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SPIDERS:
Smart Power Infrastructure Demonstration for Energy, Reliability, and Security

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National Nuclear Security Administration

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Overview

- **Background**
- **Project organization and approach**
- **Current status**
- **Controls and cyber security**

SPIDERS is building three microgrids, each with increasing capability, which will function as permanent energy systems for their sites. The project will promote adoption of microgrid technology for DoD.

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Selected Energy Surety Microgrid Projects

(Funded by DOE OE, DOE FEMP, and DoD)

- **Ft. Belvoir, MD – 300 Area**

  Developed eight conceptual designs. Presented draft designs for two different microgrids to support funding requests for ARRA and Installation Management Command (IMCOM) funding.

- **Maxwell AFB, AL (R&D project)**

  Worked with AF to identify building complex where a small microgrid can be implemented, and is currently under construction as an experimental microgrid. It was never intended to cover the entire base, and the experimental nature of its control systems are not part of the ESM approach.

- **Ft. Devens, MA, 99th Army Reserve**
- **Indian Head – Naval Surface Warfare Center, MD**
- **Ft. Sill, OK**

  Providing funding for microgrid implementation design with 700-1000 kW landfill gas distributed generation system and energy surety microgrid.

- **Kirtland AFB, NM**

  Eight ESM conceptual designs are complete. A proposal was developed which connects several buildings (currently without generators but having noncritical, but useful loads) for one microgrid on KAFB, which connects to an ESM at Sandia to evaluate coordination among connected microgrids.

- **Ft. Carson, CO (SPIDERS site)**
- **Camp Smith, HI (SPIDERS site)**
- **Ft. Bliss, TX**

  Multiple ESM designs are complete.

- **Vandenberg AFB, CA**

Energy Surety Microgrid: How it Works

- **Architecture reconfigures the the existing medium voltage (MV) network to create a microgrid backbone**
- **Connections for existing diesels are changed to allow simultaneous connection to critical building loads and also the MV network**

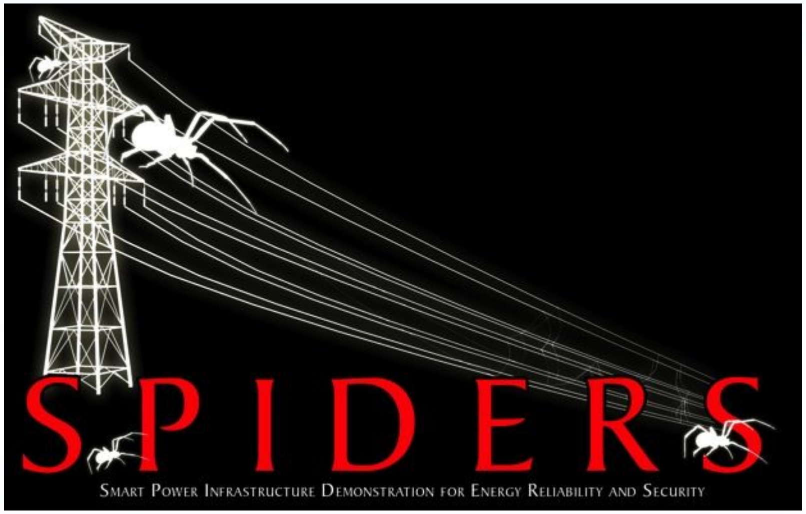
  It is not necessary to use existing emergency generators, but these are attractive choices. In the case of microgrid malfunction, these units are shielded from adverse effects and the ESM CONOPS allows restoration of existing functionality (standard automatic transfer), with provisions for portable substations as tertiary backups.
- **Generation is added as warranted depending on reliability or performance analysis**
- **During an outage, UPS carry non-interruptible critical loads as the microgrid disconnects from the utility and the diesels start**
- **The diesels are synched together on the MV microgrid network, and any other sources of energy are brought online**

ESM ENABLES IMPROVED ENERGY SECURITY

SPIDERS: Smart Power Infrastructure Demonstration for Energy, Reliability, and Security

Objectives

1. Improve reliability for mission-critical loads by connecting generators on a microgrid using existing distribution networks.
2. Reduce reliance on fuel for diesel power by using renewable energy sources during outages.
3. Increase efficiency of generators through coordinated operation on the microgrid and less excess capacity.
4. Reduce operational risk for energy systems through a strong cyber security for the microgrid.
5. Enable flexible electrical energy by building microgrid architectures which can selectively energize loads during extended outages



Lifecycle Funding Summary ($K)

	FY11	FY12	FY13	
OM	**3890**	**1440**	**1555**	**6885**
TM	**14,750**	**7720**	**7360**	**29,830**
XM	**325**	**335**	**620**	**1280**
Total	18,965	9495	9435	37,995

Technical Scope

DoD and DOE collaborate to design and implement three separate microgrids supporting critical loads at DoD bases to reduce reliance on commercial power (which becomes less reliable with increasing threat). Each is slightly larger and more complex in scope than the previous:

- Joint Base Pearl Harbor Hickam
- Fort Carson
- Camp Smith

A key part of the project is the standardization of the design approach, contracting, installation, security, and operation of these microgrids to support future applications.

