

Interoperability Test of IEEE C37.118 Standard-based PMUs

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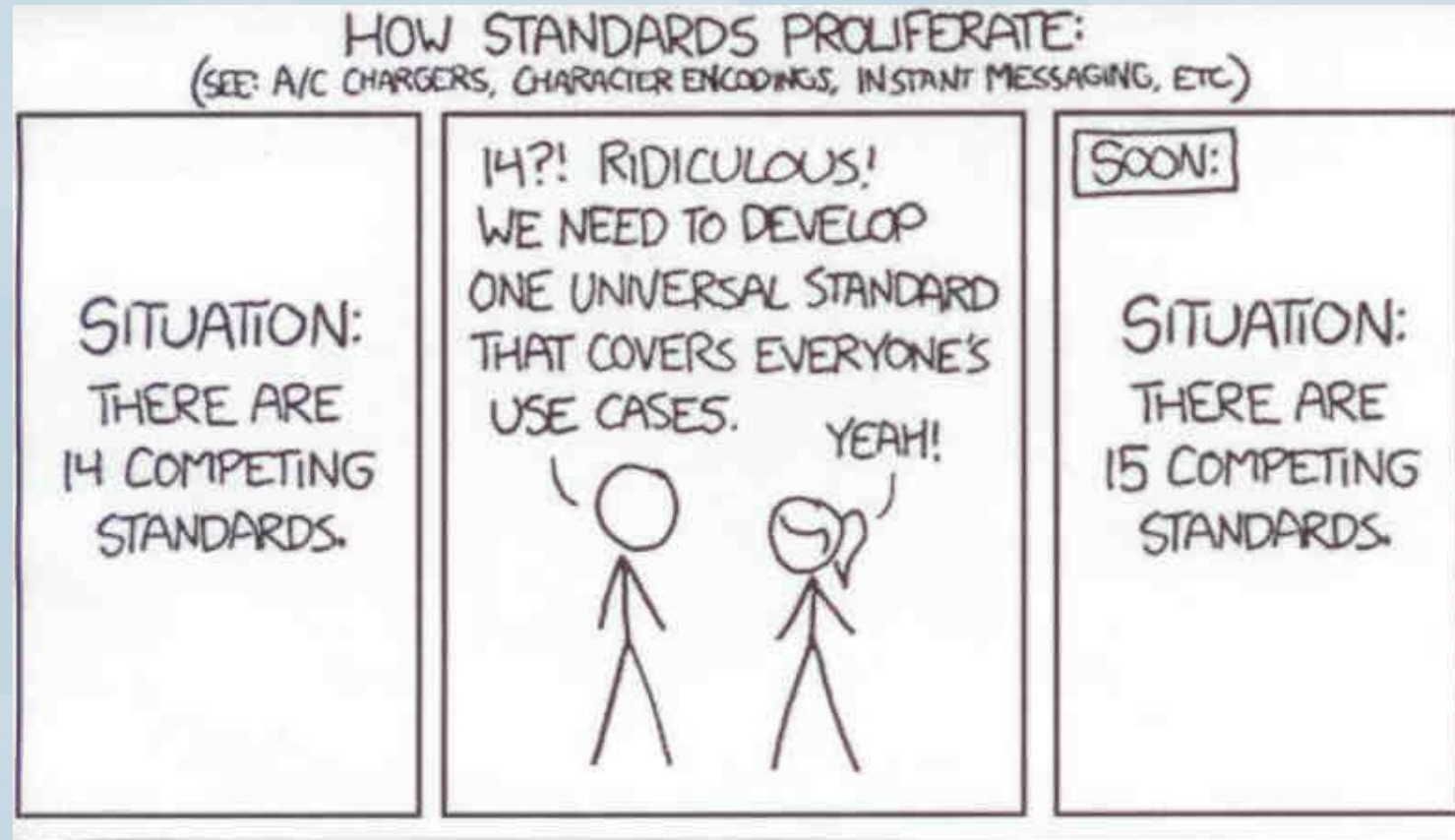
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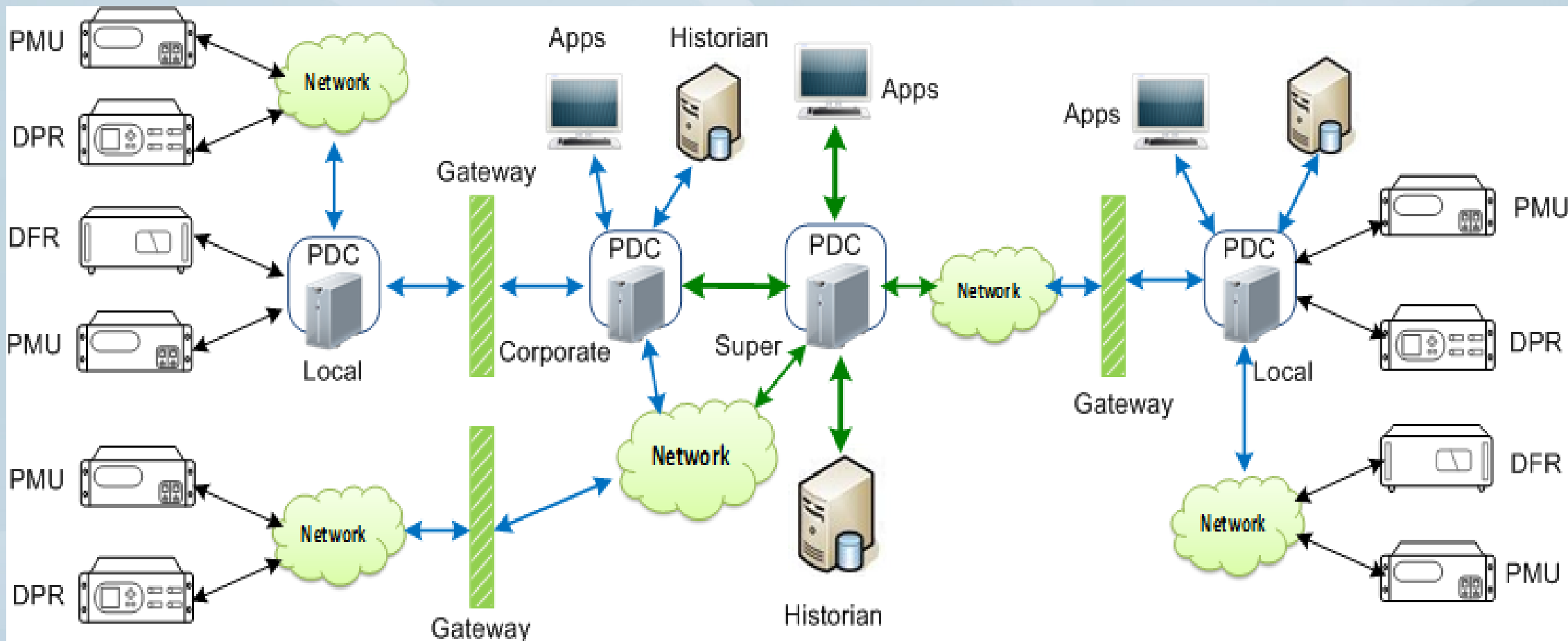
Interoperability Test for IEEE C37.118 Standard-based PMUs

