DOE/ComEd Microgrid Project at Illinois Institute of Technology

Presented by

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Illinois Institute of Technology;
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robert w. galvin center for electricity innovation

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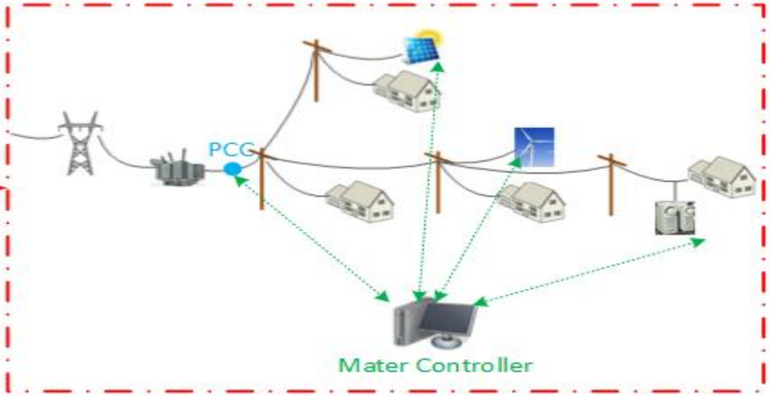
Building Block of Smart Grid: Microgrids



- 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

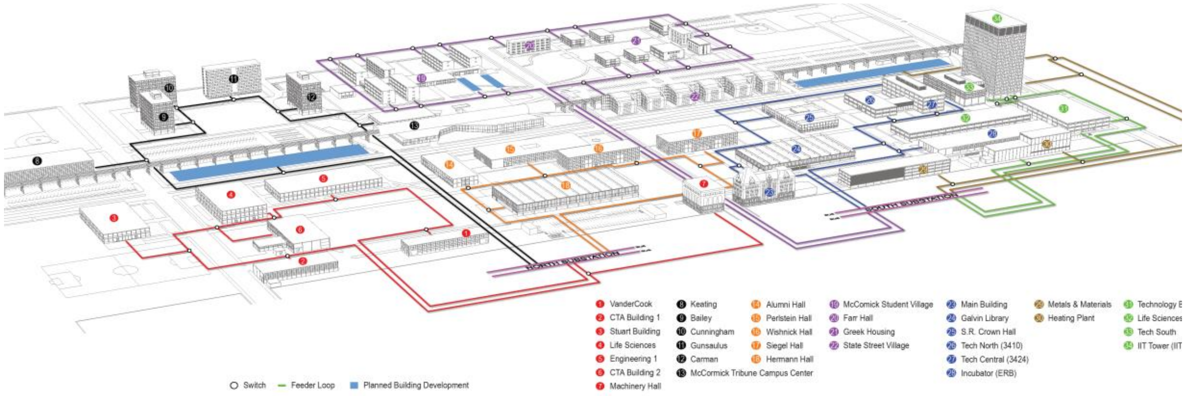
- Demonstrate higher reliability introduced by the microgrid system at IIT
- Demonstrate the economics of microgrid operations
  - Demonstrate value of ancillary services to the grid
- Allow for a decrease of fifty percent (50%) of grid electricity load via internally generated power
- Create a permanent 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

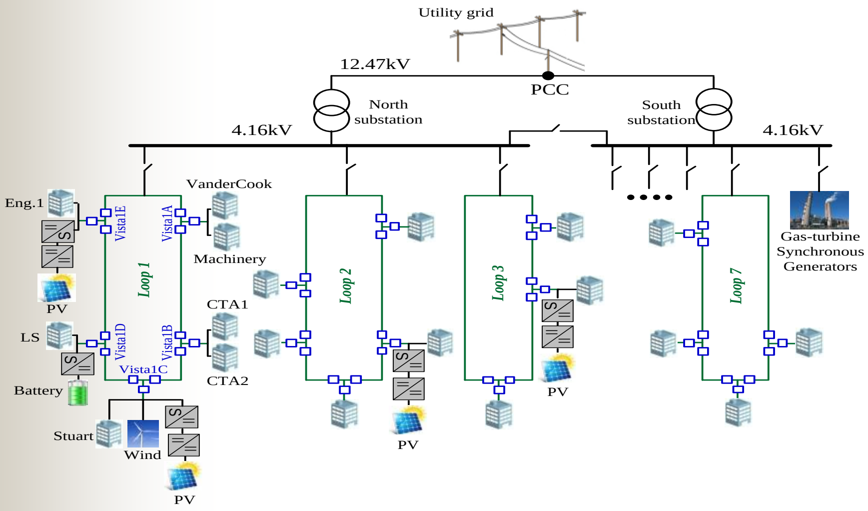
IIT Microgrid is located 2.5 miles south of downtown of Chicago and is bounded by major streets, highways, and railroads.

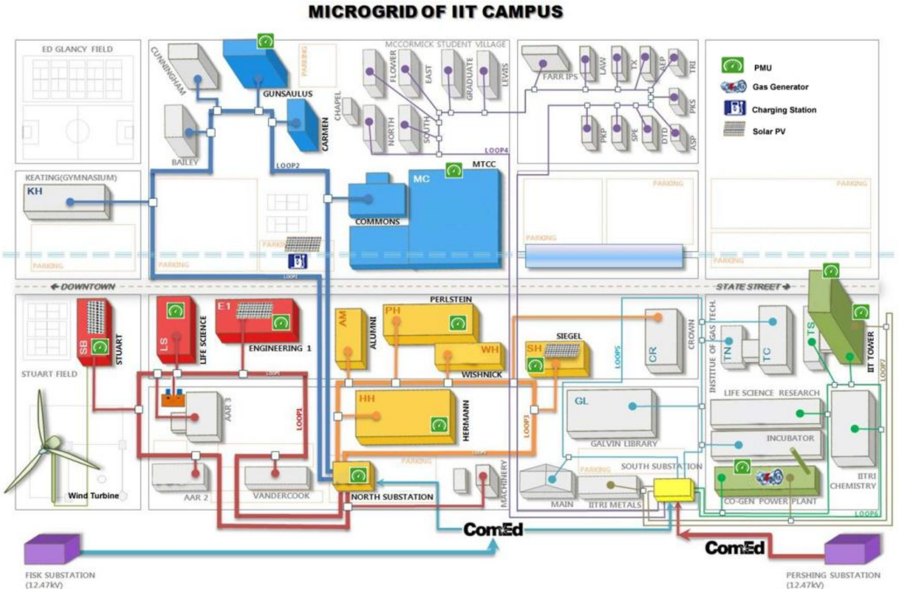
- Funded by the Department of Energy
- Located at IIT
- Involves the entire campus

