoring. Screenshot below:

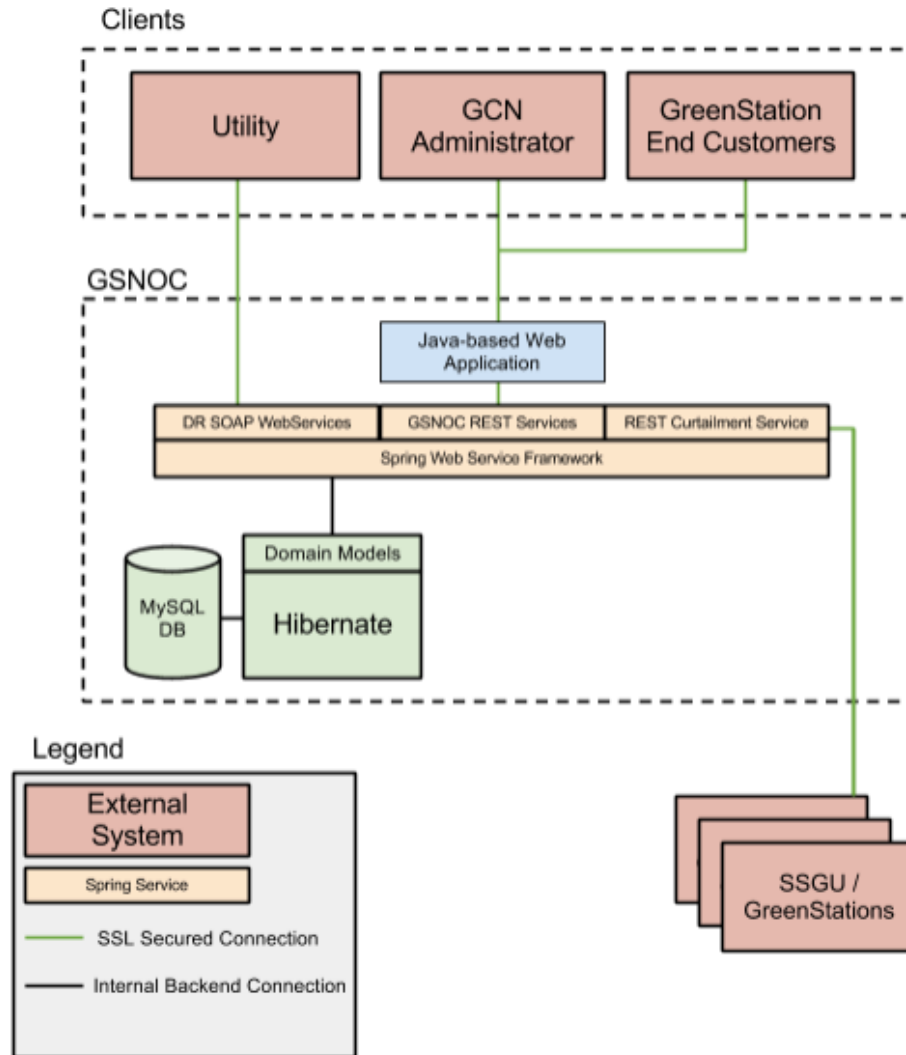
**Figure A-60. GSNI Example**



#### *Scope:*

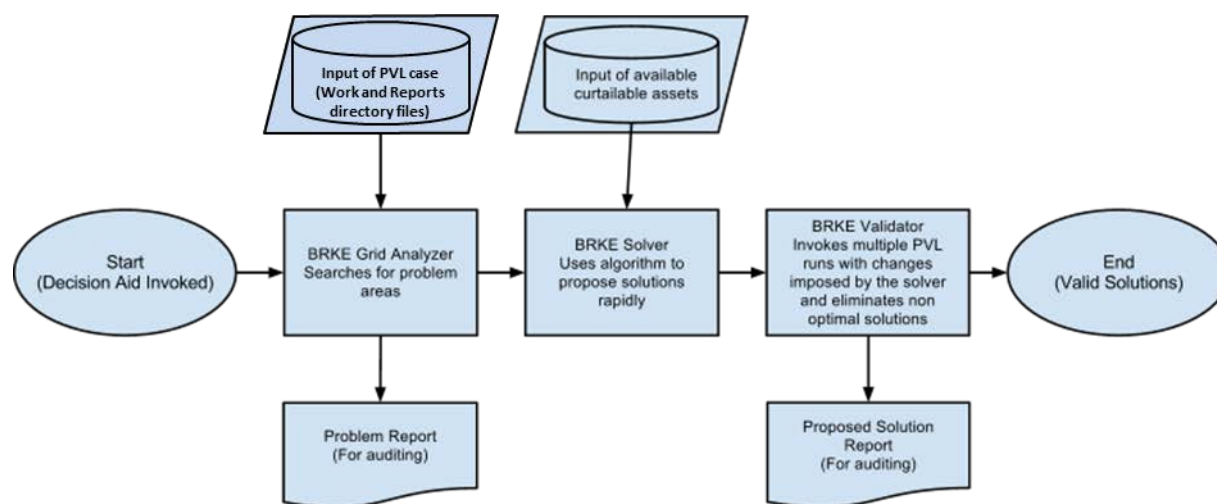
- Data collection
- Data storage
- Data query support
- Admin interface for operations and monitoring
- Configuration (does not need to be through the API)

Figure A-61. System Diagram



Within the GSNOC back end, a service was scheduled to periodically run and perform the BRKE functions. The primary functions of this service are to find overloaded or possibly overloaded grid assets, determine viable solutions to mitigate the overloads using curtailable assets, and to eliminate any solutions deemed unfeasible due to business logic. Figure A-62 below shows the Decision Aid Algorithm Flowchart.

**Figure A-62. Decision Aid Algorithm Flowchart**



For the EVSE demonstration, a remote operator was logged into GSNOC and issued a curtailment of the charging Nissan Leaf to curtail first to 50%, and then to 0%. The curtailment request was sent securely to the SysCon on-site, which then limited the output of the charger. A separate demonstration showcased the ability to remotely control energy storage assets and manually dispatch energy. Similar to the other demonstration with EVSE curtailments, specific discharge set-points were sent and the site's response to the commands was reported back in graphical form within seconds.

At the conclusion of this project, GCN will have demonstrated the GSNOC's ability to communicate securely between seven GCN sites (Avis, 7-Elevens at two locations, Walgreens, and three separate UPS systems) and Con Edison, including energy storage, EV charging, and PV generation. The output and curtailment capability across all seven systems can be aggregated. When a curtailment request is received from Con Edison, the BRKE will automatically determine the best optimized curtailment schedule in the background. Once the curtailment is enabled by Con Edison, the DSM will automate the DR requests sent to the SG assets. All of GCN's SSGUs will receive the requests and report back to GSNOC and through GSNOC the utility gets updated statuses and fulfillments of the request as part of the EDN.

#### ***A.6.4.3 Problems Encountered and Departure from Plan***

The main problems encountered were on the EDN/SSGU side. GCN learned that there is a high cost and rather significant time required to enable these systems to be sited, permitted, and installed. As time went on, the process got easier as all parties became more familiar with the requirements.

GCN encountered a significant amount of administrative burden due to their unfamiliarity with the DOE agreement requirements and the associated grant compliance reviews. GCN was required to allocate a significant amount of time to address compliance requests that were necessary to ensure conformity with



applicable federal regulations. As a result, GCN needed to scale back on the number of SSGUs that were originally planned but still will end up with eight deployments as part of this project.

GCN adjusted plans in the initial phase of the project regarding BRKE development prior to the first demonstration. Instead of focusing on control center rules and knowledge, GCN focused on managing the local site load instead. Through this effort, GCN was able to detect HVAC, refrigeration, PV, and EV charger load shifts and react appropriately with energy storage and power demand reductions. GCN demonstrated that DC fast charging for EVs (>30kW), when coupled with energy storage and software intelligence, can be deployed in scale behind the meter under existing service/meter. GCN proved that weather strongly correlates with customer load and weather forecasting tremendously improves utilization of distributed energy storage.

## **A.6.5 Product Development and Technology Transfer**

### **A.6.5.1 Publications**

The only publication of results has been in the form of a case study on 7-Eleven from summer 2013. It can be found here:

<http://greenchargenet.com/power-efficiency-products/power-efficiency-case-study>

### **A.6.5.2 Networks/Collaborations**

The success of the project has led directly to:

1. Adoption by more private-sector customers. In addition to 7-Eleven and Avis, GCN has taken the same offering (demand reduction) to UPS and Walgreens, among others. GCN hopes to broaden the footprint beyond the initial set of pilot sites in the months and years ahead.
2. California Energy Commission PON-11-602 award, combining DC fast chargers for EVs with distributed energy storage to avoid demand charges. GCN is partnered with NRG/eVgo and Chargepoint on this deployment.

### **A.6.5.3 Technologies/Techniques**

GCN developed the following:

1. The first distributed, behind-the-meter demand charge reduction system in the U.S., using Saft batteries and Princeton Power inverter
2. Algorithm and rules for managing set-points in the local operating environment
3. Weather input and correlation with demand
4. Management of EV charging in combination with energy storage
5. Cyber-secured connectivity of generation assets to Con Edison's control center

#### A.6.5.4 Patent Applications

**Table A-16. Listing of Patent Applications**

|                             |            |            |                                                                                                                                                                                     |                                |                                                                                                                   |
|-----------------------------|------------|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|-------------------------------------------------------------------------------------------------------------------|
| 83357.0005<br>(P004.01-UTL) | 13/552,623 | 7/18/2012  | "Multi-Mode Electric Vehicle Charging Station"                                                                                                                                      | Claims priority to: 61/509,010 | Pending – Ready for Examination, 1st OA prediction: 6/2015. Published 01/24/2013 (Pub. No. US-2013-0020993-A1).   |
| 83357.0008<br>(P007.UTL)    | 13/531,442 | 6/22/2012  | "Electric Vehicle Charger Testing Systems"                                                                                                                                          | None                           | Pending – Ready for Examination, 1st OA prediction: 6/2015. Published 12/26/2013 (Pub. No. US-2013-0346010-A1).   |
| 83357.0030<br>(P029-UTL)    | 13/531,450 | 06/22/2012 | "Electric Vehicle Charging Protocol Selection and Testing"                                                                                                                          | None                           | Pending – Published 12/26/2013 (Pub. No. US-2013-0346025-A1). Ready for Examination, 1st OA prediction: 6/2015.   |
| 83357.0034<br>(P030.01-UTL) | 13/066,609 | 04/19/2011 | "Single Electric Vehicle Charger for Electrically Connecting to Multiple Electric Vehicles Simultaneously While Automatically Charging the Multiple Electric Vehicles Sequentially" | Claims priority to: 61/399,490 | Pending – Published 01/19/2012 (Pub. No. US-2012-0013298-A1). Response to Restriction Requirement filed 12-31-13. |

## A.7 *Innoventive: Demand Response Command Center (DRCC)*

The Innoventive and Con Edison teams developed the following summary of SGDP activities as part of the input to the FTR. Results and information below has been used to develop the overall takeaways and lessons learned in the FTR.

