NASPI North American SynchroPhasor Initiative

Testing, Evaluation and Troubleshooting Tools for Life-cycle Management of Synchrophasor Systems

International Synchrophasor Symposium
March 22-24, 2016

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TEES | SMART GRID CENTER
TEXAS A&M ENGINEERING EXPERIMENT STATION

Agenda

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1. Introduction to Life-cycle Management
2. PMU Calibration Lab
3. Gold PMU
4. Field End-to-end Calibrator
5. Application Testing
6. PMU-Based Bad Data Detection

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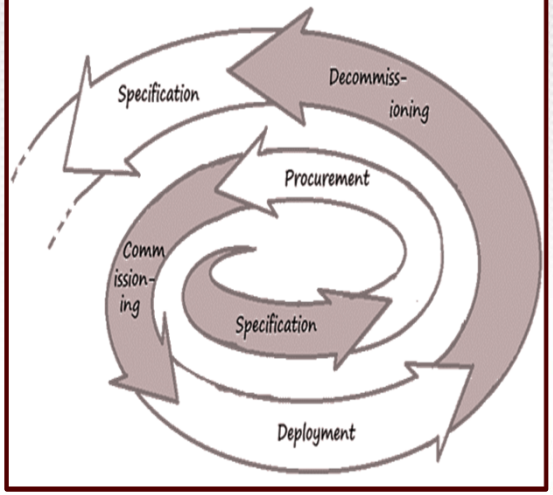
Life-Cycle Management Spiral Model

Why is needed?

- Laboratory tests are not enough
- Inappropriate installation
- Insufficient maintenance
- Improving monitoring, control and protection performance

How it looks?



What it covers?

- Equipment certification before purchase
- System commissioning
- Periodic field testing
- Continuous hidden failure checking
- Operator awareness of system *QoS* deterioration

Spiral Life-Cycle Management

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PMU Calibration Lab

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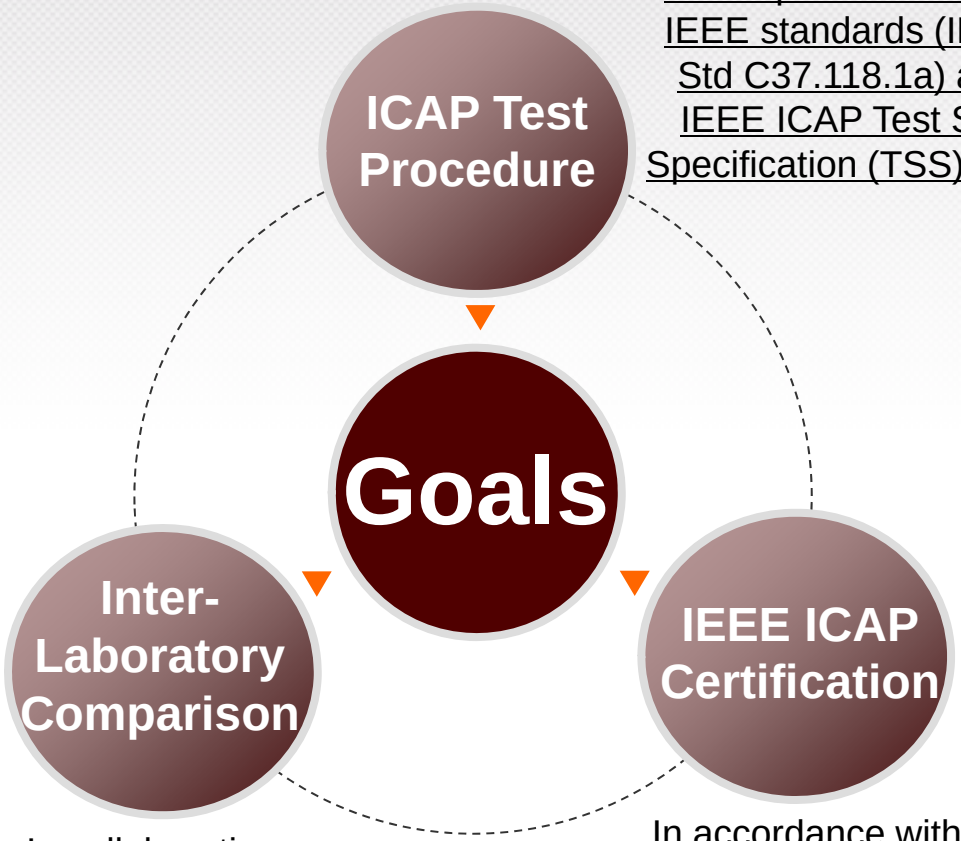
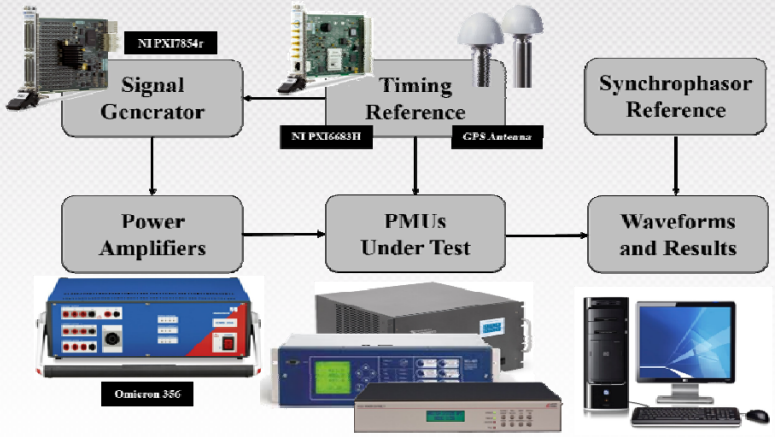


In compliance with the IEEE standards (IEEE Std C37.118.1a) and IEEE ICAP Test Suit Specification (TSS) Plan

In collaboration with NIST

In accordance with the standards ISO17065 and ISO17025



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PMU Calibration Lab

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Progress

- PMUs (or devices with PMU capabilities) from 3 different vendors are tested:
  - **National Instrument GAS**
  - **Arbiter**
  - **SEL**
- The developed test plan contains both static and dynamic tests:

Steady State Tests	Voltage/Current magnitude sweeping test
	Voltage/Current angle sweeping test
	Frequency sweeping test
	Harmonic distortion test
	Out-of-band interference test
Dynamic State Tests	Measurement bandwidth test
	Frequency ramp test
	Magnitude/Angle step test

