


AORC-CIGRE TECHNICAL MEETING

16th to 21st August 2015

The Magellan Sutera Resort, Kota Kinabalu, Sabah, MALAYSIA

Application of Real-time Phasor Domain Simulation for Wide Area Protection in Large-Scale Power Systems

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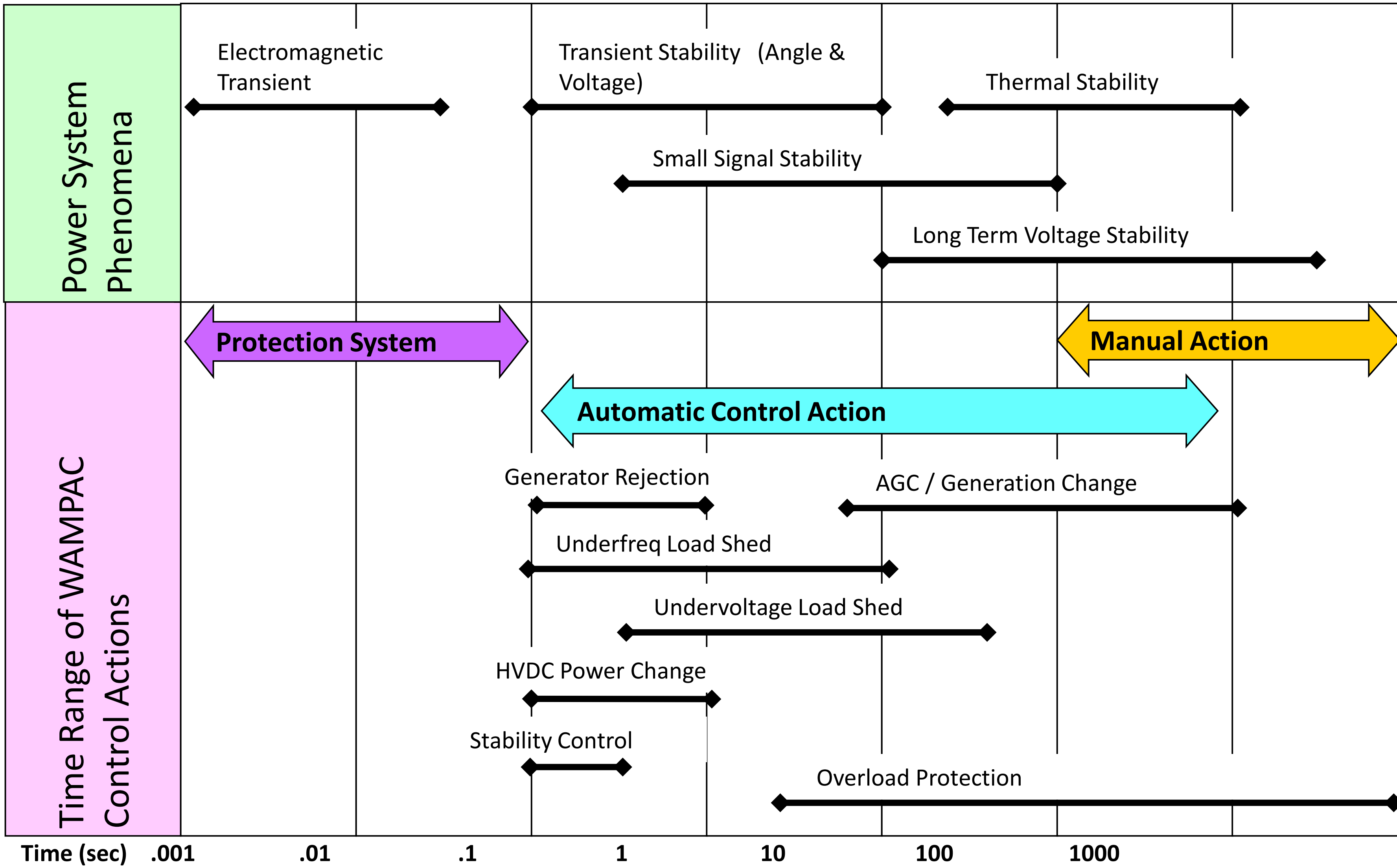
Introduction: Application Time Frame



Highlights

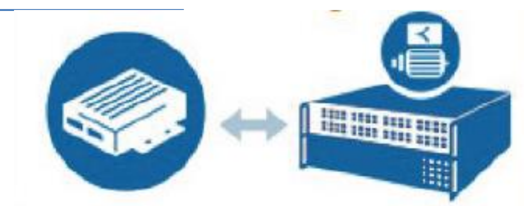
- Real Time Power System Simulator
- Features and Capability
- Example Hardware in Loop Testing

Why Real-Time Simulation?

