Implementation and Benefits of OSI PI in a Major Power Systems Research Program

OSISoft Regional Seminar
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Rick Meeker, P.E.

Center for Advanced Power Systems

Florida State University

FLORIDA STATE UNIVERSITY

Florida State University

- Founded 1851
- Enrollment   41,301   *(fall 2012)*
- Degrees Awarded   10,911   *(2011-2012)*
- Faculty   1,405   *(2012-2013)*
- Operating budget $1.1B   *(2012-2013)*
- External Funding $190M   *(2011-2012)*
- Colleges   16
- 103 baccalaureate , 115 masters, and 76 doctorate degree programs
- Designated as a State of FL "preeminent university"
- Home to the *National High Magnetic Field Laboratory* (NSF-funded, 1990)

Center for Advanced Power Systems

- Established in 2000 under a grant from the Office of Naval Research

- Lead Member of the Electric Ship Research and Development Consortium

- ~$8 million annual research funding from ONR, DOE, Industry

- DOD cleared facility at Secret level

- 44,000 square feet laboratories and offices; over $30 million specialized power and energy capabilities

Research Focus

- Electric Power Systems

- Advanced Modeling and Simulation

- Advanced Control Systems

- Power Electronics Integration and Controls

- Thermal management

- High Temperature Superconductivity

- Electrical Insulation/Dielectrics

Researchers and Staff

~110 total staff

54 Full-time staff of scientists, engineers and technicians, post-doctorates and supporting personnel

9 FAMU-FSU College of Engineering Faculty

41 Students

Research Sponsors and Customers

U.S Navy, Office of Naval Research (ONR)

- ESRDC, Cryocooled Systems, Non-linear Loads, DURIP lab equipment additions (drives and motors, high-speed gearbox)

U.S. Navy, PSM320 – Electric Ship Office

- Modeling and simulation, verification and validation through hardware-in-the-loop testing of ship system electrical components

U.S. Dept. of Energy, Office of Electricity Delivery and Energy Reliability (OE), Office of Energy Efficiency and Renewable Energy (EERE)

- EPIRS, SUNGRIN, etc.

National Science Foundation (NSF)

- Future Renewable Electric Energy Delivery and Management Systems, FREEDM (NSF)

Northrop Grumman

Bonneville Power Administration

Southern California Edison

Bruker

EPRI

Oak Ridge National Laboratory

Idaho National Laboratory

…

Stakeholder Community Engagement

- The GridWise Alliance

- The Wind Alliance

- Coalition for Commercial Application of Superconductors (CCAS)

- IEEE Standards Committees (including 1547, P45, FCL's, PSR)
- CIGRE FCL Committee

- ASME (National Energy Committee, Intersector Committee on Federal R&D)

- North American Synchrophasor Initiative (NASPI)

- NERC Smart Grid Task Force (SGTF)

- Local and Regional Economic Development Groups

Capabilities

- 7.5 MVA, 4.16kV test and evaluation facility
  - 5 MW variable voltage / variable frequency converter
  - 5 MW dynamometer
- Real-time Digital Simulator (RTDS)
  - Down to <2 µSec time step in real-time
- Integrated Hardware-in-the-Loop (HIL) testbed → 5 MW testbed + RTDS
- Low power dynamometers and converters
- Smart Grid Lab
- AC Loss and Quench Stability Lab
- Cryo-dielectrics High Voltage Lab
- High-speed machine capability, to 24,000 RPM
- MVDC test capability to +/- 10kV
- Cryo-cooled systems lab
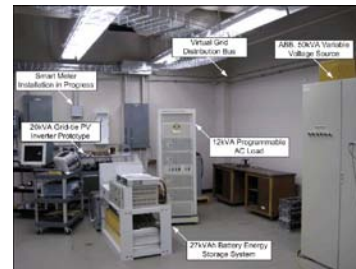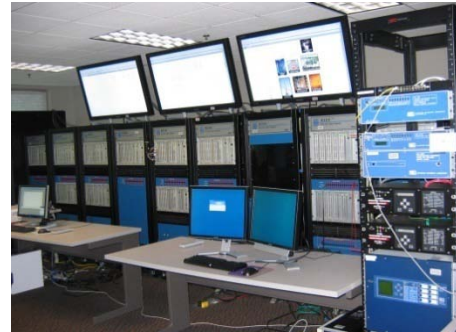
An Advanced Prototype Integrated Development, Test, and Evaluation Facility

