FINAL REPORT

ELECTRIC INFRASTRUCTURE TECHNOLOGY, TRAINING AND ASSESSMENT PROGRAM

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1.0 PROJECT OBJECTIVE AND TASKS

The objective of this Electric Infrastructure Technology, Training and Assessment Program was to enhance the reliability of electricity delivery through engineering integration of real-time technologies for wide-area applications enabling timely monitoring and management of grid operations. The technologies developed, integrated, tested and demonstrated will be incorporated into grid operations to assist in the implementation of performance-based protection/preventive measures into the existing electric utility infrastructure. This proactive approach will provide benefits of reduced cost and improved reliability over the typical schedule-based and as needed maintenance programs currently performed by utilities.

Historically, utilities have relied on maintenance and inspection programs to diagnose equipment failures and have used the limited circuit isolation devices, such as distribution main circuit breakers to identify abnormal system performance. With respect to reliable problem identification, customer calls to utility service centers are often the sole means for utilities to identify problem occurrences and determine restoration methodologies. Furthermore, monitoring and control functions of equipment and circuits are lacking; thus preventing timely detection and response to customer outages. Finally, the two-way flow of real-time system information is deficient, depriving decision makers of key information required to effectively manage and control current electric grid demands to provide reliable customer service in abnormal situations.

This Program focused on advancing technologies and the engineering integration required to incorporate them into the electric grid operations to enhance electrical system reliability and reduce utility operating costs.

Information related to management of this project, including work breakdown structure (WBS), schedule and project definition was provided in the revised Project Management Plan (PMP) attached in Appendix A. The program was completed using the following four concurrently running tasks.

Task 1 – Project Management:
Fulfill the overall program development including the review and monitoring of project tasks, facilitation of program meetings and communications, and completion of program reports.

Task 2 – Technology Identification, Assessment, and Database:
Establish a web-based database identifying and assessing technologies related to modernizing grid operations; to include technologies in use and under development and defining gap areas in need of further technology advancements.

Task 3 – Consortium Creation and Implementation:
Create a utility stakeholder consortium focused on identifying and integrating near-term, high-impact technologies.

Task 4 –Technology Integration, Optimization and Transition:

a) Incorporate technologies in a fast-track process for the engineering, optimization, verification and validation of prescribed performance criteria.
b) Integrate and transfer advanced technologies to utilities to fill the gap in technology and cost performance, including necessary training for the proper use of the technology.

2.0 DELIVERABLE / MAJOR MILESTONE STATUS

Milestone Description	Baseline	Revised	Actual	Reason for Variance
1. Program Management Plan (PMP) Revised PMP Submitted	02/05/05		02/07/05 04/19/06	02/05/05 was a Saturday; therefore, it was delivered on the next business day. A revised PMP was approved by DOE on 04/19/06. A request for a no cost period of performance extension to 04/30/07 in order to properly complete the assigned tasking was approved by the DOE on 5/25/06.
2. Quarterly Reports	04/29/05 07/29/05 10/31/05 04/28/06 07/28/06 10/30/06 01/31/07 04/31/07		04/29/05 07/29/05 10/31/05 04/28/06 07/28/06 10/30/06 01/31/07 04/30/07	Quarterly Reports delivered on time.
3. Conduct workshop on technology gap analysis (Task 2)	09/29/05		11/9 & 10/05	Due to scheduling issues, this workshop was held on November 9th and 10th, 2005 in Mesa, AZ and was co-sponsored by *CTC* and U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability (OE) and the National Energy Technology Laboratory (NETL).
4. Publish technology database on the Website with public access (Task 2)	10/31/05	2/15/06	03/03/06	The actual publish date was delayed due to copyright issues for displayed information. It was identified that even though the information gathered in the database was publicly available that most websites have copyright clauses. Approvals have been received or information limited to meet copyright requirements. The technology database is accessible on the GridApp™ Website.
5. Identify technologies for grid integration (Task 3)	10/31/05		10/31/05	
6. Technology Gap Analysis Report (Task 2)	11/30/05	02/28/06	03/07/06	Due to delay in scheduling of the Technology Gap Analysis meeting (Milestone 3), this report was delayed from the original delivery date.
7. Technology Integration, Optimization and Transition Summary Reports (Task 3)	01/31/06		12/22/05	Exelon project is completed and final report published. All other Summary Reports will be delivered at the completion of the technical activities for the corresponding projects.
8. Annual Report	02/28/06 02/28/07		02/08/06	02/28/07 Annual Report submitted as Quarterly

2.0 DELIVERABLE / MAJOR MILESTONE STATUS (Continued)

9. Hold public day event for technology showcases (Task 5)	06/30/06		04/21/06	Held the GridApp™ technology showcase and demonstration of Exelon's "Substation-in-a-Box" near Elgin, Illinois.
			07/20/06	Held the GridApp™ technology showcase and demonstration of Sothern California Edison's Synchronized Phasor Measurement System in Los Angeles, CA
			11/15/06	Held the GridApp™ technology showcase and demonstration of First Energy's Autonomous Storm Detector System near Medina, OH
10. Final Report	06/28/07	06/28/07	06/28/07	Submittal of this Final Report

NOTE: All due dates listed in this table are based on the contract award date of 01/05/05.