### A.7.1 Executive Summary

The Interoperability of Demand Response Resources Demonstration in NY (Interoperability Project) was awarded to Con Edison in 2009. The objective of the project was to develop and demonstrate methodologies to enhance the ability of customer-sited DR resources to integrate more effectively with electric delivery companies and regional transmission organizations.

The Interoperability Project demonstrated a number of innovative methods of integrating DR resources to help make the grid more efficient, improve grid reliability, and create economic value for facility owners. The project participants successfully demonstrated a number of concepts identified in the table below.

**Table A-17. Interoperability Project Research Areas**

| Research Topic                                                                                                          | Contribution of Interoperability Project                                                                                                                                          |
|-------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ability of DR to Improve Reliability in the Distribution System                                                         | DR Resources with rapid response and ability to maintain load reductions for multiple hours when needed can help maintain reliability during times of grid contingencies.         |
| Ability of DR Resources to Provide Ancillary Services to the Electric Grid                                              | This was the first application in the NYISO control area where DR resources are dispatched in the same way as a conventional generator.                                           |
| Requirements for cyber-secure interoperability between DR resources and an Electric Distribution Utility                | Demonstration of remote activation of DR resources by the utility using a secure link compliant with NIST 7268                                                                    |
| How precise controls of facility loads can be harnessed for application beyond simple peak shaving or energy efficiency | Through precise control of building loads, demonstrated ability to control resources to set points established by the Regional Transmission Operator (RTO)                        |
| The potential for an aggregation of multiple DR resources to alleviate a forecasted capacity shortage in a Control Area | Via the Virtual Generator concept, the project was able to show how a large aggregation of resources can be an economical solution to a forecasted shortage of regional capacity. |

In most cases, the technical effectiveness was extensively exercised and successfully tested. Economic feasibility was tested whenever possible and when actual test data was not available, results were obtained by system modelling.

This project was comprised of a number of discrete components that were developed and demonstrated, namely:

- **DRCC**

The DRCC represents a secure software system designed to aggregate DR resources for activation in response to various conditions of the electric grid. The DRCC was tested many times throughout the project, demonstrating technical effectiveness. In fact, the DRCC developed during this project is being utilized in a production environment to enable automatic DR for project resources. A total of 23 facilities and 20 MW of generation have been integrated into the DRCC.

- **Incremental Building Control Unit (IBCU)**

The IBCU is a set of hardware and programmed strategies that can control facility loads in response to market signals or as a tool to optimize energy efficiency. The IBCU was installed and demonstrated as part of an installation of a Thermal Storage System. Technical effectiveness of the IBCU system was tested and demonstrated. While sufficient operating experience was not acquired during the test period to enable economic feasibility to be demonstrated, results are modelled and reported later in the report.

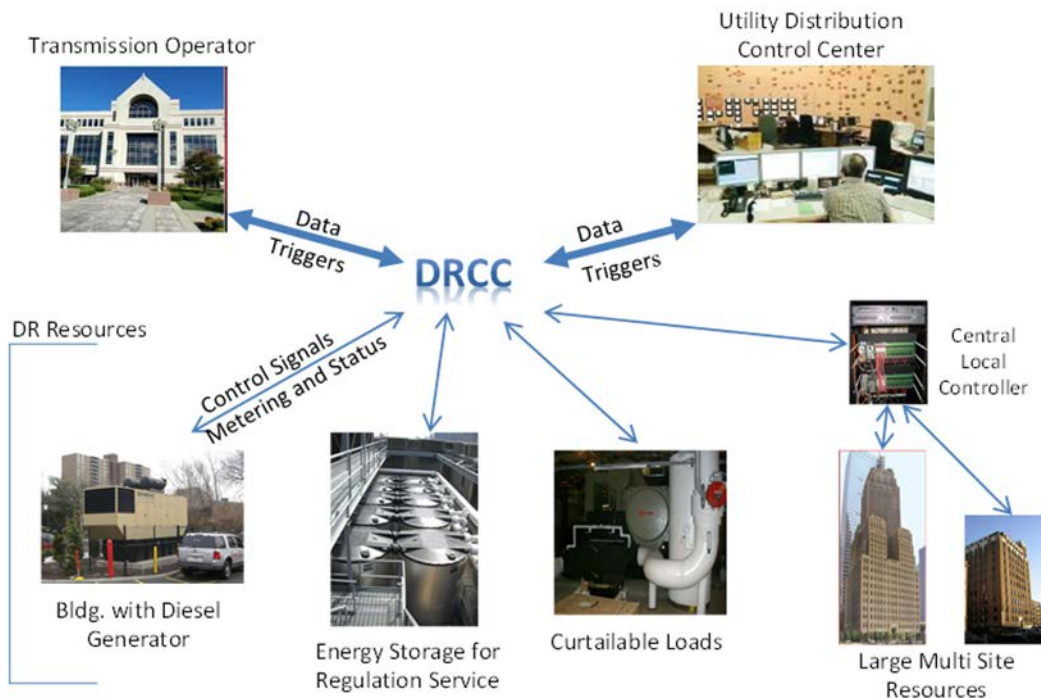
- **Thermal Storage Unit**

A 10,000 ton-hour Thermal Storage Plant (TSP) was installed at a Verizon facility, which houses office space and a telecom central office. The plant was installed to demonstrate how this technology could be used to supply valuable services to the electric grid while also optimizing energy efficiency at the facility. Testing to date has demonstrated the ability of the Thermal Storage Plant to supply ancillary services as well as its ability to reduce air conditioning demand during peak electric demand periods. Changes to local incentives for participation in DR programs led the team to reevaluate technical feasibility late in the project, resulting in greater economic benefits than originally envisioned.

- **Virtual Generator (VirG)**

A VirG is created by the activation of an aggregation of DR resources by the DRCC. This aggregated set of resources is able to supply virtual generation (VirG). A VirG is able to solve a capacity shortage on the transmission system, as well as address system contingencies in electric distribution networks. Figure A-63 illustrates the type of DR resources which may be dispatched by the DRCC. Backup power provided by standby generators is an excellent candidate to provide targeted, persistent load reduction to address network events by responding to dispatch signals from a grid operator within five minutes. Economic feasibility was examined in detail and is presented in Attachment 4. The benefits provided to the grid by the Virtual Generator are shown to be greater than the costs to supply this service. In fact, the NYISO has included the concept of the VirG in its "Reliability Needs Assessment" as a potential solution to forecasted regional shortages of capacity.

**Figure A-63. DRCC Architecture**



The project benefits electric customers, as it demonstrated new ways to integrate DR resources into the NY electric distribution grid. Integration of existing DG resources into the VirG can be established and commissioned in a short time and can be utilized to respond to forecasted capacity shortages.

The VirG can be established in a relatively short time because it requires no siting approvals or large capital expenditures, as is the case with conventional generation or transmission lines.

### **A.7.2 Project Goals and Accomplishments**

The Scope of Work included the following elements:

- Design and implement a DRCC capable of monitoring and dispatching aggregations of DR resources
- Demonstrate Interoperability of DR Resources with Con Edison DERMS
- Demonstrate remote activation of DR using an aggregation of telecom facilities while maintaining a high level of cybersecurity for these resources
- Design and install a 10,000 Ton-hour Thermal Storage System capable of supplying ancillary services such as Regulation and Reserves to the electric grid
- Design and implement an IBCU capable of directing an existing BMS to optimize efficiency and enable operating the facility to provide ancillary services such as Regulation and Reserves to the electric grid



- Develop and implement a plan to provide ancillary services such as Regulation and Reserves to the electric grid
- Design and implement a unique Closed Transition Switching Technique that could enable more end-user facilities to participate in DR Programs

In addition, subsequent to the award of the Interoperability Project, Con Edison was awarded the Secure Interoperable Open Smart Grid Demonstration Project [DE-OE0000197], and Con Edison invited Innoventive Power to participate in several milestone demonstrations. Participation in these demonstrations required the build-out of the web services portion of the DRCC for integration with Con Edison's Visualization Platform. Coordination with the SGDP afforded us further opportunities for testing the remote dispatch system of the DRCC, culminating in the Capstone Demonstration in July 2013.

Another accomplishment that was not anticipated in the original goals of the program was the design and implementation of a central load curtailment controller with cybersecurity provisions enabling it to be used within the framework of a major national telecom network. One of the Phase I goals of the project was to develop protocols between the end-use resources and the Curtailment Service Provider or Utility. Verizon was very concerned about outside demands to effect changes in its operation. To alleviate these concerns, a secure interface was developed that bridged the gap between the broader Internet and Verizon's internal control system in such a way that Verizon's staff is comfortable with its operation and security. This design will likely be replicated with other customers who desire such a level of security. The system also allows Verizon to leverage its manpower as efficiently as possible by providing sophisticated alarming and control capability via a secure remote link with every facility in its footprint.

Technical readiness of participation in ancillary service markets in the NYISO control area was demonstrated. Attachment 2 shows the project schedule and lists the buildings that have been and will be retrofitted to supply ancillary services as part of an aggregation of over 20 MW of curtailable load.

Additionally, the value of a large aggregation of DR resources was shown to be a possible solution to a forecasted potential shortage of capacity in the NYISO control area. The Virtual Generator concept is capable of being tested and implemented in less time and for less cost than conventional new generation or transmission capacity. This prompted the NYISO to identify the Virtual Generator as a possible solution to its forecasted capacity shortages. The potential closing of the Indian Point Nuclear Generating Station in 2016 would make the development of the Virtual Generator even more valuable.

Please refer to the previously submitted Final Interoperability Technical Report for further information regarding the DRCC sub-project.

## **A.8 *NYCEDC: PV, Battery Storage and BMS Integration***

The New York City Economic Development Corporation (NYCEDC) team developed the following summary of SGDP activities as part of the input to the FTR. Results and information below has been used to develop the overall takeaways and lessons learned in the FTR.

### **A.8.1 Executive Summary**

The NYCEDC serves as NYC's primary engine for economic development and job creation, and works to enhance the city's business sectors by identifying, analyzing, and addressing challenges faced by industries. With over one million buildings, aging infrastructure, the second highest energy prices in the country, and increasing demand for energy, NYCEDC recognizes that NYC is well positioned to benefit from the proliferation of energy management technologies. In order to demonstrate the viability of innovative energy management solutions to the private sector, NYCEDC developed the SGDP at the Brooklyn Army Terminal (BAT) in Sunset Park.