7.5 MVA stiff connection to utility, supplying 12.47kV and 4.16kV testbed distribution system

5 MW AC Variable Voltage and Frequency Converter for high-power waveform generation for power hardware-in-the-loop and virtual machinery. Also, with 1.15 MW DC capability.
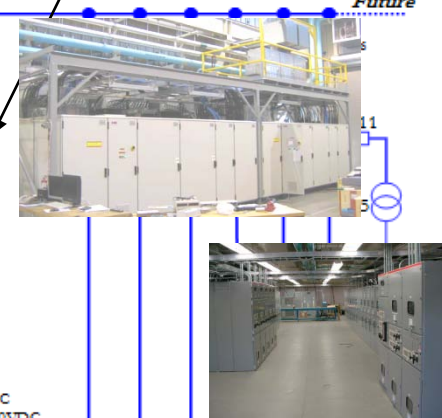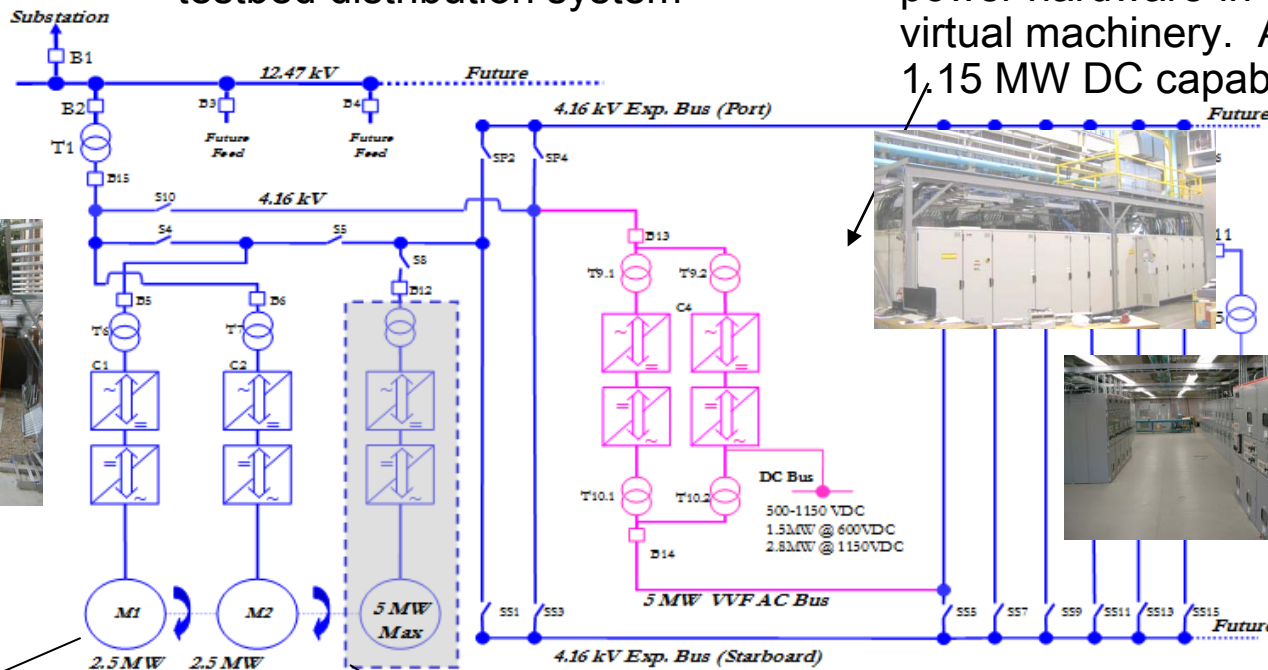
5 MW Dynamometer – (2 2.5 MW induction machines w/4Q drives

"An important aspect of the new results obtained at CAPS on the 5-MW motor is the validation of AMSC's electromagnetic, mechanical and thermal analytical models for HTS ship propulsion motors - a vital step in the development cycle for advanced electrical machines."
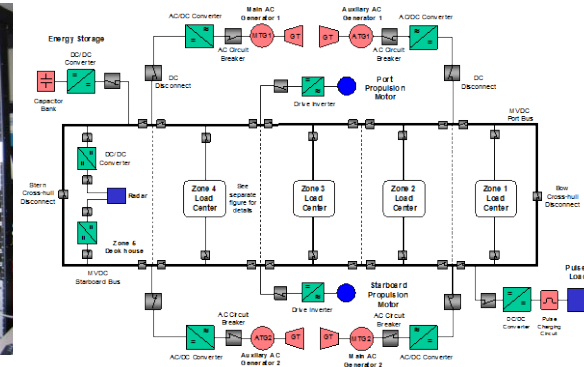-- *AMSC Press release*

Power Systems Simulation

IEEE 30-bus System

- 5 racks, dt=65 μs
- 6 machines incl. governor & v-regulator
- 36 transmission lines
- 70 breakers
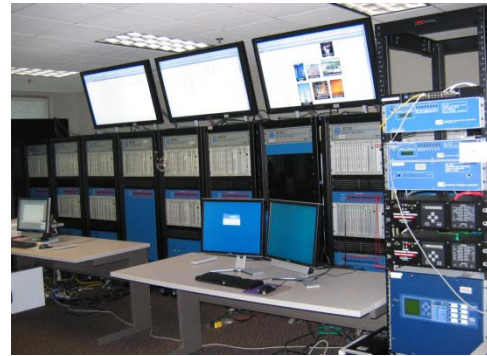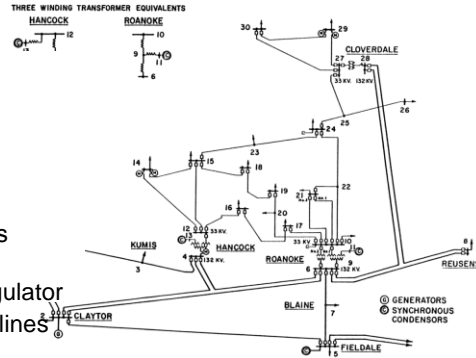
14-rack RTDS at CAPS

Ship zonal integrated power system

REAL-TIME – RTDS

- Large-scale electromagnetic transient simulator
- EMTP type simulation covers load-flow, harmonic, dynamic, and transient regime
- Real-time simulation, with time steps down to <2 μs.;   111,200 MFLOPS; 14 "racks", parallel processing
- Real-time simulation of 924 electrical nodes, plus hundreds of control and other simulation blocks
- Extensive digital and analog I/O for interfacing hardware to simulation (>2500 analog, >200 digital). Can connect in real-time to any electrical node within the simulation.
- MODBUS TCP, DNP 3.0 and IEC 61850 interfaces also available.
- Capability for remote access over VPN link
- Recent upgrade activity:
  - 2 RISC GPC's in every rack for small time step (1-2 μs)
  - Backplane upgrades - bus transfer rate improved from 125 to 60 ns
  - Increase electrical nodes per rack from 54 to 66

REAL-TIME – Opal RT, recently added

Other simulation tools in-use at CAPS:

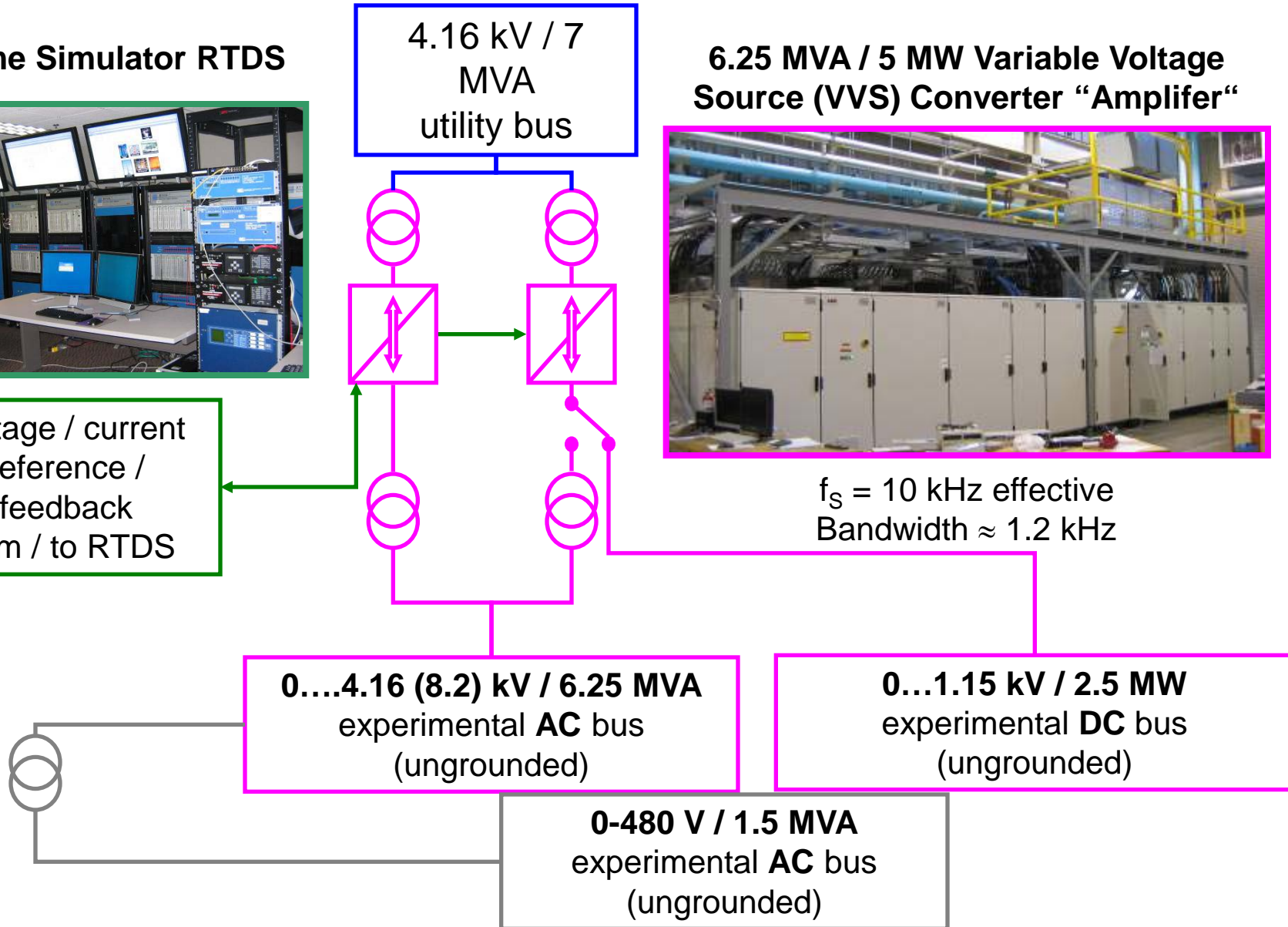- PSS/E, PSCAD/EMTDC, MATLAB/Simulink, ATP, PSPICE, ANSYS, DSPACE

5 MW PHIL Facility

Real Time Simulator RTDS

4.16 kV / 7 MVA utility bus

6.25 MVA / 5 MW Variable Voltage Source (VVS) Converter "Amplifer"

Voltage / current reference / feedback from / to RTDS

f_S = 10 kHz effective
Bandwidth $\approx$ 1.2 kHz

0….4.16 (8.2) kV / 6.25 MVA
experimental **AC** bus
(ungrounded)

0…1.15 kV / 2.5 MW
experimental **DC** bus
(ungrounded)

0-480 V / 1.5 MVA
experimental **AC** bus
(ungrounded)

Control, Protection and Information

Real-time Process Information System (OSI-PI)

- Capacity:
 - ☐ 150,000 tags
  - ☐ 15 clients

EMS/SCADA - (Areva T&D e-terra)

- Capacity: (sized for FL system)
  - ☐ 341,800 points
  - ☐ 3000 transmission buses
  - ☐ 3000 simulator buses
  - ☐ 90 generators

Commercial Protection Relays

- Schweitzer Engineering Laboratories (SEL)
  - – Distance and differential prot.
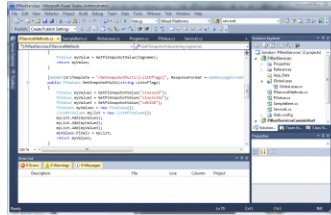- Beckwith Electric Co.
  - – Transformer and generator prot.