“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*

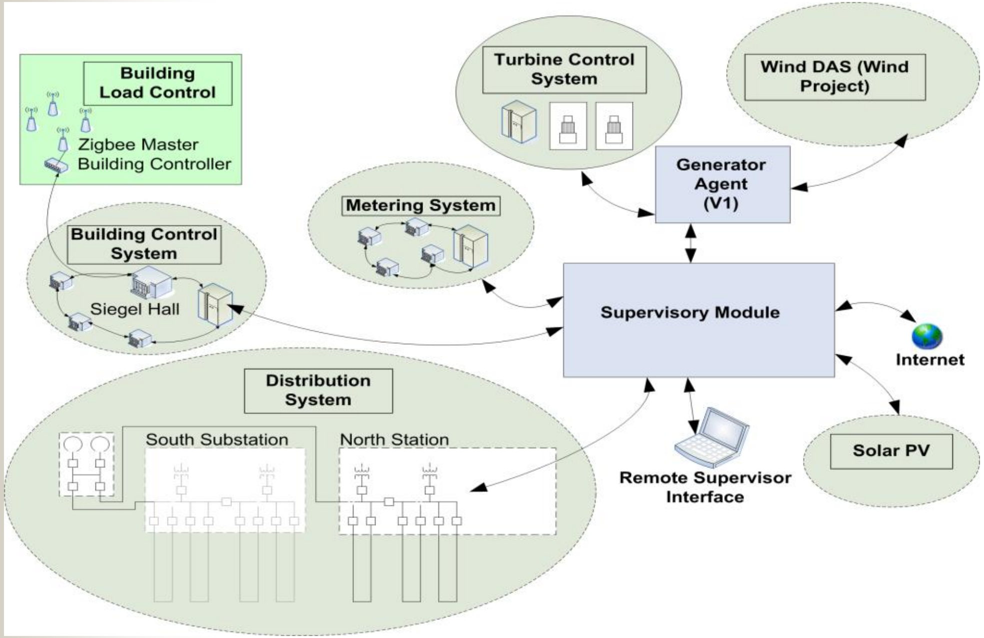


IIT Microgrid Overview





IIT Microgrid Control

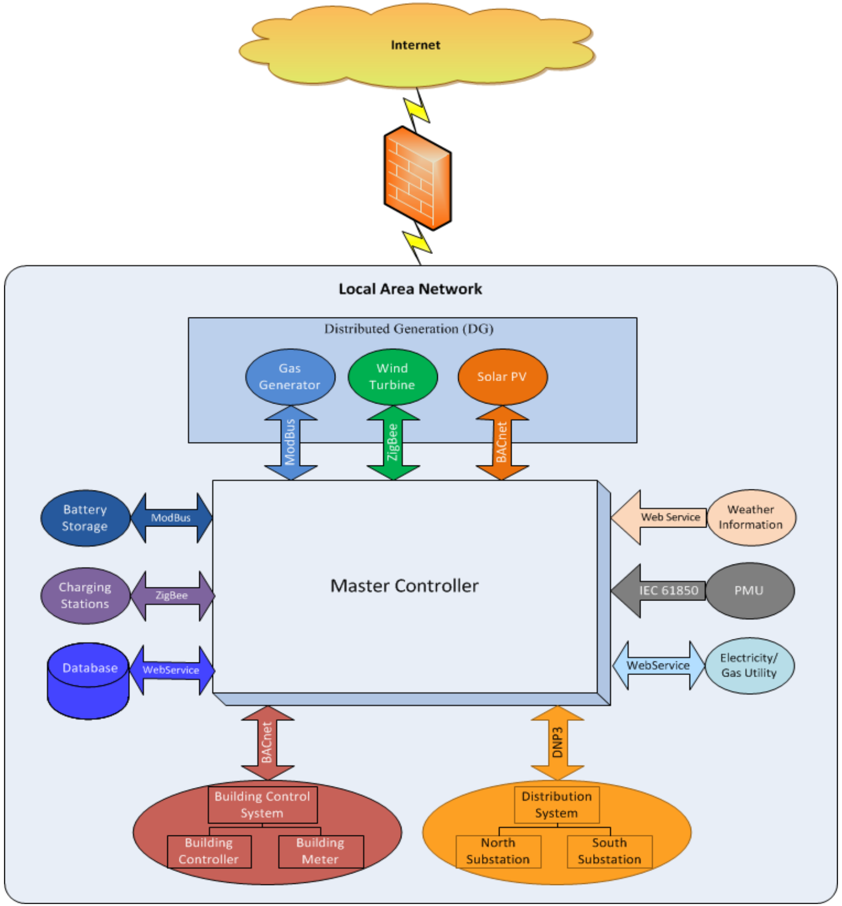


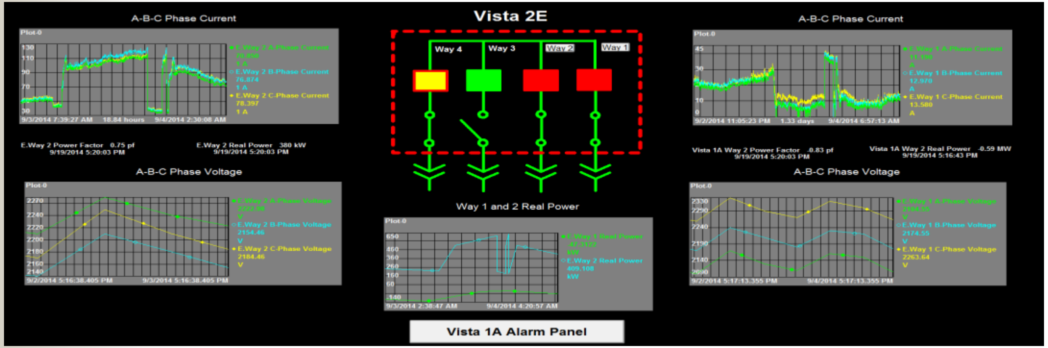
- A firewall separates the subnet that includes master controller and all the devices from the outside internet.

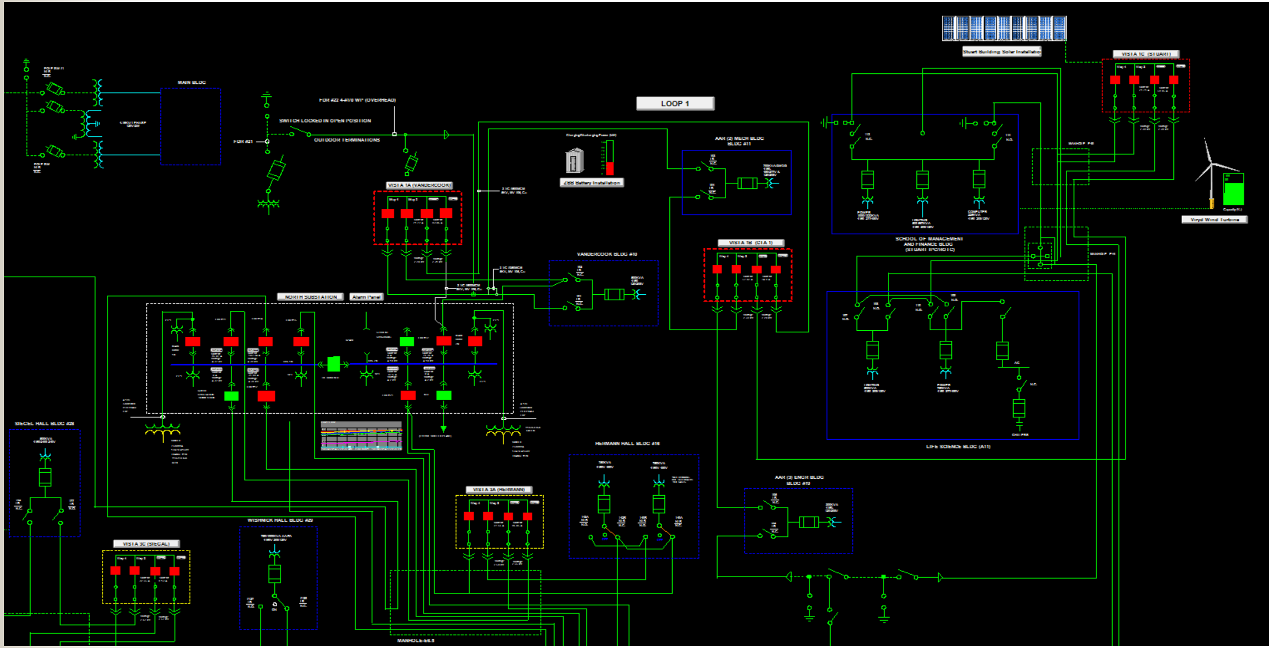
- Monitoring signals provided to the master controller indicate the status of DER and distribution components.
- Master controller signals provide set points for DER units and building controllers.
- Master controller communicates with microgrid field devices through protocols like Modbus, BACnet, DNP3,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

