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A Review on: Potential of Phasor Measurement Units (PMU)

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Abstract
The complexity of power system increases day by day and it is the need of hour to have a secure, stable and reliable power system. Various faults occurring on the power system leads to insecurity, unreliability and if not quickly cleared may lead to system blackout which is undesirable as it leads to lot of loss of revenue. So more accurate, reliable monitoring and control systems are required. Because of major blackouts in the history the need and importance of PMUs has increased many folds.This paper reviews the potential of PMU in power system and industries.

Key Words: PMU, SCADA, GPS, WAMS, PDC

1. Introduction

Phasor measurement unit (PMU) is a device or a function in a multifunction device that produces synchronized phasor, frequency, and rate of change of frequency (ROCOF) estimates from voltage and/or current signals and a time synchronizing signal [1]. PMU was developed in 1980s. The Bonneville Power Administration (BPA) is the first utility to implement comprehensive adoption of synchrophasors in its wide area monitoring system (WAMS). The Western Electricity Coordinating Council (WECC) has been an industry leader in realizing the potential of the Phas. Measurement Unit (PMU) technology and developing first industry prototypes and applications [3]. For the past years SCADA system has been used for monitoring and control of the power system but this system has certain shortcoming like providing only the steady state view of the system not the dynamic view, that also with high data flow latency, so it is the necessity to shift to the new technology. Synchronized measurement technology (Wide area measurement) is considered to be one of the most important technologies in the future of power systems due to its unique ability to sample analog voltage and current waveform data in synchronism with a GPS-clock and compute the corresponding frequency component from widely dispersed locations that enables to provide dynamic view along with the steady state [2]. The advantage of referring phase angle to a global reference time is helpful in capturing the wide area snap shot of the power system.

The main elements of Phasor Measurement Unit (PMU) are as shown in Fig. 1 [2].

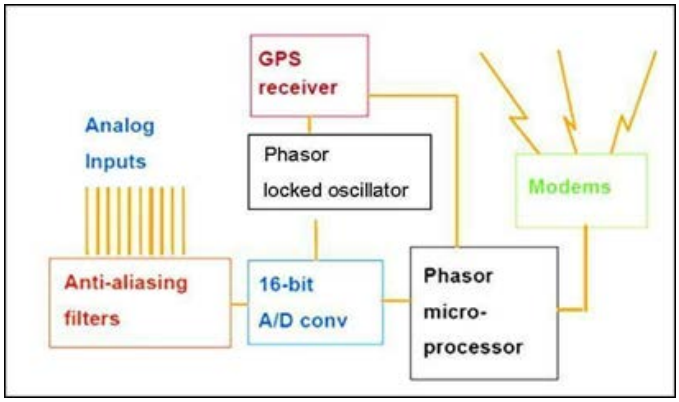

Figure 1: Basic Block Diagram of PMU

The analog inputs in the basic block diagram are the voltages and currents obtained from the secondary winding of the three phase voltage transformers (PTs) and current transformers (CTs).

Then these analog inputs go into an anti aliasing filter. Anti aliasing filter are devices which limit the bandwidth to satisfy the Nyquist criterion. Thus they are used to filter out the input frequencies that are higher than the Nyquist rate. “As in many relay designs one may use a high sampling rate (called oversampling) with corresponding high cut-off frequency of the analog anti-aliasing filters. This step is then followed by a digital ‘decimation filter’ which converts the sampled data

to a lower sampling rate, thus providing a 'digital anti-aliasing filter' concatenated with the analog anti-aliasing filters [2]". The analog AC waveforms obtained are digitized by an analog to digital convertor.

A phase lock oscillator along with Global Positioning System reference source provides the needed high speed synchronized sampling with 1 microsecond accuracy. The phasor microprocessor calculates the phasor using digital signal processing technique and uploads to phasor data concentrator (PDC).

Global Positioning System The synchronized time is given by Global Positioning system. It uses the high accuracy clock from satellite technology. The first GPS system was developed by United States, Department of Defence. Without GPS providing the synchronized time, it is hard to monitor whole grid at the same time. The GPS system consists of 24 satellites in six orbits at an approximate altitude of 10,000 miles above the surface of the earth.

1. Potential Of PMU

Broadly classifying applications of PMUs are [3]:-

- Analysis and avoidance of outages that have extreme manifestations in blackouts
- Market and system operations

In addition to this general analysis, very detailed analysis of key individual applications resulted in the following outcome in report are:

Application that either have a major improvement impact with PMUs or cannot be implemented without PMUs: angle frequency monitoring and visualization post-mortem analysis model benchmarking outage prevention including planned power system separation, state measurement and real time control. For other application non PMU technologies are available [3]. The low hanging fruit application those opportunities for which need immediate, PMU are required infrastructure requirement are relative modest. These applications are angle/frequency monitoring and visualization, and post-mortem analysis (including compliance monitoring). The state estimation improvement conventional SE improvement or evolutionary improvement boundary condition SE and state measurement or revolutionary application development [3].

