# Wide Area Monitoring, Control and Protection of Power System

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## ABSTRACT

The increasing demand of load without considerable increase in transmission resources has posed numerous constraints and challenges in the power system monitoring and performance. The issues of deregulation trend in the industry and the requirement of better network monitoring, leads to the development of the solutions for wide area monitoring(WAM), protection and control, than the currently used methods which are mostly good for local area monitoring, protection and control. The purpose is to increase the overall system efficiency and reliability for all power stages via significant dependence on WAM as distributed intelligence agents with improved monitoring, protection, and control capabilities of power networks. The necessity for WAM has gained worldwide acceptance, and a number of WAM systems have been established, or initialized, in different power utilities throughout the world.

This paper addresses some issues and defines a strategy towards the coordination of local and wide-area controls and protections to ensure power system grid security. The strategy relies on the integration of the latest PMU technology and data processing to deploy different types of control actions and special protection schemes**.**

## Index Terms

Wide-area Monitoring, Power System Control, Synchronized Measurements, Sense making, Phasor measurement unit (PMU).

## 1. INTRODUCTION

WAM became one of the most recent technologies that are popular for upgrading the traditional electric grid. This upgrade has become a necessity to modernize the electricity delivery system following the occurrence of major blackouts in power systems around the world. In early 1980s, synchronized phasor measurement units (PMUs) were first introduced and since then have become the ultimate data acquisition technology, which will be used in wide area measurement systems with many applications that are currently under development around the world [8].Presently, Phasor Measurement Units (PMUs) are the most accurate and advanced synchronized measurement technology available. They provide voltage and current phasors and frequency information synchronized with high precision to a common time reference. The measurement functions of a PMU are based on numerical algorithms. These algorithms must be both computationally efficient and suitable for real-time applications, particularly when the measurements are used to support dynamic-response applications. In this system, the necessary synchronized voltage and current phasors are produced by PMUs. The measurement data from these PMUs is transmitted through a Wide-Area Network (WAN).

In the past, analysis was an application of PMUs without wide-area communication where data was archived locally. However, it was not a useful tool for online (dynamic) control. Recently, Real-Time Control (RTC) of WAMS became a powerful control and analysis tool that provides a new view of power systems. This is achieved by improving communication network capabilities while maintain PMUs as a main component in the network. To achieve the potential benefits, advancements in time synchronization, must be matched by advancements in the areas of networks and data communication, where communication channels have become faster and more reliable in transmission and receiving PMU data from remote nodes to a central system. This will requires the development of applications, intelligent database, decision support system and expert systems that operate on data provided by PMUs. Although academia, vendors, utilities, and consultants have developed a large number of methods and algorithms and performed system analysis and studies to apply the technology, like any other advanced tool, PMUs requires the expertise to develop algorithms. For example, one of the proposed applications of PMUs is their use on control for monitoring, alarm, and control operations.

## 2. TECHNOLOGY INFRASTRUCTURE

### 2.1 Phasor Measurement Technology

The technology of synchronized phasor measurements is well established. It provides an ideal measurement system with which to monitor and control a power system, in particular during conditions of stress. it measures positive sequence (and negative and zero sequence quantities, if needed) voltages and currents of a power system in real time with precise time synchronization. This allows accurate comparison of measurements over widely separated locations as well as potential real-time measurement based control actions. Very fast recursive Discrete Fourier Transform (DFT) calculations are normally used in phasor calculations. Figure 1 shows a typical synchronized phasor measurement system configuration. The GPS transmission is received by the receiver section, which delivers a phase-locked sampling clock pulse to the Analog-to-Digital converter system. The sampled data are converted to a complex number which represents the phasor of the sampled waveform. Phasors of the three phases are combined to produce the positive sequence measurement. Any computer-based relay which uses sampled data is capable of developing the positive sequence measurement. By using an externally derived synchronizing pulse, the measurement could be placed on a common time reference. hus, potentially all compute syncmeasurement.

