# Effective Utilization of PMU data for Triggers and Continuous Recording and communication experiences using Digital Fault Recorder

NASPI

Feb 24, 2011

Dr. Krish Narendra, PhD
VP Technology and Quality

Tony Weekes, P. Eng
Manitoba Hydro

© ERLPhase Power Technologies Ltd. All Rights Reserved.

# Outline

- ERLPhase – History, Products, New Generation Devices
- TESLA Power System Recorder with Phasor Measurement Unit (PMU)
- Advanced PMU Functionalities
- Continuous PMU data Recording
- Communication Redundancy and PMU Recording using IEC 61850
- MB Hydro PMU Communication experiences and Tests
- Conclusions

# ERLPhase - History

- ERLPhase was formed in 2007 as the next generation of APT Power Technologies and the Relay/Recorder division of NxtPhase T&D Corp.
- ERLPhase is a subsidiary of Easun Reyrolle Ltd of India, an expanding international company. A major in the field of power management, encompassing protection, control, automation, metering and switchgear.

# ERLPhase - History

- R&D, engineering, production and customer support base in Winnipeg, Canada.
- Center of Excellence for the transmission level grade relay and recorder products.
- Direct sales responsibility into the America's plus support the international marketing group for rest of the world.
- Application engineers and sales managers throughout USA, Canada and Latin America.

# ERLPhase – Products

ISO 9001:2008 QMS
Certified Organization
Download Certificate PD

## Products

10 Year WARRANTY

dnp Distributed Network Protocol

Our relay & recorder line provides smart, easy-to-use protection & monitoring of electrical power systems.

### Recorders

TESLA Multi-timeframe
Disturbance Fault Recorders

TESLA 4000

TESLA 3000

TESLA LITE

### Relays

Bus Protection
B-PRO 4000
B-PRO 8700

Line Protection
L-PRO 4000
L-PRO 2100

Transformer Protection
T-PRO 4000
T-PRO 8700

Distribution Protection
& Management
F-PRO 5100

### OTHER PRODUCTS

- TESLA 4000
- TESLA 3000
- TESLA LITE
- RecordBase Central Station
- PMU+CDR Modules
- L-PRO 4000 Relay
- L-PRO 2100 Relay
- B-PRO 4000 Relay
- B-PRO 8700 Relay
- T-PRO 4000 Relay
- T-PRO 8700 Relay
- F-PRO 5100 Relay

### DOCUMENTS

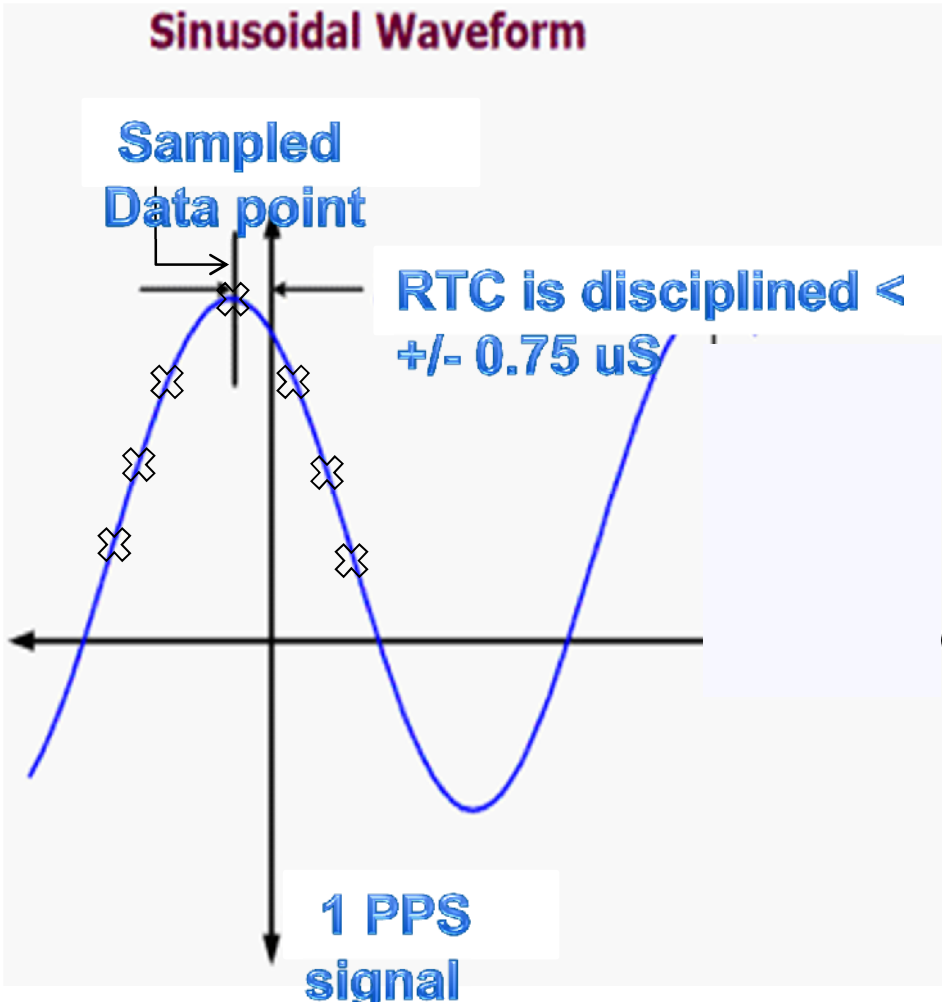
- Data Sheets
- Brochures
- Manuals
- Certifications
- Ordering Templates

