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Advancements in Wide Area Protection Monitoring and Fault Detection Using PMU

Anagha.V.Ravindranadhan, Anna Baby

PG scholar, Dept. of EEE, Adi Shankara College of Engineering & Technology, Mattoor, Kalady, Kerala, India[1]

Asst. Professor Dept. of EEE, Adi Shankara College of Engineering & Technology, Mattoor, Kalady, Kerala, India[2]

ABSTRACT: In order to improve power system monitoring, control and performance, measurement systems associated to power system should be strong and synchronised. Wide area measurement system is an emerging concept developed in order to fulfil the above objectives. Such a system has to communicate information to remote station, but all information should be time synchronised which neutralises time difference between the information's. PMU provides a complete observability upon the power system. The conventional system does not provide such an advantage as the measurements are not time synchronised. When the phasors are synchronised to Universal Time Coordinated they are termed as synchrophasors.

KEYWORDS: PMU, Time Synchronisation, Wide Area Monitoring Protection and Control (WAMPAC), Global Positioning System (GPS)

I.INTRODUCTION

Electrical power system is a complex system which incurs with many issues day by day, so it is very important to make the electrical supply reliable and uninterrupted. Wide area monitoring protection and control is a novel method proposed to bring about the local information of selected areas to remote locations to work against vast disturbances. Phasor is a representation of sinusoidal waveform which is time invariant in frequency and amplitude and has a magnitude and angle.PMU provides current and voltage phasor, frequency, rate of change of frequency and all this information are synchronised with a global positioning system. This time synchronised methodology is of high precision and accuracy. In conventional system distance relays are used and on a fault, chances are more for relay malfunction in tune with the zone division. So a novel method versatile to detect all malfunctions in transmission system is mandatory. Thus the PMU measurement has turned out to be a need. The synchronised phasor measurement unit was introduced in early 1980 and since that time it has turned out to be a mature technology with lot of applications which are still under developing stage. The scope of PMU increased with the happening of blackouts around the world. Hence the wide area measurement system using PMU and Phasor data concentrator .The data provided by PMU are accurate and exact sequence of events could help to analyse the malfunctions that has contributed to the catastrophic failure of power system.

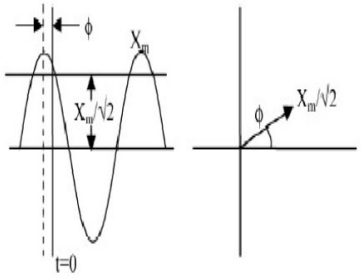

Fig:1

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A pure sinusoidal signal can be represented by unique complex number known as a phasor, Fig: 1.

Consider sinusoidal signal

$$X(t)=Xm\cos(wt+ø)\ .$$

Hence the phasor representation of this sinusoid is given by

$$X= Xm/\sqrt{2}\ (cosø+ jsinø).$$

The magnitude of phasor is the RMS value of sinusoid and phase angle is ø. These measurements have been sited to monitor large generating sites, major transmission path, significant control points.PMU provide all significant state measurements including voltage magnitude, voltage phase angle and frequency .PMU installed in substations sent data to utility control centres. This allows data to be used in System Protection Centre .PMU measure bus voltages and all significant line currents. The measurements are sent to Phasor Data Concentrator (PDC). PDC correlates data time tag to create system wide measurement. WAMPC is used to detect abnormal system conditions and take corrective actions intended to minimise the risk of wide area disruptions.

II.SYSTEM MODEL AND ASSUMPTIONS

The whole design is done in MATLAB SIMULINK and the results are analysed to validate the efficiency of the system. Initially PMU model has to be realised and the model is installed in various locations of a wide area monitoring system. The wide area monitoring system has been provided with various loads such as industrial, domestic and commercial to show the performance of PMU upon load variations. By tracking the difference between the outputs of PMU in and out of the system we could prove it is suffice for a wide area monitoring protection and control. On going to the fault detection in PMU positive phase angles and voltages should be extracted from the PMU. The positive phase angles are measures in the counter clockwise direction in real axis. If the frequency is not constant the input signal may have harmonics and non harmonic components. Here the voltages are used as reference polarising quantity. When a fault happens the direction of power flow reverses. On considering the wide area measurement system consider all buses and find the magnitude of positive sequence voltage and find the minimum voltage. The fault will be incurred in that area, and it is necessary to calculate positive sequence current angles of all lines connected to the faulted area. Compare the angle differences and gets the absolute differences to get the faulted line .The proposed method also tracks upon the frequency and also rate of change of frequency. Thus it could be concluded that PMU could detect abnormalities associated to power system and is helpful for phasor data collection for various applications.