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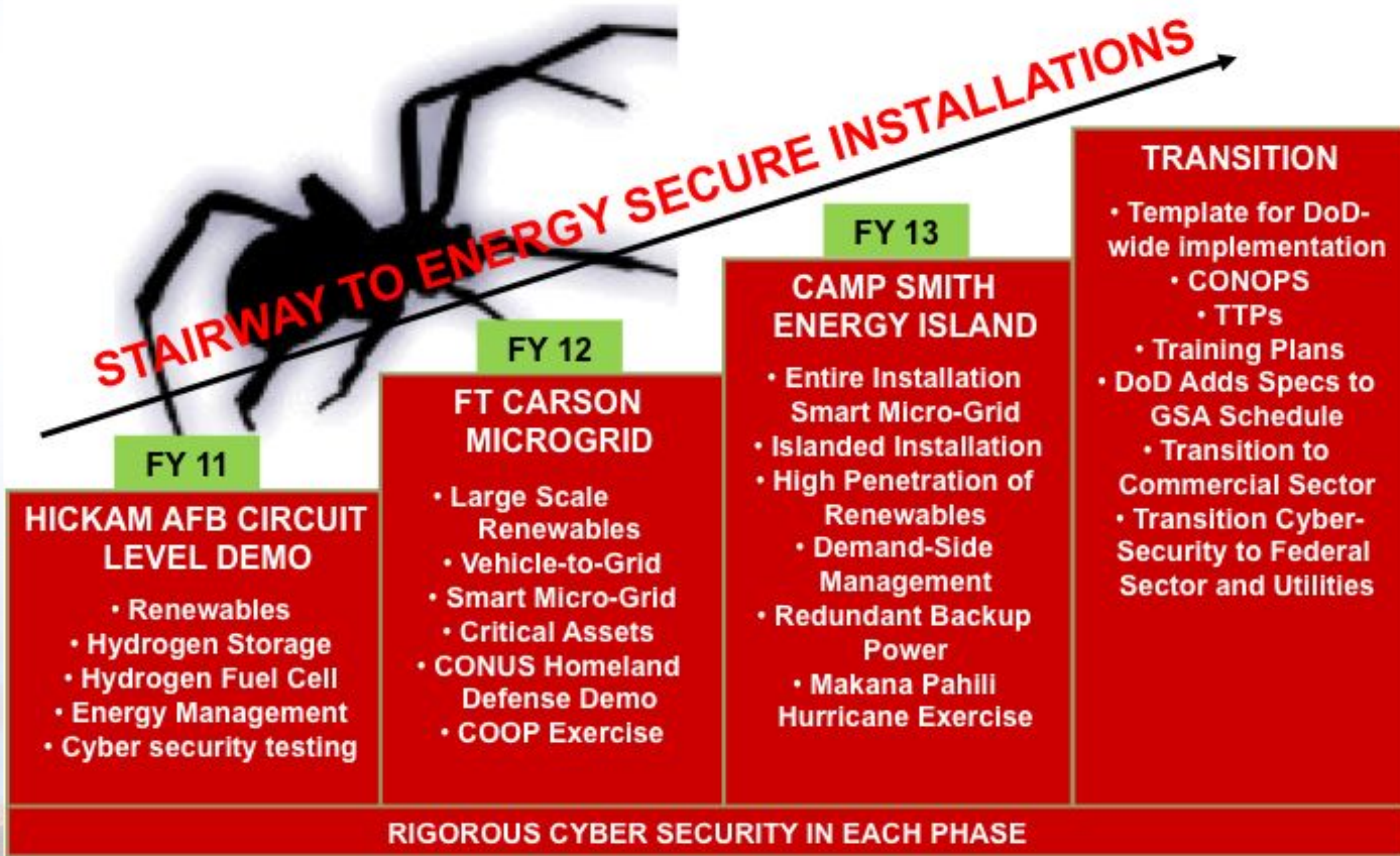
SPIDERS Technical Approach