2. Avoidance of outages

For example, major reliability improvements have been made after major blackouts events in the US in 1965, 1977and 19 96.PMU provides early warning systems, detecting and analyzing thermal limits and angular, voltagesmall signal stability, faster system restoration (including natural disasters), post disturbance data analysis etc.

3.1. Market and system operations and planning

Transmission congestion in de-regulated environment is complex to handle. The grid operator wants to avoid congestion as it incurs congestion costs and add limits to the transfer capability of the power system. For day today congestion management, actual flow on a line as compared to a nominal transfer capability based on them all limitations voltage limitation or stability limitation. Congestion relief occurs through the ability of the PMU to calculate actual transfer limits instead of conservation limits imposed due to angle and voltage constraints.

2.2. Real Time Monitoring & Control

Phasor measurement technology facilitates the dynamic real-time capture or view of system operating and parameters. This information provided to the system operators increase operational efficiency under normal system condition and allow the operator to anticipate detect and correct problem during abnormal system condition or faulty condition. Whereas in SCADA system the state is estimated but in PMU it is directly measured.

PMU technology is beneficial in

Angular separation analysis and alarming

Monitoring of long-duration, low frequency, inter-area

Monitoring and control of voltage stability

2.3. Post Disturbance Analysis

The aim of a post mortem or post disturbance analysis is to reconstruct the sequence of event after a power system disturbance has occurred e.g. in case of system failure/system blackout. The application of phasor measurement to these process potential benefits in the high degree of time synchronization that is available only through the use of PMUs. Post disturbance analysis typically involves a team of engineer, technical persons collecting and studying data from multiple recorders that are dispersed throughout the whole grid. GPS synchronized data recording helps to reduce the time spent on analysing the vast amount of data for post disturbance studies. The time reduction can be from month to day or even hours depending on the volume of data.

3. Power System Restoration

For system restoration after an event there are standard procedures that are to be followed by the utility. These procedures are generally based on some standard set of system condition and associate operating parameters. The dynamic nature of the power system, particularly following outage or unusual events, create the risk that the condition on which the operating procedures are based may not exit at the time restoration effort are undertaken. PMU measurement therefore can provide a valuable input into the decision processes, as the measurement are real time quantise that give the operators current information on the system status. The angle measurement is a primary used in power system restoration procedures and with the help of PMU phase angle of the system is directly known but in case of SCADA it is to be estimated.

4.1. Adaptive Protection Description

Adaptive protection is a philosophy of protection design that provides for adjustments in protection functions, automatical ly, as system conditions change [3]. The protection scheme adapts within defined parameters to prevailing system condition unlike conventional protective system that responds to fault or abnormal events in a fixed predetermined manner. The protection application that are identified as best suited for use with PMU are out of step relays adaptive line relays, adaptive reclosing and fault location. Introduction of PMU data offer either new functionalities or enhanced operation of existing relay function.

4.5. Overload Monitoring and Dynamic Rating

In transmission of electrical energy there are certain limits that are posed the overload capacity of the transmission lines. Easy to use cost effective technology to enable real time monitoring and dynamic rating of transmission line has a major potential to avoid overloads and optimally utilize transmission lines. Line capacity is limited by performance of the conductor at high temperature and by safety standard that specify the minimum ground clearances. The use of PMUs can offer some degree of monitoring at a high time resolution. The same PMUs can be used for other purpose olso.

4.6. Energy management systems

Sideig A. Dowi, Gengyin Li described the use of PMU in improving the energy management system (EMS) functions in [4]. Dynamic state estimation is proposed under normal operating and bad data conditions using Decoupled current measurement. It is a new method for introducing PMU in DSE. The new model is able to predict the state variables of the system for the next instant of time, based on the preceding system state so it is useful for giving longer decision time to the system operator & other functions like security assessment, economic dispatch can be performed in advance.

In [5] a distributed architecture for PMU is presented. In distributed system several small functions working independently to provide a complete functionality of PMU. The different stages are able to added, modified or removed easily without

affecting overall functionality of the rest of the system. The proposal automation in this paper works on the framework of IEC 61850 process. Distribution PMU architecture is capable of providing different applications with suitable inputs like local state estimation, use of non-conventional instrument transformer like Rogowski coils substation automation enhancements.

4. Conclusion

PMU application offer large reliability and financial benefits power system if implemented across the interconnected grid. Therefore, it provides motivation for regulators to supports development of this technology and its application. PMU technology is instrumental in improving early warning system. System integrity protection scheme (SIPS), detecting and analyzing thermal limits and angular voltage and small signal stability faster system restoration including natural disasters post disturbance data analysis dynamic state estimation, energy management system. For some of that application such as data analysis angular stability warning, PMUs offer means and benefits not possible with any other technology. In addition, individual utilities could realize financial benefits if several integrated applications are deployed using basic PMU system infrastructure.

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