III.BASIC MEASUREMENT CONCEPT

The phasor measurement unit in Fig: 2 are capable of measuring the synchronised voltage and current phasor in power system. The commercialisation of GPS with accuracy of timing pulses in order of one microsecond made possible the commercial production of phasor measurement units. It is a promising device for future power system. The distinction from other measurement modules is its capability to provide synchronised data's from widely dispersed locations, the analog inputs are the voltages and currents provided by the secondary winding of the three phase voltage and current transformers. These analog inputs go into an anti-aliasing filter. An Antialising filter is analog devices which limit the bandwidth to satisfy the Nyquist criterion. This filters out the input frequencies that are higher than the Nyquist rate with respect to the corresponding cut-off frequency of the analog anti-aliasing filters. This signal is then given to a digital decimation filter which converts the sampled data to a lower sampling rate. The analog AC waveforms are digitized by an analog to digital convertor for each phase. 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.

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Synchrophasor standards are:

- **Standard IEEE 1344**

The idea of synchronized phasor was developed in 1980 and hence came the synchrophasor standard IEEE 1344 by 1995. This was created to introduce synchrophasors to the power industry and set basic concepts for the measurement and methods for data handling. It introduced a Phasor measurement unit (PMU) which is a device and estimates synchrophasor equivalent quantities for an AC input.

- **Standard IEEE C37.118-2005**

This standard provides a method to qualify the measurement, tests to be sure that the measurement conforms to predefined definition, and error limits for the test. It also defines a data communication protocol, including messages formats for communicating this data in a real time system. In the first major improvement, C37.118 added a method for evaluating a PMU measurement and requirements for steady-state measurement. Total vector error or TVE compares both magnitude and phase of the PMU phasor estimate with the theoretical phasor equivalent signal for the same instant of time. TVE provides an accurate method of evaluating the PMU measurement Second C37.118 expanded the communication method to include higher order collection and improved identifications. The basic status was improved to include indications of dataQuality.PMU identification was added to all messages. The concept of phasor data concentrator (PDC) which included data from several PMUs introduced. Data type and classes were indentified. The underlying data communication protocol was left to users, and several industry based standard methods have been developed that support C37.118.The standard C37.118-2005 has been very successful. Dynamic measurements were not addressed in C37.118-2005 due to time and test experience constraints In addition, frequency measurements have always been a part of the data reporting, but the standard has no requirements for them. These issues and the growing need to address the communication compatibility with standard IEC61850.

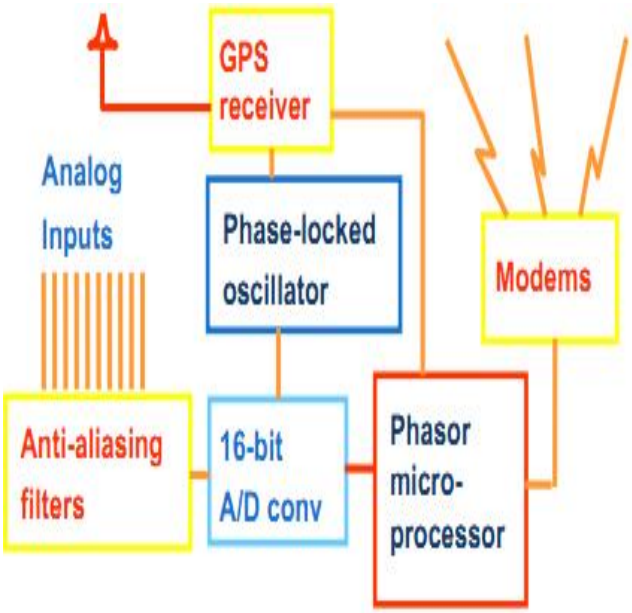

Fig: 2

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V. RESULT AND DISCUSSION

The PMU module was designed - Fig: 3 , Here the three phase signal is accepted and it is discretised to extract sequence components. The magnitude and phase angle is obtained as output. Frequency is also evaluated.