By implementing the project, analyzing the outcomes, and sharing lessons learned, the BAT SGDP has the potential to support the growth of this new industry in NYC, create local jobs, and attract private investment in the development and widespread adoption of innovative energy technologies. These technologies offer the potential to help the City of New York reach its PlaNYC sustainability and resiliency goals, including a 30% reduction in citywide greenhouse gas emissions by 2030, as well as supporting Con Edison's Utility of the Future initiative.

### **A.8.2 Project Goals and Accomplishments**

The completed BAT SG system integrates three main components: 1) a 100 kW solar PV array, 2) a BMS and 3) a 720 kWh battery for on-site energy storage capable of delivering 100 kW for four hours. The project set out to demonstrate the benefits of on-site renewable energy generation coupled with energy storage and management systems to reduce demand on the grid, offset energy costs, and advance NYC's PlaNYC sustainability objectives by reducing greenhouse gas emissions associated with energy generation and use. Additionally, the project findings will benefit the industry as a whole by sharing lessons learned and best practices to support acceleration across NYC.

Considering the battery's size and capabilities with an analysis of the electric load profile at BAT, the project team determined that participation in DR/capacity markets would be the most financially optimal use of the battery. The BMS at BAT was integrated with Viridity Energy's V-Power software as planned, and controls the battery operation (i.e., discharging and charging as needed for DR events).

**Figure A-64. 720 kWh Battery Installation at BAT**



The project accomplished its overall goals and objectives to demonstrate the capabilities of SG technologies in NYC. Although the project's battery and PV system sizes were limited due to financial constraints, the system at BAT demonstrates that integrated solar PV and energy storage systems are feasible for NYC buildings and present opportunities for financial benefits. The project's economic value includes cost savings from on-site energy generation and improved operational efficiency at the building level. While the system is currently being used for DR, its design could also enable power price arbitrage and peak shaving to reduce demand charges, depending on the future needs of the building. Through the BAT SG project, the project team was also able to identify key challenges at industry-wide and local levels, namely issues surrounding financing, permitting, and building and fire code regulations. The demonstration project at BAT will serve as a case study to guide industry stakeholders through the development and implementation of similar projects, thereby supporting the growth of the industry in NYC. An expansion of SG and energy storage technologies in NYC will support more sustainable energy use and enhance the resiliency and intelligence of the grid, mutually supporting the goals of the City's PlaNYC and Con Edison's Utility of the Future.

### **A.8.3 Project Activities**

In December 2010, NYCEDC executed a Sub-award Agreement with Con Edison to participate in the U.S. DOE SGDP through Con Edison. In spring 2011, NYCEDC procured Plaza Construction through a competitive request for proposal (RFP) for system design and construction management. Through the specifications outlined in the RFP, the system would include a 500 kW rooftop solar PV array and a 2MWh battery to be installed in the basement. A valve regulated lead acid (VRLA) battery was selected for its safety record, maintenance-free design, versatility in orientation options, ventilation-free design, and its ability to be installed indoors. VRLA batteries are also typically lower cost and maintenance than other battery chemistries, and met NYC fire and building code regulations.<sup>4</sup> Both the PV and battery systems would be integrated through a BMS and have the ability to be remotely controlled using Viridity Energy's V-Power software. After analyzing expected PV production and developing strategies for

---

<sup>4</sup> A lithium-ion iron phosphate (Li-ion FeP) battery was also considered, as it shares many of the same characteristics as VRLA batteries. However, Li-ion FeP batteries were at the time relatively new; no New York City Fire Code specifications existed, and obtaining approval for Li-ion FeP batteries in the timeframe needed was not feasible.

optimizing the battery use, it was estimated that the PV system would produce 750,000 kWh and save an estimated \$120,000 in displaced energy costs per year, while the battery system would be used for peak shaving to reduce demand charges and operational costs at BAT.

**Figure A-65. 100 kW Solar PV Array at BAT**

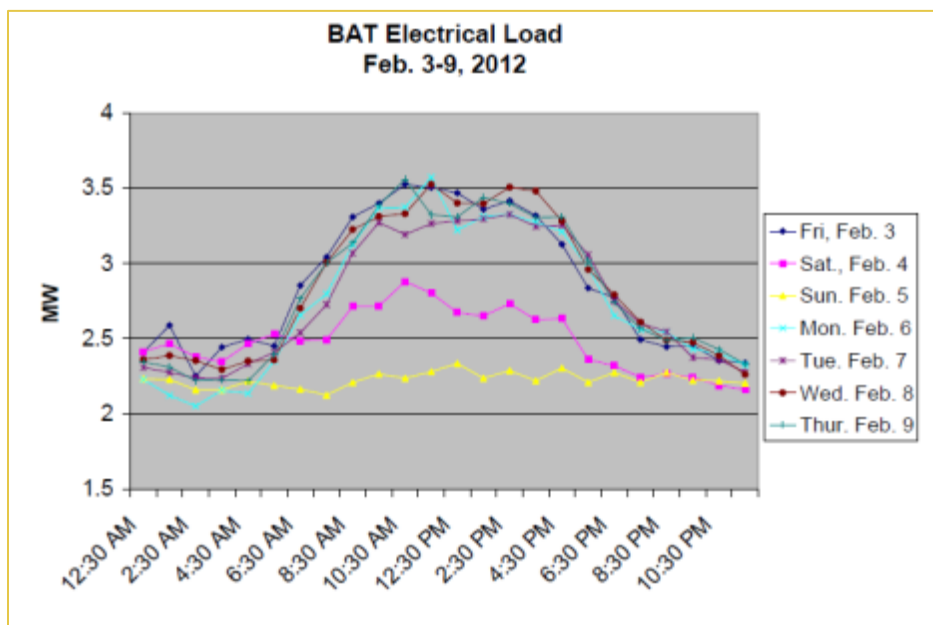


The project's total budget was originally estimated to be \$9.5 million, to be funded from a combination of \$3.5 million from NYCEDC and \$4.5 million from the DOE SGDP through Con Edison. It was anticipated that the remaining costs would be financed through federal New Market and Investment Tax Credits, including the 1603 Treasury Grant Program, which was phased out on December 31, 2011. When obtaining such tax credits became infeasible, the project scope and budget were reduced to include only the funds available from NYCEDC and the DOE. A cost share of 47% of total project costs (up to \$4.5 million) would be provided by the DOE SGDP, with NYCEDC contributing the remaining 53%. Despite the reduced budget, it was decided to maintain the same technology demonstration objectives, but simply scale back the capacities of the relevant components (to a 100 kW PV array and 720 kWh battery). In spring 2012, the construction manager, Plaza Construction, procured subcontractors Future Energy Development and Kanta Electric to design and install the PV and battery systems. Kanta Electric purchased the VRLA battery from Hitachi, who contributed a 50% cost share towards the total cost of the battery. ABM Systems provided the BMS, and Viridity Energy provided the capabilities for remote control and monitoring of the battery through their V-Power software.

The project team determined that potential revenue would be highest from participation in DR programs. This option was selected after exploring a variety of alternative uses, including the following:

1. **Peak shaving:** Operating the battery to avoid demand charges could result in cost savings; however, following an analysis of the load profile at BAT (see below figure), the project team concluded that there is no true peak that could be shaved by the battery alone. The profile shows that the load curve remains relatively flat for ~8 hours on weekdays, when the building is in use by the tenants. As the bulk of the total load at BAT is controlled by tenants, opportunities were limited for supplementing the battery's output through reducing consumption. Without a more pronounced spike, using the battery for peak shaving was determined not to offer a high likelihood for demand charge reduction, and thus not economically beneficial.

Figure A-66 BAT's Energy Load Profile with Flat Peak



2. Energy arbitrage: The team explored the possibility of buying and storing lower cost off-peak power and discharging the lower cost power during periods of higher cost peak demand electricity. However, this approach is only viable with a time-of-use energy price contract, where BAT has a fixed price energy contract. The system's design includes the use-case, however. If BAT's future energy prices justify this mode of operation, the system is able to operate in a timed charge/discharge program to take advantage of lower cost off-peak power.

Construction at the BAT began in January 2013. In addition to the installation of the PV and battery systems, a battery room was constructed to house the battery cells. The battery room was designed to meet fire code and building code requirements, provide structurally sufficient flooring, and to accommodate the VRLA battery technology. The room features an HVAC system, hydrogen gas detection and alarm system linked to an outside exhaust system, fire-rated walls, structural improvements to the battery room floor, acid-resistant flooring, a pre-activated dry sprinkler system, and a tempered safety shower and eye bath. An on-site controller allows for direct control and programming of the battery inverter, which is also controlled through the BMS, located on the first floor in the building's operational offices. The solar PV system was commissioned in August 2013, and has produced over 61 megawatt-hours of electricity through April 2014, averaging approximately 6.8 megawatt-hours per month. The integrated battery and BMS system was commissioned in October 2013.

In March 2014, tests of system operation showed that actual performance met or exceeded design specifications, and NYCEDC entered into an agreement with Viridity Energy to optimize and control the battery operation remotely. An operational plan was developed by Viridity Energy and approved by NYCEDC in April 2014. On May 1, 2014, the BAT began participating in three DR programs:

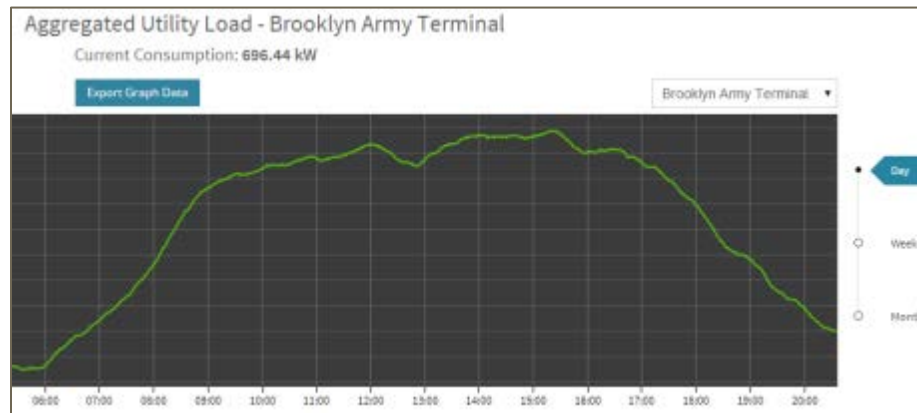
- NYISO Special Case Resources (SCR) Program
- Con Edison DLRP

- Con Edison Commercial System Relief Program (CSRP)

For each program, advance notice (~24 hours, varying between programs) for a DR event is given. When an event is called, the battery will discharge 100kW for a four-hour period (for a total of 400kWh). Participants in the programs receive a monthly reservation payment per kW of energy available during their enrollment in the program, as well as additional payments for each kWh reduced during an event. NYSIO's program runs during the summer and winter, whereas the Con Edison programs run May 1<sup>st</sup> – Oct 31<sup>st</sup>.

