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A Survey on Phasor Measurement Unit For Power System

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Abstract: **Power system is the integral part of any business. It is available everywhere in form of simple or complex form. In this technical era it is has grown mandatory for industries to avail the flawless power continuously and in a secured manner. It has become the basic necessity for every person on this earth hence it is mandatory to develop the efficient models with smart fault controlling options. This paper reviews the latest Phasor Measurement Unit (PMU) technology development and applications in power system dynamic analysis. The methods and algorithms in the reviewed works are all in accordance with NERC recommendations and fit well in the new trend of wide-area protection and control. The reviewed technology can be utilized and combined in the future to address power system online dynamic simulation, control and protection.**

Keywords: **PMU, Real Time Data, Fault Diagnosis, Cascading Failure.**

I. Introduction

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 to get the overview of the power system. It is necessary to learn the effective utilization of this technology as it provides its applications in mitigating blackouts and learning the real time behavior of the power system.

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. 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 reporting rate of the PMU limits the maximum modulation frequency that the PMU can accurately measure. When the modulation frequency reaches half of the PMU reporting rate, the Nyquist frequency, the PMU cannot determine the modulation parameters. This is the basis for one of the requirements in the Standard. The Standard requires that certain signals outside of the Nyquist frequency from the nominal frequency, called out-of-band interference, must cause less than 1 % Total Vector Error (TVE). Note: PMUs sample the power signal waveforms at a rate much higher than their reporting rate. Thus, PMUs use a combination of analog and digital filtering to achieve this specification. When testing PMUs for higher frequency modulation requirements, the PMUs must reject this modulation and the “true” phasor is the phasor of the signal fundamental, which is not changing its amplitude and frequency [2].

Basic PMU Architecture

The samples from the voltage and current inputs are collected by the A/D (Analog to digital converter) at the rate of 48 samples/cycle but independent of the1pps input. The sampling interval is controlled by a well proven frequency tracking algorithm in order to respond dynamically to changes in system frequency. This data is sent to the measurement

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processors which handle the GPS and IRIG-B inputs and provides synchronized phasor measurements. In addition to that a communication processor handles the Ethernet communication. Figure 2 below shows the basic PMU architecture. The synchronized measurements are transmitted upstream over Ethernet (TCP or UDP).

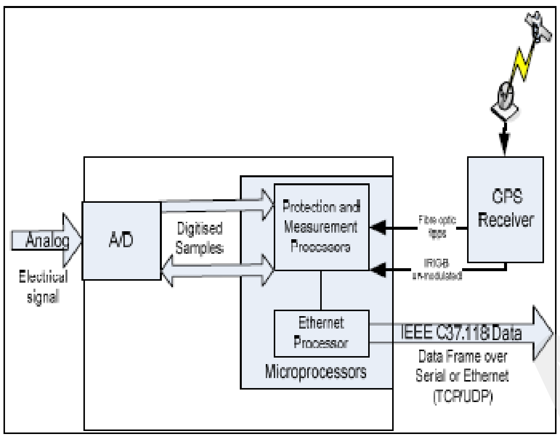

Figure 1: Phasor Measurement Architecture

The measurement window is centred on the GPS input, which corresponds to UTC (Coordinated universal time). The measurement window would be as below (Figure 2), with 24 samples taken from before the GPS pulse arrived and 24 samples after. Any phase shift between the centre of the window and the GPS pulse, which can be up to half of sampling interval, is taken into account using a 37.5 MHz internal CPU clock and compensation is applied to the filtered result. The PMU also generates internally a reference time tag every 20 ms (if nominal frequency is 50 HZ) to provide measurements till the next GPS pulse arrives [3].