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.



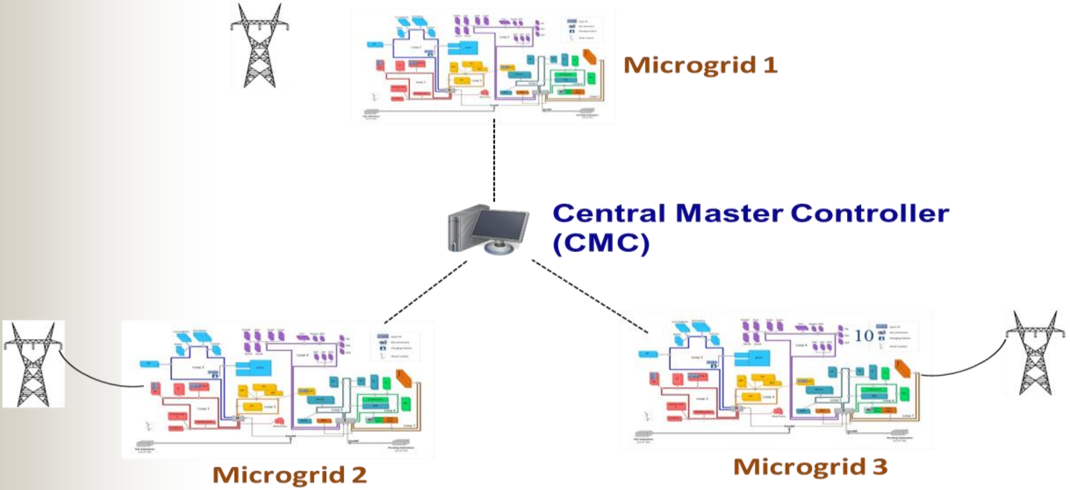

Vista 2E
A-B-C Phase Current
Way 4
Way 3
Way 2
Way 1
E.Way 2 Power Factor 0.75 pf
9/19/2014 5:20:03 PM
E.Way 2 Real Power 380 kW
9/19/2014 5:20:03 PM
Vista 1A Way 2 Power Factor -0.83 pf
9/19/2014 5:20:03 PM
Vista 1A Way 2 Real Power -0.59 MW
9/19/2014 5:16:43 PM
A-B-C Phase Voltage
Way 1 and 2 Real Power
Vista 1A Alarm Panel

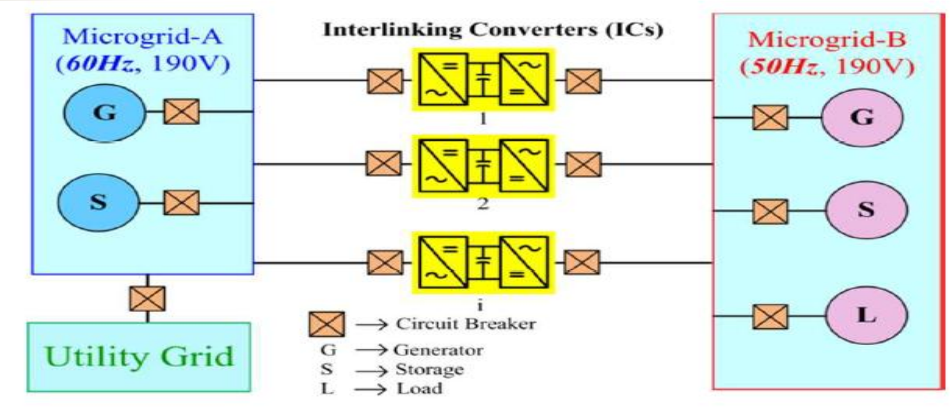

LOOP 1

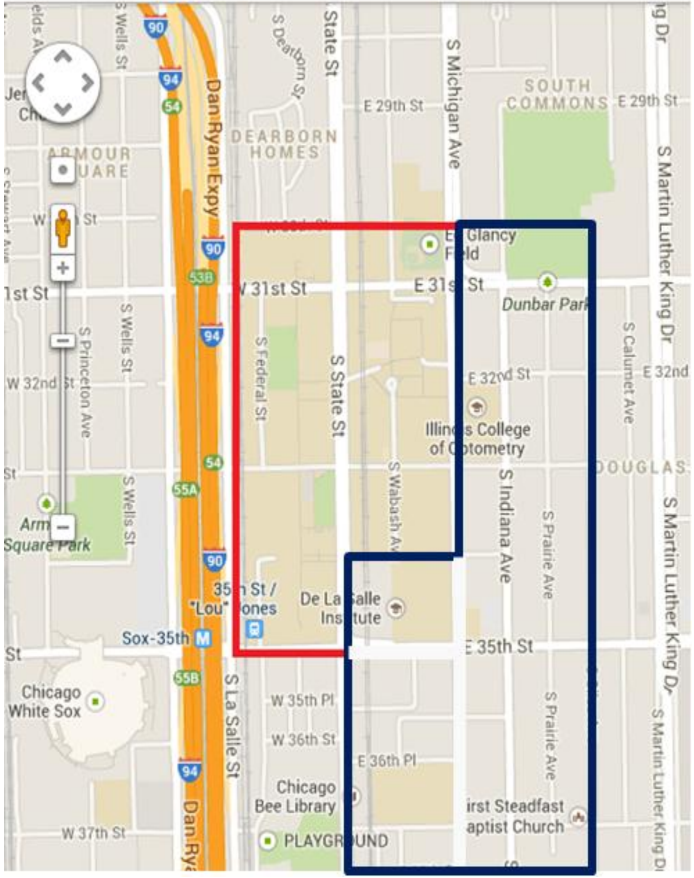
Cost of the IIT Microgrid

- 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

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Technology Product and Testing Providers