The annual revenue generated from enrollment in the DR programs is approximately \$25,000, varying based on the amount of DR events called. Meanwhile, the PV array is expected to generate an estimated 100.8 megawatt hours annually, yielding \$15,130 in reduced annual energy costs. In total, the system is expected to generate \$40,380 of revenue per year, yielding an approximate payback period of 11 years.

**Figure A-67. Viridity V-Power Energy Management Dashboard**



The BAT SG project meets the technical objectives of the demonstration. Although the reduction in system size will impact the financial benefits that the project was originally envisioned to deliver, the project demonstrates the concept and capabilities of SG technologies and will allow NYCEDC and project partners to share lessons learned in order to overcome financial, technical and regulatory barriers identified, such as:

#### **A.8.3.1 Financial**

While the factors that lead to the scope and budget reduction are important to understand, key measures of the project's impact are the energy savings and revenue stream generated through the PV production and participating in DR programs (~\$25,000 per year). These savings and revenues are largely fixed based on a system's total delivered power, which is independent of future reductions in capital costs or improvements in technology. Therefore, future systems modeled after BAT, but with newer technologies and built at lower costs, will yield stronger financial performances.

#### **A.8.3.2 Technical**

While battery chemistry options were limited to lead acid types at the onset of the project, energy storage technology is rapidly evolving, as are the regulations governing it. As of March 2014 revisions to the fire code now allow for a wider variety of battery chemistries:

- Lithium-ion (Li-ion)
- Lithium metal polymer
- Nickel cadmium (Ni-Cd)
- Non-recombinant
- Recombinant
- Stationary storage
- VRLA
- Vented (flooded) lead-acid

While the revisions to the fire code show progress has been made, these new chemistries have not yet been approved for applications outside emergency power systems; the Fire Department of New York (FDNY) has yet to evaluate the implications of daily usage of these new chemistries; thus, new projects would be required to apply for a variance if pursuing these battery chemistries. It is likely, however, that new regulations for advanced battery technologies will be adopted in time, allowing future projects greater flexibility to select the battery that best matches the project site and requirements. With these advancements in technology, the cost of future battery systems could be substantially lower per unit of delivered energy.

#### **A.8.3.3 Regulatory**

The need to construct the battery room to meet fire and building codes added significant cost and construction time. Net of the DOE contribution and the battery cost-share, NYCEDC's total project costs were approximately \$2.2 million; however, only 20% of these costs were directly associated with the SG system components (battery, PV, and BMS). Future projects could avoid some of these costs by siting in locations already equipped with ventilation systems meeting relevant codes, and that do not require the types of structural modifications that were necessary at BAT.

In addition to FDNY and DOB regulations, as a historic building, BAT is subject to State Historic Preservation Office (SHPO) regulations; as a result, additional measures needed to be taken to ensure compliance. These additional requirements should be considered when planning future projects as they resulted in additional construction time and cost. Finally, undertaking this project as a public entity required additional time for project initiation. As a City agency, NYCEDC is bound to City procurement requirements, and was required to procure a construction and design team via a competitive public RFPs; projects not limited by the same time constraints as public entities should have more flexibility for the planning and designing of systems to meet their specific needs.

The BAT SG project successfully demonstrates the viability of integrated DG and energy storage systems and the benefits of energy management technologies, and will serve as an example for industry stakeholders, supporting the growth of the sector in NYC.

#### **A.8.4 Product Development and Technology Transfer**

##### **A.8.4.1 *Web site or other Internet sites that reflect the results of this project***

- <http://www.nycedc.com/industry/clean-technology-energy>
- Agrion Energy Storage Initiative (forthcoming; expected in early June 2014)

##### **A.8.4.2 *Networks or collaborations fostered***

NYCEDC fostered various networks and collaborations through the development and implementation of the SG installation at BAT, including the following:

- Con Edison – DOE SGDP lead
- General Contractors
  - Plaza Construction – Construction Manager
  - Cosentini Associates – BMS design
  - Mitchell–Giurgola Architects – design
  - altPower Inc. – PV system Design
  - Future Energy Development – battery design
  - Kanta Electric Corp. – electrical systems
- Equipment Providers
  - Hitachi – battery provider
  - Princeton Power – battery inverter provider
  - Solar Energy Systems, LLC – PV system equipment
  - Suntech – PV provider
  - Advanced Energy – PV inverter provider
  - ABM Systems – BMS provider
- Viridity Energy – software and DR program partner
- Agrion – clean-tech industry network (organizing New York Energy Storage Initiative)

##### **A.8.4.3 *Technologies/Techniques***

The SG project at BAT demonstrates the ability to use software to remotely control energy assets (in this case, a battery), allowing for performance optimization and yielding the greatest financial returns. Viridity Energy's V-Power software allows for remote control of the discharging and charging of the battery system at BAT, and provides real-time monitoring of the system's overall performance, including the financial impacts gained through operating the system. The V-Power software is integrated with a BMS which controls the battery inverter and issues commands for the battery to charge or discharge (either manually or following an automatic schedule). The BMS also monitors PV production, providing a comprehensive picture of the SG System's performance. Taken together, these technologies can provide



data that can assist in bringing transparency to and accelerating investment in SG, solar, and energy storage by building owners, financial institutions, and other key stakeholders.

## **A.9 *Gehrlicher: Streamlined PV Design and Installation***

### **A.9.1 Executive Summary**

In 2013, Con Edison contracted Gehrlicher Solar America Corp. to install a 40 kWac solar installation at Con Edison's 4 Irving Place headquarters. By integrating this installation into the project, Con Edison gained hands-on experience with the process of installing equipment on NYC commercial building rooftops. This project was unique in that this behind-the-meter solar installation was completed atop a 19th-story roof of a NYC landmark building housing multiple tenants.

More than 200 panels were installed. The panels were manufactured in the United States by Suniva Inc. The company has also connected the solar array to a remote monitoring system that is updated every 15 minutes and enables Con Edison operators to monitor the production of the panels in real time. Con Edison completed the installation in only five weeks.

An added benefit to the public is that the system supplies enough electricity to light two floors at the Con Edison headquarters and will save Con Edison ratepayers about \$7,000 a year in electricity costs.

### **A.9.2 Project Goals and Accomplishments**

The accomplishments met the goals and objectives of the project.

Goals and objectives:

- Design a PV electric generation system with the highest possible capacity per:
  - o Existing structural/spatial conditions at Con Edison's Auditorium/Cafeteria rooftop; and
  - o Existing electrical service conditions at the determined-location of PV system interconnection.
- Acquire all permits and approvals from Authorities Having Jurisdiction (AHJs) and the utility.
- Install and commission the PV system.

Accomplishments:

- All permits and approvals were received from local AHJs, including NYC DOB, Environmental Control Board (for electrical review and inspection), Landmarks Preservation Commission, and Con Edison's DG Dept. for utility interconnection.
- PV system was successfully installed, inspected, and commissioned. It is currently operating at its full capacity.

### **A.9.3 Project Activities**

#### **A.9.3.1 Logistics**

Lack of high-capacity freight elevators, inability to use a crane in busy traffic and on high-rise roof, and limited loading dock space in concert with existing high volume of delivery traffic, proved troublesome



in our efforts to mobilize our project material and construction equipment to the project site. On-site conditions only allowed slower and more deliberate methods to move all the material to the rooftop.

#### ***A.9.3.2 Weather Issues and Delays***

Unfortunately, NY experienced abnormally inclement weather conditions during this past winter. Snowy and icy conditions were often confronted and detrimentally affected the construction efficiency and schedule. In the case of moderate snow events, pilings of snow required re-allocation of labor hours to clean the snow off of the roof (construction area) and PV modules. And in severe snowstorms or in compilations of multiple snow events in series, schedule delays were necessary to prevent installation errors and, more importantly, construction safety hazards.

#### ***A.9.3.3 Installation Hours***

Racking structural requirements of Con Edison's PV system included mechanical attachments that chemically bond to the concrete substrate of the existing Auditorium/Cafeteria roof structure. This type of work entails cutting and removal of roof membrane and insulation as well as drilling into and applying epoxy adhesive to the existing concrete decking. Due to potential hazard of moisture introduction, the entire mechanical attachment installation procedures had to be performed during dry weather conditions, which often conflicted with only short notices. In addition, the periods of drilling into the concrete decking had to be very carefully coordinated with Con Edison's use of their Auditorium in order to minimize disruption due to noise and vibration.

#### ***A.9.3.4 Removal of the Existing Stanchions***

During initial site survey, there existed a large antenna structure on the southeast section of the Auditorium/Cafeteria roof. Had it remained, it would have not only reduced the total PV system array area, but also would have reduced the efficiency of the PV system due to its shading effects on its surroundings. In order to maximize the PV system's size and its power/energy output, a resolution to remove the structure was concluded. A roofing manufacturer-approved contractor was hired to remove the entire structure, as well as to seal the roof membrane after its removal.

#### ***A.9.3.5 Electrical Interconnection***

In order to be able to carry the full back-feed current of the PV system's output, one of the 100-amp branch circuit breakers was upgraded from 100-amp rating to 150-amp rating, and the conductors between the two panel boards were upgraded as well. "EDC" was replaced with a brand-new 400-amp Square D panel board that has two 150-amp main circuit breakers on opposite ends of its bus, one for its utility main source, and the other for the PV system source.

In lieu of the previously existing feeder splice connections a 100-amp branch circuit breaker was added to the new panel board as its source and feeder protection.

The demonstration was intended to provide Con Edison with firsthand knowledge of the challenges of a behind-the-meter solar installation, the complexities and logistical challenges of installing solar on a high-rise building in NYC, the process for meeting landmarks certification, and to provide a test bed for connecting behind-the-meter solar to operator visualization systems. Given the challenges mentioned above, Con Edison believed that this is representative of a worst-case installation.

### ***A.10 Softstuf: Smart Grid Disturbance Monitor (SGDM)***

The Softstuf team developed the following summary of SGDP activities as part of the input to the FTR. Results and information below has been used to develop the overall takeaways and lessons learned in the FTR.

#### **A.10.1 Executive Summary**

*Executive summary provided in the main report.*

#### **A.10.2 Project Goals and Accomplishments**

The main goals and objectives of the project included technical effectiveness and feasibility, field performance and scalability, universality and signature analysis capabilities, and commercialization. These are described in more detail below.