- Rapid Control Prototyping
  - Motor Control
  - Power Electronics Control

Virtual controller   Real devices

- Hardware-In-the-Loop Testing
  - Power Electronics Controllers
  - (MMC, Drives, PV, Plugin Hybrid, Etc.)
  - WAMPAC system



Real controller   Virtual Devices

- Real-Time Simulation of Power Systems & Power Electronics

Real-Time Simulation Model Time Step

Application	Typical Frequency	Typical Time Step	Simulation Technology
Transient Stability Simulation (PHASOR)	100 Hz	1-10 ms	
Robotics / Aircraft simulation	1 000 Hz	1 ms	
Electromagnetic Tran Simulation (EMT)	z	50 us	Intel CPU 3.3 Ghz
Low frequency Power Electronics Simulation	100 000 Hz	10 us	
FEM PMSM Motor with Inverter	2 500 000 Hz	0,4 us	FPGA
High Frequency Power Electronics Simulation	5 000 000 Hz	0.2 us	

ePHASORsim

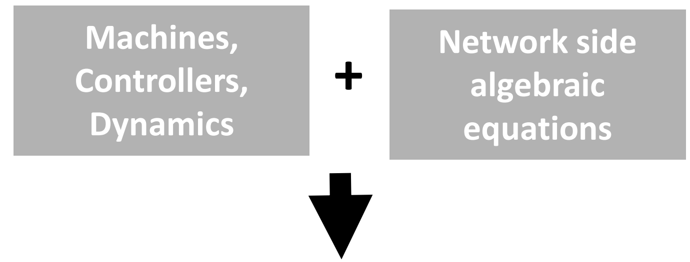
What is ePhasorSim?

Real-time transient stability simulator

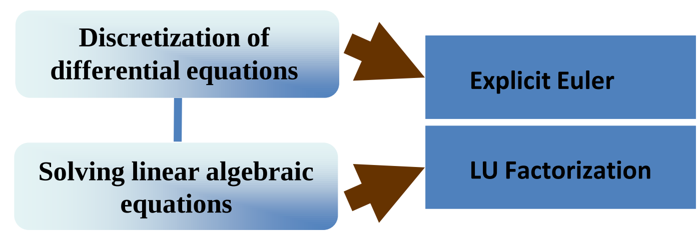
- Large-scale power systems
- Transmission, distribution and generation

Phasor domain solution

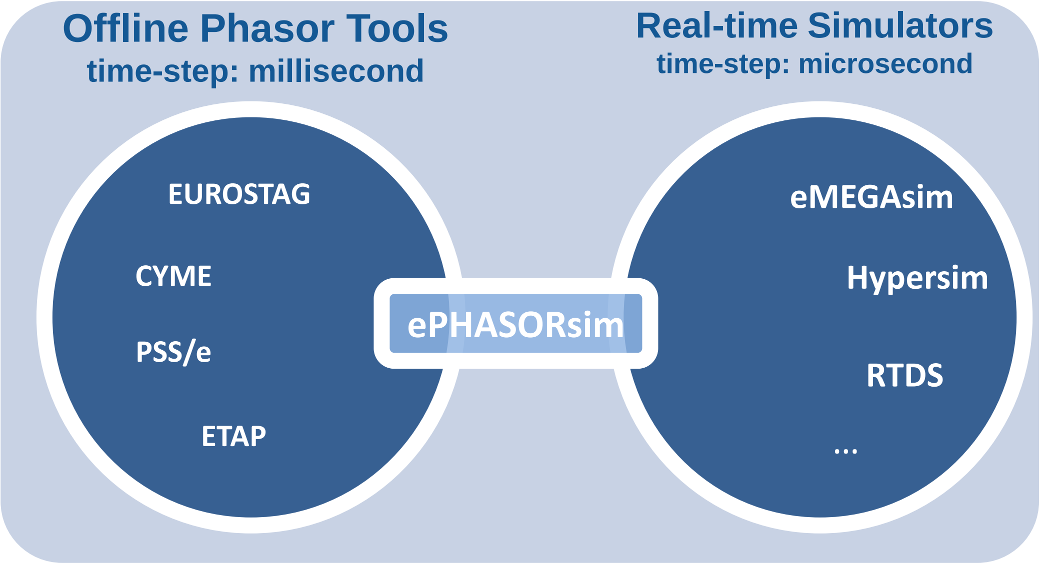
- Nominal frequency
- Positive sequence (balanced systems) OR
- 3-phase (unbalanced systems)
- Time-step in the range of few milliseconds



$$\begin{cases} \dot{x} = f(x, V, t) \\ 0 = g(x, V, t) \\ x(t_0) = x_0 \end{cases}$$



