

PMU Emulator for Power System Electromechanical Dynamics Simulators

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NASPI WG Meeting

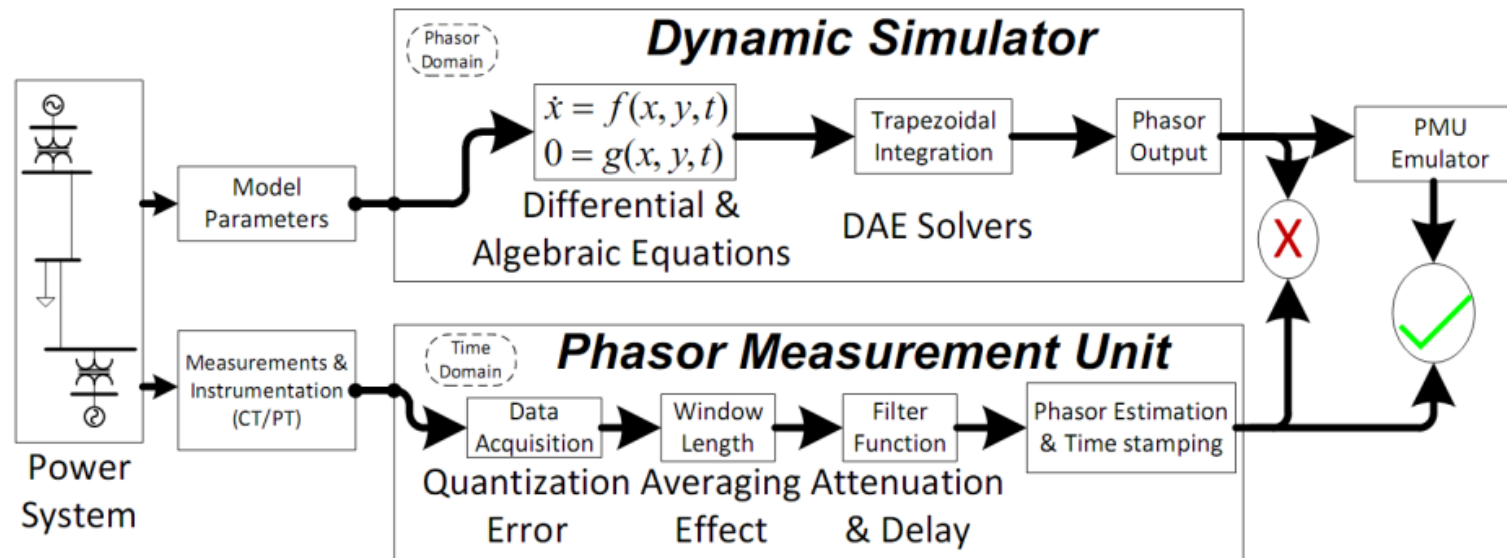
Albuquerque, NM

April 25, 2018



PMU Measurements vs Phasors from Dynamic Simulations

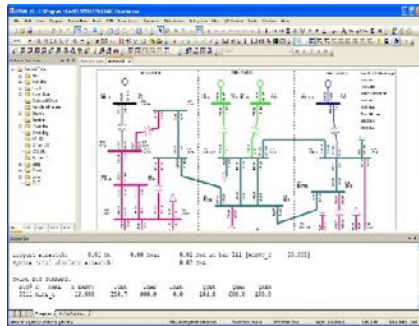
- Phasor values obtained from dynamic simulation tools may differ from synchrophasors measured by PMUs in the field
- How a PMU works:
 - Analog signal sampling - A/D Conversion
 - Digital filtering → magnitude attenuation & phase offset
 - Phasor estimation
 - algorithm e.g. DFT
 - window length - P & M class PMUs



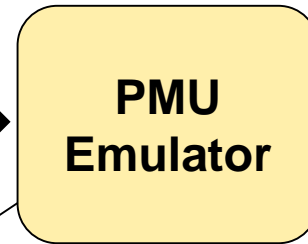
PMU Emulator

- PMU Emulator: interfaced with power system dynamics simulators, and produces “simulated synchrophasors” taking into account PMUs internal signal processing

Dynamics Simulation Software
(PSS/E, PSLF, TSAT etc)