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PMU Calibration Lab Performance Evaluation

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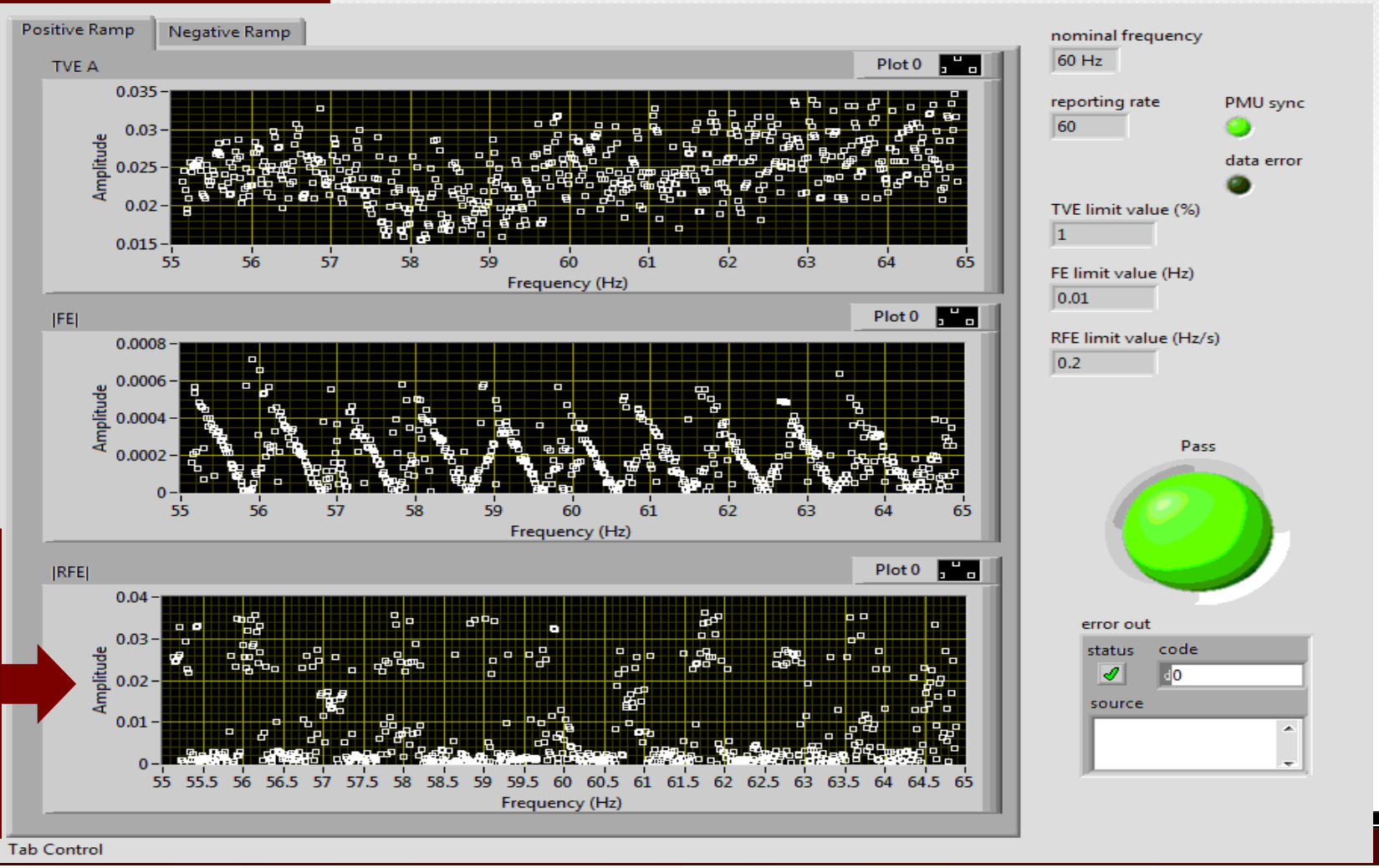
Sample PMU Test Results

Frequency Ramp Dynamic Test

Total Vector Error

Frequency Error

Rate of Change of Frequency Error



Amplifiers

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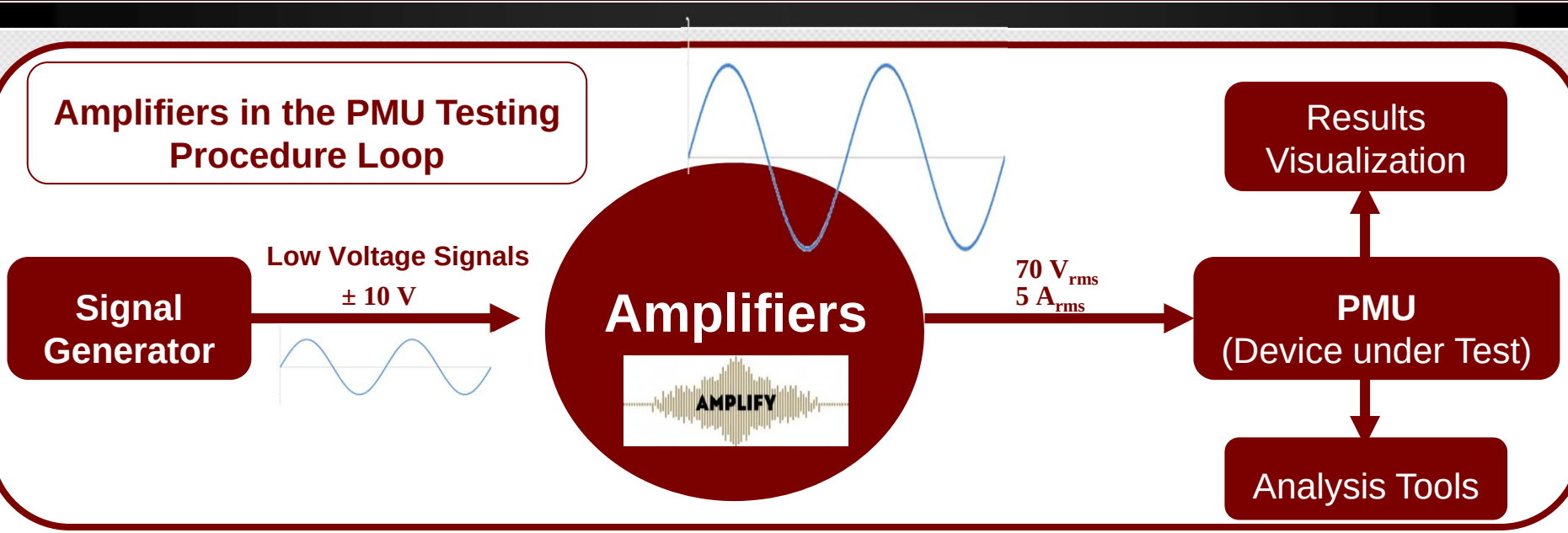
Amplifiers in the PMU Testing Procedure Loop



Why Amplifiers Matter for PMU Testing?

