SIRFN Capability Summary
Oak Ridge National Laboratory

Introduction

The Distributed Energy Communications and Controls (DECC) Laboratory offers a unique test bed for testing distributed energy resources, responsive loads, smart inverter and microgrid controls, communications and protection. The DECC is a systems integration laboratory and provides the whole solution to ORNL's smart grid technologies. The DECC laboratory is connected to and is part of the ORNL campus distribution system and thus DECC testing offers "real-world" testing of these control schemes and technologies which a number of utility industry colleagues have indicated is needed to verify the control functions developed for these technologies. The DECC laboratory has evolved from the testing of a single smart inverter to multiple inverters and by the end of FY12 will be capable of microgrid testing with on-grid and islanding capabilities as well. The DECC laboratory encompasses all areas including renewable and DER integration, building automation, EV/PHEV integration, mircrogrids, distribution automation, cyber security, simulation and testing, and data acquisition and analysis. The laboratory is leveraging sister projects to offer power flow control of the cable between inverter test systems so that the impedance can be varied and also our ownership and operation of the ORNL distribution system allows us to reconfigure and change system conditions for a broader range of testing. The overall ORNL campus is evolving to be a sustainable environment with renewables, EV charging, smart meters, synchrophasors and responsive loads thus offering an overall smart distribution functionality for DECC testing.

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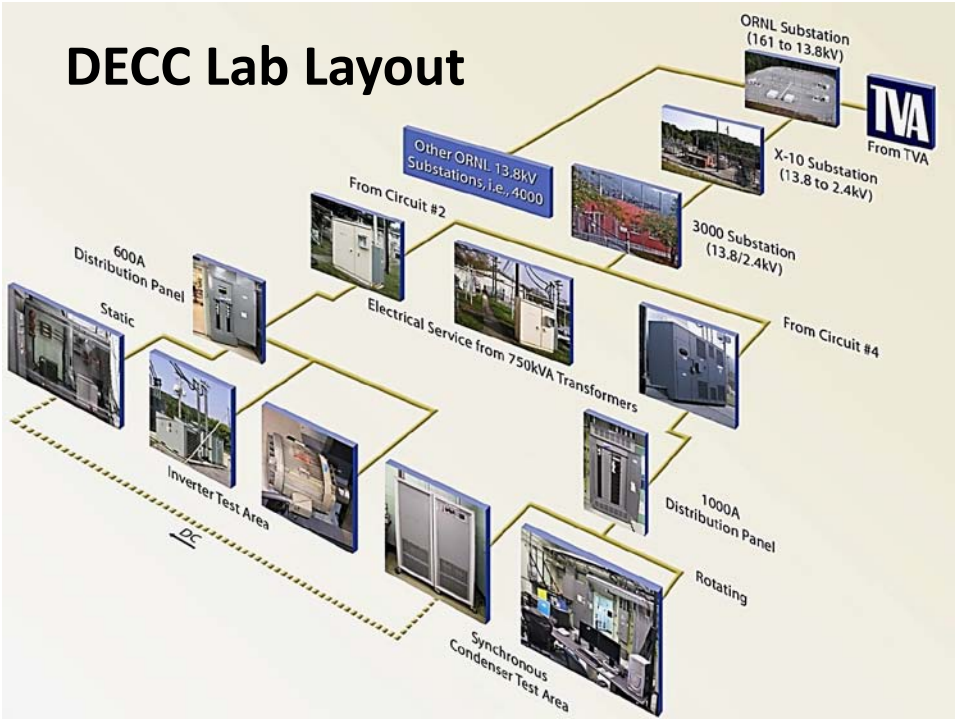

Website URL: http://www.ornl.gov/sci/decc/

Renewable Energy and DER Integration

Desired Level of SIRFN Participation: 3

- 1 = Low 2 = Med 3 = High

Description of Activities

- Utility grid interface inverters for distributed energy resources such as fuel cells, solar cells, or microturbines
- STATCOMs for reactive power compensation
- Active power filters for harmonic compensation
- Multilevel converters for utility applications such as static var generation, voltage regulation, harmonic compensation, back-to-back intertie of two asynchronous systems, HVDC applications, and distributed generation/utility interfaces
- Development of novel techniques to calculate active and reactive power under unbalanced or nonlinear conditions
- Deliver stored energy from vehicle to grid (V2G)
- DECC Lab PV Test System
- Advanced low-cost carbon fiber manufacturing for structural components in renewable generation

