Duke Energy Smart Grid Laboratory

Energy Production and Infrastructure Center (EPIC)

DUKE ENERGY

Laboratory Capabilities

Dr. Sukumar Kamalasadan
Lab Director
skamalas@uncc.edu

Dr. Yamilka Baez
Lab Manager
YBaez-Rivera@uncc.edu

UNC CHARLOTTE

Energy Production and Infrastructure Center (EPIC)

http://epic.uncc.edu/

http://desgl.uncc.edu

Overview

UNC CHARLOTTE

EPIC

Duke Energy Smart Grid Laboratory

A Laboratory for Smarter Grid Research

Mission and Lab Focus

- Primarily supports the education, research and outreach activities related to modernizing the power grid.
- Laboratory is a unique state-of-the-art facility designed to perform advanced studies and tests in modern power systems.
- The facility includes a real-time digital simulation test-bed that perform smart grid device testing, education and professional training in grid modernization.
- A server backbone, using powerful high performance servers, is interfaced with this facility to make it a unique power analysis laboratory.

UNC CHARLOTTE

EPIC

Duke Energy Smart Grid Laboratory

- Educational and Research Activities:
  - Emulation of power, control and communications
  - Grid Modernization, Generator exciter testing
  - Model validation and integration

UNC CHARLOTTE

EPIC

Equipment List:

- SEL
- Real – Time Simulators
- Power Amplifier
- Measurement Equipment
- PV Simulator
- Loads

Protection, Automation & control System
Protection, Automation & control System
3 Rack RTDS Simulator/Cubicles/Software
Rack RTDS Cubicle
Real-Time Computer Exp System
RS90-3Pi-SNK-EXTD-480-Programmable 90 kVAPower System
Tektronix PA4000 4CH pwr analyzer w/ Tektronix DP03034 Oscilloscope
Tektronix PA4000 4CH pwr analyzer w/ Tektronix DP03034 Oscilloscope
Protection, Automation & Control system (421)
Protection, Automation & Control system (421)
Protection, Automation & Control system(487B)
Line Current Differential Prot & Auto system(311L)
Line Current Differential Prot & Auto system(311L)
Advanced Line Differential Protection, Automation & Control system (411L)
Other SEL equipment
PV Simulators (5)
Smart Grid Server
San/Network/Data/Bak up
DigSilent - Software
DSA Tools - Software
EMTP-RV - Software
PSCAD - Software
PSSE - Software
CYME - Software
RSCAD - Software RTDS
Hypersim - Software OPAL-RT
RT-LAB - Software OPAL-RT

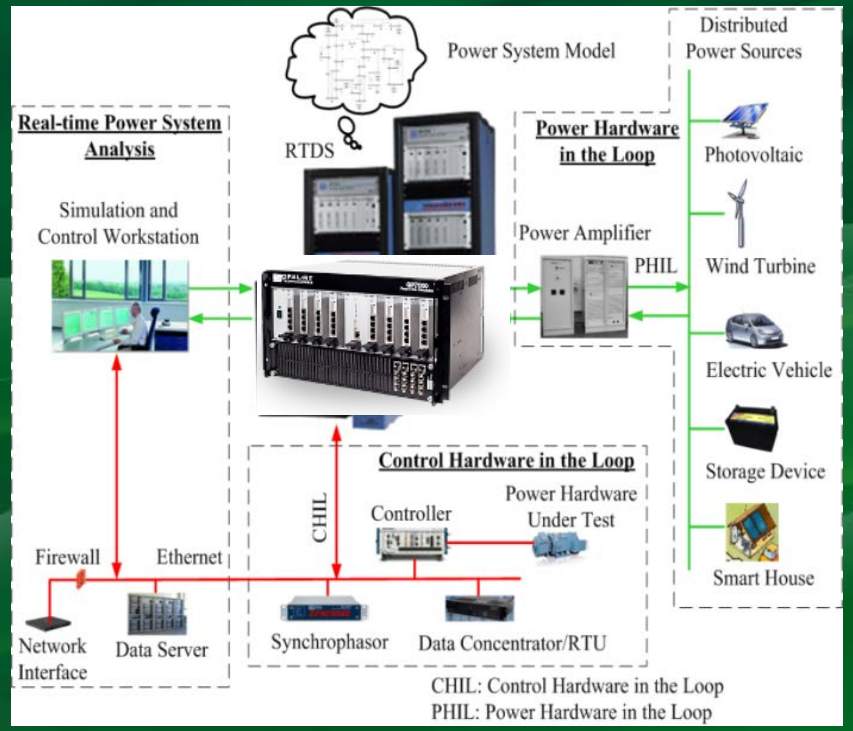
Duke Energy Smart Grid Laboratory

- Lab Equipment & Modules:
  - RTDS digital simulator (4 Rack)
  - OPAL RT digital simulator (1 Rack)
  - SEL Synchrophasor testbed
  - OPAL RT HyperSIM (1 Rack)
  - Data Storage & SCADA Gateways
  - Interoperability and Security Tools
  - Simulation Software

UNC CHARLOTTE
EPIC

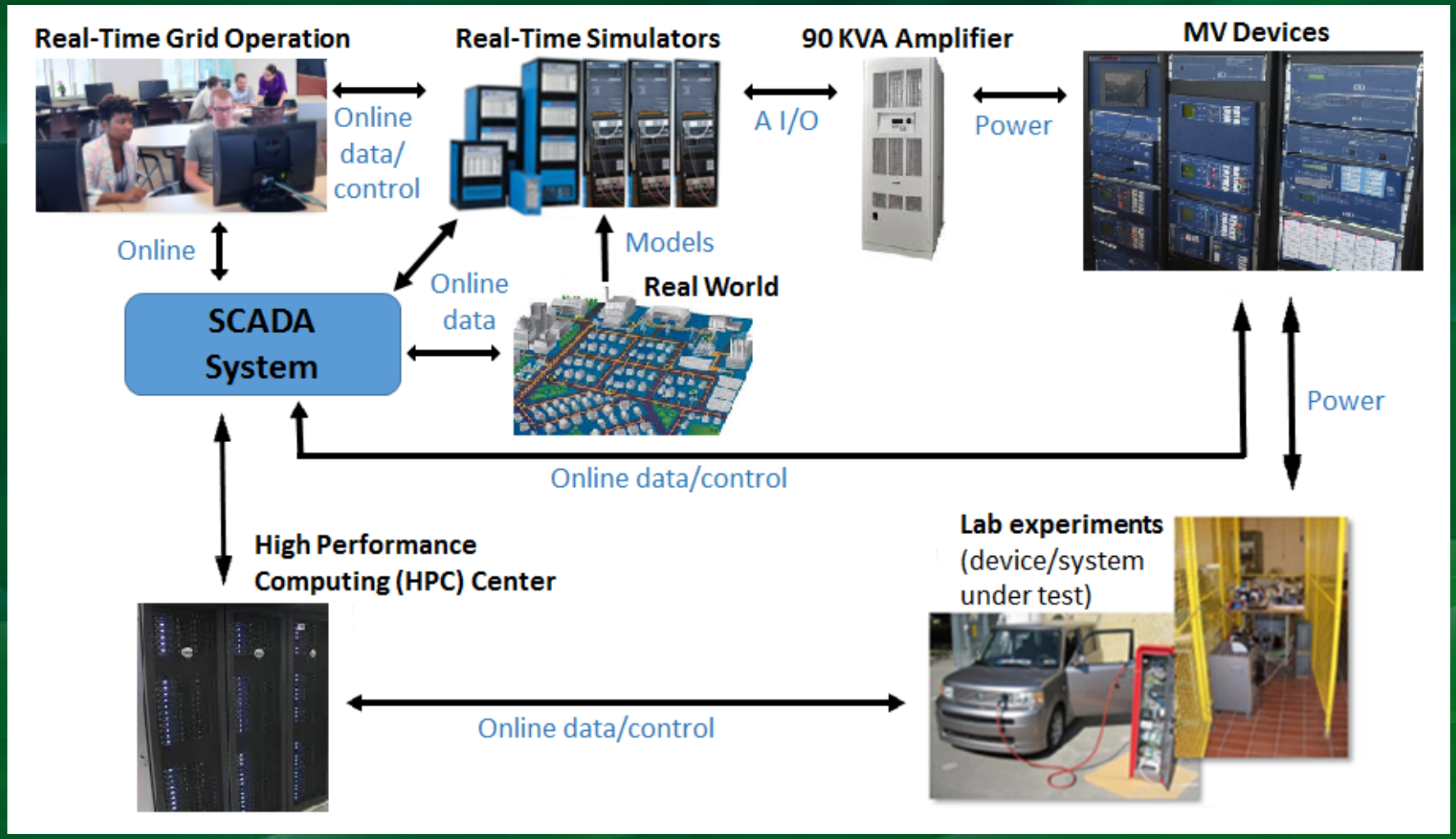
Duke Energy Smart Grid Laboratory

- Test Bed for:
  - Real-time G-T&D simulations
  - Integration of electric vehicles
  - Protective relay testing
  - HiL Controls (HVDC, SVC, FACTS, Exciters)
  - Phasor measurement-based techniques
  - Model validation and control



