Verifying Interoperability and Application Performance of System Solution Containing PMUs, PDCs, and Communication Networks

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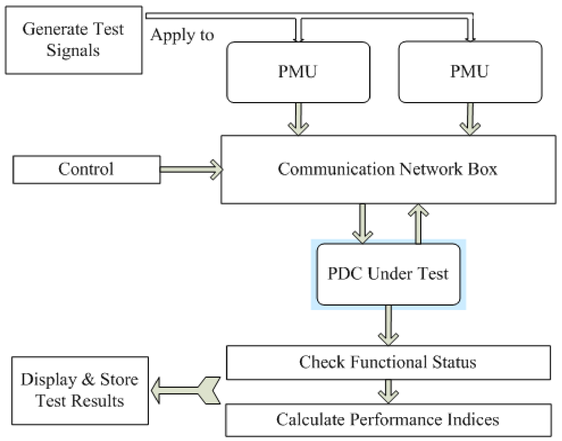
Conformance Test

♦ Each PDC is tested using input data stream packets defined in C37.118.1 and C37118.2-2011. The test approach is as follows:

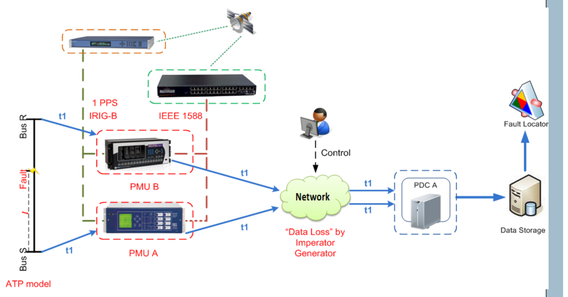


Overview

The test procedures for verifying Interoperability and performance of systems consisting of PMUs, PDCs and communication networks connecting them are developed.

The overall test methodology includes verification of:

- ***Conformance performance*** of the PDCs, aimed at verifying the core features of a specific PDC.
- ***Interoperability*** among different PMUs, PMU-enabled IEDs, PDCs and associated communication network.
- ***Application performance*** with variations of PMUs, PMU-enabled IEDs, PDCs and associated communication network



PMU and PMU-enabled IED	SEL 421 x2	SEL 351	GE N60	ABB RES 521
	SIEMENS R	USI 2002	AMETEK	NI PMU
PDC	GPA OpenPDC	SEL 3373	OSIsoft PI	EPG ePDC
Time Synchronization	Symmetricom Xli	RuggedCom 2288	AREVA P594	Hopf 6875

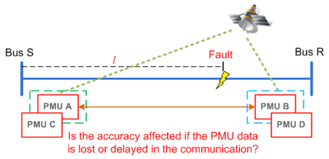
Application Test

The selected Fault Location algorithm uses two-end synchronized phasor measurements.

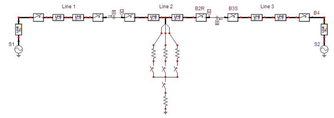
Estimated location (%):

$$x = \frac{\dot{V}_S - \dot{V}_R + Z_L \cdot \dot{I}_R}{Z_L \cdot (I_S + I_R)} \times 100\%$$

VS is the sending-end voltage, VR is the receiving-end voltage, IS is the sending-end current, IR is the receiving-end current, ZL is the line impedance.



Transient voltages and currents generated from the ATP/EMTP are used for application tests.



Line length = 40 mile
Source voltages: Sending end: VS = 230 kv, Receiving end: VR = 230 kv
Source impedance:
Both sources: 3.48 + 49.88jΩ
Frequency = 60 Hz
Transmission line impedance (per mile): z = 0.0815 + j0.7785Ω

Conformance Test

♦ "Guide for Phasor Data Concentrator Requirements for Power System Protection, Control, and Monitoring" gives description of eighteen functions a PDC can perform.