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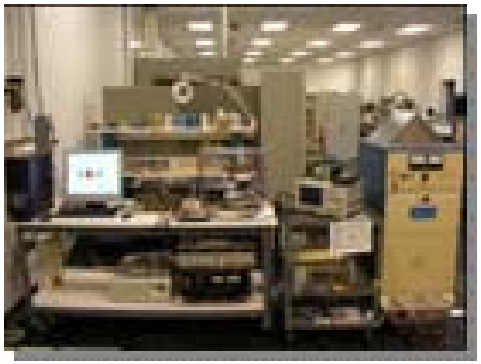

50kW PV Array supply 400-600Vdc, 135Adc

Website URL: http://peepsrc.ornl.gov/index.shtml

SIRFN Subtask 2.1

Renewable Energy and DER Integration

Desired Level of SIRFN Participation: 3

- 1 = Low 2 = Med 3 = High

Description of Activities

Integration of DER/DR/ES/EV

✓Power conversion
✓Voltage/VAR support
✓Advanced controls
❑B2G
❑ Volt/Var Optimization (CVR)
❑Interoperation
❑Power flow
❑Central control & monitoring
❑Device Protection

Distribution Automation

✓Load and source modeling, testing
❑Layered Architecture
❑Data acquisition and communication
❑Optimize Voltage schedule and load sharing
❑Center operation and distributed autonomous control

✓ Prior year accomplishment
❑ FY12 focus
❑ Out Years

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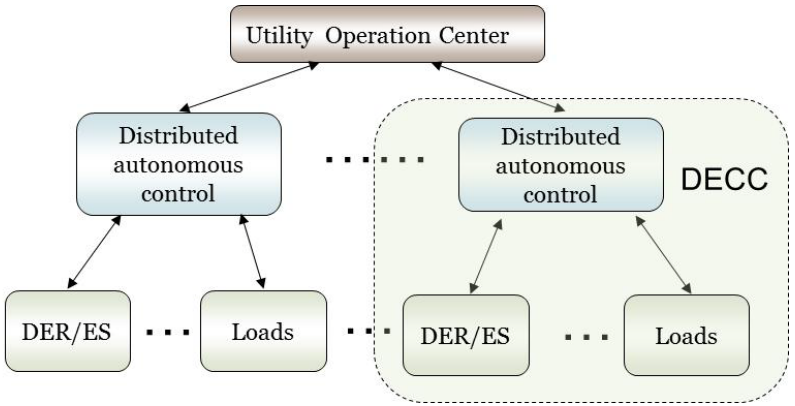

Microgrids

✓Grid Interconnection
❑Voltage & frequency stability
❑On-grid & islanding operation
❑With or without synchronous generation
❑Transition from on-grid to islanding and back
❑Inverter mode switching (i.e., P2030)
❑Microgrid Protection
❑Multiple and embedded microgrids

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Building Automation

Desired Level of SIRFN Participation: 3

- 1 = Low 2 = Med 3 = High

Description of Activities

- The Maximum Energy Efficiency Building Research Laboratory (MAXLAB) is under development and will include a new standalone laboratory building and two light commercial building "flexible research platforms (FRPs)." The FRPs provide, for light commercial buildings, what the research houses provide for housing–unoccupied research apparatus with known occupancy effects on energy consumption because occupancy effects are simulated during the tests. The FRPs expose 'test buildings' to natural weather conditions for purposes of R&D leading to system/building-level advanced energy efficiency solutions for new and retrofit light commercial building applications. The platforms provide the opportunity to prove solutions in a low risk environment so they can be accepted with speed and scale in actual commercial buildings. Using the FRPs, essentially everything about the 'test buildings' can be changed and evaluated to capture interactive effects, reduce costs and energy consumption, and provide physical validation of models.
- Evaluating preproduction prototypes of new energy-efficiency products in realistic test beds

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PEV Integration

Desired Level of SIRFN Participation: 3

- 1 = Low 2 = Med 3 = High

Description of Activities

- Advanced soft-switching inverter topologies
- Packaging technologies for EMI minimization as well as space and weight reduction
- DSP-based control technologies for motor drives
- Electric, hybrid electric, plug-in hybrid, and fuel cell vehicle traction drives
- Motor-assisted turbochargers & auxiliary drives
- Multilevel inverters for high voltage and/or high power motor drives
- Wide bandgap materials-based power electronics and high temperature packaging
- Testing, characterization, and modeling of power devices
- Modeling and simulation at the device, module, and system levels
- DC-to-DC converter
- Wireless charging magnetically couples an electric source with a car battery
- Advanced 3-D additive manufacturing of complex components