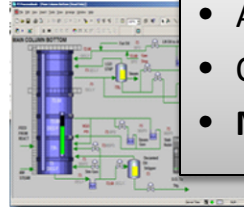Power System Simulation, Control, and Information Systems Development, Test, Evaluation, and Demonstration Facility
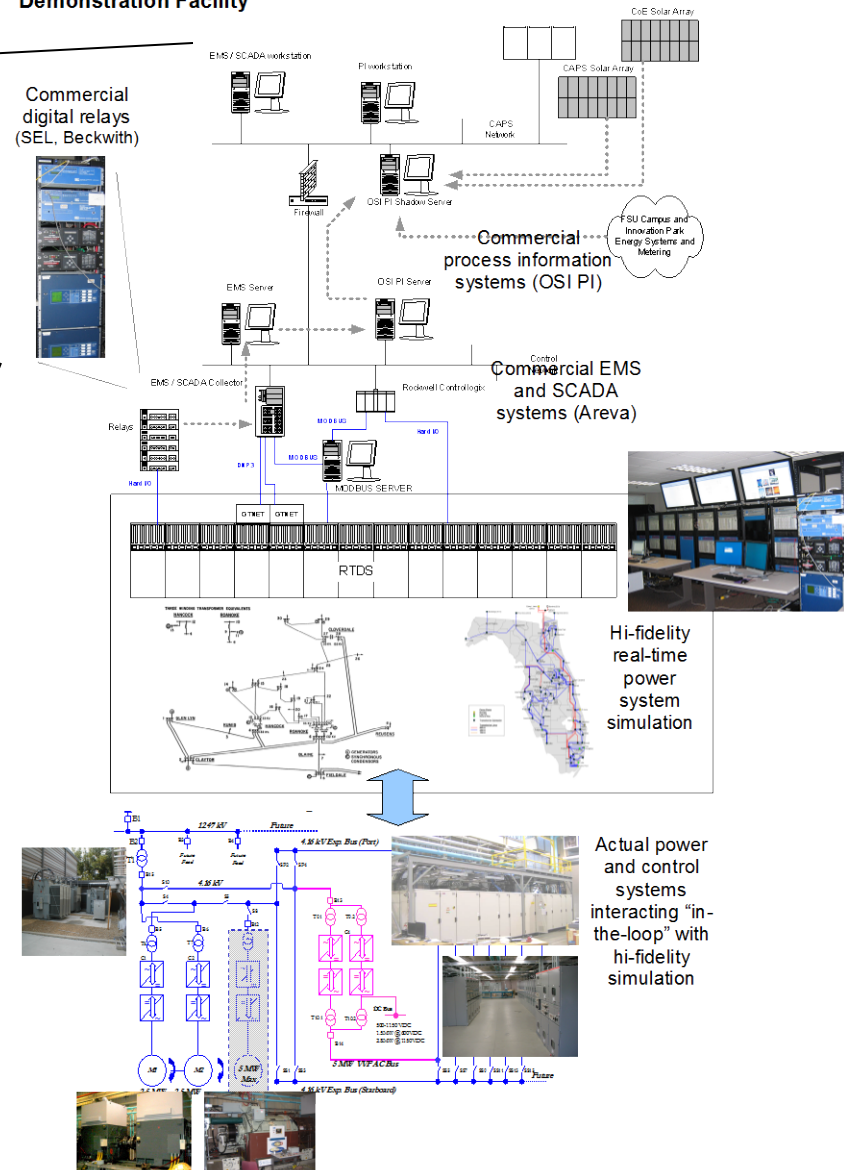
FSU CAPS OSI PI System Architecture

Misc PI Clients:
PI OLEDB
PI Notifications
PI SMT − Administration
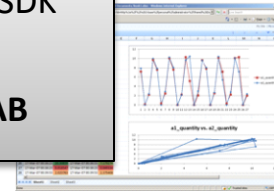PI Explorer − AF Administration

Microsoft Visual Studio
Advanced Calculation Engine (ACE)
Programming

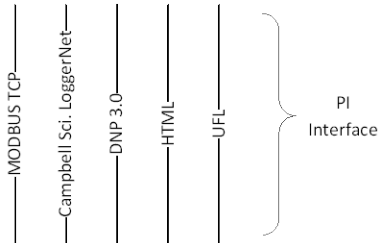PI ProcessBook

- API w/SDK
- OPC
- **MATLAB**

Excel DataLink

Web Client

Third party PI to PI transfers

TCP port 5450

PI Interface Computer
Located in CAPS Lab

TCP port 5450

MODBUS TCP
Campbell Sci. LoggerNet
DNP 3.0
HTML
UFL

PI Interface

PI Server 2010
Hosted in Virtual Machine
(domain authentication enabled)

PI components:
PI Server
PI AF Server
PI Notifications Server
Advanced Calculation Engine
PI OLEDB Provider
Microsoft Components:
IIS − for PI Notification Acknowledgement

SharePoint 2010

Sharepoint Server
(Kerberos enabled)

PI components:
PI WebParts
PI Data Services

SQL Server 2008 R2
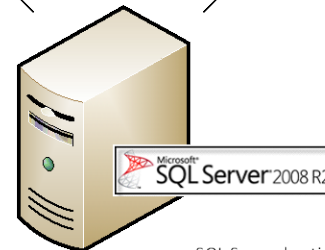
SQL Server

SQL Server hosting PI Application
Framework (AF) databases and
sharepoint databases

FSU CAPS PI Licensed Components

- PI Server: 150,000 tags

- Interfaces:
  - MODBUS Ethernet (TCP)
  - DNP 3.0
  - Campbell Scientific Loggernet®
  - C37.118 (synchrophasor / PMU communications)
  - Alstom Grid e-terra® Habitat (ESCA HABConnect)
  - OPC
  - HTML
  - Universal File and Stream Loader (UFL)
  - FFT
  - Rockwell ControlLogix
  - PI-to-PI

- Desktop tools: 15 concurrent users
  - DataLink
  - ProcessBook

- rtWebParts

- PI vCampus
  - Development platform
  - 5 licenses

Benefits of PI

- Utility familiarity
- Commercial-industrial grade solution
  - Reliable
  - Supported
  - Scalable
  - Performance
  - Features and flexibility
  - Many interfaces available & tested
- Enterprise scalability and PI-PI supports collaboration:
 - With utilities
  - With other universities

PI in Electric Power Systems R&D Environment

- Historian, data from real-time *simulation* of electric power systems

- Real field measurement data from lab systems
  - Hardware-in-the-loop (HIL testbed)
  - Local solar PV and inverter systems

- Real field measurement data from utility systems
  - Distribution circuits
  - Solar PV plants
  - PMU's
  - …

Electric Power Grid Operation and Control - Virtual

- Electric power systems simulated in real-time
- Utility, defense (e.g. Navy ship), or otherwise
- Hi-fidelity simulations in RTDS
- Many different systems from many different sources / owners possible

Power System Simulation, Control, and Information Systems Development, Test, Evaluation, and Demonstration Facility