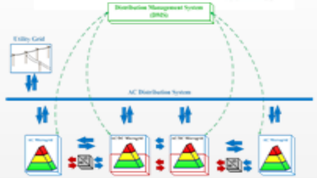
QUANTA TECHNOLOGY

S&C ELECTRIC COMPANY
Excellence Through Innovation

Schneider Electric

Project Lead & Electric Utility
Key Technology: Microgrid Controller

ComEd
An Exelon Company



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)

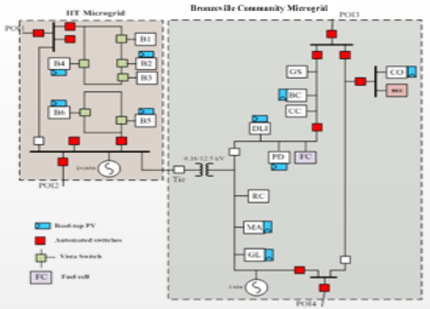
Microsoft

Microsoft Solution Platform

OSIsoft

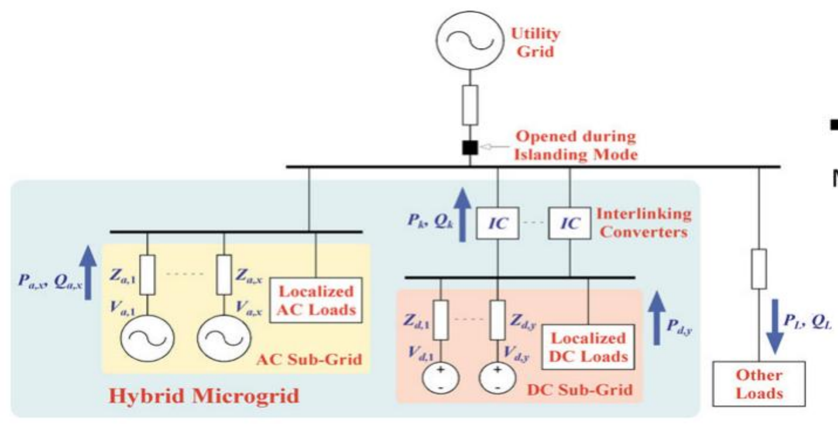
OSIsoft PI Systems

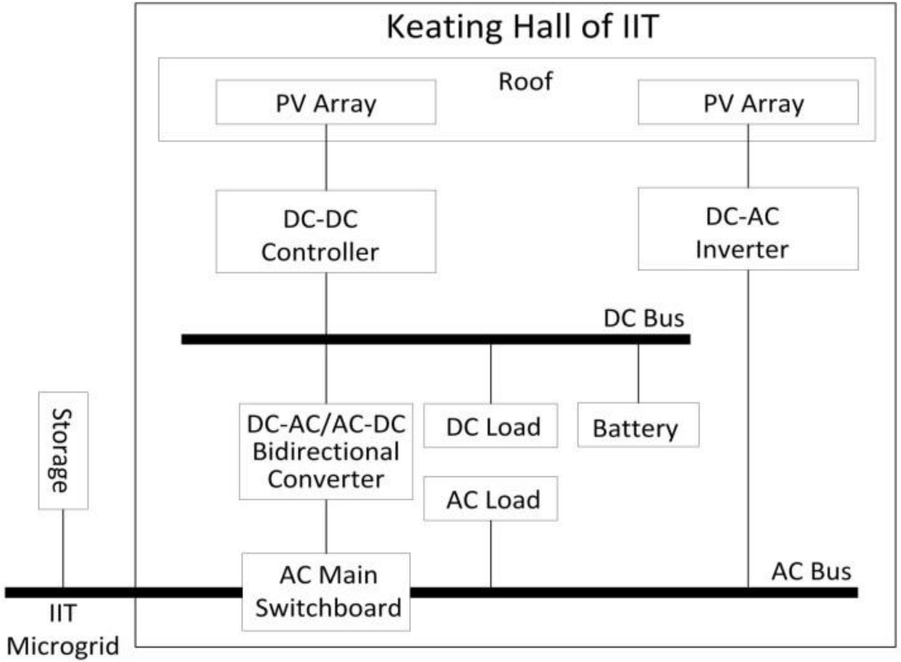
Database and Solution Platform Providers



Bronzeville Community Microgrid (BCM Design Model)

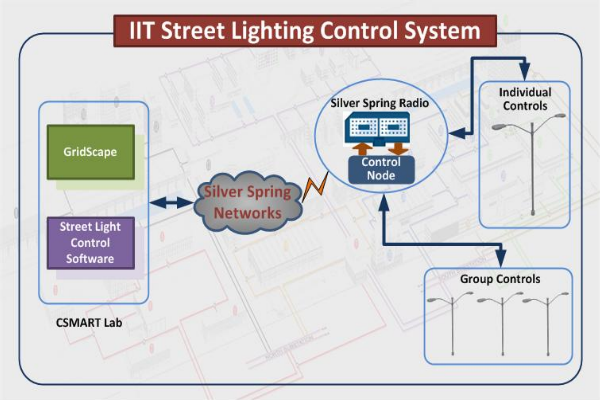
DC Microgrid at IIT





CSMART:

(Center for Smart-Grid Applications, Research, and Technology)



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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?