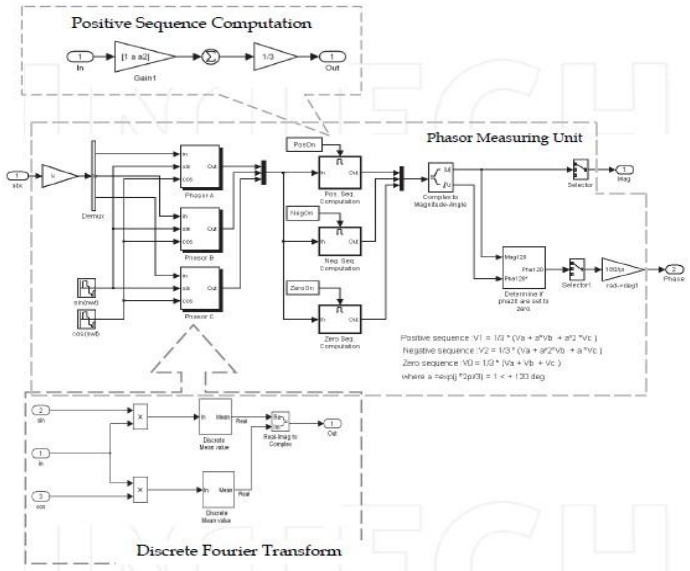

Fig: 3

Wide area monitoring protection and control

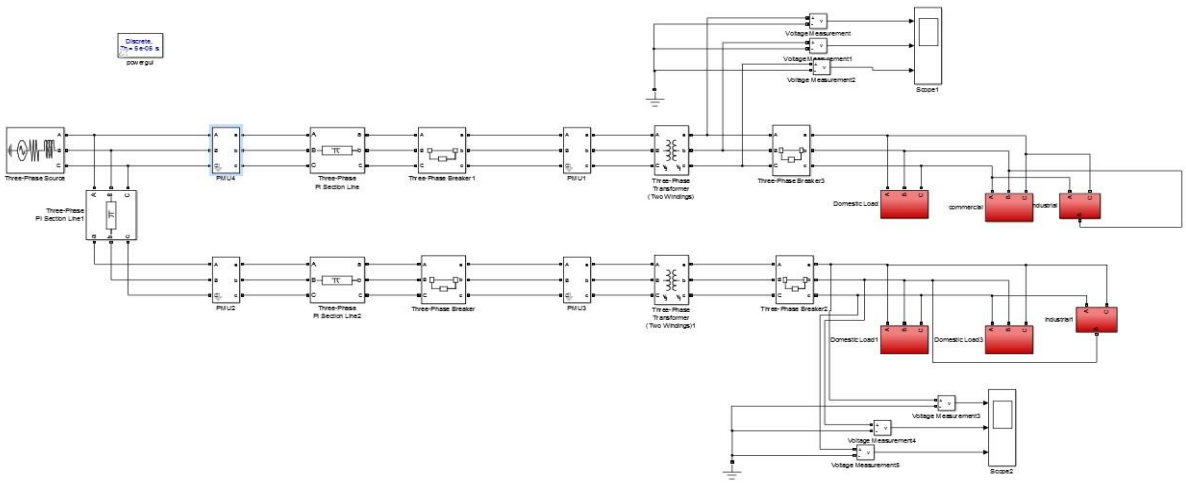

Fig: 4

In Fig4: The PMU designed in Fig 3 is placed in a wide area. The wide area is chosen so as to show the changes in measurements by various pmu dispersed in various locations. For the same, we have kept four PMU with a minimum distance of 200km between two of them.

