A New PMU Based Technique For Fault Detection In Transmission Lines

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Abstract- *Electric power systems account for a critical part of our society energy infrastructure. The power transmission systems are nowadays operated on the brink of their technical limits and hence they cause to instabilities and cascading failures than before.The objective of protection scheme is to keep the power system stable by isolating only the components that comes under the fault. The modernized power grids are complex and hence need to be monitored, control and protected by wide area measurement system (WAMS). The applications of PMUs in power system are extended to protection, control and monitoring of wide area of power system. Phasor Measurement Unit (PMU) has the ability to identify and track the phasor values of voltage and current synchronously on a power system in real time, which is crucial to the detection of disturbances and characterization of transient swings. The conventional methods that are been used for protection are not as accurate as the PMU because PMU uses GPS system for time synchronized data. The principle of the protection scheme depends on comparing positive sequence voltage magnitudes at each bus during fault conditions inside a system protection centre to detect the nearest bus to the fault. The purpose is to increase the overall efficiency and reliability of power system for all power stages via significant dependence on WAMS as distributed intelligence agents with improved monitoring, protection and control capabilities of power network.*

Keywords- Global Positioning System (GPS), Phasor Measurement System (PMU), Wide Area Measurement System (WAMS).

I. INTRODUCTION

Electrical utility have to face increasingly complex issues day by day in continuously evolving business management. System-wide disturbances are challenging problem as power system is more complex. There are some issues like power grid operate closer to their maximum capacity, need for accurate and better monitoring of the network, etc. When a major power system disturbance occur in a system the protection and control action are required to stop power system degradation, restore system to a normal state and minimize the impact of disturbance [1]. The present control actions are not suitable for a fast developing disturbance and may be too slow.

Wide Area Monitoring System (WAMS) is the modern concept in power system that has the capability of real time monitoring. WAMS became one of the most recent technologies that are popular for upgrading the traditional electric grid. The definition of WAMS is described on the [2, 3]. This upgrade has become a necessity to modernize the electricity delivery system following the occurrence of major blackouts in power systems around the world. Recent blackouts throughout the world have affected reliability of power supply in the electrical grids.

Presently, [4] the main technology used in it is PMUs and is the most precise and advanced technology. It gives information about the current and voltage Phasor, frequency and rate of change of frequency. This all information is synchronized with a high accuracy to a common reference time provided by GPS [5]. Effective utilization of this new technology is very much helpful to mitigate blackouts and to learn the real time behaviour of the power system. Time synchronization is not a new concept or a new application in power systems [6]. As technology advances, the time frame of synchronized information has been steadily reduced from minutes, to seconds, milliseconds, and now microseconds. This technology has been made possible by advancements in computer and processing technologies and availability of GPS signals. We are rapidly approaching an era where all metering devices will be time synchronized with high precision and accurate time tags as part of any measurements [7].

Phasor Measurement Unit (PMUs) are high speed power system devices which provides time-stamped synchronized measurements of phasors of voltage and currents in a real time which then be used for calculating voltage and current magnitudes, phase angles, real and reactive power flows, etc. [8]. The synchronization is achieved by the same time sampling of voltage and current waveforms from Global Positioning System (GPS) satellite timing signals. Synchronized phasor measurement gives the standards of power system monitoring, control and protection of the system to new level [9]. The advantage of referring phase angle with reference to global time is helpful for protection, monitoring and control of wide area power system.

II. PHASOR MEASUREMENT UNIT

PMU is the new technology which provides phasor information (both magnitude and phase angle) in common time reference. This technology is widely acknowledged as one of the most promising development in real time for protection, monitoring and control. The advantage of this new technology of referring phase angle to a global time reference is very much helpful for monitoring wide area network. PMU devices are now installed everywhere in the world to get GPS time synchronized information. With the advancement in technology, the microprocessor based instrumentation such as protection Relays and Disturbance Fault Recorders (DFRs) incorporate the PMU module along with other existing functionalities as an extended feature. Some important applications of PMU are as follows:

- Adaptive relaying
- Instability prediction and state estimation
- Improved control strategies
- Fast frequency regulation
- Fault and disturbance recording
- Transmission and generation modelling verification
- Wide area protection
- Fault location