SPIDERS Participants

PACOM, NORTHCOM, DOE, DHS

DOE National Laboratories

DOEP&P Power Surety Task Force

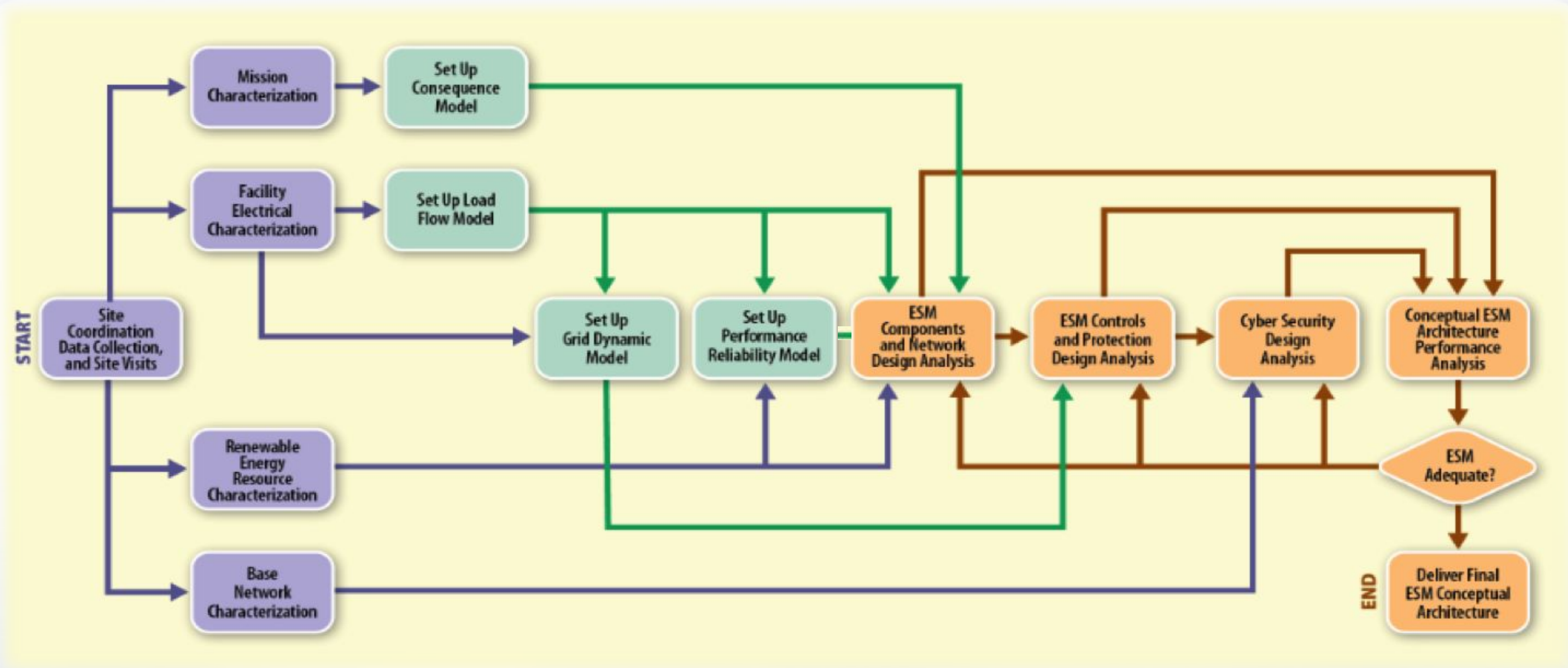
Military Services

Military Facilities Organizations

Local Utility Companies

States of Hawaii & Colorado

SPIDERS Technical Approach



- **Design Phase**
  - **Conceptual design – What are the microgrid requirements and what energy assets are needed?**
  - **Preliminary design – What are the microgrid functional requirements? How do we control and secure it?**
  - **Detailed design – Create a buildable construction specification, teaming with industry.**
- **Installation and Testing**
- **Operation and Transition**

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SPIDERS JCTD Status

- **DHS is no longer a JCTD sponsor (still a partner contributing in kind), means overall funding numbers are different now**
- **Implementation Directive, Management Plan, other JCTD administrative requirements are on track**
  - CONOPs, Tactics, Techniques and Procedures (TTPs), Integrated Assessment Plan, Operation Demonstration/Utility Assessment (OD/UA), Technical Transition Agreement (TTA), etc.
- **Hickam and Carson RFP releases announced at GovEnergy**
- **Hickam bid package released; industry day held August 25**
  - Contract to be awarded 10/14/2011
  - Carson industry day held August 25
  - Bid package to be released mid-October; will include conceptual design only
  - Contract to be awarded January 15, 2011

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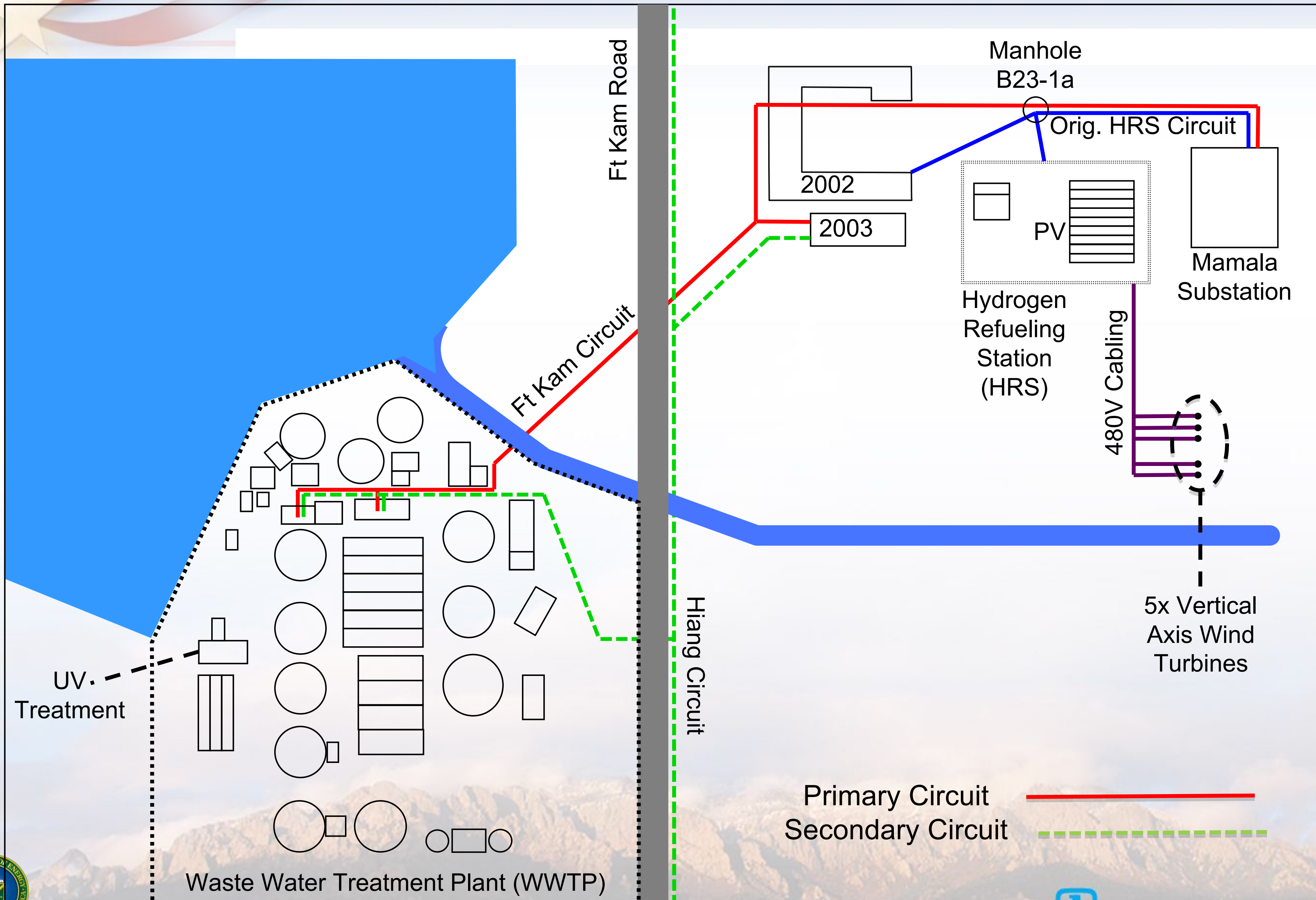
JBPHH Existing Electrical System