Hi-fidelity real-time power system simulation

Actual power and control systems interacting "in-the-loop" with hi-fidelity simulation
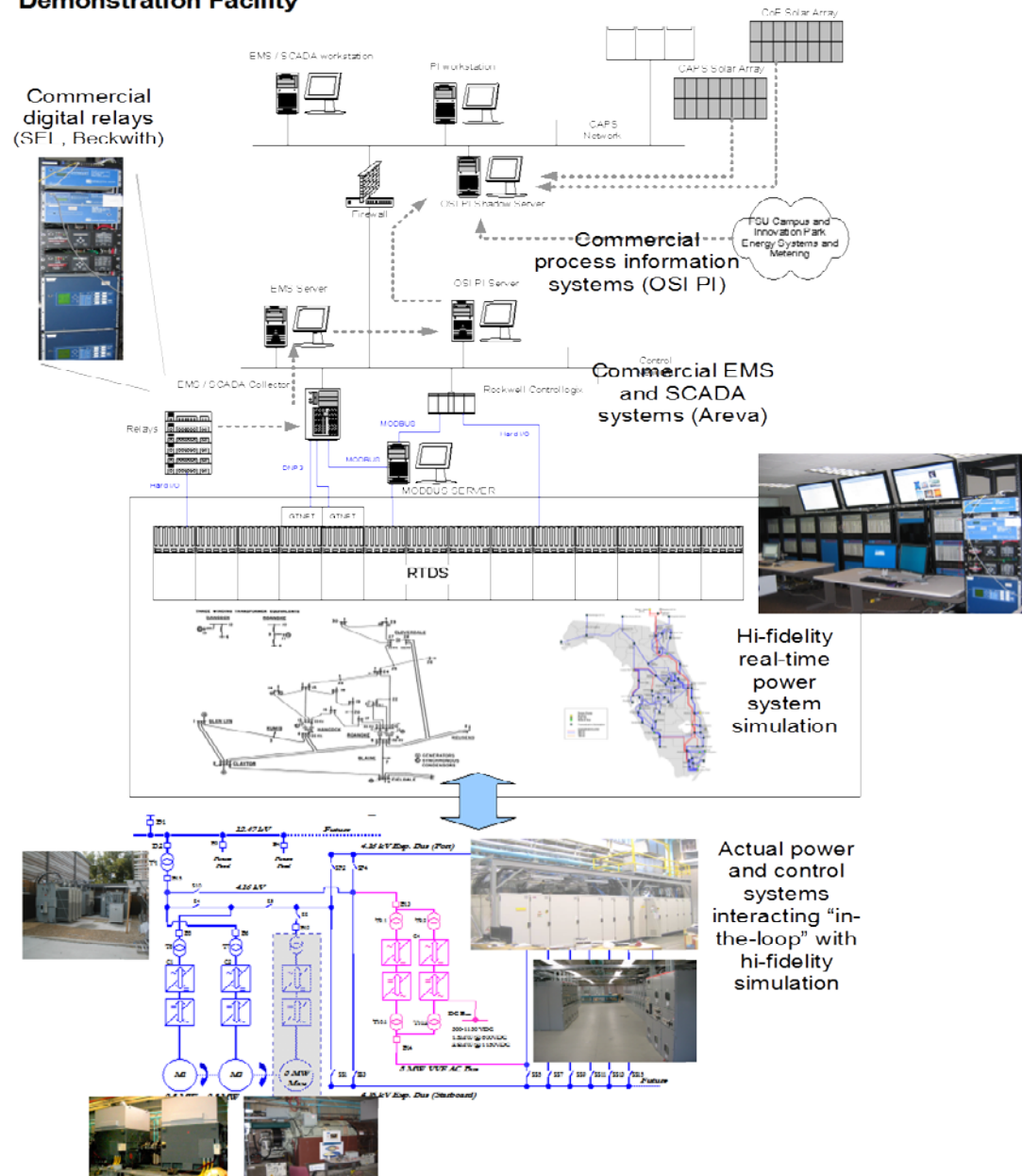
SUNGRIN Project

Universities

FSU Center for Advanced Power Systems (CAPS) *(lead institution)*

University of Central Florida, Florida Solar Energy Center (FSEC)

Utility Industry

- Florida Power and Light (FP&L)
- Florida Municipal Power Agency (FMPA)
- Florida Reliability Coordinating Council (FRCC)
- Gainesville Regional Utilities (GRU)
- Jacksonville Electric Authority (JEA)
- Lakeland Electric
- Orlando Utilities Commission (OUC)

Industry Suppliers

- AMEC
- OSISoft
- SMA

U.S. DEPARTMENT OF **ENERGY** | Energy Efficiency & Renewable Energy

SUNGRIN - Focus Areas

- PV and load variability characterization and impact

- Power system circuit model development (distribution and transmission; Florida circuits)

- High-penetration PV impact analysis with FL utility circuit models and data

- Development and testing (including HIL) of Power electronics, storage, and control solutions and strategies
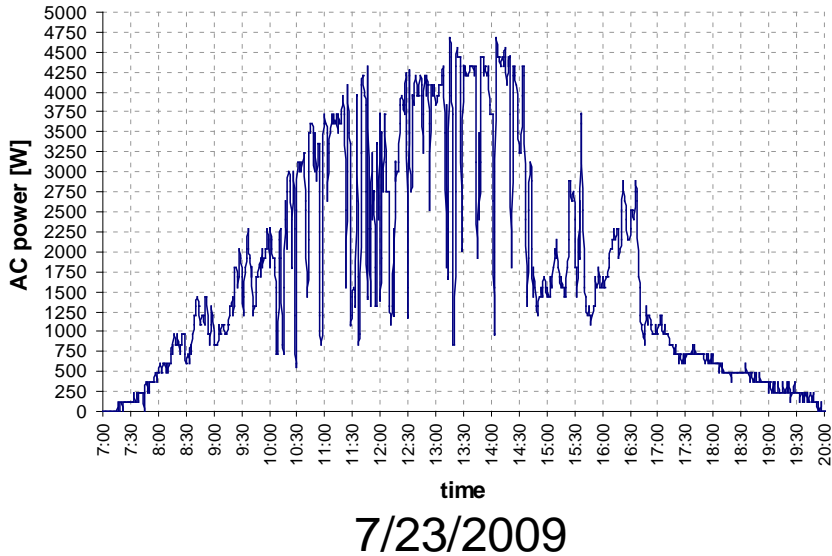
- Outreach and engagement