1. Introduction
2. IEEE C37.118 Standard
3. Interoperability Test Method for PMUs
4. PMU Interoperability Test Suite & Test Cases
5. Interoperability Tests for Commercial PMUs
6. Summary

How not to do interoperability



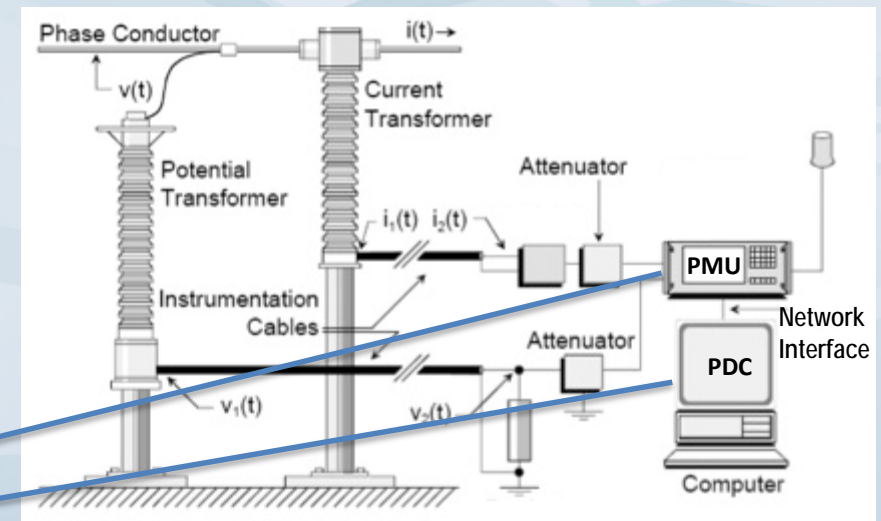
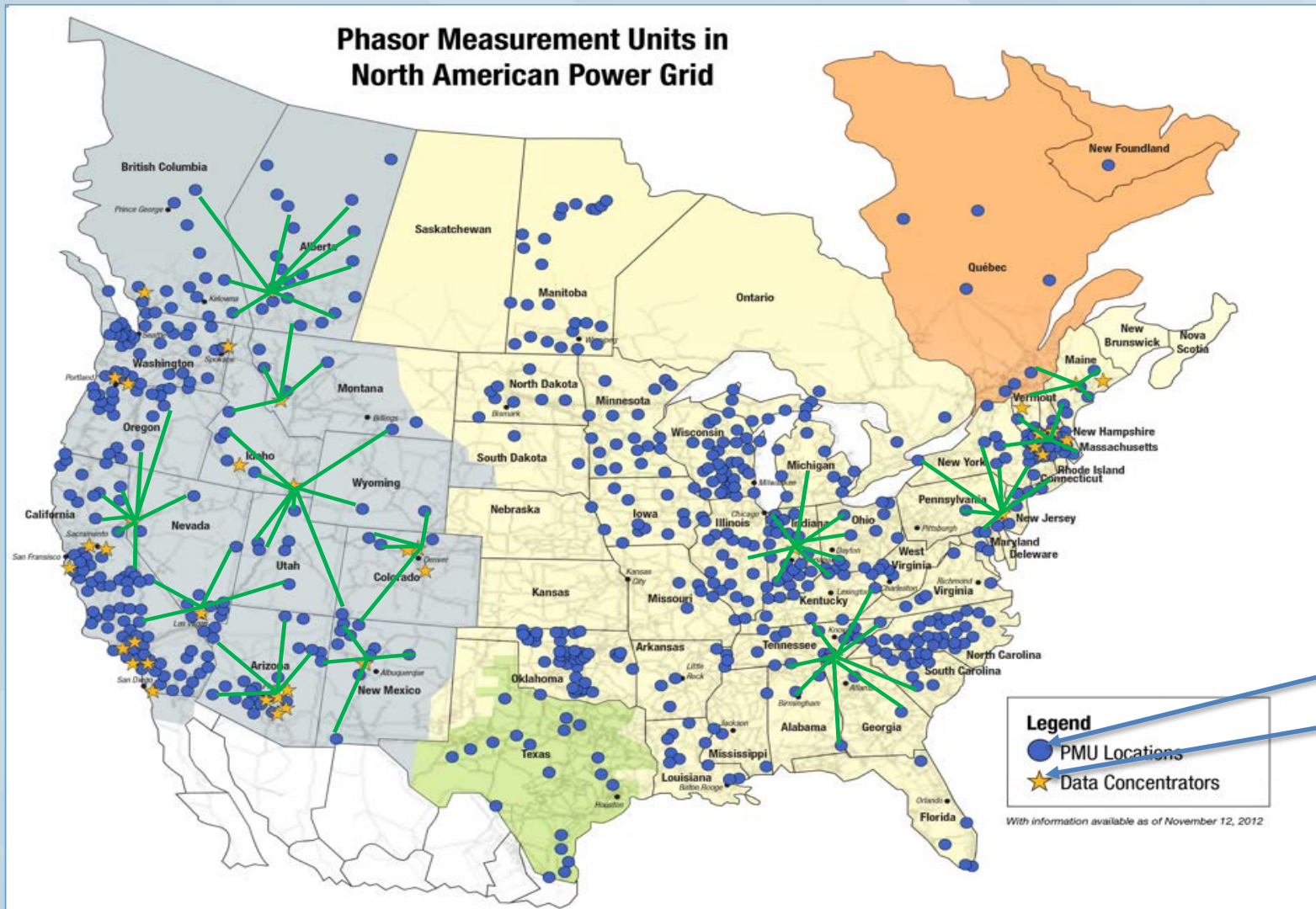
1. Introduction



Example of Wide Area Monitoring, Protection and Control System (WAMPACS)

(Source: Electric Power Research Institute (EPRI))

1. Introduction (Cont'd)



Source:
<http://www.digikey.dk/en/articles/techzone/2014/jan/low-cost-microcontroller-based-phasor-measurement-units-improve-smart-grid-reliability>

Source: North American SynchroPhasor Initiative (NASPI)

1. Introduction (Cont'd)

Challenges of WAMPACS:

Challenge 1: How to make thousands of PMUs to work together?

Challenge 2: How to exchange, share synchrophasor's data to achieve data interoperability?

Solution: standardizing synchrophasor data formats, communication protocols and interfaces

However: PMUs may not be interoperable even if they conform to the IEEE C37.118 standards. The main reasons are:

- the standard has mandatory and optional functions;
- some definitions in the standard are ambiguous, not clear; and
- different developers or implementers may have different interpretations of the standards, which result in different implementations.