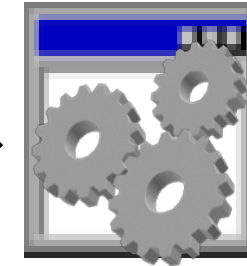


Simulated
Phasors

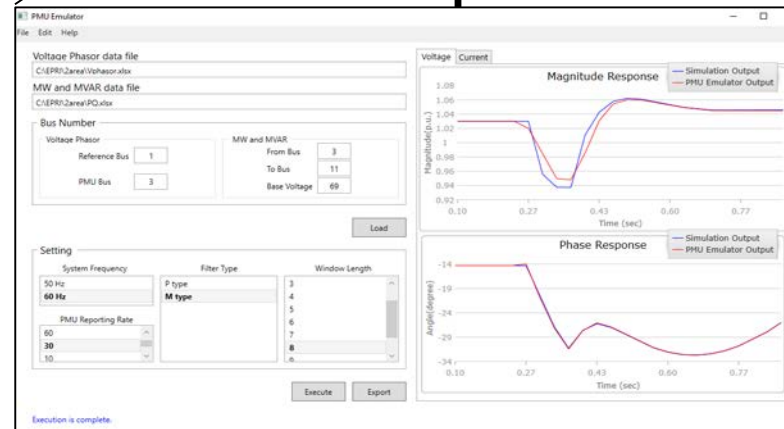


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Synchrophasor
Application

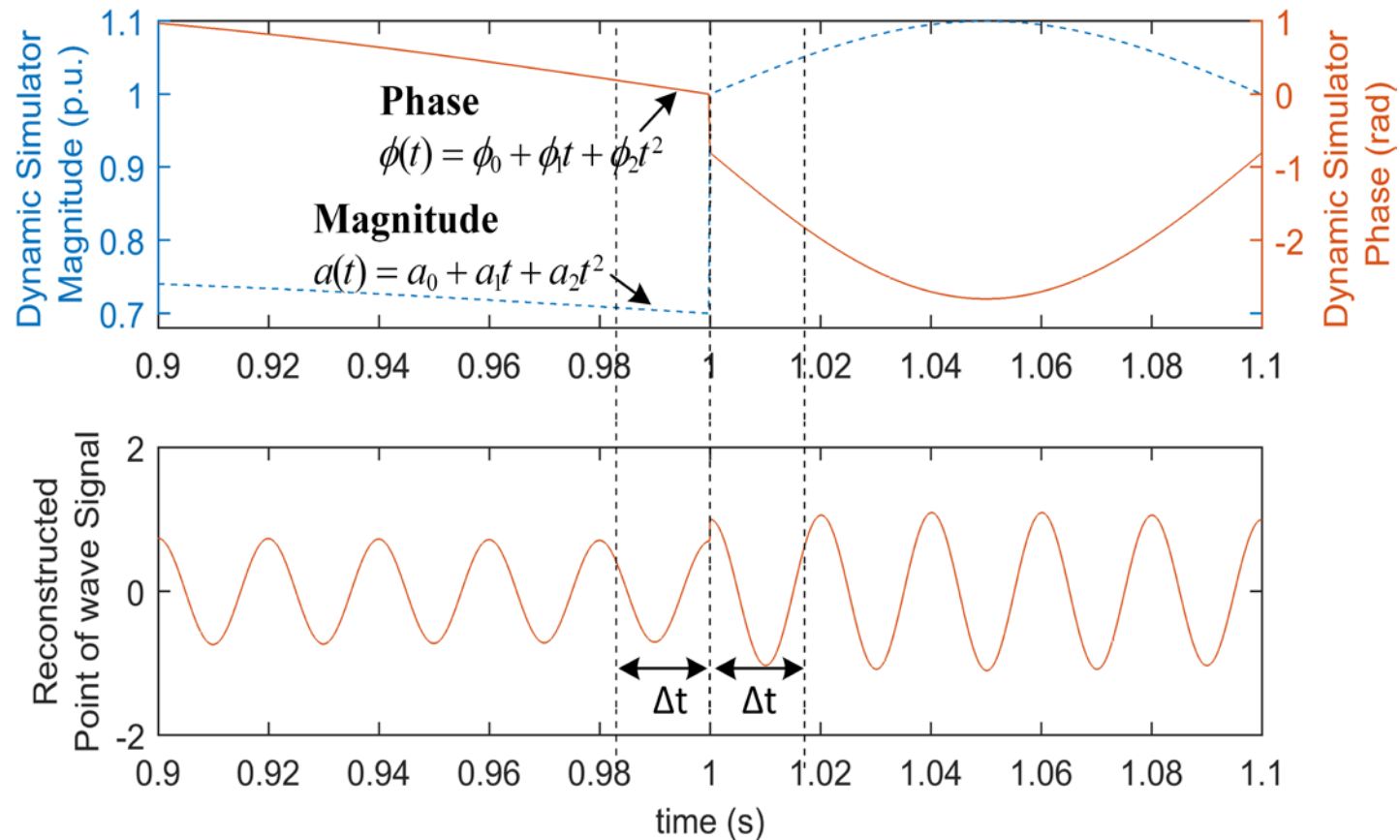


Proof-of-concept software



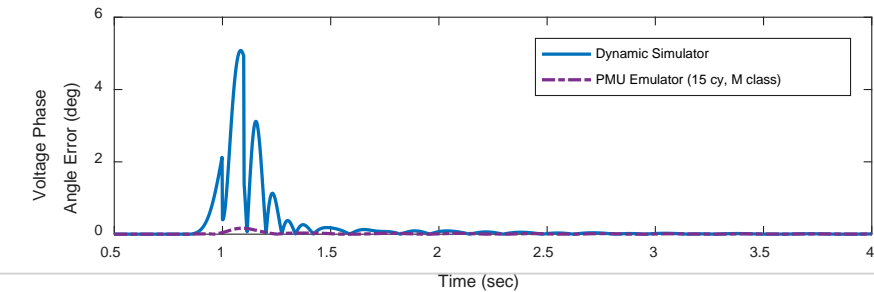
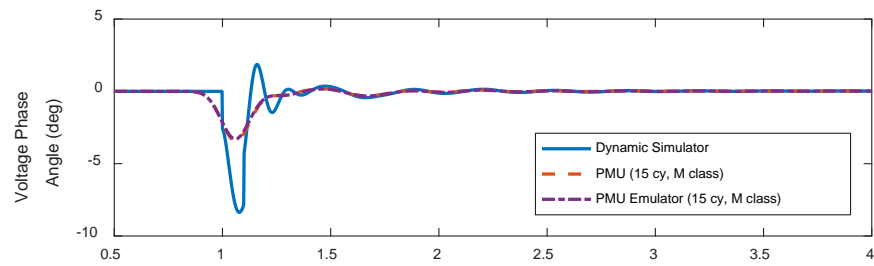
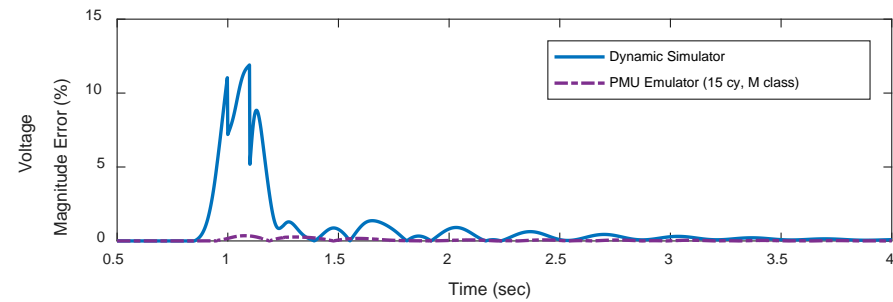
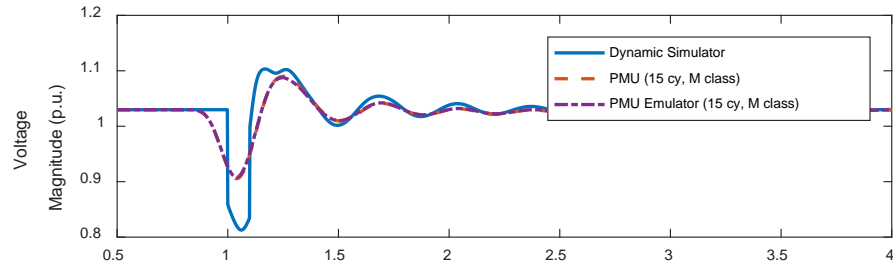
PMU Emulator - Algorithm