3.0 SIGNIFICANT EVENTS AND ACCOMPLISHMENTS

Date	Description
11/8-9/05	Conducted the first GridApp™ Board of Directors and Steering Committee meetings in Mesa, AZ.
11/8-9/05	A technology gap analysis workshop was conducted in conjunction with the DOE OE and NETL in Mesa, AZ with the theme of "Developing the Modern Grid"
2/7/2006	During the DistribuTECH 2006 conference in Tampa, Florida, The Utility Automation & Engineering Transmission & Distribution (T&D) announced that the DC-IN-A-BOX™ Substation Design was selected as the Project of the Year Award in the category of T&D engineering. The project was featured in Utility Automation & Engineering T&D's March 2006 issue.
3/2-3/06	Conducted the second GridApp™ Board of Directors and Steering Committee meetings in Rancho Cucamonga, CA, hosted by Southern California Edison.
3/7/06	Delivered the Technology Gap Analysis report to DOE OE.
3/17/06	Coordinated and facilitated the GridApp Steering Committee Meeting by teleconference to vote on the Strategic Projects presented.
04/21/06	Held the GridApp™ technology showcase and demonstration of Exelon's "Substation-in-a-Box" near Elgin, Illinois.
6/6-7/06	Conducted the third GridApp™ Board of Directors and Steering Committee meetings in Farmington Hills, MI, hosted by DTE Energy.
6/30/06	Idaho Power and FirstEnergy were awarded the first Strategic Project of the GridApp Consortium for the implementation of an Advanced Capacitor Control System.
07/13/06	DTE was awarded a Strategic Project to test and demonstrate the S&C TripSaver™ Dropout Recloser system as a product that will reduce the frequency of overhead lateral momentary outages.

Significant events and accomplishments (Continued)

08/23/06	PGE was awarded a Strategic Project for the Gen-on-Sys control protocol. This standardized protocol is for linking distributed resource assets to any utility system control center, including standardized naming conventions and data structures for all forms of DR and uniform graphics and report generation features for developing customized screens.
9/19-20/06	Conducted the fourth GridApp™ Board of Directors and Steering Committee meetings in Portland, OR, hosted by Portland General Electric.
09/30/06	Completed the Phase I Final Report for the Distribution Systems Fault Locator (DSFL).
11/15/06	Held the GridApp™ technology showcase of FirstEnergy's "Autonomous Storm Detector" near Medina, OH.
11/14-15/06	Conducted the fifth GridApp™ Board of Directors and Steering Committee meetings in Wadsworth, OH, hosted by FirstEnergy.
11/2006	Idaho Power signed a contract with Schweitzer Engineering Laboratories, Pullman, WA to develop and support an ACCS based on Schweitzer's SEL 3351 Substation Computer. Throughout December and January Schweitzer and Idaho Power worked to develop the prototype SEL 3351 ACCS. Idaho Power placed the prototype SEL 3351 ACCS in service early March 2007 and the system has been performing to plan. A second SEL3351 ACCS is being developed for FirstEnergy; this system will have Nextel cellular communications rather than the analog radio communications utilized by Idaho Power.
2/20/07	Coordinated and facilitated the interim GridApp Board of Directors and Steering Committee meeting by teleconference to discuss projects, membership, path forward and the arrangements for the April 2007 meetings.
03/14/07	Held the GridApp™ technology showcase and demonstration of Sothern California Edison's Synchronized Measurement and Analysis in Real Time (SMART) System in Alhambra, CA.
04/25/07	Conducted the sixth GridApp™ Board of Directors and Steering Committee meetings in Washington, DC, hosted by *CTC*. This meeting was scheduled in conjunction with the DOE Grid Week activities.

4.0 PROGRAM ACCOMPLISHMENTS

This Final Report satisfies the last deliverable of the Electric Infrastructure Technology, Training and Assessment Program. The report provides an overview of the program activities and accomplishments over the period of performance of the program. The report covers original hypotheses, approaches used, problems encountered and departure from planned methodology. The report also provides *CTC*'s assessment of the impact of this Program on advancing technologies and the engineering integration to incorporate them into the electric grid operations to enhance electrical system reliability and reduce utility operating costs.

4.1 Project Management

This program was awarded on September 30, 2004. *CTC* successfully managed this task to ensure that the scope, schedule, and budget met those defined under this cooperative agreement. The task activities included: preparing for and participating in the DOE meetings (kickoff, Electric Distribution Transformation Program annual review, and out-briefs); preparing the program management plan (PMP), preparing quarterly progress reports, an annual progress report, and a program final report.

The progress reports were submitted within 30 days after the reporting period end date. The content of the quarterly and annual progress reports contain, but are not limited to the results of work completed to date, a comparison of actual accomplishments versus previously established goals for that period, any anticipated problems or delays along with actions that will be taken, and explanations for deviations from the original Program award in schedule, milestones, costs, key personnel, and consortium member participation.

4.2 Technology Identification, Assessment and Database

CTC has identified near-term technologies and their integrated platforms (where applicable), currently in use or under development, with applications to monitor and manage electricity delivery, including power flow, power quality, permanent electrical faults, incipient electrical faults, and substation equipment conditions. The following technology areas were investigated:

- Sensors
- Communication Media
- Communication Standards Development
- Interoperable Architecture
- Power Electronics
- Demand/Load Management
- Distribution Operations/Automation
- Infrastructure Security and Protection (physical and cyber)
- Modeling and Simulation
- Advanced Conductors
- Phasor Measurement Sensors

The technology/platform identification was achieved through a combination of literature/Internet searches for publicly available information and surveys/direct contacts with utilities, technology providers, DOE principal investigators, the Electric Power Research Institute (EPRI) and researchers at universities and national laboratories currently conducting related research and development (R&D).

All technologies identified were grouped by technology areas, and organized into an internet accessible database, which can be updated within follow-on programs supporting GridApp™ as new technology information becomes available. The function areas include: Demand Side Management, Power Electronics, Communications Architecture, Communications Media, Modeling and Simulation, Advanced Conductors, Advanced Distribution Automation, Infrastructure Security and Sensors and Monitors.

The database is available to the public and to technology developers/providers/users for interactive reviews and updates via the website developed for the utility consortium organized under this Program (www.gridapp.org). *CTC* continues to provide technical oversight and final approval to ensure technical integrity of Web database contents.