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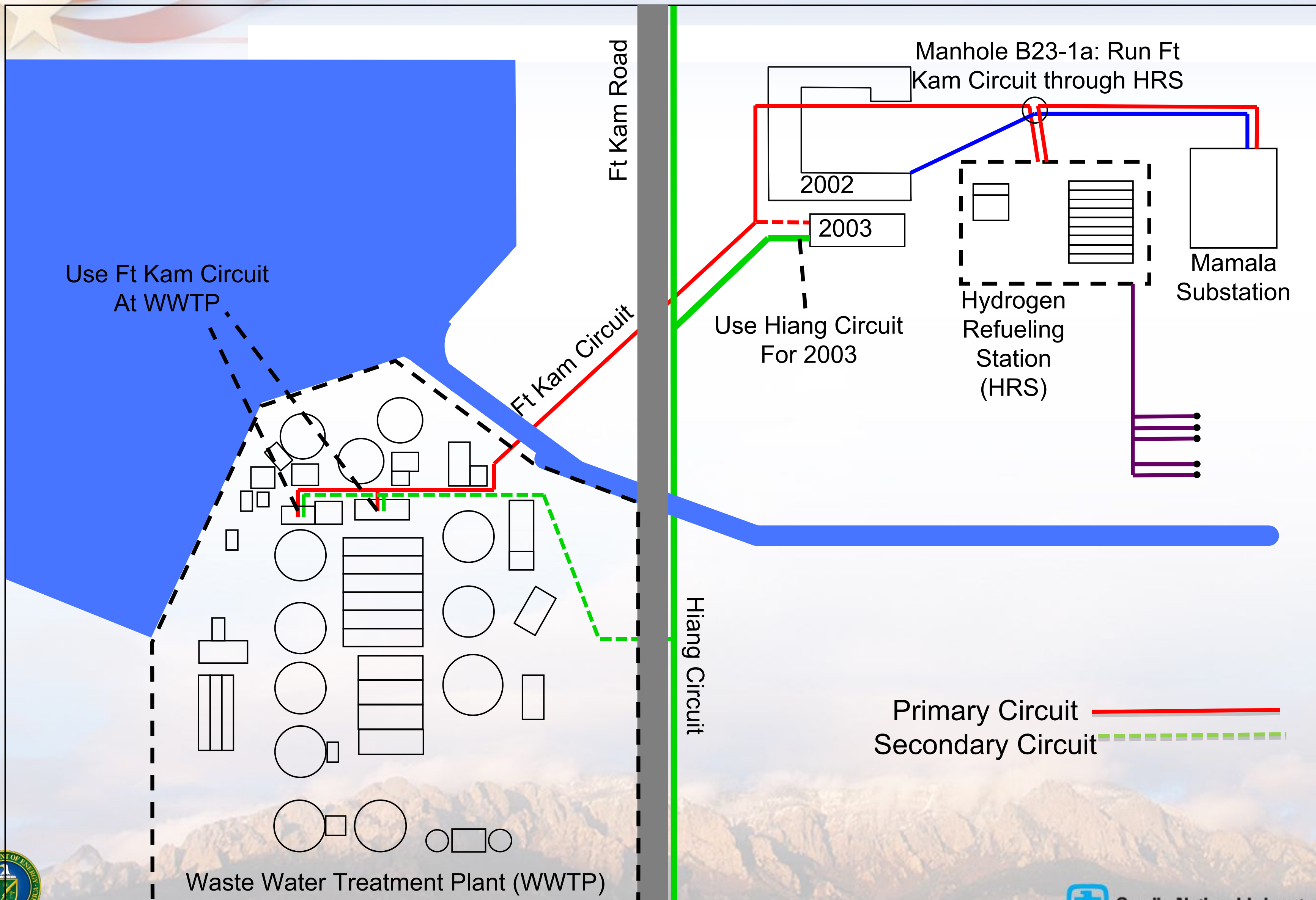
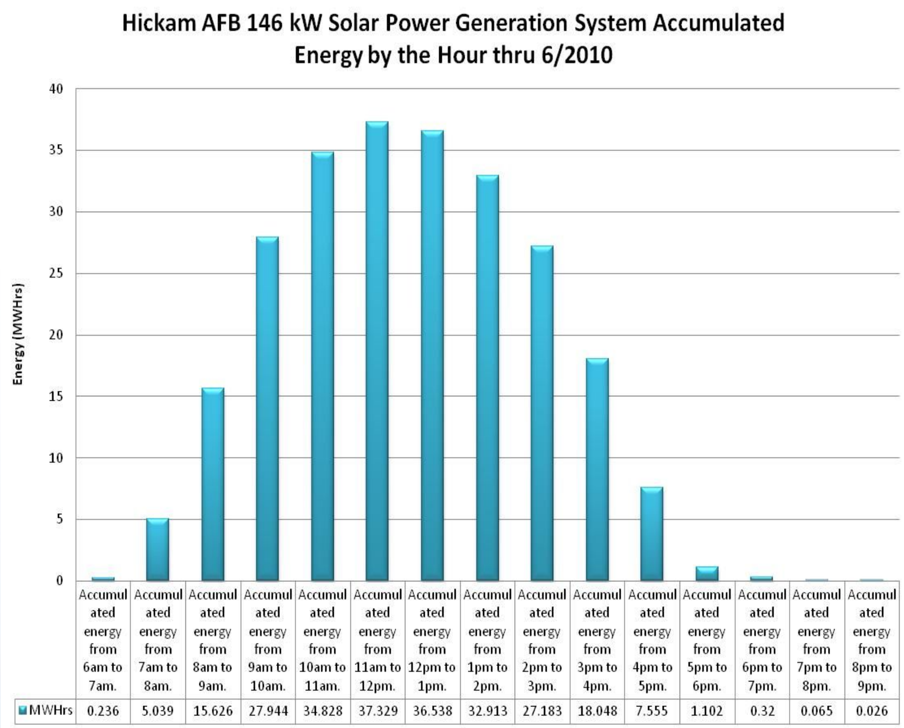
JBPHH SPIDERS Electrical System Reconfiguration