Phasor is a representation of a sinusoid waveform that is time invariant in amplitude and frequency. Consider a sinusoidal voltage wave function given by,

$$V(t) = A\cos(wt + \theta)$$

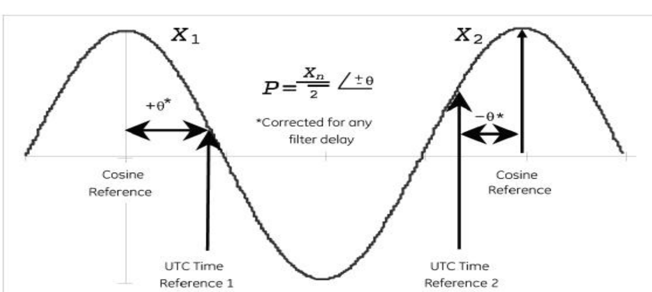

Figure 1. Phasor representation of sinusoidal waveform

A phasor represents this function as a complex number V with a magnitude A and a phase angle which can be written in a shorthand angle notation V=A $\angle\theta$. In many calculations, RMS value is used rather than magnitude. Therefore a scale factor of $1/\sqrt{2}\angle\theta$ is applied in the phasor representation which results in the phasor notation becoming

$$V(t) = A/\sqrt{2}\angle\theta\ .$$

PMU is a device which is used to collect and provide instantaneous phasors from desire places of applications, attached with an instantaneous time and date of measuring which is called time stamped data. Estimated phasors are called as synchrophasors. The phasors that is estimated from samples using a standard time as the reference for a measurement, and has common phase relationship as remote sites.

Although a constant phasor implies a stationary sinusoidal waveform, but it is necessary to deal with phasor measurements which consider the input signal over a finite data window in practice. In many PMUs the data window is in use which is one period of the fundamental frequency of the input signal. If the power system frequency is not equal to its nominal value, then the PMU uses a frequency-tracking step and therefore estimates the period of fundamental frequency component before the phasor is estimated. So, It clearly shows the input signal may have harmonic or non- harmonic components. The job of the PMU is to separate the fundamental frequency component and find its phasor representation. In phasor estimation calculations, very fast recursive discrete Fourier transform (DFT) calculations are normally used. a positive sequence voltage and phase angle of the positive sequence current is used in the suggested technique. To represent the input signal sampled data are used. Before data samples are taken, it is necessary that antialiasing filters be applied to the signal. The antialiasing filters are analog devices which limit the bandwidth of the pass band to less than half the data sampling frequency (NY Quist criterion). If Xk {k=1, 2, 3,........, N-1} are the N samples of the input signal taken over one period, then the phasor representation of an input signal is given by,

$$X = \frac{\sqrt{2}}{N}\sum_{K=0}^{N-1} xk\ e^{-jk\frac{2\pi}{N}}$$

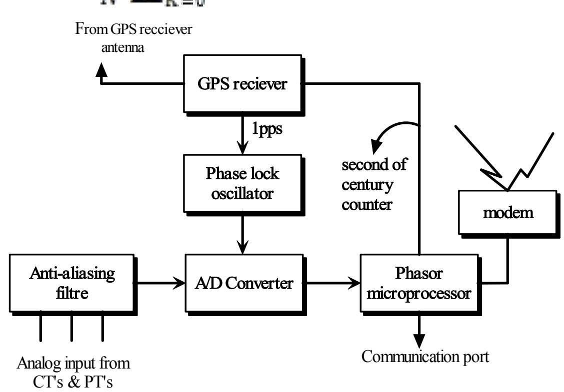

Figure 2. Block diagram of PMU

Real Time Monitoring & Control:

This application of phasor measurement technology facilitates the dynamic, real-time capture of system operating conditions. This information, provided to the system operator, allows for increased operational efficiency under normal system conditions and allows the operator to anticipate, detect and correct problems during abnormal system conditions. With comparision of current EMS monitoring software which uses information from state estimation and SCADA over several second intervals, time-synchronized PMUs gives introduction to the possibility of directly measuring the system state instead of estimating it which is based on system models and telemetry data. In real time,As measurements are reported 20-60 times per second, PMUs are well-suited to track grid dynamics.

There is only one known technology that can offer real time monitoring application which is nothing but Phasor measurement technology and It has benefist in three specific areas:

- **Angular separation analysis and alarming** – It enables operators to assess stress on the grid. And it allows early identification of potential problems both locally and regionally by Measurement of phase angle separation.
- **Monitoring of long-duration, low frequency, inter-area oscillations** – It gives accurate knowledge of inter-area oscillations allows operators to adopt a power transfer limit higher than the limit currently in use.
- **Monitoring and control of voltage stability** – It provides for a backup to EMS voltage stability capability.