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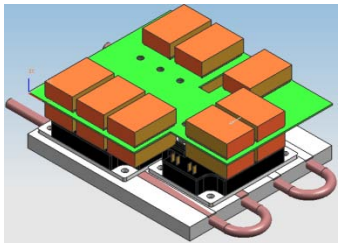

Website URL: http://www.ntrc.gov/

SIRFN Subtask 2.4

Microgrids

Desired Level of SIRFN Participation: 3

- 1 = Low 2 = Med 3 = High

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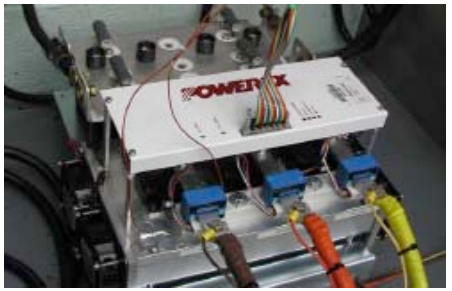
Description of Activities

- The overall ORNL campus is evolving to be a sustainable environment with renewables, EV charging, smart meters, synchrophasors and responsive load thus offering an overall smart distribution functionality for DECC testing.
- Solar assisted charging stations
- The tracking solar array is a prominent feature of ORNL's east campus quad. At its peak output of 4.2 kW, the array produces about half of the power needed by an average Tennessee home each year.
- A stationary 288-ft array of 168 solar panels converts the sun's light into direct current (DC) electricity. The electricity produced helps two buildings at ORNL achieve net zero energy status (i.e., the energy provided by on-site renewable energy sources equals the energy used by the buildings).
- By installing wireless sensors and replacing faulty traps along the 12 miles of its steam lines, ORNL expects to save as much as $675,000 per year.



Website URL: http://sustainability-ornl.org/Pages/home.aspx

SIRFN Subtask 2.4

Microgrids

Desired Level of SIRFN Participation: 3

- 1 = Low 2 = Med 3 = High

Description of Activities

Micro-grid Design & Modeling– Convert an entire installation to micro-grid and enable generation balancing and intentional islanding for extended continuity of operations

Visualization and Real-time Monitoring - Utilizing ORNL's GridEye technology to enable reliable operations of variable generation.

Smart Grid Technologies & Systems Integration - Incorporate technologies to enable automated load balancing, automatic system re-configuration, and local volt/var control with distributed resources and clean energy technologies

- ***Responsive Load Management –*** Optimizing efficiency, provide dynamic load shedding, and utilize load as a reliability resource

Cyber-security – Defense in-depth against cyber-physical attack through the application of virtual secure enclaves and resilient controls

Logistics & Transportation Analysis – analyze vehicles, routes, transfer points, and retail locations that are a part of the typical fuel supply chain.

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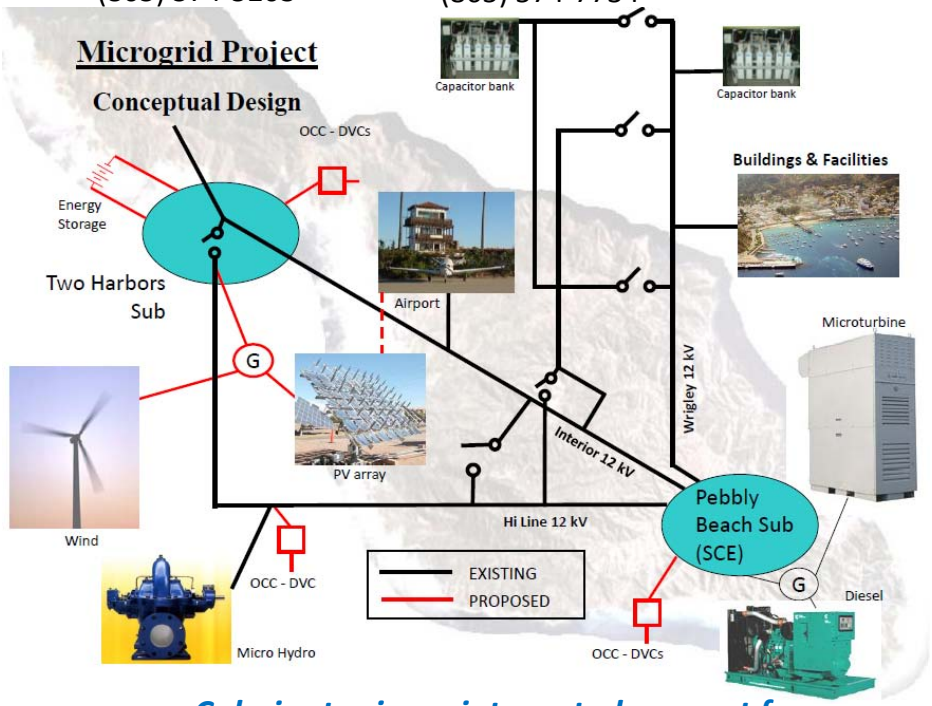

