OPAL-RT TECHNOLOGIES

FROM IMAGINATION TO REAL-TIME

OPAL-RT's Synchrophasor Aplications in Real Time: Power Systems, Testing and Development

Overview

- Company Backgrounds and domains of expertise
- OPAL-RT in the Electric domain: from phasor modelling to fast switching power electronic
- OPAL-RT's PMU-oriented applications

  -Power Systems Studies: Advanced Applications using Model-Based Design (Control, monitoring, protection)

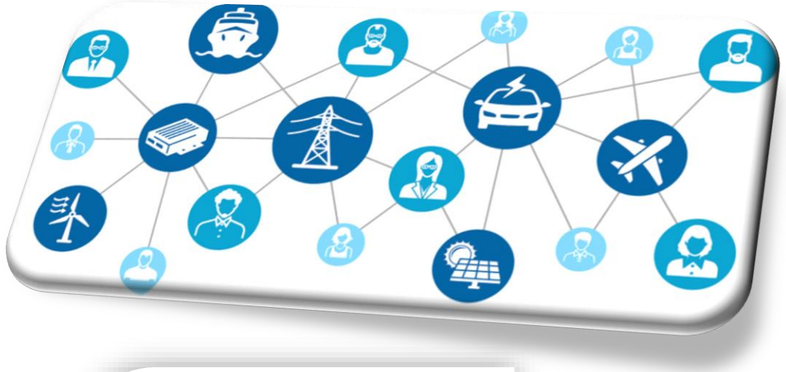
  -Testing and certification: Visimax

  -Control design using virtualized synchrophasors and PMU prototyping devices (NI's GAS)
- Conclusions

Company Background

Company background

- **Some Facts**
  - Established in 1997 – Corporate office in Montreal
  - Over 140+ Employees worldwide
  - More than 500 customers worldwide in Academic and Industrial sectors
- **Corporate Mission**
  - To provide solutions and expert services for design research, studies and testing in the fields of electrical and power electronics systems
  - To provide Engineers with open simulators that use the latest COTS computer technology
- **Long-Term Vision**
  - A real-time simulator on each engineer’s or researcher’s desk
  - Simulators interconnected and working for designing and studying large and multi-disciplinary systems.
  - Imagination will be the only real limit to complex system design.



OPAL-RT's Domains of Expertise

- OPAL-RT's domains of expertise and list of customers (partial)

Aerospace and defence

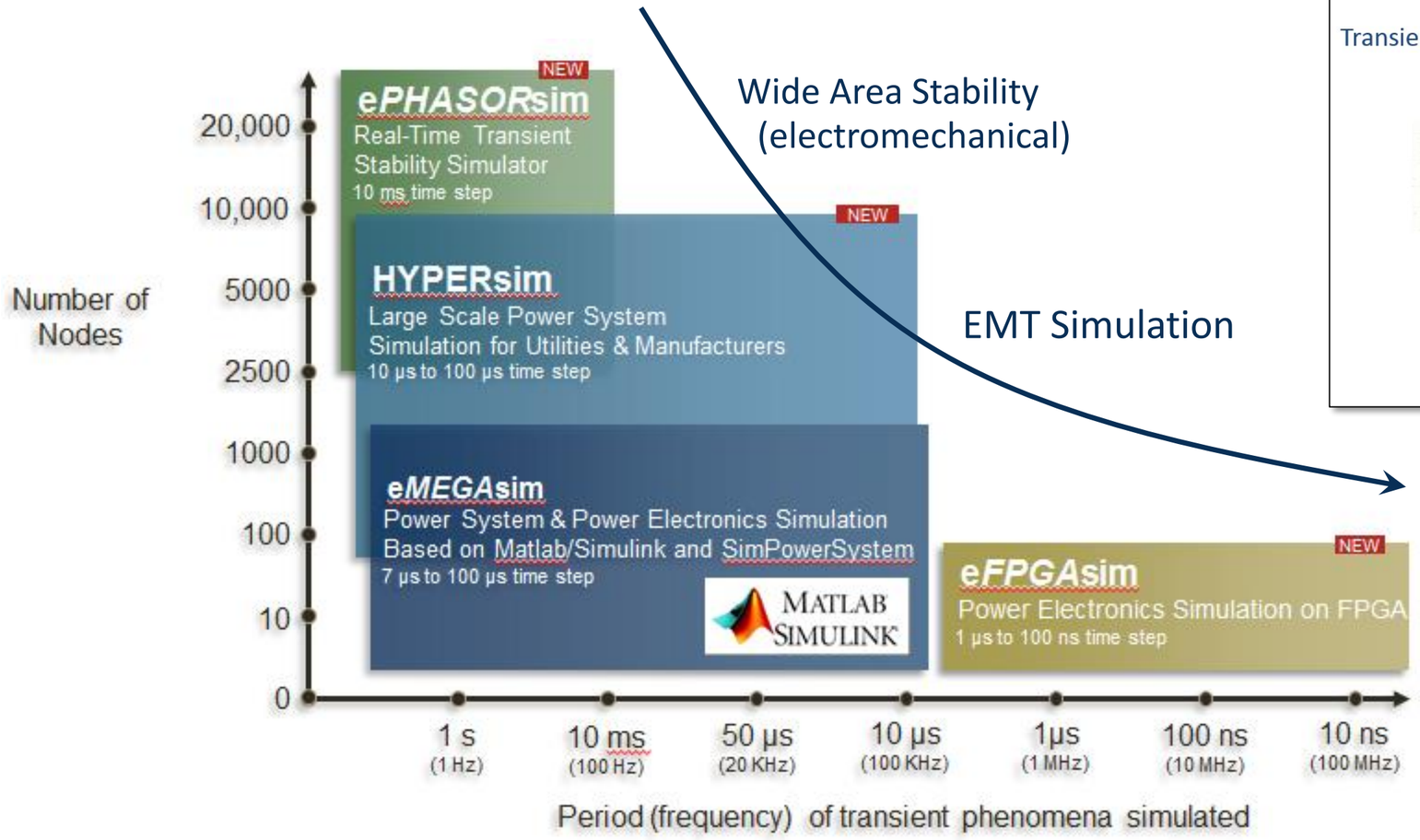
Automotive

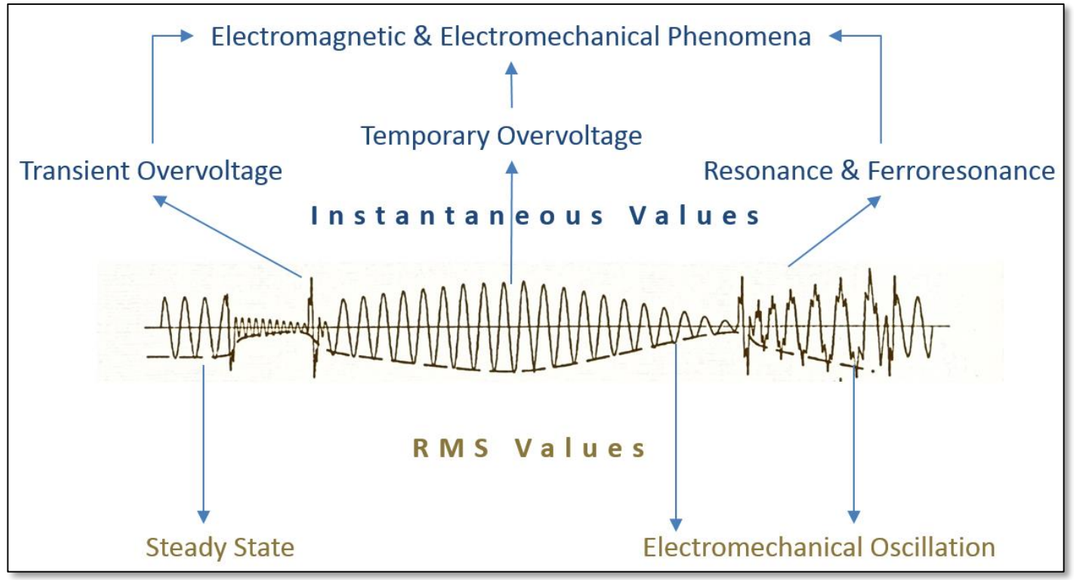
Electric

Research and academic

OPAL-RT TECHNOLOGIES

- OPAL-RT in the **Electric domain**: from phasor modelling to fast switching power electronic





Fast Power Electronics,
FACT, STATCOM, MMC, …

OPAL-RT's PMU-oriented applications

Power Systems Studies: Advanced Applications using Model-Based Design (Control, monitoring, protection)

- OPAL-RT's software and hardware is compatible with C37.118 protocol (Slave and master):The C37.118 (Synchrophasor Protocol) is the IEEE standard for using synchrophasors in power systems.