# TESLA Power System Recorder with PMU

| DFR | DSR | SER | PQR | LTR | CDR | PMU |
|---|---|---|---|---|---|---|
| Digital Fault Recorder | Digital Swing Recorder | Sequence of Event Recorder | Power Quality Recorder | Trend Recorder | Continuous Disturbance Recorder | Synchrophasors |
| 0 - 30 sec | 1 - 30 min | | | 1 - 90 day | 4-140 day | Real Time |

# ADVANCED DFR PMU FUNCTIONALITIES

- Synchronized sampling with IRIG signal (1 PPS)
  - One sample insured to be within 0.75µs of UTC pulse




**Benefits:**

- **Improved fault location due to synchronized sampled phasor from both ends.**
- **Line current differential protection validation**

# ADVANCED PMU FUNCTIONALITIES…

- PMU Recording based on system events
  - Triggered PMU magnitude and angle record
  - Used for slow time-varying events
  - Record at 1 sample/cycle
  - 10 second to 15 minute record with automatic extension
  - Extend up to 30 minutes under multiple trigger conditions

**Benefits:**

- **Very valuable because PMU data record is triggered by and associated with an event, and all related data is recorded**
- **Recorded data is identical to streamed data, so the DSR effectively acts as a local PMU recorder – first level of redundancy**

# ADVANCED DFR PMU FUNCTIONALITIES…

- Long Term Trending PMU Data
  - Long term PMU magnitude, angle, and frequency record
  - User can define up to 60 trends
  - Record at defined sample rate – 10 to 3600 seconds
  - Maintain log for 90 days
  - Configure to overwrite or stop when full
  - Configure trend-full output contact

**Benefits:**

- **Capture long term variances**
- **Long term trending PMU data effectively acts as a local PMU recorder – second level of redundancy**

# Continuous PMU data Recording…

- Continuous PMU data Recording
  - Record up to 36 phasors from 6 to 60 Hz
  - Records stored locally (onboard) on 4G flash memory
  - Exceeds NERC CDR standards (PRC-002-1)
    - Record anywhere from 3 to 140 days, depending upon config
  - Automatic data overwrite
  - User selectable range of data can be retrieved

**Benefits:**

- **Effectively acts as a local PDC – third level of redundancy**
- **Provides for delayed recovery of post-event data**

# Continuous PMU data Recording…

- CDR – Continuous PMU Recording
  - NERC Requirements ( 6Hz and 9 channels)

| Number of channels * | Sample rate (RMS records per second per channel) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 6 | 10 | 12 | 15 | 20 | 30 | 60 |
| 36 | 38 | 22 | 19 | 15 | 11 | 7 | 3.8 |
| 24 | 56 | 33 | 28 | 22 | 16 | 11 | 5.5 |
| 18 | 73 | 44 | 36 | 29 | 22 | 14 | 7 |
| 12 | 106 | 63 | 53 | 42 | 31 | 21 | 10 |
| 9 | 136 | 81 | 68 | 54 | 40 | 27 | 13 |