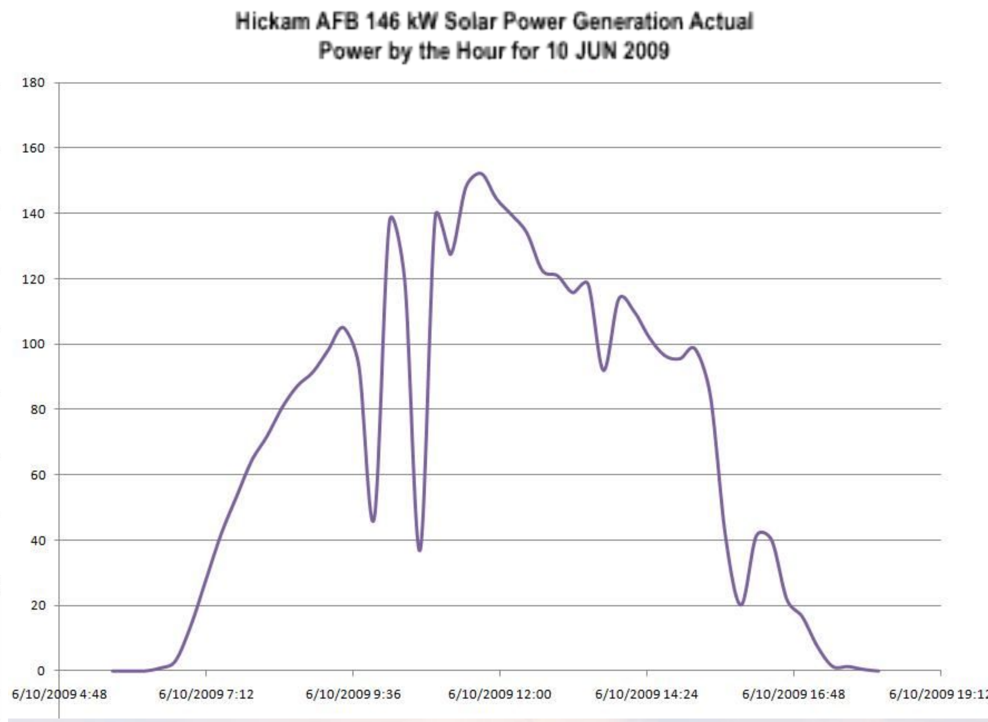


Site Characterization: Renewable Energy

- **Nominal (left) and variable (right) solar curves for existing facility**
- **Important to consider both as ESM performance depends on PV energy**