ePhasorsim…



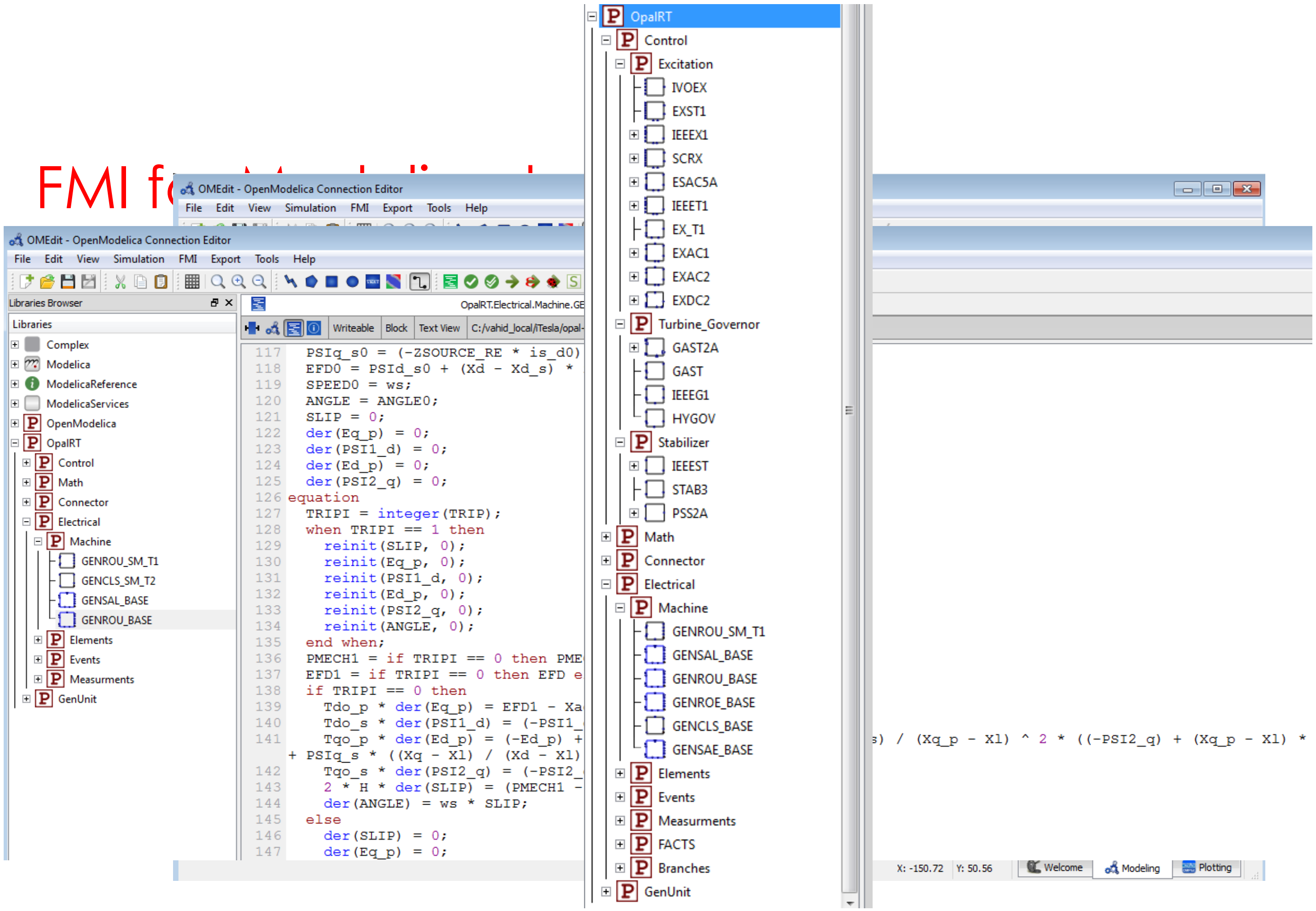
ePHASORsim is a TS-type simulation tool that **not only** runs offline **but also** runs in real-time on RT-LAB enabled simulators

Features of ePhasorsim

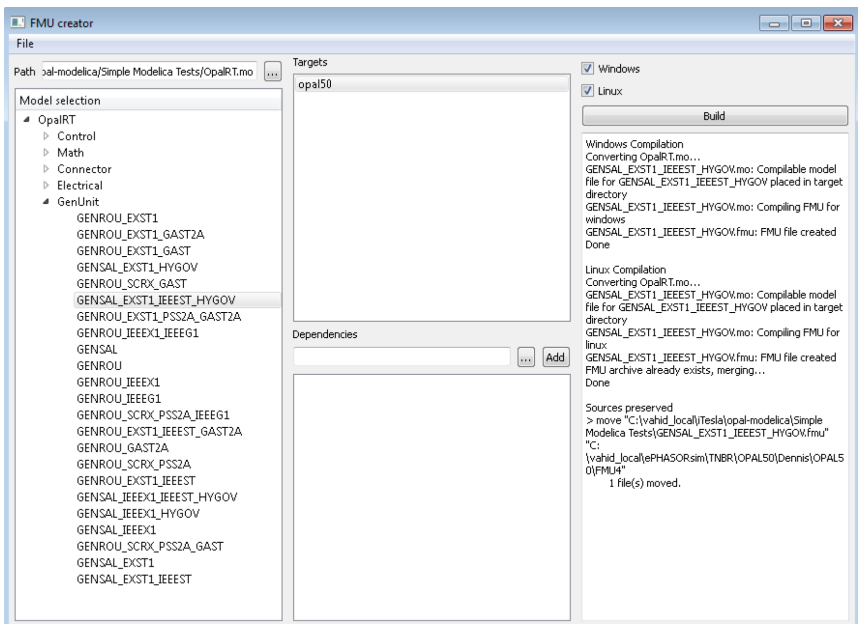
- High performance computation:
  - systems in size of 20k buses on single core CPU
- Built-in positive sequence and 3-phase library:
  - Machine, Sources, Transformers
  - Simulation of Transmission and Distribution Systems
- Flexible data input format:
  - Excel and PSS/e
- Interactive, On-the-fly changes of parameters: Loads, Generators, Create Faults, Transformer Taps etc
- Parallel processing
  - Automatic decomposition of network
- Ethernet protocols and I/Os
  - DNP3, C37.118, Modbus, IEC 61850, IEC 870-5-101 and 104
  - Analogue and Digital Input Output
- Support User Define Model , FMI: Functional Mock-up Interface