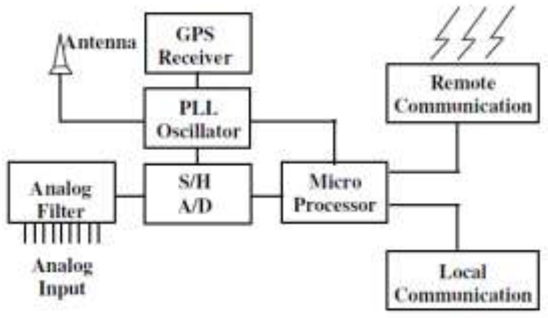


**Fig1. Block Diagram of PMU**

## 2.2 Communication Technology

Communications system is the important part of the wide area system. These systems distribute and manage the information needed for operation of the wide area relay and control system. The communications network will need to be designed for fast, robust and reliable operation. Among the most important factors to consider in achieving these objectives are type and topology of the communications network, communications protocols, and media used. These factors will in turn effect communication system bandwidth, usually expressed in bits per second (BPS), latency in data transmission, reliability, and communication error handling. Presently, electrical utilities use a combination of analog and digital communications systems for their operations consisting of power line carrier, radio, microwave, leased phone lines, satellite systems, and fiber optics. Fiber optic systems are the newest option. They are expensive to install and provision, but are expected to be very cost effective. They have the advantage of using existing right-of-way and delivering communications directly between points of use. In addition they have the very high bandwidth needed for modern data communications.

# 3. WORKING OVER A POWER SYSTEM

One recent developed technique which is used is WAMPAC with time synchronized measurement. It is a technique which transports the local information of selected areas to the remote location to work against the vast disturbances. PMU gives information about the current and voltage phasor, frequency and rate of change of frequency. These parameters are synchronized to a common reference time provided by Global positioning System (GPS). GPS operation is based on mathematical measurement algorithms [3]. With the development of technology advancements, the time delay in synchronized information has been steadily reduced from minutes, to seconds, milliseconds, and now microseconds.The Figure 2 shows the block diagram of suggested model, constituting a transmission line, PMUs on both ends of transmission line, which are used to get data from CT and PT and then calculates the real time Phasor of current, voltage, frequency and rate of change of frequency. These Phasor are synchronized with the time provided by GPS, all this data is transferred to the local PDCs (Phasor Data Concentrator), which in turn sends data to super PDC and then super PDC gives that data to data server.

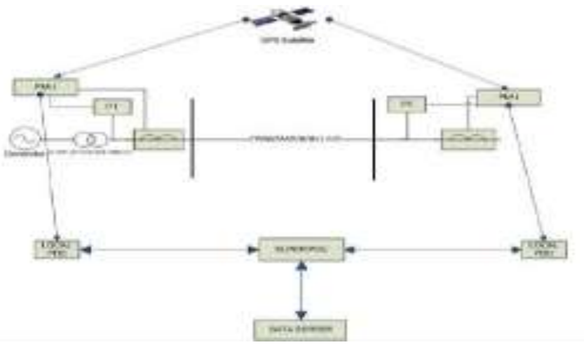

**Figure 2: Block diagram of WAMPAC**

## 3.1 State Of The Art and Related Work

As until today typically dedicated applications targeting either monitoring, protection or control are developed, the section is divided in these fields. Fig 3 summarizes essential wide-area applications emphasizing the partial overlapping of the three domains that should be addressed in an integrated WAMPAC system [2].