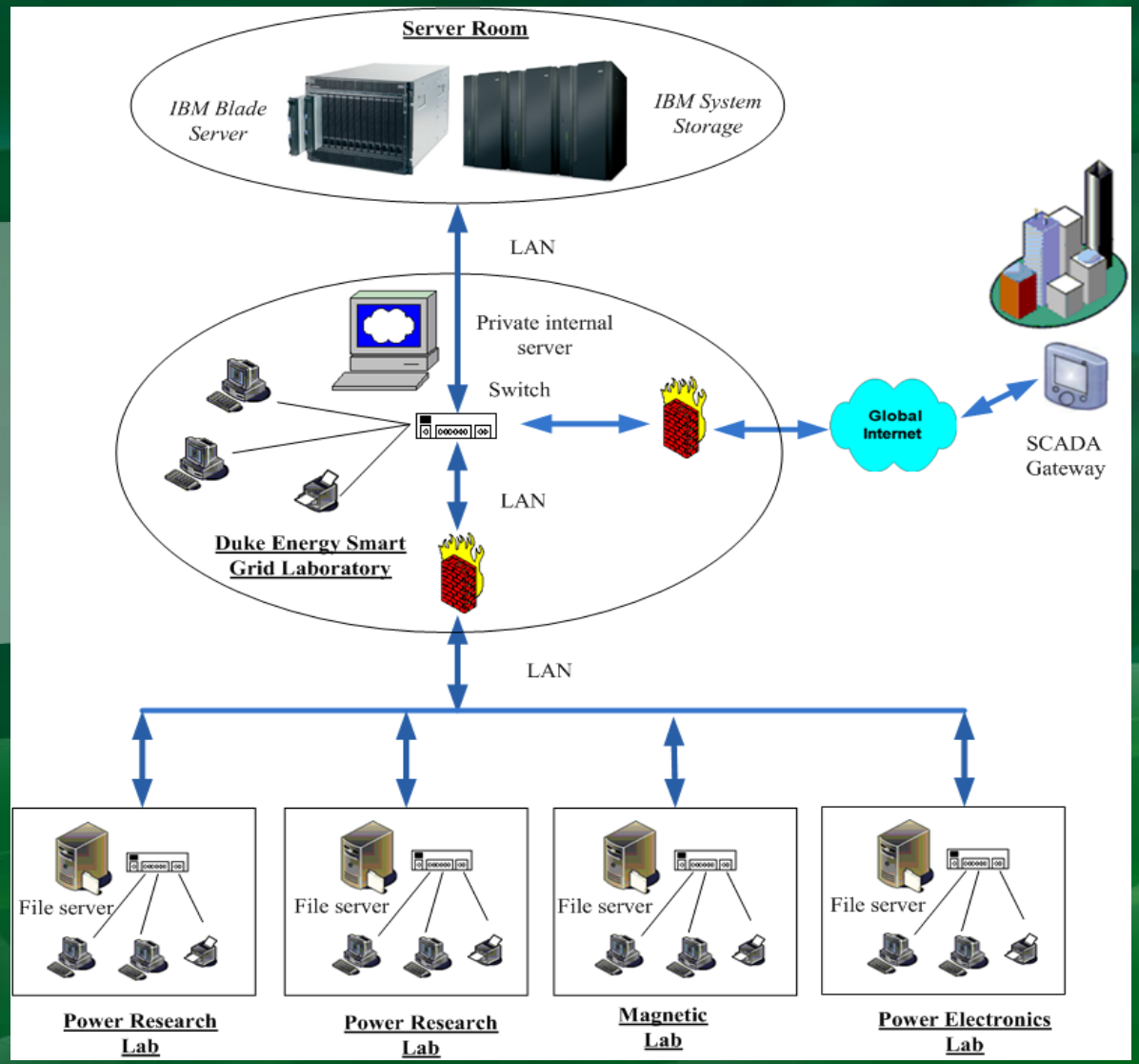
UNC CHARLOTTE
EPIC

DESG Laboratory Configuration



UNC CHARLOTTE
EPIC

DESGL Communication Network



UNC CHARLOTTE

EPIC

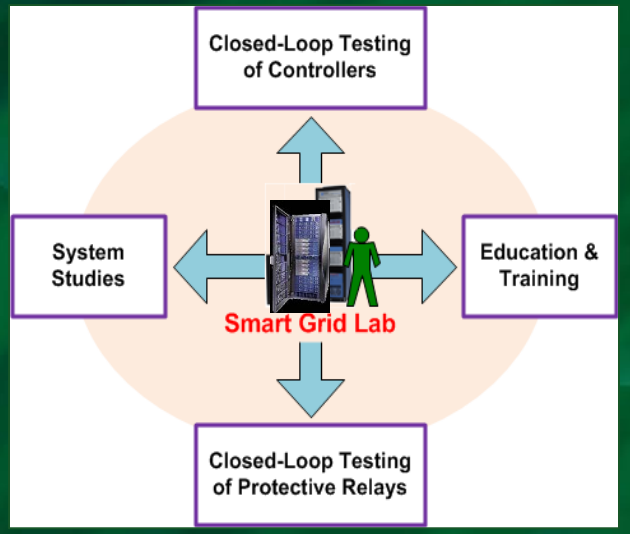
Capabilities

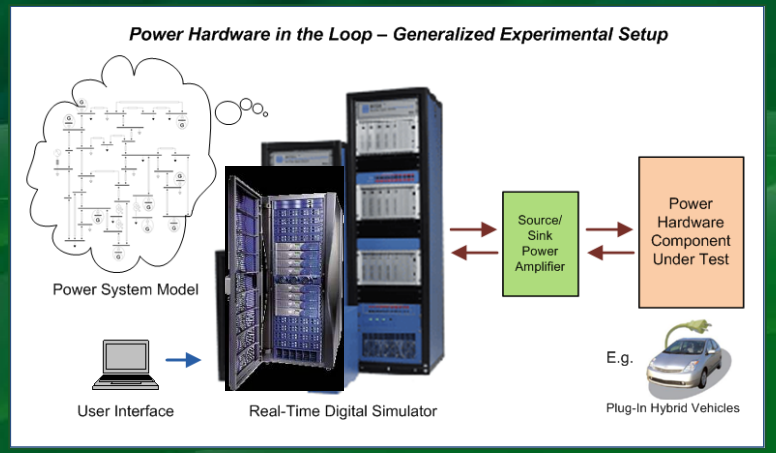
UNC CHARLOTTE

EPIC

Main Focus Areas

- Real-time power system simulation platform:
  - Precise modeling and analysis of dynamic and transient phenomena
  - Hardware-in-the-loop (HIL) testing of monitoring, protection and control devices
  - Power Hardware-in-the-loop (PHIL) simulations
    - Example: Integrating renewable energy resources (PV Panel, Wind Generator, Storage devices) to power grid- real-time simulation and testing

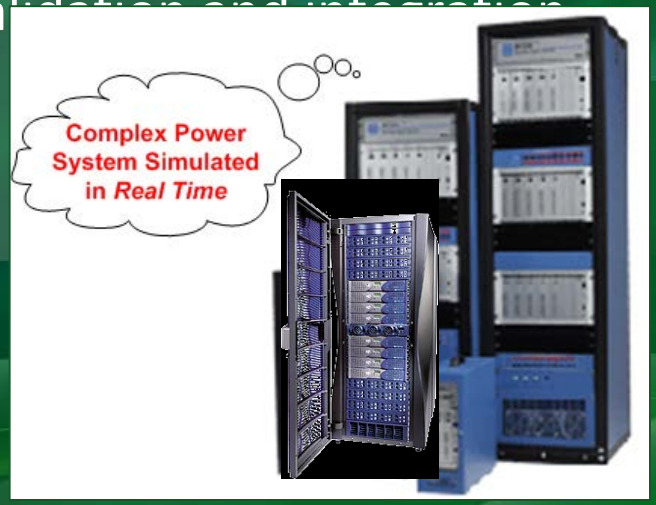




UNC CHARLOTTE
EPIC

Main Focus Areas

- *Real-Time Power System Simulation & Testing*
- Research & Educational Activities:
  - Hardware in the loop testing, model validation and integration
  - Grid Modernization, T&D Automation, Generator exciter testing
  - Real-time simulation of power, control and communication devices
  - Real-time simulation of protective devices
- Test Bed for:
  - Contract Research
  - Graduate Research Projects
  - Undergraduate Projects (Senior Design)



Real-Time Digital Simulator (RTDS®)

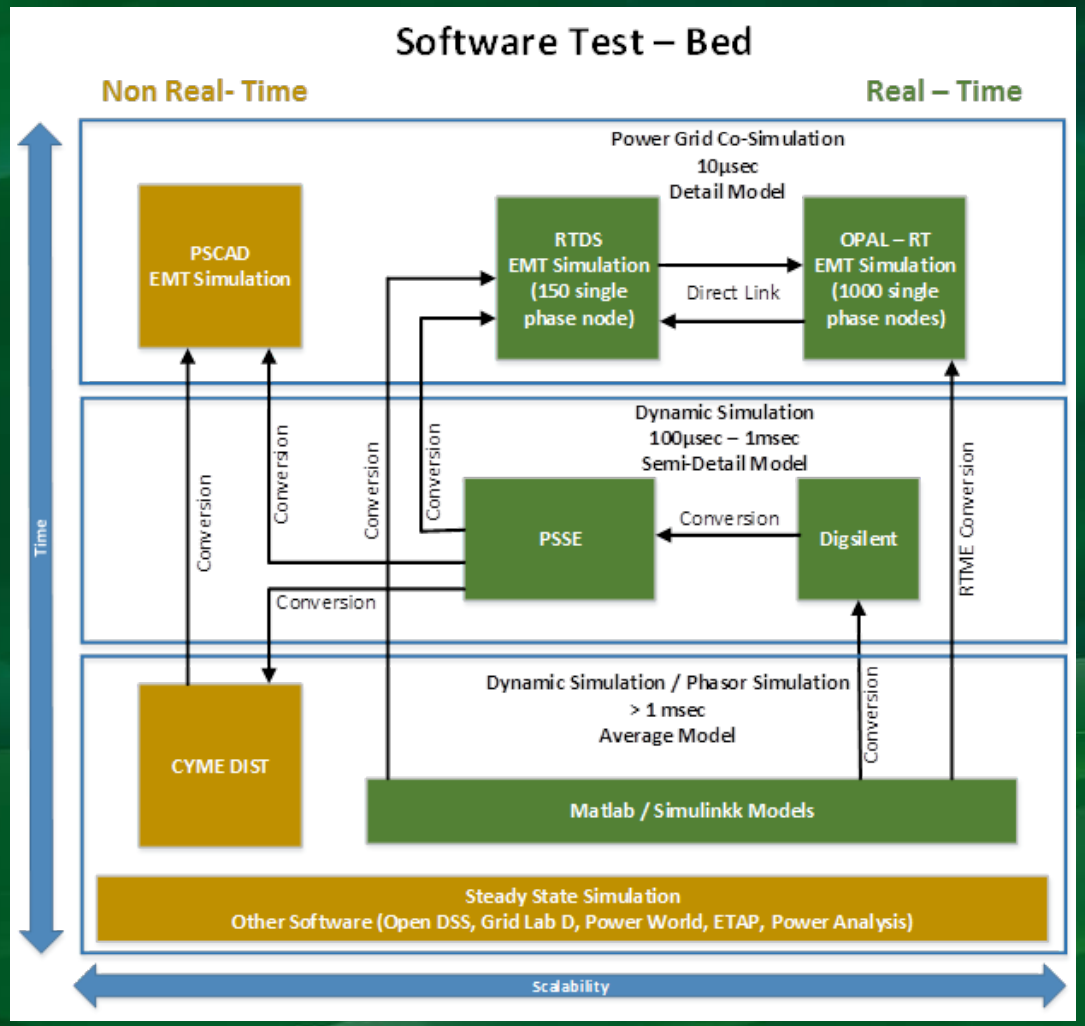
UNC CHARLOTTE
EPIC

Test Beds

UNC CHARLOTTE

EPIC

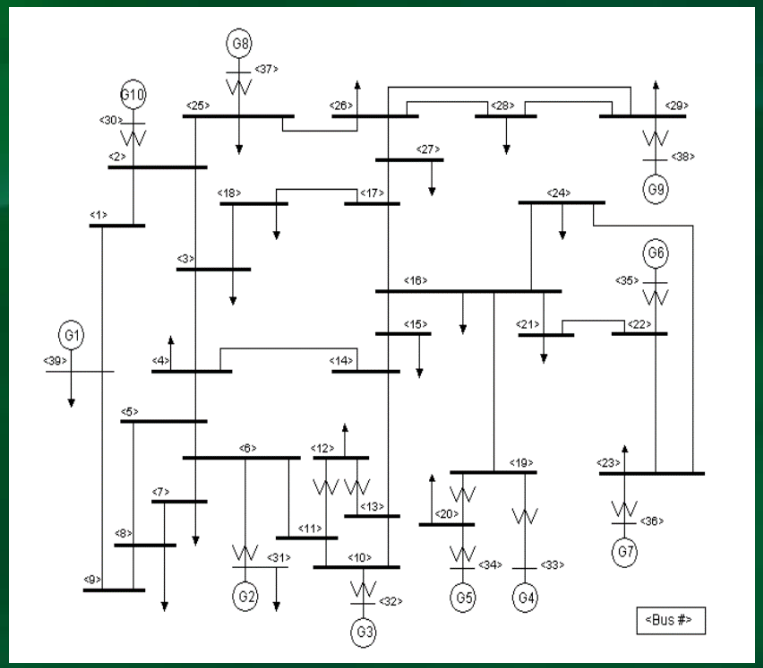
Software Test - Bed

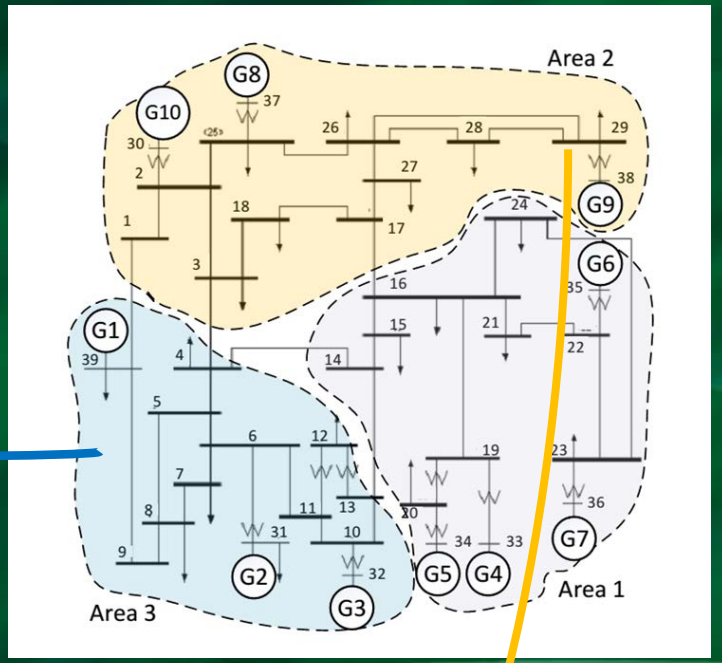


- Perform advanced studies and tests in modern power and energy systems
- Eliminates the redundancy of design and development of models
- Use for testing and evaluation of device functionality, dynamic and stability studies PHiL, and CHiL