- Amplifiers could change conditions under which PMUs should be tested by introducing additional modulations, distortions, unwanted phase shifts, etc.
- Our test results proves the fact that selection of different amplifiers will affect the PMU test performance differently.
- Amplifier test plan has been developed in response to recognize the general amplifier performance for PMU testing.

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Gold PMU

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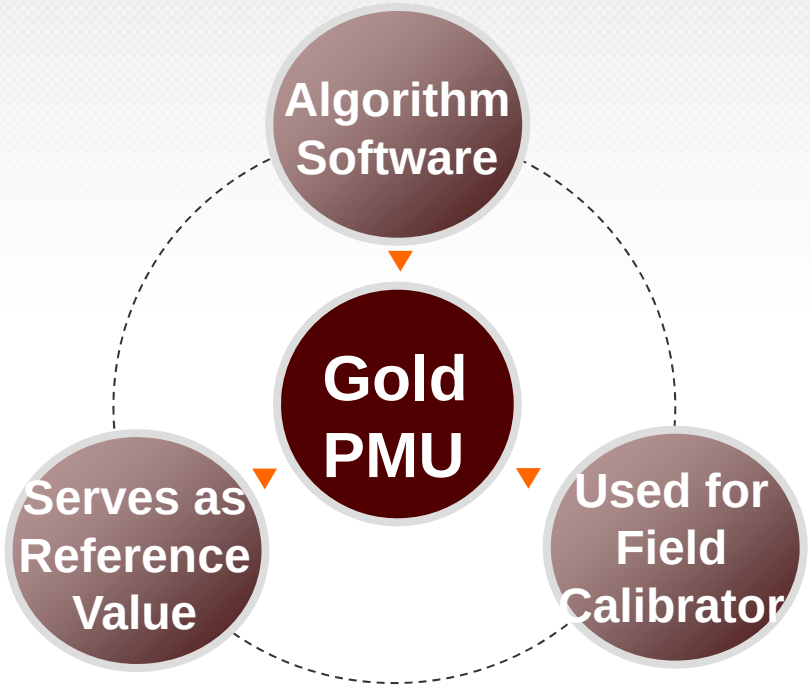
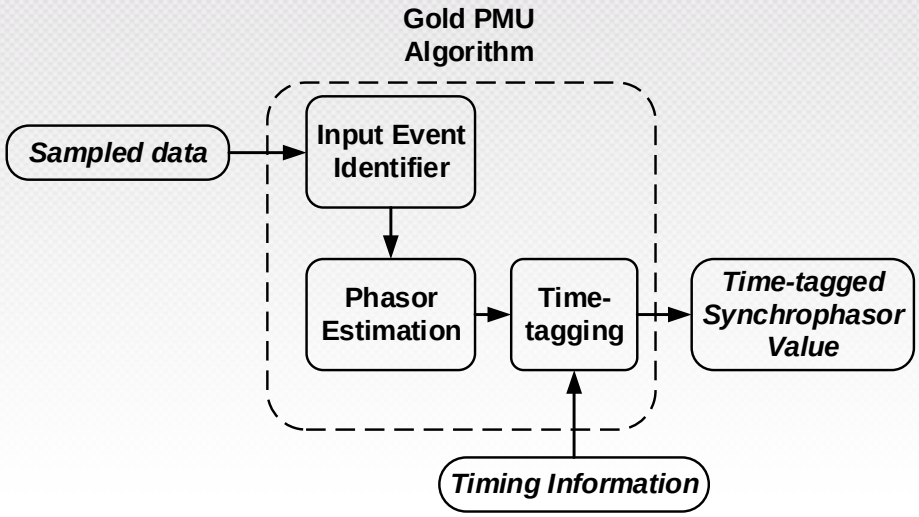
Gold PMU characteristic





ROCOF Test Results

Test Type	IEEE Standard	2nd Order Polynomial Fitting	Proposed Method
Steady-State Test	0.4(P) 0.1(M)	44	5×10^{-4}
Harmonic Test	0.4(P)	60	10^{-3}
Frequency Ramp Test	0.4(P) 0.2(M)	60	0.04
Modulation Test	0.2(P) 2(M)	8	0.2

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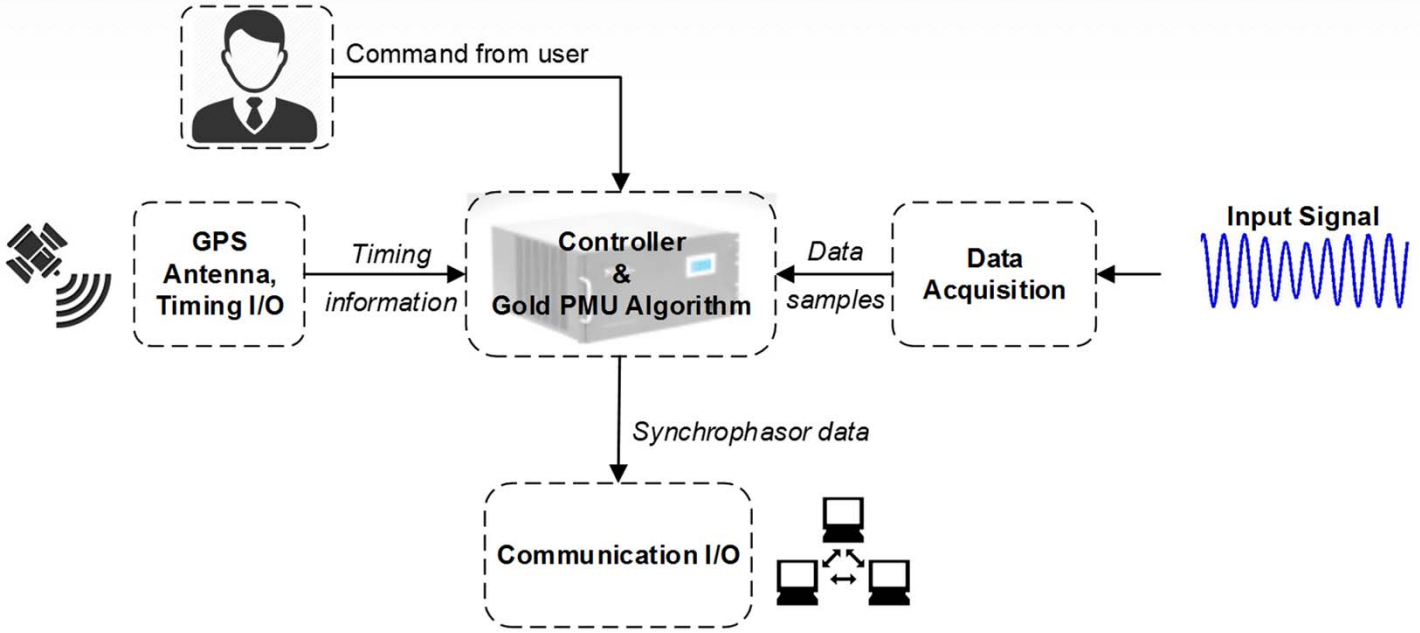
Gold PMU Implementation