IEC

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

ENTERPRISE ARCHITECT

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

CIMTool

Choose the appropriate subset

CIM Adapter for PI AF

SISCO

Creates and manages AF Library

Manages AF Elements and Relationships

IEC

Standardized XML File Formats

Instances

Changes

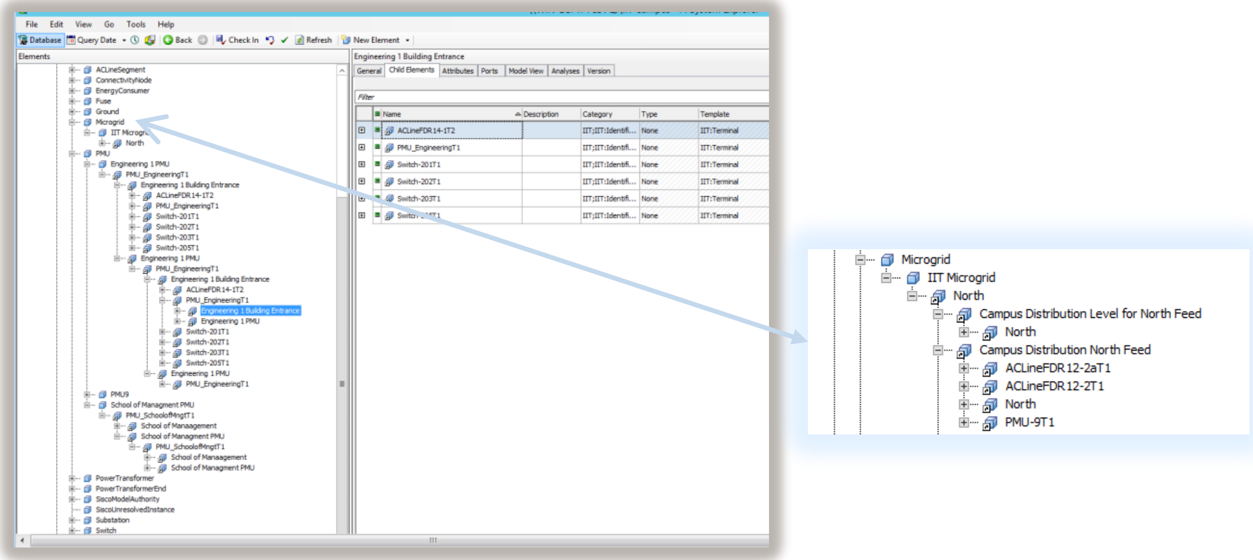
OSIsoft, LLC   Common Information Model

- 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

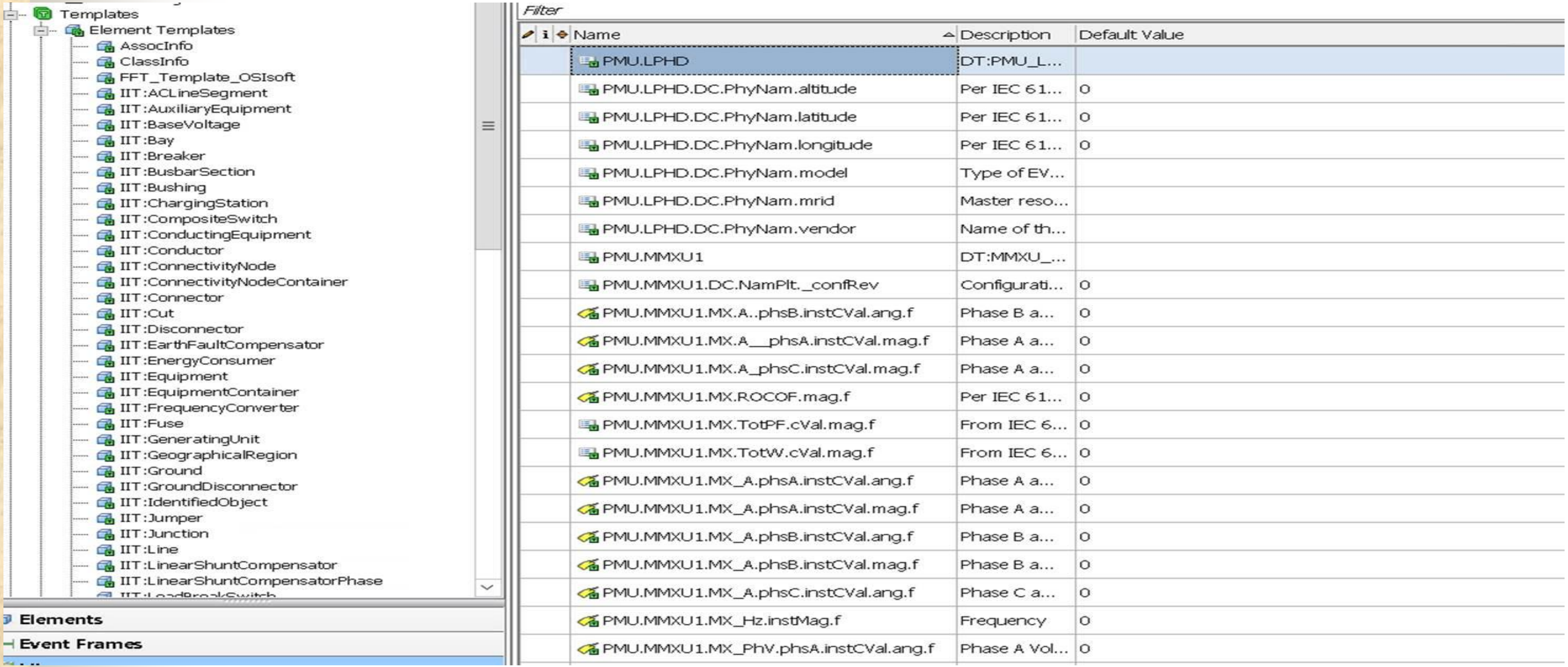
Microgrid Extensions to IEC 61970 CIM standard