UNC CHARLOTTE
EPIC

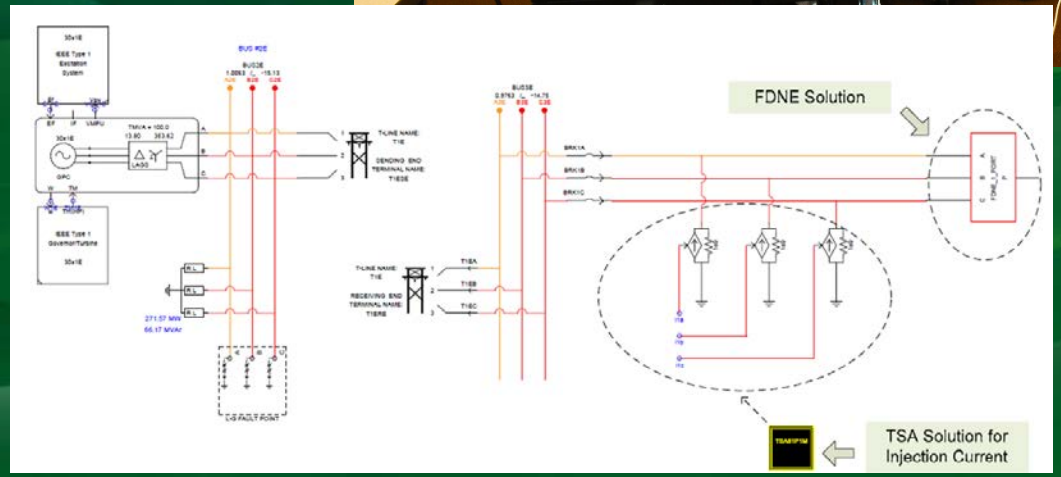
RTDS/OPAL- RT Software Test – Bed

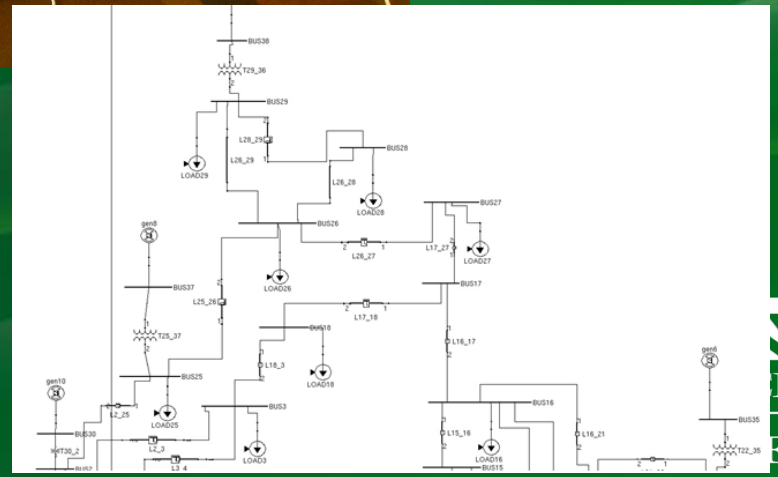




UNC CHARLOTTE
EPIC

RTDS/OPAL- RT Co-Simulation Test Bed

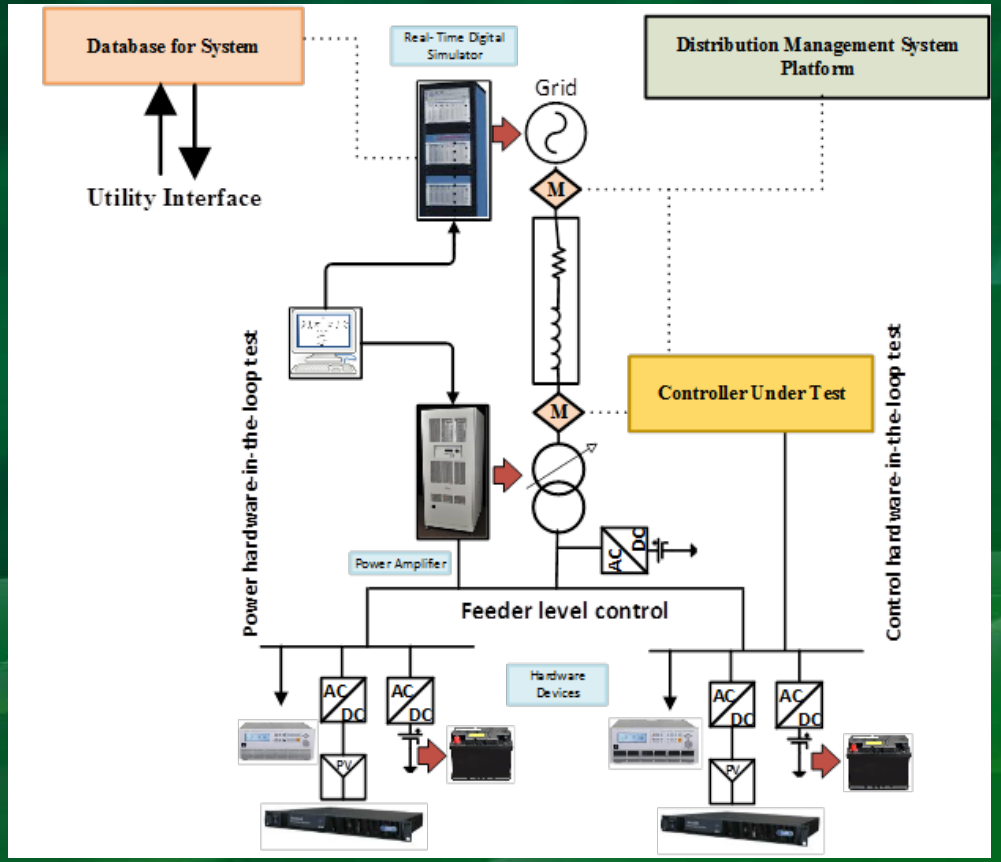




CHARLOTTE
EPIC

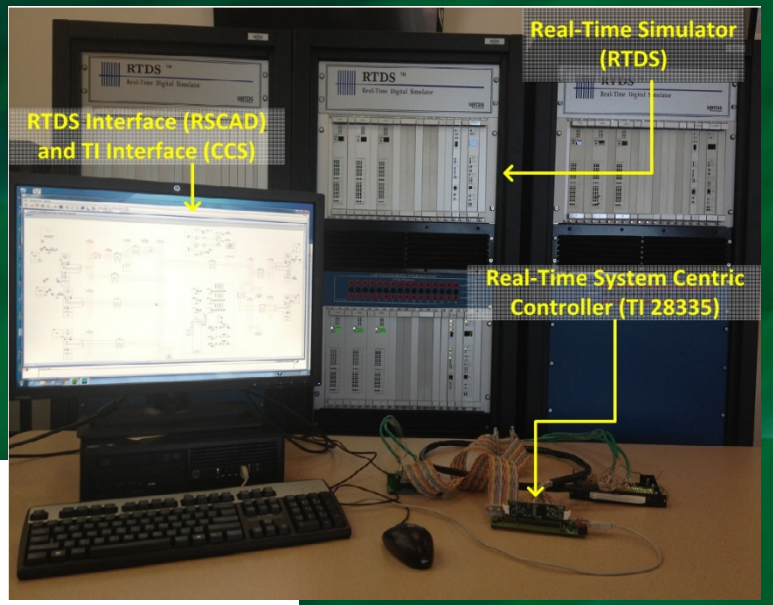
PHiL and CHiL Test - Bed

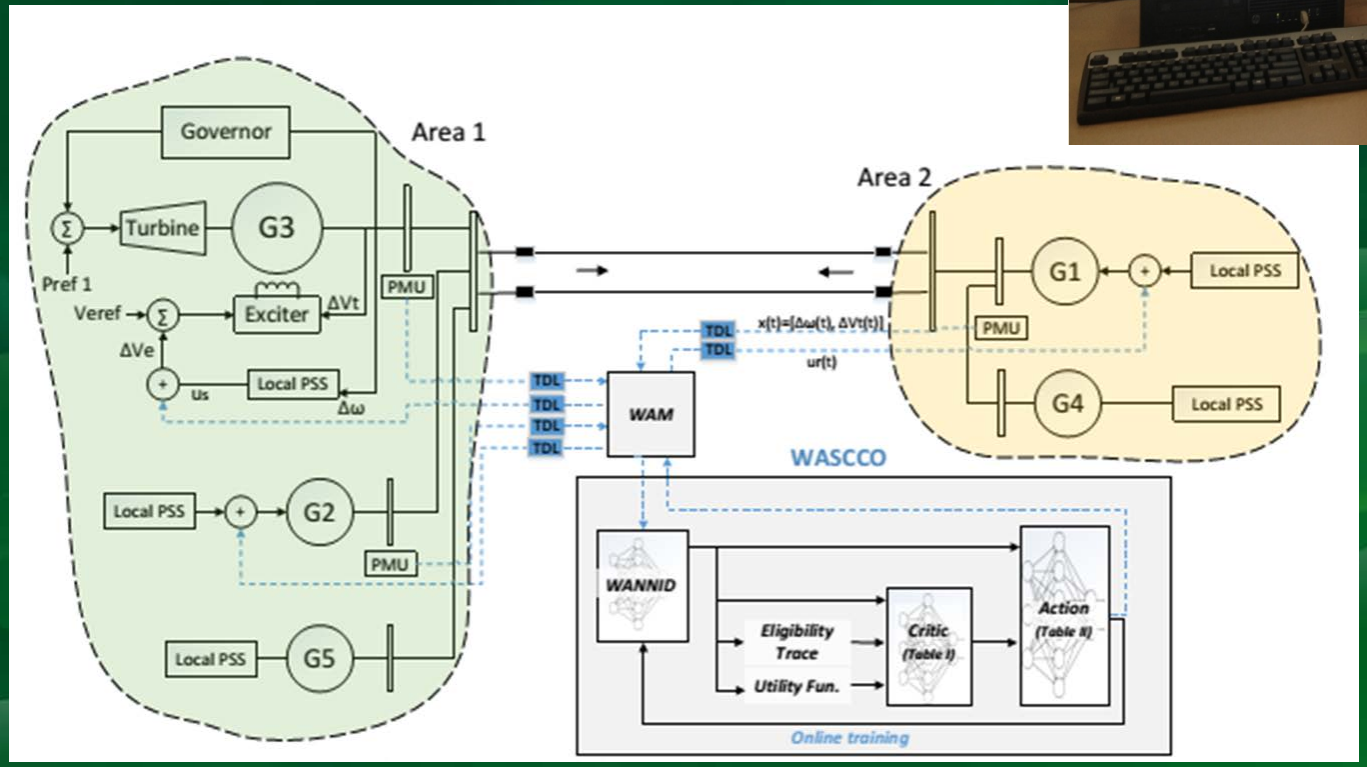
- Study the impact of renewable distributed generation and distributed storage
- Analysis of renewable integration
- Synchrophasors
- PMU's
- Study faults and operating conditions of protective relays
- Interface with Utility for data and device validation
- Study Harmonics, HVDC, FACTS, etc.