***Number of days the continuous data can be stored on DFR***

***Sample rate - RMS record per second per channel.***

***With 9 channels configured with a sample rate of 6 records/second/channel the DFR can store upto 136Days of data.***

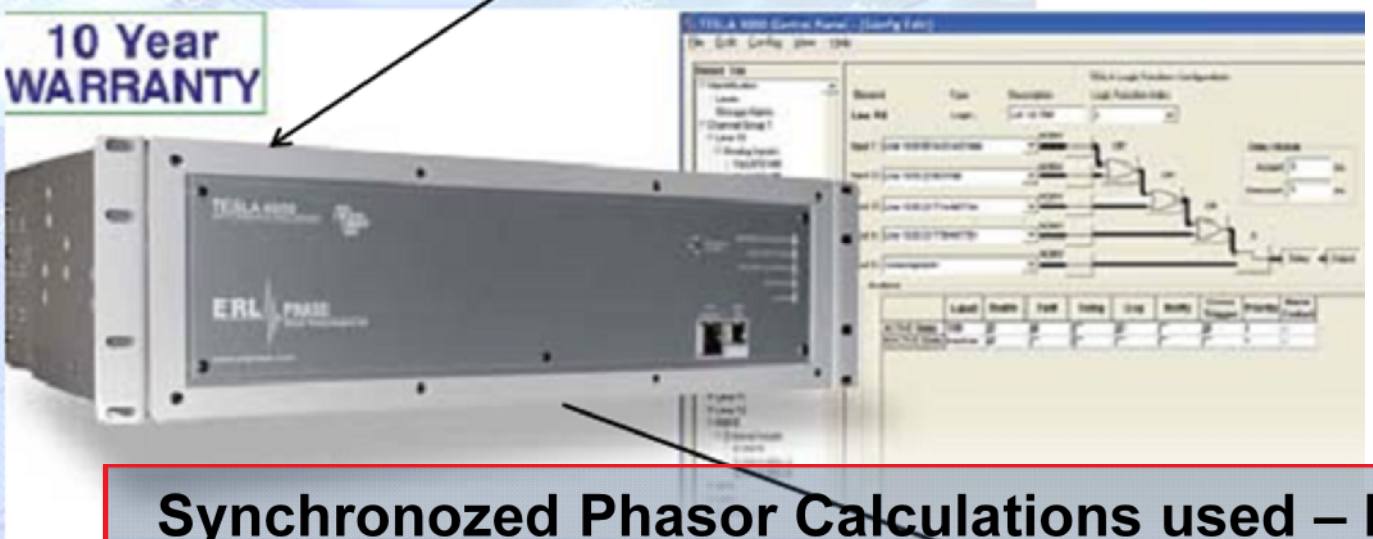
# Communication Redundancy…

- Dual Fibre Optic Ethernet Ports ( 4000 SERIES)
  - The DFR is designed to have 2 independent physical MAC addresses.
  - PMU data can be streamed simultaneously over two Ethernets to two independent PDCs

**Benefits:**

- **Provides communication redundancy in the event of communication failure – reduction in capital cost on the redundant PMU**