In conjunction with a DOE effort focusing on defining Grid Modernization Technologies, *CTC* held a technology gap workshop to gain input from industry stakeholders (utilities, universities, consultants and government officials). *CTC*, jointly with workshop participants, conducted a short-term and mid-term technology gap analysis by assessing existing technology status against the defined requirements to develop a modern grid. The technology areas in need of further system integration, optimization and advancement were documented and provided to the DOE in a separate report entitled Gap Analysis Report, attached as Appendix B.

4.2.1 Electric Infrastructure Gap Analysis

Problem / Need
There are many varied technology gaps in the electric utility industry – many small and isolated, while others are pervasive throughout the industry. Often, enabling technologies to address these gaps are just becoming available, but are not yet mature, or have not been standardized sufficiently enough to become fully effective. Common technology gaps need to be addressed to realize industry needs for the future.

Goals and Objectives
Support a focus for the direction of resources to developmental efforts in the utility industry that will provide the optimum benefit in the shortest amount of time. Gather information from a number of sources. Review documents from utility consortiums, conferences, and public forums. Hold a workshop to gather pertinent feedback from utilities, academia, research organizations, and government agencies.

Accomplishments
Information was gathered from a number of sources including utility contacts and industry experts. Numerous documents from utility consortiums, conferences, and other public forums were reviewed. A workshop was held to gather pertinent feedback from utilities, academia, research organizations, and government agencies. Well-positioned industry representatives were consulted individually to obtain their candid thoughts. The input was assimilated into a snapshot of current electric grid technology needs and gaps.

The technology areas identified in the report are as follows:

- Communications Technologies and Protocol Standardization
- Fault Location, Signature Analysis, and Anticipation
- Better System State Estimation, Alarm Processing, and Visualization Tools
- Equipment Condition Assessment to Prioritize Maintenance Expenditures
- Standardization in Multiple System Operation/Control Areas
- Robust Electronic Power Switching Equipment
- Efficient and Cost Effective Energy Storage Capabilities
- Technology and Financial Incentives for Business and Residential “Load-Side” Power Management

Some of these identified areas were expanded upon throughout further electric infrastructure development within this project.

4.2.2 GridApp™ Technology Database Development

Problem / Need
A common central area for information dissemination is necessary to support the electric utility need to easily obtain information on relevant technologies in the transmission and distribution electrical utility arena.

Goals and Objectives
Identify technologies for monitoring and managing electricity delivery. Provide performance, cost, applications, maturity, and points of contact.

Accomplishments
The Electric Infrastructure Technology Database identifies technologies and their integrated platforms for monitoring and managing electricity delivery. The database offers pertinent information on technologies and platforms, including performance, cost of the devices, applications, maturity, and points of contact. The targeted application areas include: identification, localization, and prediction of faults, real-time monitoring

to support distribution operations, and other significant technologies impacting the electrical grid.
The database provides technology information with respect to integration into grid operations. Access to such information allows utility companies to become more proactive in maintenance and operation activities, thus avoiding outages and increasing reliability.

4.2.3 Portable arc flash technology assessment

Problem / Need
Arc flash hazards are a very serious concern for personnel working on electrical equipment, many arc flashes occur as a result of disturbances caused during equipment maintenance. Technologies exist to detect an occurrence of an arc using light levels, heat, pressure, corona and sound. Existing arc flash detection systems are designed for permanent installation in electrical switchgear and enclosures or used as preventative maintenance tools.

Goals and Objectives
Identified candidate technologies for detecting and clearing an arc flash event using available arc detection systems and the interaction with circuit breakers through appropriate communication interfaces in a small package that is reliable and easy to configure and use.

Accomplishments
Technologies were down selected to those of the highest likelihood for success with three technology possibilities remaining. Johns Hopkins, Mikron and ABB are confident that they can develop a usable system to meet the project objectives of quick arc flash detection in a portable system to open the energized circuit for arc removal. Further development will require that all systems be tested under appropriate operating conditions. All systems need to be designed to meet size, weight, power system and communications requirements following any initial proof of concept development.

4.2.4 Utility communication technologies for distribution system automation assessment

Problem / Need
Communication needs are ubiquitous throughout all aspects of the technical world. Electrical transmission and distribution are no exception. Trends in today’s energy market are toward increased electrical power consumption, while the addition of transmission and distribution capacity is occurring at a slower pace. This means that the existing infrastructure must be utilized ever-closer to its capacity. This exacerbates the need for more accurate monitoring and control of these electrical systems, and therefore increased and more reliable communications. There are many

available communication technologies - each have strengths and weaknesses. Many devices communicate through proprietary communication protocols, which cause inter-operability issues. The need exists for standardized, flexible, robust, redundant, self-healing, transparent communications systems which can be incorporated into the existing infrastructure to improve 2-way communications further down into the distribution systems.

Goals and Objectives

The primary goal of this assessment effort was to identify some of the most promising communications technologies which could enable enhanced communications within distribution systems. Widespread implementation of these technologies would provide opportunities for the utilities to optimize effective utilization of their current distribution infrastructure through 2-way distribution automation communications/control. It will also enable load-side management of electrical load/demand by providing residential and smaller commercial customers the ability to monitor electrical rates real-time, and make decisions on the timing of their significant electrical loads – consequently allowing them a larger say in managing their energy costs. This should benefit both the consumers and the utilities.

Accomplishments

A wide-ranging assessment of current and developing communications technologies was executed. Multiple key communications issues were identified, including standardization, interoperability, reliability, and affordability. Wireless communications technologies were identified as some of the most promising for present and future implementations. A further assessment, focused on wireless technologies in electrical distribution applications was performed. The “Electric Utility Distribution Wireless Communications Network Wireless Technology Assessment” is also attached to this report as Appendix C. Wireless communications technologies are often the most cost effective choice available today. Also, their independence of physical connections (phone lines, fiber, etc.) permits them to provide improved reliability in times of severe conditions that lead to loss of network connections (downed phone lines and power lines). This assessment concluded that wireless mesh radio network communications was one of the best technologies for further exploitation. It also identified some significant gaps/needs to be addressed, including power supply (primarily battery life), the need for on-board radio node programmability, and lower overall cost per communication node.