1. Introduction (Cont'd)

Challenges of WAMPACS

Challenge 3: How to assure that these standard-based PMUs produced by different vendors can work together to guarantee the interoperability of PMUs?

Solutions:

- develop interoperability test methods for PMUs;
- conduct Plugfests or interoperability tests of PMUs; and
- certify PMUs based on interoperability tests conducted by laboratories accredited by organizations such as the IEEE-SA Conformity Assessment Program (ICAP).

2. IEEE C37.118 Standard

PMU Standard	Descriptions
IEEE 1344-1995	defined three kinds of messages: data frames, header frames and configuration messages
IEEE C37.118-2005	replaced IEEE 1344-1995, which included both measurement requirements and real-time data transfer requirements.
IEEE C37.118.1a-2014	defined synchrophasor measurement requirements including dynamic performance
IEEE C37.118.2-2011	defined synchrophasor data transfer requirements. Extended IEEE C37.118-2005 with a new CFG-3 message and a continuous time quality (CTQ) field in the SYNC word.

2. IEEE C37.118 Standard (Cont'd)

IEEE C37.118.2 Message & Communication Protocol

Message type	Messages	Data frame	Description	M/O
Command	Data	Stop	Turn off transmission of data frames	M
		Start	Turn on transmission of data frames	M
	Header	Header	Send HDR frame	M
	Configuration	CFG-1	Send CFG-1 frame	M
		CGF-2	Send CFG-2 frame	M
		CGF-3	Send CFG-3 frame	O
Response	Data	Data Frame	Measured data	M
	Header	Head frame	Human-readable information about the PMU, the data sources, scaling, algorithms, filtering, or other related information	M
	Configuration	CFG-1 Frame	PMU/PDC capabilities	M
		CFG-2 Frame	Measurements currently being reported in fixed length fields	M
		CFG-3 Frame	Measurements currently being reported in variable length fields	O

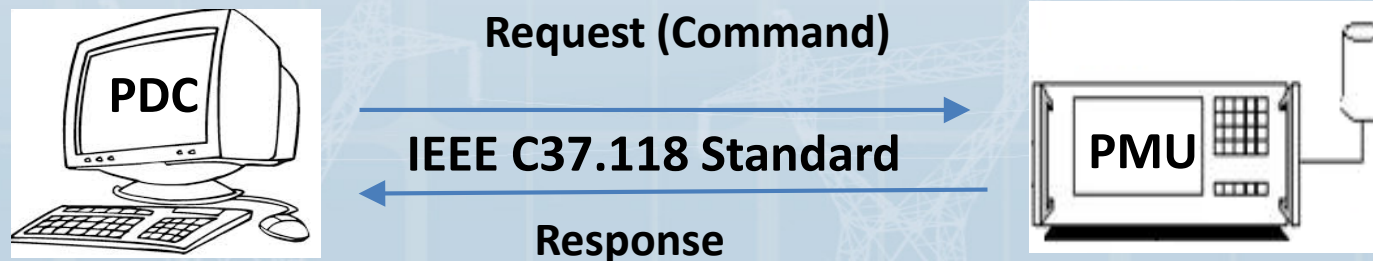
3. Interoperability Test Method for PMUs

Interoperability (IEEE):

- The ability of two or more systems to **exchange information** and to **use the information** that has been exchanged.

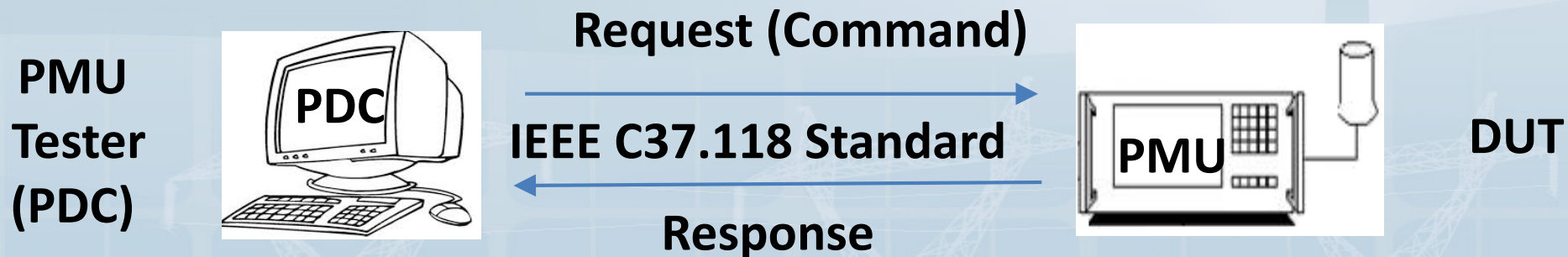
The PMU can be interoperable with the PDC if:

- the PDC can send the **Requests** to the PMU based on the IEEE C37.118 standard;
- the PMU can receive, understand the **Requests** from the PDC, take the corresponding action based on the request, then return the **Responses** to the PDC based on the **Requests** of the IEEE C37.118 standard;
- the PDC can receive, understand the **Responses** from the PMU; and
- the PMU and PDC can interact jointly to execute specific functions or tasks.