Gold PMU Hardware Implementation

- Acts as a PMU reference, interfaced to the field end-to-end calibrator
- Composed of CPU, Data Acquisition, Timing, Communication Modules…



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Gold PMU Use Case

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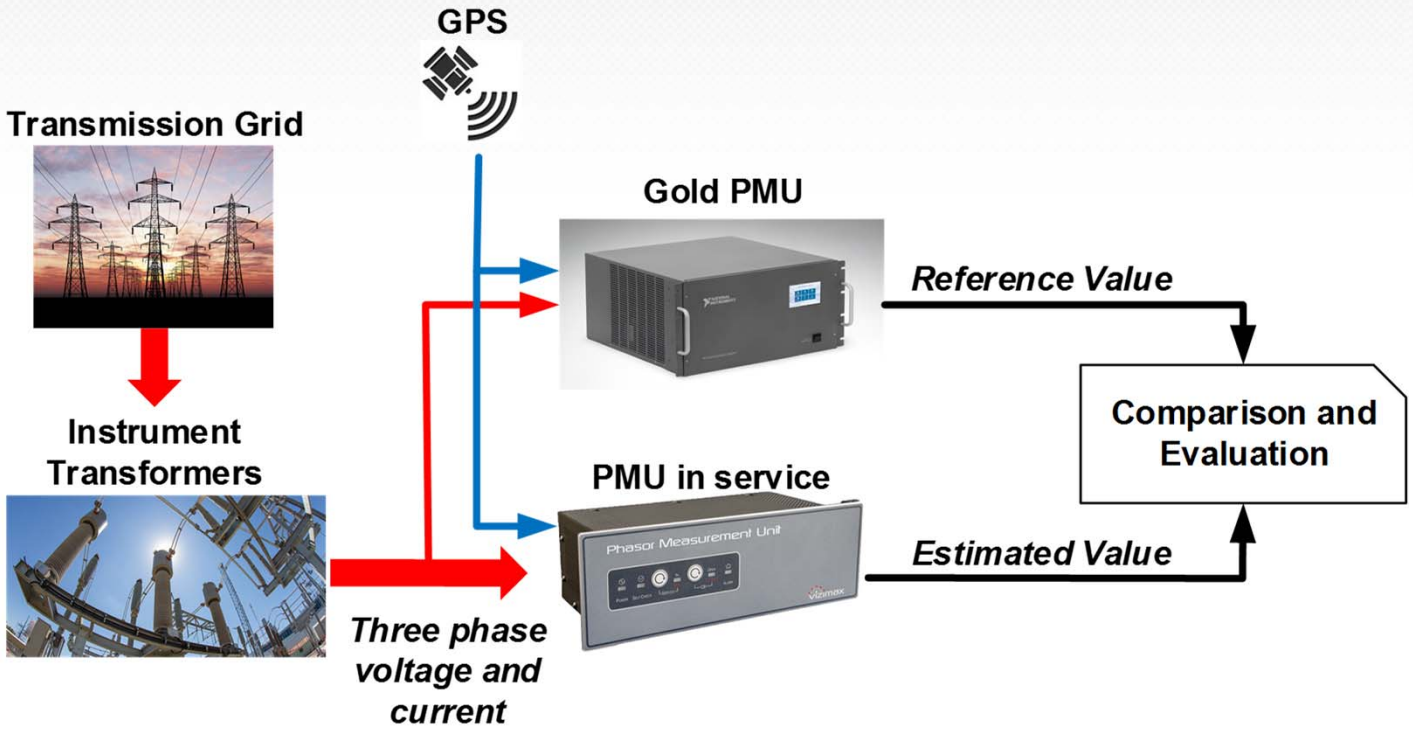
Use Cases – Installed in Substations

- Perform testing and calibration for in-service PMU.
- Portable so that it can be used for PMU testing and calibration.



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Portable Field End-to-End Calibrator

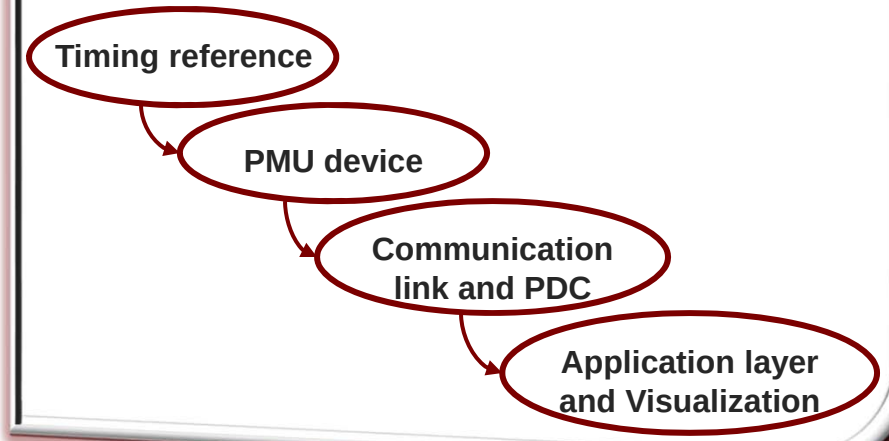
Testing in the field environment

Periodic maintenance testing of the PMUs

- Periodic testing is desirable due to possible degradation of the equipment over time
- Testing is conducted according to IEEE standards
- PMUs are tested in substation