**Figure A-68. Softstuf Test Facility with Simulator and Test Set**



##### ***A.10.2.1 Technical Effectiveness***

- **Objective:** Prove the technical effectiveness of the SGDM prior to delivery to Con Edison by running an extensive set of tests repeatedly in the lab environment.
- **Accomplishment:** A substation simulator was designed and a state of the art power system test set was procured (see Figure A-68). The simulator and test set were used extensively to test the SGDM prior to delivery. Both transient and dynamic test plans were conducted and the successful performance of the SGDM in detecting and reporting on fault and disturbance conditions proved its technical effectiveness. At the end of the project, the simulator and test set were delivered to the Con Edison Learning Center.

#### ***A.10.2.2 Economic Feasibility***

- ***Objective:*** Prove the economic feasibility by deploying the SGDM on live circuits without having to plan for outages or disturb existing equipment.
- ***Accomplishment:*** The Con Edison success in service deployment at the Farragut substation proved the economic advantage in installation over traditional monitoring systems. Figure A-69 shows a picture of the in service deployment of the sensors at one of the relay houses at Farragut. (Two panels with sensor infrastructure are shown for monitoring primary and backup protection.)

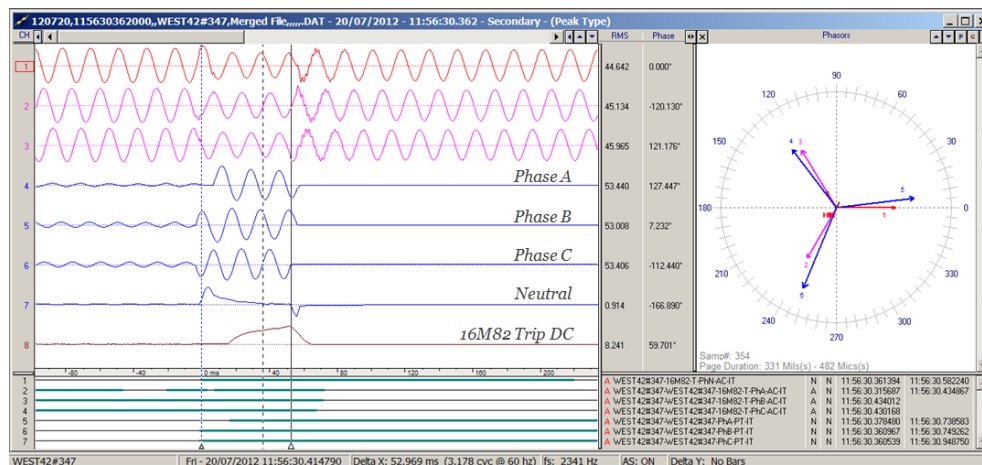
**Figure A-69. In-Service Deployment at the Farragut Substation**



### A.10.2.3 Field Performance

- **Objective:** Verify the technical effectiveness of the SGDM by monitoring performance of the deployed sensors at the Farragut substation.
- **Accomplishment:** Fault and disturbance conditions are rare, random events. It was unclear if any such conditions would occur during the life of the project. However, a number of disturbances did occur in 2011 and 2012 including but not limited to a major 345kV transformer event, a phase angle regulator fire, and Hurricane Sandy. The performance of the sensors during these real-life disturbances successfully verified their effectiveness in discovery and cataloging of fault signatures based on targets, fault magnitude and duration. An example of an unbalanced three phase fault that was captured by the sensors on 7/20/2012 is shown in Figure A-70.

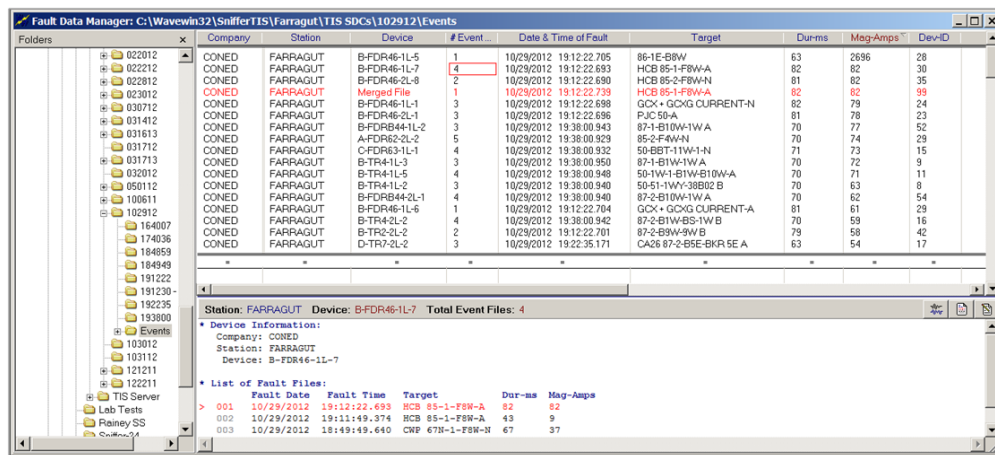
**Figure A-70. Multiphase Fault-Captured by the Sensors (30,000 Amps Magnitude)**



#### A.10.2.4 Data Management and Scalability

- **Objective:** Prove the data management capabilities and scalability by deploying the SGDM expert software on a central server located at Irving Place (main Con Edison building).
- **Accomplishment:** The software was successfully deployed on the server and the performance was monitored for an extended duration. The results demonstrated the data management capabilities of the software in ranking disturbances and organizing/cataloging data records based on date and time of occurrence. The deployment further demonstrated scalability with the software receiving and processing high speed data from thousands of sensors reporting through a large array of recorders, switches, concentrators, and fire walls. A copy of the expert software is shown in Figure A-71.

Figure A-71. SGDM Software Installation at the 4IP Server



| Company | Station  | Device       | # Event | Date & Time of Fault    | Target                 | Dur-ms | Mag-Amps | Dev-ID |
|---------|----------|--------------|---------|-------------------------|------------------------|--------|----------|--------|
| CONED   | FARRAGUT | B-FDR46-1L-5 | 1       | 10/29/2012 19:12:22.705 | 86-1E-BRW              | 63     | 2696     | 28     |
| CONED   | FARRAGUT | B-FDR46-1L-7 | 1       | 10/29/2012 19:12:22.893 | HCB 85-1-FBW-A         | 82     | 82       | 30     |
| CONED   | FARRAGUT | B-FDR46-2L-8 | 2       | 10/29/2012 19:12:22.890 | HCB 85-2-FBW-N         | 81     | 82       | 35     |
| CONED   | FARRAGUT | Merged File  | 1       | 10/29/2012 19:12:22.739 | HCB 85-1-FBW-A         | 82     | 82       | 99     |
| CONED   | FARRAGUT | B-FDR46-1L-1 | 3       | 10/29/2012 19:12:22.696 | GXX+ GXXG CURRENT-N    | 71     | 79       | 24     |
| CONED   | FARRAGUT | B-FDR46-2L-1 | 3       | 10/29/2012 19:12:22.696 | PJC 59-A               | 81     | 78       | 23     |
| CONED   | FARRAGUT | B-FDR46-4L-2 | 3       | 10/29/2012 19:38:00.943 | 87-1-B10W-1W-A         | 70     | 77       | 52     |
| CONED   | FARRAGUT | A-FDR62-2L-2 | 5       | 10/29/2012 19:38:00.929 | 85-2-F4W-N             | 70     | 74       | 29     |
| CONED   | FARRAGUT | C-FDR63-1L-1 | 4       | 10/29/2012 19:38:00.932 | 50-BBT-11W1-N          | 71     | 73       | 15     |
| CONED   | FARRAGUT | B-TR4-1L-3   | 3       | 10/29/2012 19:38:00.950 | 87-1-B1W-1W-A          | 70     | 72       | 9      |
| CONED   | FARRAGUT | B-TR4-1L-5   | 4       | 10/29/2012 19:38:00.948 | 50-1W1-B1W-B10W-A      | 70     | 71       | 11     |
| CONED   | FARRAGUT | B-TR4-1L-2   | 3       | 10/29/2012 19:38:00.940 | 50-51-WY-38B02-B       | 70     | 63       | 8      |
| CONED   | FARRAGUT | B-FDR46-4L-1 | 4       | 10/29/2012 19:38:00.940 | 87-2-B10W-1W-A         | 70     | 62       | 54     |
| CONED   | FARRAGUT | B-FDR46-1L-6 | 1       | 10/29/2012 19:12:22.704 | GXX+ GXXG CURRENT-A    | 81     | 61       | 29     |
| CONED   | FARRAGUT | B-TR4-2L-2   | 4       | 10/29/2012 19:38:00.942 | 87-2-B1W-B5-1W-B       | 70     | 59       | 16     |
| CONED   | FARRAGUT | B-TR5-2L-2   | 2       | 10/29/2012 19:12:22.701 | 87-2-BBWW-9W-B         | 79     | 58       | 42     |
| CONED   | FARRAGUT | D-TR7-2L-2   | 3       | 10/29/2012 19:22:35.171 | CA26 87-2-BSE-BKR SE A | 63     | 54       | 17     |

| Station  | Device       | Total Event Files |
|----------|--------------|-------------------|
| FARRAGUT | B-FDR46-1L-7 | 4                 |

| Device Information:  |
|----------------------|
| Company: CONED       |
| Station: FARRAGUT    |
| Device: B-FDR46-1L-7 |

| List of Fault Files:                              |
|---------------------------------------------------|
| 001 10/29/2012 19:12:22.693 HCB 85-1-FBW-A 62 82  |
| 002 10/29/2012 19:11:49.374 HCB 85-1-FBW-A 43 9   |
| 003 10/29/2012 18:14:49.640 CWP 67H-1-FBW-N 67 37 |

#### A.10.2.5 Universality/Reusability

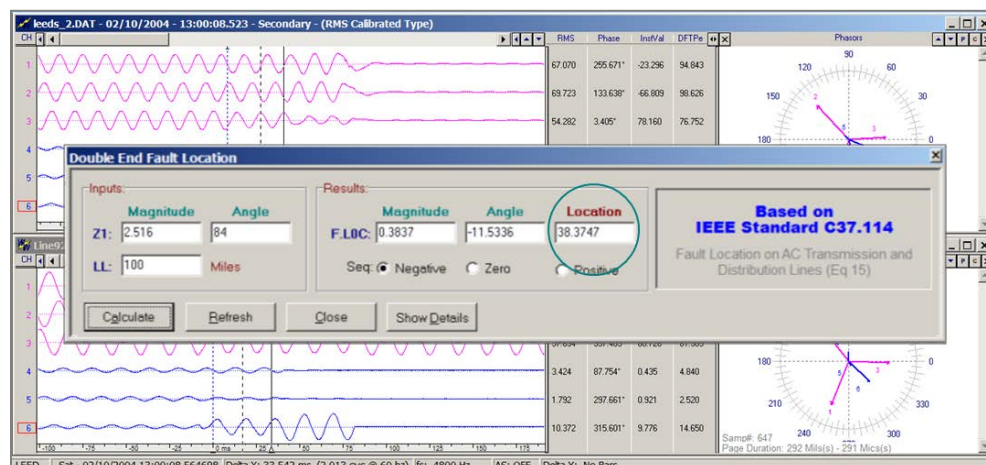
- **Objective:** Ensure universality by supporting IEEE Standards COMTRADE and COMNAME which enable the SGDM to work with disturbance data from other types of monitoring devices.
- **Accomplishment:** The software was successfully developed in compliance with these standards and the data from the new sensors is also saved in compliance with the standards. Users can analyze data from the new sensors with their own compliant software, or they can use the new software to analyze data from their own monitoring devices such as digital relays, fault recorders, phasor measurement units, power quality monitors, and so forth.