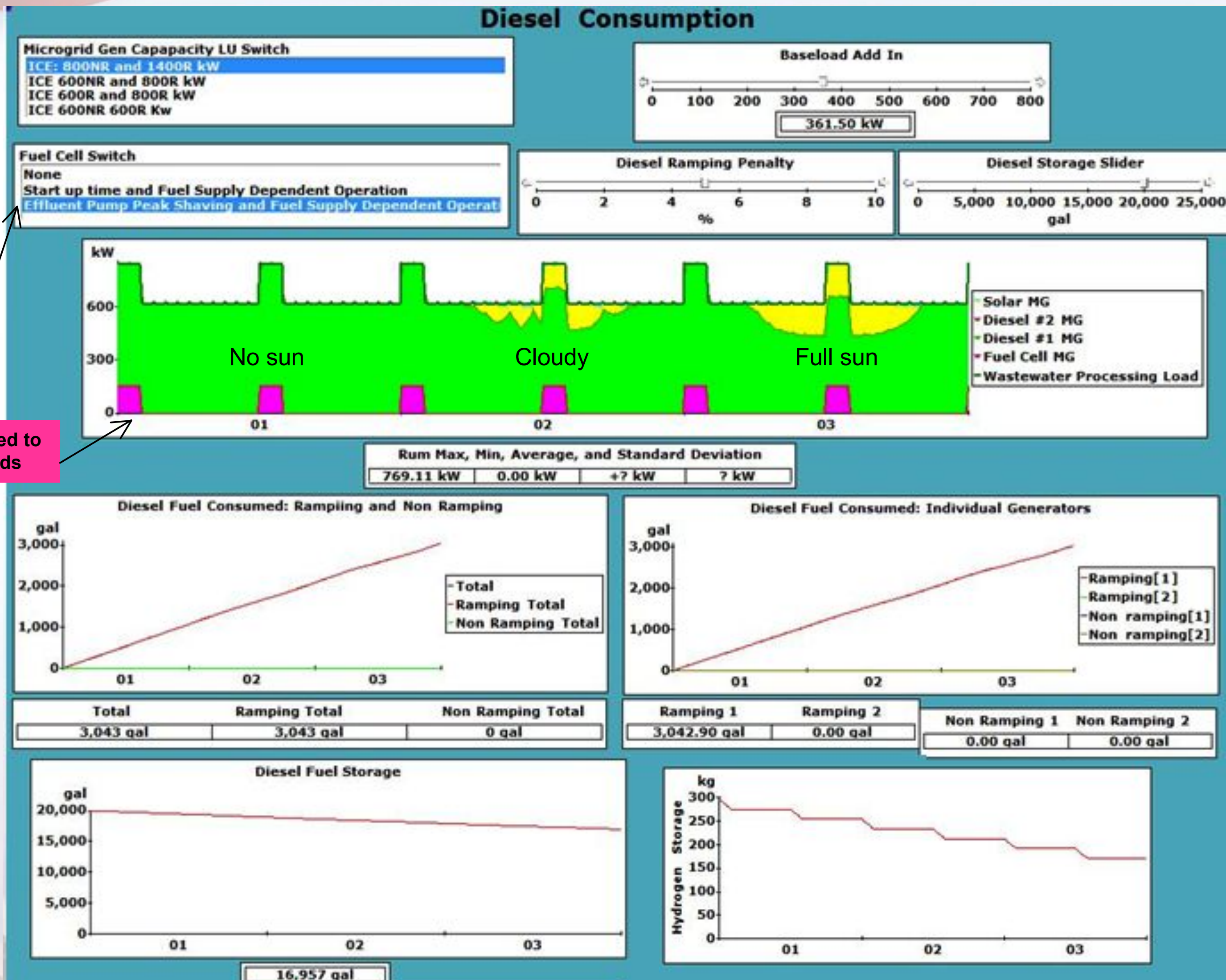


Accumulated solar generation



Solar output varies due to cloud cover

Systems Dynamics Modeling



Fuel cell used to follow loads

Systems Dynamics Design Modeling

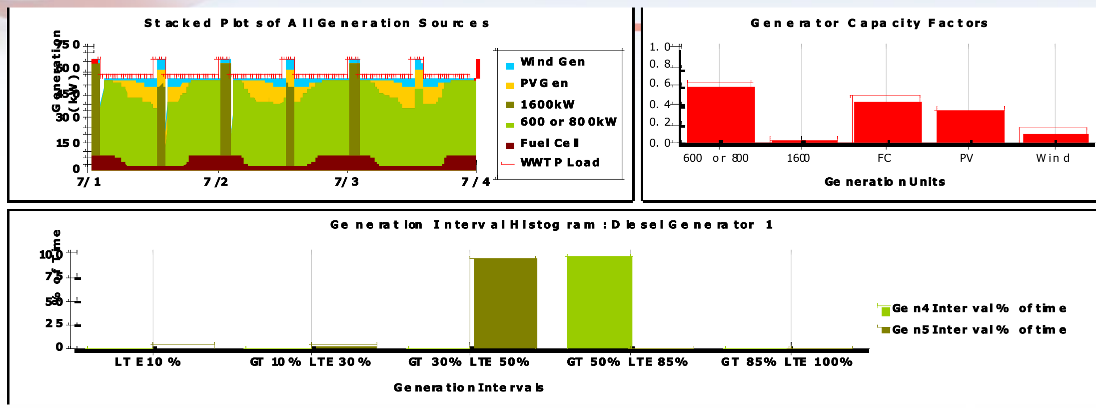


Figure 5.1: 560kW load, 600kW and 1600kW diesel generator, 100kW fuel cell

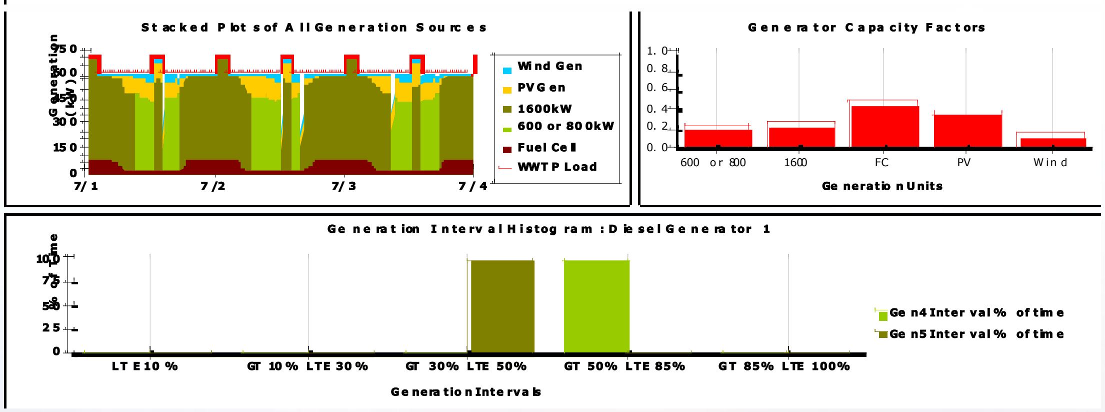


Figure 5.2: 615kW load, 600kW and 1600kW diesel generator, 100kW fuel cell

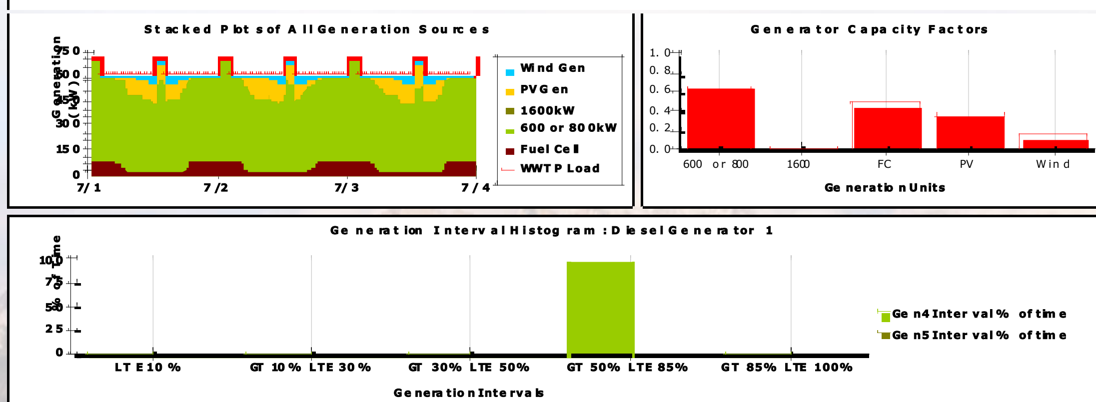


Figure 5.3: 615kW load, 800kW and 1600kW diesel generator, 100kW fuel

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Optimization-based Design Modeling

Metric of Interest	600kW Optimal	800kW Optimal	1600kW Suboptimal	1600kW Optimal	Base Case	Objective	Limit	Units
Variable Cost	**1,176,000**	**960,000**	**549,000**	**610,000**	**0.0**	**1,200,000**	**1,500,000**	dollars