Nested testing of the Synchrophasor system

- In case when bad data is detected
- Testing layer by layer of the system



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Portable Field End-to-End Calibrator – Use Case 1

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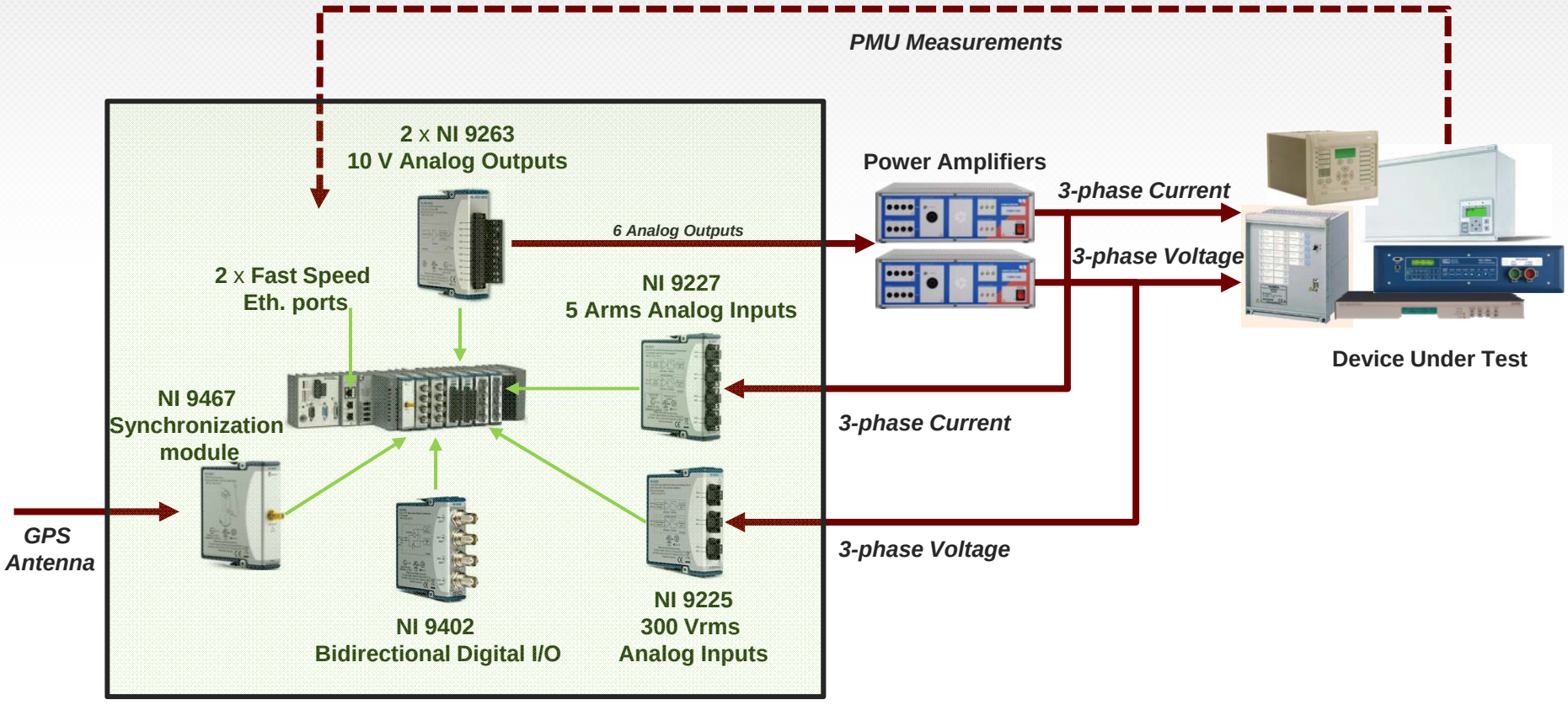
Periodic Maintenance of the PMU



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Portable Field End-to-End Calibrator – Use Case 2

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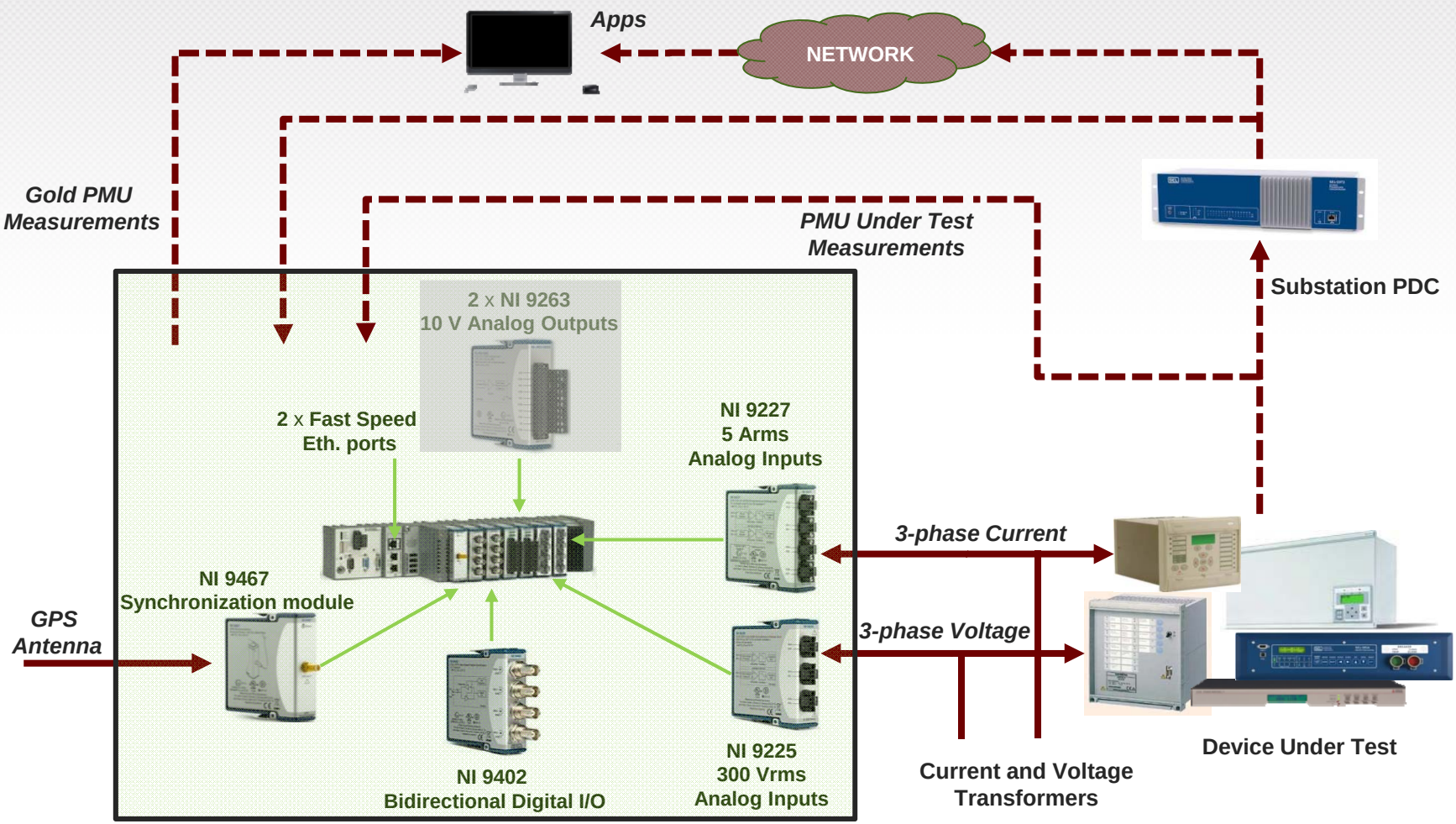
Nested Testing