4.2.5 Advanced energy storage assessment

Problem / Need

Although electricity cannot be directly stored (cheaply), it can be easily stored in other forms and converted back to electricity when necessary. The additional value of the electricity during peak demand can cover the cost of storing power produced at night. As demand continues to expand, storage can play a crucial, multi-functional role since storage facilities are designed to excel in a dynamic environment. Other factors driving the introduction of storage technologies include reduced environmental impact, solving many of the challenges regarding the increased use of renewable energy sources, and enhancing energy security measures.

Goals and Objectives
Assess the possibility of maintaining a ready-reserve cache of energy using storage technologies to help overcome such challenges as: low utilization of power facilities, transmission congestion, renewable energy generation market improvement and the prevention of losses from unreliable power quality for end-use consumers.

Accomplishments
CTC reviewed energy storage applications in enhanced power quality, renewable support and utility support application areas. Comparisons were developed comparing various storage technologies advantages and disadvantages. Each technology was detailed and highlighted for appropriate applications.

Energy storage technologies as a class will need to overcome many obstacles to both continue developing their competitiveness and increase their market penetration. Some of the major hurdles include the following:

- Raising the visibility of the technology and its capabilities
- Proving the economic competitiveness of storage technologies
- Learning how to capture the value streams created by the facility
- Avoiding the trap of having the hype surrounding the technology overtake its realistic near-term capabilities and disappoint potential clients and adopters

Energy storage technologies are different because they provide multiple benefits to multiple beneficiaries. They not only enable more than one activity to operate more efficiently and reliable, but they also provide widespread enhanced stability and security benefits. Finally, because these technologies promote an evolutionary rather than a revolutionary change to how the power industry operates, they are far more readily adoptable, and they make sense now and in the future.

4.3 Consortium Creation and Implementation

CTC began the creation of a consortium of utility stakeholders focused on identifying and providing near-term, high-impact, widely applicable technologies that will help modernize the U.S. electrical grid. The consortium utilizes a fast-track methodology for engineering, optimization, verification, and validation of selected high-impact technologies that also includes the transition of best technologies and best practices into broader use by member utilities. The stakeholder benefits include engineering integration of grid modernization technologies that individual utilities do not have or can not undertake providing best technologies and practices with a viable market size for commercialization success and providing a collective voice of the utility industry on the importance of technology investments.

CTC serves as the organizer, manager, and technical support providing management support as well as funding support for the consortium operation. The Board of Directors (BOD) and Steering Committee were organized by *CTC*. All GridApp™ projects are managed and supported technically by *CTC*. *CTC* provided engineering expertise to move the project technically thorough the development process. Part of the development was the facilitation necessary for Technology Integration Working Groups that were formed for all projects as they progress to completion. These working groups allowed the project development to include input from the other consortium members. *CTC* channeled the input to technically support the project outcome. The consortium name, GridApp™, logo, and external website were created by *CTC*. The technology database, developed in Task 2, is one of the items hosted on the consortium website.

The BOD is comprised of the GridApp™ Charter members and *CTC*. The Steering committee is the entire GridApp™ membership. Charter members must agree to the designated agreement which includes implementing a project with at least a $300,000 budget. *CTC*, through DOE contributions, fund $100,000 to each charter member meeting the program requirements.

Sponsor members contribute an annual $50,000 membership fee but receive information and may participate in working groups for each of the GridApp™ projects. They also have the opportunity to submit projects to be funded out of Sponsor member fees. These projects are voted on by the Steering Committee. Upon technical and funding approval the member project is approved to begin activities.

The GridApp™ consortium Charter members for the initial program year of 2006-2007 were Exelon, American Electric Power (AEP), Southern California Edison (SCE), Southern Company and FirstEnergy. Due to utility management and budget changes both AEP and Southern Company were forced to withdraw from the consortium prior to their project completion and representative funding disbursement. AEP and Southern Company did participate in GridApp™ meetings and conference calls up through November 2006.

The GridApp™ Sponsor members include DTE Energy (DTE), Idaho Power, Portland General Electric (PGE), PPL Electric Utilities (PPL), and Salt River Project (SRP).

All of the GridApp™ projects were evaluated for selection using the following criteria which are aligned with the strategic goals of the EI Program:

- Must be a high impact project that needs further development and will advance present state-of-the-art
- Project addresses high-priority utility needs in which the technology is broadly applicable across the utility industry
- There is soundness, technical merit, and innovation of the proposed approach and its incremental progress toward topic or subtopic solution
- Must have an effective Project Management Plan
- There is high probability of project success
- Tangible benefits resulting from this project have been established and documented
- The cost and schedule are reasonable
- A reasonable path to commercialization has been identified

Each project as part of the statement of work (SOW) is required to hold technical working group meetings, complete monthly reports, hold an on site demonstration of the technology, and submit a project final report.

CTC management activities included the interpretation and maintenance of the GridApp™ consortium by-laws, organizing and facilitating periodic consortium management meetings, recruiting other interested utilities for membership enhancement, providing technical support to the projects and implementing a process to identify beneficial near-term technologies.

The loss of the two GridApp™ Charter members left available funding for alternative projects. *CTC* redirected the funding into the development of wireless technology needs within the utility infrastructure.

Future enrollment into the GridApp™ consortium for the 2007-2008 project year is underway. Although AEP and Southern Company are still not members, DTE has moved from a Sponsor member to a Charter member. This will offset the loss of Exelon as a Charter member due to the lack of a qualifying charter member project. Exelon has maintained active in the consortium as a GridApp™ Sponsor member.

