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Phasor Measurement Unit (PMU) Communication Experience in a Utility Environment

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SUMMARY

Phasor Measurement Unit (PMU) technology provides phasor information (both magnitude and phase angle) in real time. The advantage of referring phase angle to a global reference time is helpful in capturing the wide area snap shot of the power system. Effective utilization of this technology is very useful in mitigating blackouts and learning the real time behavior of the power system. With the advancement in technology, the micro processor based instrumentation such as protection Relays and Disturbance Fault Recorders (DFRs) incorporate the PMU module along with other existing functionalities as an extended feature. The IEEE standard on Synchrophasors (C37.118) specifies the protocol for communicating the PMU data to the Phasor Data Concentrator (PDC). This paper shares the utility experience of the PMU data communication aspects. A microprocessor based DFR with a PMU capability, installed at a substation is considered for the study. The PMU communication (data traffic) and its interaction will be the focus of this contribution. The effect of sending the real time PMU data packets over the network with other routine network activities in a Utility environment will also be analyzed and discussed. Compared to routine network traffic, the PMU data packets traffic is negligible. The communication link used is a secured LAN with a speed of 100Mbs and the PMU data packets are transmitted over the TCP/IP protocol between the PMU and the PDC.

KEYWORDS

Phasor Measurement Unit (PMU), Power Systems, Phasor Data Concentrator (PDC), Global Time Reference, IRIG-B, Disturbance Fault Recorder (DFR), Microprocessor based Relays.

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1. INTRODUCTION

With the increase interest in the Wide Area Monitoring, Control and Disturbance Analysis, and to minimize the future black outs caused due to the cascade tripping, there is a growing interest in the microprocessor based relays and disturbance recorders to provide an additional Phasor Measurement Unit (PMU) measurement and reporting [1-6]. The recent IEEE C37.118 [1] standard on the synchrophasors outlines certain stringent requirements in terms of how to precisely measure the phase angle with respect to the global time reference – the coordinated universal time (UTC), and how to report the phasor information. The standard also specifies the Total Vector Error (TVE) allowed in evaluating the phasor for different compliance level to allow interoperability between different vendor PMUs. The purpose of this paper is to discuss the communication aspects of PMU data in a Utility environment. A Micro Processor Based Digital Fault Recorder (DFR) with a PMU is considered for the analysis, which is carried out as per the C37.118 for different compliance levels. The paper discusses interaction of the various communication traffic along with the PMU data packets. The DFR described in this investigation is a multi-time frame recording system used to monitor electrical power systems. It can record up to 36 analog channels and 64 digital (status) channels and store up to 1000 recordings.

2. PMU with a DFR

The DFR used in this investigation is a multi-time frame recording system used to monitor electrical power systems. It can record up to 36 analog channels and 64 digital (status) channels and store up to 1000 recordings. Up to four recorders can be operated as a cooperative group to achieve greater numbers of channels. The DFR can record data simultaneously in three time domains: high-speed transient fault (up to 384 samples/ cycle), low speed dynamic swing (up to 30 minutes), and continuous trend (10 second to 1 hour intervals). Wide varieties of triggers are available to initiate recording. The recording system consists of a recorder, analog input isolation modules and Graphical User Interface (GUI) software. There are various analog input isolation modules available to interface to signal sources. Modules are available to connect to standard signals found in a typical electric power substation including secondary ac voltage and current and low-level dc voltage and current signals. These modules can generally be installed up to 300 meters from the recorder unit, allowing them to be located near the source of the signals being monitored. The GUI software provides tools to configure the recorder, trigger, retrieve and manage records and display real time measured values. The GUI software also includes a graphical record display and an analysis software sub module. An optional data retrieval and management data base program is available to automatically collect and store records from multiple DFRs (refer Figure 1).