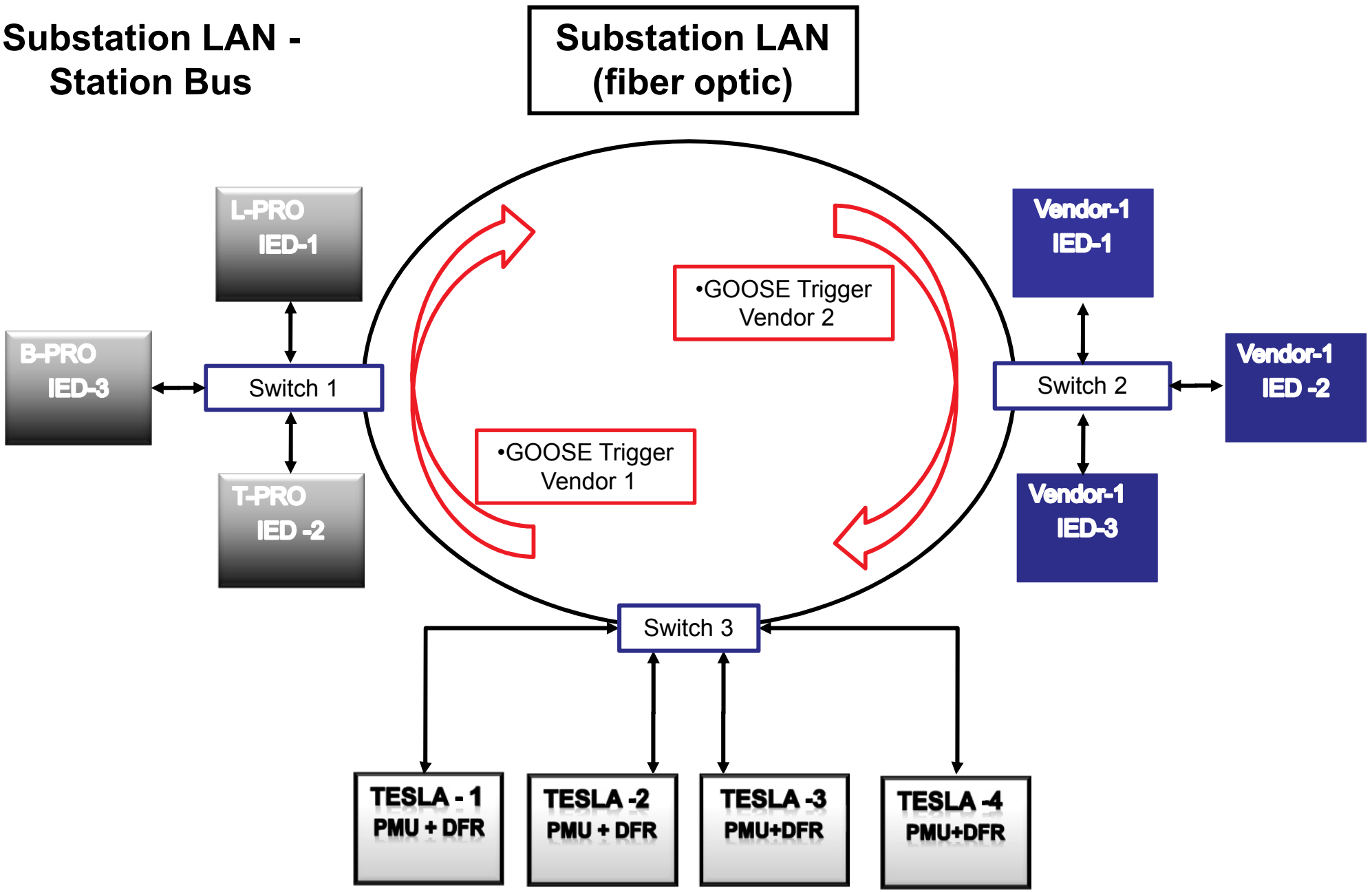
# TESLA PMU data flow




## Synchronozed Phasor Calculations used – PMU data

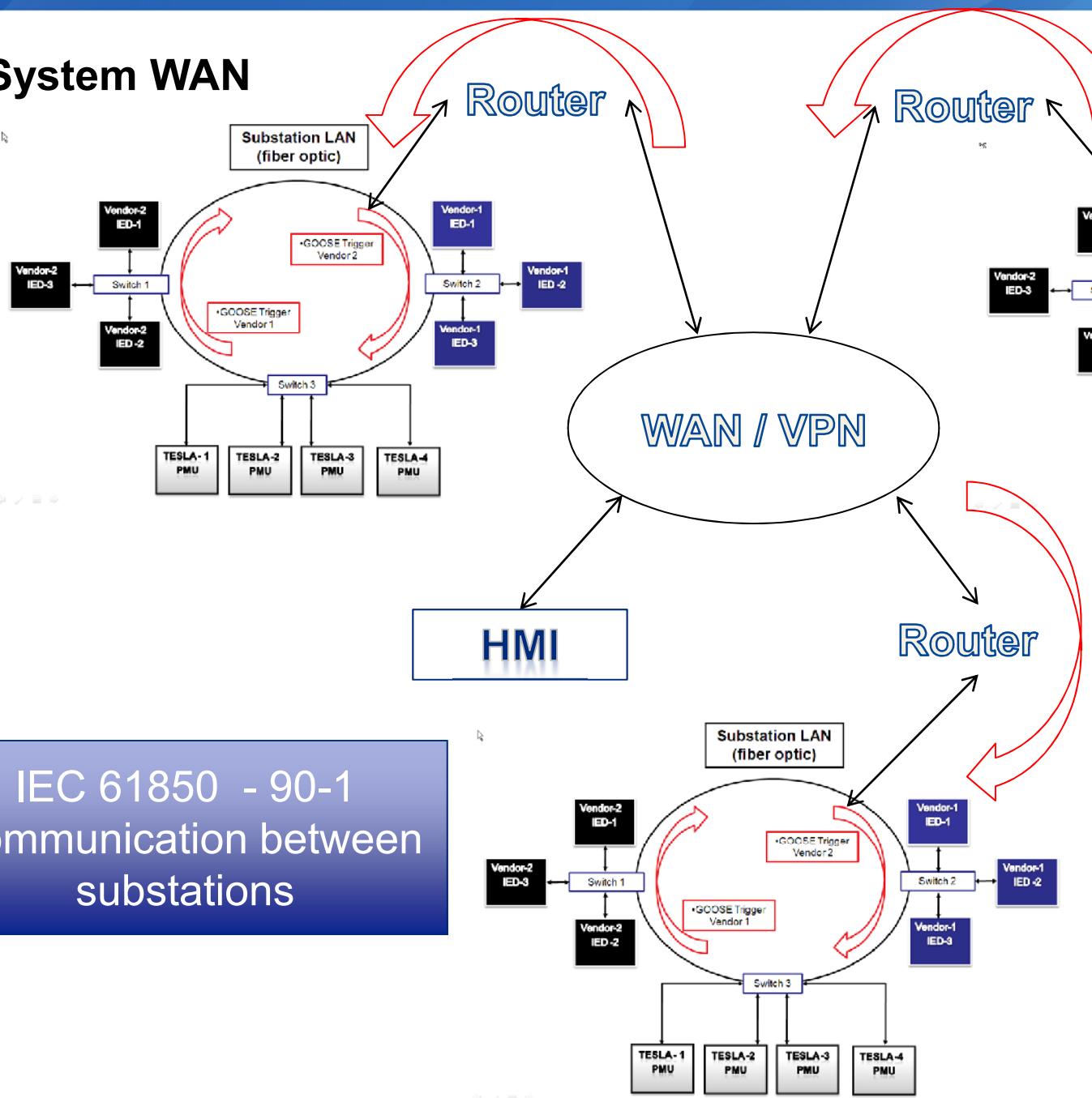
| DFR | DSR | SER | PQR | LTR | CDR |
|---|---|---|---|---|---|
| Digital Fault Recorder | Digital Swing Recorder | Sequence of Event Recorder | Power Quality Recorder | Trend Recorder | Continuous Disturbance Recorder |
| 0 - 30 sec | 1 - 30 min | | | 1 - 90 day | 4-140 day |