The consortium allows for eight Sponsor Members. With five currently committed, further enrollment is necessary to improve the utility participation in the program. Through a peer-to-peer process *CTC* is utilizing the advice and influence of existing consortium members to gain commitments for the three remaining Sponsor Member positions as well as direct utility contact through one on one utility communication. Prime candidates identified include Austin Energy, Pacific Gas and Electric (PGE), and Public Service Electric and Gas (PSE&G). *CTC* personnel are contacting and visiting these and other prominent utilities in an ongoing enrollment effort for the 2007-2008 contract year and any possible follow on years of GridApp™.

4.4 Technology Integration, Optimization and Transition

Technology identification under this Task came from various means.
They include:

- Consortium Members – Consortium members assess, identify and provide near-term, high-impact, widely applicable technologies. These technologies have to meet specific criteria and be approved by fellow consortium members. The technologies are reviewed for technical merit to advance the state of the practice, applicability to address high priority utility needs, replication and implementation to the electric utility industry, and reasonableness of cost and schedule.
- Technology Gap Analysis – The technology gap analysis assisted in identifying technologies needs. The predominant gaps that were identified are as follows:
  - Communications Technologies and Protocol Standardization
    - *CTC* is executing activities under the Center for Grid Modernization (CGM)
  - Fault Location, Signature Analysis, and Anticipation
    - *CTC* project phase I performed under this tasking with development continuing under the CGM
  - Equipment Condition Assessment to Prioritize Maintenance Expenditures
  - Standardization in Multiple System Operation/Control Areas
  - Robust Electronic Power Switching Equipment
  - Technology and Financial Incentives for Business and Residential Load-Side Power Management
- Technology Database – Technologies were identified as commercially off the shelf (COTS), near-COTS, in development or R&D. The original intent was to include possible COTS technologies into the investigation. Although the database provides an excellent knowledge base of utility technologies and their commercialization potential, the top level products identified within it were already being reviewed through one of the other technology identification means.

A technology selection process was created and has been utilized for project investigation. All technologies selected for system integration through the previously named means have met all specific evaluation criteria including: technical value, broad industry applicability, technical scope, management approach, probability of success, tangible outcomes, cost/schedule and potential path to commercialization.

Based on the technology gap analysis conducted under Task 2, the technologies reviewed focused on priority industry needs which parallel the following technology gaps:

- Communications technologies and protocol standardization
- Fault location, signature analysis and fault anticipation
- Equipment condition assessment for maintenance prioritization
- Standardization in system operations and controls
- Advanced electronic power switching equipment
- Efficient and cost effective energy storage capabilities
- Effective demand-side load control

Verification and validation (V&V) of the selected technologies was conducted either at the technology vendor/utility facilities, *CTC*'s Johnstown, PA facility, or both, depending on the individual technology and the levels of collaboration established between *CTC* and the technology providers/utilities. The program funding supported three core technologies and three additional strategic technologies.

CTC worked with consortium members, other prominent utilities and other key industry stakeholders to define near-term, high-impact, widely applicable technologies for system integration. In concert with each technology, *CTC* coordinated with utilities and technology developers to solicit collaboration focused on the integration and transition of the technology to ultimately achieve broad industry application. Each technology was supported with an associated working group consisting of interested consortium members that supported the broad industry input to the technology integration.

Each technology included a showcase event to gain broad acceptance of the consortium members and technology partners. The one-day events were planned to include a workshop session on the technology along with an interactive demonstration to viewing and discuss the technology.

As part of this technology transition, each technology integration included training sessions to educate utility personnel on the use of the individual technologies. The training plans were jointly developed by the participating utility, the industry partner, *CTC*, and the consortium members.

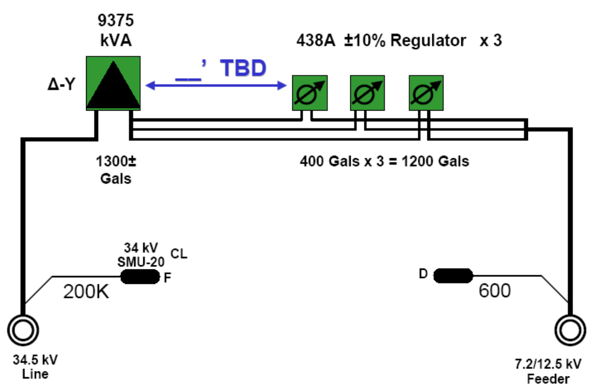
Core technology integrations carried out by the consortium members are as follows:

4.4.1 Exelon – Distribution Substation in a Box (DC-IN-A-BOX™)

Problem / Need

Area development is requiring electric utilities to growth the existing electric infrastructure. This growth often requires new and expanded substations to be constructed. A method to accommodate substation sitting using a less objectionable design while lowering substation costs is needed.

Goals and Objectives
Develop a self-contained compartmental transformer and recloser system to replace a typical 10MVA utility substation.
Obstacles / Solution
Exelon designed and constructed a Substation in a Box, a self-contained compartmental transformer with a 3Ø vacuum recloser mounted in the low voltage compartment. Each Substation in a Box provides one "high capacity" 12 kV feeder. Three separate URD ±10% regulators are used to provide voltage regulation on the 12 kV feeder. Both the incoming 34 kV and the outgoing 12 kV are underground. Figure 1 is the conceptual one line for the installation.



Accomplishments
The DC-IN-A-BOX™ transformer was specially designed to provide the exact same thermal capabilities as a traditional 9375 kVA Substation transformer. While a traditional Substation transformer is a 7500 kVA with forced air-cooling, the DC-IN-A-BOX™ achieves a 9375 kVA rating without the use of forced air cooling. The normal electrical ratings of the DC-IN-A-BOX™ are 9.7 MVA and 425 amps. The emergency rating is 13.7 MVA and 600 amps.

The DC-IN-A-BOX™ offers a smaller footprint and is more aesthetically appealing using all underground cabling. The installation requires no barbed wire topped fence for security and personal protection and no spill containment is required. The system uses completely enclosed boxes with no exposed energized parts.