- 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



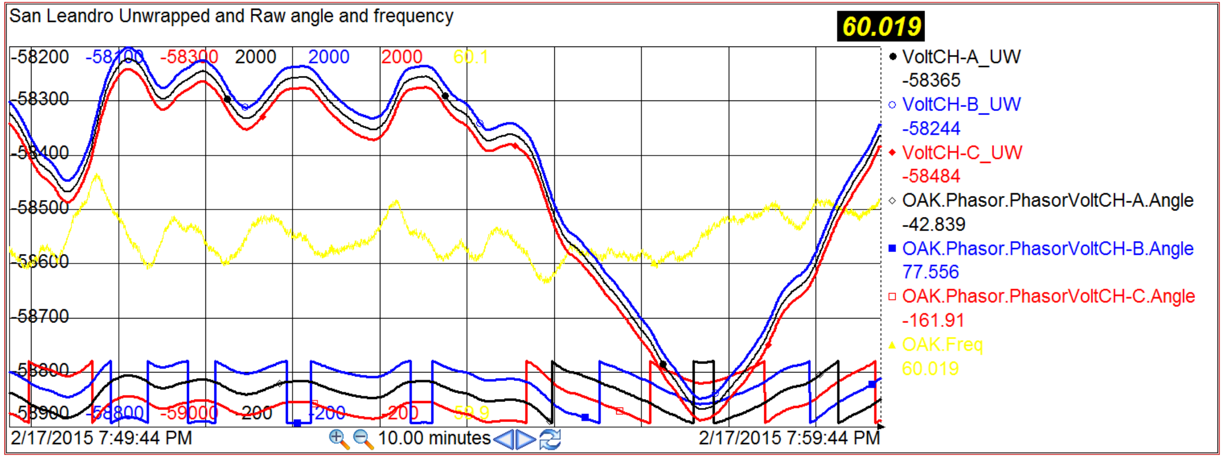
MicroGrid data structure AF Templates



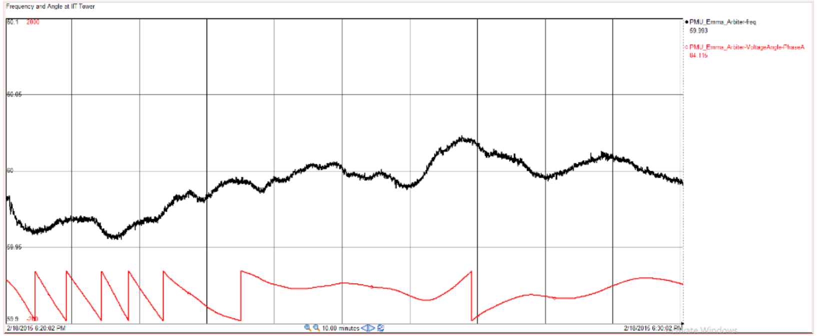
Added AF Templates

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