# PMU Recording using IEC 61850 GOOSE



# PMU Recording using IEC 61850 GOOSE....

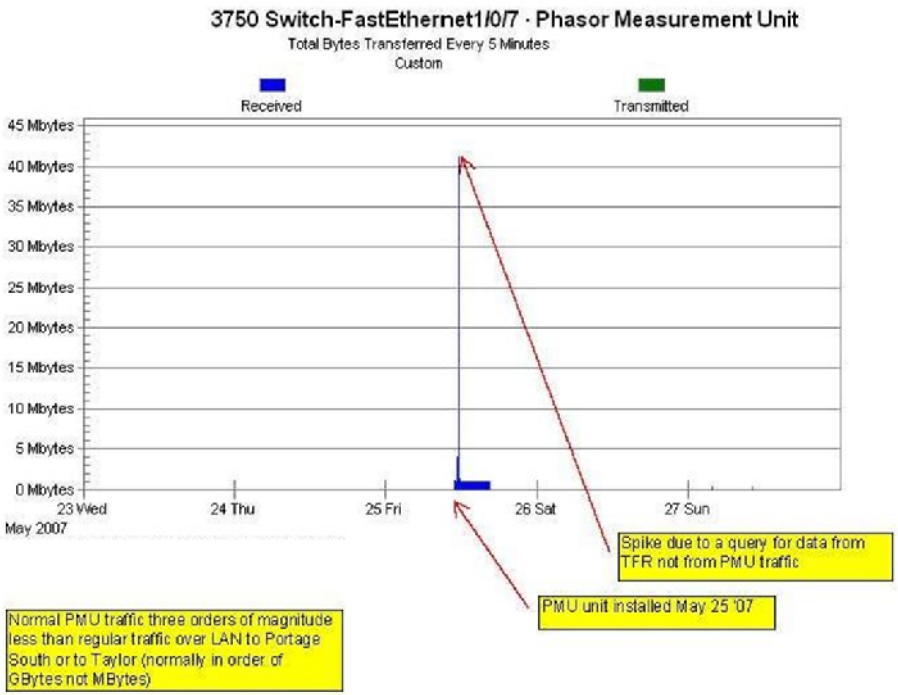
## System WAN

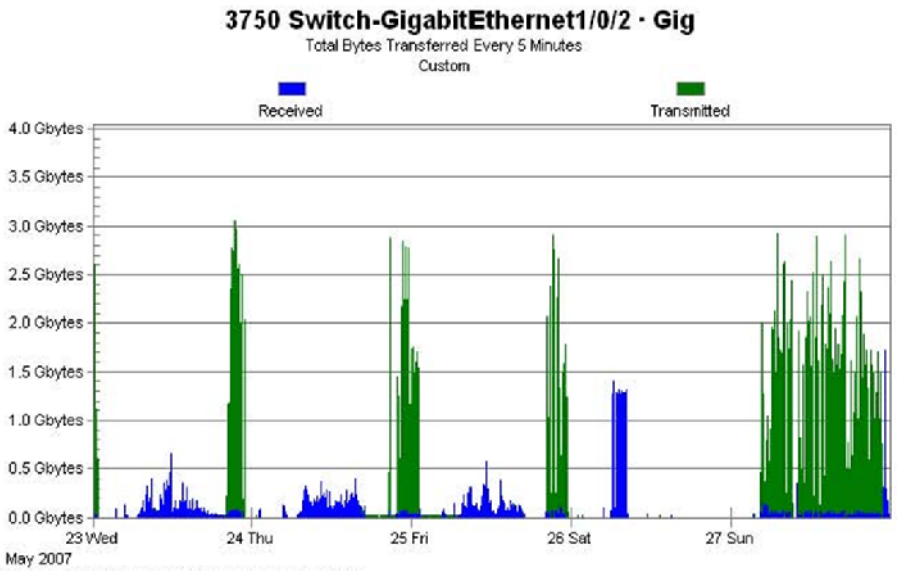



IEC 61850 - 90-1 Communication between substations

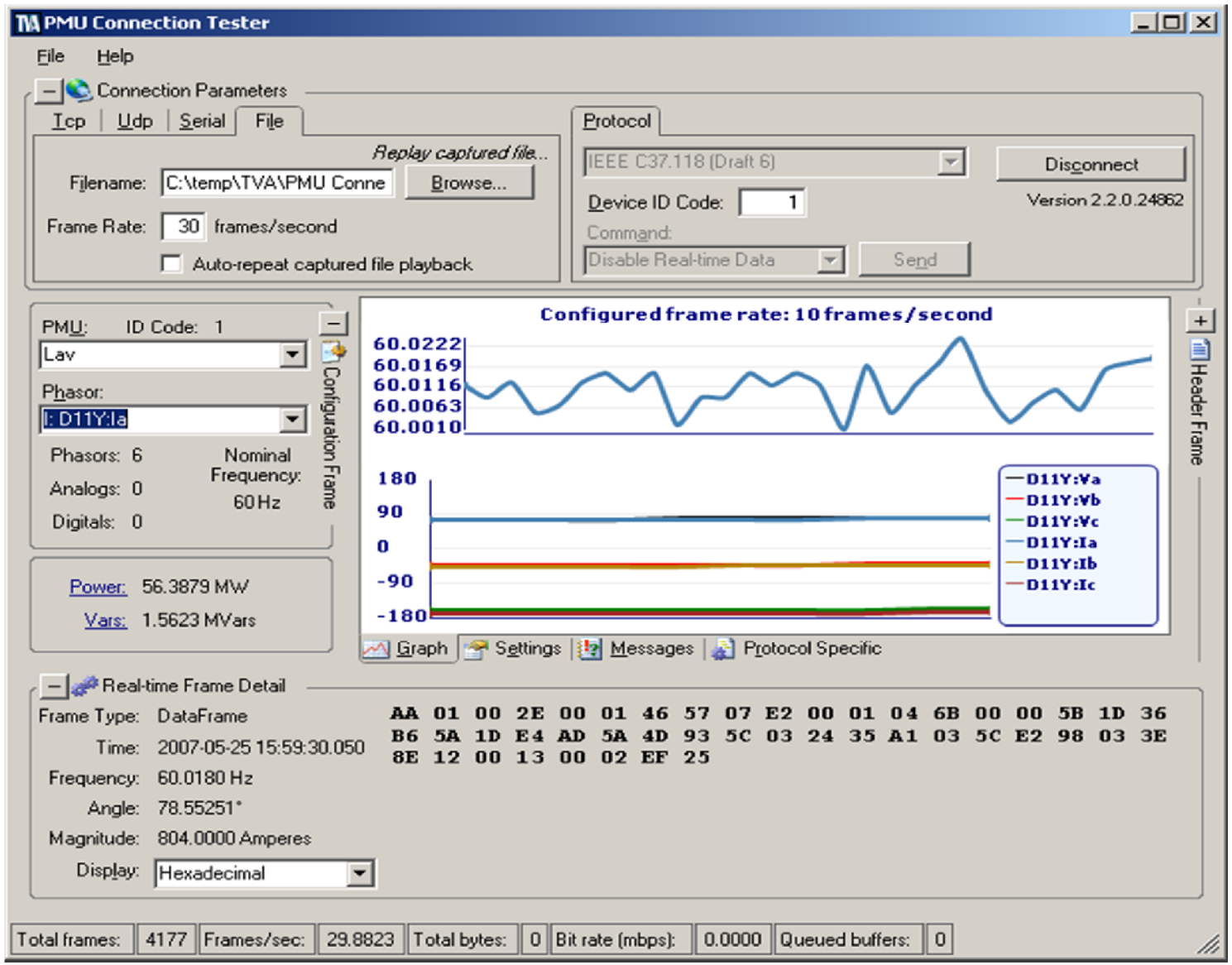
- Load Shedding
- Capacitor bank switching
- Distance Relay Operation validation
- Voltage profile during swing conditions