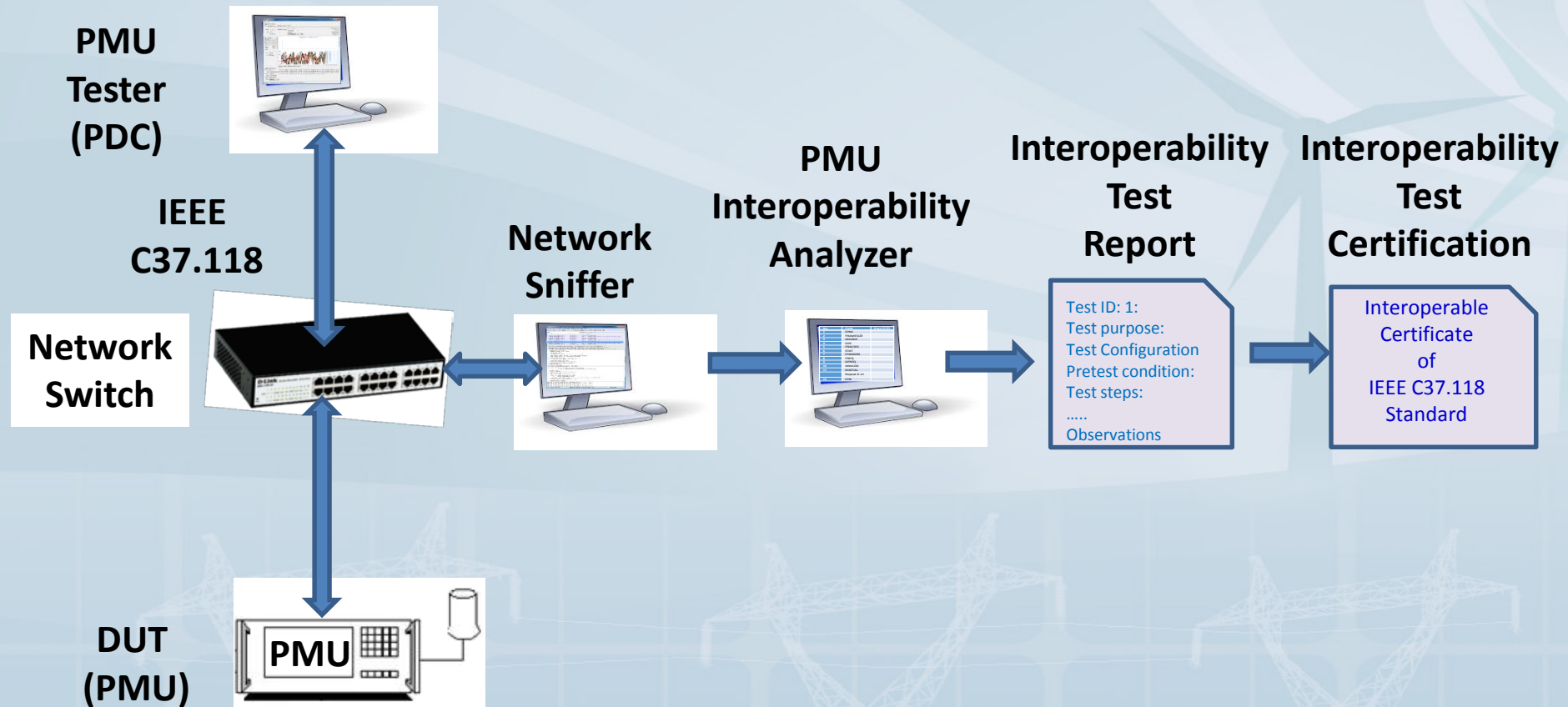
3. Interoperability Test Methods for PMUs (Cont'd)

- **Interoperability test** is a process to **verify** that two or more implementations of the same standard by two systems or devices can interoperate.
- **Interoperability test of PMU** is a process to **verify** if PMU (server implementation) can be interoperable with the PMU Tester (client implementation) based on IEEE C37.118.
- **PMU Tester**: An implementation of C37.118.2 client, which can send the C37.118 **Request** to the DUT (PMU) and receive the C37.118 **Response** from the PMU. PDC is a kind of PMU Tester.



3. Interoperability Test Method for PMUs (Cont'd)

Architecture for Interoperability Test Method for PMUs



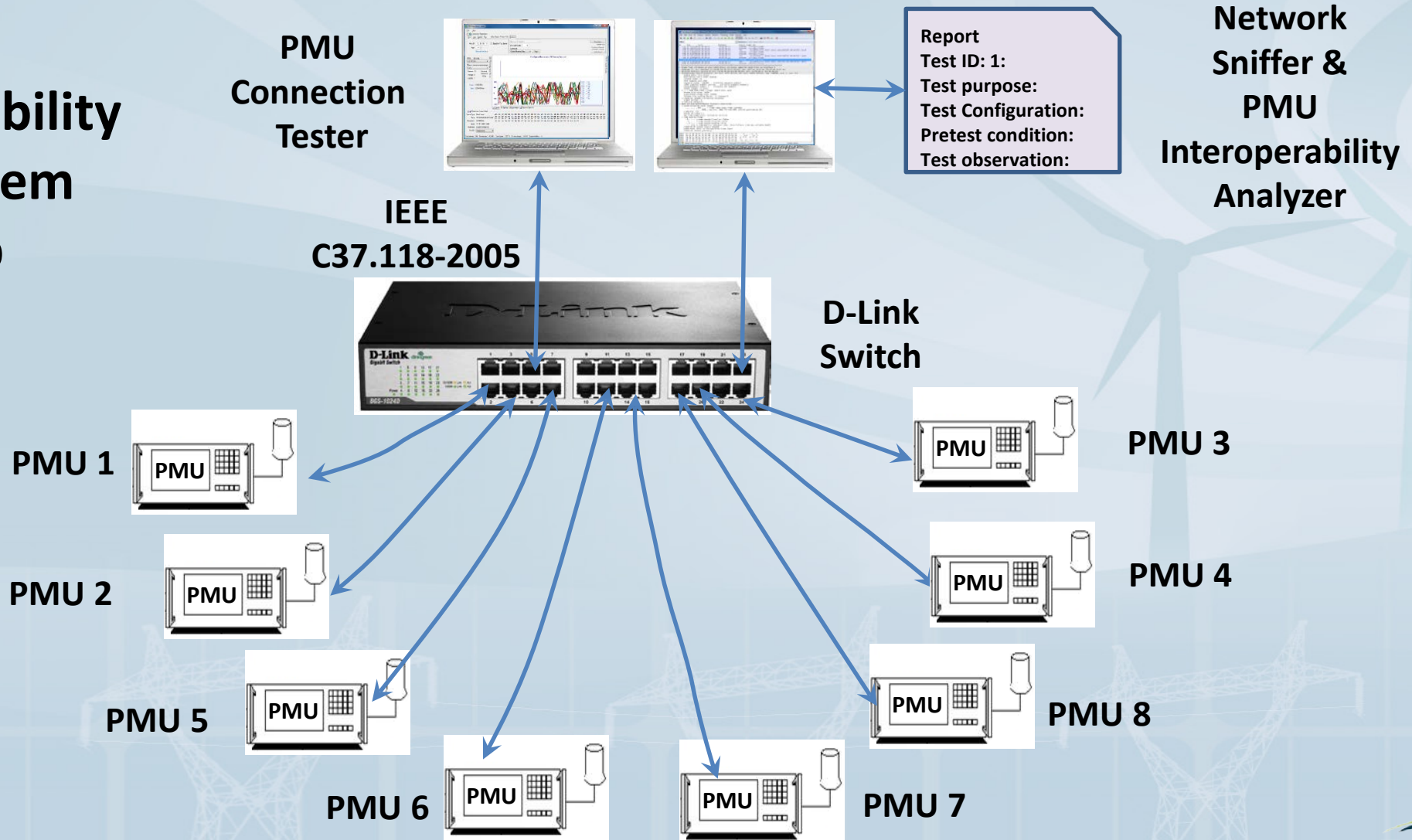
3. Interoperability Test Methods for PMUs (Cont'd)

PMU Interoperability Test Suite & Test Cases for C37.118.2

Interoperability Levels		Test Case No.	Test Case Name	Command ID	Response
Level 2	Level 1	1	Send CFG-1 Frame	0100	CFG-1 Frame
		2	Send CFG-2 Frame	0101	CFG-2 Frame
		3	Send Header Frame	0011	Header Frame
		4	Turn on Transmission of Data Frames	0010	Data Frame
		5	Turn off Transmission of Data Frames	0001	None
		6	Send CFG-3 Frame	1000	CFG-3 Frame