Culminates in an integrated concept for a DoD-wide approach to ensure installation energy security

- *Reliable, secure power*
- *Reduce or eliminate categories and quantities of fuel and equipment*

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Distribution Automation

Desired Level of SIRFN Participation: 2

- 1 = Low 2 = Med 3 = High

Description of Activities

- Conductor-connector system that provides higher strength to secure the overhead conductor systems and higher electrical conductance to maximize power flow
- Smart connectors to monitor connector health against failure and premature replacement
- Advanced metering infrastructure system that includes smart meters, cell relay, and a collection engine and data management system
- Smart sensors with integrated circuit logics for intelligent distribution components
- Power flow control using magnetic amplifiers providing smooth, simple, cheap and reliable control of power flows

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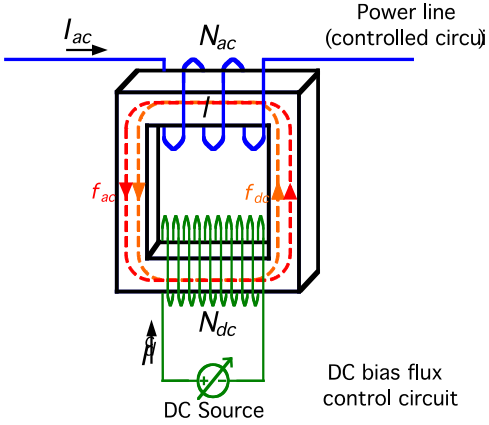
Three Phase 320 Amp Current Source for Electrical Meters

WECO F2150 Three Phase for Meter Testing and Calibration



Cybersecurity

Desired Level of SIRFN Participation: 3

- 1 = Low 2 = Med 3 = High

Description of Activities

- Integration of computational and physical resources to ensure system operation under adverse conditions
- Operation through outage or attack
- Predictive awareness
- Security in the cloud
- Self-protecting data and software
- Trustworthy wireless for critical infrastructure sites
- Advanced security acceleration for the Smart Grid
- Cyber-physical solutions
- Developing and demonstrating a system for conducting cyber security vulnerability detection of smart grid components and systems by performing static analysis of compiled software and device firmware
- Secure wireless network using ORNL hybrid spread spectrum waveform

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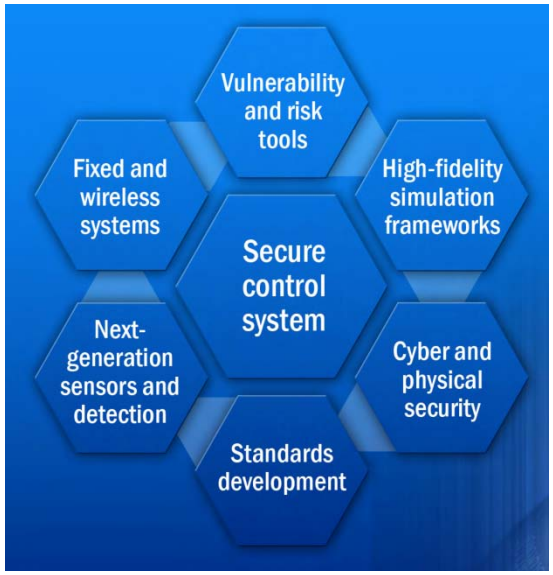

Website URL: http://www.ornl.gov/sci/ees/mssed/

Summary of Capabilities for Simulation and Testing

AC and DC sources:

- Advanced conductor testing to ensure operation over life of system
- High-current, low-voltage dc power induces thermal cycles on conductor
- Application of DC distribution to existing AC infrastructure

Powerline Conductor Accelerated Test Facility (PCAT)

- Controlled current or temperature
- Conductor and accessories
- Up to 300 C
- 2400 feet of conductor
- Low Voltage, 0 to 400 Vdc
- High Current, up to 5,000 Adc

VERDE: Visualizing Energy Resources Dynamically on the Earth. Applications to visualizing microgrids, renewable investment strategies and policies, and grid dynamics have been demonstrated in VERDE.