UNC CHARLOTTE
EPIC

Real-Time Control Test Bed





UNC CHARLOTTE
EPIC

Research Areas

UNC CHARLOTTE

EPIC

Projects

- Device Functionality Testing
  - Closed-loop testing of physical devices
  - Protective relays, metering devices, and PMUs
  - Digital controllers for FACTS and system automation
- System Integration Testing
  - Protection scheme testing
  - Closed-loop system and sub-system testing
  - Integration of renewables and micro-generation
  - Interoperability Test-bed and communication/data management
- Real-Time Power System Studies
  - High Speed Power System Studies
    - Impacts of renewable energy resources
    - Investigation of switching events, power quality and transients
    - Assessment of operation strategies, contingencies and restoration plans
  - System level modeling and control
  - Distribution system studies
  - NERC's standards compliance study, validation, and testing

UNC CHARLOTTE

EPIC

Research Projects Examples

UNC CHARLOTTE

EPIC

Example Project 1: Power System Wide Area Controller

- Advance Adaptive PSS designs and validation in RTDS:
  - Temporal Differences as the solver of reinforcement learning Problem
  - Small-signal stability analysis in offline mode
  - Fast Fourier Transform techniques for evaluation
  - Tuning the cost function based on energy or eigenvalue analysis
  - Value Priority for working with conventional controllers

NSF CAREER: A new generation of scalable intelligent supervisory loop based algorithm for complex system control and optimization

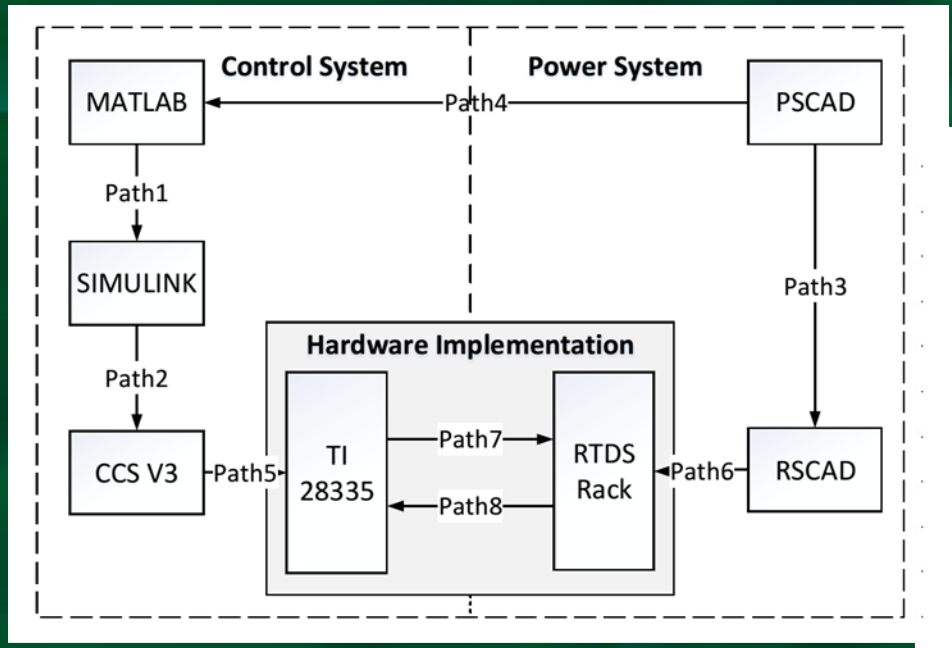
Award # ECS 0748238, PI: Sukumar Kamalasadan

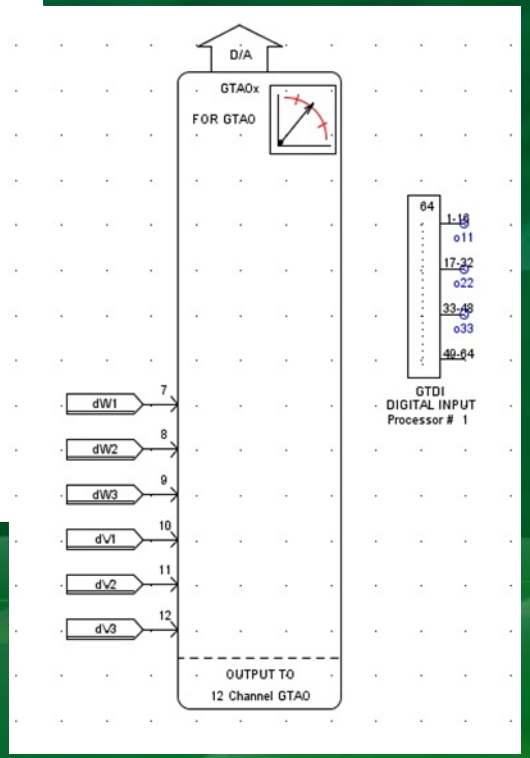
UNC CHARLOTTE

EPIC

Power System Wide Area Controller

Path 7: GTDI
Path 8: GTAO





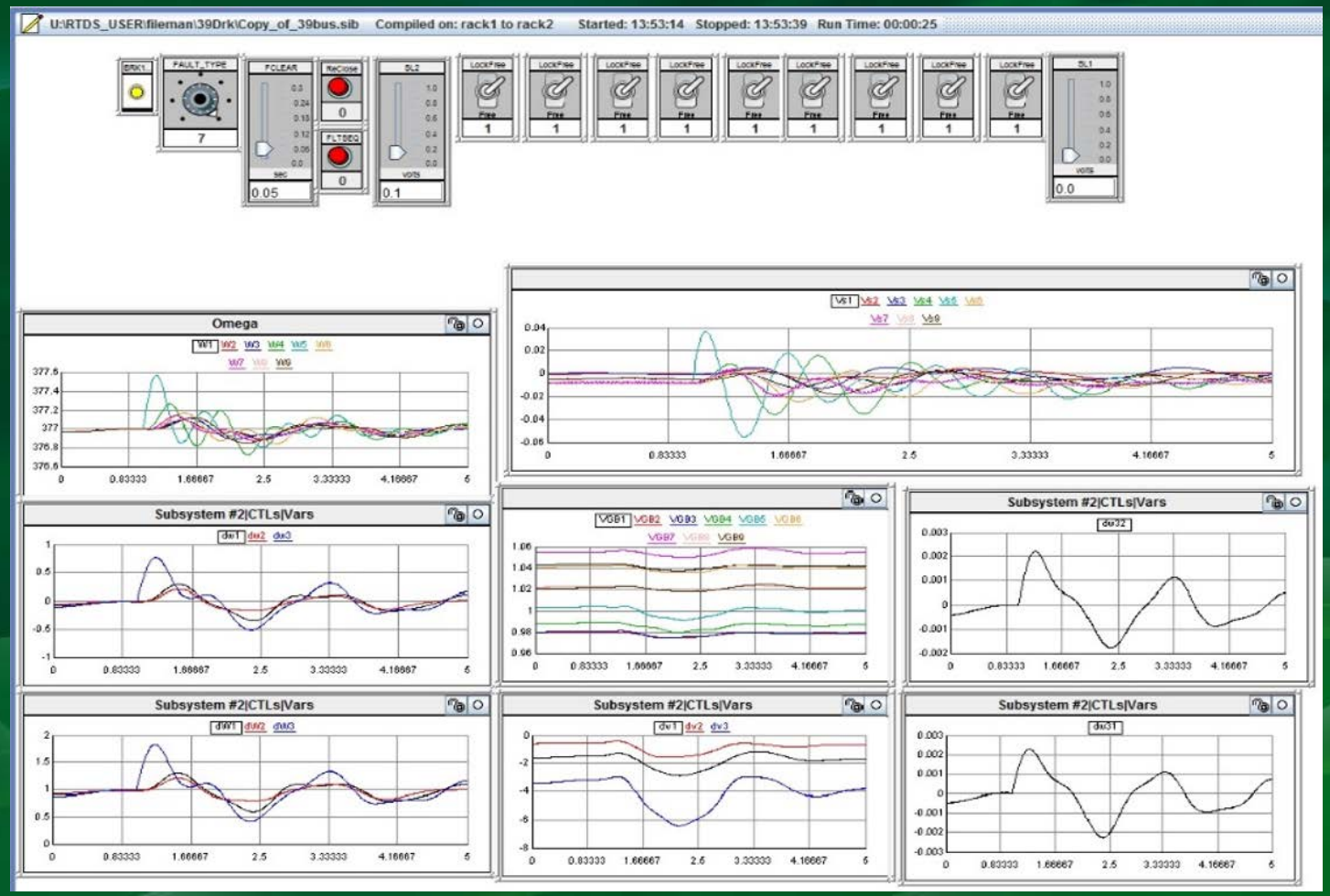
Power Grid Model in Real-time Digital Simulator

Real-Time System-Centric Controller in TI Board

Intelligent System-Centric Controller in Simulink

UNC CHARLOTTE
EPIC

Power System Wide Area Controller

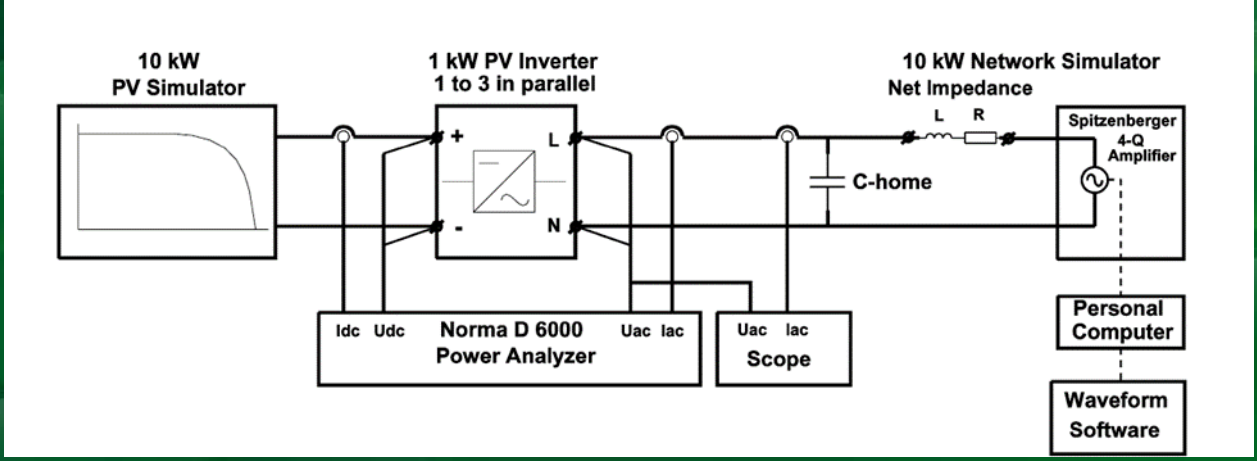


UNC CHARLOTTE

EPIC

Example Project 2: Harmonics

- Study Power Quality – Harmonics found in projects with PV penetration
- Study Harmonics based on amount of PV penetration, topologies and control options
- Study Real time Harmonics – Power Hardware in the loop