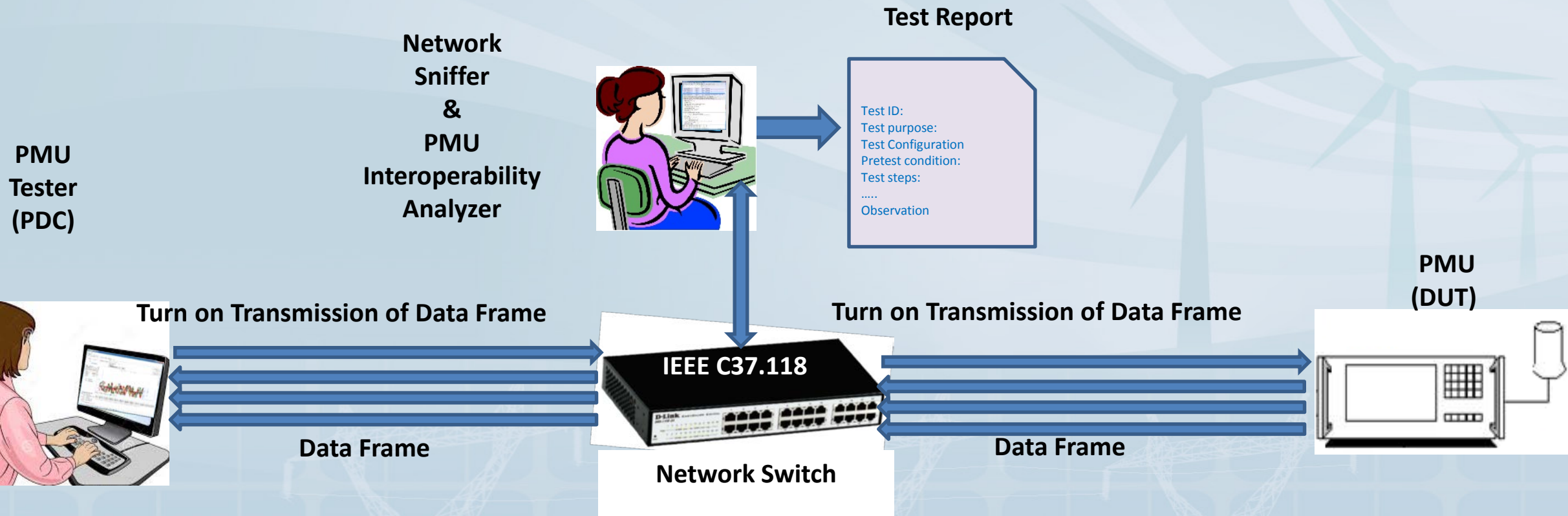
4. Interoperability Test for Commercial PMUs

PMU Interoperability Test System Setup



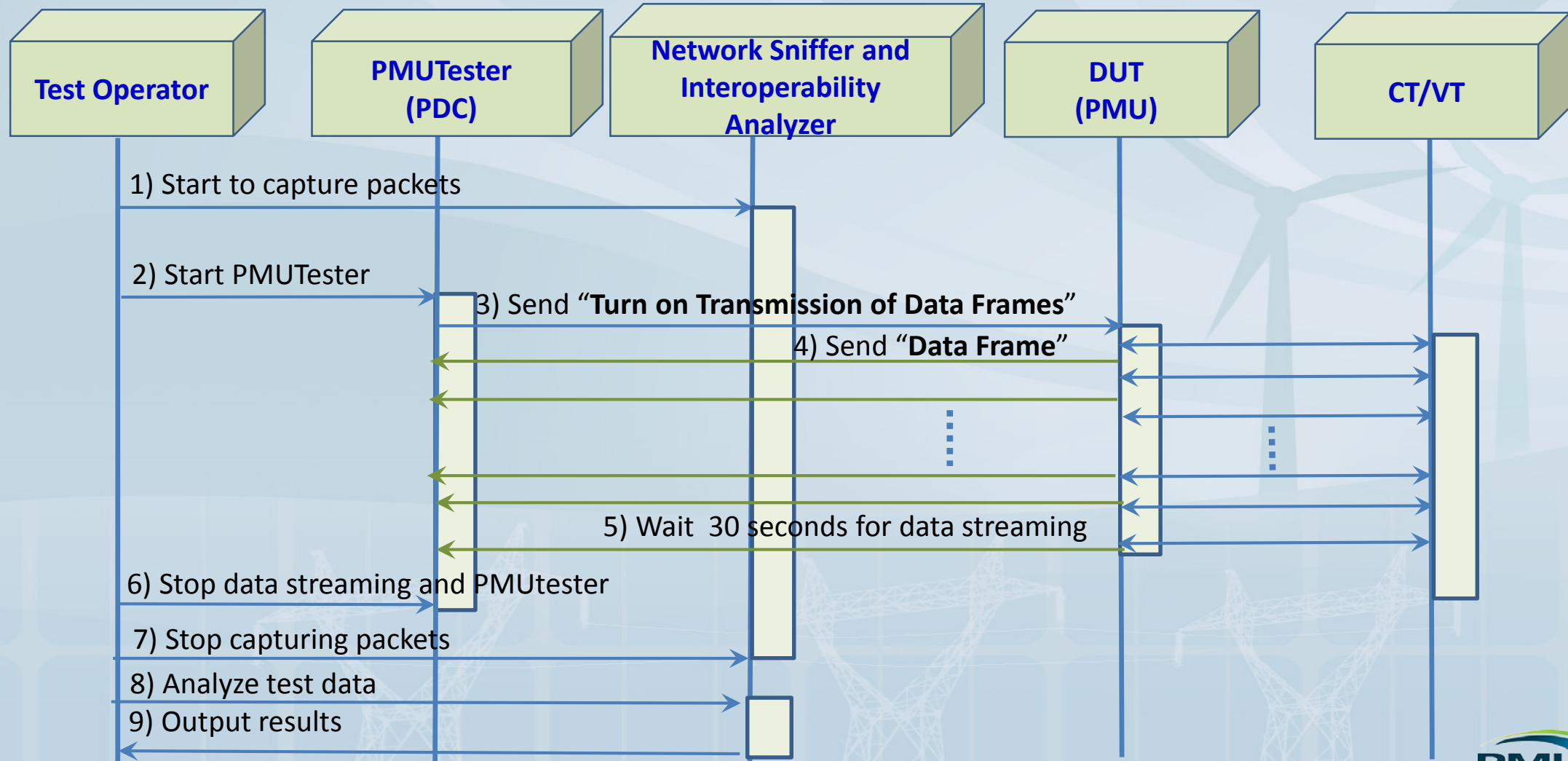
4. Interoperability Test for Commercial PMUs