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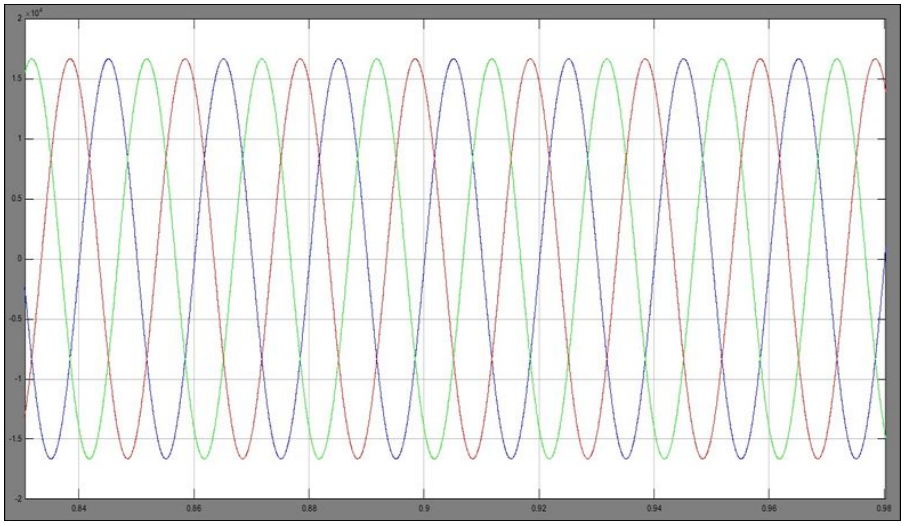

Fig5: Voltage

Fig: 5 -We have provided with voltage at input and how effectively the PMU tracks the voltage is shown here

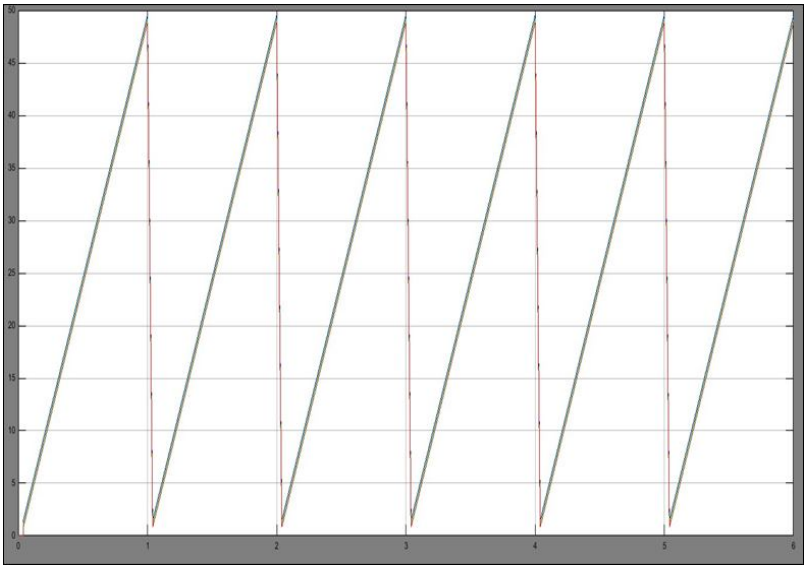

Fig: 6 Frequency

Fig: 6 - shows the frequencies at the three phases, evaluated by counting the zero crossing in every cycle to rate the frequency

Voltage and current of faulty area is to be evaluated and this is done by extracting the evaluated parameters from the PMU's in various locations and analyzing the results by incorporating symmetrical and unsymmetrical faults in various location of wide area (Fig 4).