- The C37.118 Slave block can be used to emulate the behavior of a real PMU:
  1. Each C37.118 block can handle 128 phasor inputs (128 magnitude & 128 angle),
  2. 128 analog inputs, and 128 digital inputs
  3. The frequency deviation from nominal and frequency rate of change are also inputs
  4. Timestamp input (Spectracom TSync-PCIe board)
  5. Supported protocols **:** TCP, UDP, TCP/UDP.
  6. Each C37.118 block can have its own IP address
  7. Configurable Parameters: nominal frequency , data reporting rate , Configurable scaling units ,etc
  8. Etc
  9. etc
  10. http://www.opal-rt.com/c37118

- The C37.118 Slave block can be used to emulate the behavior of a PDC

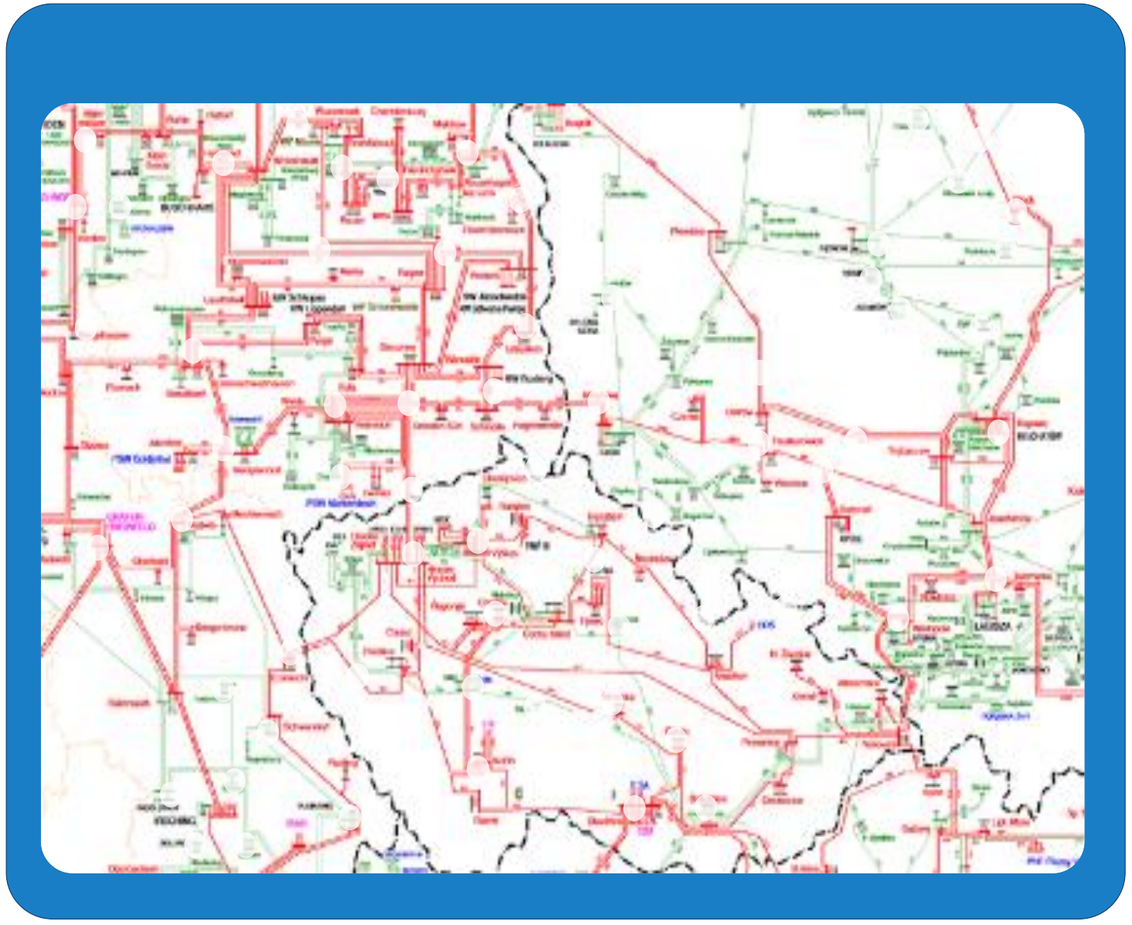
With the **C37.118 protocol compatibility** of our different softwares (Hypersim, eMEGAsim, ePHASORSIM) and **our AO capabilities**, researches can implement different setups and test benches…

Supervisory control and Data Aquisition (SCADA)

EPHASORsim is ideal for implementing training simulators network operator, SCADA test systems, validating complex global control algorithms and protection schemes:

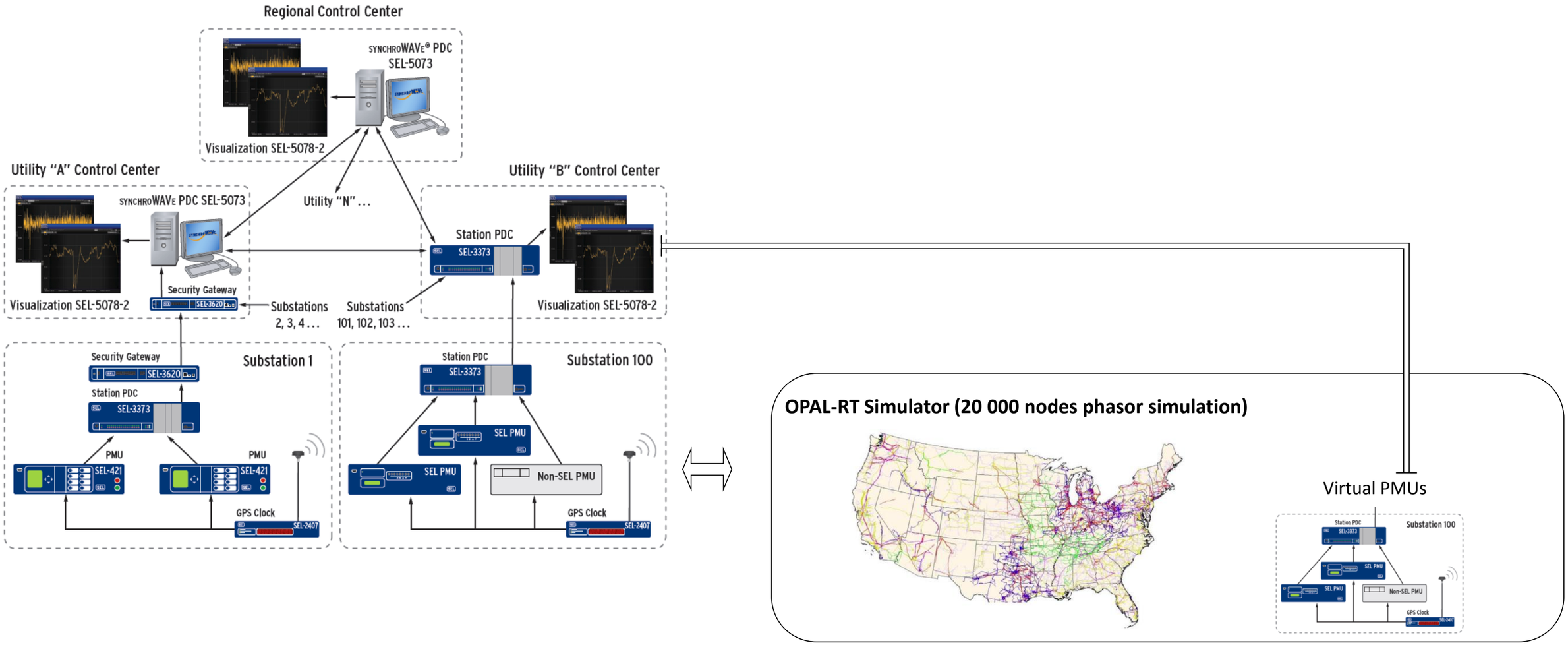
Simulation of up to 20,000 buses
Compatibility with C37.118, DNP3 and Modbus
Real-time monitoring of electrical and control signals.
Wide range of I / O ports.
Compatibility PSS / e, OpenModelica, DIGSilent

ePHASORsim characteristics

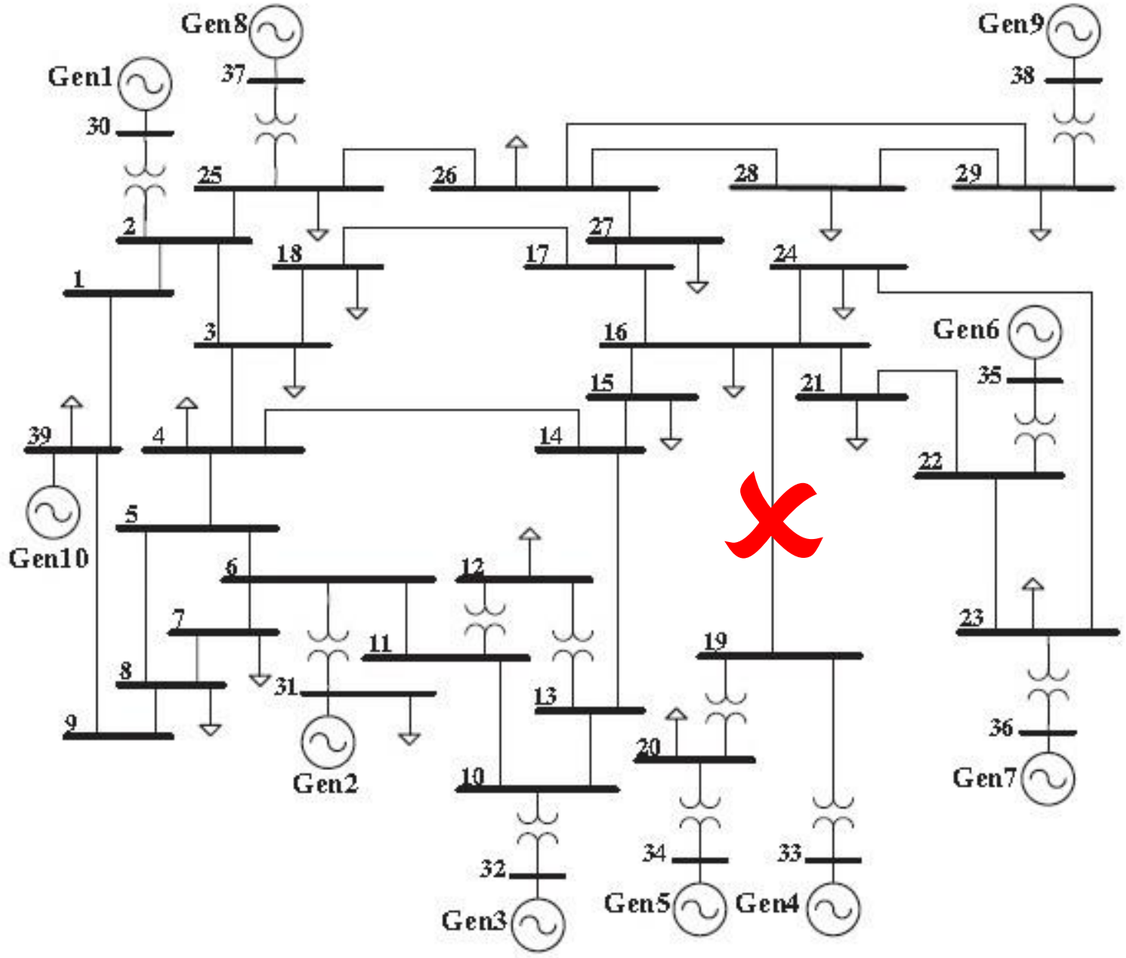


- Transient stability for very large systems
- Phasor solution with simulation time in the order of milliseconds
- Matlab / Simulnk compatible library.
- Ideal for the simulation of different events, controls and control settings.
- Advanced HIL