#### A.10.2.6 Advanced Analysis

- **Objective:** Develop a number of specialized algorithms for measuring fault location, detecting current transformer (CT) saturation, timing breaker operations, and modeling fault currents.
- **Accomplishment:** The specialized algorithms were successfully developed, coded and repeatedly tested in the lab environment. The algorithms were also tested in the field. For example, the fault location algorithm was successfully benchmarked by Con Edison using data from available digital relays and fault records and is currently being used as one of their primary sources for locating faults. (An example location is shown in Figure A-72.) The CT saturation algorithm,

based on harmonics, was also verified by a number of disturbances captured by the sensors and other types of devices.

**Figure A-72. Double-Ended Fault Location Display with Synchronized Ends**



#### A.10.2.7 Commercialization

- **Objective:** Make the SGDM commercially available in whole and in part by packaging, advertising, and soliciting investment capital.
- **Accomplishment:** The process of commercialization was initiated during the project and has taken center stage at Softstuf since the end of the project. The SGDM was properly package in small, modular units that can be deployed on a small or large scale basis. The results were utilized at a number of additional installations at Con Edison and at a number of other utilities including two nuclear power plants. In all installations, the sensors and software were essential in identifying root causes of fault and disturbance conditions. As for the tasks of advertising and soliciting investment capital, they have proved to be the most difficult ones. Softstuf has so far showcased the SGDM at a number of professional conferences, solicited a number of major manufactures for investment capital, and is in the process of developing a web site for marketing the SGDM. The future of this technology is very promising and the commercializing efforts will continue. The pace of growth will depend on whether or not Softstuf can procure the needed investment capital.

### A.10.3 Project Activities

The DOE SG funding through Con Edison started for Softstuf in October 2010 and ended in June 2012. Softstuf continued, at its sole expense, to provide support and maintenance services for the installed equipment until December 2013. The project activities were multifold and proceeded in parallel. The main focus was on building the simulator, delivering the sensors and supporting hardware, and installing the SGDM software on the central server.

#### A.10.3.1 Simulator

The simulator, representing a substation with three feeders, was designed and assembled at the Softstuf Lab at 333 Bainbridge Street in Philadelphia. The feeders are a ring bus mimic with two analog schemes

(electromechanical protection) and one digital scheme (numeric relay). The simulator is equipped with a state of the art three phase current/voltage injection test set and includes sensors, concentrators, a server with the SGDM software, and a breaker simulator mounted in a panel to mimic a substation control board. A barebones diagram of the mimic control board is shown in Figure A-73, and a simplified schematic of the simulator is shown in Figure A-74.

The simulator and test set were used for application of various types of fault and disturbance conditions including balanced and unbalanced faults (phase to phase and phase to ground faults) designed to challenge both the sensors and the developed software. The simulator and test set were invaluable in demonstrating the features of the SGDM which are not easily done on in service equipment because fault occurrences are unpredictable by nature.

**Figure A-73. Simulator Mimic Board**

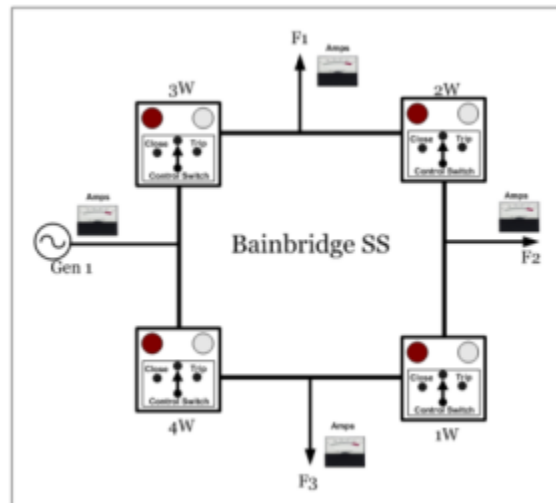
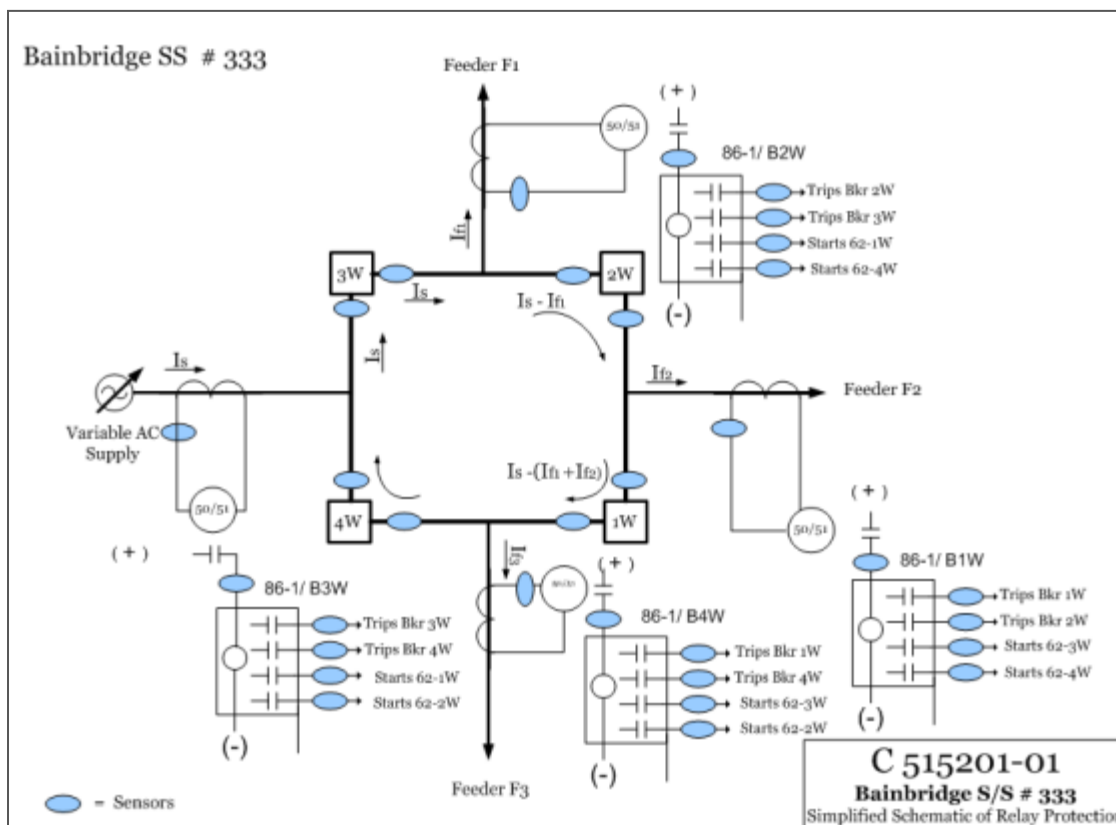


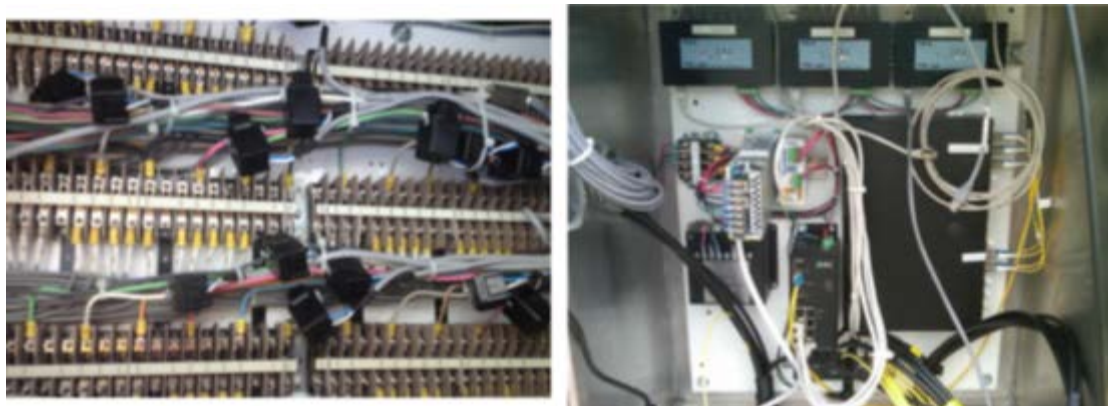
Figure A-74. Simplified Schematic of the Substation Simulator



### A.10.3.2 Sensors and Infrastructure

Over 1,000 sensors were produced and delivered to Con Edison within the first three months of the project start. The required infrastructure was also procured and delivered along with the sensors. The required infrastructure included 100 sampling units, 40 network switches, four data concentrators, and other supporting components such as cables, connectors, and power supplies. A picture of one of the Con Edison sensor deployments at a 345kV breaker is shown in Figure A-75.

Figure A-75. Breaker Monitor: Sensors (left), Samplers, and Switches (right)

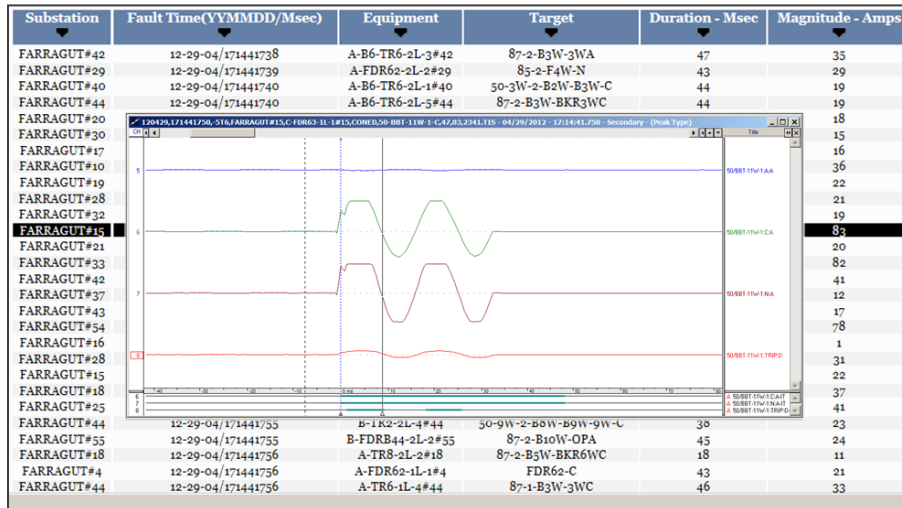


The sensors connect to the sampling units, which broadcast their measurements thru the switches to the data concentrators. The data concentrators process the incoming measurements at the microsecond level and generate waveform captures of any detected fault or disturbance signatures. The captures include both pre- and post-fault measurements and are transmitted to the central server upon occurrence (report by exception). A picture of the deployed data concentrators is shown in Figure A-76.