UNC CHARLOTTE
EPIC

Harmonics – PHiL Test Bed

PV Simulator

Loads

Power Analyzer

Controller

Inverter

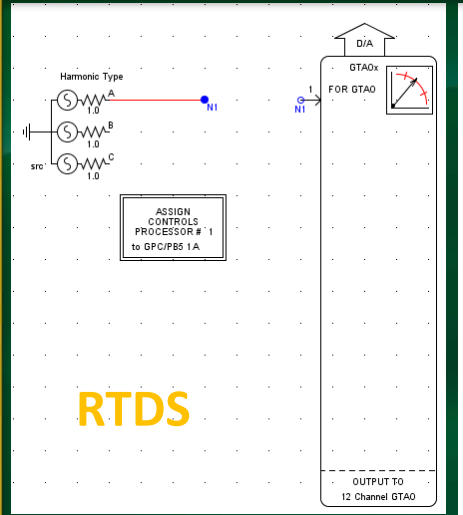
Power Amplifier 90KVA

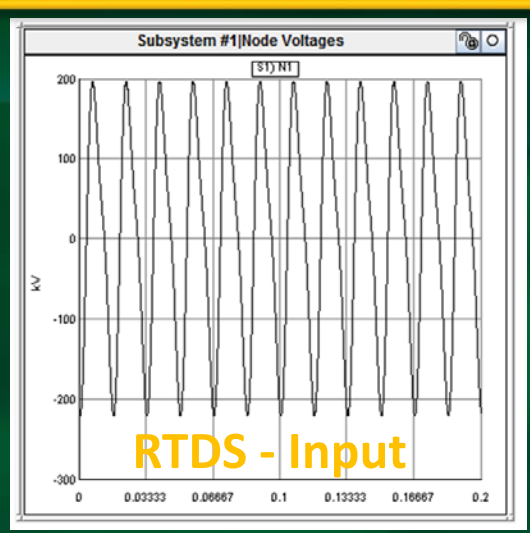
RTDS Connect with PA to send input signal or system schematic data

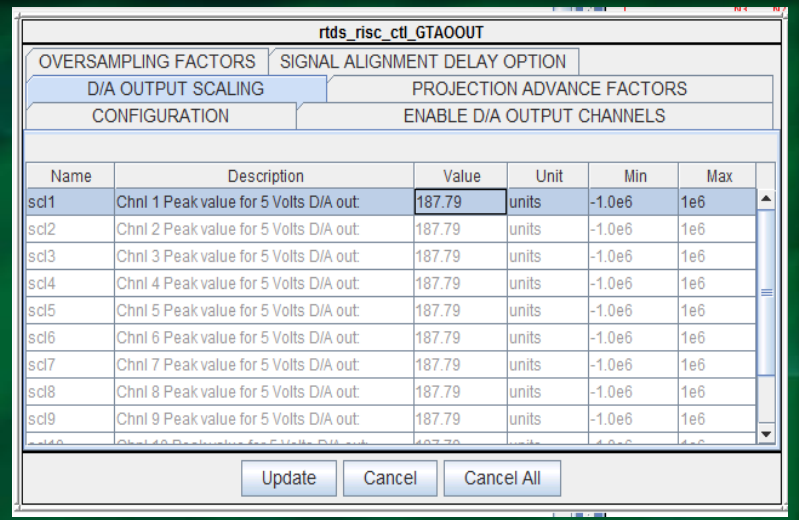
UNC CHARLOTTE

EPIC

Harmonics – PHiL Test Bed







Power Amplifier

Harmonics Measure as System Output

lf_rtds_sharc_sld_SRC

MONITORING | SIGNAL NAMES | REMOTE FAULTS
HARMONICS | POSITIVE SEQUENCE RRL | HARMONIC SOURCE INITIAL VALUES
CONFIGURATION | PROCESSOR ASSIGNMENT | NUMBER OF HARMONICS

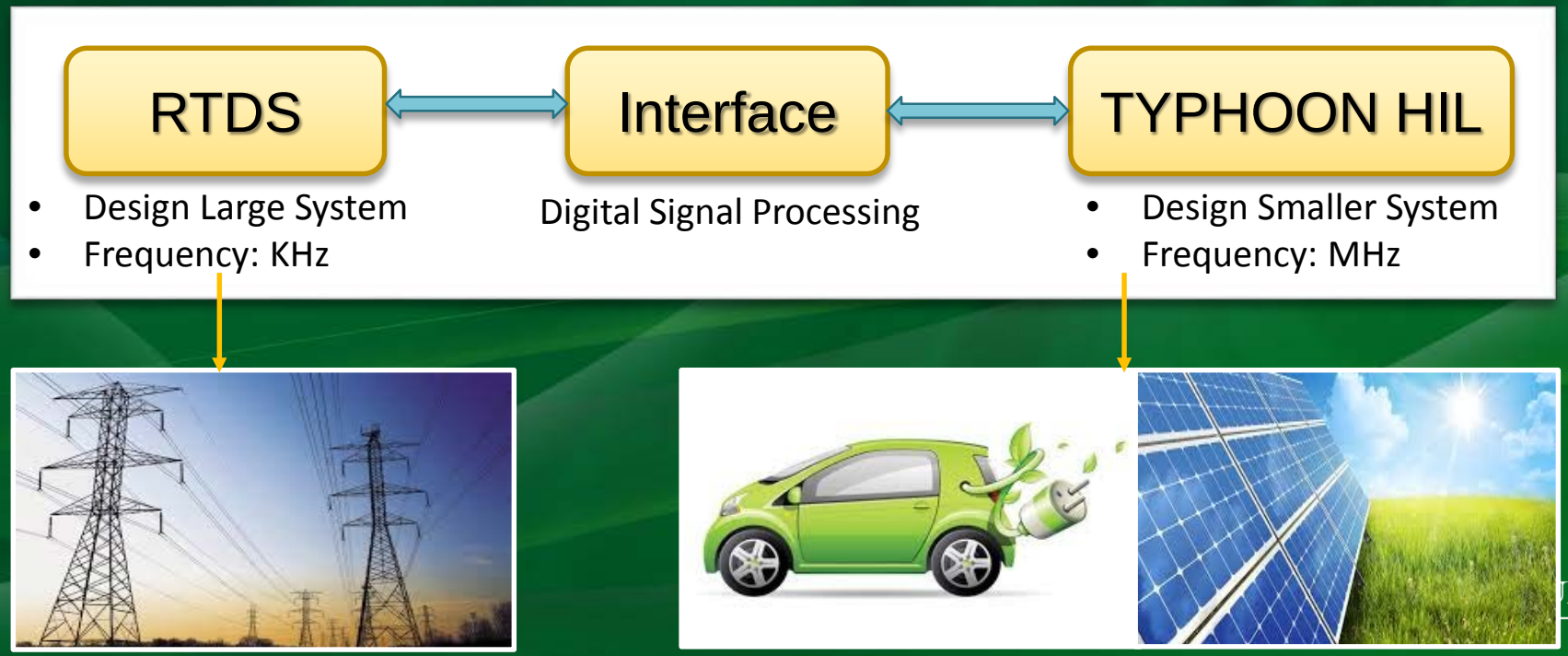
Name	Description	Value	Unit	Min	Max
HN1	Harmonic Number	2		1	99
Mag1	Harmonic Magnitude	0.1	p.u.	0	1E38
Ph1	Harmonic Angle	20	deg	-360	360
HN2	Harmonic Number	2		1	99
Mag2	Harmonic Magnitude	0.1	p.u.	0	1E38
Ph2	Harmonic Angle	30	deg	-360	360
HN3	Harmonic Number	2		1	99
Mag3	Harmonic Magnitude	0.08	p.u.	0	1E38
Ph3	Harmonic Angle	0.0	deg	-360	360
HN4	Harmonic Number	2		1	99
Mag4	Harmonic Magnitude	0.05	p.u.	0	1E38
Ph4	Harmonic Angle	0.0	deg	-360	360

Update | Cancel | Cancel All

CHARLOTTE
EPIC

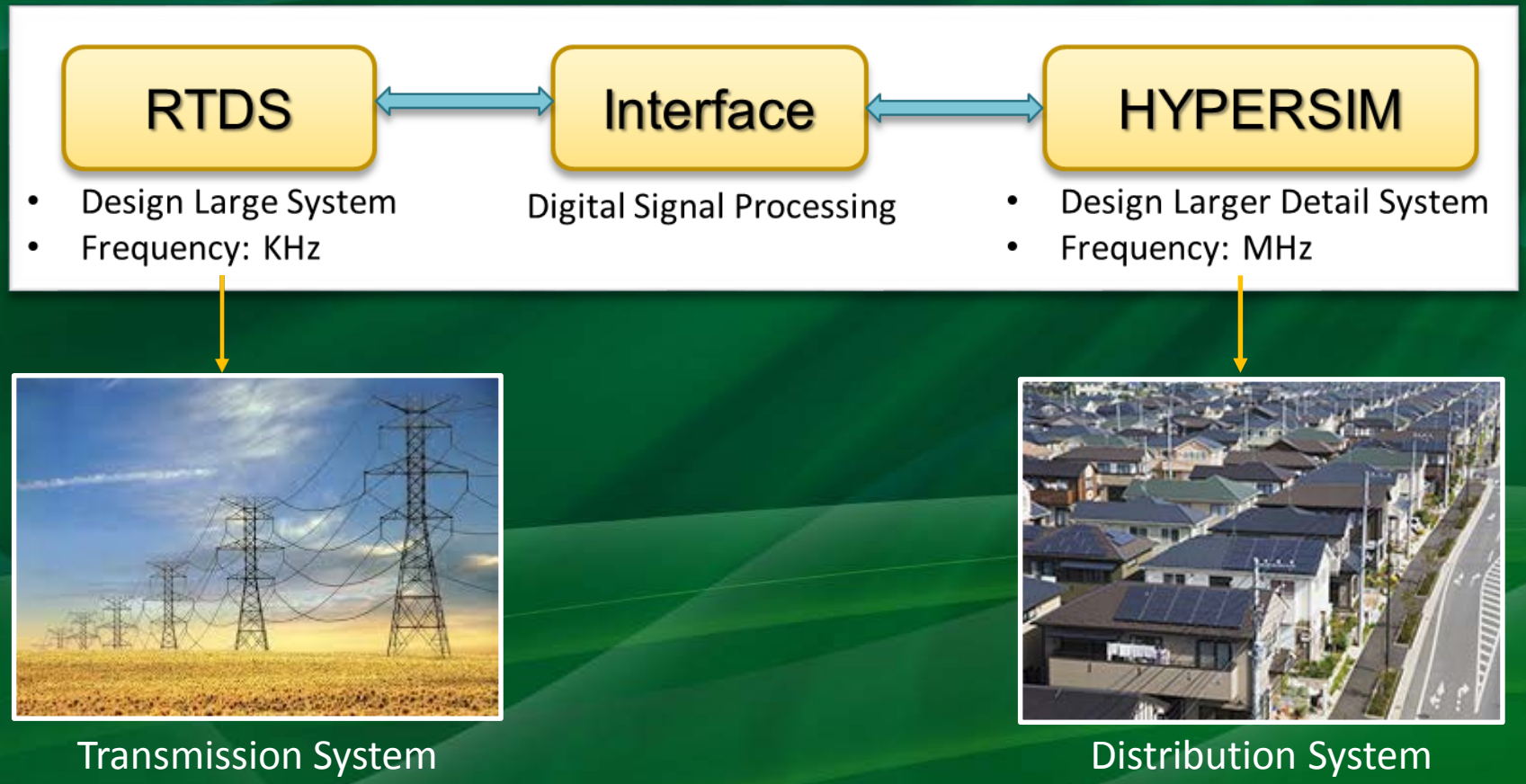
Example Project 3:
SCE: Co - Simulation

- Distributed simulation of complex subsystems at different time steps
- Interface different real time simulators
- Simulate subsystems in different simulations
- Study and Analysis of test cases