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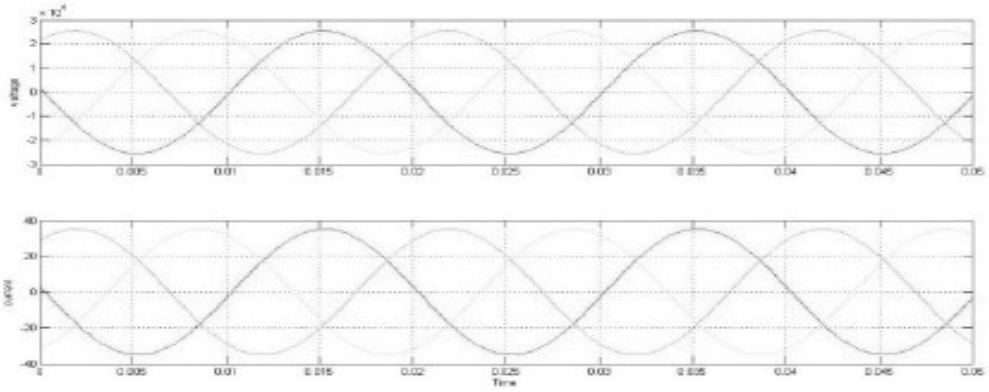
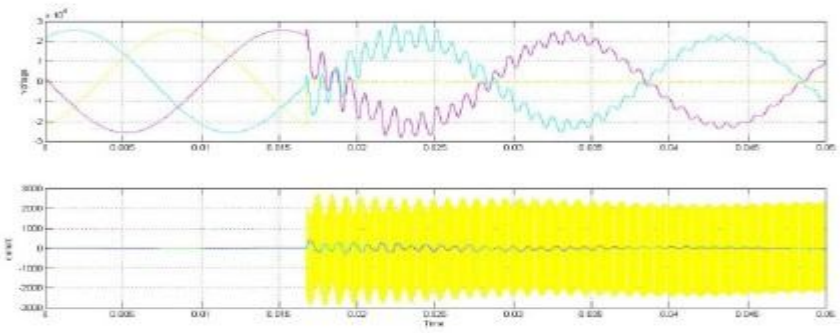


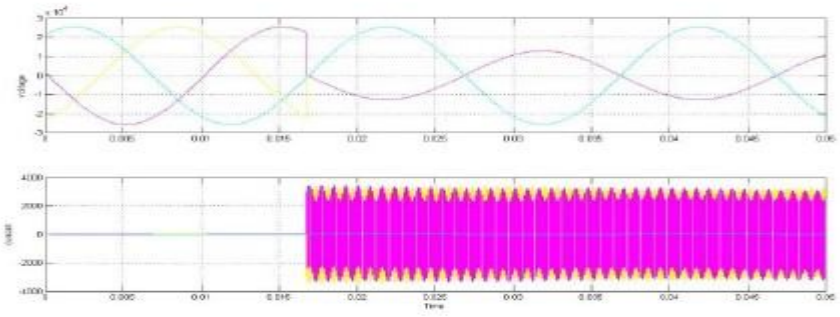
Fig: 7



LG fault

Fig: 8

Fig 8 shows the voltage and current when a line to ground fault occurs in the wide area and what could be the possible output of PMU near to the faulted area.



Line To Line Fault

Fig: 9

Fig 9 provides the PMU output for a Line to Line fault in wide area.

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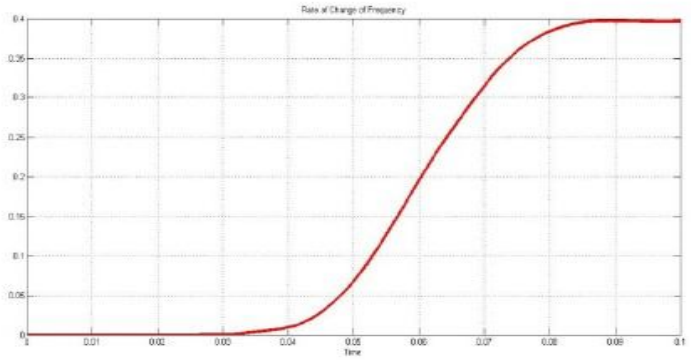

Rate of change of frequency

Fig: 10

VI.CONCLUSION

The present day power system has many major challenges and the most important one is the faults happening in measurement. So it is important to find an alternate to the issue. Power system issues has been analysed and some of the major issues where addressed. PMU system was designed and execution of wide area monitoring protection and control was conducted. Fault detection in transmission system was performed with the aid of synchrophasors. The PMU system was analysed and concluded as a better measurement system for the future power system.

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