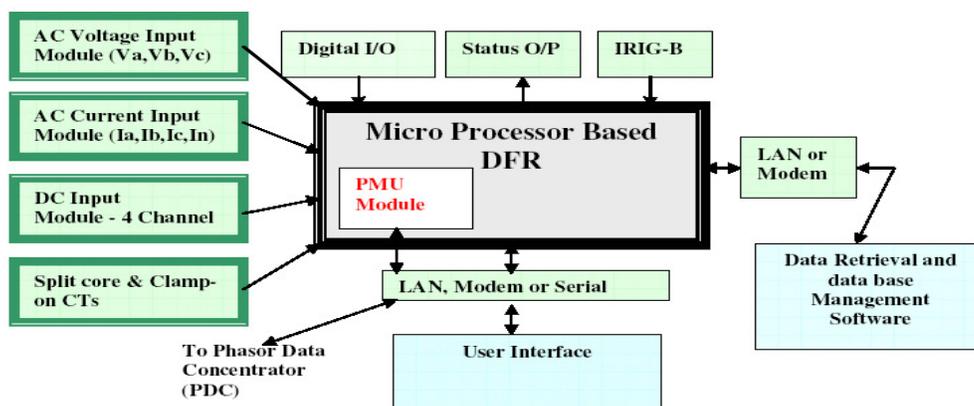


Figure 1: Schematic view of a PMU module in a Microprocessor based DFR

PMU functionality is an optional software product feature on this DFR. The PMU functionality will comply with IEEE C37.118 – 2005 [1]. Up to 12 user selectable phasors - as individual phase quantities or three-phase positive, negative or zero sequence phasors or summated phasors - can be transmitted via Ethernet, Serial port, or Modem at rates up to 60 frames each second. The PMU functionality is designed to work simultaneously with the existing DFR features such as triggering, recording, and trending. This means, simultaneously you can connect to the DFR using the GUI software and view metering quantities, modify configuration settings, transfer records over Modem and stream PMU data over Ethernet or vice-versa.

In order to reliably transmit the PMU data, it is required to connect IRIG-B signal from a reliable Global Positioning System (GPS) clock or receiver to the DFR through standard BNC (Bayonet Neill Connector) connector. The GPS signal must comply with the specification as mentioned in the IEEE C37.118 standard [1].

3. PMU Communication Protocol

The synchrophasor standard C37.118 [1] defines the concept of “frames” for transmitting data from a PMU to a PDC. The standard does not impose any restriction on the communication media itself. Basically a Configuration frame, Data frame, Header frame and a Command frame are specified. These have a particular structure and data type associated with them. Configuration frame, Data frame, and Command frame are binary type and Header frame is of ASCII type. The Data frame is the most frequently transmitted message based on the PMU sample rate, and the typical size is of the order of few hundreds of bytes. The variable size in the Data frame is the number of phasors, and analog and digital signals transmitted, depending on the PMU capability. Hence for example, if a serial communication is chosen to transmit the PMU data, the data transfer capability depends on the baud rate of the communication port. The following table shows the typical data transfer capabilities, assuming that the PMU supports up to 12 phasor channels.

Baud rate, (bps)	Reporting rate (frames / second)							
	10	12	15	20	25	30	50	60
9,600	12	12*	10*	6*	4*	2	0	0
19,200	12	12	12	12	12	10	4*	2
38,400	12	12	12	12	12	12	12	10
56,700	12	12	12	12	12	12	12	12
115,200	12	12	12	12	12	12	12	12

Table 1.0 : Estimated number of phasor channels that can be transmitted at various baud rates and PMU reporting rates over serial port.

*Calculated required bandwidth is very close to the actual baud rate, actual number of phasors may be less than the estimate. The above estimates were calculated for the case - 1 start bit, 1 stop bit, 8 data bits and no parity bit – total 10 bits to transmit for each byte.

