DOE/ComEd Microgrid Project at Illinois Institute of Technology

Presented by
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Building Block of Smart Grid: Microgrids

- Protect critical infrastructure from power losses in the event of physical or cyber disruptions to the bulk electric grid.
- Locally integrate renewables and other distributed generation sources and provide reliable power to customers.
- Ensure that critical operations can be sustained during prolonged utility power outages.
- Power grid will be the “grid of grids” in the future.
DOE Project Objectives

- Demonstrate higher reliability introduced by the microgrid system at IIT
- Demonstrate the economics of microgrid operations
  - Demonstrate value of ancillary services to the grid
- Allow for a decrease of fifty percent (50%) of grid electricity load via internally generated power
- Create a permanent twenty percent (20%) decrease in peak load from 2007 level
- Defer planned substation through load reduction
- Offer a distributed system design that can be replicated in urban communities.
Boundaries of IIT Microgrid

IIT Microgrid is located 2.5 miles south of downtown of Chicago and is bounded by major streets, highways, and railroads.

- Funded by the Department of Energy
- Located at IIT
- Involves the entire campus

“The perfect power system will ensure absolute and universal availability of energy in the quantity and quality necessary to meet every consumer’s needs. It is a system that never fails the consumer.” Bob Galvin
IIT Microgrid Overview
IIT Microgrid Control

- Monitoring signals provided to the master controller indicate the status of DER and distribution components.
- Master controller signals provide set points for DER units and building controllers.
- Master controller communicates with microgrid field devices through protocols like Modbus, BACnet, DNP3, etc.
- Building controllers communicate with sub-building controllers through a Zigbee wireless control and monitoring system to achieve a device level rapid load management.

- A firewall separates the subnet that includes master controller and all the devices from the outside internet.
Microgrid Communication

- Complex communication (i.e. multiple protocols) means more potential vulnerabilities and unintentional errors.
- Linking to the Internet may introduce common vulnerabilities.
- Wireless communication (e.g. Zigbee) may incur more potential vulnerabilities.
- More network nodes means more exploitable entry points and vectors.
- Extensive data gathering and two-way information flows may broaden potential for compromises of data confidentiality.
Cost of the IIT Microgrid

- Total project cost: $13.6M
  - $7.6M from DOE, $6M Cost Share
  - $9.5M Implementation, $4.1M Research and Development

- Deferred Investment Cost at IIT Microgrid
  - The IIT Microgrid project has deferred $7,000,000.

- Reduction in total annual marginal CO2 emissions (%) =
  - 1 - (49,078,224.44/52,536,042.84) = 6.58%

- The total annual saving at IIT Microgrid is $1,171,878.60.
Community Microgrid
Community Microgrid at IIT

Technology Product and Testing Providers

- Quanta Technology
- S&C Electric Company
- Schneider Electric

Project Lead & Electric Utility
Key Technology: Microgrid Controller

- ComEd
- McCom (Master Controller for Microgrid)

Technology Developers

- Illinois Institute of Technology
- University of Denver
- Alstom Grid
- Argonne National Laboratory

Bronzeville Community Microgrid (BCM Physical System)

Database and Solution Platform Providers

- Microsoft CityNext
- Microsoft Solution Platform
- OSIsoft PI Systems

Bronzeville Community Microgrid (BCM Design Model)
DC Microgrid at IIT

Keating Hall of IIT
- PV Array
- DC-DC Controller
- DC-AC Inverter
- DC Bus
- AC Main Switchboard
- AC Bus
- Storage
- DC-AC/AC-DC Bidirectional Converter
- DC Load
- Battery
- AC Load

Hybrid Microgrid
- Localized AC Loads
- Localized DC Loads
- Interlinking Converters
- Other Loads

Utility Grid
- Opened during Islanding Mode
CSMART: (Center for Smart-Grid Applications, Research, and Technology)
Project Objectives

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A commercial grade replicable microgrid system

- **Key attributes:**
  - Easy to configure
  - Easy to maintain
  - Integration with any network flow model
  - Easy for new users to understand
  - Able to control frequency and voltage in both connected and island mode
  - Seamlessly connect and disconnect from the grid
  - Able to control direction of power internally for Conservation Voltage Reduction
  - Able to sell ancillary services to the connected grid (fast regulation, curtailment, etc.)
  - Able to provide uninterruptable power to critical loads inside the microgrid
Why Standards and Standards-based Models?

- Avoid “spaghetti” software between applications
  - Avoid multiple copies of same data in multiple formats from different vendors
  - Use a single copy of the data that is compatible with all applications

CIM and IEC 61850 are global standards that provide 90% of what is required for a microgrid information model

- Need a highly detailed model of the power system
- Standard file format
- A model that power system software vendors will adopt

CIM and IEC 61850 provide standard mechanisms for expansion, thereby allowing the microgrid solution to be developed and commercialized.
How does the IEC Modeling Process Work?