III. PROPOSED TECHNIQUE

The condition of the fault occur on transmission line is mainly detected by two components. First is reduction in voltage of the transmission line because of the fault occurrence. The other component is the direction of the power flow after occurrence of the fault. Fault current direction is determined with the help of phase angle with respect to reference quantity. Direction of fault will be known by comparing the phase angle of the transmission line voltage and current. Mostly the voltage is used as reference polarizing quantity. The fault current phasor lies within two distinct forward and backward regions with respect to the reference phasor, depending on the power system and fault condition [10, 11]. Power flow in a given direction will result in a phase angle between voltage and current varying around its power factor angle ±. When the direction of power is opposite this angle becomes (180 ±) and when the fault goes in reverse direction, the phase angle of the current with respect to voltage will be (180 −) [11].

The main theme of this technique is only to detect the faulted area. Comparison of the measured values of the positive sequence voltage magnitude at main bus for each area is used to achieve this. The result of this in the minimum voltage value which shows the nearest area to the fault. Additionally, the absolute differences of the positive sequence current angles are calculated for all lines interconnected with this faulted area. On comparing these angles with each other, the maximum absolute angle difference value is selected to identify the faulted line. This operation can be mathematically shown as follows:

$$Min\ \{|V1|, |V2|\ ..\ |Vm|, ...\ .|Vn|\} \tag{1}$$

Where, PMU measures the positive sequence voltage magnitude of area “1”, “2”, “3”, “m”, to “n”. When the fault occurs on the grid output of the (1) shows the minimum positive sequence voltage magnitude. From this calculation the nearest area to the fault can be determined. In this case this area is shown by “m”.

After that there is need to compare the absolute differences of positive sequence current angles for all lines connected to this faulted “m” with the interconnected nearby area and then selecting the maximum one. This can be shown as:

$$Max\ \{|\emptyset m1|,\quad |\emptyset m2|,\quad |\emptyset m3|, ...\ |\emptyset mn|\} \tag{2}$$

Where, m and n are the interconnected area which shows the absolute difference of the positive sequence current angle of the transmission line. This can be shown as:

$$|\Delta\emptyset mn| = |\emptyset mn - \emptyset nm| \tag{3}$$

IV. TRANSMISSION LINE MODEL

As shown in fig. below, 220 KV interconnected transmission line network, 100 km transmission line. Generating station on one side and on the other side is load both are connected through interconnected lines. Fig. Is used to verify and explain the new principle of protection. Different fault conditions are simulated on that line using MATLAB software. The transmission line positive and zero sequence parameters are R1=0.10809Ω/km, R0=0.2188Ω/km, L1=0.00092H/km, L0=0.0032H/km, C1=1.25*10−8f/km, C0=7.85*10−9f/km. The distributed parameter model of transmission line is considered for analysis. A sampling frequency of 20 KHz for a system operating at a frequency of 50 Hz is used in this study. To demonstrate the potential of the approach only few cases of fault occurrence are demonstrated here.

When double line to ground fault occurs on the transmission line, the faulted signals of three phase voltage signals and three phase current signals are shown below in fig. 5. The fault is located on line 1 connecting area "2" and area "3" as shown in fig. When fault occurs the line connected between area "2" and area "3" are affected. The double line to ground faults voltages are shown in fig. 4. Three phase current of the lines related to faulted area in fig. 5. Positive sequence voltage magnitude for each bus is shown in fig. 6. Similarly, different fault conditions are simulated on the system using the proposed technique algorithm.