4. Communication traffic in a Utility environment

The communication traffic in a utility environment will vary depending on the bandwidth of the communication medium and on the characteristics of the applications sharing the communications infrastructure. At MB Hydro the mainly fibre based communication infrastructure has a very high bandwidth. In the test case below (more detail in section 5 to follow), a query to an existing TFR (transient fault recorder with PMU capability) transmits a total of 45 MB of data in 5 minutes or on average 150 KB/s. If there was only expected one query per day, the average data throughput becomes a very small number (520 Bytes per

second) when compared to the bandwidth of the medium which in this case is 600 MB per second. Although the average bandwidth is small, the data does appear as a large burst of information and if 1000 PMUs were queried at the same time this could have a very significant impact on the data network (150 MB/s on average over 5 minutes, and higher if one considers the burst and not the average). All system deployments will have to look very closely at the amount of information being retrieved and how often it is queried. Systems that rely on lower bandwidth media such as microwave radio will have to be carefully planned, as the number of PMUs ultimately planned for the wide area network may become an issue with regards to response times.

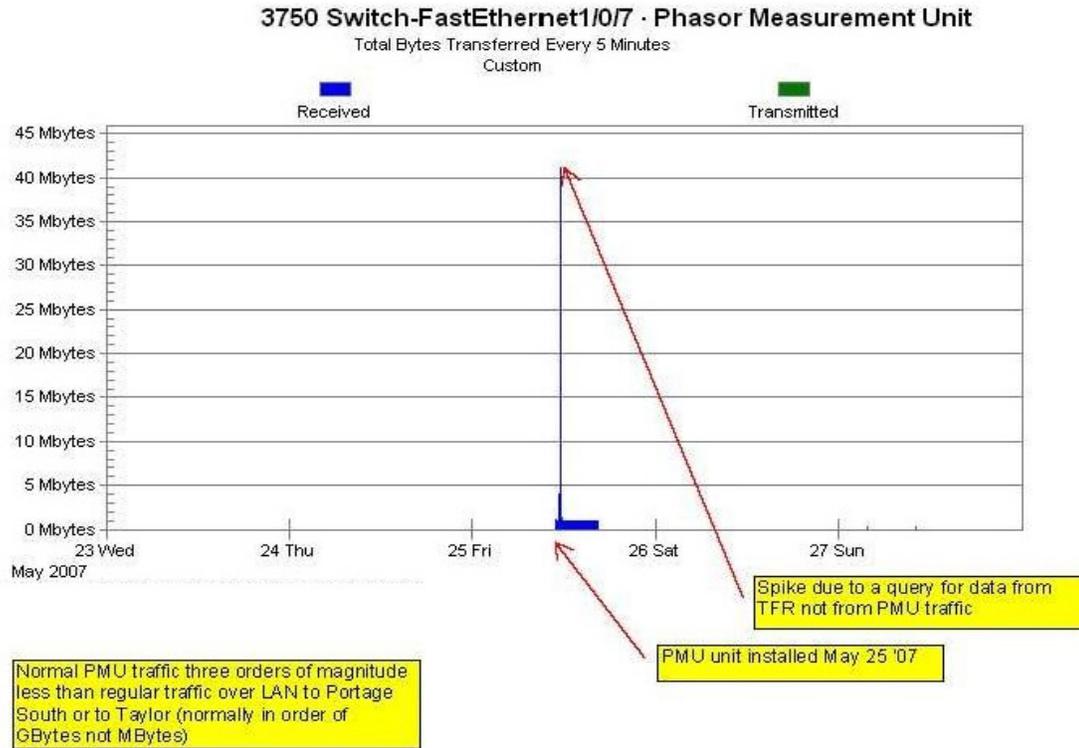


Figure 2: Typical Query to a Transient Fault Recorder and normal PMU traffic just after installation