UNC CHARLOTTE
EPIC

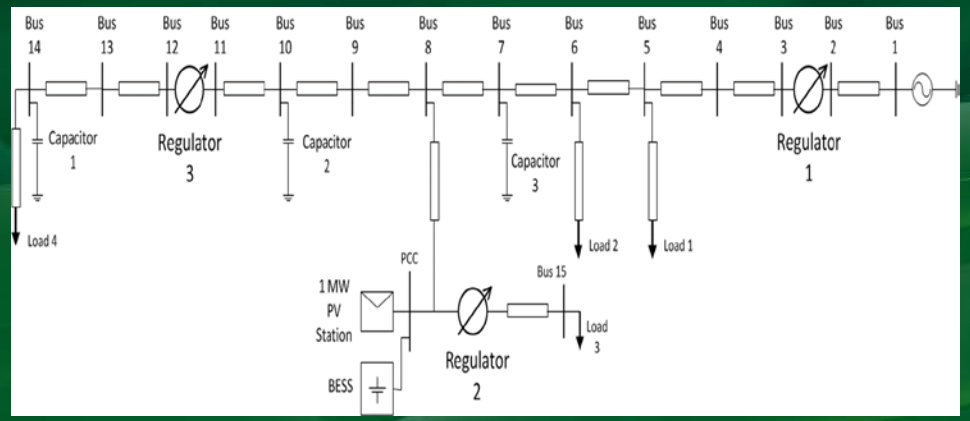
SCE Co-Simulation

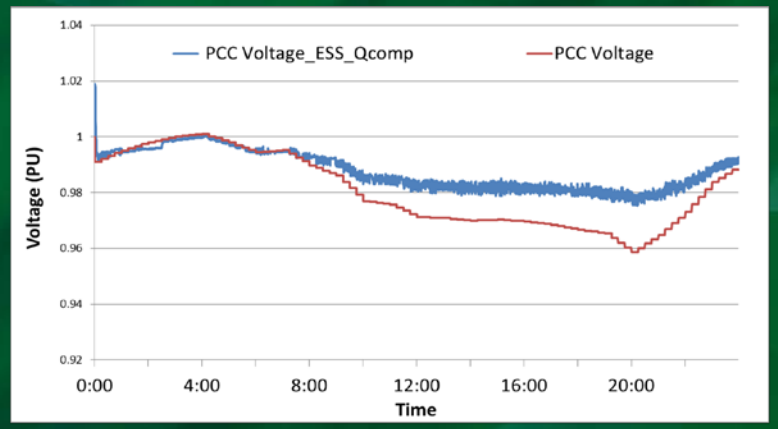


UNC CHARLOTTE
EPIC

Example Project 4: Energy Storage Control Management

- Study implementation of energy storage applications
  - Renewables (PV) Capacity Firming
  - Energy Time Shift
  - Voltage Support



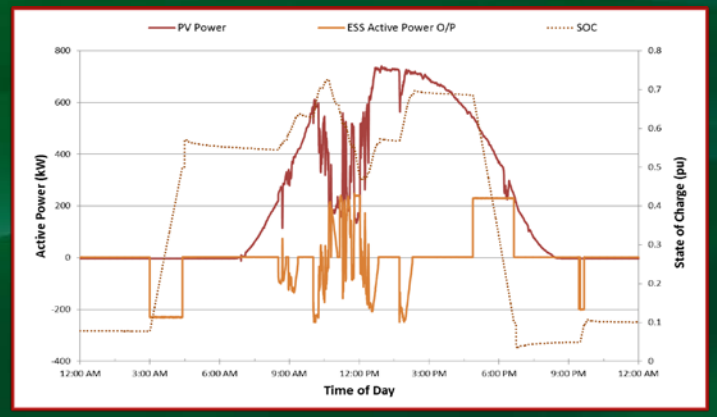


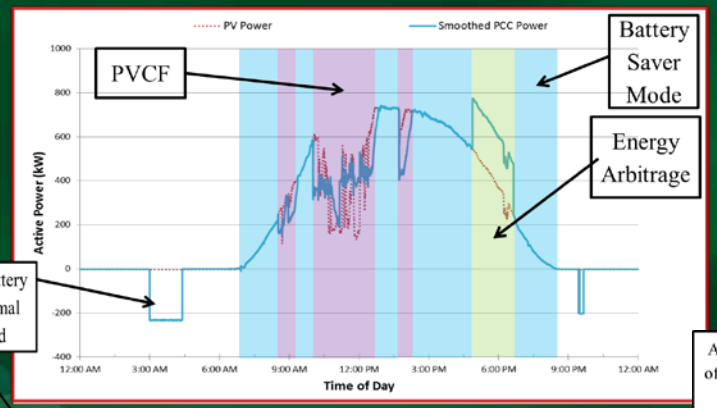
	Case	PCC Voltage		SS Voltage		Reg1	Reg2	Reg3
		Min	Max	Min	Max			
Voltage Regulators: ON	*ESS: Off*	0.974	1.003	0.988	1.01	2	7	8
	ESS Compensation	0.978	1	0.986	1.0051	0	1	3
Voltage Regulators: OFF	*ESS: Off*	0.958	1.002	0.976	1.005	N/A	N/A	N/A
	ESS Compensation	0.976	1	0.986	1.005	N/A	N/A	N/A

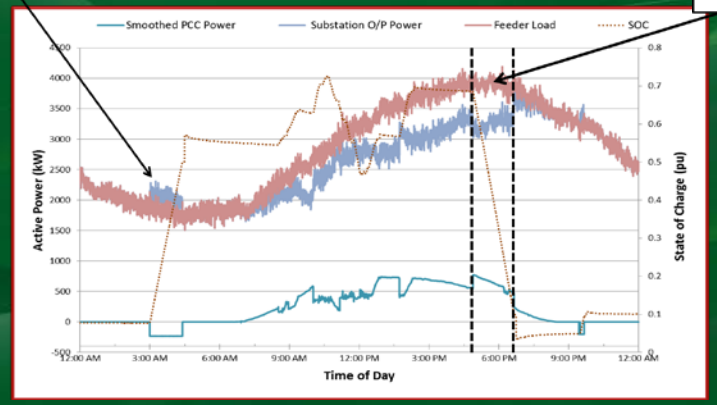
UNC CHARLOTTE
EPIC

Energy Storage Control Management

Practical Implementation





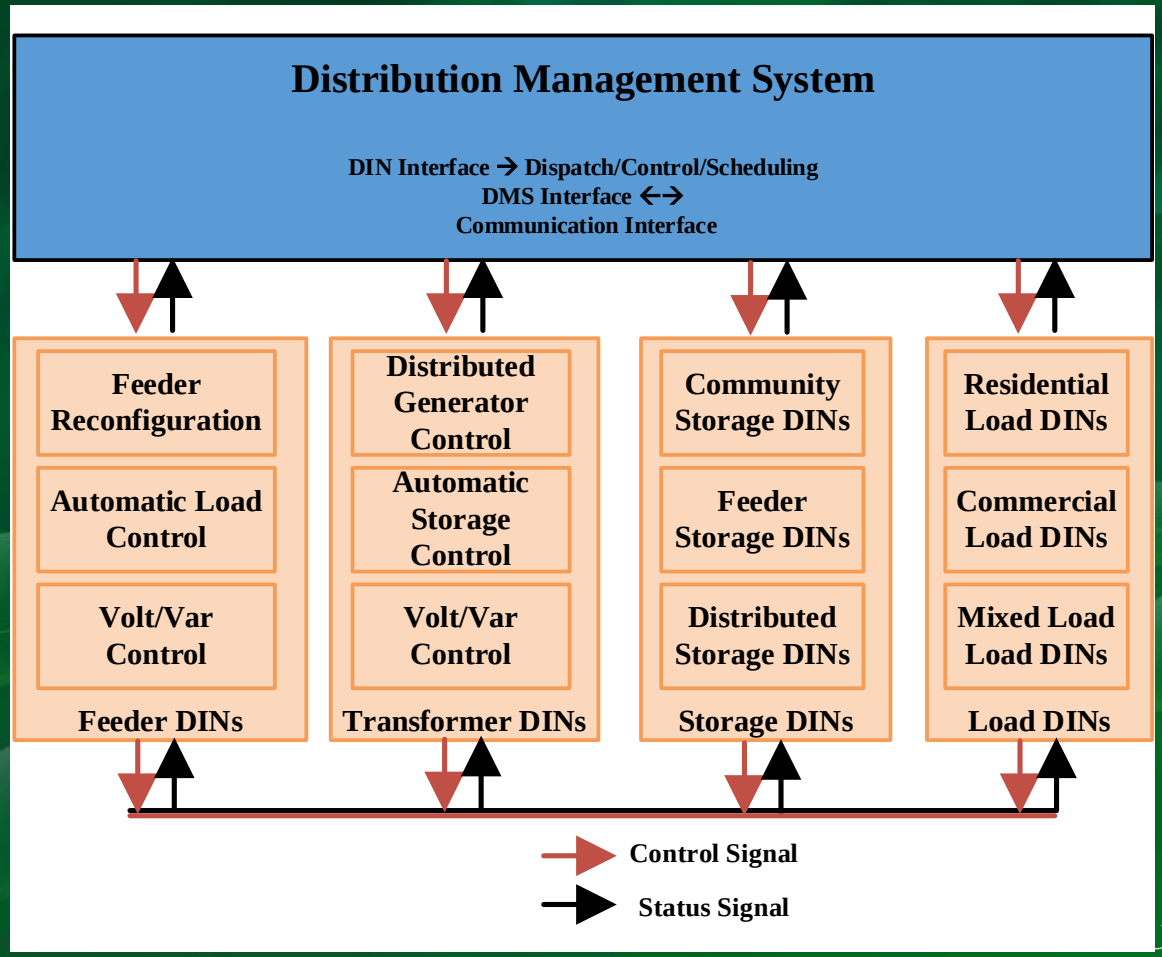


- A new control method for multiple applications of BESS in the SMS, that allows three main functions of BESS, energy time shift, PVCF and Voltage Support integrated to perform optimal battery management based on State of Charge.
- PVCF using a BESS is effective in smoothing power swings of double the capacity of the battery used.
- Consideration of SoC during PVCF application to allow proper coordination with ETS leaded to more efficient peak load shaving.
- Voltage support application was successful at tightening the voltage band at the PCC of the tested feeder with feeder voltage regulators offline.