# PMU Communication Traffic in a Utility Environment

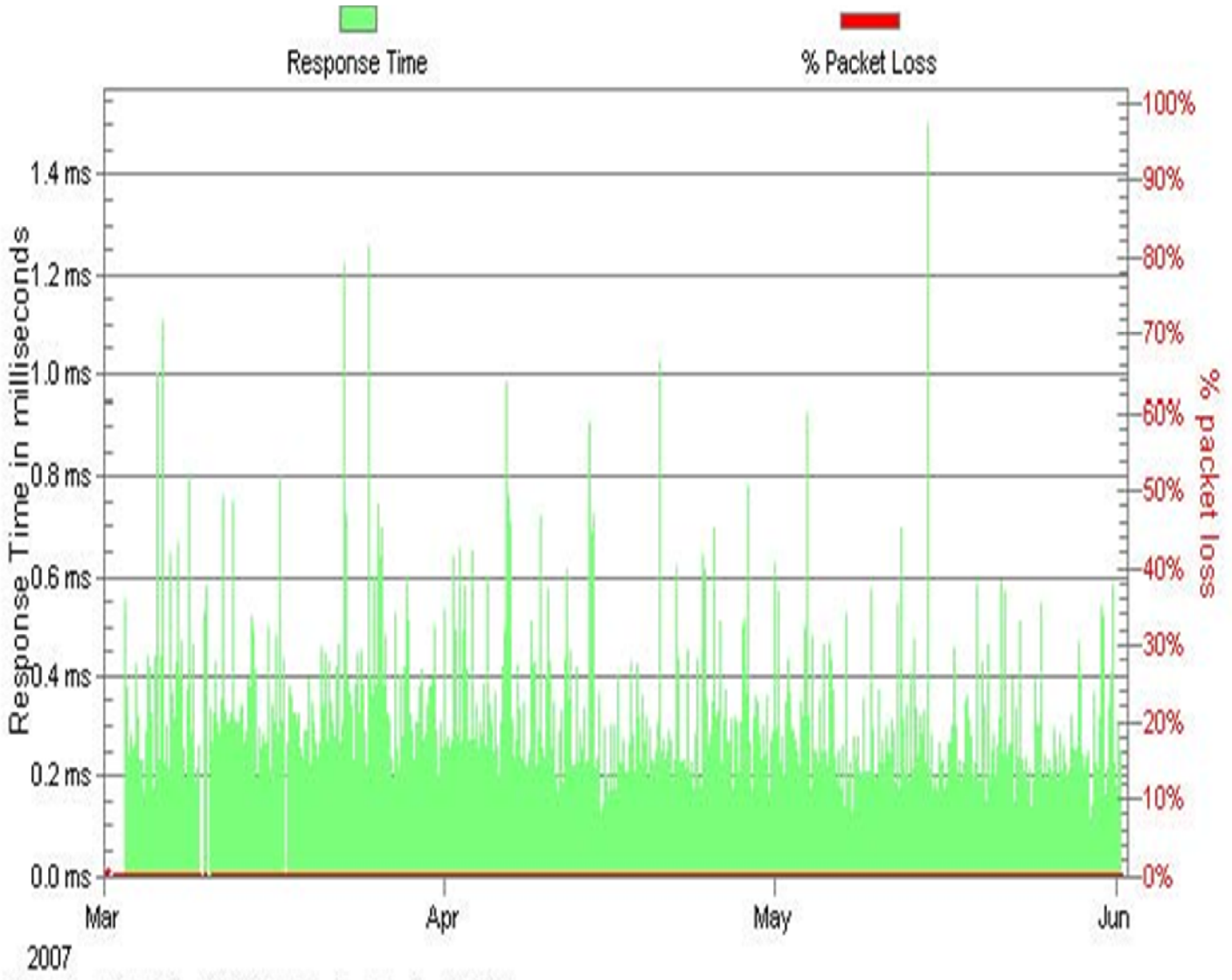


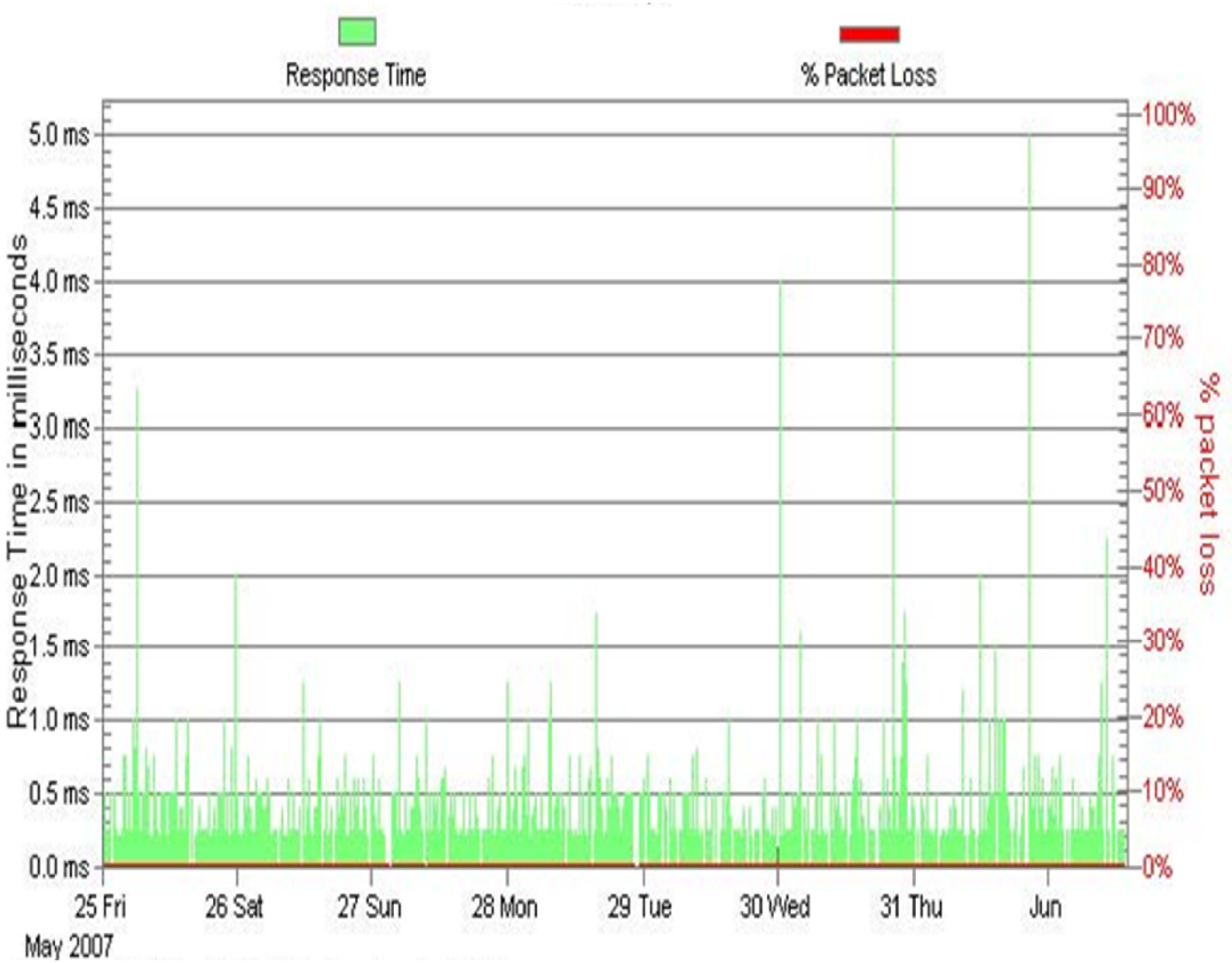
# Test Cases


PMU Connection Tester
File
Help
Connection Parameters
Tcp
Udp
Serial
File
Replay captured file...
Filename:
C:\temp\TVA\PMU Conne
Browse...
Frame Rate:
30
frames/second
Auto-repeat captured file playback
Protocol
IEEE C37.118 (Draft 6)
Disconnect
Device ID Code:
1
Version 2.2.0.24862
Command:
Disable Real-time Data
Send
PMU:
ID Code: 1
Lav
Phasor:
I: D11Y:Ia
Phasors: 6
Analogs: 0
Digitals: 0
Nominal Frequency:
60 Hz
Configuration Frame
Power:
56.3879 MW
Vars:
1.5623 MVars
Configured frame rate: 10 frames/second
60.0222
60.0169
60.0116
60.0063
60.0010
180
90
0
-90
-180
D11Y:Va
D11Y:Vb
D11Y:Vc
D11Y:Ia
D11Y:Ib
D11Y:Ic
Header Frame
Graph
Settings
Messages
Protocol Specific
Real-time Frame Detail
Frame Type:
DataFrame
Time:
2007-05-25 15:59:30.050
Frequency:
60.0180 Hz
Angle:
78.55251°
Magnitude:
804.0000 Amperes
Display:
Hexadecimal
AA 01 00 2E 00 01 46 57 07 E2 00 01 04 6B 00 00 5B 1D 36
B6 5A 1D E4 AD 5A 4D 93 5C 03 24 35 A1 03 5C E2 98 03 3E
8E 12 00 13 00 02 EF 25
Total frames:
4177
Frames/sec:
29.8823
Total bytes:
0
Bit rate (mbps):
0.0000
Queued buffers:
0

# Test Cases .....


Response Time
% Packet Loss