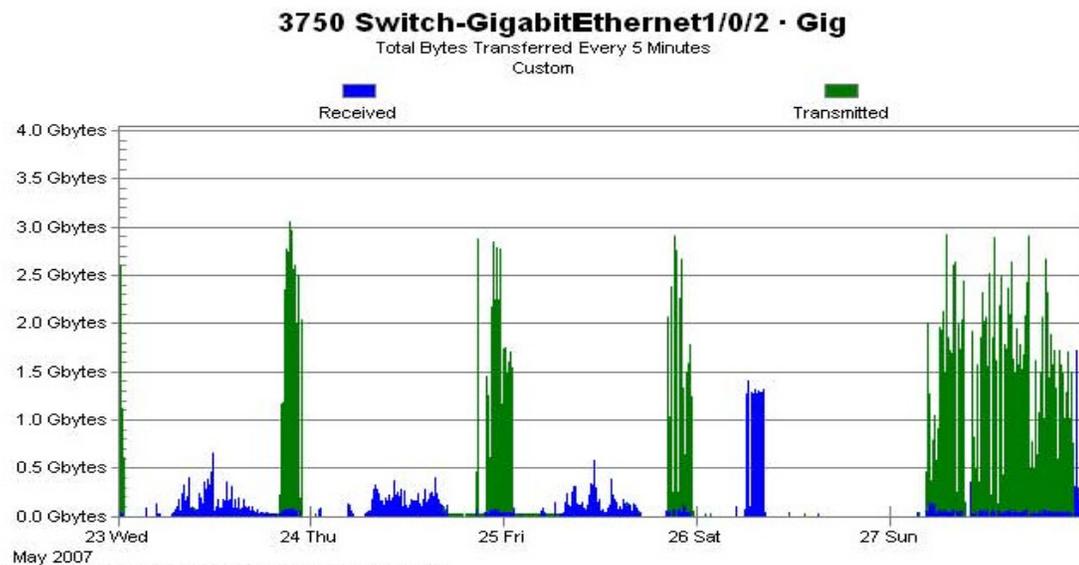


Figure 3: Typical communication traffic in a utility environment

5. Test Cases

The PMU was installed in the field after the calibration as per the DFR requirements. The location was chosen at our Laverendreye site as this site already has a DFRs. This site also allows for later upgrade of existing DFRs with PMU with a minimal effort. The current phasors were chosen to be monitored from the designated line Y51L as this line carried the main portion of tie-line L20D which exports power to the United States. The local area network chosen was a secured communication network so that we would be non-invasive to the existing station protection network. Clip on CTs (split core) were also chosen so that we could be non-invasive to existing CTs already used at the station. Physical location of the PMU with DFR was chosen in a free panel of the 19 “rack close to the LAN connection and PTs and CTs. Power supply was already available and no alarming was adding for this temporary installation. The existing GPS clock with an extra IRIG-B port was used as an input to the PMU. In the future, several such PMU devices can be installed over this network through our LAN and with in MB Hydro firewall. This facilitates the installed PMUs to get around the many cyber security issues.

The PMU data was transferred to a Phasor Data Concentrator, which was installed on a laptop computer. The PDC is a TVA PMU test Connector software, which is a free version and can be downloaded from [7].