- Point On Wave based (POW) compensation
 - POW signal reconstruction
 - Application of phasor estimation algorithm and filters on reconstructed signal
 - Reported synchrophasors time stamped at the center of the data window.

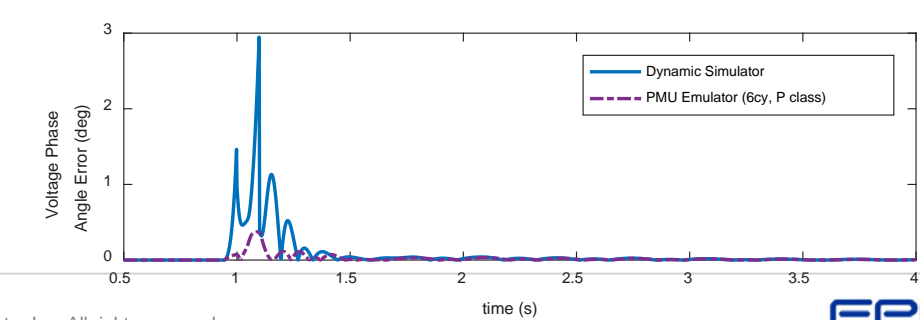
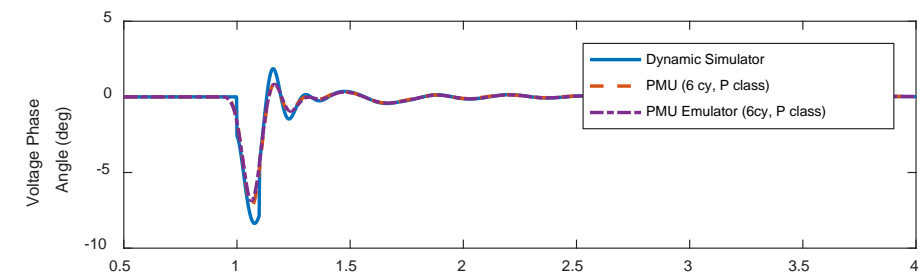
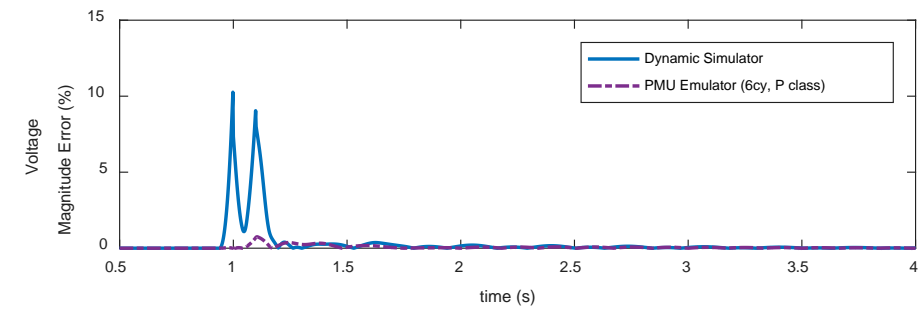
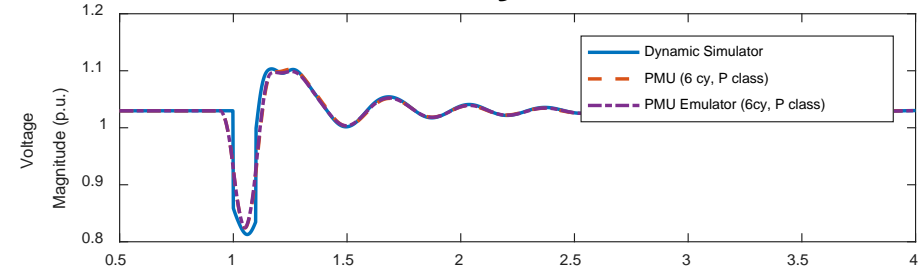