**Recognized Process**
- Model maintenance tooling chosen by IEC
- File formats are standard
- Creates documentation as model is maintained
- CIM Adapter translates model information into AF

**IEC Architect**
Edit the model in standard UML and start from base model from IEC

Choose the appropriate subset

- Creates and manages AF Library
- Manages AF Elements and Relationships

**CIM Tool**

**Instances**

**Changes**

**Standardized XML File Formats**
Objectives:

- Low cost method of configuring AF database
- Efficient method to configure the network flow model
- Ease of migration to other microgrids
- Automatic tagname creation per IEC 61850 standard
- Automatic tag configuration using OSIsoft 61850 “connector”
- Easy to modify and maintain via CIM incremental updates
- CIM messages to the network model
- Interoperable with any network model accepting CIM XML
- Share information with other microgrids and the area electric power system
Microgrid Extensions to IEC 61970 CIM standard

- Microgrid
- PMU
- AC lines with PMU
- Breakers-switches with PMU
- Transformers with PMU
- DERs (PV, Battery, EV charging with PMUs)
- CHP with PMU
- Caps and reactors with PMUs
MicroGrid Specific AF Templates
**MicroGrid data structure AF Templates**

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<th>Description</th>
<th>Default Value</th>
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Added AF Templates

- Unwrapped angle
- Angle differences
- Event detection
- Grid Failure detection
  - FFT
- System model identification (Realization)
Example of Unwrapping Angles

San Leandro Unwrapped and Raw angle and frequency

- VoltCH-A_UW
  -58365
- VoltCH-B_UW
  -58244
- VoltCH-C_UW
  -58484
- OAK_Phase.PhasorVoltCH-A.Angle
  -42.839
- OAK_Phase.PhasorVoltCH-B.Angle
  77.556
- OAK_Phase.PhasorVoltCH-C.Angle
  -161.91
- OAK_Freq
  60.019

Angles at IIT Microgrid
Angle differences, using Element Relative displays
PI ProcessBook automatic GIS display from AF
Example Waterfall chart for the FFT
Cyber Secure Synchrophasor Platform (CSSP)

- HA running on two SEL 3355 substation hardened servers
- Hot failover interfaces (IEC 61850, C37.118, Modbus, DNP3, OPC)
- PI FFT for grid failure detection
- Configuration tested at Idaho National Laboratory
CSSP Architecture for Microgrids
SEL 3355 Substation hardened PCs – Microgrid Controller

**Operating System:**
Microsoft Windows Server 2012 R2 (64-bit)

**Chassis and Mounting:**
3U Horizontal Rack-Mount

**Processor:**
Intel i7-3612QE Quad Core 2.1 GHz

**Temperature Range:**
–40° to +60° C

**Expansion Slots:**
5 Slots: 1 PCI, 2 PCIe-x1, 2 PCIe-x4

**Power Supply A:**
High Voltage: 125/250 Vdc or 120/240 Vac

**Power Supply B:**
High Voltage: 125/250 Vdc or 120/240 Vac

**RAM Slot 1:**
8 GB DDR3 1333 MHz ECC Mini-UDIMM

**RAM Slot 2:**
8 GB DDR3 1333 MHz ECC Mini-UDIMM

**SSD Slot 1:**
120 GB Industrial-Grade SLC SSD

**SSD Slot 2:**
120 GB Industrial-Grade SLC SSD

List price = $8085
Dynamic Event Triggering and Power Oscillation Modeling from Phasor Data

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PMU: device which measures waveforms of alternating current (AC) electricity in a phasor representation using a common time source (GPS)

Synchronized and real-time measurements of:
- Phase angle (for power flow)
- Frequency [Hz]
- Real Power [W] and Reactive Power [VAR]
- Dynamic behavior of power flow

Fast sampling (60 or even 120Hz) of many signals
- Demand on data/storage
- Data management

Software Development and Results
A preliminary of active management

Data management of synchronized PMU data in OSIsoft PI server and interface to Matlab GUI for analysis, plotting, event detection and dynamic modeling

Automatic event detection implemented in Matlab GUI
Real-time event detection development PI template Dynamic models

When event occurs, one must identify event and dynamics.
Contribution: automatically characterize an event (identify dynamics)

Approach:
- For sustained oscillations: fixed length Parallel FFT (PFFT) on downsampled data for high freq. resolution
- For damped oscillations: estimation of linear finite order model with automatic realization algorithm

End Result:
- Heat plots for observing change in frequency
- Linear finite order models for power flow dynamics
- Models can be used for simulation/damping control

Main Matlab GUI
Event Detection and Analysis
Modeling with Realization

Detection of events via Filtered Rate of Change (FRoC)
Allows for automatic real-time event detection

Modeling of events via Parallel FFT and Realization
Allows for:
- Real-time visual confirmation of event and formulation of linear low order dynamic models
Commercial microgrid Summary

The US Department of Energy selected ComED/IIT/OSIsoft to demonstrate commercial grade microgrid controllers in a highly competitive bidding process.

Business Challenges

A. Provide uninterruptable power to critical loads
B. Rapid restoration after storms or disasters
C. Lower carbon emissions

Solution(s)

A. Build a standards based solution
B. Implement in AF
C. Application of advanced decoupled control with PMUs as measurement devices

Results and Benefits

- Income from sales of ancillary services
- Income from carbon credits
- Allows Utility to integrate more renewable
- Lower cost of distribution inside grid

Argonne Labs, University of Denver, S&C, AlstomGrid, and Schneider Electric are also involved.
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Questions

Please wait for the **microphone**
before asking your questions

State your
**name & company**
THANK YOU