4.4.2 FirstEnergy - Autonomous Storm Detection; Adaptive Relaying

Problem / Need

Adaptive relaying is a proven technique for reducing nuisance power outages that result from weather related events such as lightning strikes or high winds. The issue is that the technique can only be effectively applied at substations that include SCADA systems that can be used to change the relay settings. A system needs to be developed that can implement autonomous adaptive relaying that is independent of SCADA.

Goals and Objectives
The goal of adaptive relaying is to automatically change the relay settings based on weather conditions that exist at any given time. FirstEnergy will demonstrate an autonomous storm detector (ASD) that does not require connection to a SCADA system.

Accomplishments
FirstEnergy has conducted research, development and design of an Autonomous Storm Detector (ASD) system for installation at substations that does not require connection to a SCADA system. For this project, FirstEnergy will demonstrate their ASD technology at substations in the FirstEnergy service territory. GridApp™ members had the opportunity to participate in the demonstration of the ASD system at FirstEnergy. FirstEnergy installed and monitored ASD's at substations in the FirstEnergy service territory. FirstEnergy is pursuing opportunities to commercialize the ASD system. Several GridApp™ members are interested in installing ASD's as demonstrations in their service territory.

4.4.3 Southern California Edison – Synchronized Phasor Measurement Technology including real-time system monitoring

Problem / Need
Electric power systems are always in a state of stress. System operators need to monitor the system to be prepared to take corrective action if the system becomes overstressed. Existing monitoring equipment has a delay of seconds or even minutes. System operators need information in real time. A Synchronized Phasor Measurement System has the capability to provide real time information to system operators.

Goals and Objectives
Develop a real time display of the electric power system using Synchronized Phasor Measurement information.

Accomplishments
Southern California Edison (SCE) has conducted research, development and design of Synchronized Phasor Measurement Systems for over eight years. SCE has previously developed their Power System Outlook (PSO) tool for off-line viewing and analysis of phasor measurement data. For this project, SCE developed and deployed their Synchronized

Measurement and Analysis in Real Time (SMART®) tool for use in real time viewing of synchronized phasor information. An obstacle for the project was the reluctance of introducing another monitoring tool in the system operations center.

GridApp™ members had the opportunity to participate in a demonstration of the PSO tool at SCE. GridApp members had the opportunity to participate in monthly working group teleconferences. SCE developed and deployed the SMART tool into the SCE system operations center. The managers of the system operations center have received training on synchronized phasor measurement information and the system operators are being trained. GridApp members had the opportunity to participate in a demonstration of the SMART tool at a Technology Showcase Meeting at the SCE system operations center. SCE is pursuing opportunities to commercialize the SMART tool.

4.4.4 Idaho Power - Advanced Capacitor Control System

Problem / Need
Address common utility problems in voltage and reactive power management which impact several operational concerns including loss efficiency, optimization of system capacity and investment, maintenance and condition indication of line capacitors, interaction between the distribution and transmission system, and most importantly, quality service for customers.

Goals and Objectives
Find a cost-effective way to improve customer power quality and optimize existing transmission and distribution infrastructure efficiency. Modernize, automate and institutionalize the control and reporting of reactive power management and devices on the grid by installing automated capacitor control systems.

Accomplishments
Idaho Power developed an automated capacitor control system consisting of a PC located in a substation, analog radio communications (basically a CB) and radio controlled capacitor switches. The substation PC runs software developed by Idaho Power that automatically switches distribution line capacitor banks on and off to correct the distribution line power factor. The switching of the capacitor banks is based on a priority level predetermined by the utility.

Idaho Power partnered with Schweitzer Engineering Laboratories (SEL) of Pullman, WA to develop a commercial version of their capacitor control system. Idaho Power and Schweitzer chose the SEL 3351 substation PC as their hardware platform. From this platform Idaho Power and SEL worked to migrate Idaho Power's capacitor control algorithm to the SEL

3351 and add in flexibility with regards to communication methods. At this time the SEL 3351 Advanced Capacitor Control System (ACCS) is capable of utilizing analog radio communications and Nextel cellular communications. SEL will also provide all hardware and software support for future installations of the SEL 3351 ACCS. In February 2007 Idaho Power installed the prototype version of the SEL 3351 ACCS, within minutes of installation and power-up the unit began closing capacitor banks to regulate the power factor on the distribution lines under its control. Idaho Power has reported that the unit has been performing flawlessly. A second unit will be installed by FirstEnergy in May 2007 at the Jersey Central Power and Light (JCPL) Kenville, NJ substation.

4.4.5 DTE Energy –S&C Electrical Protection Trip Device

Problem / Need
Temporary faults on overhead distribution circuits are a growing problem for electric utilities with over 90% of momentary outages occurring on circuit laterals. These faults translate into lost revenue, as crews must be dispatched to find and replace the blown fuse or switch a substation breaker back on. The overwhelming majority of momentary outages occur specifically on lateral distribution circuits. This is due to increased vulnerability on these lines from increased vegetation exposure. A replacement for single use fuse protection is required to support increased reliability and reduced customer outages.

Goals and Objectives
Samples of the S&C TripSaver™ units were tested in a utility laboratory setting and subsequently installed on troublesome distribution lines. Proper training and technical standards were developed to support electrical line crew needs for installation and maintenance. Beta versions will be installed in selected sites and their operation monitored. The outcome of the test results will be analyzed with S&C Electric Company and other GridApp™ members.

Accomplishments
GridApp™ provided input to S&C to enhance the design of the TripSaver™ Dropout Recloser, a product that suits the need of decreasing the frequency of overhead lateral momentary outages. DTE received a quantity of TripSaver™ products from S&C for internal test and evaluation. DTE located distribution lines suitable for TripSaver™ evaluation, researching areas with a high instance of temporary faults. Proper training and technical standards for installation and maintenance of the TripSaver™ Dropout Recloser were developed by DTE.