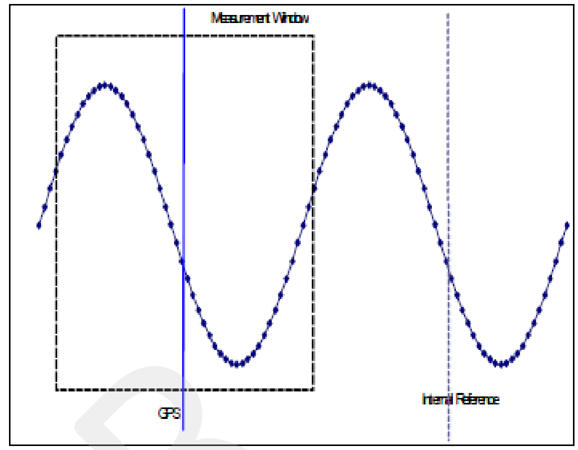

Figure 2: Measurement Window

Fundamentals of PMU

A pure sinusoidal waveform can be represented by a unique complex number known as a phasor. Consider a sinusoidal signal

$$x(t) = X_m \cos(\omega t + \emptyset) \quad (1)$$

The phasor representation of this sinusoidal is given by

$$x(t) = \frac{X_m}{\sqrt{2}} e^{j\emptyset} = \frac{X_m}{\sqrt{2}} (\cos\emptyset + j\sin\emptyset) \quad (2)$$

Note that the signal frequency *w* is not explicitly stated in the phasor representation. The magnitude of the phasor is the rms value of the sinusoid $\frac{X_m}{\sqrt{2}}$ and its phase angle is ϕ , the phase angle of the signal in above equation (1). The sinusoidal signal and its phasor representation given by and (2) are

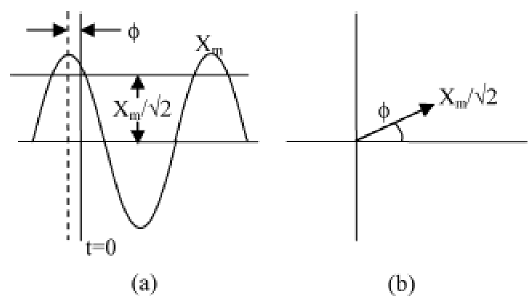

Figure 3: Phasor representation of a sinusoidal signal. (a) Sinusoidal signal. (b) Phasor representation.

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Benefits of Using PMU

Some of the advantages of using PMU are depicted as follow [5]:

- Real Time Monitoring and Control.
- Power System State Estimation
- Real-Time Congestion Management
- Benchmarking, Validation and fine tuning of System Models.
- Post-Disturbance Analysis
- Power-System Restoration.
- Protection and Control Applications of Distributed Generation.
- Overload Monitoring and Dynamic Rating.
- Adaptive Protection.
- Planned Power System Separation.

Applications of PMUs in Power Systems

The synchronized phasor measurement technology is relatively new, and consequently several research groups around the world are actively developing applications of this technology. It seems clear that many of these applications can be conveniently grouped as follows:

- Power System Real Time Monitoring
- Advanced network protection
- Advanced control schemes

II. Related Work

Kaushik Das [April 2012] stated about the novel hybrid state estimation method using traditional SCADA (Supervisory Control And Data Acquisition) and newly deployed limited PMU (Phasor Measurement Unit) measurements [6]. The paper presented the estimation technique that could be utilized for faster control actions such as transient stability analysis, FACTS devices control, voltage stability analysis, etc.

Joe H. Chow [June 15, 2011] stated about Phasor Measurements at a bus of the receiving end of the Network and the estimated PV curve for the transient portion of the data.

Farrokh Aminifar [February 2010] stated about a model for the optimal placement of contingency-constrained phasor measurement units (PMUs) in electric power networks. The paper included a low execution time as well as global optimality that make the method suitable for large-scale power system applications.

J. C. Cepeda [2012] proposed the approach to determine suitable PMU locations that allows ensuring observability of slow and fast dynamic phenomena. They used Monte Carlo-based simulations to iteratively evaluate the system fast dynamic coherency, as well as the bus oscillatory modal observability.

Neuman Petr [2010] stated about analysis of synchrophasors and also to calculation of parameters of 400 kV line, V430 – „HRD-CHR“, which was measured on both ends. The data filtration and analyse were performed on commercial available SW toolboxes of MATLAB, e.g., Spectral Analysis was performed on Signal Processing Toolbox.

Conclusion

In this paper the review of Phasor Measurement System is presented. The paper is supported with various literature reviews and provides a brief about the subject.

The information presented in the paper holds its validity and can be referred to as the updated version for the year 2013. The reviewed technology can be utilized and combined in the future to address power system online dynamic simulation, control and protection.

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