Response Time in milliseconds
% packet loss
1.4 ms
1.2 ms
1.0 ms
0.8 ms
0.6 ms
0.4 ms
0.2 ms
0.0 ms
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Mar
Apr
May
Jun
2007

# Test cases…


Response Time
% Packet Loss
Response Time in milliseconds
% packet loss
5.0 ms
4.5 ms
4.0 ms
3.5 ms
3.0 ms
2.5 ms
2.0 ms
1.5 ms
1.0 ms
0.5 ms
0.0 ms
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
25 Fri
26 Sat
27 Sun
28 Mon
29 Tue
30 Wed
31 Thu
Jun
May 2007

# Conclusions

- The DFR's advanced PMU recording based on triggers helps correlating the data with system events
- The DFR stores Continuous Recording of PMU data using 4GB on-board flash memory and hence provides data redundancy in the event of communication failure with PDC
- Communication bandwidth increase requirement has not increased with PMU traffic at this specific location
- Careful planning is needed for lower bandwidth media depending on the applications.
- Steady-state PMU TVE can be verified on the bench prior to installation and includes error due to time synchronization implicitly in the angle error.

# Questions?

Dr. Krish Narendra, PhD
VP Technology and Quality
knarendra@erlphase.com
204-477-0591 x230

Tony Weekes, P. Eng
Manitoba Hydro

© ERLPhase Power Technologies Ltd. All Rights Reserved.