Demonstrating Results – Voltage Phasors

M-Class - 15 cycles window

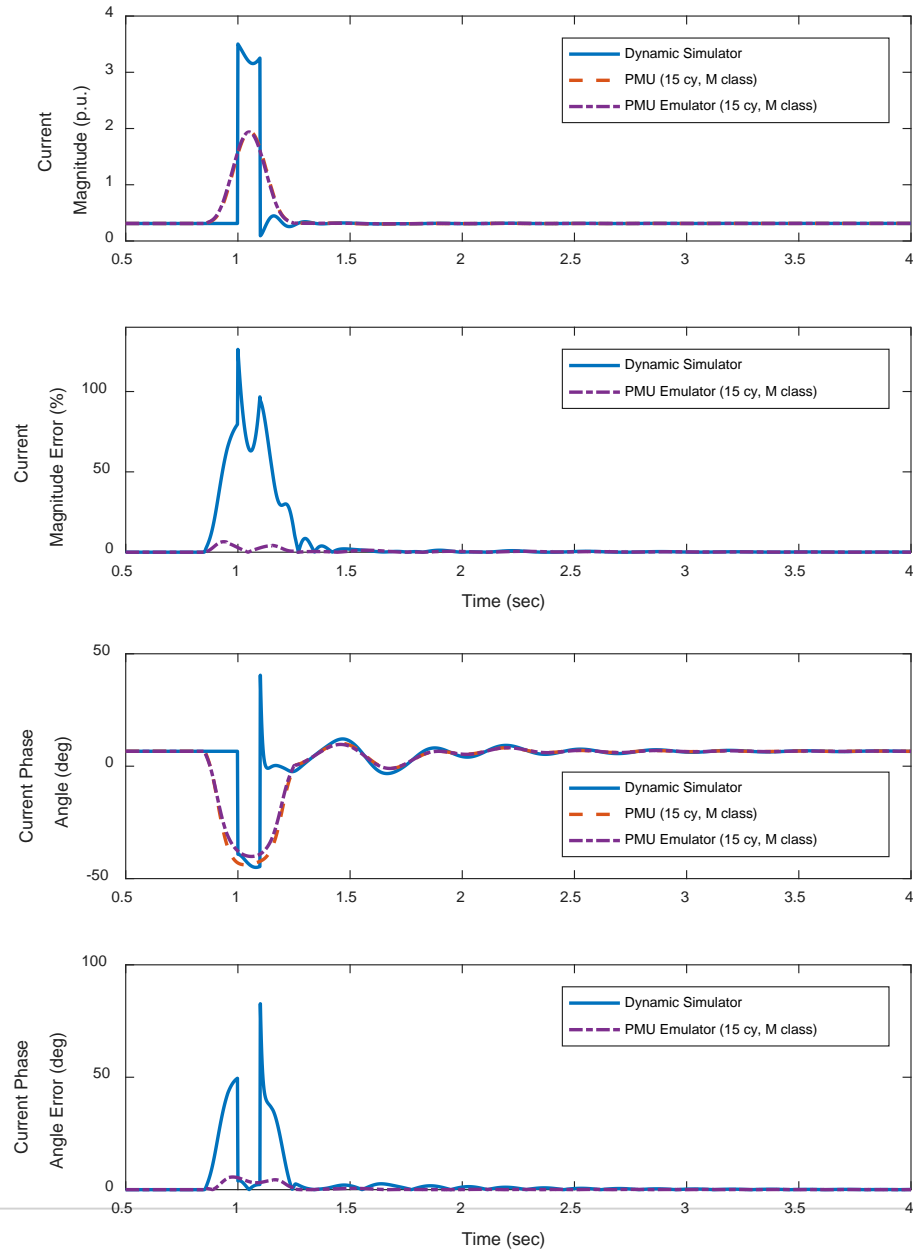


P-Class - 6 cycles window

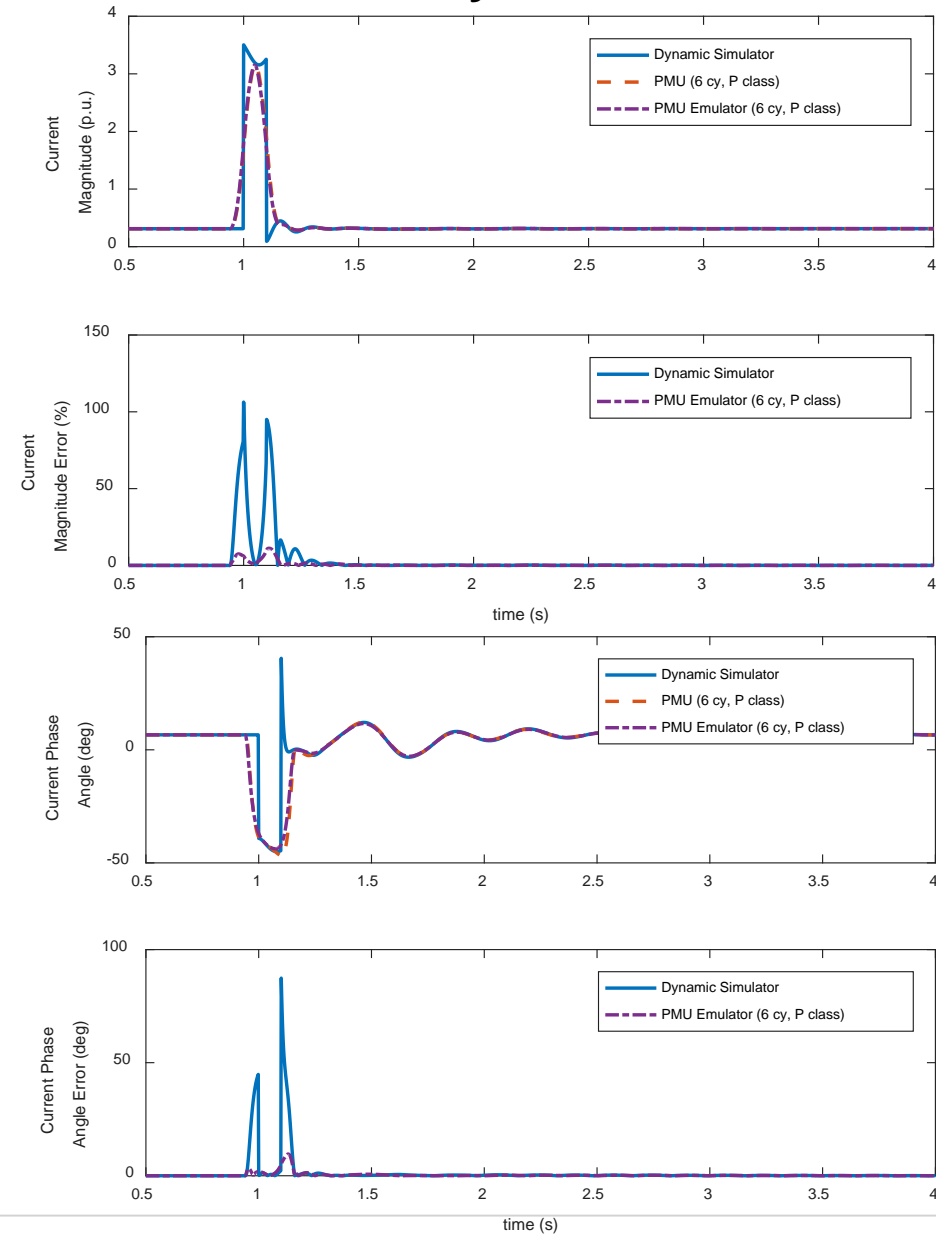