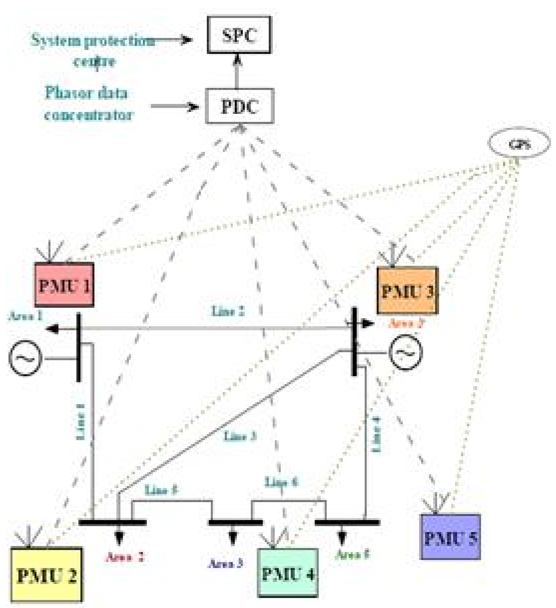

Figure 3. Matlab simulink block diagram

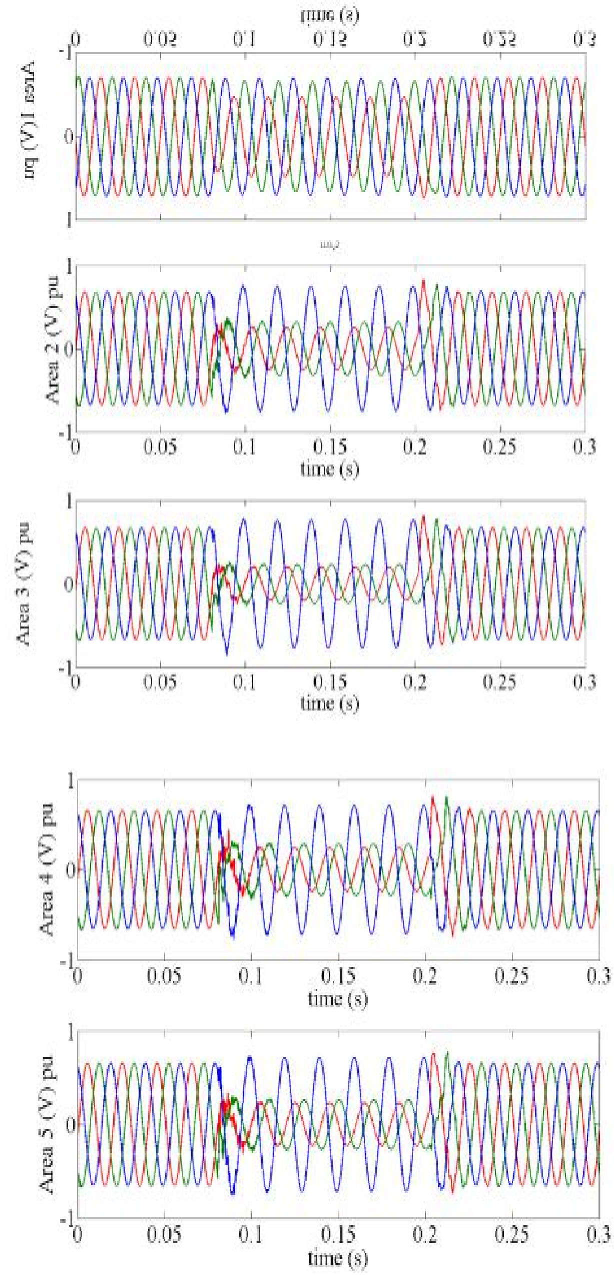

Figure 4. Three phase voltage signal at each bus

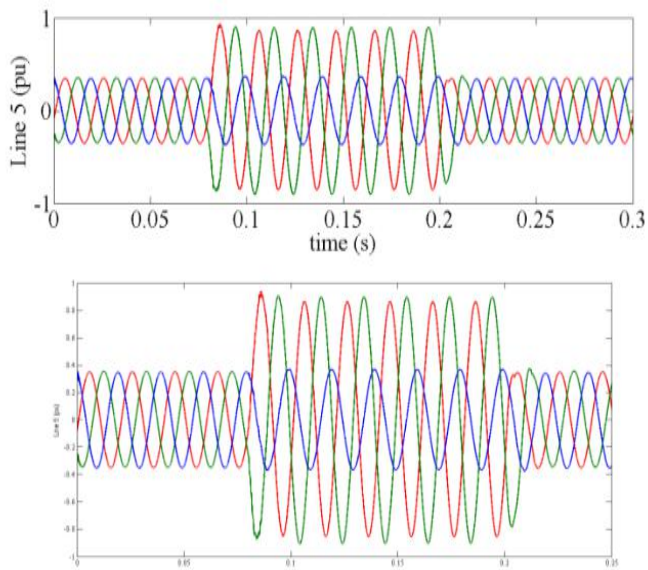

Figure 5. Three phase current signals for line connected to faulted area

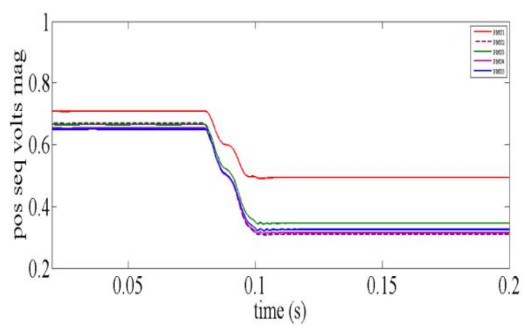

Figure 6. Positive sequence voltage magnitude for each bus

V. CONCLUSION

In this paper a new fault location algorithm for interconnected transmission lines has been presented. The algorithm uses the positive sequence voltage and current synchrophasors measured at each line end, and its main objective is to detect different fault locations. The algorithm has been tested for several fault types in along an interconnected transmission line and the results are in close agreement with the results published in the literature for other fault location algorithms faults in the line. The proposed technique is more accurate and reliable. This technique is adaptive and of high performance.

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