Example - Hybrid system with virtual and real PMUs



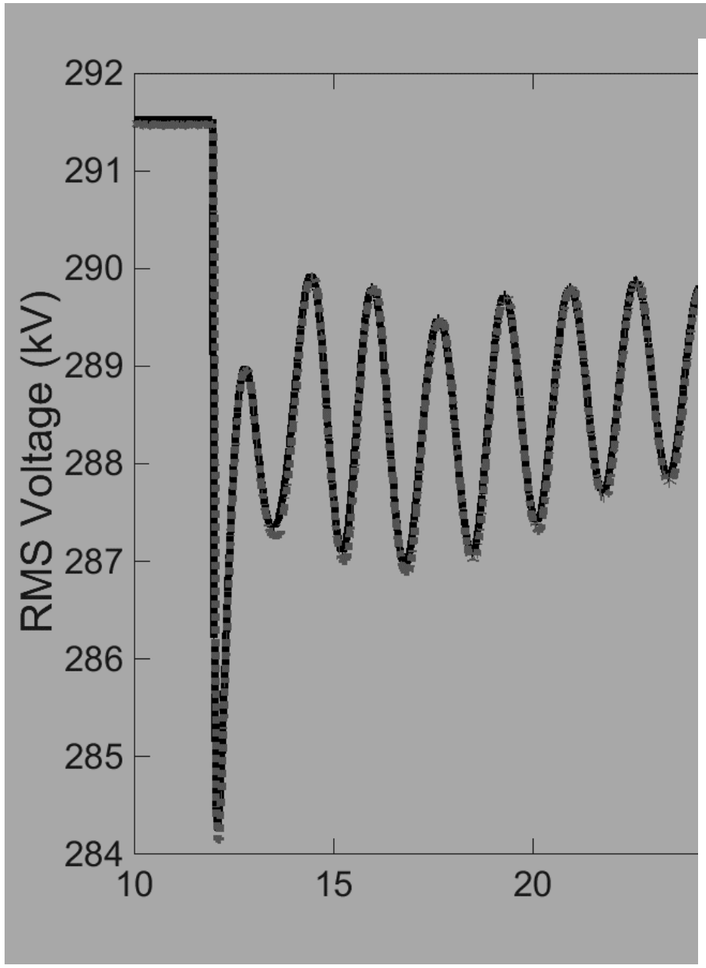
Virtualized PMU Dynamics with ePHASORsim

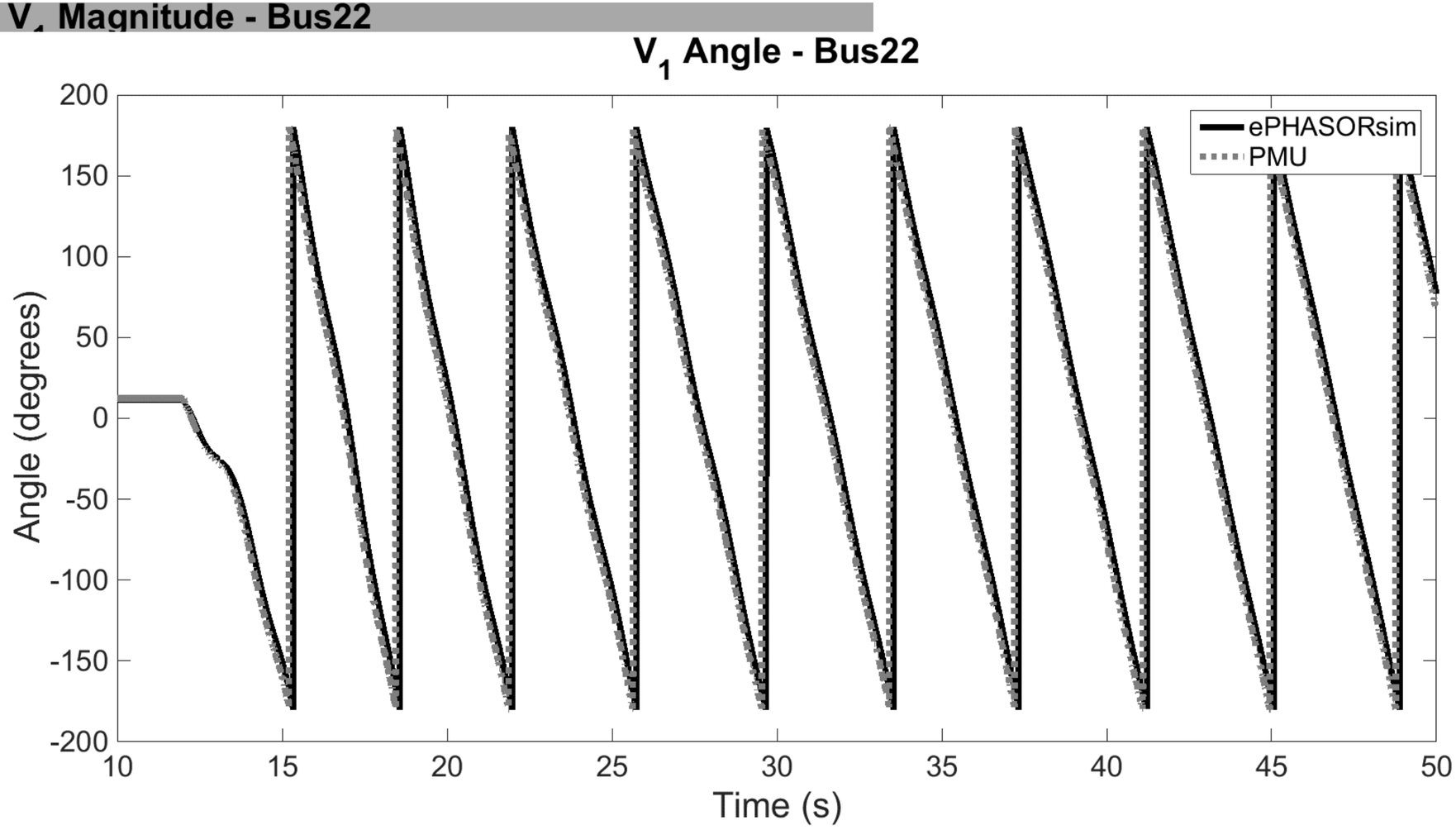


- How to simulate PMUs in Real-Time?
- How to design, study, and test a Wide-Area **Control and Protection** Schemes?
- How to ensure sufficient test coverage?

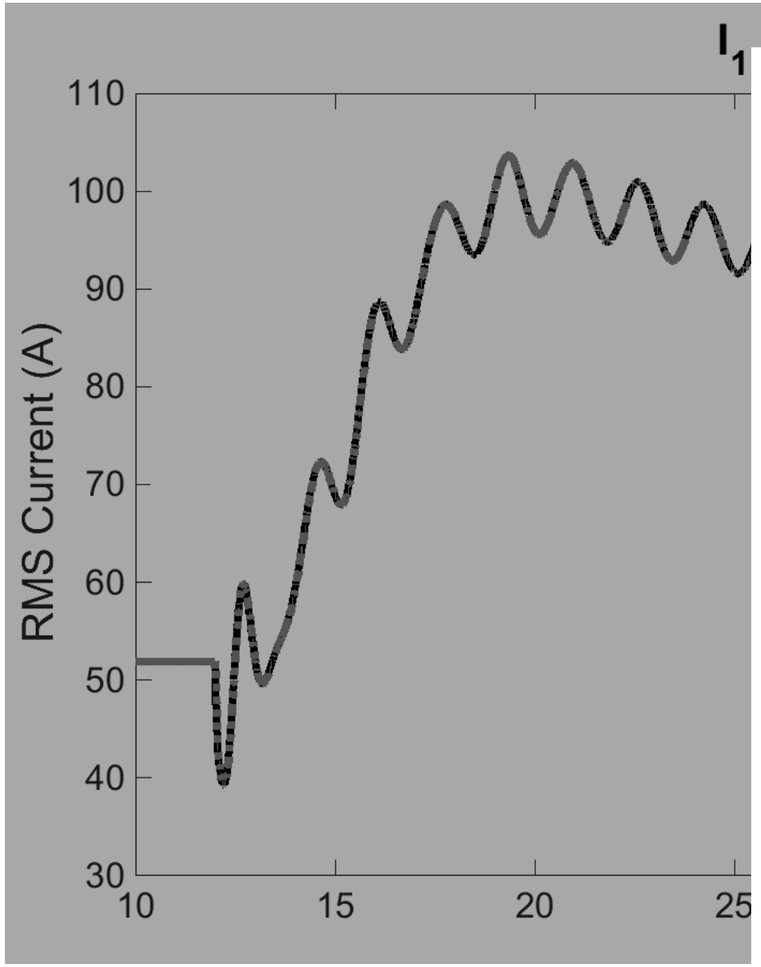
- Let’s look at the dynamic response of a PMU compared to ePHASORsim…