Interoperability Test Case of Turn on Transmission of Data Frames



4. Interoperability Test for Commercial PMUs (Cont'd)

Interoperability Test Procedures Turn on Transmission of Data Frames



4. Interoperability Test for Commercial PMUs (Cont'd)

Test Case of Turn on Transmission of Data Frames

PMU
Connection
Tester
Screenshot

PMU Connection Tester

File Help

Connection Parameters

Tcp Udp Serial File Default System IP Stack: IPv6

Host IP: 192. 92. 92.104 Establish Tcp Server

Port: 4712 Network Interface

Protocol: IEEE C37.118-2005

Device ID Code: 4

Command: Enable Real-time Data Send

Disconnect Version 4.5.5

Configure Alternate Command Channel Not Defined

PMU: ID Code: 4

NI STATION

Phasor: (Selected is reference angle)

V: V1+

Phasors: 7 Nominal Frequency: 60 Hz

Analog: 8

Digital: 1

Power: 0.0000 MW

Vars: 0.0000 MVars

Configured frame rate: 60 frames/second

56.3758

54.1714

51.9671

49.7627

47.5584

180

90

0

-90

-180

V1+

VA1

IA1

VB1

IB1

VC1

IC1

Graph Settings Messages Protocol Specific

Real-time Frame Detail

Frame Type: DataFrame

Time: 2015-07-15 19:22:32.050

Frequency: 47.5173 Hz

Angle: 5.97648425253968°

Magnitude: 0.0000 (0.0000) kV

Display: Hexadecimal

Total frames: 0 Frames/sec: 0.0000 Total bytes: 0 Bit rate (mbps): 0.0000 Queued buffers: 0

4. Interoperability Test for Commercial PMUs (Cont'd)

Interoperability Analysis: Test Procedures

pmu4-connection-test.pcap [Wireshark 1.12.6 (v1.12.6-0-gee1fce6 from master-1.12)]

Filter: Expression... Clear Apply Save

No.	Time	Source	Destination	Protocol	Length	Info
1641	91.644969	192.92.92.120	192.92.92.104	SYNCHROPHASOR	72	Command Frame, data transmission on
1642	91.649772	192.92.92.104	192.92.92.120	SYNCHROPHASOR	170	Data Frame
1643	91.650456	192.92.92.104	192.92.92.120	SYNCHROPHASOR	170	Data Frame
1645	91.651001	192.92.92.104	192.92.92.120	SYNCHROPHASOR	170	Data Frame

Frame 1641: 72 bytes on wire (576 bits), 72 bytes captured (576 bits)

- Ethernet II, Src: dell_36:87:bc (f0:1f:af:36:87:bc), Dst: National_17:79:0e (00:80:2f:17:79:0e)
- Internet Protocol Version 4, Src: 192.92.92.120 (192.92.92.120), Dst: 192.92.92.104 (192.92.92.104)
- Transmission Control Protocol, Src Port: 64881 (64881), Dst Port: 4712 (4712), Seq: 181, Ack: 110935, Len: 18
- IEEE C37.118 Synchrophasor Protocol, Command Frame
 - Synchronization word: 0xaa41
 -100 ... = Frame Type: Command Frame (0x0004)
 -0001 = Version: IEEE C37.118-2005 initial publication (1)
 - Framesize: 18
 - PMU/DC ID number: 4
 - SOC time stamp: Jul 15, 2015 19:23:54.000000000 UTC
 - Time quality flags
 - ..0. = Leap second direction: False
 - ..0. = Leap second occurred: False
 - ...0 = Leap second pending: False
 - 0000 = Time quality indicator code: Normal operation, clock locked (0x00)
 - Fraction of second (raw): 71393
 - Command data
 -0010 = Command: data transmission on (0x0002)
 - Checksum: 0x26df [correct]

0000 00 80 2f 17 79 0e f0 1f af 36 87 bc 08 00 45 00 .../.y... .6...E.
 0010 00 3a 7f e9 40 00 80 06 00 00 c0 5c 5c 78 c0 5c ...@... ..\x.\
 0020 5c 68 fd 71 12 68 cb 5f 0f 99 7a 1c 37 5f 50 18 \h.q.h... .z.7.P.
 0030 7f b3 39 c6 00 00 aa 41 00 12 00 04 55 a6 b3 4a ..9...AU..J
 0040 00 01 16 e1 00 02 26 df&

IEEE C37.118 Synchrophasor Protocol (synph... Packets: 3155 · Displayed: 3155 (100.0%) · Load time: 0:00.060 Profile: Default

Steps	Description	Pass/Fail (P/F)
1	Start Network Sniffer to capture packets	P
2	Start PMUTester	P
3	Send a “Turn on Transmission of Data Frames” command from the PMUTester to the DUT	P
4	Send a “Data Frames” response from the DUT to the PMUTester	P
5	Wait for 30 seconds for data streaming	P
6	Stop data streaming and PMUTester	P
7	Stop capturing packets	P
8	Analyze PMU interoperability	P
9	Output results	P

4. Interoperability Test for Commercial PMUs (Cont'd)

Interoperability Analysis: Data Frame Command Message

pmu4-connection-test.pcap [Wireshark 1.12.6 (v1.12.6-0-gee1fce6 from master-1.12)]

Filter: Expression... Clear Apply Save

No.	Time	Source	Destination	Protocol	Length	Info
1641	91.644969	192.92.92.120	192.92.92.104	SYNCHROPHASOR	72	Command Frame, data transmission on
1642	91.649772	192.92.92.104	192.92.92.120	SYNCHROPHASOR	170	Data Frame
1643	91.650456	192.92.92.104	192.92.92.120	SYNCHROPHASOR	170	Data Frame
1645	91.651001	192.92.92.104	192.92.92.120	SYNCHROPHASOR	170	Data Frame

Frame 1641: 72 bytes on wire (576 bits), 72 bytes captured (576 bits)

- Ethernet II, Src: Dell_36:87:bc (f0:1f:af:36:87:bc), Dst: National_17:79:0e (00:80:2f:17:79:0e)
- Internet Protocol Version 4, Src: 192.92.92.120 (192.92.92.120), Dst: 192.92.92.104 (192.92.92.104)
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- IEEE C37.118 Synchrophasor Protocol, Command Frame
 - Synchronization word: 0xaa41
 -100.... = Frame Type: Command Frame (0x0004)
 -0001 = Version: IEEE C37.118-2005 initial publication (1)
 - Framesize: 18
 - PMU/DC ID number: 4
 - SOC time stamp: Jul 15, 2015 19:23:54.000000000 UTC
 - Time quality flags
 - .0. = Leap second direction: False
 - ..0. = Leap second occurred: False
 - ...0 = Leap second pending: False
 -0000 = Time quality indicator code: Normal operation, c'clock locked (0x00)
 - Fraction of second (raw): 71393
 - Command data
 -0010 = Command: data transmission on (0x0002)
 - checksum: 0x26df [correct]