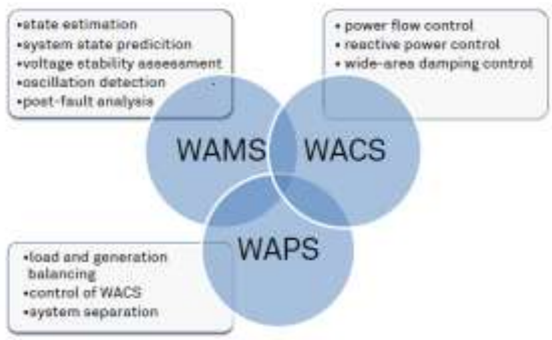


**Fig3: Applications for wide-area monitoring, wide-area protection and wide-area control**

## 3.2 Wide-Area Monitoring

A key enabler for modern wide-area monitoring systems (WAMS) is the introduction of multiple PMUs placed at several locations in the network as a complement to conventional measurements. The PMUs enable the availability of time synchronized snapshots of the network including voltage and current phase angles. A variety of WAMS applications has been proposed using these wide-area measurements. PMUs create a picture showing the stability status of the nodes in the monitored area. PMUs take this picture at the same reference time. Using real-time information from PMUs and automated controls to predict, identify, and respond to system problems; a smart grid can automatically avoid or diminish power outages, power quality problems and supply disruptions [5].A Phasor network consisting of PMUs spread throughout the power system, PDC collect the information from PMUs and GPS time stamping can provide a theoretical accuracy of synchronization better than 1 microsecond.The current magnitude for transmission line and generator are measured by PMU. Generator current is higher than transmission line because at generator terminal potential of 11kv, but at transmission line it is 500kv. The current magnitude is measured for all the phases and all the values are real and time synchronized taken at simultaneous time. Similarly the voltage magnitude is measured for all phases and time synchronized.

## 3.3 Wide-Area Control

The wide area controller is the centralized portion which is the major body of the whole wide area smart grid architecture which got its smart control due to its computational engine and information user defined cases. Due to these situations the WAC perfectly control its region through bidirectional communication.Wide-area control systems (WACS) can be deployed that exceed the functionalities of local control and respond faster than manual control from a control center. Besides the benefit of fast control in contingency cases, dynamic control is of growing importance along with the rise of fast controllable equipment such as HVDC and FACTS devices.PMU is a device for synchronized measurement of ac voltages and currents and the most common time reference is the GPS signal, having precision better than 1 microsecond. The calculated values from both ends of transmission line send to remote location and compared with their respective GPS time, to control the power flow. In the control room there are some pre-defined algorithms ,those values(send by the PMU) are then compared with those algorithms, if there is a difference in the values of voltage current and phase angle then the power that will flow is changed ,so to overcome that a signal is generated send it to the local area control room. Frequency load shedding format is the last control step for preventing electric power system from blackouts. It is the most universally used control system to balance the load and power demand. It performed with shedding the suitable amount of load for removing the overload situation in numerous steps with each step have its own set frequency and percent of load to be shed. The introduction of PMU in power system allows adaptive load shredding scheme in which the amount of quantity of load to be shed is determine adaptively according to the amount of the interruption.

## 3.4 Wide-Area Protection

The fast evolution of WAMS enables real-time processing of wide-area measurement data for the use in system protection applications. Comprehensive studies on Wide-Area Protection Systems (WAPS) with focus on the development of versatile fully automatic protection systems, which are able to handle large disturbances and to prevent extensive blackouts in large power systems The response time of protection system is in the range of milliseconds up to minutes. It depends on the application and the communication infrastructure. So in all such cases there is a need of protection which consists of the following factors:

- Classification of the disturbance
- Location of the disturbance
- Identification and prediction of disturbance

In an environment where the protected area is large, it would be very hard to design a protective or emergency control scheme based on fixed parameter settings [5]. Adaptive approach is preferred in such circumstances, possessing ability to adjust to changing conditions. Relays that participating in wide-area protection and control should preferably be adaptive i.e. should satisfy minimum requirements of having the ability to communicate with the remaining system.