Demonstrating Results – Current Phasors

M-Class - 15 cycles window



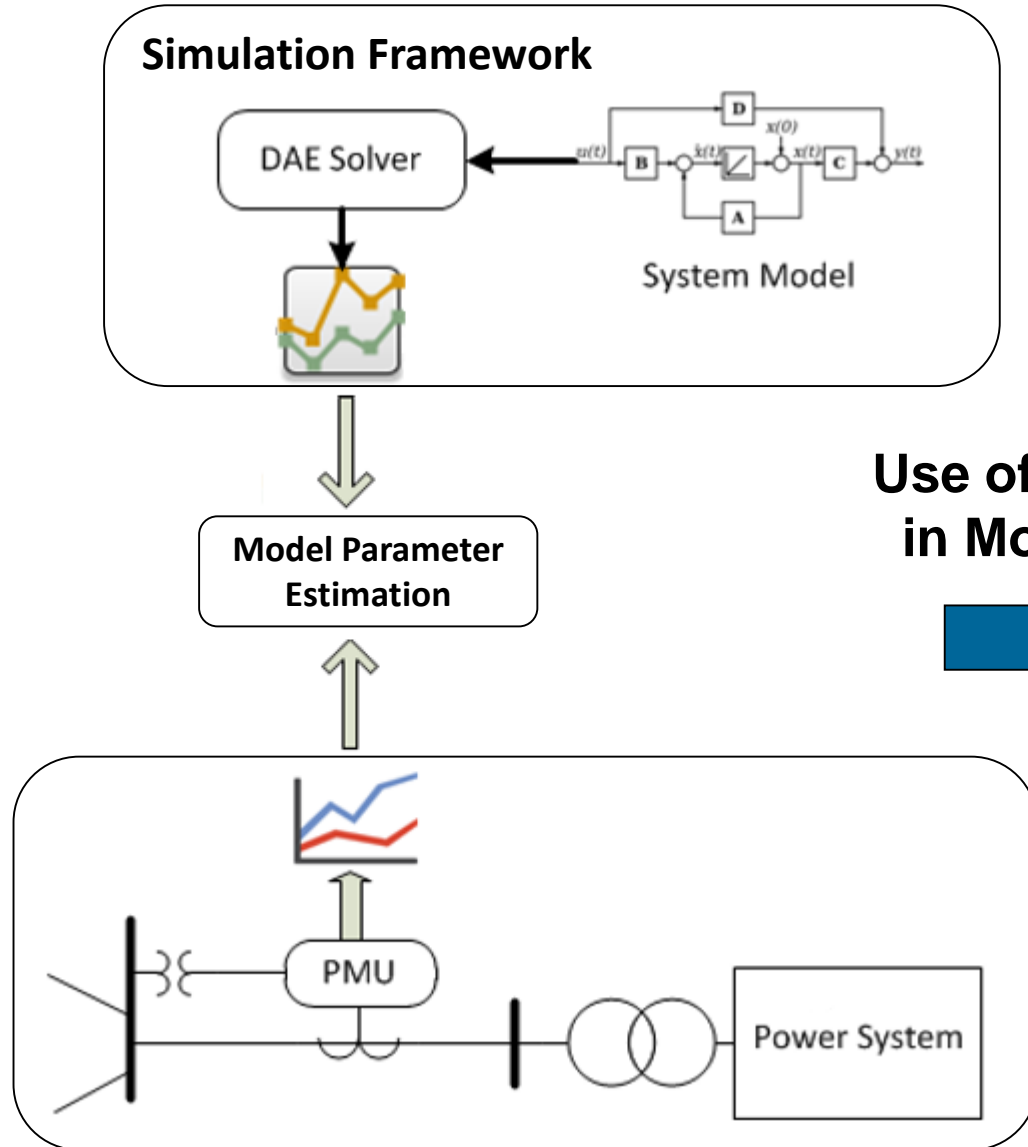
P-Class - 6 cycles window



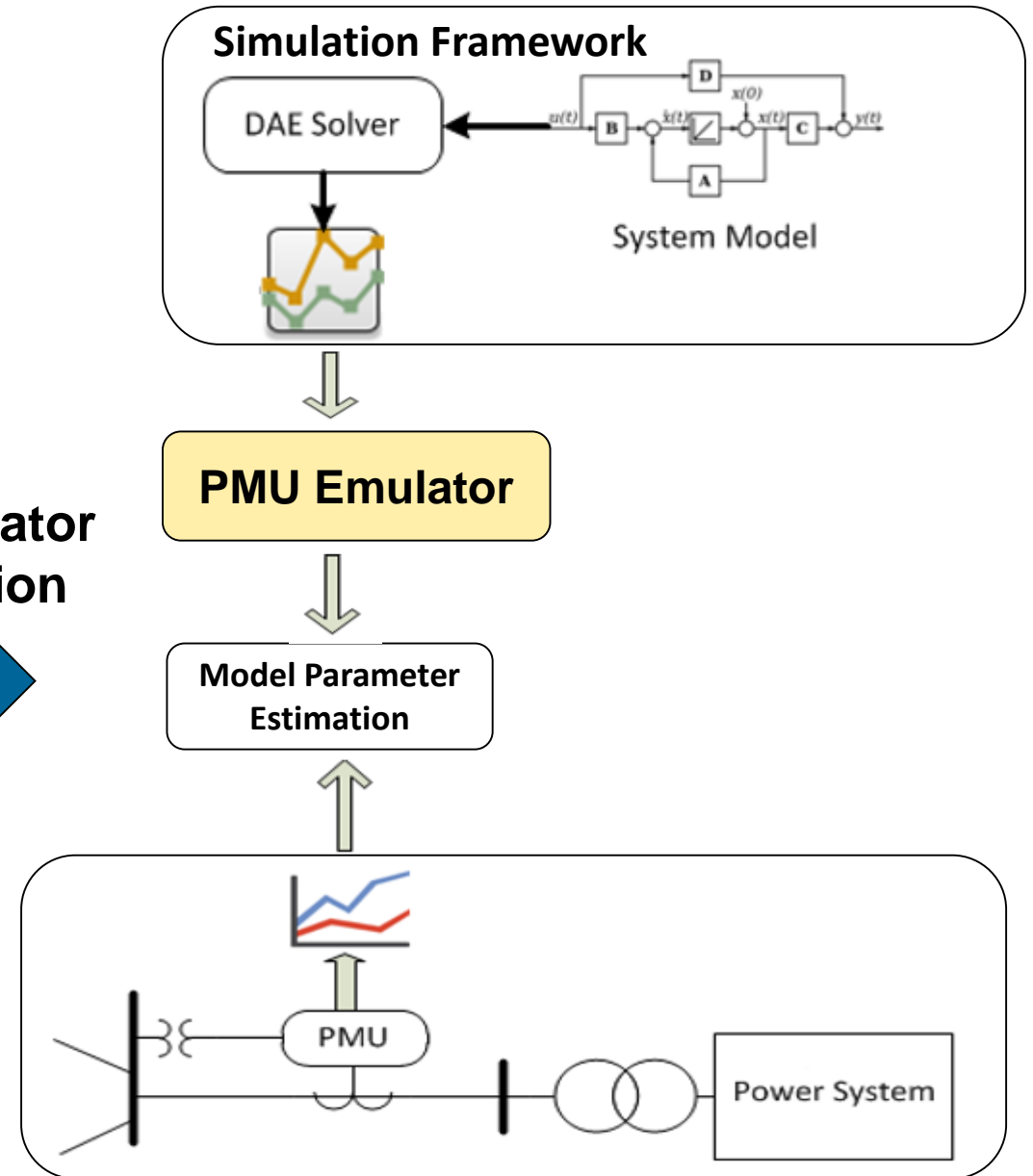