Storage:

Flow Batteries: efficient, economical, and safe flow batteries with high power capabilities for the Grid

- Innovation of new materials and processes
- Balance of plant & electrical elements
- Short stack field testing in 'small-Grid' setting
- Scale-up for large-scale Grid storage
- Modeling at all stages

Controls:

- Power Electronics
- Smart Technologies – fault current limiter

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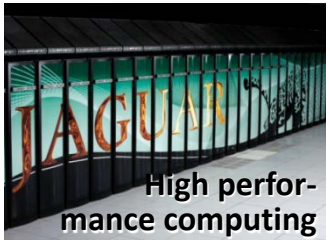

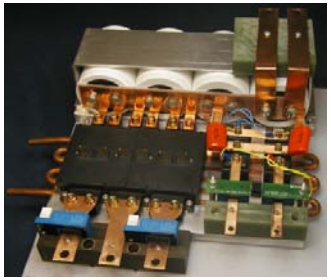

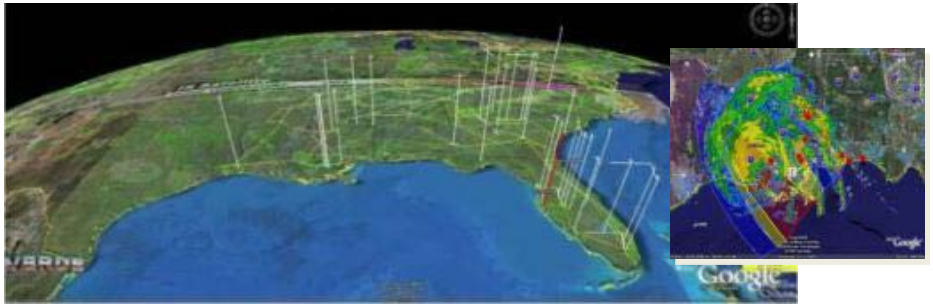

Summary of Capabilities for Data Acquisition and Analysis

Data Acquisition:

Grideye – Wide-area grid monitoring network

Provides situational awareness at the transmission and distribution level

- Frequency monitors to collect real-time data
- Low cost monitors compared to phasor measurement units
- Real-time display of frequency swings
- Real-time display of phase angle
- Provide input for dynamic modeling
- Goal is to deploy over 1,000 systems across country

Computer Analysis:

MatLab is a numerical computing environment and fourth-generation programming language. Simulink is a commercial tool for modeling, simulating and analyzing multi-domain dynamic systems. Both numerical computing and modeling. Simulink provides for faster development of smart and microgrid controls for testing at DECC.

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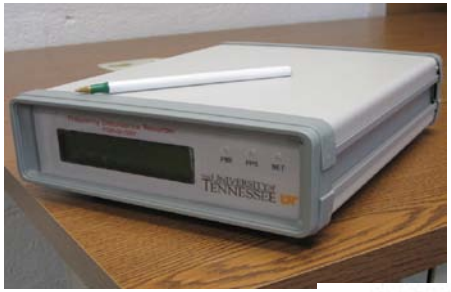

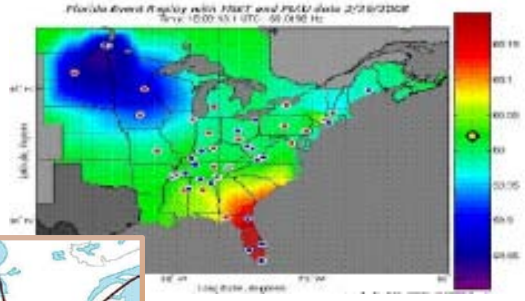

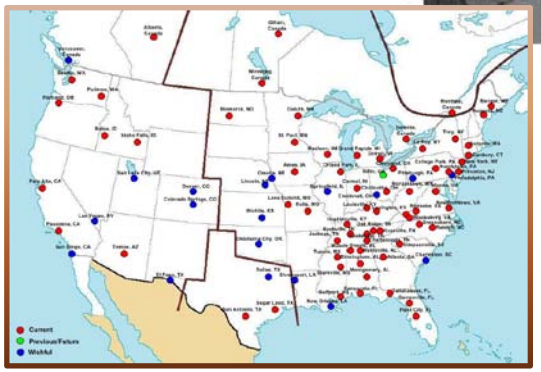

GridEye Sensors placed across the USA can detect abnormal operating modes in real time.