## 3.5 Phase Angle Monitoring

Through PMU monitor real time Phase angle of different nodes accurately because it is time synchronized and accurate PAM is too much important for a power system [4]. PAM enables access in real time to the accurate phase angle difference between any pair of buses. PAM allows prediction of potential problems both locally and regionally. System operators and area coordinators can be assisted by PAM in a variety of real time operational situations, such as monitoring angle separation or rate-of-change of angle separation between two buses or two parts of a grid to determine stress on the system. The phase angle value across an opened tie line or an opened circuit breaker would guide an operator in circuit breaker closing. Closing would take place only if the phase angle was below a preset threshold. The information obtained from PMUs can be also included in the CB interlocking logic.

## 3.6 Frequencies and Rate of Change of Frequency Monitoring

Frequency and rate of change of frequency can be measured through PMU. Change in frequency can reflect the change in impedance of power system component. The rate of change of frequency gives the measure stability. Figure shows the model of frequency and rate of change of frequency measurement block. This model is integrated in PMU.

# 4. PROPOSED PLATFORM FOR WAMC

The core idea of the WAMC systems is the centralized processing of the data collected from various locations of a power system, aiming at the evaluation of the actual power system operation conditions with respect to its stability limits. Fundamental structure of the WAMC system can be explained from both from the hardware and software point of view.

## 4.1 Hardware Platform

The hardware can be explained based on the three stages of the data handling in WAMC.

- Data acquisition
- Data delivery
- Data processing

## 4.2 SOFTWARE PLATFORM

The software packages can be divided into following groups.

- Object linking and embedding (OLE) for a process control (OPC) server connecting the PMUs to the platform.
- The platform itself—storing the data and linking the software packages together.
- A GUI interpreting the result of the measurement and instability assessment to the user.
- OPC history data access (OPC HDA) provides a set of standard interfaces that allow clients to access historical archives of measurements to retrieve and store the data in a uniform manner.

# 5. ADVANCE APPLICATION BASED ON WIDE LOCATION

When enough measurements are available, it is possible to completely detect the status of each network element and to calculate each voltage and current of the network. This opens up for more advanced applications as described in the following sections.

### 5.1 Line Temperature Monitoring

Loading of the lines is in many cases constrained more by thermal limits than by voltage instability concerns. The thermal limit of a line is usually set according to conservative and stable criteria, i.e. high ambient temperature and no wind [1].This results an assumption of very limited cooling possibilities and thus low loading. However, often the ambient conditions are much better in terms of possible cooling. This is possible if an on-line working tool for line temperature assessment is available. One of the algorithms serves precisely this purpose.

### 5.2 Power Oscillation Assessment

Assessment is the algorithm used for the detection of power swings in a power system. The algorithm is fed with the selected voltage and current phasors. The algorithm processes the input phasors and detects the various swing (power oscillation) modes [6].

### 5.3 Frequency Stability Assessment

Frequency Stability Assessment receives the data from Basic Monitoring. The Frequency Stability Assessment algorithm estimates the impact of such a power unbalance on the frequency. If the estimated frequency is not acceptable, the proposed actions to reach the desired frequency are computed and proposed [7] .

### 5.4 Measures against frequency/angular instability

Frequency/angular instability occurs after the tripping of generators or heavily loaded trans- mission lines.

In the event of imbalance of generation and load, the optimal actions have to be determined to restore equilibrium taking the actual network topology into account. To prevent the spreading of frequency instability, which leads to large area disturbances, it is necessary to have information available on the power system conditions at several locations in terms of voltage and current phasors. In addition to this, a defence plan has to be established to determine which circuit breakers are to be blocked or to be tripped for under-frequency initiated load-shedding or, as last defence measure, islanding of subsystems.

## 6. CONCLUSION

The paper addresses the main reasons for execution of WAMPAC systems. A typical WAMPAC structural design is presented with its main building blocks (PMUs). It described online monitoring applications to significantly reduce investment cost for utilities while guaranteeing high levels of dynamic grid loading and availability. The paper also provided a general idea of the main WAMPAC applications and demonstrates some applications that is, dynamic recording, real time system state determination, phase angle and disturbance propagation monitoring, estimation of load model parameters, as well as protection and control related applications.

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