0000 00 80 2f 17 79 0e f0 1f af 36 87 bc 08 00 45 00/.y... 6...E.
 0010 00 3a 7f e9 40 00 80 06 00 00 c0 5c 5c 78 c0 5c ...@... ..\x.
 0020 5c 68 fd 71 12 68 cb 5f 0f 99 7a 1c 37 5f 50 18 \h.q.h...z.7_P.
 0030 7f b3 39 c6 00 00 aa 41 00 12 00 04 55 a6 b3 4a ..9...A...U..J
 0040 00 01 16 e1 00 02 26 df&

IEEE C37.118 Synchrophasor Protocol (synph... Packets: 3155 · Displayed: 3155 (100.0%) · Load time: 0:00.060 Profile: Default

Data Frame Command Message																																						
No.	Field	Size (bytes)	Value	Pass/Fail (P/F)																																		
1	SYNC	2	AA 41	P																																		
	<table border="1"> <thead> <tr> <th>Byte No.</th> <th>Sync</th> <th>Value</th> <th>Pass/Fail (P/F)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sync</td> <td>AA</td> <td>P</td> </tr> <tr> <td>2 (Frame type and version)</td> <td>Bit 7:</td> <td>0 for this standard.</td> <td>0</td> <td>P</td> </tr> <tr> <td></td> <td>Bits 6-4</td> <td>Frame Type</td> <td>100: Command Frame (4)</td> <td>P</td> </tr> <tr> <td></td> <td>Bits 3-0</td> <td>Version number</td> <td>0001: C37.118-2005(1)</td> <td>P</td> </tr> </tbody> </table>				Byte No.	Sync	Value	Pass/Fail (P/F)	1	Sync	AA	P	2 (Frame type and version)	Bit 7:	0 for this standard.	0	P		Bits 6-4	Frame Type	100: Command Frame (4)	P		Bits 3-0	Version number	0001: C37.118-2005(1)	P											
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	Bits 3-0	Version number	0001: C37.118-2005(1)	P																																		
2	FRAMESIZE	2	00 12 (18 bytes)	P																																		
3	IDCODE	2	00 014 (4)	P																																		
4	SOC	4	55 A6 B3 4a (Jul 15, 2015 19:23:54.000000000 UTC)	P																																		
5	FRACSEC & TQ Flag	4	01 16 e1 (71393)	P																																		
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		6: LS Direction	0	P																																		
		5: LS Occurred	0	P																																		
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6	CMD	2	0010 (2)	P																																		
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0010	Data frame on (0x0002)	P																																				
7	EXTFRAME	0-65518		N/A																																		
8	CHK	2	0x 26 df (correct)	P																																		

4. Interoperability Test for Commercial PMUs (Cont'd)

Interoperability Analysis: Data Frame Response Message

pmu4-connection-test.pcap [Wireshark 1.12.6 (v1.12.6-0-gee1fce6 from master-1.12)]

Filter: Expression... Clear Apply Save

No. Time Source Destination Protocol Length Info

1641 91.644969 192.92.92.120 192.92.92.104 SYNCHROPHASOR 72 Command Frame, data transmission on

1642 91.649772 192.92.92.104 192.92.92.120 SYNCHROPHASOR 170 Data Frame

Frame 1642: 170 bytes on wire (1360 bits), 170 bytes captured (1360 bits)

Ethernet II, Src: National_17:79:0e (00:80:2f:17:79:0e), Dst: Dell_36:87:bc (f0:1f:af:36:87:bc)

Internet Protocol Version 4, Src: 192.92.92.104 (192.92.92.104), Dst: 192.92.92.120 (192.92.92.120)

Transmission Control Protocol, Src Port: 4712 (4712), Dst Port: 64881 (64881), Seq: 110935, Ack: 199, Len: 1

IEEE C37.118 Synchrophasor Protocol, Data Frame

Synchronization word: 0xaa01

.....0000..... = Frame Type: Data Frame (0x0000)

.....0001..... = Version: IEEE C37.118-2005 initial publication (1)

Framesize: 116

PMU/DC ID number: 4

SOC time stamp: Jul 15, 2015 19:23:54.000000000 UTC

Time quality flags

.0. = Leap second direction: False

.0. = Leap second occurred: False

.0. = Leap second pending: False

....0000 = Time quality indicator code: Normal operation, clock locked (0x00)

Fraction of second (raw): 9500000

Measurement data, using frame number 1578 as configuration frame

Station: "NI STATION"

Flags

0. = Data valid: Data is valid

0. = PMU error: No error

.0. = Time synchronized: clock is synchronized

.0. = Data sorting: By timestamp

0. = Trigger detected: No trigger

..0. = Configuration changed: No

....00. = Unlocked time: Time locked, best quality (0x0000)

.....0000 = Trigger reason: Manual (0x0000)

Phasors (7)

Phasor #1: "V1+ " 0.00V/_ -89.77'

Phasor #2: "VA1 " 0.00V/_-167.13'

Phasor #3: "IA1 " 0.00A/_-135.42'

Phasor #4: "VB1 " 0.00V/_ 157.63'

Phasor #5: "IB1 " 0.00A/_ 81.45'

Phasor #6: "VC1 " 0.00V/_-167.14'

Phasor #7: "IC1 " 0.00A/_-167.14'

Actual frequency value: 48.623215Hz

Rate of change of frequency: -288.768219Hz/s

Analog values (8)

Analog value #1: "P1 " 0.000

Analog value #2: "S1 " 0.000

Analog value #3: "Q1 " 0.000

Analog value #4: "PF1 " 0.986

Analog value #5: "P2 " -0.000

Analog value #6: "S2 " 0.000

Analog value #7: "Q2 " 0.000

Analog value #8: "PF2 " -0.572

Digital status words (1)

Digital status word #1: 0x00ff

Checksum: 0xb4ee [correct]

0000 f0 1f af 36 87 bc 00 80 2f 17 79 0e 08 00 45 00 ...6... /y...E.

0010 00 9c b5 7d 40 00 40 06 4b 45 c0 5c 5c 68 c0 5c ...3@.0. KE:\h.\

0020 5c 78 12 68 fd 71 7a 1c 37 5f cb 5f 0f ab 50 18 ...v.h.qz. 7...P.

0030 07 21 9f 2f 00 00 aa 01 90 74 00 04 55 a6 b3 4a ...1./... 1...U...P.

0040 00 90 f5 60 00 40 37 eb b1 90 bf c8 8d 7b 39 08 ...@? ... (9.

0050 00 00 c0 3a b0 5f 3a 13 67 d9 c0 17 44 6f 39 ac g...Do9.

0060 00 00 40 30 14 42 39 34 2d 6b 3f b5 15 39 94 @0.B9. -K?..9.

0070 00 00 c0 3a b2 a8 3a 7e 36 18 c0 3a b2 c2 42 42 3- 6...BB

0080 7e 2c c3 90 62 55 34 c1 71 ba 34 c4 3c 30 33 83bu4. q.4.<03.

0090 e9 61 3f 7c 5b f2 b4 aa 93 36 35 15 37 98 34 f4a? [... 65.7.4.

00a0 e1 cd bf 12 52 2d 00 ff b4 eeR... ..