Functions Under Test	PDC A	PDC B
Data Alignment	S	S
Data Communication	S	**Not support serial port communication**
Data Validation	S	S
Synchrophasor data transfer protocol support	**IEEE C37.118 IEEE 1344-1995 BPA PDCstream Virginia Tech FNET SEL Fast Message Macrodyne**	**IEEE C37.118 Macrodyne Virginia Tech FNET PDCStream OPC DA 3.0 Comtrade**
Synchrophasor data transfer protocols conversion	S	S
Format and coordinate conversion	S	S
Latency calculation	S	S
Reporting rate conversion	S	S
Data Buffering	S	S
Configuration	S	S
Phase and magnitude adjustment	S	S
PMU/PDC Performance Monitoring	S	S
Data gateway	S	S
Data Aggregation	Not tested	
Robustness	Not tested	
Redundant data handling	S	S
Duplicate data handling	Not tested	
Data re-transmission request	N	N

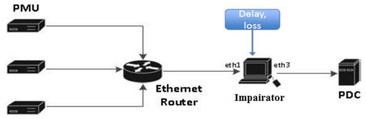
* S stands for "Satisfied", F stands for "Failed", "N" stands for "Don't have this function".

Communication Network Box

The Comm. Network Box performs three functions:

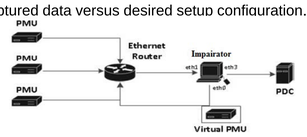
♦ *Impairment Generator:*

- Emulates the typical impairments in the communication network scenarios.



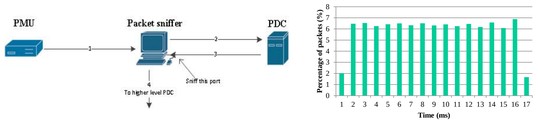
♦ *PMU Emulator-Virtual PMU ("Listeners")*

- Records input and output data streams within predefined time window
- Verifies the captured data versus desired setup configuration.



♦ *PDC Data Processing Time Measurement*

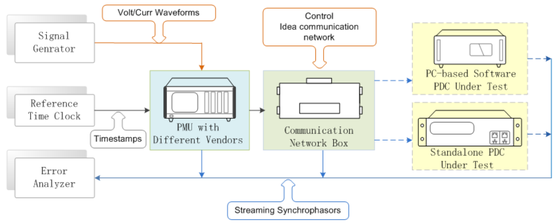
- Taps packets towards and from PDC
- Matches packets to and from PDC as pairs
- Calculates time difference between a packet going to PDC and leaving from PDC



Average processing time: 8.50 ms
Maximum processing time: 32.80 ms

Interoperability Test

♦ *The interoperability between the PMUs and PDC.*



Test Scenarios

PDC under test	PMU	Communication Network	Testing Items	Performance Index
Software PDCs	Reference PMU and PMUs, PMU-enabled IEDs from different vendors	TCP/IP, UDP/IP, UDP/IP multi-casting	Defined in Conformance	Function status and compliance test
		IPv4 and/or IPv6		
Hardware PDCs		Data Protocols (IEEE C37.118-2005, IEEE 1344 etc.)		

Interoperability test result summary

	PMU A	PMU A*	PMU B	PMU C	PMU D	PMU E	PMU F	PMU G	PMU H
PDC A	S	S	S	S	S	S	S	S	S
PDC B	**F**	**F**	**F**	S	S	S	S	**F**	S
PDC C	Not available yet								
PDC D	Not available yet								

* PMU A-1 is an upgraded firmware of PMU A.
** S stands for "Satisfied"; F stands for "Failed".

Application Test

♦ **A general procedure for performing the communication network test is:**

1.Generate test signals using ATP and convert the data files into the LabVIEW format

2.Feed test signal to PMU A and PMU B, and collect synchrophasors from PDC A. This procedure is automated by the software delicately developed for such test;

Target	Test Configuration	Fault Variation
Communication Network Traffic: None, 30%, 50%, 70%; Latency: 0-5s Jitter:	Reference time clock	Location: 10%, 30%, 50%, 70%, 80% Type: 3L; Inception: 90˚; Resistance: 0 Ω
	PMU and PMU-enabled IEDs	
	Software PDC and Hardware PDC	

3.Run the fault location algorithm using collected synchrophasors;

4.Record the estimated location and compare to the reference value;

5.Change communication network by exchanging a products in the end-to-end solution and repeat the test

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NASPI North American SynchroPhasor Initiative