Mean generator efficiency	**36.7**	**36.2**	**31.6**	**31.6**	**30.7**	**37**	**30**	percent
Average diesel deferred	**855**	**631**	**584**	**583**	**0**	**600**	**300**	gals/outage
Percent of time CLNS > 0	**0.25**	**0.25**	**0.50**	**0.25**	**9.8**	**0**	**1**	percent
Mean CLNS (when CLNS > 0)	**115**	**132**	**104**	**137**	**202**	**0**	**400**	kWh/outage
Fitness	**4.849**	**4.786**	**4.19**	**4.33**	**-118.4**	**N/A**	**N/A**	(unitless)
Primary diesel	600kw	800kW	1600kW	1600kW	N/A	N/A	N/A	N/A
Secondary diesel	1600kW	1600kW	600kw	600kw	N/A	N/A	N/A	N/A
Average CO2 deferred	9.49	7.01	6.48	6.48	0.0	N/A	N/A	tons/outage
Mean CLNS (all simulations)	0.29	0.33	0.52	0.34	19.8	N/A	N/A	kWh/outage
Average starts (primary)	0.978	0.978	0.988	0.988	0.988	N/A	N/A	starts/outage
Average starts (secondary)	0.048	0.048	0.048	0.048	0.988	N/A	N/A	starts/outage
PEM fuel cell size	160	100	100	90	0	N/A	N/A	kW
Additional hydrogen storage	0	0	0	0	0	N/A	N/A	kg