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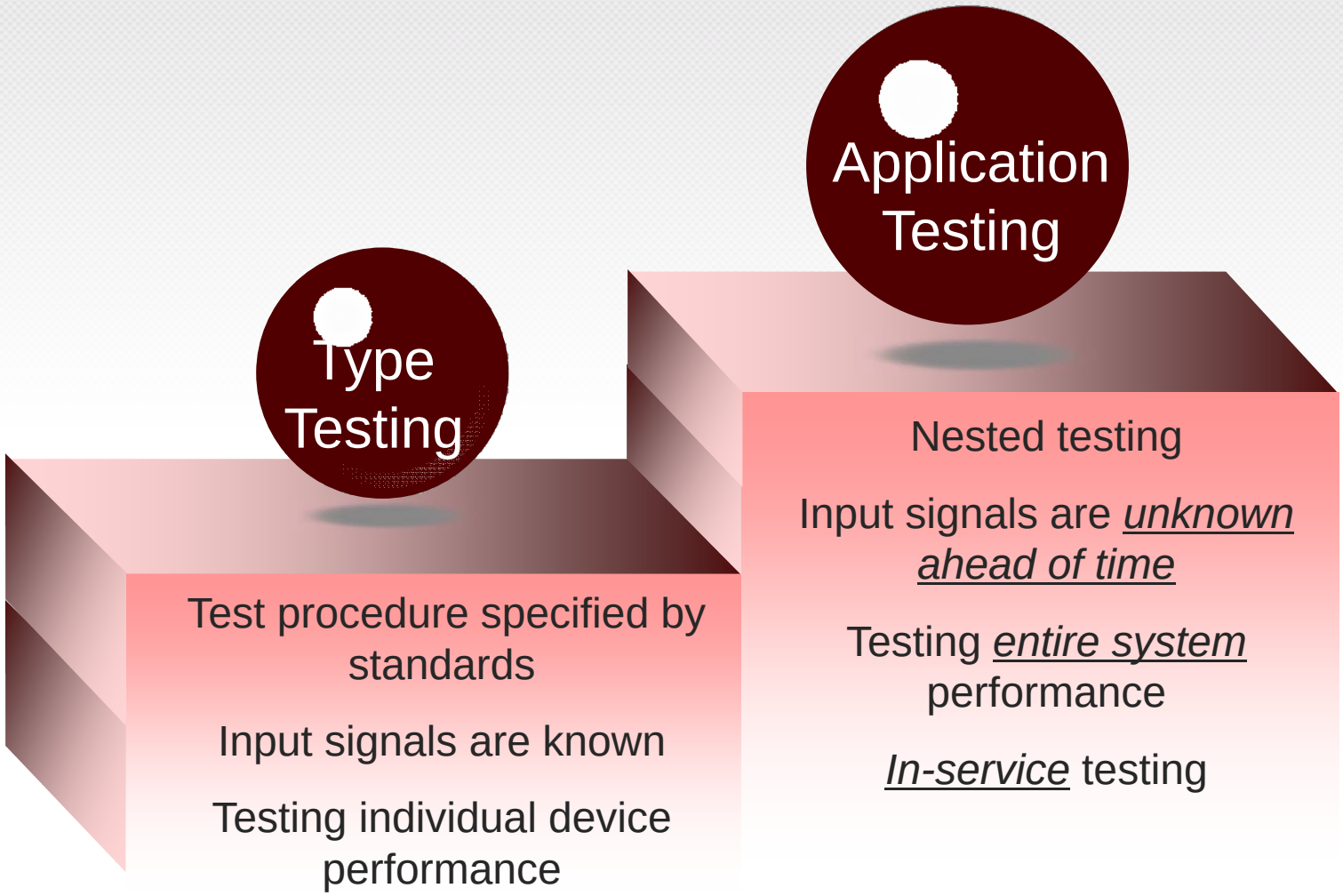
Application Testing



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Application Testing Use Cases

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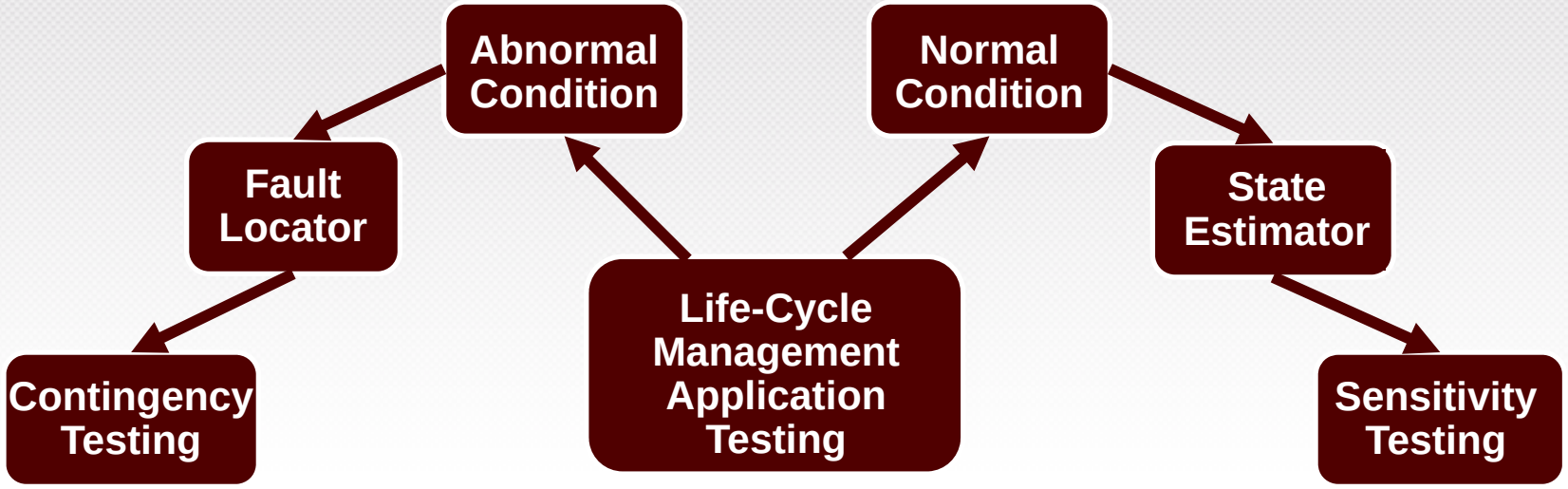