Functional Mock-up Interface

- FMI f

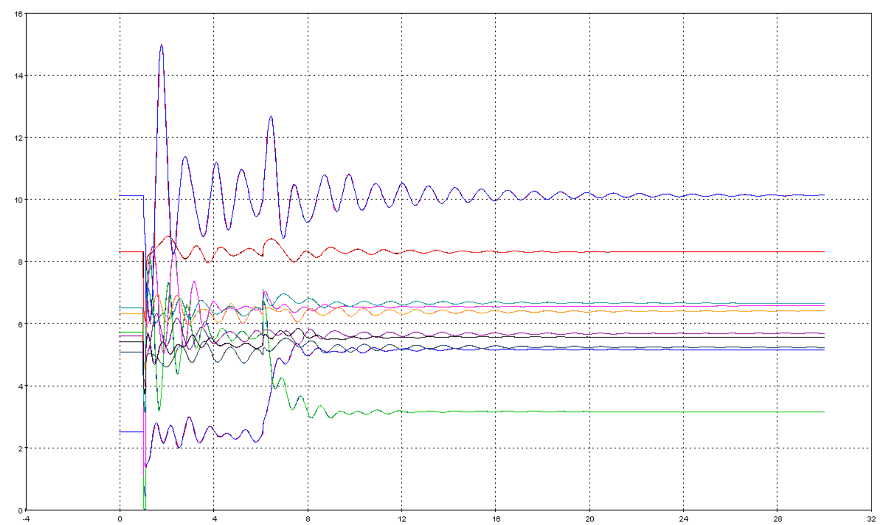


ePHASORsim FMU Creator

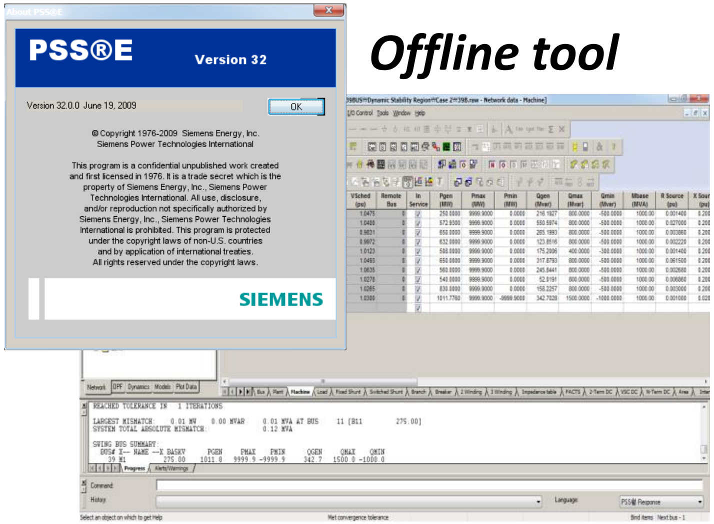


FMUs are loadable directly from

- Excel Template
- PSS/e *.dyr file



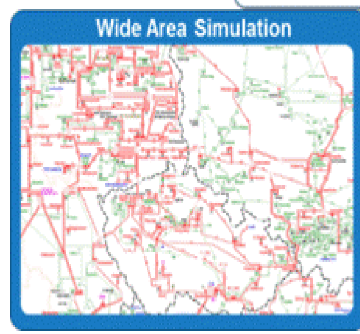
Preparing the Real Time Simulator

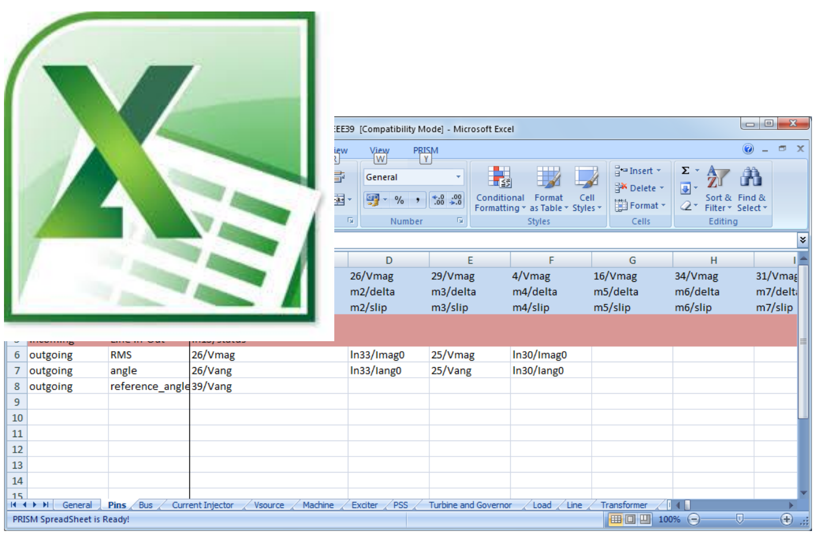


Offline tool