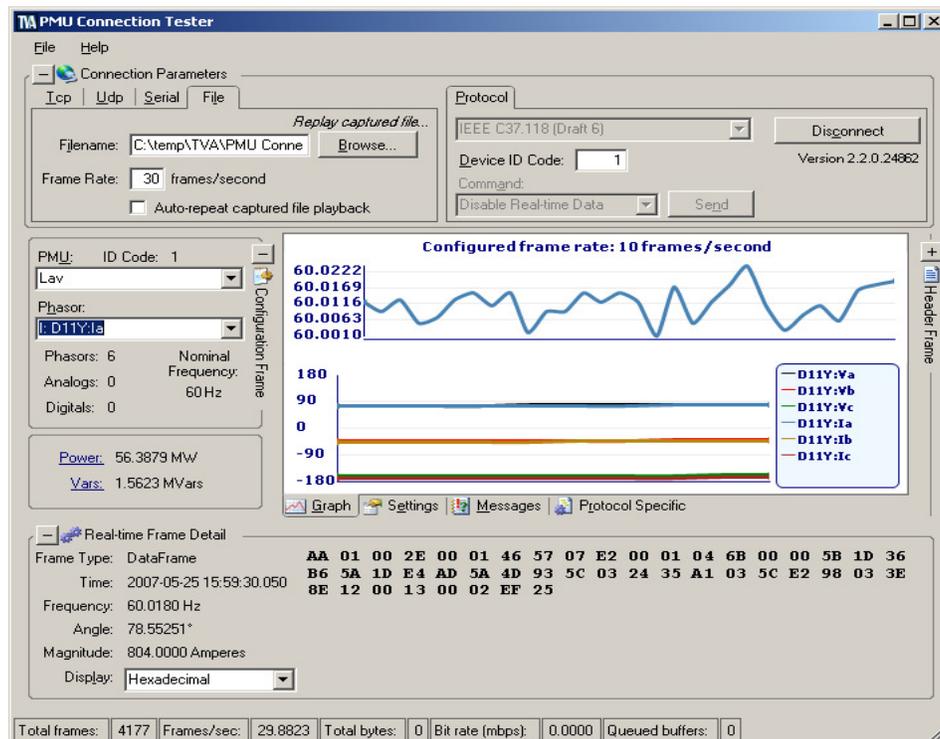


Figure 4: PMU data communication snapshot as depicted by the PDC capture

The phase angle rotates continuously depending on the deviation of the frequency from the nominal system frequency. Dynamic tests were not performed on this PMU installation, as we could not inject into PTs and CTs at the site. Dynamic tests will be considered for the future

installations. The type of CT used was an ASEA IMBE-245 A4 CT with a metering error is 0.3%, and the protection/relaying error is 10% for all core taps, and a TRENCH TEMF230 CVT, the error specification for both taps is 0.3WXYZ, 1P; Metering: 0.3%; Protection/Relaying: 1%.

The bandwidth at the station was also monitored to get an idea of how much of an increase could be expected with the six phasors monitored at a frame rate of 30/second.

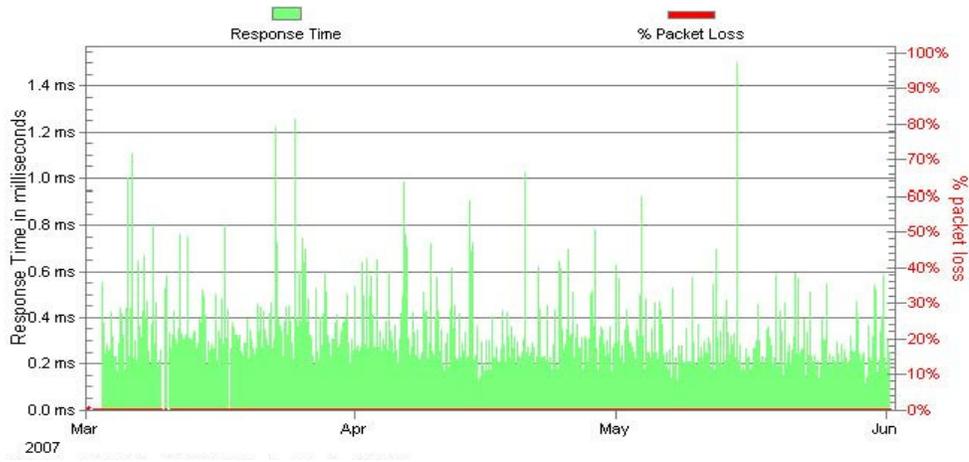


Figure 5: Monthly average response time and percentage packet loss

The above switch response shows a nominal ‘% packet loss’ of 15% compared to as high as 95% for certain events happening in the recorder. Similarly, if we zoom in just last week the switch response below shows maximum response times as long as 5 ms compared to a nominal 0.2 ms response time.