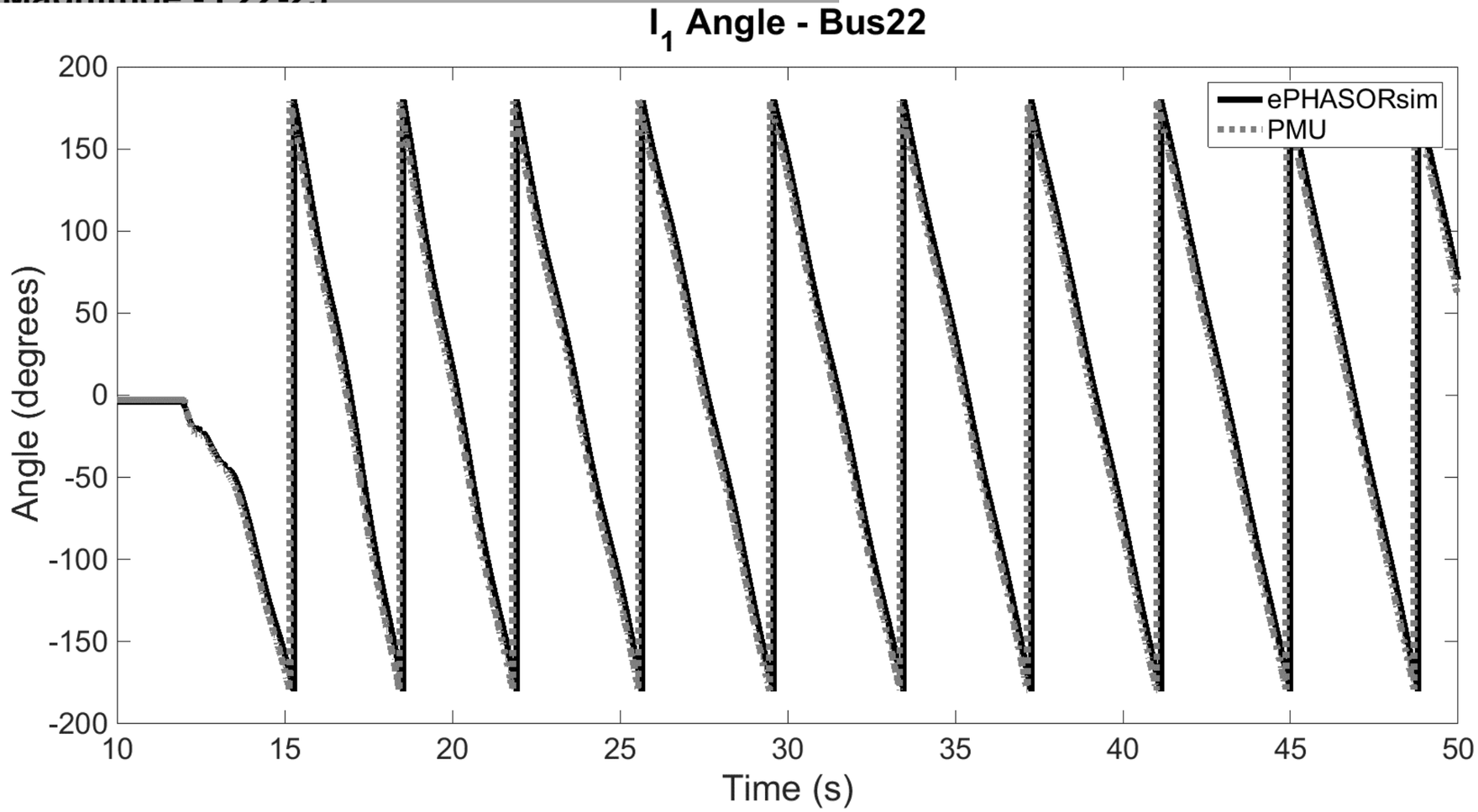
Virtualized PMU Dynamics with ePHASORsim





Virtualized PMU Dynamics with ePHASORsim





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Communication protocols and Smart grids

Automation and information: pillars of smart grids. OPAL-RT offers the tools to develop and test the control schemes of the electric grid of the future

-C37.118: synchrophasors

-DNP3: sistemas de automatización

-IEC 61850: -GOOSE
-SV

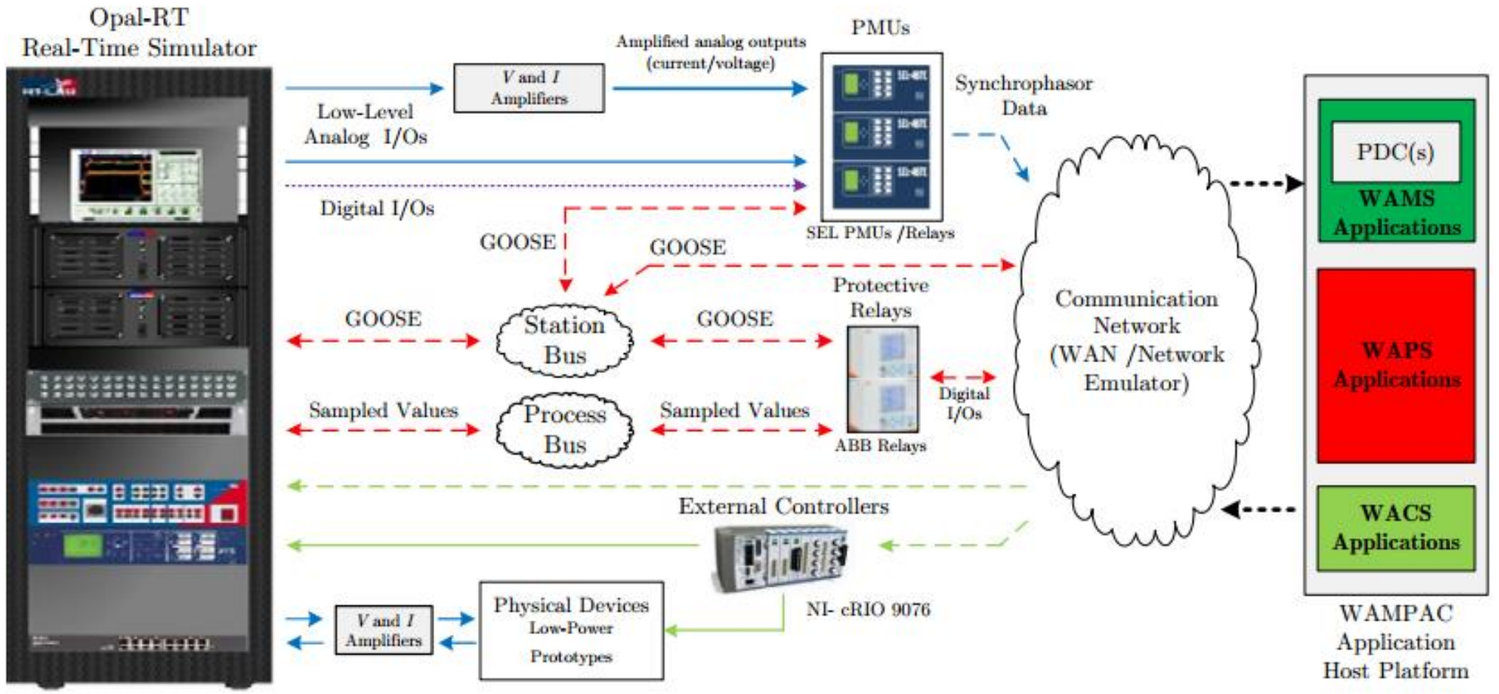
-MODBUS:

Smart Grid application

ROYAL INSTITUTE OF TECHNOLOGY

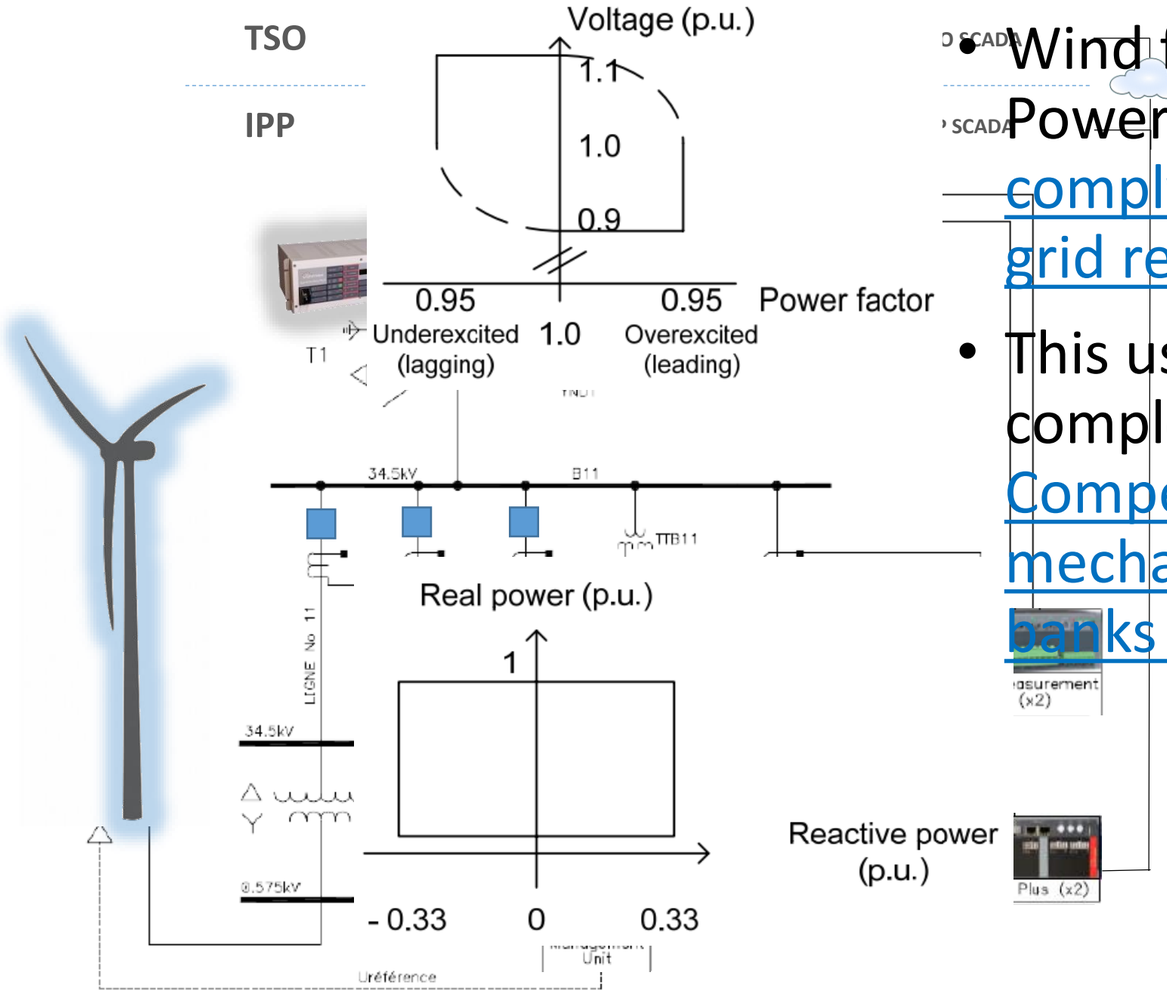
SmarTS Lab
Smart Transmission Systems Laboratory

The SmarTS Lab Architecture



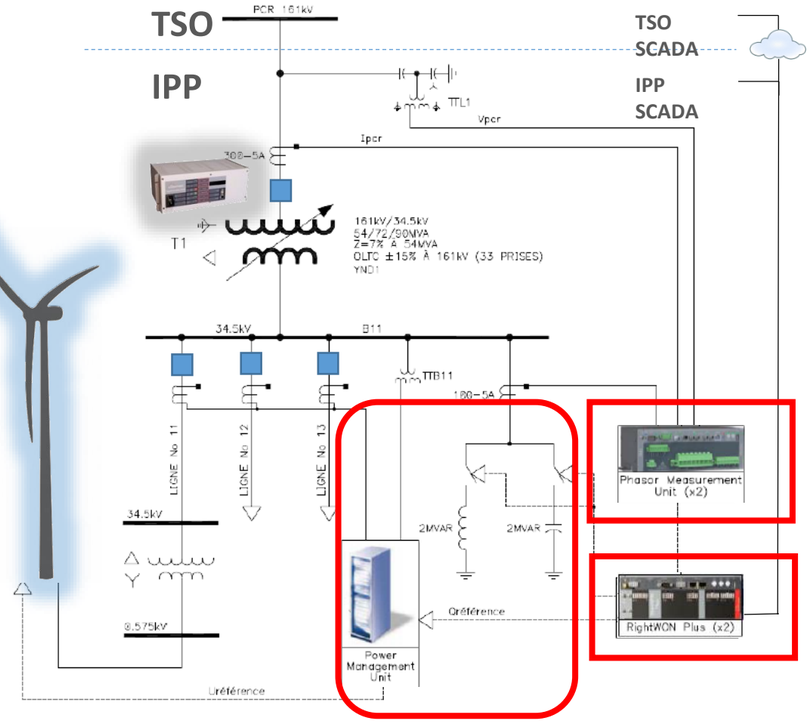
OPAL-RT TECHNOLOGIES

Model-based design – Mont-Rothery Wind Farm in Canada



- Wind farms and other Independent Power Producers (IPP) have to comply with a number of network grid requirements
- This usually means installing complex and costly Static VAR Compensators (SVC) and/or mechanically switched capacitor banks and shunt reactors.

Model-based design – Mont-Rothery Wind Farm in Canada



- Uses a VIZIMAX PMU to **monitor** voltages and currents at the PCC (120 fps)
- An industrial controller receives C37.118 streams, does the calculations, corrections using PID loops and makes decisions
- The controller sends setpoints to the Wind Power Control Unit.
- The controller also controls mechanically switched capacitor banks and shunt reactors that allow meeting the requirements.

- Time to commission the system with full test coverage ?

OPAL-RT's PMU-oriented applications

Testing and certification: Visimax

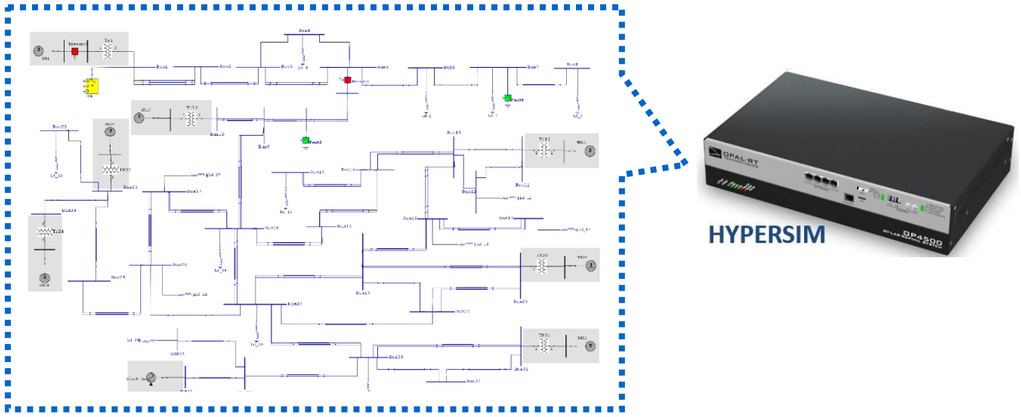
About vizimax ENERGY 3.0

- **The Company**
  - Established in 2008 from a merger between Snemo (1977) and STR (1988)
  - Provides innovative solutions for energy applications – Power Grids, Power Generation , HV/MV Equipment, Heavy Industry
  - Customers in over 35 countries
- **Products**
  - Phasor Measurement Unit
  - Analog Merging Unit
  - SynchroTeq™: Controlled switching device (CSD)/Inrush current limiter
  - RightWON™: Substation automation controller
- **Mission**
  - To help optimize how Energy is Generated, Transported & Distributed
  - To protect as much as possible their customers' assets by focusing on innovation, quality, and customer service

Collaborations with Hydro-Quebec Research Institute (IREQ)

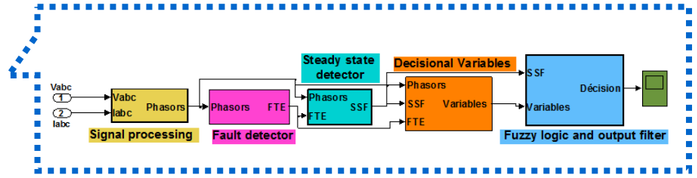
OPAL-RT TECHNOLOGIES

- **OPAL-RT and IREQ signed a strategic collaboration agreement for the shared commercialization and development of HYPERSIM (2012)**



vizimax ENERGY 3.0

- **Agreement for integration of estimation algorithms resulting from research at IREQ. Algorithms have been enhanced by VIZIMAX for accurate real-time estimation and standard compliance.**



- **Other collaborations for validation of automation and control equipment and certification for use on the Hydro-Quebec grid.**