PMU Emulator – Use Cases- Model Validation

Proposed Practice

Typical Practice

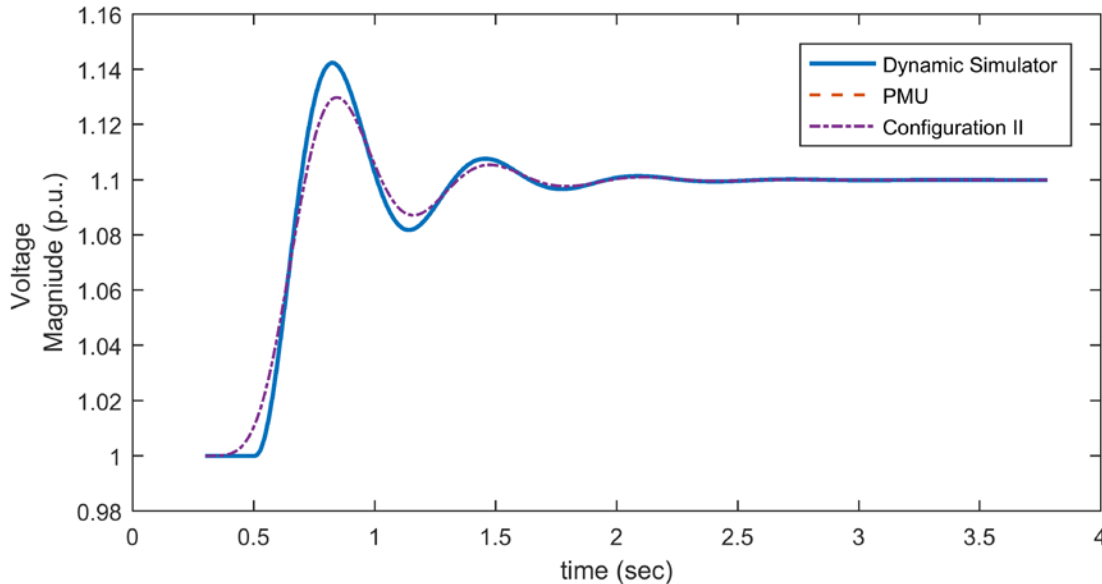
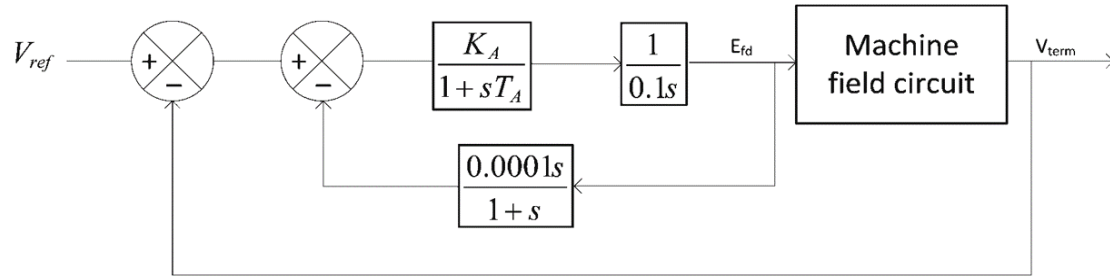