Due to production and testing delays, the installation of the TripSaver™ beta versions was delayed. The systems will be installed in the selected sites and monitored for a period of three months following installation.

The anticipated reliability and possibilities for commercialization of the product will be analyzed following the site testing. GridApp™ will aid in the commercialization of a product that is suitable for purchase off the shelf including finalizing training and technical standards. The consortium members will be informed and educated on the results and use of this technology.

4.4.6 Portland General Electric – Distributed Generation Control System Advancement

Problem / Need
Portland General Electric's (PGE) GenOnSys system provides data acquisition and reporting capability for monitoring distributed resources (DR) via a SCADA system. The GenOnSys system requires several features in order to be used as a universal application by other utility companies. These features include the development of standardized protocols for linking to any utility system control center, standardized naming conventions and data structures for all forms of DR and uniform graphics and report generation features for developing customized screens for the various types of DR being used.

Goals and Objectives
Develop the identified enhancements to the GenOnSys application and make the software available for use by other GridAPP members. The ultimate goal is for the GenOnSys application to become the standard DR monitoring application used by utility companies. Create a new database structure for GenOnSys, with the IEC Component Object Model (COM) naming conventions. Migrate PGE's existing GenOnSys database structure to the new IEC database format. Operate and test PGE's distribution resources with GenOnSys and the new database format. Provide feedback to the IEC Committee on PGE's implementation of COM database with GenOnSys

Accomplishments
PGE worked with GridApp™ team members to identify and define issues, methods, data-structures and protocols for integrating distributed resources into their working systems. They identified common software elements required by the GridApp™ members and defined the data structures and protocols required by the team members. From this PGE defined a common data reporting structure acceptable to the team. The requirements were implemented into the existing GenOnSys application. The completed software application will be demonstrated to the GridApp™ members prior to project completion.

4.4.7 Distribution fault location

Problem / Need

A perturbation in any part of the electrical utility system would risk propagating a domino effect throughout the transmission network, as experienced in the 2003 Northeast blackout. Thus, the ability to model such scenarios, their risks and resulting effects, and preventative and responsive measures is critically needed to harden those areas with identified vulnerabilities. The quick and accurate location and resolution of electrical faulted circuits is important for system reliability and essential for quick system restoration. The Distribution System Fault Locator (DSFL) is an interactive methodology to perform steady state fault location within electrical distribution systems.

Goals and Objectives
The DSFL software will predict the location of low impedance, permanent faults in distribution power systems through the use of a methodology and implementation strategy. This tool will be useable as a module in existing power system development software systems. The DSFL will be expandable to include temporary fault evaluation.

Accomplishments
The use of a modeling approach that combines heuristic rules with an optimization method combined with data captured by recording devices at substations as well as customer phone calls and the status of distribution equipment will define possible fault locations. A genetic algorithm is used to narrow down the possible fault locations.
The DSFL software program takes into account the accumulated knowledge and uses a genetic algorithm optimization method to quickly predict a small number of potential fault locations. This then enables a maintenance team to locate the fault quickly by reducing the search area to specific locations.

5.0 FINANCIAL REPORT

Budget Category	Approved Budget	*Project Expenditures Cumulative to Date 09/30/04 - 04/30/07
Total Salaries	$880,949	$895,542
Travel	$98,029	$88,873
Equipment	$11,876	$7,821
Materials & Supplies	$53,383	$46,206
Subcontracts	$494,319	$493,486
Total Direct Costs	$1,538,556	$1,534,928
Total Indirect Costs	$1,322,248	$1,325,058
Total Direct & Indirect Costs	$2,860,804	$2,859,987

* Project expenditures to be finalized upon final invoicing from *CTC* billing.

6.0 LESSONS LEARNED / PROBLEMS ENCOUNTERED

- Commitment as a Charter Member was withdrawn by AEP due to a project delay resulting from a renewed focus by AEP management to address short term reliability issues including those associated with failing components. *CTC* met with AEP to discuss their technology and determined to further investigate wireless technologies to establish state of the art. *CTC* has completed the initial wireless technologies report and is reviewing the development of low cost wireless options integrated into utility equipment under the CGM program.
- Core Charter project development has been a slow process throughout the electric infrastructure program. Utility human resource constraints and legal issues regarding the contractual charter membership agreement have extended the anticipated project period of performances. The three 2006-2007 Core Charter projects were completed by April 30, 2007.
- The final sponsor membership for the 2006-2007 project period left three positions open. Gaining commitments for the remaining sponsor member positions has been difficult due to utility budget issues, human resource constraints and company distractions such as reorganizations and mergers. The existing sponsor members; although, feel that they have received a significant cost benefit for their membership fee.
- Gaining commitments from utilities in Texas is complicated by the seemingly similar activities associated with the Texas Center for the Commercialization of Electric Technologies (CCET). Efforts are underway to show the clear distinction between GridApp™ and CCET activities and to discuss collaboration opportunities.
- Coordinating, managing, facilitating and providing technical input to a utility consortium where members do more than spend funding is not a small effort even when members and contributors are convinced that the mission of technology transition for commercialization is needed.
- The continuation of GridApp™ will be dependent upon the peer to peer support and communication. Without this close utility interaction for program development and project success, significant governmental funding will be required to continue the GridApp™ activities.
- The time required to organize and implement the GridApp concept took longer than expected. This was attributed obtaining the appropriate approvals from management and attorneys.
- The ability to fill membership was challenging due to the competing needs for utility funding and the newness of the consortium (i.e. ROI and history)

7.0 TECHNOLOGY TRANSFER

As stated on DOE's TECHnology PARTNERships website (http://techtransfer.energy.gov/) "Technology transfer can mean many things – technical assistance to solve a specific problem, use of unique facilities, licensing of patents and software, exchange of personnel, and cooperative research." *CTC* and several utility members have performed technology transfer activities as part of this cooperative agreement. As previously described in the background and accomplishments of each project under the GridApp umbrella, all of the projects within this program are classified as technology transfer.