Solar PV Plant Data

- Used in Project for:
  - Studying variability of the resource
  - Input to models for validation and analysis
- Leveraging OSI PI real-time database – lab capability developed with cost-share contribution from prior DOE-funded Electric Power Reliability Infrastructure and Security (EPIRS) project
- Leverage existing solar data collection at FSEC from PV installations across the state.
- Connect to utility partner project sites and other sites across the state.
- Statistical analysis of time-series data.
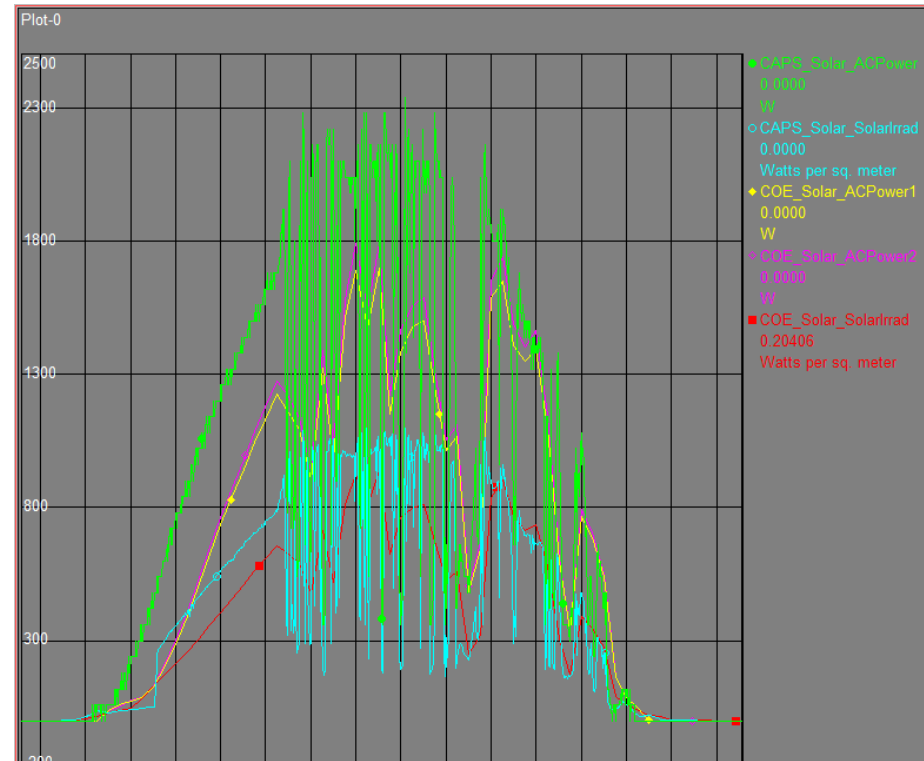- Examine, diurnal, seasonal, geographical and local variations
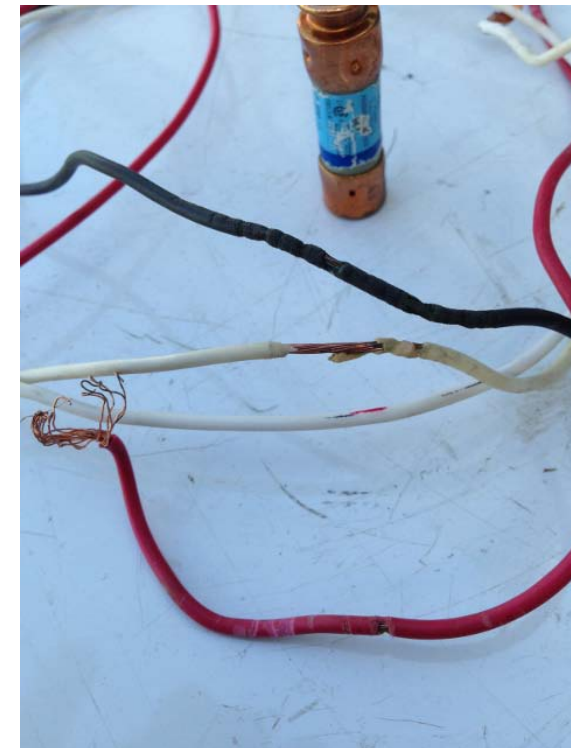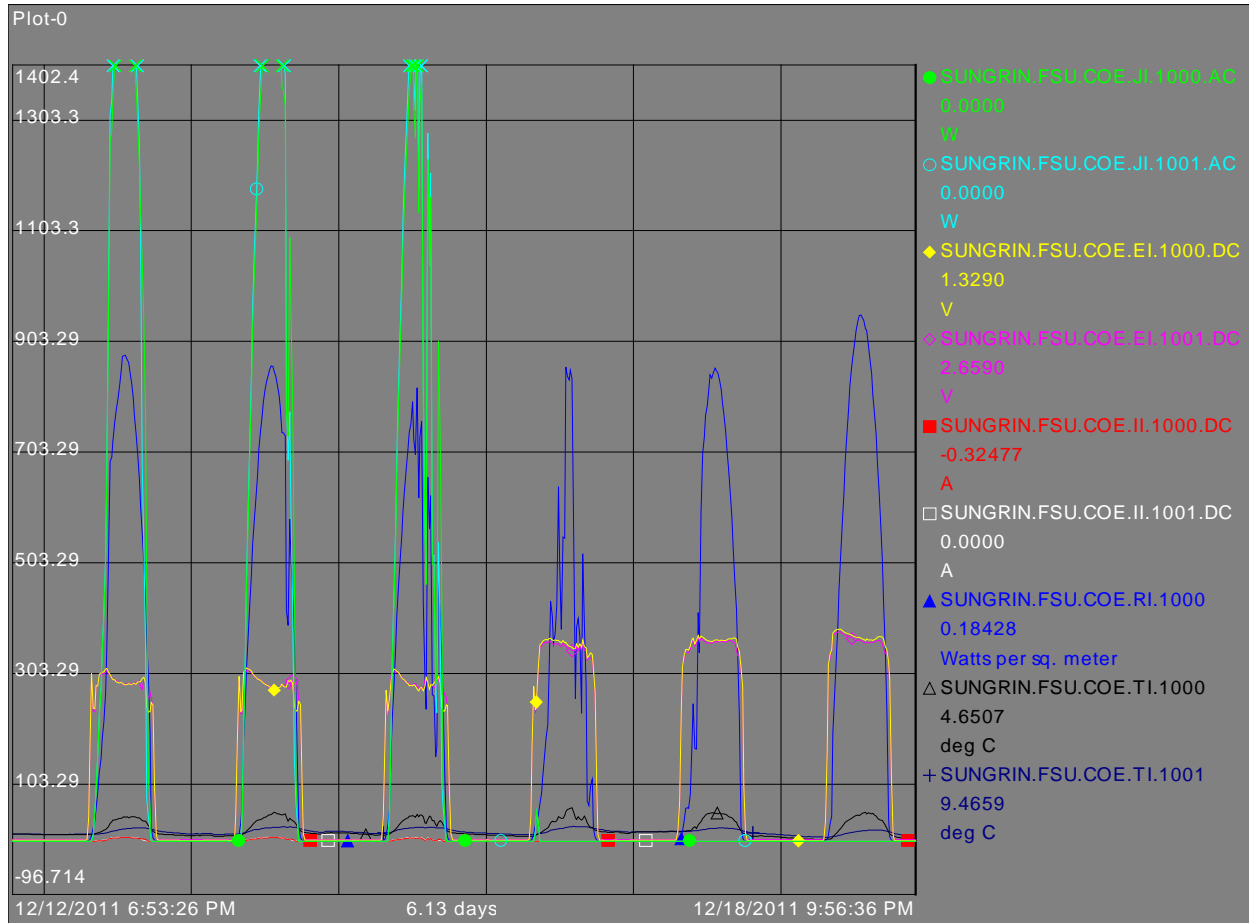
On-site systems