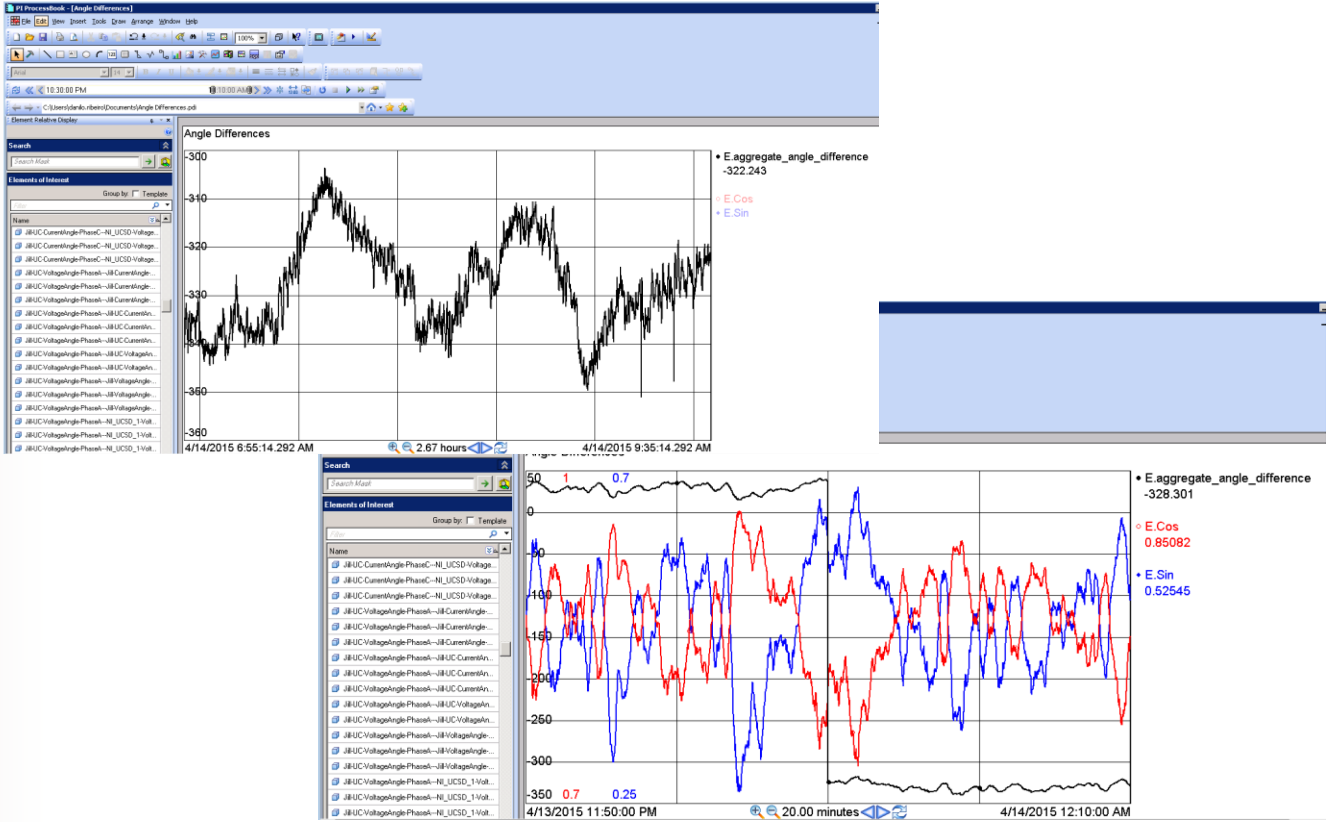
Example of Unwrapping Angles



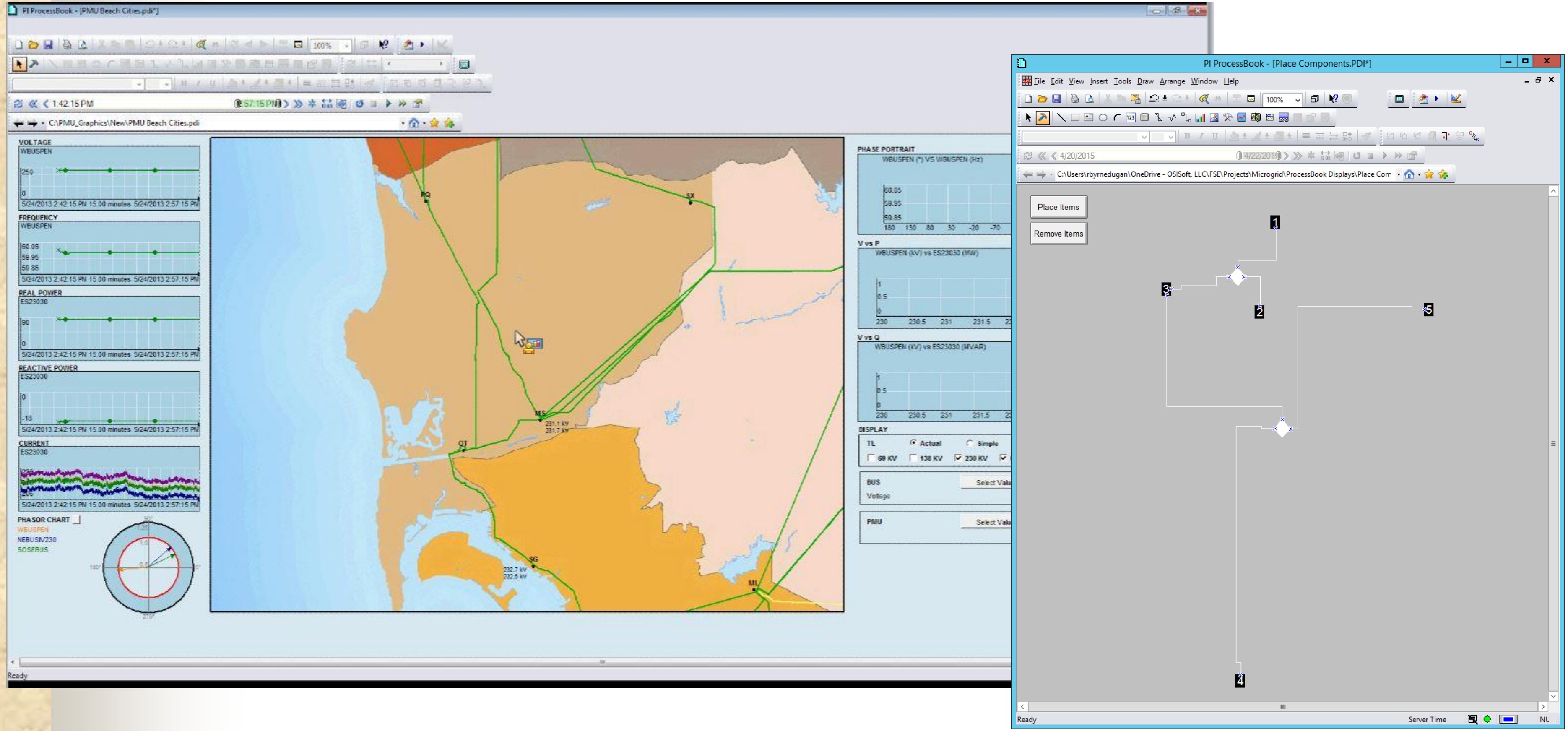
Angles at IIT Microgrid



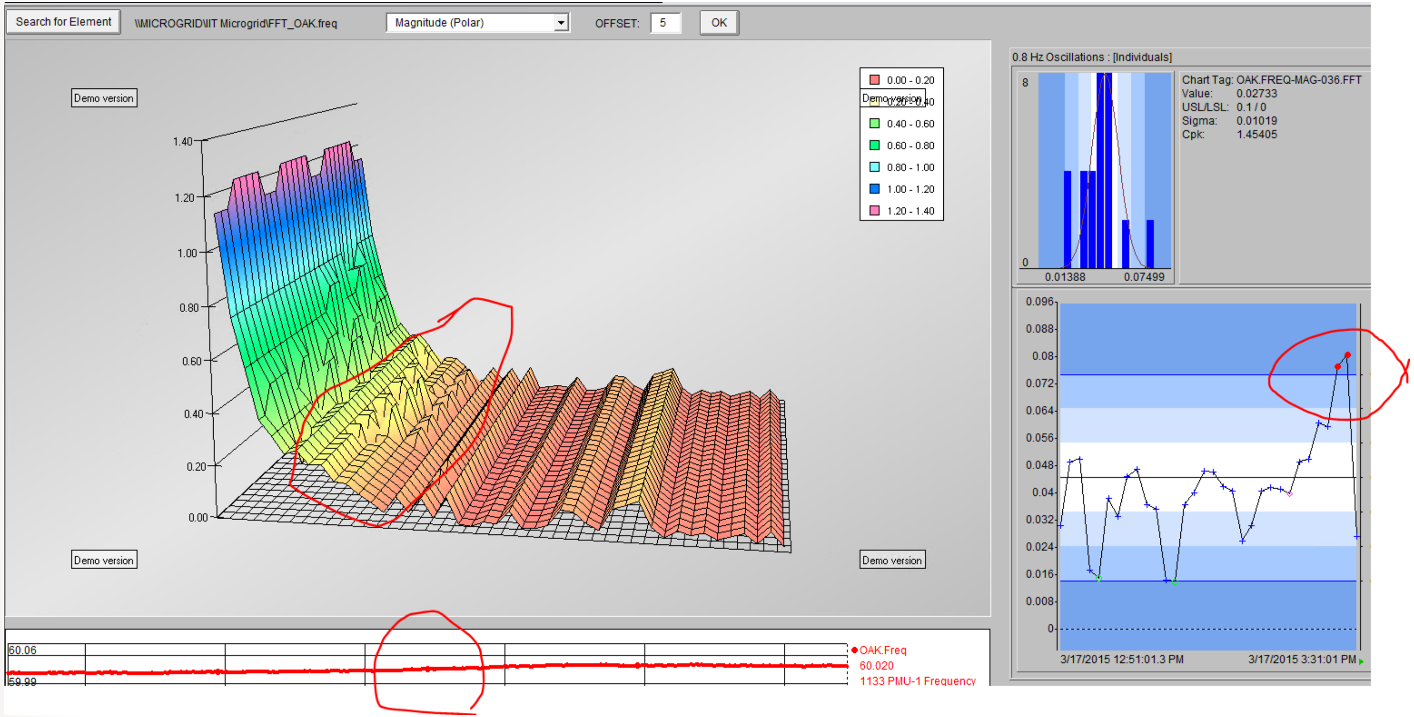
Angle differences, using Element Relative displays