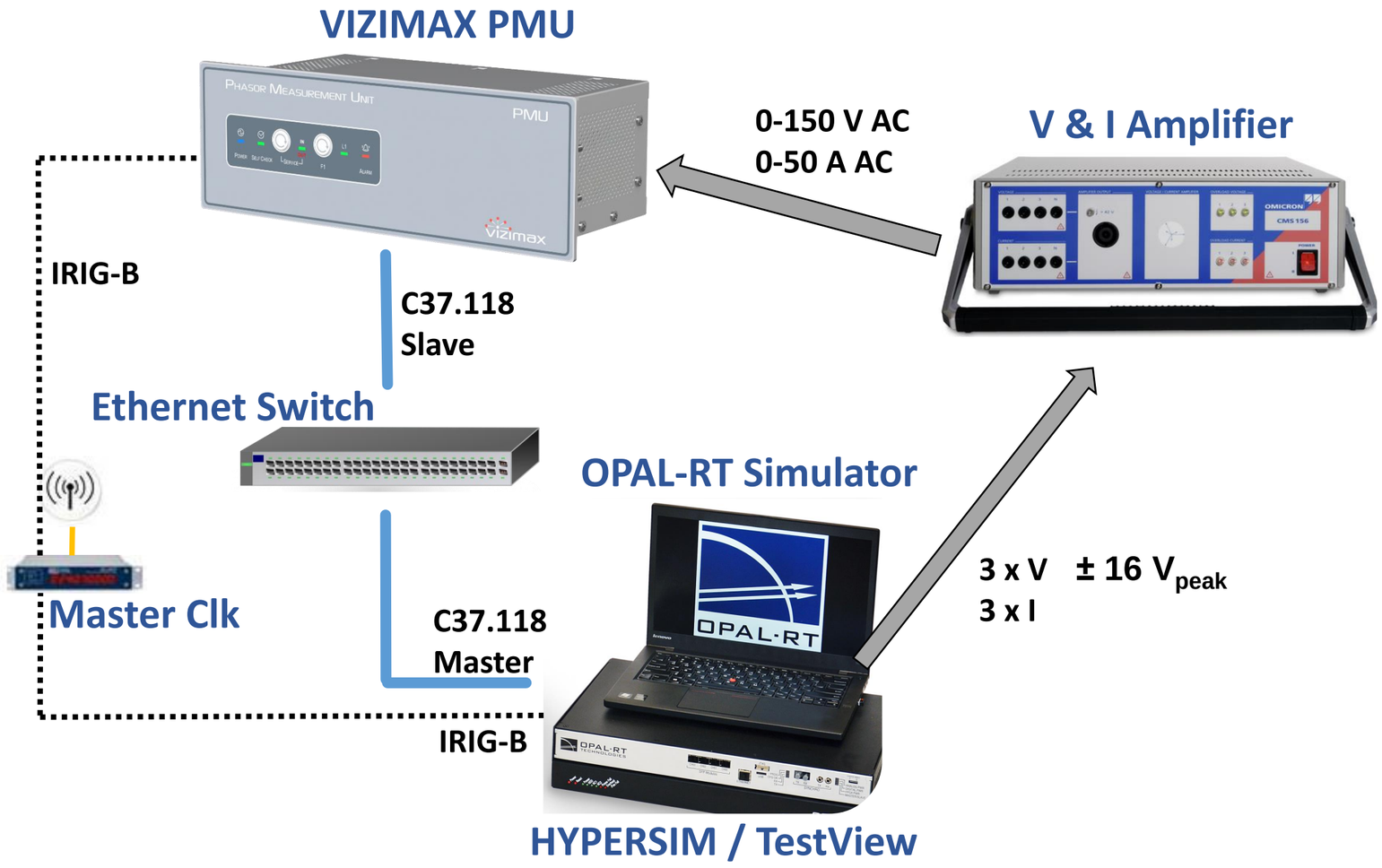
Collaboration VIZIMAX  OPAL-RT

- **Automated testing of PMUs based on C37.118.1**
  - Study requirements of the IEEE std
  - Program test sequence using OPAL-RT Hardware and TestView software
  - Calibration of the test equipment
  - Help validating the VIZIMAX PMU using automated test-set – faster and larger test coverage

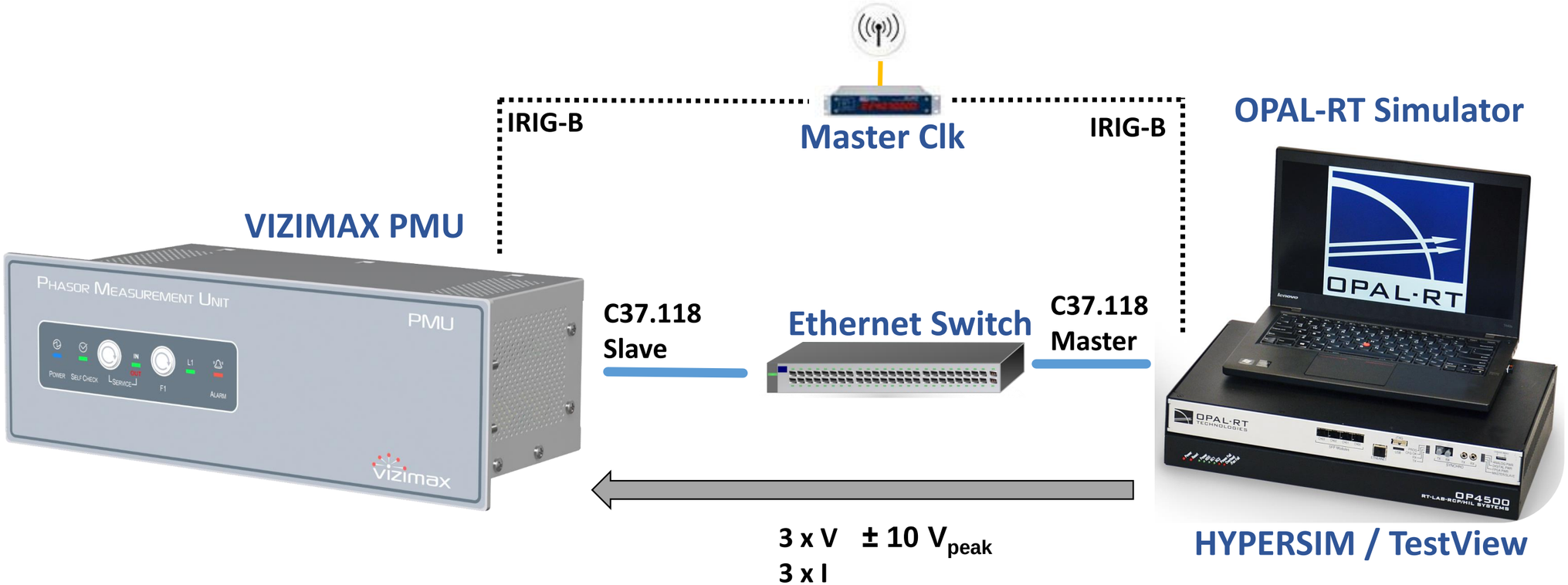
- **Develop a PMU - foreseeing IEEE-ICAP certification**
  - Develop their own test bench using an OMICRON CMC-256plus universal calibrator
  - Provide a low-voltage input version of their PMU to OPAL-RT
  - Help validating the performance of OPAL-RT test equipment on specific tests