CAPS PV, July 23 2009

NW Florida PV Variation

7/23/2009

5/18/2010

Capacity: 5940 W
Utility Conn: City of Tall.
Arrays: Schott, SAPC –165
Inverters: SMA 2500U
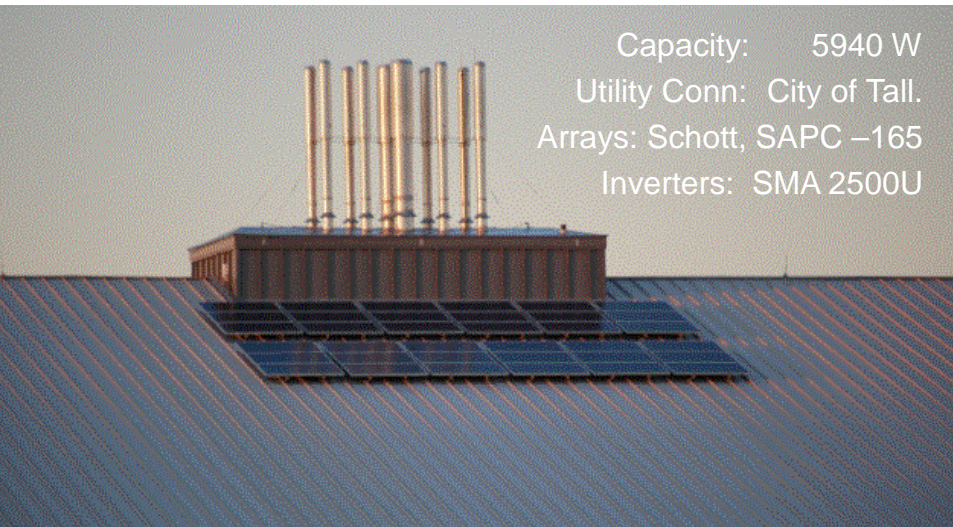
System Failure at College of Engineering