**Figure A-76. Data Concentrators Deployment at the Farragut Control House**



**Figure A-77. SGDM Software Deployment at the 4IP Central Server**



### A.10.3.3 Central Server

The server was provided by Con Edison and Softstuf was given secure access to remotely deploy, monitor and refine the performance of the software. The software was successfully deployed, the performance was monitored for an extended period, and the software was then refined accordingly. A picture of the software is shown in Figure A-77. The software receives sensor data captures from the concentrators in the field and includes an expert module designed to organize the sensor data based on monitored circuits and time of fault occurrence. The software also includes an adaptive engine that processes and ranks the data captures based on fault magnitude, duration and targets. A number of additional interfaces are also provided for manual diagnostics and visual purposes including sequence of events reports (SOE) and three phase metering displays as shown in Figure A-78 and Figure A-79. Access to the server ended at the end of the project (December 2013).

Figure A-78. Sequence of Events for Diagnostics and Analysis

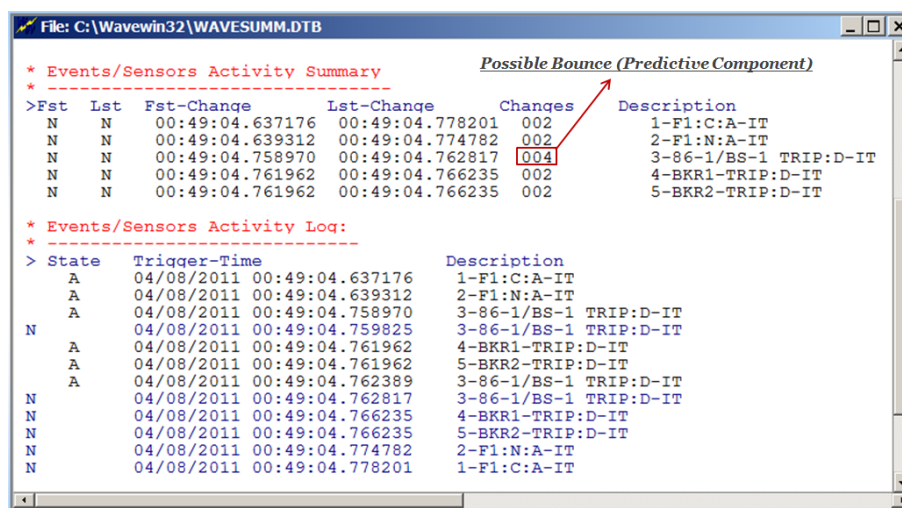
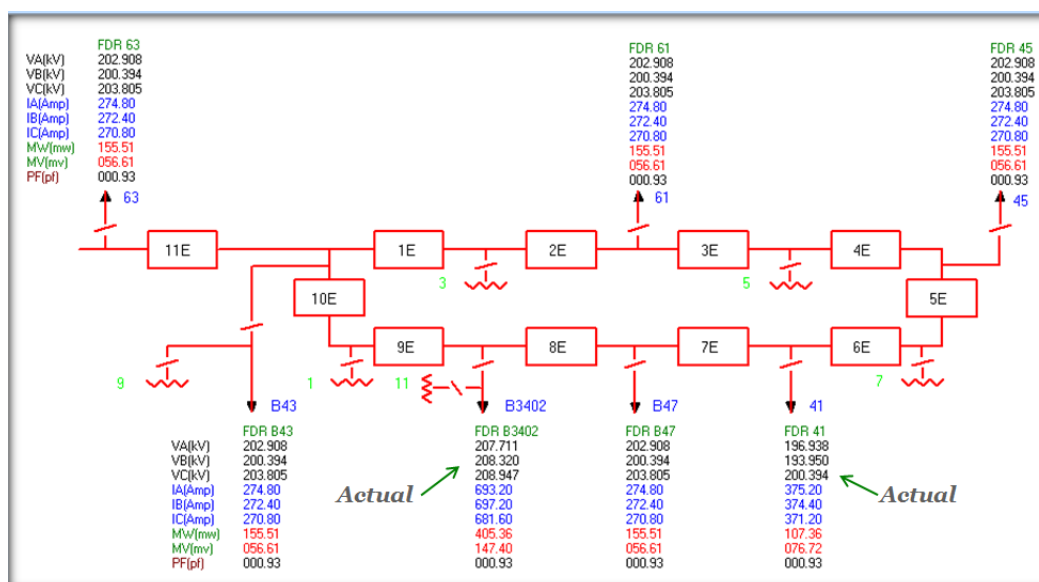


Figure A-79. Three-Phase Metering Application with Real-Time Values



#### **A.10.3.4 Synchronization**

One of the most challenging parts of the project was synchronizing the data from all of the sensors. For the software to work properly the data had to be synchronized to a resolution of less than one millisecond. Initially, a state of the art GPS clock was used to synchronize the data concentrators in the control house but due to latency issues with the network switches the time tags for the sensors would drift at times up to a resolution of 10 milliseconds. To solve the latency issues, Softstuf procured an array of GPS clocks with inter-range instrument group (IRIG-B) and pulse per second (PPS) time signals and Con Edison installed the clocks at the sensor level by connecting their signals to the sampling units. The burden of installation required additional budgets and lengthened the project duration but the solution was highly effective.

#### **A.10.4 Product Development and Technology Transfer**

The SGDM is a modular design. Each component is available as an independent product. Users may use the full depth and breadth of the SGDM solution as described in this report, or may just choose to use a particular type of sensor with their own solutions. The sensor products developed during the project are listed at [www.wavegrid.net](http://www.wavegrid.net) under the Products tab. Detailed manuals with schematics and user guides are available under the Downloads tab. The site was developed by Softstuf to help market the sensors technology to the industry. The site also includes new types of specialized sensors called “Intelligent Electronic Sensors” that were developed independent of the project but that are in line with the natural evolution of the technology. The new sensors pack enough intelligence onboard in order for analysis and discovery to occur inside the sensor without having to stream data for analysis at a central location.

Two technical papers that describe a number of the aspects of the technology were developed by Softstuf and published at the Fault and Disturbance Analysis Conference which is the most prestigious conference on the subject in North America. The first paper was presented in 2010 and the second one in 2013. Both papers were very well received and both won the “Best Paper Award” for the year. The conference is organized by the Transient Recorders Users Council (TRUC) and sponsored by Georgia Tech. Copies of the papers are also available at the website under the Downloads tab. The future for this technology is very promising.

## A.11 CALM: ISM and Decision Aid

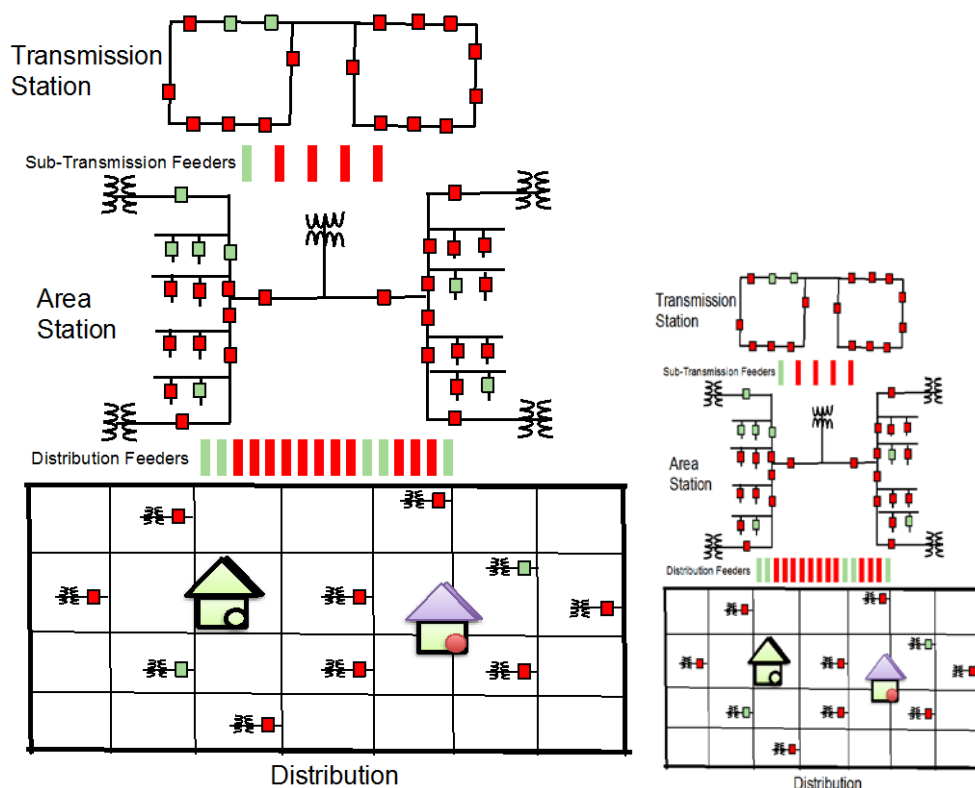
The CALM team developed the following summary of SGDP activities as part of the input to the FTR. Results and information below has been used to develop the overall takeaways and lessons learned in the FTR.