Use of PMU Emulator in Model Validation



PMU Emulator – Use Cases- Model Validation - Example

- Parameter estimation of generator exciter model – IEEE T1
- Parameter estimation with and without PMU Emulator for different PMU settings



PMU Settings (Cycle, Window)	True K_A (p.u.)	True T_A (sec)	Estimation with PMU Emulator		Estimation without PMU Emulator	
			K_A (p.u.) Error(%)	T_A (sec) Error(%)	K_A (p.u.) Error(%)	T_A (sec) Error(%)
8 cycles, Triangular	8	0.01	7.9998 0.0024	0.0099 0.0413	7.9357 0.8034	0.0088 11.9543
	15	0.01	14.9996 0.0026	0.0099 0.0393	14.8596 0.9362	0.0087 12.8717
15 cycles, Hamming	8	0.01	7.9998 0.0016	0.0099 0.0409	7.7702 2.8725	0.0057 43.0149
	15	0.01	14.9997 0.0019	0.0099 0.0411	14.5378 3.0810	0.0053 46.6787
20 cycles, Hamming	8	0.01	7.9998 0.0018	0.0099 0.0368	7.5875 5.1561	0.0019 81.0211
	15	0.01	14.9997 0.0019	0.0099 0.0411	14.2252 5.1656	0.0004 95.8872

PMU Emulator Software

PMU Emulator

File Edit Help

Voltage Phasor data file
 C:\EPR\PMU Emulator\Sample Data\Vohasor.xlsx Browse

MW and MVAR data file
 C:\EPR\PMU Emulator\Sample Data\PO.xlsx Browse

PMU information file
 C:\EPR\PMU Emulator\Sample Data\PMU Information.txt Browse

PMU information data

PMU Serial No.	Channel ID	Volt Bus	From Bus	To Bus	CKT No.	V Base (kV)	Ref. Bus
1	1	1	1	5	1	69	3
1	2	3	3	11	1	69	1
1	3	11	7	8	3	69	1
2	1	5	8	9	3	69	1
2	2	5	0	0	0	0	1