A major program component with significant impact was the creation of the GridApp™ Consortium, managed and operated by *CTC*. The GridApp™ Vision, as defined by GridApp™ Consortium members, is to be the premier organization utilized by electric industry stakeholders for the demonstration, validation, integration and transition of new grid-related technologies into broad industry deployment. The Consortium allows for a free flow of discussion ranging from industry needs to specific company solutions. It also provides necessary funding for technologies coming out of the R&D stream to move the last steps to system integration and broadly deployment to the industry. Each technology project includes a Project Working Group, organized and managed by *CTC*, which enables each GridApp™ member to participate in each and every project. A number of utilities use the Consortium as their opportunity to garner best practices and technology applications from utility industry leaders, in effect using the Consortium as their technology adoption pipeline. To date, GridApp™ members are performing or have completed projects in excess of $1.6 million which includes utility cost share of over $1.3 million.

The following are excellent example of the typical GridApp Consortium technology transfer projects:

Exelon has just installed its 18th DC-IN-A-BOX™ at ComEd. The estimated benefits are approximately $200K per site for a current savings total of $3.6 million. For example, the last DC-IN-A-BOX™ that was installed was delivered, installed on the pad, wired and subsequently energized within 10 days. This probably saved 12-18 weeks over a conventional distribution engineering solution. In terms of technology deployment beyond Exelon, Detroit Edison has implemented a version of the DC-IN-A-BOX™ without the internal circuit breaker as a result of the success of this project. Other utilities are considering deploying the technology in their systems.

The SCE SMART® project is a culmination of a successful effort in the application and visualization of Transmission Phasor Measurement. This program, along with SCE off line analysis capabilities, allows the operations group to observe system stress, take applicable action and avoid potentially cascading transmission outages. As discussed in a presentation by Rick Sergel the CEO of NERC during DOE GridWeek activities in April 2007, phasor monitoring is an important solution to reliability issues and sees that it should be mandatory. SCE is identifying the potential commercialization possibilities of the SMART at this time.

The DTE TripSaver™ project is to assist in the integration and testing of the S&C Electric Company TripSaver™ Dropout Recloser to move the technology closer to commercialization and broad deployment. Temporary faults on overhead distribution circuits are a growing problem for electric utilities with over 90% of momentary outages occurring on circuit laterals. The S&C TripSaver™ Dropout Recloser was developed to address this issue. Numerous modifications and design enhancements occurred that are directly related to this project and the involvement of the GridApp™ Project Working Group members. It is anticipated that the TripSaver™ will have a significant impact on the reliability of distribution systems in the future by significantly reducing customer outage minutes and improving customer satisfaction. It will also result in utility and customer cost savings due to a reduction of the number and length time of utility crew callouts.

The PGE Distributed Energy Resources (DER) Control project is to modify the current PGE GenOnSys DER control software data structure into the current draft model developed by the International Electrotechnical Commission (IEC). The IEC has been working on a joint project with the assistance of IEEE and EPRI to establish the Component Object Model for DER. The IEC is a worldwide organization for standardization comprising all national electrotechnical committees. The data structure will be used for integrating internal combustion generation, microturbines, solar photovoltaic arrays, wind, hydro and energy storage technologies into utility transmission systems. The ultimate benefit of this project is to provide interoperability and control of DER to reduce system reinforcement costs, improve reliability and provide for system energy surety.

The Idaho Power ACCS project addresses common utility problems in voltage and reactive power management which impact several operational concerns including: optimization of loss efficiency, capacity, investment, interaction between the distribution and transmission system, and most importantly quality service for customers. Secondly, additional benefits are realized through maintenance and reporting status of capacitor bank operations (functional or failure), thus allowing for a more rapid response of field personnel to blown fuses or other issues requiring attention. Finally, the monitoring of the reactive power signature at each substation clearly indicates when additional capacitor banks are required due to load growth. The goal of this project is to first, enable each utility to modernize and automate; second, to institutionalize the control and reporting of reactive power management on the grid. FirstEnergy Corporation is already an active partner in this project and is in the process of installing a system in a substation in New Jersey. In mid November 2006, Idaho Power signed a contract with Schweitzer Engineering Laboratories, Pullman, WA to develop and support an ACCS based on Schweitzer's SEL 3351 Substation Computer. Throughout December and January Schweitzer and Idaho Power worked to develop the prototype SEL 3351 ACCS. Idaho Power placed the prototype SEL 3351 ACCS in service early March 2007 and the system has been performing to plan. A second SEL3351 ACCS was developed for FirstEnergy; this system will have Nextel cellular communications rather than the analog radio communications utilized by Idaho Power. This unit was schedule to be deployed in early May 2007 at FirstEnergy's Kenville, NJ substation.

The DSFL project, completed by *CTC*, will significantly enhance ability of distribution utilities to provide protection, operational and planning personnel with improved fault diagnosis technologies. These technologies will enable anticipation, location, isolation and restoration of faults and failures with minimum human input and fast response time. The resultant benefits include a reduction of customer outage minutes, improved customer satisfaction and a reduction of operating costs associated with traditional forms of fault location such as patrolling an entire line on foot or in a vehicle. Software demonstrations/testing are currently being conducted at DTE and AEP. Discussions are underway with PSCAD engineering tool users including Progress Energy, Pacific Gas & Electric (PG&E), SCE and Xcel Energy. A presentation on the technology and benefits of the phase II activities of DFAS, the Advanced Fault Analysis System (AFAS) was presented at the 2007 EPRI Power Quality Applications (PQA) and Advanced Distribution Automation (ADA) Joint Conference and Exhibition.

APPENDIX A

PROGRAM MANAGEMENT PLAN

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APPENDIX B

GAP ANALYSIS REPORT

Analysis Report.pdf

APPENDIX C

WIRELESS TECHNOLOGY ASSESSMENT

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