PI ProcessBook automatic GIS display from AF



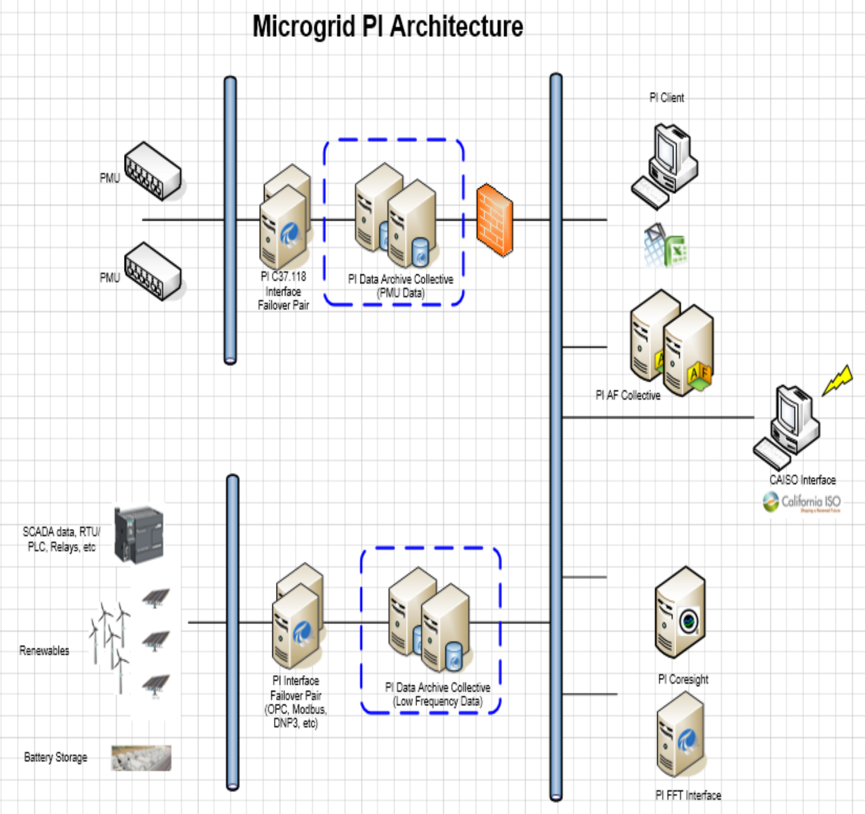
Example Waterfall chart for the FFT



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

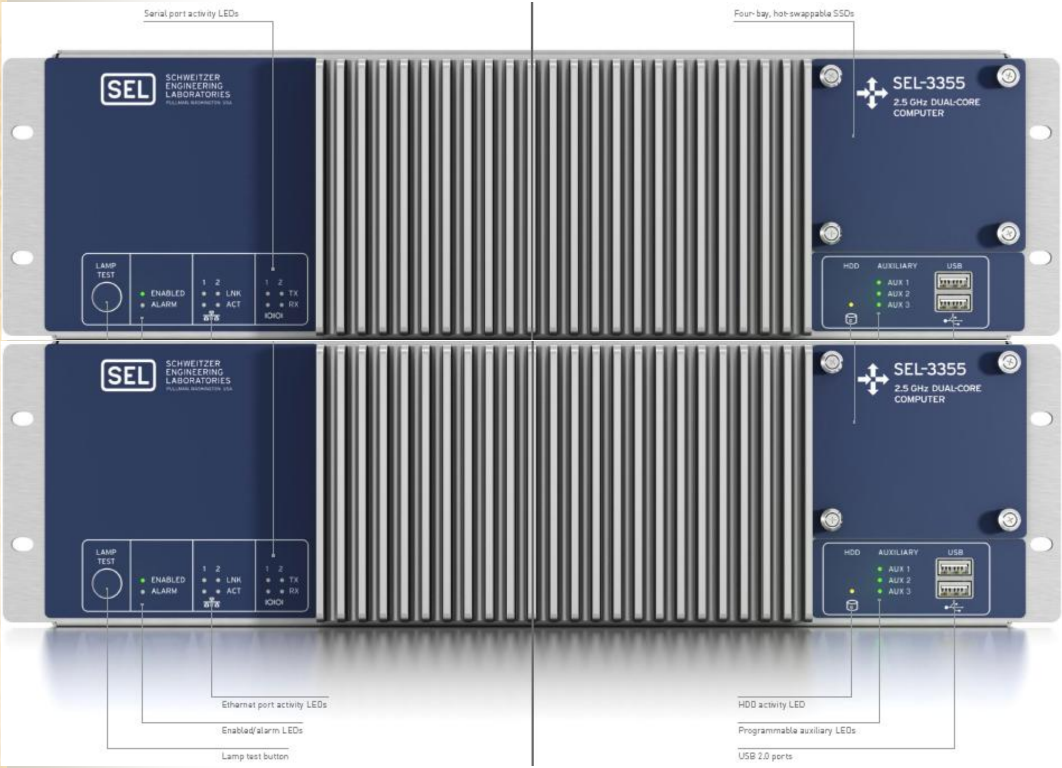
CSSP Architecture for Microgrids



PI System Products	Description
PI Data Archive 1 (PMU)	PI Collective for storing High Frequency Data
PI Data Archive 2 (Low Frequency)	PI Collective for storing Low Frequency Data
PI AF Server	PI Asset Framework (AF) Collective for data organization. Includes configurable analytics and PI Event Frames
PI C37.118 Interface	Collection node of Phasor Measurement Units Data (C37.118 Protocol)
PI Interfaces (Other)	Collection nodes for low frequency data (DNP3, Modbus, OPC, meters, renewables, etc).
PI FFT	PI Fast Fourier Transform (FFT) allows for calculation of real time FFTs
PI Coresight Server	iPad and web-based tool to perform ad hoc analysis on PI System Data
PI Clients	PI Processbook (dynamic interarctive process displays), PI Datalink (create reports and detailed calculations with PI System data in Excel), PI Coresight (perform ad hoc analysis)

Notes:	
Operating Systems	Machines may be physical or virtual. Please consult the Virtualization and The PI System White Paper
CAISO Interface	Communication node to CAISO. A few PI technologies may be used for data transfer, namely: PI Cloud Connect, PI to PI, direct PI connection, among others

SEL 3355 Substation hardened PCs – Microgrid Controller



Operating System:
Microsoft Windows Server 2012 R2 I (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

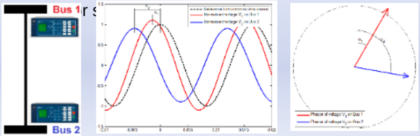
Raymond A. de Callafon (UCSD) & Charles H. Wells (OSIsoft)

callafon@ucsd.edu cwells@osisoft.com

System Identification and Control Laboratory

Phasor Measurement Unit
Detailed Information on Power Flow

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



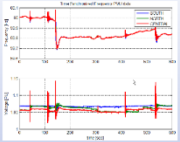
Synchronized and real-time measurements of:

- 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

Dynamic Event Triggering
Mark Events in PMU Data in Real-Time



Single PMU can produce more than a dozen signals at 60Hz

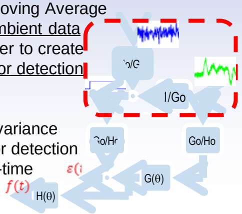
Contribution:

automatically detect an event

(identify timing & trigger)

Approach:

- Auto Regressive Moving Average (ARMA) filter for ambient data
- Rate-of-Change filter to create FRoC signal $f(t)$ for detection



End Result:

- $f(t)$ has minimum variance
- $f(t)$ can be used for detection
- $f(t)$ computed real-time

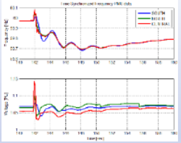
Power Oscillation Modeling
Formulate Dynamic Models from Event Data

When event occurs, one must identify event and dynamics.

Contribution:

automatically characterize an event

(identify dynamics)

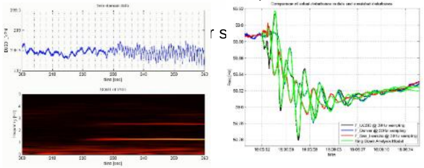


Approach:

- 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 reallization algorithm

End Result:

- Heat plots for observing change in frequency
- Linear finite order models for power flow



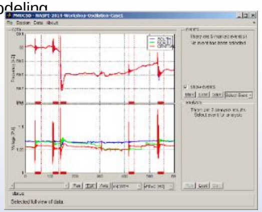
Software Development and Results
A preliminary of active management

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

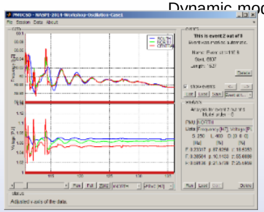
Automatic event detection implemented in Matlab GUI

Real-time event detection development PI template

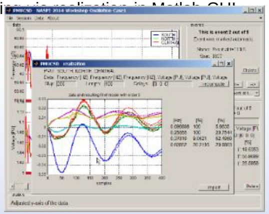
Dynamic modeling via realization in Matlab GUI



Main Matlab GUI



Event Detection and Analysis



Modeling with Realization

Summary

Detection of events via Filtered Rate of Change (FRoC)

Allows for automatic real-time event detection

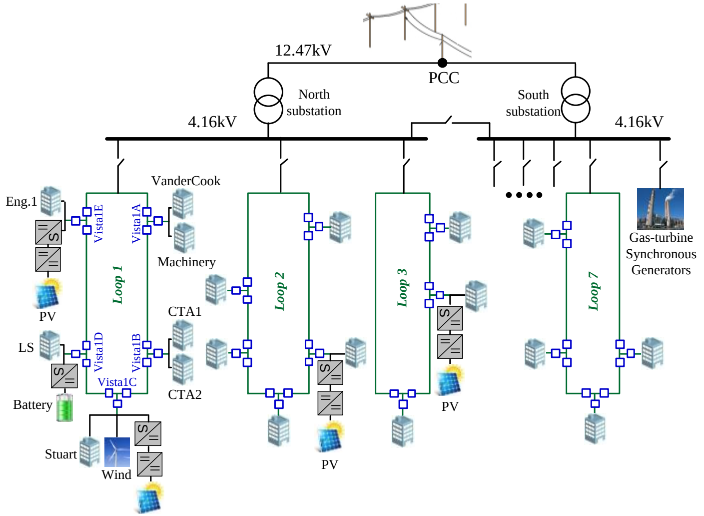
Modeling of events via Parallel FFT and Realization

Allows for

- Real-time visual conformation 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.



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OSIsoft

ComEd An Exelon Company

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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Principal Investigator

ComEd/IIT

Chuck Wells

cwells@osisoft.com

Industry Principal

OSIsoft, LLC

Questions

Please wait for the microphone before asking your questions

State your
name & company

THANK YOU