Network & Dynamic models

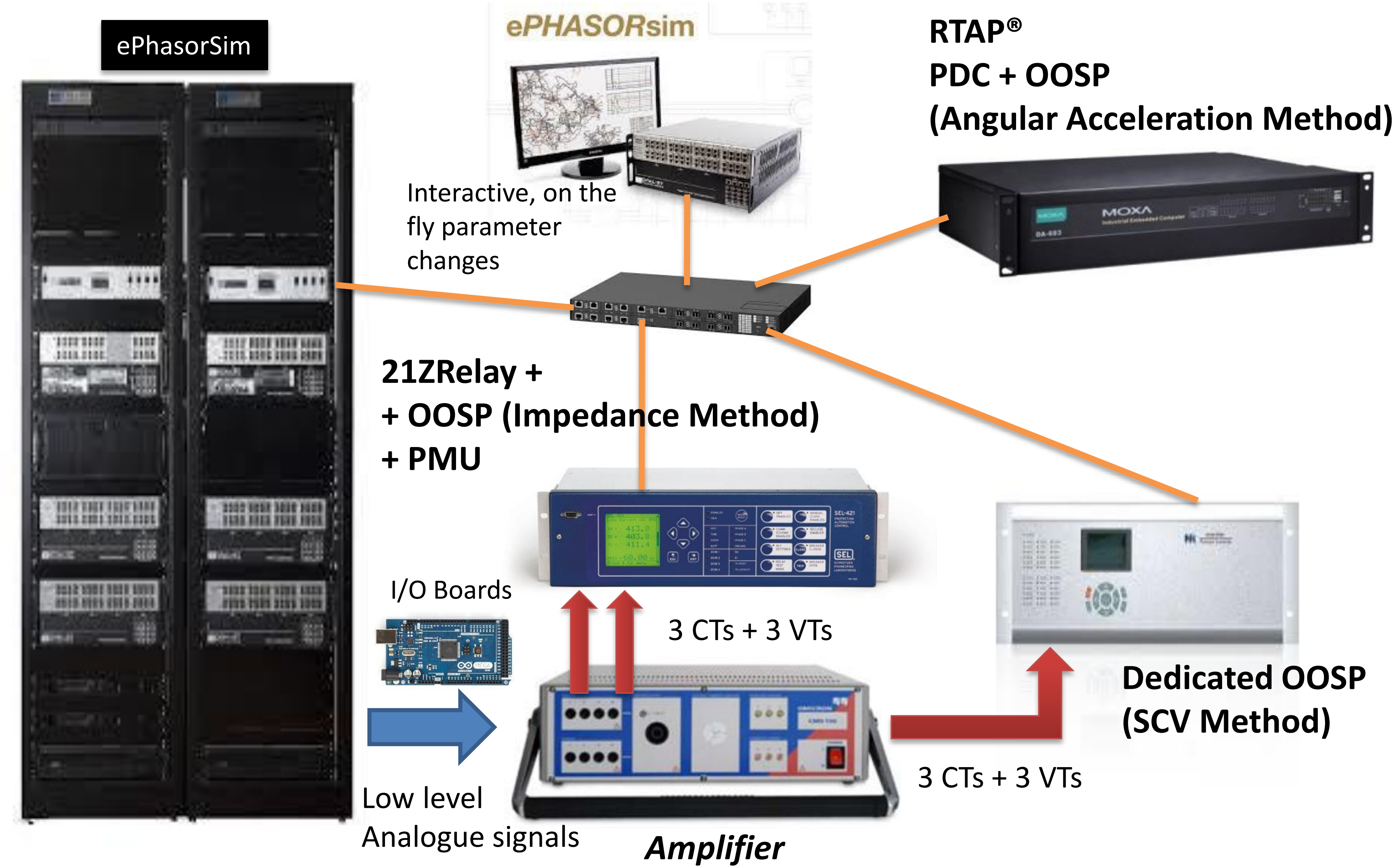
ePHASORsim





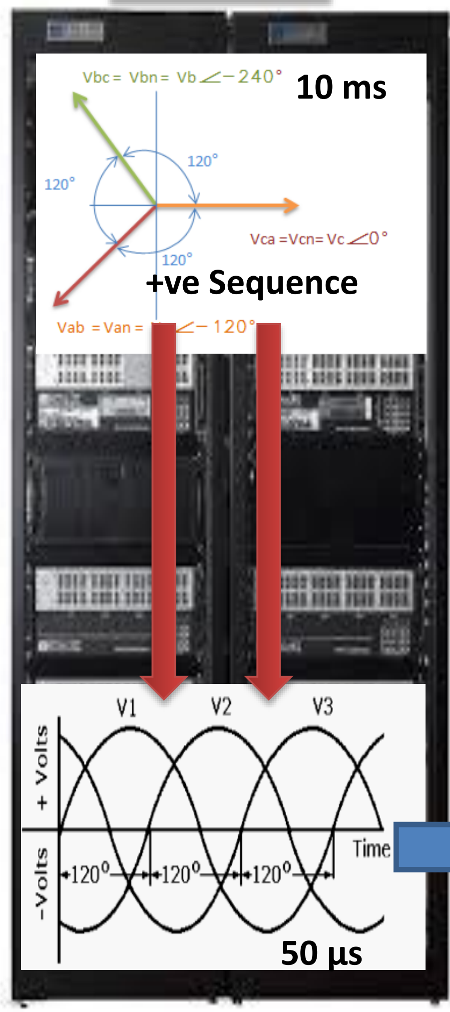
Interface pins

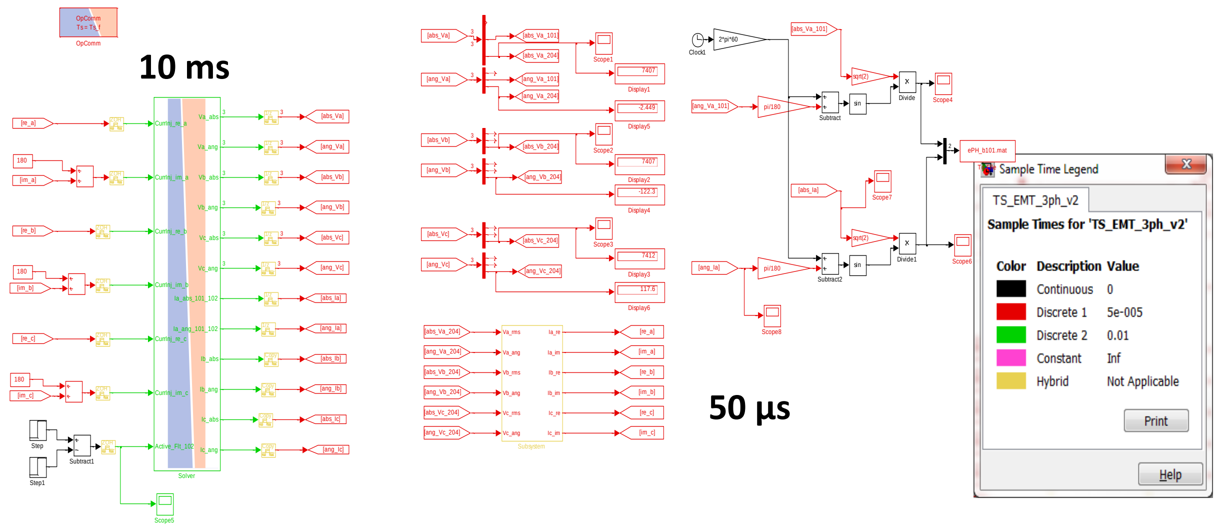
Out Of Step Protection System Test Setup



Phasor Domain to Time Domain Simulation

ePhasorSim





Rate transition enable sinusoidal waveform calculation for output for actual IED testing