# Utility-Scale PV – Jacksonville Solar

- 15 MW DC; 12.6 MW AC
- Online Nov. 2009
- Owner: PSEG;
- Power to JEA under PPA
- 100 acres
- 24kV distribution feeder
- 230kV substation
- Feeder length : 9 miles
- PV location: 4.8 miles
- Max. ckt. load <12.6 MW
- Inverters (20):
  – SMA Sunny Central 630 HE
- Panels (~200,000):
  – First Solar FS-275
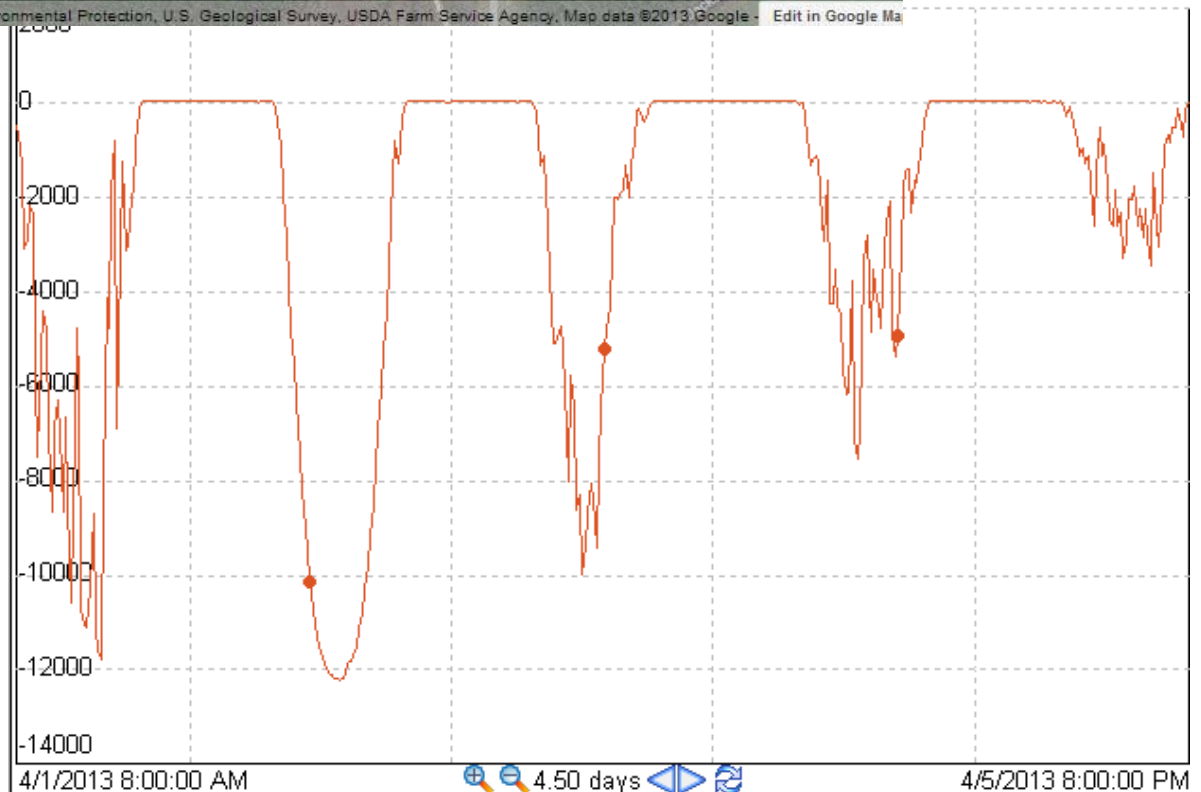
Use of PI – CAPS Open House Demo
Monitoring and Controlling Solar PV on Electric Distribution Circuit
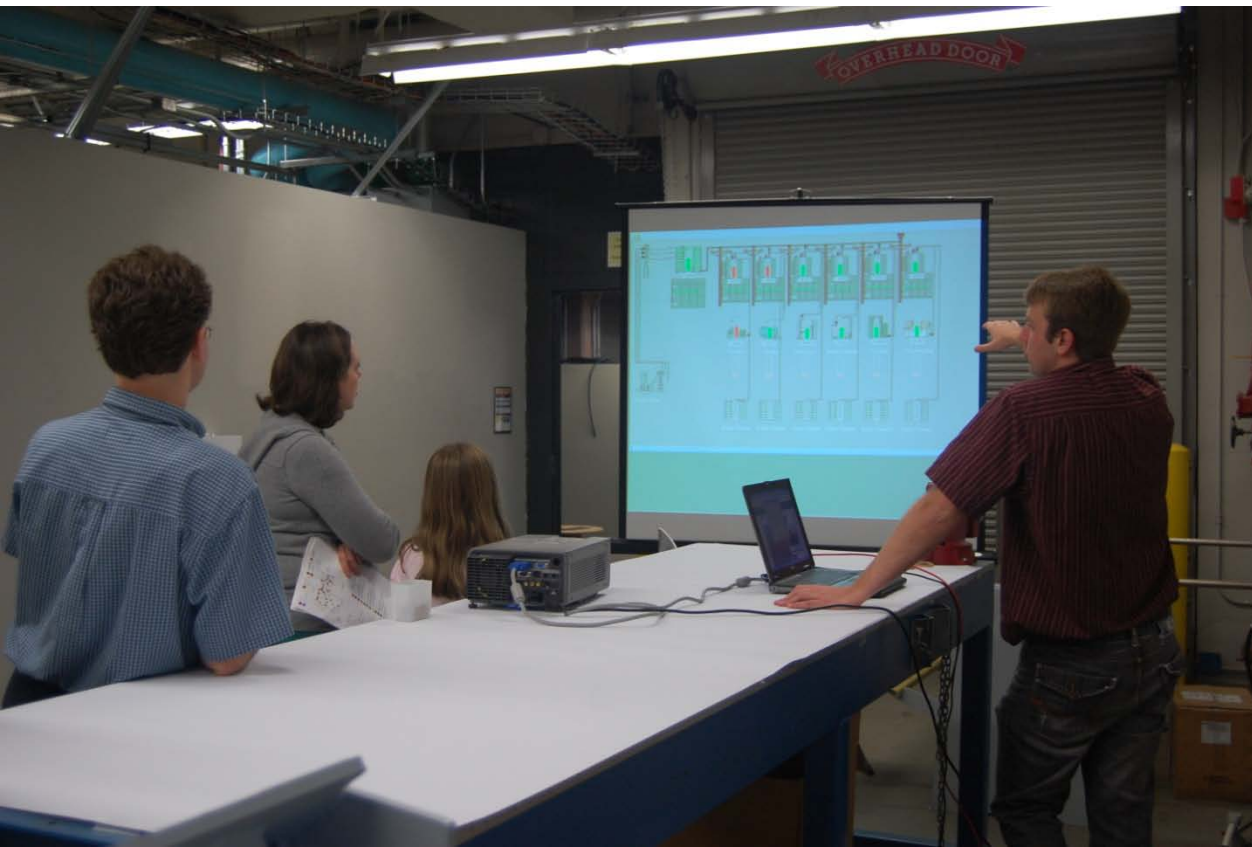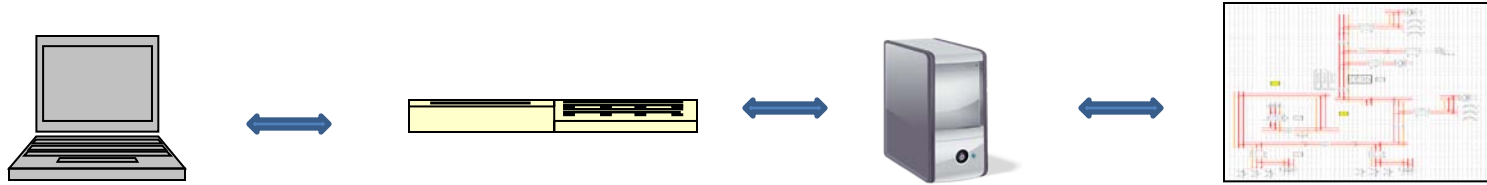
- Real-time distribution circuit model running in RTDS

- Live data in PI display from RTDS via PI

- User setpoint values to utility circuit entered in PI display, sent to RTDS

Thank You

Questions ?

Rick Meeker, P.E.
Program Development Manager
Industry Partnerships
850.645.1711

meeker@caps.fsu.edu

Center for Advanced Power Systems
at Florida State University
2000 Levy Ave., Building A, Tallahassee, FL 32310
http://www.caps.fsu.edu/