A Software Based Real-time Synchrophasor System Emulator

ePMU

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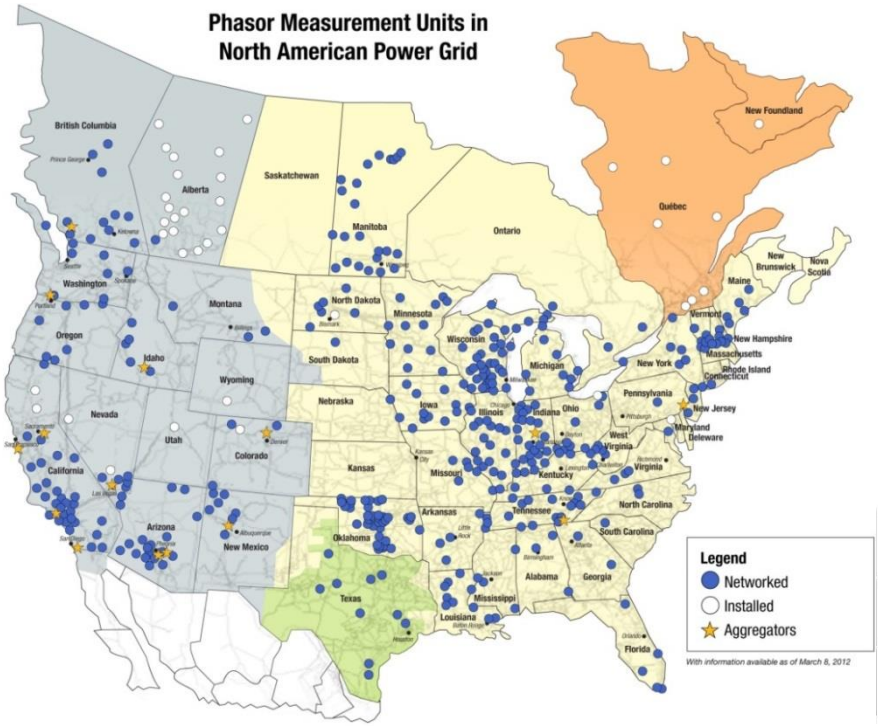
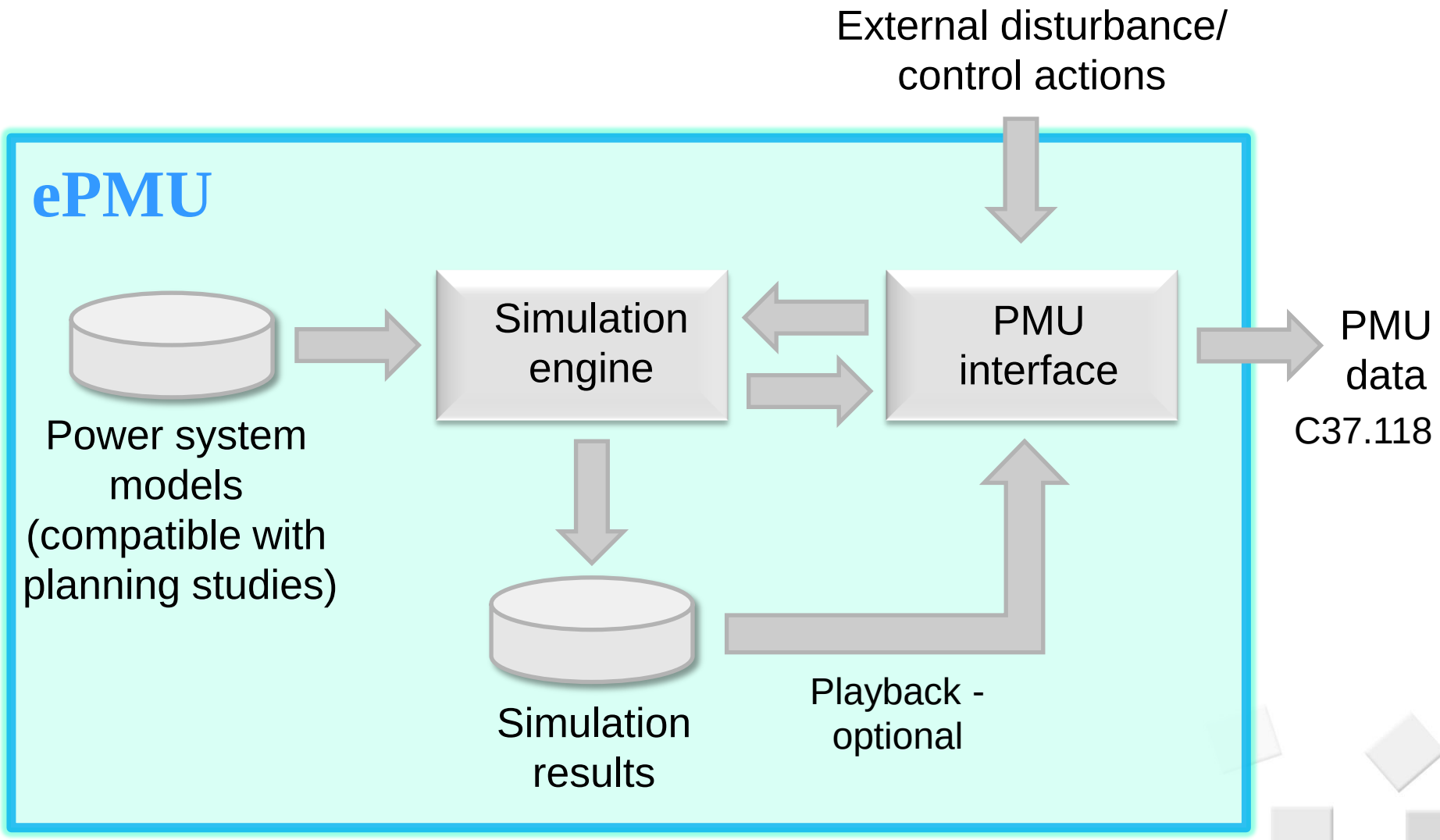
PMUs