UNC CHARLOTTE
EPIC

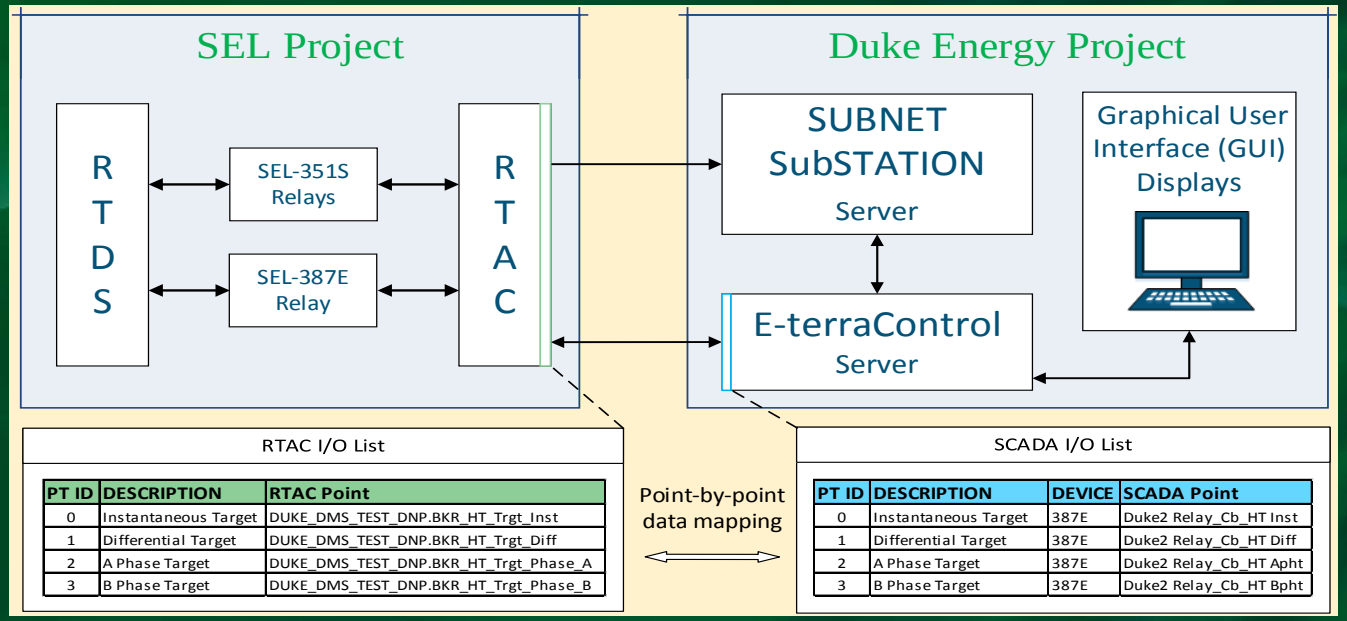
Example Project 5: SCADA and DMS Test - Bed

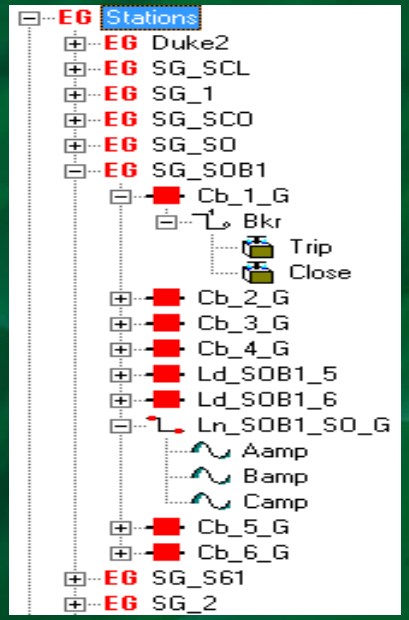
- Can handle big data from the power grid (Utility Interface)
- Network Visualization in Real Time
- Analytical and Remedial Actions
- Planning and Implementation of System Protection Schemes
- SCADA receive status signals as well as control

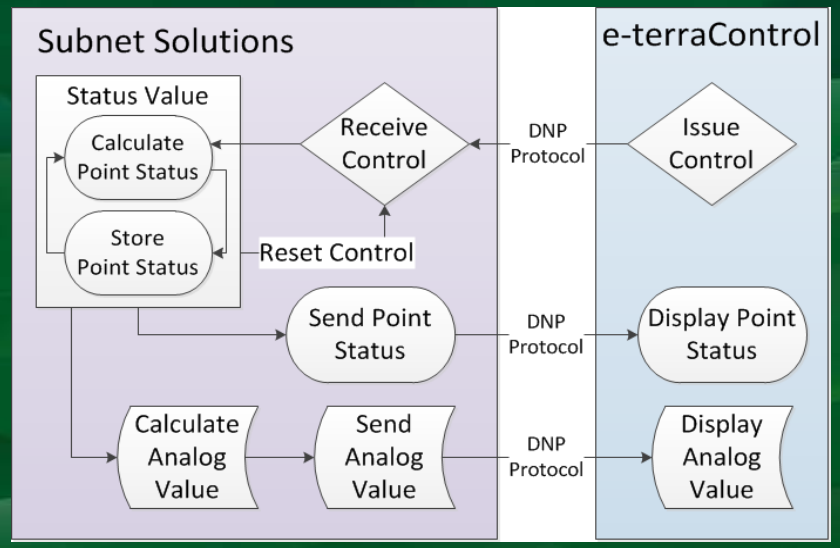


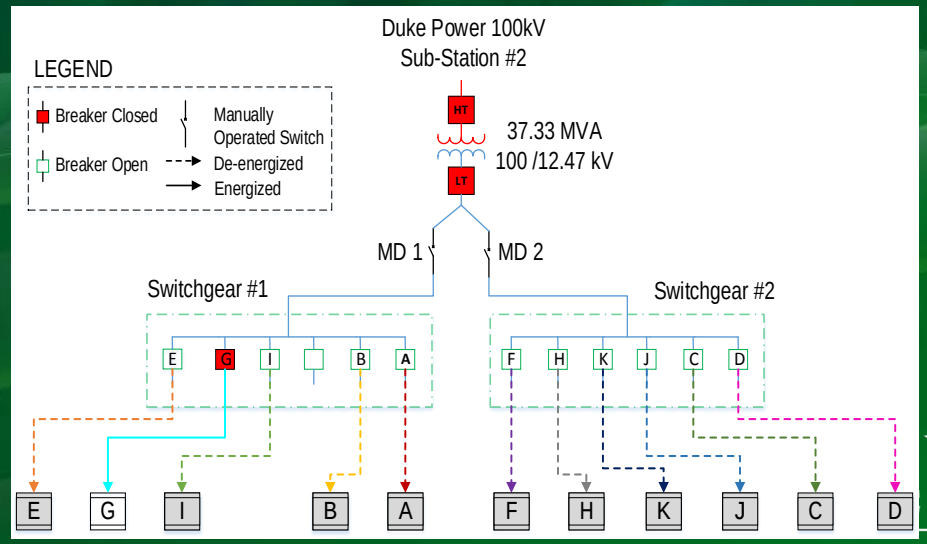
UNC CHARLOTTE
EPIC

Distribution Management System







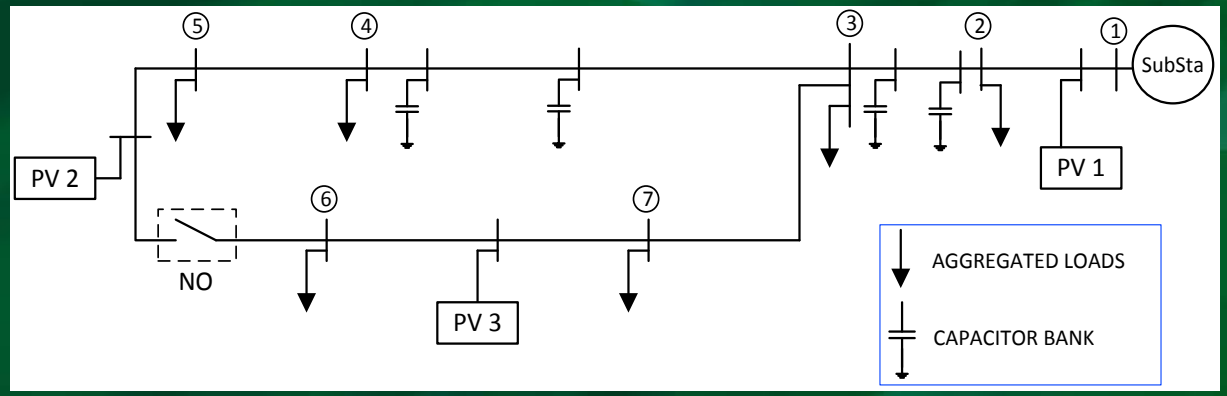


CHARLOTTE EPIC

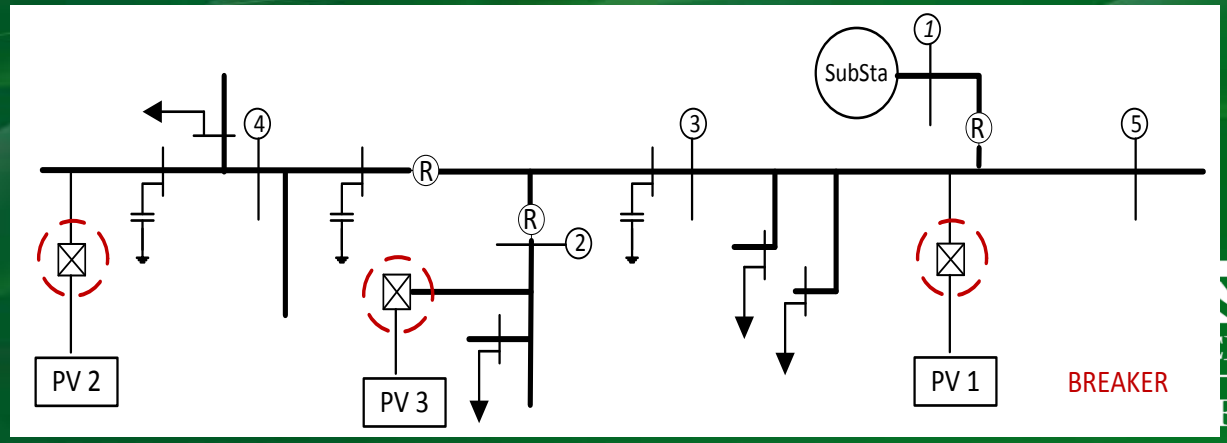
Example Project 6: PV Integration and Penetration Study

- Study of PV integration in a residential feeder and a rural feeder
- Study multiple cases of PV penetration levels
- Study steady-state and dynamic models (substation, voltage regulators, cap banks, breakers, loads, islanding, etc.)
- Assess mitigation strategies