OOS Relay 1

3 CTs + 3 VTs

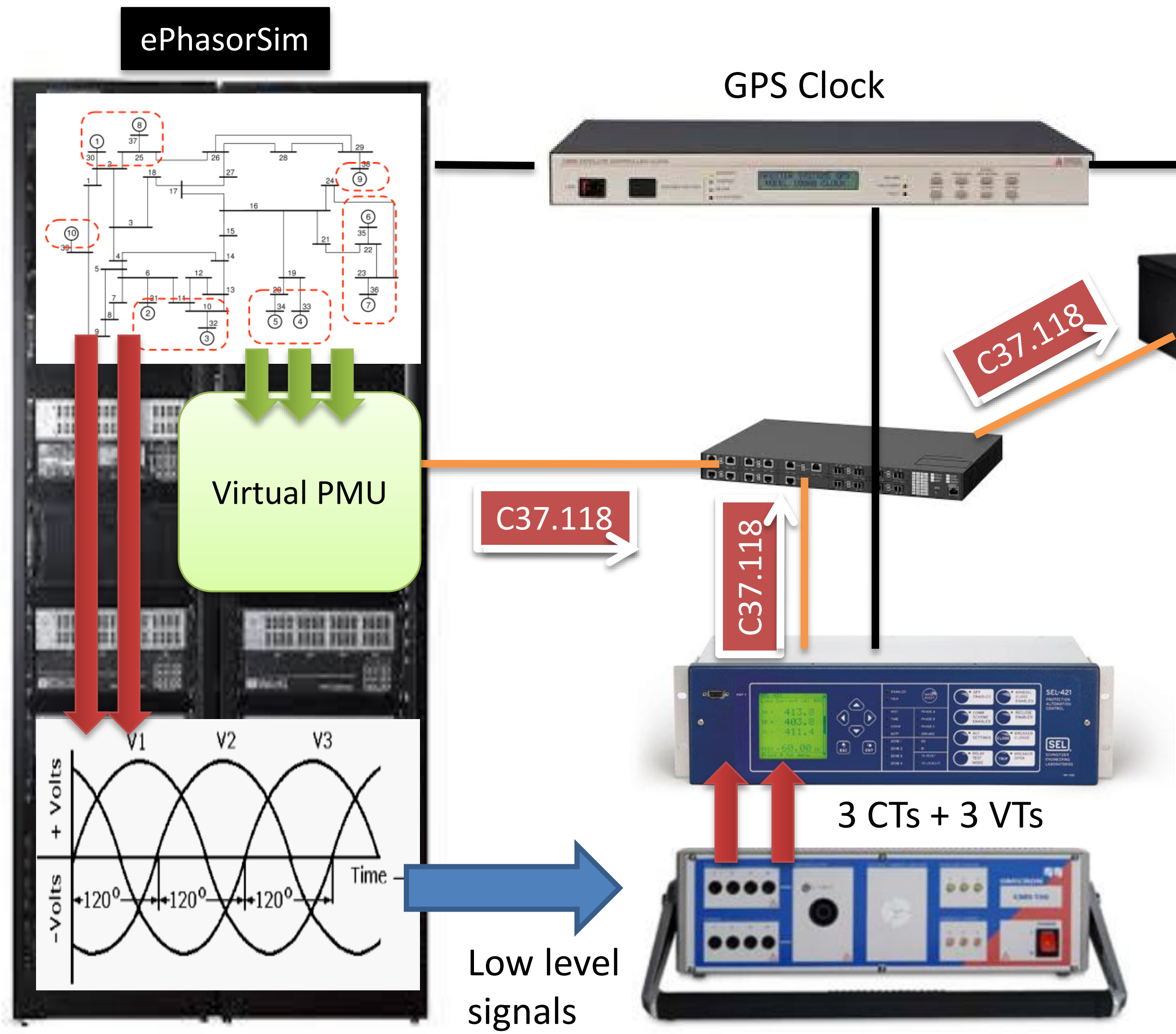
Low level signals

Amplifier

OOS Relay 2

3 CTs + 3 VTs

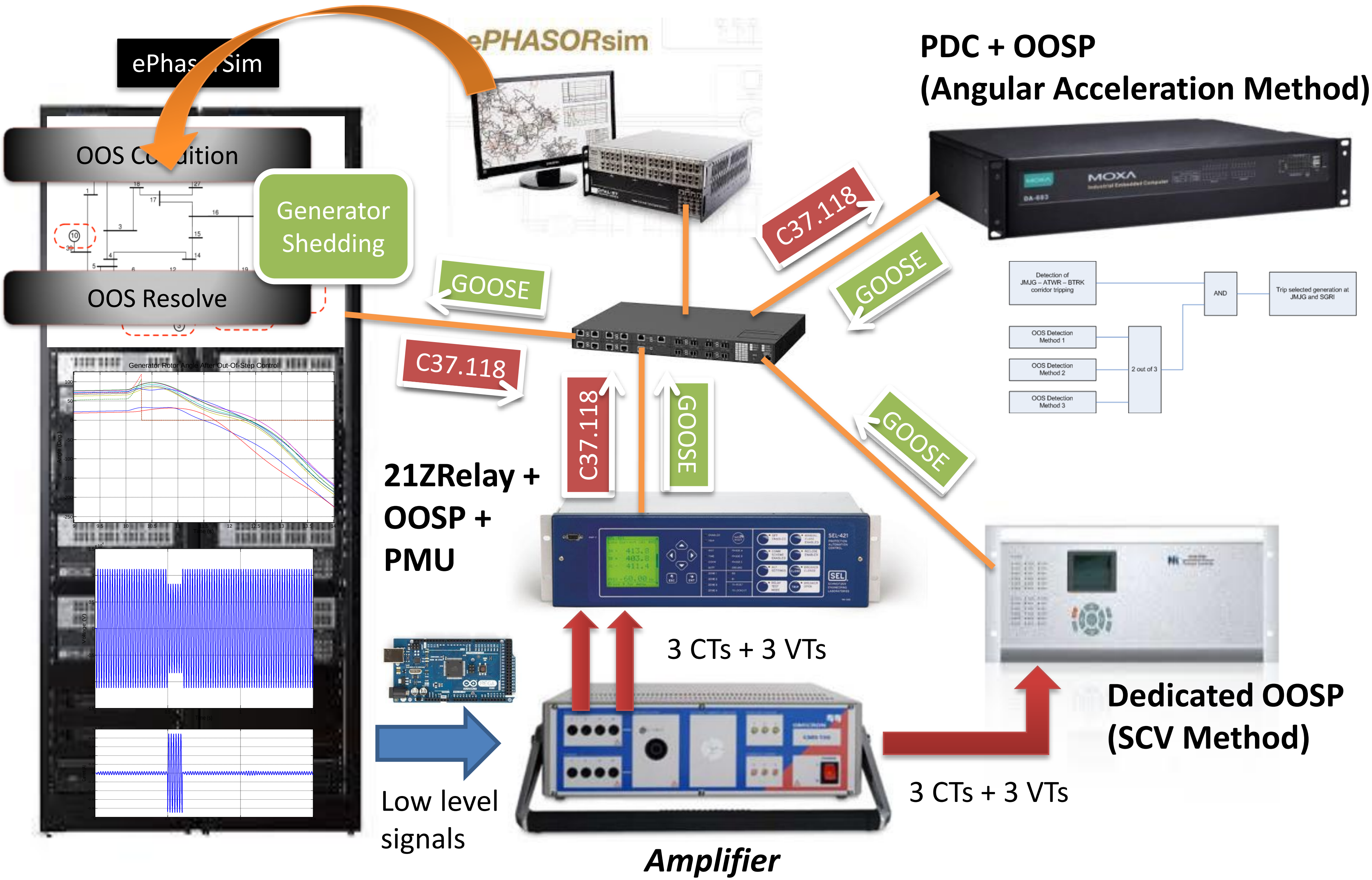
Testing a Synchrophasor-Based System



Synchrophasor: -

- Practically unlimited number of PMU data available
- New WAMPAC concept and methodology can be prototyped and thoroughly tested before actual deployment
- Testing of actual PMU specification compliance and phasor calculation latency