- The PMU technology is getting very popular
- Applications are moving to control rooms for real-time visualization, analysis, and controls of grid conditions
- Some of these are mission critical and should be carefully tested and validated
- This calls for a test bed for PMU applications
  - Historical PMU data can be used, but it may be difficult to find the right data for the testing purpose



Simulation-Base PMU Network Emulator



ePMU

- A software product developed by Powertech to generate emulated PMU network
  - Commercially available now
- Uses TSAT (also from Powertech) as the simulation engine
  - Results are positive sequence phasor values
  - Simulations are controlled to progress at near real-time
- The PMU interface is based on a prototype developed by Washington State University
- Runs on Windows platform – no special hardware or third-party software is required

Main Features of ePMU

- Capable of handling very large power system models
  - Testing shows that near real-time simulations can be achieved for system models of up to 10,000 buses*
  - For even larger system models, an option is available to save simulation results and then to play back at real-time
  - Supports common network and dynamics models
- Supports real-time disturbance/control actions
- Streams synchrophasor format data (C37.118)
- Configuration capabilities
  - Assignment of PMU at any bus, generator, and branch in the system
  - PMU data reporting rate and communication (TCP) port

* Conditions may vary depending on system topology and dynamic models

Target Applications of ePMU

- Data Source
  - Provide data source for training purposes, such as dispatcher training simulator (DTS)
  - Test and validate wide-area situational awareness tools
  - Help design and develop decision support, intelligent diagnoses and analysis applications for grid events.

- System Studies
  - Studies of automated controls (e.g. SPS) in system operations
  - Examine “what if” scenarios in short-term operation studies
  - Determine appropriate PMU locations
  - Assist planning study and system models validation

Real-Time Control Actions

- Network topology changes, load and generation shedding, dynamic model parameter changes, etc.
  - Add line
  - Trip line
  - Reconnect line
  - Switch shunt
  - Trip generator
  - Shed load
  - Change control model setpoint
- Such control actions can be sent to simulation engine as the simulation goes at real-time
  - In the C37.118 format through the same TCP port for PMU data streaming

PMU Assignment

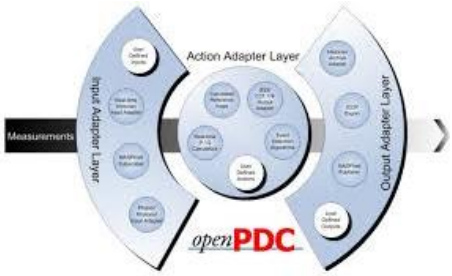
- At any location in the system for bus, generator, and branch
- A set of standard quantities are available for each PMU assigned