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Cyber Security

- **Cyber security**
  - Key/encryption/authentication compatibility
  - Logging/forensics/tamper adequacy
  - Acceptable impacts from security overhead
- **Incompatibilities can cause vulnerabilities (e.g. lack of support for an important security service)**
- **Complexity and variability of technology tends toward configuration errors and vulnerabilities**
- **How is the Cyber Security Architecture determined?**
  - Best practices/requirements (i.e. DoD DIACAP, C&A/PIT, STIGs, NIST, etc)
  - Analysis of the actual system, using a risk management approach, to adapt and augment as necessary based on system-specific requirements
- **Note that the development of a Cyber security architecture is a separate effort from the Cyber experiment activity being conducted by PACOM**

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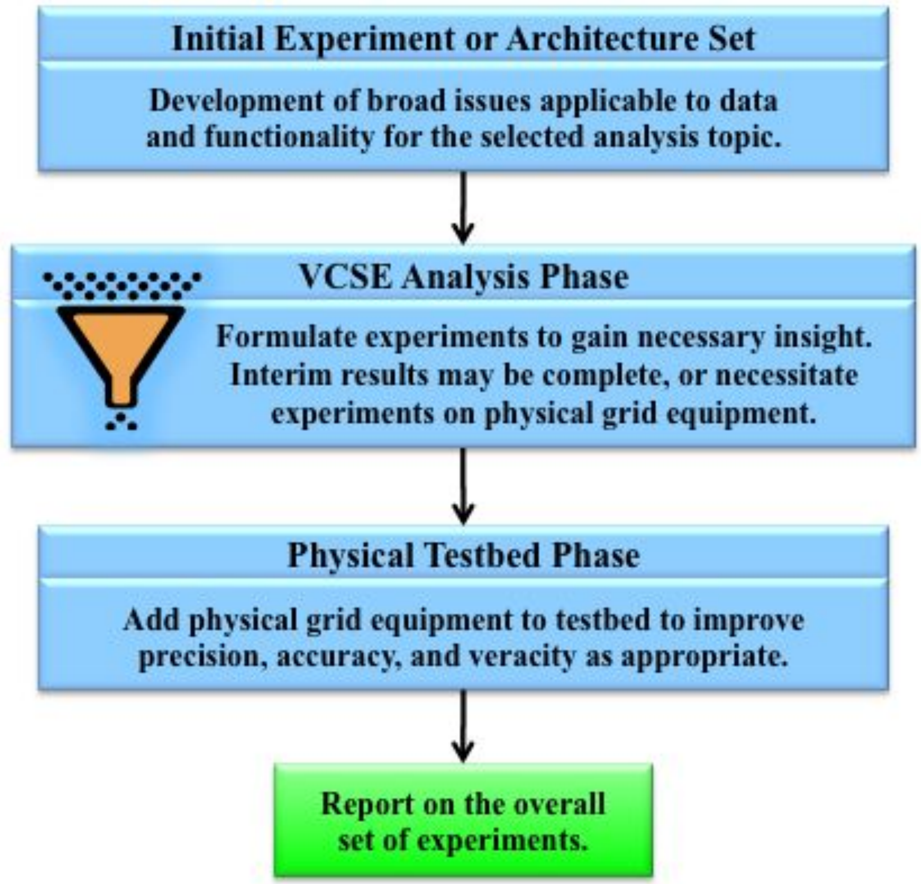
Controls Systems Design

- **Controls use cases:**
  - Automated grid management and control – frequency, voltage, load management, etc (anything automated, second-to-second requirements)
  - Supervisory control – human-in-the-loop grid management (i.e. base command decides to energize priority load)
  - Protective relaying – specific channels dedicated to coordination between relays (also automated, time sensitivity on the order of cycles)
  - Microgrid configuration management – remote device (re)configuration, downloading fault data, engineering configuration and management, etc.
  - Connections to other systems: with utility systems for ancillary services, and with building systems for efficiency / load management
- **Controls design must ensure expected microgrid performance meets standards for power quality, voltage, frequency, protection, etc.**
- **We protect the DATA and the FUNCTIONALITY associated with these.**

Cyber Security Design

- **Test cases for cyber**
  - Usability: how difficult is it to install, maintain, and use the cyber security architecture? Does it function reasonably (i.e. it can't take 20 minutes to log into a system)?
  - Functionality: how well does the cyber security architecture function against possible attacks?
  - Transparency: does the cyber security architecture interfere with normal operations (i.e. it can't introduce latency on a protective relaying channel)?
- **Design is supported by testbed environments (perhaps of the simulated-emulated-physical sort) over microgrid design domains of controls, communications / networking, and the electrical energy system**
- **Test system assets can be retained to support red team/auditing practice**



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Virtual Control Systems Environment (VCSE) Heterogeneous Simulation Technologies

Domain	Physical	Emulated	Simulated
Control	PLC, SCADA, relays, historian…	Virtual SCADA server; Soft PLC; VMWare ESXi, virtual historian…	RTU model, relay model, simulated ladder logic…
Network	Cables, firewalls, routers, NIDS…	DynaMIPS (CISCO router); QEMU…	OPNET (SITL), routing model, wireless channel model…
Power Grid	(1)	N/A	Solar/wind models, SimPowerSystems, load flow software…

(1) Not yet integrated with VCSE, may include diesel generators, PV system, breakers, batteries…

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