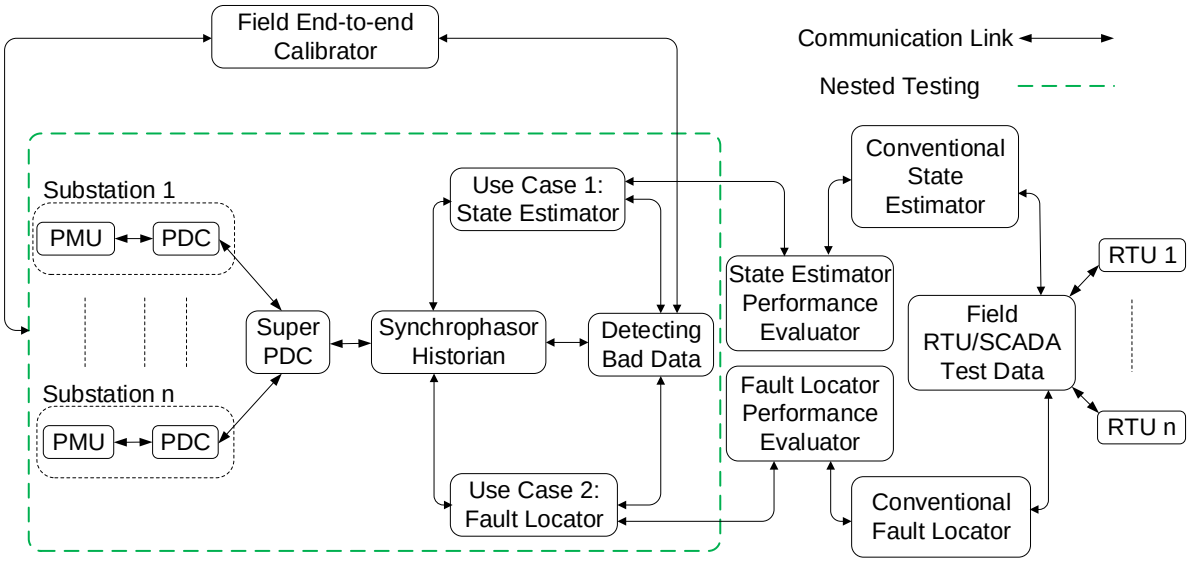

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Application Testing Implementation

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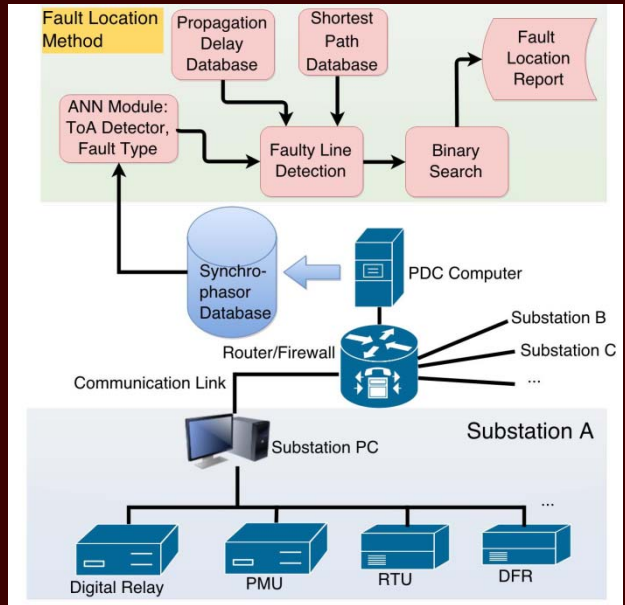