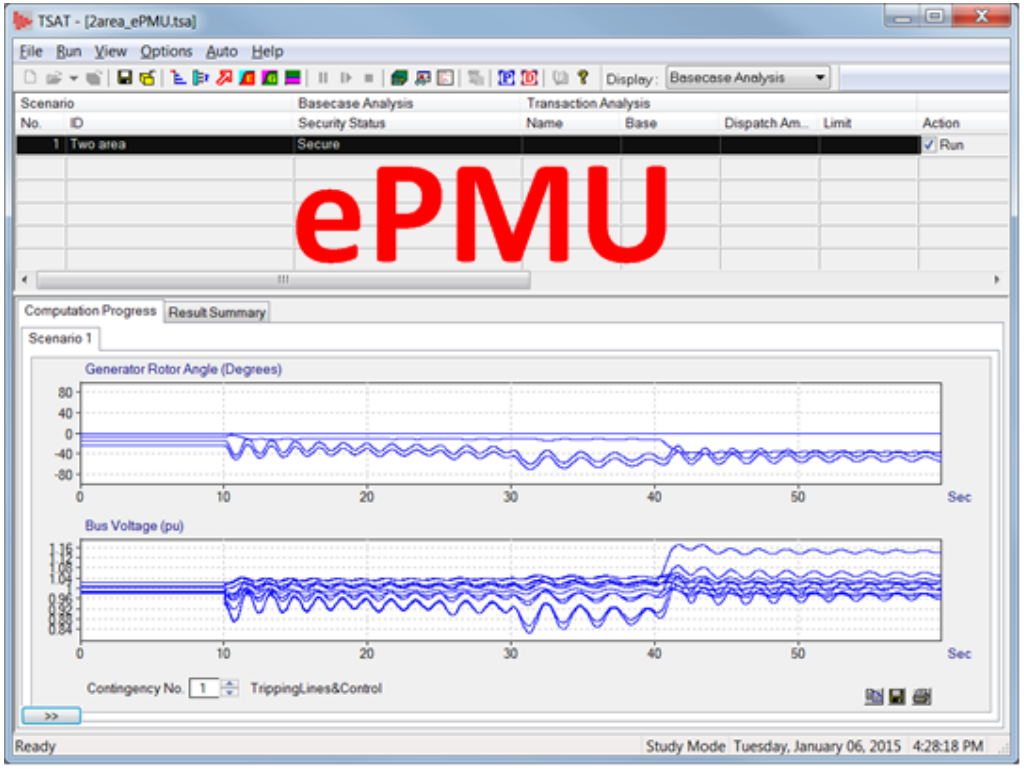
PMU DATA QUANTITIES

Generator		**Branch**		**Bus**	
Name	*Unit*	Name	*Unit*	Name	*Unit*
Generator ω_r	*Hz*	From-bus f_v	*Hz*	Bus f_v	*Hz*
Terminal V_m	*Volt*	From-bus V_m	*Volt*	Bus V_m	*Volt*
Generator θ_r	*Rad*	From-bus θ_m	*Rad*	Bus θ_m	*Rad*
Generator I_m	*Amp*	Branch I_m	*Amp*		
Generator β_m	*Rad*	Branch β_m	*Rad*		

ω_r : Rotor speed
θ_r : Rotor angle
V_m : Voltage magnitude
I_m : Current magnitude
f_v : Frequency
θ_m : Voltage angle
β_m : Current angle

Connectivity





TCP/IP

e-terra*phasorpoint*

ALSTOM

PHASOR RTDMS

Real Time Dynamics Monitoring System

Electric Power Group

Oscillation Monitoring System

WASHINGTON STATE UNIVERSITY

Powertech

An Example

- An example is shown to illustrate the operation of **ePMU**
- A reduced WECC model is used
  - The model is created for BC Hydro on-line DSA
  - 8795 buses
  - 1359 generators including 10 types of generator models, 12 types of governor models, 30 types of exciter models, and 8 types of PSS models
- The event simulated
  - Load ramping up in the Vancouver area, picked up by governor actions
  - A couple of BC Hydro 500 kV line tripping; one is triggered by the external user action
- The simulation is performed at near real-time
  - The results are sampled and streamlined at 30 frames per second
  - The speed performance can be monitored

An Example – ePMU Operation Animation

- Powertech ePMU
  - A software product developed by Powertech to generate emulated PMU network
- Alstom Grid PhasorPoint
  - Synchrophasor Advanced Applications Framework and Visualization

Real-time grid stability monitoring for simulation and training

Powertech ALSTOM

Conclusions - ePMU Advantages

- Speed and performance
  - Get simulated PMU data for large system models
  - Generate time-synchronized PMU data for long period of time (minutes to hours)
- Flexibility
  - Support a wide range of models, for example, renewables, user-defined models, special protection system models
  - Such models are usually available from planning or operational studies
  - Models can be “tuned” to include certain features, for example, oscillatory modes, for testing PMU applications
  - Assign PMU at any locations in the system
  - Apply disturbance/control actions externally
- Low cost to run and maintain

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