Urban Feeder – 43MVA

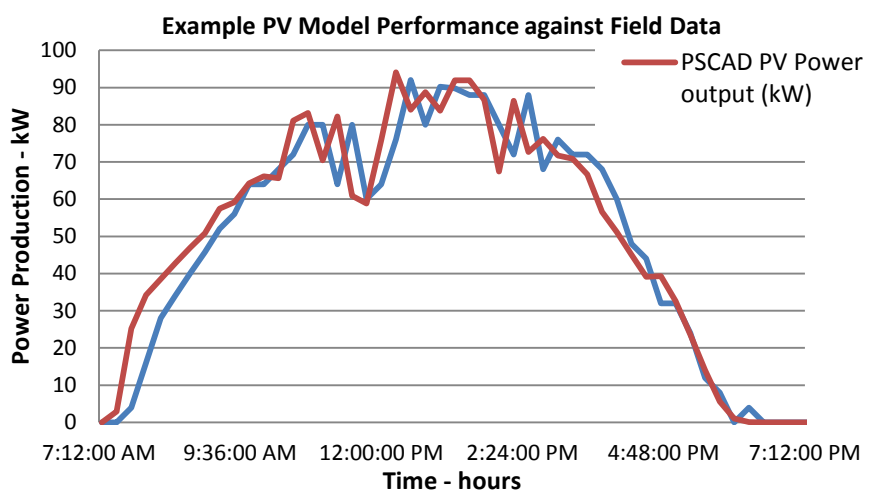


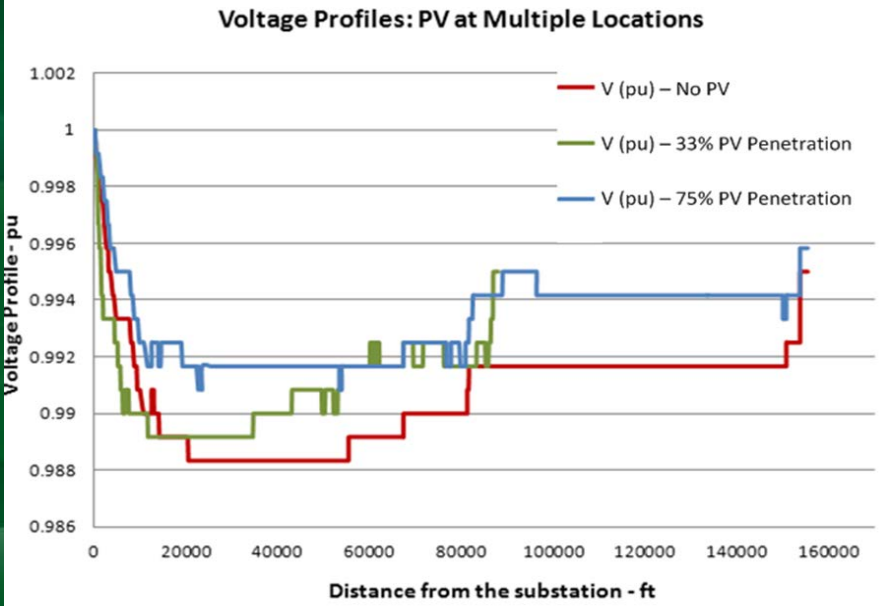
Rural Feeder – 30MVA

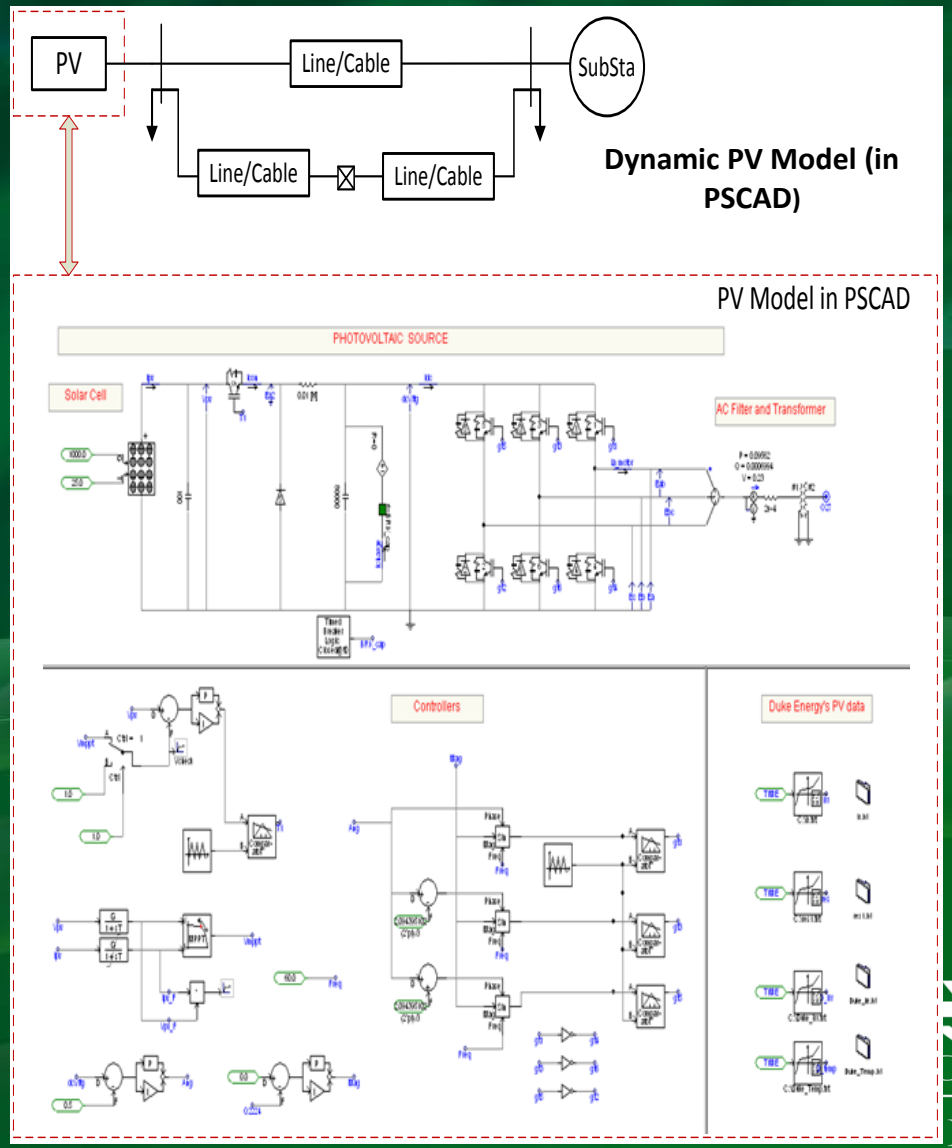


CHARLOTTE
EPIC

PV Integration and Penetration Study





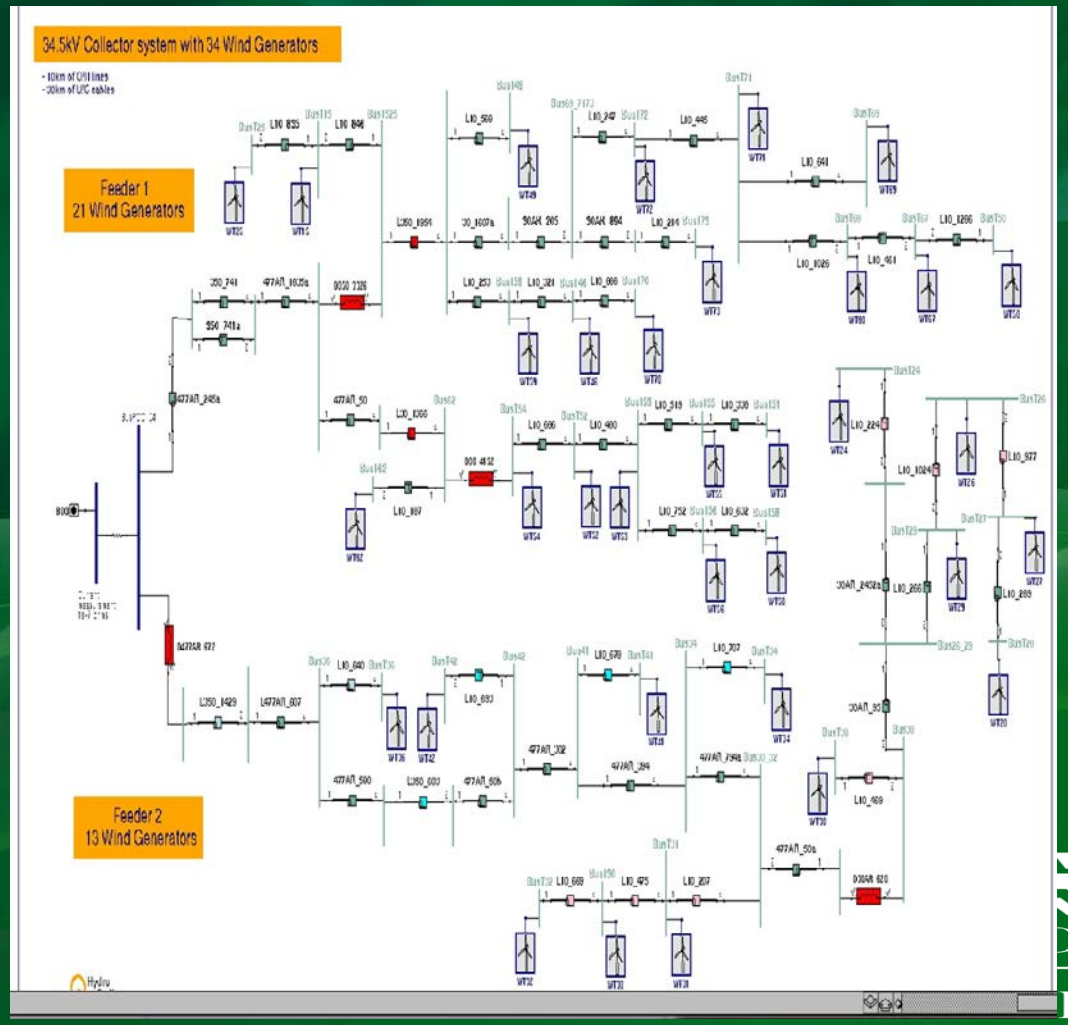


CHARLOTTE

EPIC

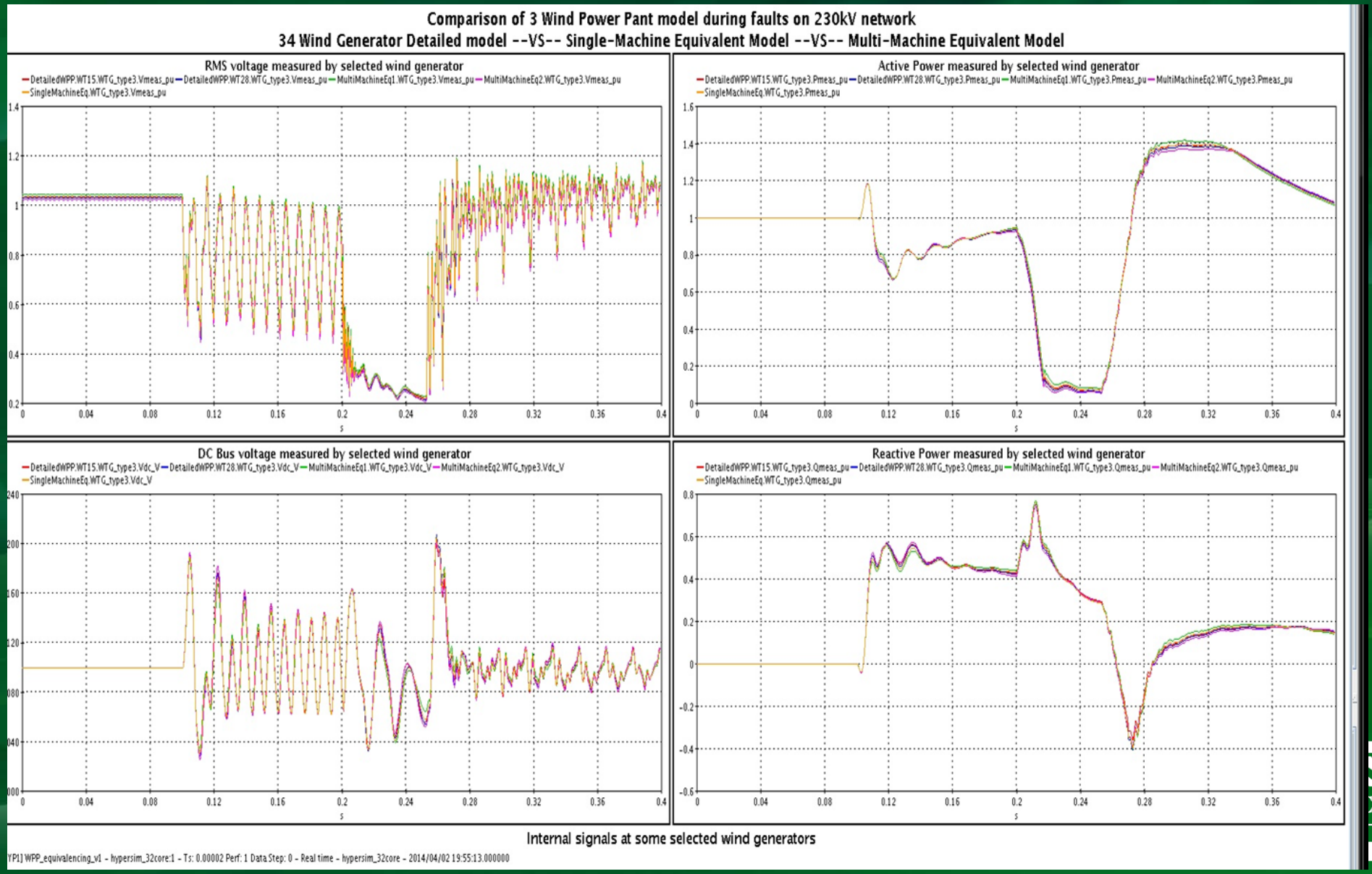
Example Project 7: Wind Integration Study

- Study Voltages and Currents in a 34 Wind Generator System in a Real Time Simulator (HYPERSIM)
- Compare voltages and currents of a detail model, single machine equivalent, multiple machine equivalent model



CHARLOTTE
EPIC

Wind Integration Study



CHARLOTTE

EPIC