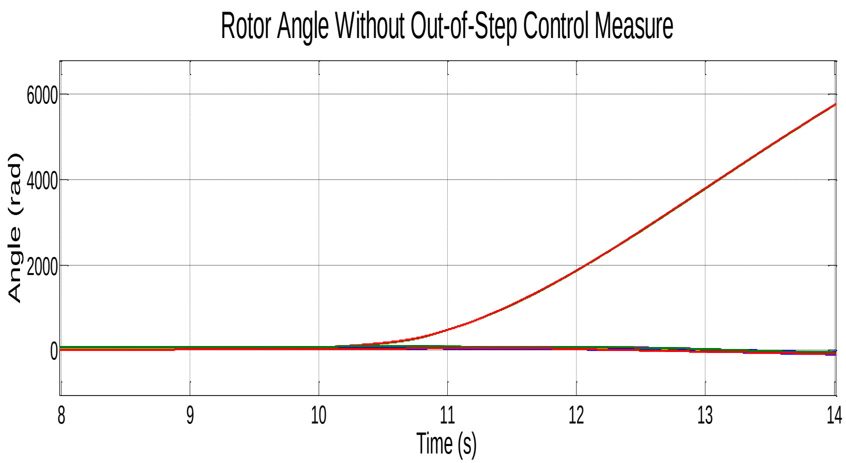
Out Of Step Protection System HiL Test

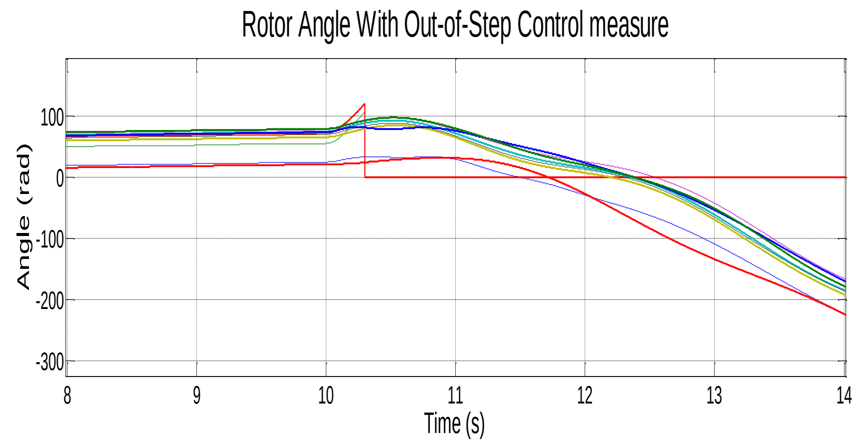


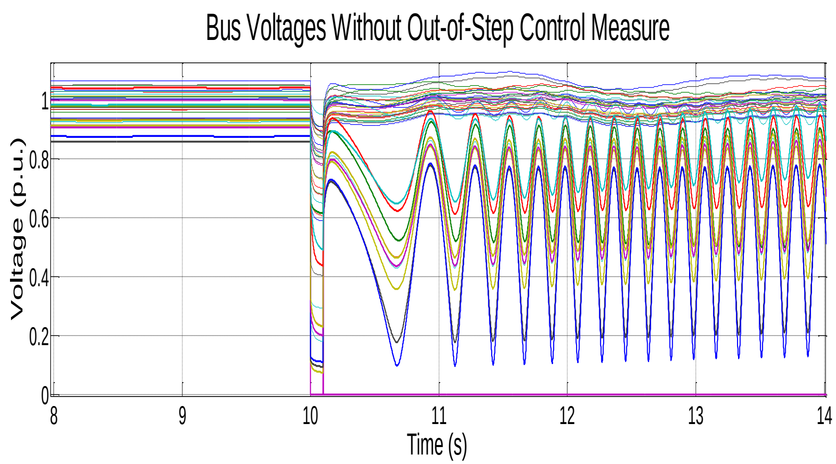
Sample Test Results

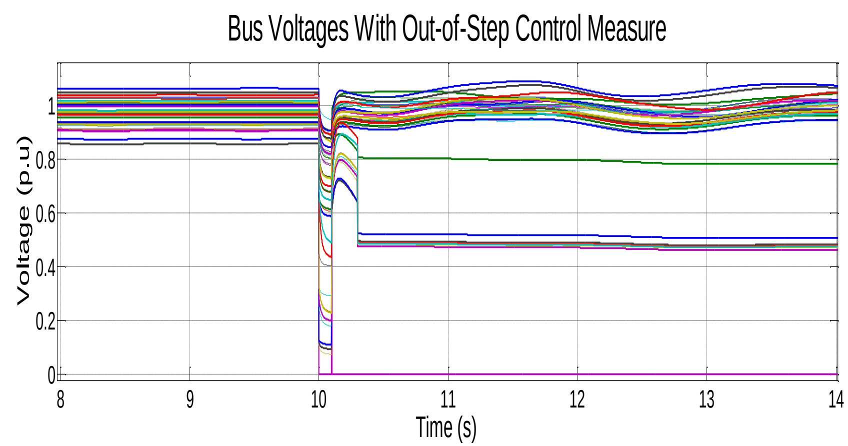
No Control Action

With Generator Shedding Action









Summary

- Enable comprehensive functional and performance testing of WAMPAC under controlled environment be actual deployment
  - Entire grid model can be included
  - Various grid conditions, loads and generation patterns
  - Testing scenarios not possible in actual system test
- Operator training on newly develop WAMPAC applications
- Rapid prototyping of new concepts or ideas
- Increase collaboration between utility and universities

Summary

- Continuous improvement and tuning of the models shall be carried out to ensure the simulation results are as close as possible to actual grid
  - Every time when grid disturbance occurs
  - Using data from PMU-Based dynamic recorder
  - Perform model and model parameters validation

THANK YOU

Q & A