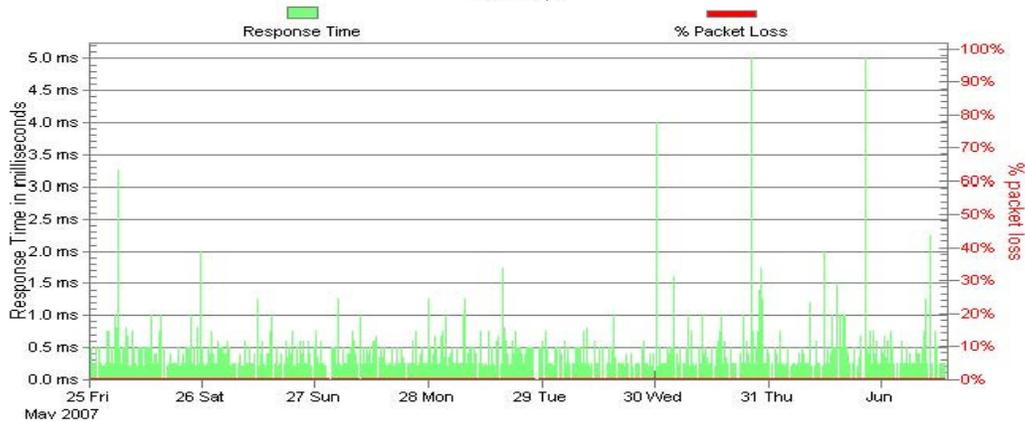


Figure 6: Weekly average response time and percentage packet loss

Prior to the installation (May 22 '07) there is little change in the response time or packet loss from before the installation on May 23 '07 (see below). The spike shown on May 23 up to 4.5 ms was from a request for data from that recorder.

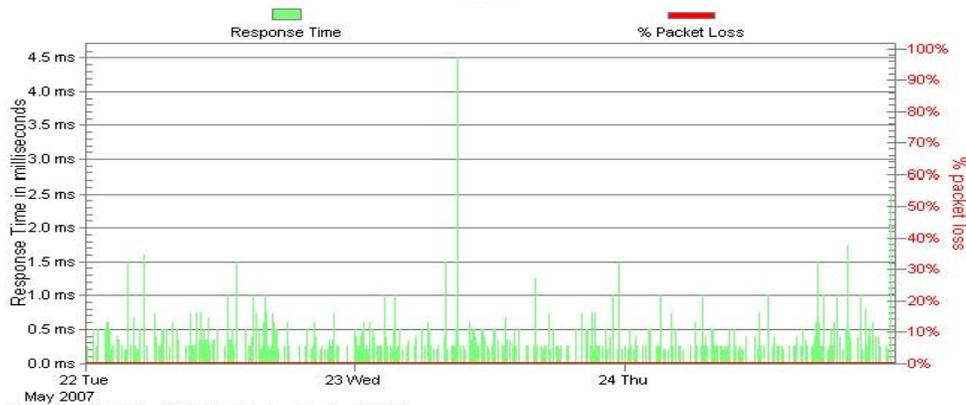


Figure 7: Daily average response time and percentage packet loss

6. Conclusions

From the studies carried out, in a typical utility environment described in this study, it has been found that the communication bandwidth requirement of PMU data traffic at this specific location is negligible compared to the other existing routine network activities. All system deployments will have to look very closely at the amount of information being retrieved and how often it is queried. Systems that rely on lower bandwidth media such as microwave radio will have to be carefully planned, as the number of PMUs ultimately planned for the wide area network may become an issue with regards to response times.

The PMU installed meets the criteria of C37.188 (Total Vector Error is about 0.3%). With the PMU unit calibrated to correct errors from the standard test set, one can expect only the field PT and CT errors need to be compensated to obtain the accurate phase angle.

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