PMU Test Setup

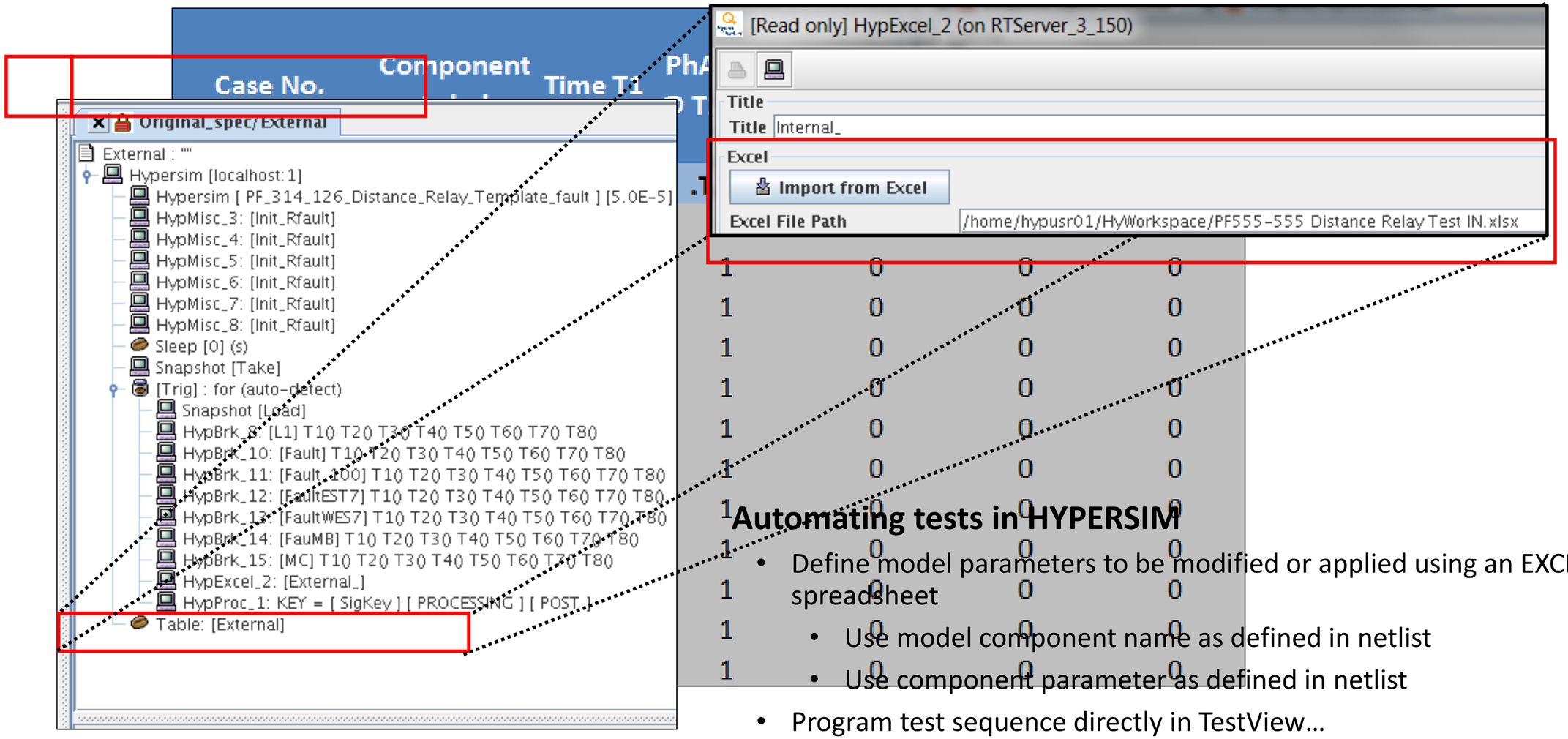
Typical PMU Test Setup



PMU Test Setup using Low-Voltage Interface



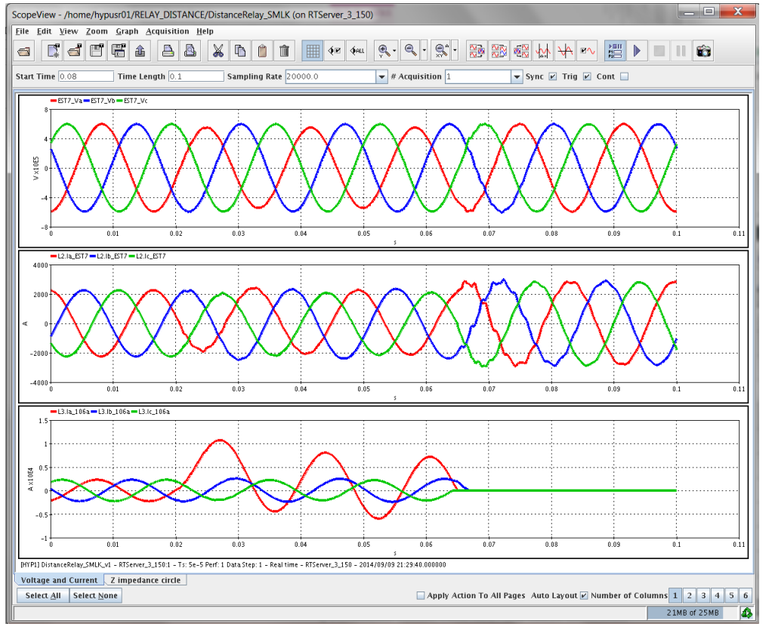
Test Automation using TestView

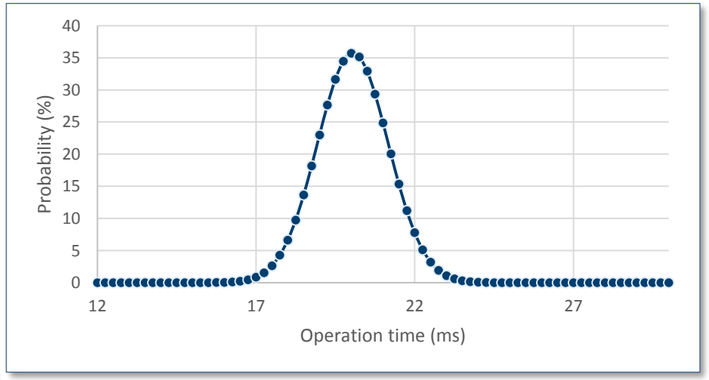


Automating tests in HYPERSIM

- Define model parameters to be modified or applied using an EXCEL spreadsheet
  - Use model component name as defined in netlist
  - Use component parameter as defined in netlist
- Program test sequence directly in TestView…
- Or import EXCEL test sequence

Test Automation using TestView





Client: **OPAL-RT Technologies Inc.**
Title: TestView Sequence

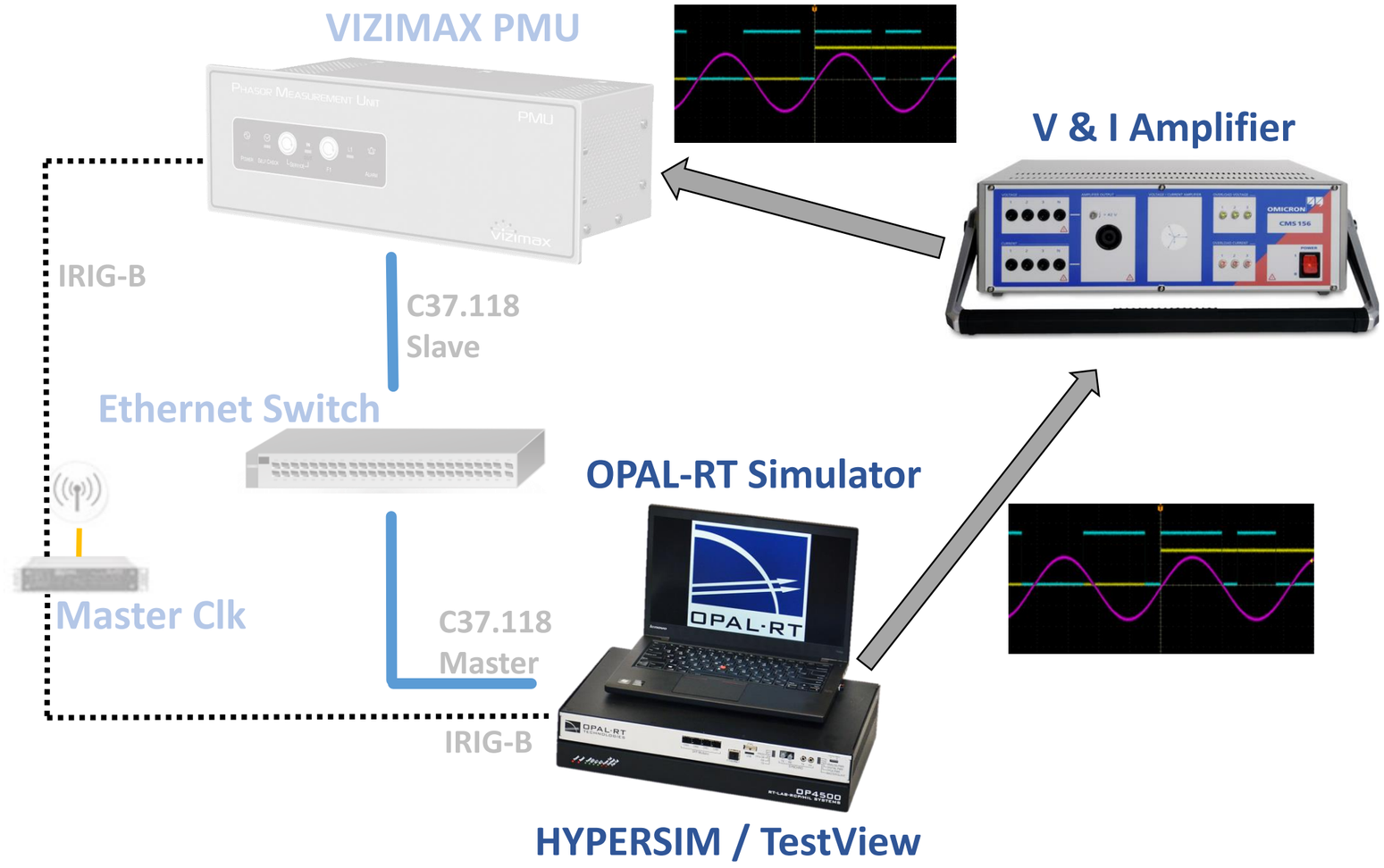
Date: 10/11/2014
Project No.: PF555-555
Rev. : 2.0

Test	Seq.	StartDate	Fault Type	Location	POW	Rf
Internal-1	1	Wed, 15 Oct 2014 16:36:30:994 EDT	A-gnd	0	0	0.01
Internal-1	2	Wed, 15 Oct 2014 16:36:30:994 EDT	A-gnd	0	0	15
Internal-1	3	Wed, 15 Oct 2014 16:36:30:994 EDT	A-gnd	0	45	0.01
Internal-1	4	Wed, 15 Oct 2014 16:36:30:994 EDT	A-gnd	0	45	15
Internal-1	5	Wed, 15 Oct 2014 16:36:30:994 EDT	A-gnd	0	90	0.01

Generate test reports

- View test waveforms in ScopeView and automate printing of .pdf report for each test
- Output post-processed values calculated during test in a pre-formatted EXCEL spreadsheet
- Analyze data in EXCEL or ScopeView