+ - Load

Settings

System Frequency
 50 Hz
 60 Hz

PMU Serial No. 2

Filter Type
 P
 M

Window Length
 1
 2
 3
 4
 5
 6
 7
 -

PMU Reporting Rate
 Same as simulation
 60
 30
 10

Execute

PMU 1 Ch. 1 PMU 1 Ch. 2 PMU 1 Ch. 3 PMU 2 Ch. 1 PMU 2 Ch. 2

Voltage

Magnitude Response

Current

Magnitude Response

Phase Angle

Phase Response

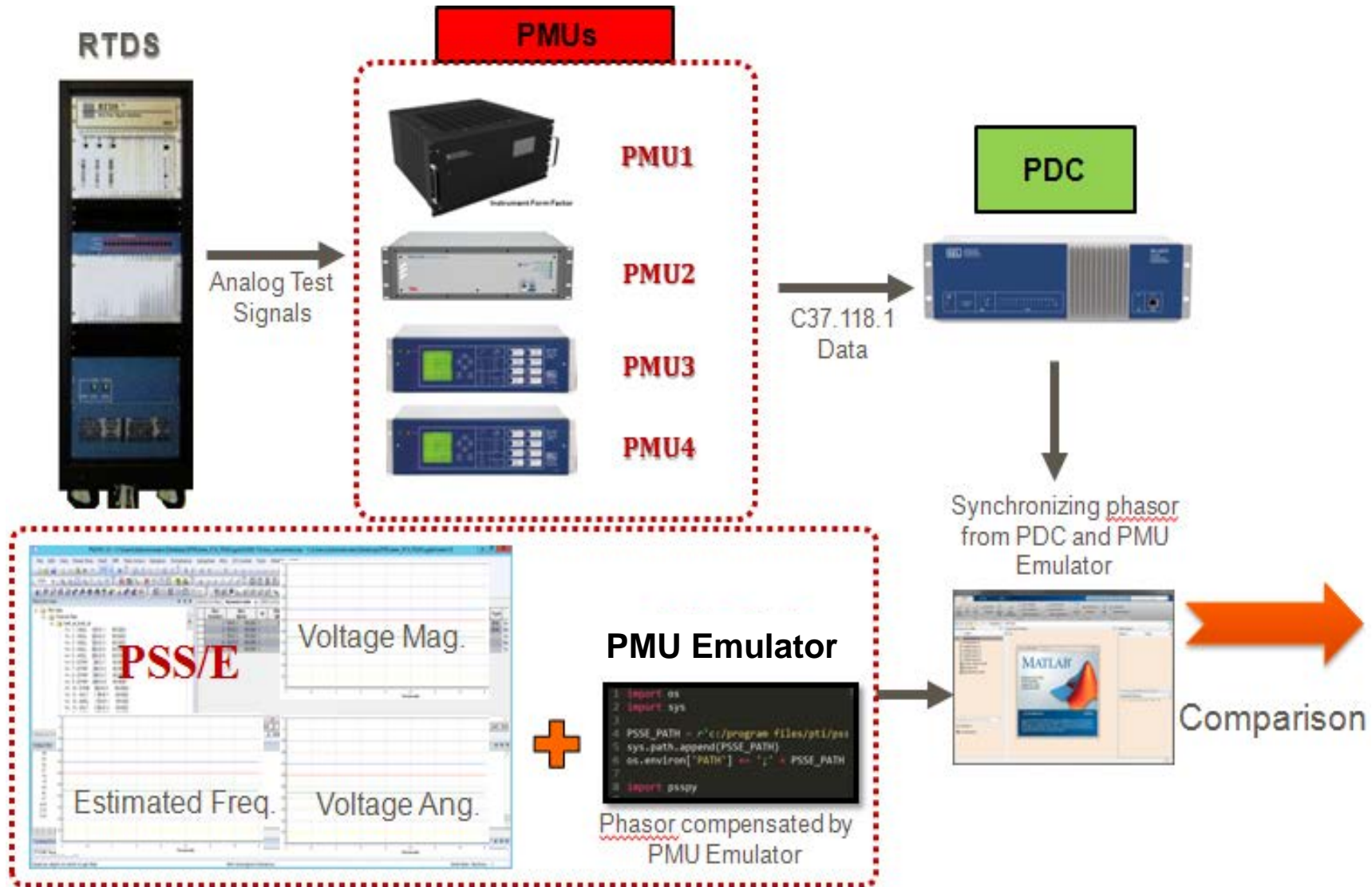
Export

Execution is complete.

- Also developed scripts for dynamic simulators (TSAT, PSS/E etc) to generate PMU Emulator input files (simulated voltage phasors and power) with the required format

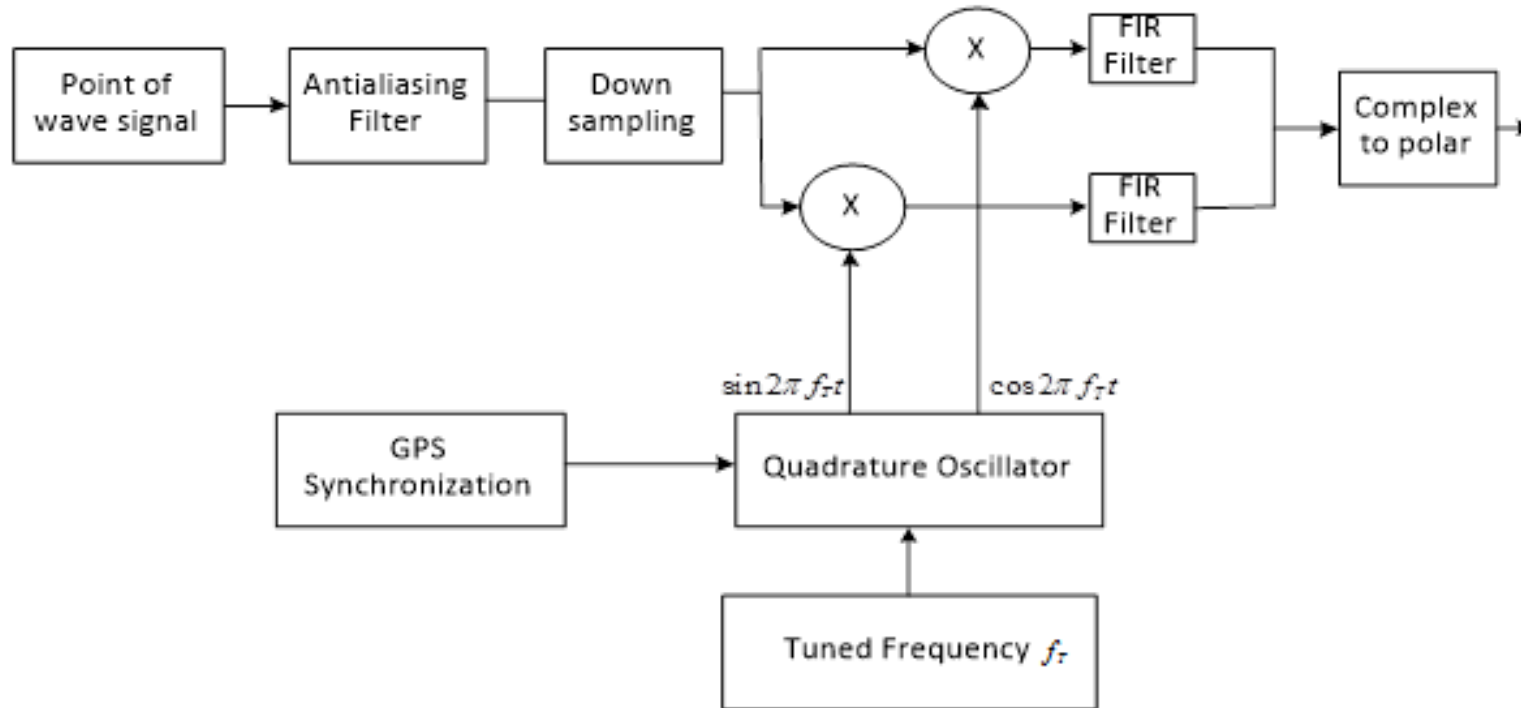
<https://membercenter.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=00000003002010741>

Benchmarking PMU Emulator with Hardware PMU



PMU Emulator – Vendor PMU Library

- Objective: Include in the PMU Emulator a library of commercial PMU models
- PMU vendors approached
- Required information is proprietary and requires NDA



Requested information sample

- Sampling frequency of the point of wave signal
- Transfer function of antialiasing filter
- Down sampling frequency, if any
- Length of the data window used for single phasor estimation
- FIR filters used
- Lengths of the FIR filters used (e.g. 8 cycles)
- ...

Next Steps

- Tech Transfer: Case Studies
- Vendor Engagement: Collaboration with vendors for implementation of PMU Emulator in commercial platforms





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