No.	Field (Data Frame)	Size (bytes)	Value	Pass/Fail (P/F)
1	SYNC	2	AA 01	P
	Byte No.	Sync	Value	Pass/Fail (P/F)
	1	AA	AA	P
	2	Bit7: 0a	0	P
		Bits:6-4:Frame Type	000: Data frame	P
		Bits:3-0:Version	0001: C37.118-2005 (1)	P
2	FRAMESIZE	2	00 74 (116)	P
3	IDCODE	2	00 04 (4)	P
4	SOC	4	55 A6 B3 4A (Jul 15, 2015 19:23:54.0000000000 UTC)	P
5	FRACSEC & TQ Flag	4	00 90 f5 60 (9500000)	P
	Byte No.	FRACSEC and TQ flags	Value	Pass/Fail (P/F)
	4	Bits: Time Quality Flag	Bit:7 Reserved 0 Bit:6 LS Direction 0 Bit:5 LS Occurred 0 Bit:4 LP Pending 0 Bits:3-0 TQ indicator 0000	P P P P P
	1-3	FRACSEC	Bits:23-0 FRACSEC 90 f5 60 (9500000)	P
6	STAT	2	"NI STATION"	P
	Bit. No.	Station Flags	Value	Pass/Fail (P/F)
	15:	Data valid	0 (data is valid)	P
	14:	PMU error	0 (no error) (l)	P
	12:	Time Sync (clock synchronization)	0 (sync)	P
	11:	Data Sorting by timestamp	0 (by timestamp)	P
	10:	Trigger detected	0 (no)	P
	09:	CFG change	0 (no)	P
	03-02:	Unlock Time	00 (locked)	P
	01-00:	Trigger reason	0000 (manual)	P
7	PHASORS	4 x PHNMR Or 8 x PHNMR (7)	#1: "V1+ " 0.0V/_-89.77 37 eb b1 90 bf c8 8d 7b #1: "VA1 " 0.0V/_-167.13 39 08 00 00 c0 3a b0 5f #1: "IA1 " 0.0V/_-135.42 3a 13 67 d9 c0 17 44 6f #1: "VB1 " 0.0V/_-157.63 39 ac 00 00 40 30 14 42 #1: "IB1 " 0.0V/_-81.45 39 a4 2d 6b 3f b5 f5 15 #1: "VC1 " 0.0V/_-167.14 39 94 00 00 c0 3a b2 a8 #1: "VC1 " 0.0V/_-167.14 3a 7e 36 18 c0 3a b2 c2	P P P P P P P
8	FREQ (Actual Freq.)	2 / 4	42 42 7e 2c (48.623215 Hz)	P
9	DFREQ (Rate Of Change Of Freq.)	2 / 4	C3 90 62 55 (-288.768219 Hz/s)	P
10	ANALOG (Analog word.)	2 x ANNMR Or 4 x ANNMR (8)	34 c1 71 ba (P1, 0.0) 34 c4 3c 30 (S1, 0.0) 33 83 e9 61 (Q1, 0.0) 3f 7c 5b f2 (PF1, 0.986) B4 aa 93 36 (P2, 0.0) 35 15 37 98 (S2, 0.0) 34 f4 e1 cd (Q2, 0.0) Bf 12 52 2d (PF2, -0.572)	P P P P P P P P
11	DIGITAL (Dig status word)	2 x DGNMR (1)	#1: 00 ff	P
	Digital#	Value	Pass/Fail (P/F)	
	1	00 ff (0.0)	P	
	Repeat 6-11			N/A
12	CHK	2	0xb4 ee[Correct]	P



4. Interoperability Test for Commercial PMUs (Cont'd)

Test Report of Turn on Transmission of Data Frames

Test case No.	4	
Test case name	Turn on Transmission of Data Frames	
Functional statement	The PMUTester sends a "Turn on Transmission of Data Frames" command to the DUT (PMU), the DUT shall continuously sends "Data Frame" responses back to the PUMTester, after the DUT receives this command from the PMUTester.	
Functional Requirement	Mandatory	
Standard references	IEEE C37.118.2-2011	
Test Purpose	To verify if the DUT shall continuously sends "Data Frame" responses back to the PMUTester, after the DUT receives a "Turn on Transmission of Data Frames" command from The PMUTester.	
Test Resource	Hardware	<ul style="list-style-type: none"> • One or a few PMUs • A network switch • A Laptop computer for PMUTester • One Laptop computer for network sniffer and synchrophasor packet analyzer
	Software	<ul style="list-style-type: none"> • PMUTester software (e.g. PMU Connection Tester) • A network sniffer (e.g. Wireshark) • A synchrophasor packet analyzer (application software)
Test setup	See Figures in previous slides	
Test conditions	<ul style="list-style-type: none"> • Network protocol: TCP (port 4712), UDP (port 4713), TCP/UDP over Ethernet, or RS 232 • Nominal frequency: 50 Hz or 60Hz • Report rate: specified in Table 1 • Test parameters: voltages, currents 	
Test operators	Eugene Song	
Test date	9/10/2015	
.....		

4. Interoperability Test for Commercial PMUs (Cont'd)

Preliminary Results of Interoperability Test of IEEE C37.118-2005 Standard-based Commercial PMUs

Interoperability Test		PMU1 (TCP)	PMU2 (TCP)	PMU3 (TCP)	PMU4 (TCP)	PMU5 (UDP)	PMU6 (TCP)	PMU7 (TCP)	PMU 8 (TCP)
Turn Off	Procedures	P	P	P	P	P	P	P	P
	Command	P	P	P	P	P	P	P	P
	Response	P	P	P	P	P	P	P	P
Turn On	Procedures	P	P	P	P	P	P	P	P
	Command	P	P	P	P	P	P	P	P
	Response	P	P	P	P	P	P	P	P
Header	Procedures	P	P	P	P	P	F	P	P
	Command	P	P	P	P	P	P	P	P
	Response	P	P	P	P	P	F	P	P
CFG-1	Procedures	P	P	P	P	P	P	P	P
	Command	P	P	P	P	P	P	P	P
	Response	P	P	P	P	P	P	P	P
CFG-2	Procedures	P	P	P	P	P	P	P	P
	Command	P	P	P	P	P	P	P	P
	Response	P	P	P	P	P	P	P	P
Overall		P	P	P	P	P	P(80%)	P	P

- P-Passed
- F-Failed

5. Summary

- Developed interoperability test specification draft of PMUs including:
 - PMU interoperability test methods
 - PMU interoperability test suite and six test cases
 - PMU Interoperability test report template
- Conducted interoperability tests of 8 commercial PMUs
- Provided preliminary results of interoperability test of 8 commercial PMUs
- Future plans:
 - conduct tests of additional commercial PMUs,
 - verify the interoperability test methods, and
 - standardize the interoperability test specification for PMUs to support interoperability certification of PMUs.

Interoperability Test Specification Draft of IEEE C37.118.2 Standard-based PMUs

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Questions???