Calibration capability of the test setup

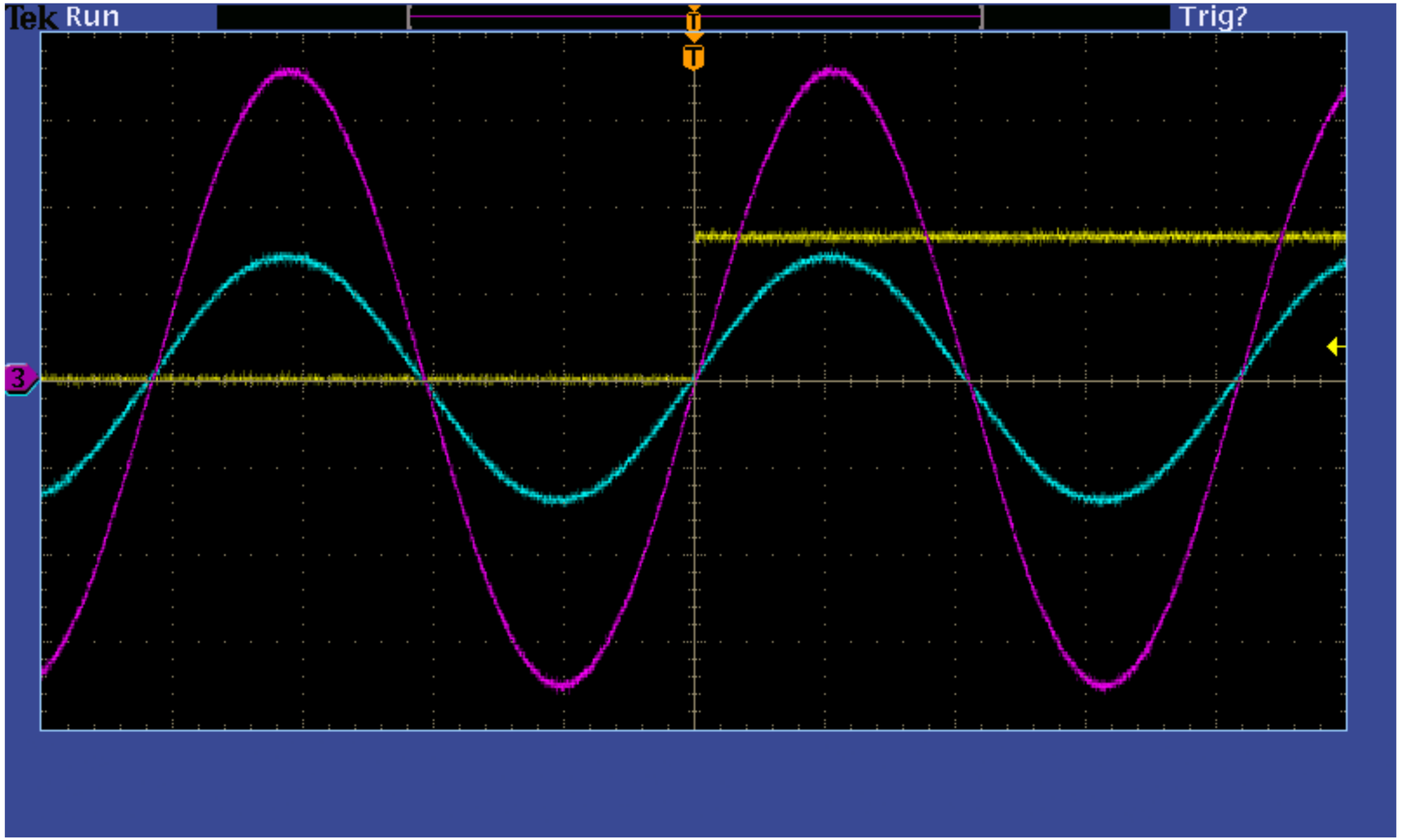


Calibration capability of the test setup

1 PPS from Master Clock

Simulator Output

Amplifier Output



$$V_{ref} = \delta a \cdot \{A \sin(2\pi f \cdot [t + \Delta t] + \varphi)\}$$

Basic calibration variables

Summary of C37.118.1 Tests

Test	Influence quantity	P Class Criteria	M Class Criteria
Signal freq. Range	Signal frequency ±2Hz for P class ±5Hz for M class	TVE <1% FE <0.005Hz RFE <0.4Hz/s	TVE / FE / RFE <1% / <0.005Hz / <0.1Hz/s
Signal Mag. (V/I)	Voltage magnitude 80% to 120% for P class 10% to 120% for M class Current magnitude 10% to 200%	TVE <1% FE<0.005Hz RFE<0.4Hz/s	TVE <1% FE<0.005Hz RFE<0.1Hz/s
Harmonic Dist.	2nd to 50th harmonic 1% for P class 10% for M class	TVE <1% FE<0.005Hz RFE<0.4Hz/s	TVE <1% FE<0.025Hz
Out-of-Band Interf.	10Hz - f0-Fs/2 and f0+Fs/2 – 120Hz 10% for M class only	No requirement	TVE <1.3% FE<0.01Hz
Meas. BW **Phase & Amp. Modulation**	0.1Hz – min (Fs/10, 2) for P class 0.1Hz – min (Fs/5, 5) for M class	TVE <3% FE<0.003*Max Mod Freq RFE<0.18*pi*Max Mod Freq^2	TVE <3% FE<0.003*Max Mod Freq RFE<0.18*pi*Max Mod Freq^2
Freq. ramp	±2Hz for P class ±5Hz for M class	TVE <1% FE<0.01Hz, RFE<0.4Hz/s	TVE <1% FE<0.01Hz, RFE<0.2Hz/s
Phase step change **Mag. Step change**	±10° ±10% of nominal magnitude	Delay time 1/(4*Fs) TVE response time 2/f0 Overshoot, undershoot 5% of step FE response time 4.5/f0 RFE response time 6/f0	Delay time 1/(4*Fs) TVE response time 7/Fs Overshoot, undershoot 10% of step FE response time max(14/f0, 14/Fs) RFE response time max(14/f0, 14/Fs)
Reporting latency	1000 consecutive reports	2/Fs	7/Fs

Control design using virtualized synchrophasors and PMU prototyping devices (NI's)

Industry Trends

- **Rapid evolution of technology and standards**
  - *Instrument Customization*
  - *Future-proof architecture*
  - *Increased device complexities due to political, economic, social factors*

- **Better operational efficiency**
  - *Multiple logical devices on the same physical unit*
  - *Flexible communication protocols*
  - *Distributed intelligence*

- **Increased security awareness**
  - *Compliance to NERC-CIP*
  - *Compliance to IT standards*

Developing Next-Generation IEDs

Computers

Processing Power

Open Source

I/O Expandable

Programmable

Software-Defined (Open)

GAP

Instrumentation Class Measurements

Embedded Processing Power

Reliable & Robust

I/O Expandable & Standards-Based

Open source & Programmable

Software-Defined (Open)

T&D Instrumentation

Measurements

Embedded

Reliable & Robust

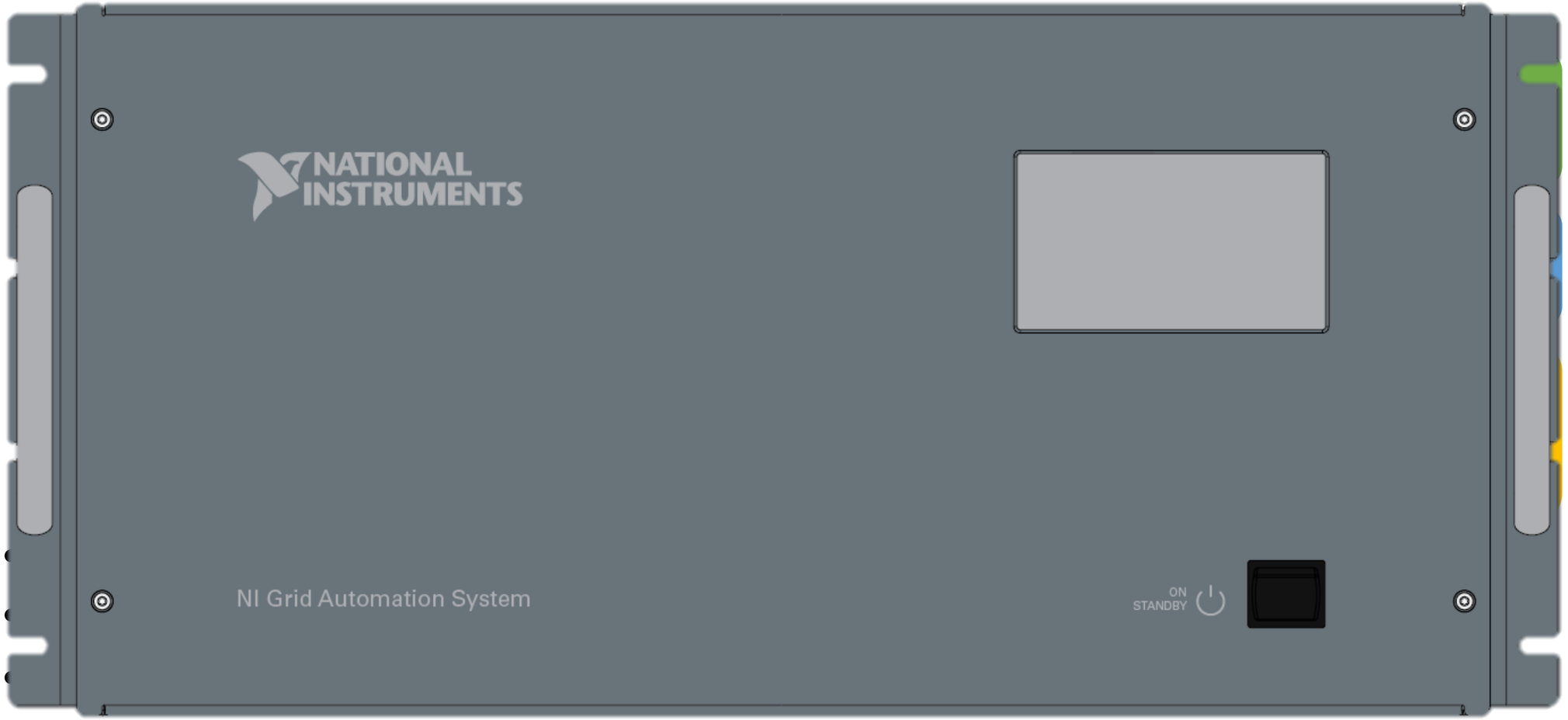
Standards-based

Vendor-Defined (Closed)

OPAL-RT TECHNOLOGIES

NI Grid Automation System

An FPGA-based Platform



OPAL-RT TECHNOLOGIES

Extensive Set of Analog & Digital I/O

Over 200 C Series I/O Modules

- **Analog Input**
  - Up to 1MS/s, simultaneous sampling
  - 4, 8, 16, and 32-ch options
  - Built-in signal condition for sensors
    - Strain gages, accelerometers, thermocouples, RTDs
  - 20A (continuous) , 100A (10s), Withstand: 500A (1s) , 1250A (1/2 cycle)
  - 800 VRMS L-E (continuous), Withstand: 1000 VRMS L-E (10s)
  - 12, 16 and 24-bit resolution
  - Available ch-to-ch isolation
- **Analog Output**
  - Up to 100 kS/s simultaneous updating
  - Up to 16-ch per module
  - 10 V, ±20 mA
  - Isolation
- **Digital I/O**
  - Up to 10 MHz timing
  - Counter/timer, PWM
  - 8 and 32-channel options
  - Up to 250VDC with automatic thresholds
- **Specialty**
  - 2-port CAN modules
  - Brushed DC servo motor drive
- **Timing Synchronization**
  - IEEE 1588
  - GPS with optional anti-spoofing technogy
- **Custom/Third Party Modules**
  - LIN, Profibus, WLAN, MIL-1553, ARINC-429, and more …

Thanks!

Questions?