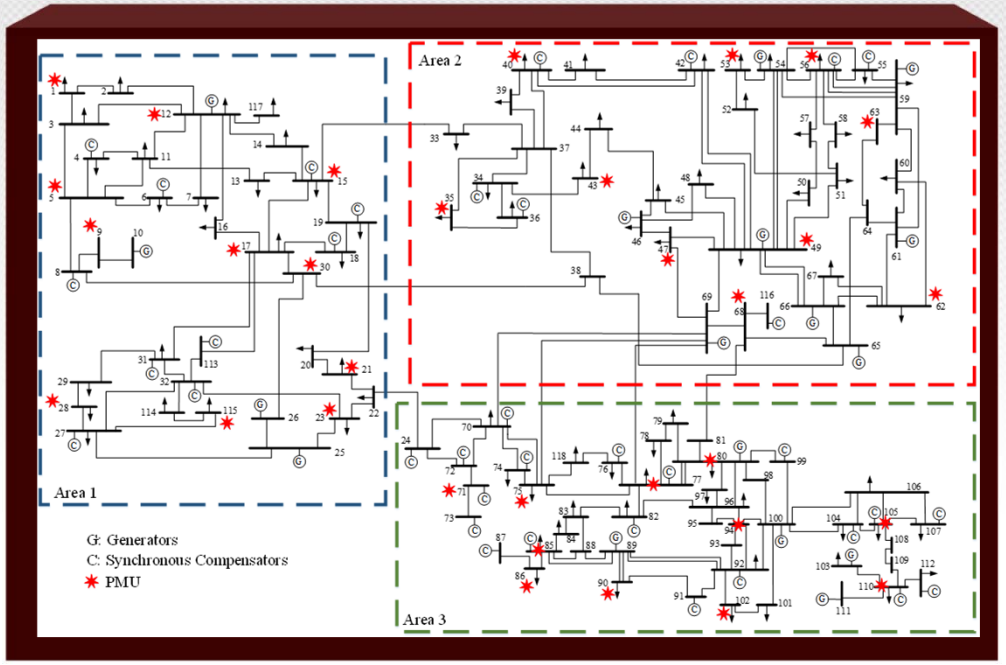

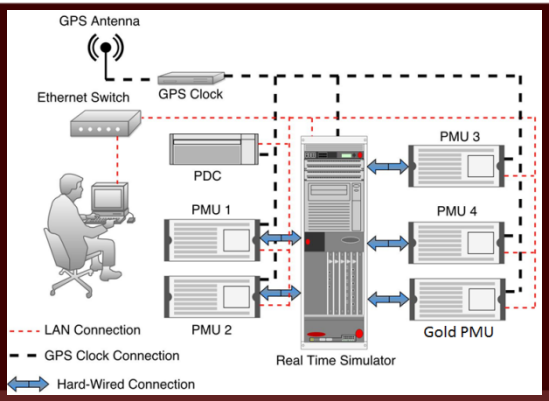

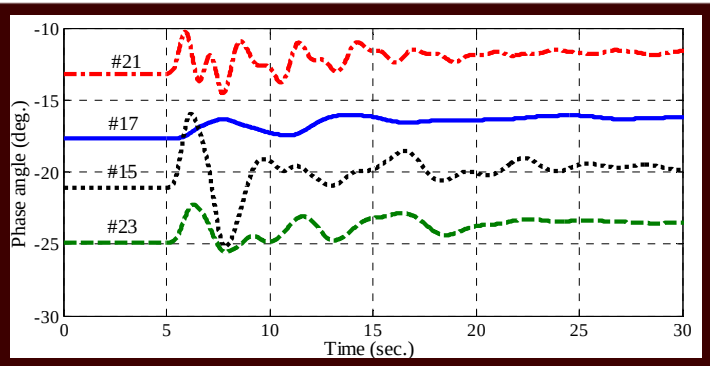

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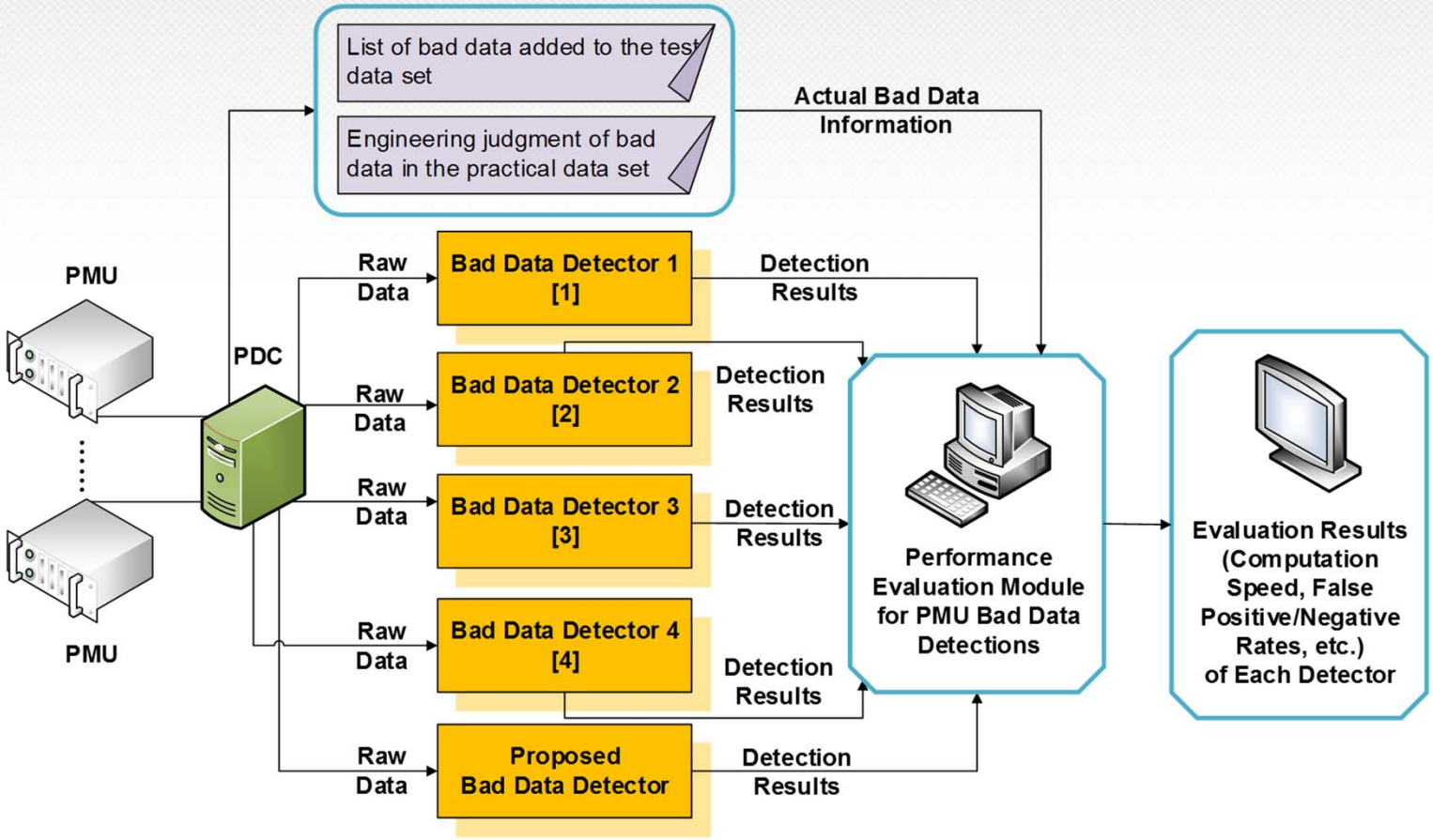
PMU-Based Bad Data Detection in Enhanced State Estimation



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Conclusion

- Testing and Certification Equipment and Protocols
- Certification Lab for Device and End-to-end Testing
- Initial Gold PMU Algorithm to Be Used as Synchrophasor Reference.
- Field Calibrator using Gold PMU Algorithm
- Application End-to-end Nested Testing & Bad Data Detection

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Thanks

Any Question?

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