### A.11.1 Executive Summary

CALM Energy's demonstrated technology included:

- Its ISM Decision Aid platform for use by transmission and distribution operators
- Its building smart node energy optimization controller

Figure A-80. Reliability

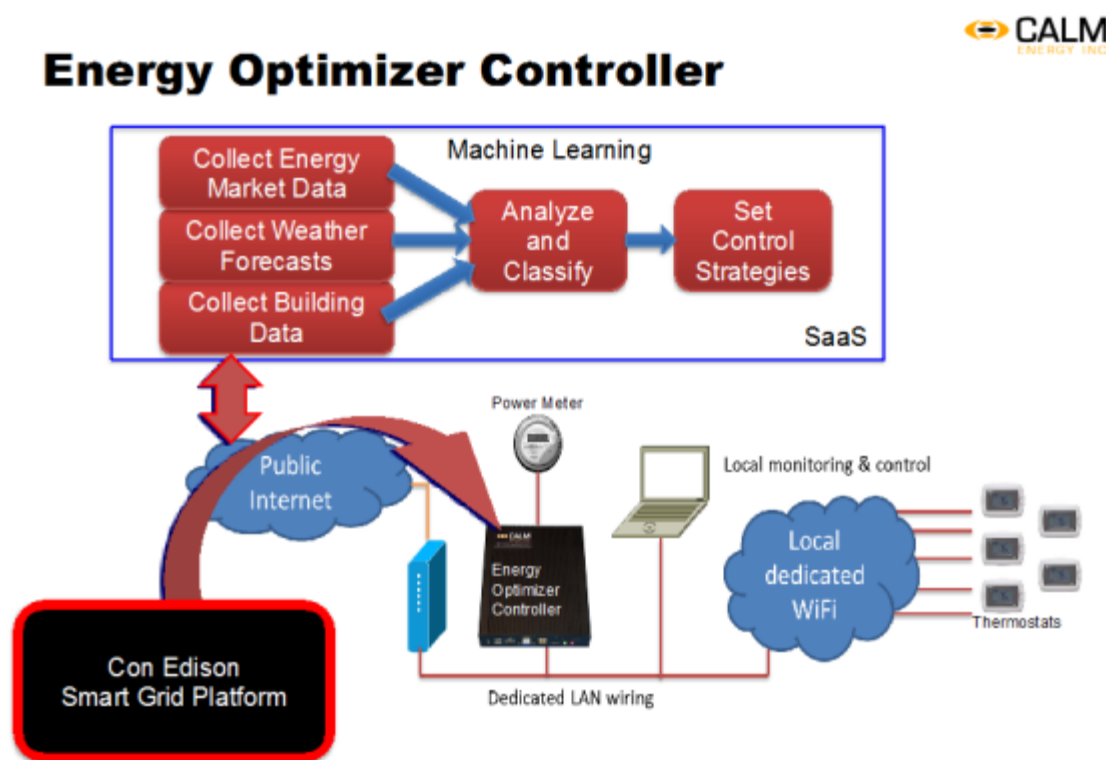


Having continuous automated detection of predicted vulnerabilities in the transmission and distribution system versus reacting to emergencies after they happen will improve grid reliability and reduce costs, especially given increasing uncertainty in intermittent customer loads and supplies (e.g., energy storage, EVs, and PVs). Most catastrophic incident investigative reports developed by utility management investigative teams after an incident occurs, using existing legacy historic data, determine with pinpoint accuracy multiple precursors to an incident that had they been detected in advance by operations and properly acted upon, could have been prevented or at least could have significantly mitigated the incident. The ISM decision aid platform demonstrates the viability of such technology in detecting and acting in advance on predicted incidents to prevent major outages through software intelligence

implemented for an Area Substation and its distribution network where the ISM has fully integrated knowledge of both the transmission system and the distribution system, and served customers surrounding the Area Station. The ISM decision aid platform was demonstrated as part of the capstone demonstration using off-line transmission system, area station, distribution system, and customer data from the Long Island City network and North Queens Area Station. It is believed that the ISM Decision Aid holds promise of supporting the prevention and mitigation of these types of major outages. Besides improved reliability, the ISM decision aid holds promise of improving energy efficiency within the grid through scheduled modulation of customer's loads and greater certainty in managing electrical component peak loads to their capabilities, improving the planned and real-time dispatch of generation sources and DR.

In addition to the ISM Decision Aid, CALM Energy demonstrated its building smart node energy optimizer (EO) controller, through funding from CALM Energy and NYSERDA, to interoperate with the utility's SG DERMS platform developed by Siemens.

Figure A-81. EO Controller



The Smart Node EO Controller communicated with the Con Edison DERMS SG Platform using NIST SG standards of cyber-security for monitoring the state of the building and initiating DR to curtail load on the electric grid. The demonstration of CALM Energy's Smart Node Controller for buildings using the latest NIST SG standards and having the smart node controller communicating directly with the Siemens platform provides proof that such technology can be deployed by the regulated utility to improve grid reliability and energy efficiency without a third-party NOC. This portion of the



demonstration was initially a NYSERDA/CALM project that was added to the demonstration, as it was a fit with the original intent of the SGDP to demonstrate cyber-secure interoperability for automated DR.

### **A.11.2 Project Goals and Accomplishments**

The primary goals and objectives of the overall project as proposed to the DOE were to research, develop, and demonstrate SG advancements for utility operations for improving grid energy efficiency and reliability. An additional goal of the project, being a 2009 ARRA-funded project, was to provide jobs to stimulate the economy.

Major accomplishments of the project included:

- Development and demonstration via simulation of a Transmission to Distribution to Customer integrated GIS/Virtual-SCADA based decision aid and controller.
- Progress toward developing and demonstrating CALM's patented technology
- ISM Decision Aid project with NYSERDA development and demonstration
- Development and demonstration of a low cost building EO controller for small and mid-sized commercial buildings that communicates directly with Con Edison's DERMS Platform
- Development and demonstration of low cost thermostatic control of multiple HVAC units in tow building through the EO controller using building's existing internet
- Development of EO capabilities to reduce peak loads and reduce energy usage at the building

Partway through the project, an additional task was added, at no additional cost to the DOE, to demonstrate the successful interoperation of the NYSERDA/CALM-funded smart node building controller with the DOE project-funded DERMS system.

This successfully demonstrated end-to-end communication between utility-based control systems and a building controller, without the need for an intermediate data center, in full compliance with all relevant cyber-security specifications and standards. This additional demonstration highlights a new proven capability for direct interaction between utilities and customers that exceeded the DOE original scope of work.

### **A.11.3 Project Activities**

The initial project proposal to the DOE and the hypothesis of the SGDP activities were to collaborate with the recipient and sub-recipients to develop and demonstrate a novel approach to utility operations that included, detection of predicted anomalies, analysis leading to optimized recommendations for surgically scheduled initiation of DR. The planned methodology of lean sprints of software development commonly referred to as agile software development was performed by CALM Energy, making the execution of the ISM Decision Aid scope of work simpler to perform, with results outperforming expectations.

CALM's original plan was adjusted due to the replacement of Boeing with Siemens/TIBCO. As such, CALM's development actions were conducted independent of the DERMS platform.

#### **A.11.4 Product Development and Technology Transfer**

CALM Energy's participation in the SGDP advanced the development of two pieces of technology: The ISM Decision Aid platform, funded directly by this project, and the CALM EO building controller, funded by NYSERDA and CALM Energy, which were both demonstrated as a part of this project. The ISM Decision Aid Platform is a prototype. Certain features are readily available to be piloted in production, while other portions still need substantial development. The building energy controller is in prototype production at two buildings and is being sold to channel partners.

The CALM/NYSERDA-funded building controller development and demonstration is still on going with NYSEDA and is presently a product being sold to channel partners for monitoring and energy cost reductions within buildings. CALM anticipates DR to be an additional valuable functionality for buildings as the utility industry moves towards NIST standards of cyber-secure automated DR.

##### **A.11.4.1 Modeling**

(This section refers to the ISM Decision Aid and associated modeling.)

##### **Model Description**

The purpose of the ISM Decision Aid is to improve reliability by intelligently targeting DR both prior to an incident and as an incident unfolds. The model answers five questions:

1. *"What parts of Area Station, distribution feeders, and transmission system are predicted at risk of failure?"* where risk is calculated based on a learned forecasted load and a subsequent power flow analysis is performed leveraging an existing distribution feeder matrix-based power flow analysis, coupled with power flow analysis for every component within the Area Station, including sub-transmission.
2. *"What is the impact of a failure?"* where impact is the failure triggering overloads and failures in other parts of the network and area station. Additional simulations are performed for 1<sup>st</sup> contingency analysis for every component within the Area Station and every distribution feeder fed from this area station.
3. *"What demand reduction is needed?"* at a level of detail down to the individual substation and distribution feeder and customer: exactly where, when, and by how much should demand be reduced, in order to mitigate the predicted risks associated with overloading?
4. *"How should I reduce demand?"* or, more specifically, which customers should I contact to automatically request DR? The model answers this question based on data about individual customer history and DR behavior when-called, aggregated to create a DR schedule that is likely to yield the required reduction in demand.
5. *"Am I getting the relief I asked for?"* or more specifically, what is the measured performance of the automated scheduled and initiated request to reduce demand on specific distribution feeders that are relieving the distribution feeder, Area Station or sub-transmission feeder or transmission system?

The model depends upon accurate data about the network itself (obtained from the utility's T&D model and integrated data communication architecture), upon individual and aggregate customer response data (obtained via learning from records of past curtailment requests and customer response).

### **Performance Criteria**

The model is performant to the extent that:

- Model predictions of network load track actual data obtained from metering and monitoring gear,
- Model predictions of failure impacts track actual failures, when run using historical data,
- Model predictions of customer response to DR requests track actual response, when run using historical data.
- Model-recommended reductions in load translate, in practice, into reduced number of overloads and reduced tendency of failures to propagate into catastrophic network outages.

### **Testing Results**

Validation occurred through repeated simulations of identical model states and data indicating consistent output results. Validation also occurred through verification of similar results through hand calculations and use of Excel spreadsheet models. It was initially intended to demonstrate model performance criteria over three years of operational testing upon integration.

### **Model Theory**

1. For forecasting Area Station load, the model uses historical data from weather, station loads, and sparse AMI loads. The algorithm uses a proprietary learning technique to predict station load based on updated weather forecasts and learned experience.
2. For power flow analysis, the model uses a combination of existing PVL matrix-based power flow analysis with CALM's proprietary power flow analysis to determine, based on predicted station load and feeder loading, what will be the loading at any point in the area substation.
3. For simulations of contingencies, the model uses the same power flow analysis above with modified station configurations.
4. For analysis of specific component failures within a station, the model simulates the relay protection scheme of breaker isolation through a rules-based engine, which then triggers a power flow analysis using shifted load analysis obtained from Con Edison's PVL matrix- based power flow for distribution feeders. The model uses this shifted power flow analysis to determine predicted overloads in distribution feeders.
5. The system uses a tracing algorithm to identify, for every predicted overloaded distribution feeder, all potential DR scenarios. The model uses a superposition analysis of the five closest loads to any distribution feeder transformer, which is then amalgamated for potential scheduling of load curtailment. The model then analyzes and compares potential response scenarios using a rules-based approach, with data derived from observed customer and network response to past calls for DR. From this analysis, the operator is provided with a suggested schedule of load curtailment based on a genetic optimization algorithm, where the operator can accept these suggestions or dial in other values of scheduled curtailment.

For the Smart Node Building Controller, our methods of energy optimization through models are proprietary information outside the scope of this project.



A Functionality and Operations User Guide has been provided for the ISM Decision Aid. No such manual exists at this time for the Smart Node building controller as the project is still ongoing.