Transmission Line Protection by Using Synchrophasor

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Abstract— The paper aims at studying the Synchrophasors technology which overcomes various limitations of the power system. The basic limitation of control from a substation has been shifted to central control by the means of this technology. These schemes based on the Synchrophasors technology are also known as Wide Area Measurement Systems (WAMS). The technology aims at visualization of magnitude and angle of each phase of the three phase voltage/current, frequency, rate of change of frequency and angular separation at every few millisecond interval (say 40 milliseconds).

Key words: Synchrophasor, Negative sequence impedance, Global positioning system, PMU, SCADA, phase angle, impedance

I. INTRODUCTION

The most common technology adopted today is SCADA(supervisory control and data acquisition). SCADA is a system operating with coded signals over communication channels so as to provide control of remote equipment (using typically one communication channel per remote station). The supervisory system may be combined with a data acquisition system by adding the use of coded signals over communication channels to acquire information about the status of the remote equipment for display or for recording functions.

Even after the popularity of the system there are many short comings which are mentioned in this paper. Hence there has been advancement in the research of a new technology called the 'Synchrophasor Technology' State Estimation (SE) solution are derived from SCADA data, SCADA provides the state of the power system. Whereas Synchrophasor technology can supplement and eventually replace the SCADA technology. There are many advantages of synchrophasor technology over SCADA 1) direct measurement (as values are Calculated using model-based SE solution from SCADA data);2) time-stamped data, which is accurate within tens of microseconds and 3) high resolution.

THe Synchrophasor technology has been first introduced in 1980s. After that American Electric Power (AEP), Bonne ville Power Administration (BPA), Southern California Edison (SCE), New York Power Authority (NYPA), universities such as Virginia Polytechnic Institute (VPI), have been conducting R&D to explore and advance the application of synchrophasor technology. Recently, The R&D pace has accelerated due to active participation and leadership provided by US Department Of Energy (DOE) and North American ElectricReliability Corporation (NERC).

II. WHAT DO YOU MEAN BY SYNCHROPHASOR???

A sinusoidal voltage or current waveform is describe as an electrical phasor, electric phasor is a complex number which consists of magnitude and relative angle, When these phasors are measured simultaneously and synchronized with a precise clock that is through GPS (Global Positioning Satellite),than these phasors are referred to as Synchrophasor. Synchrophasor can be defining as time-synchronized phasor measurements.

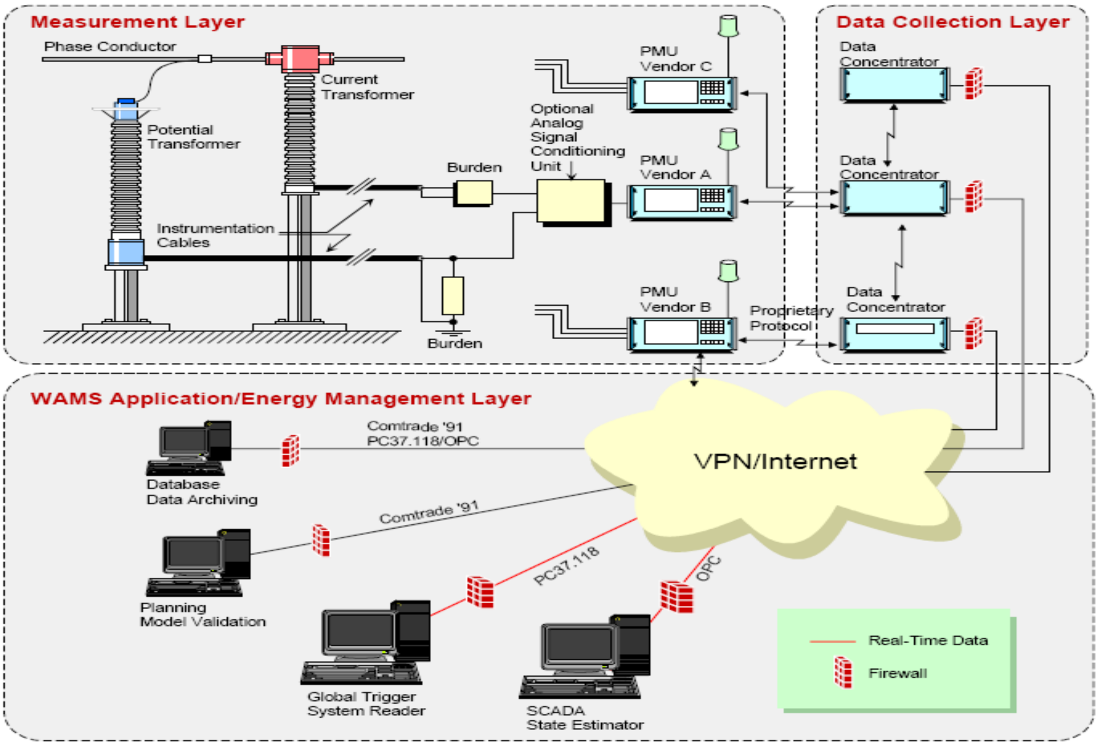


Fig. 1: Synchrophasor Infrastructure

Broadly synchrophasor consists of 1) Measurement Layer, 2) Data Collection Layer 3) Application Layer. Measurement layer made up of several PMUs,; Data Collection Layer, made up of phasor data concentrators (PDCs) and Application Layer, made up of tools which are use to convert the PMU data into real time information for grid operators or for off-line analysis.

Typically, PMU data from a transmission substation consist of the positive-sequence bus and/or line voltage phasors, line current phasors, bus frequency and line MW/Mvar flows. All these values are time-stamped using Universal Time Coordinate (UTC) standard and synchronized using GPS communication. PMU data have high-resolution, with sampling rate in the 10-60 samples per second range. PMUs can also measure individual phase voltages, phase currents, as well as harmonics.PMU data are positioned to provide situational awareness across a wide area of power system.Synchrophasor technology for monitoring and control will facilitate the evolution of the existing grid into a smarter transmission grid.

A. Synchrophasors Working:

A reference waveform is created in each PMU based on satellite clock same standard Reference are taken on each PMU; so that voltages and current from anywhere in the system can be compared. It can be better understand by diagram given below.

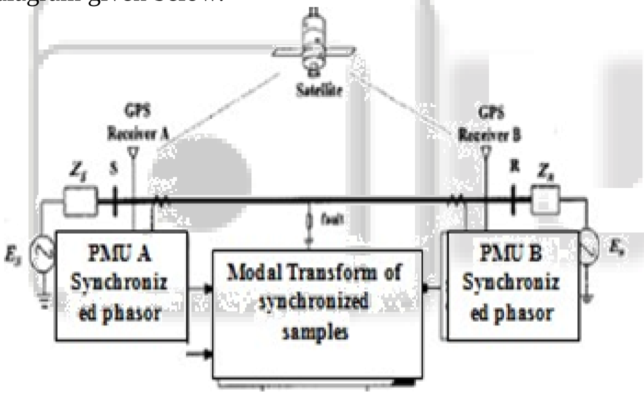


Fig. 2: A diagrammatic explanation of synchronism via GPS

Consider a sinusoidal wave function

Consider a sinusoidal wave function

$$V\ (t) = A\cos(2 * \pi * f * t + \theta)$$

Synchronized phasor can be given as "the magnitude and angle of a cosine signal as referenced to an absolute point in time."

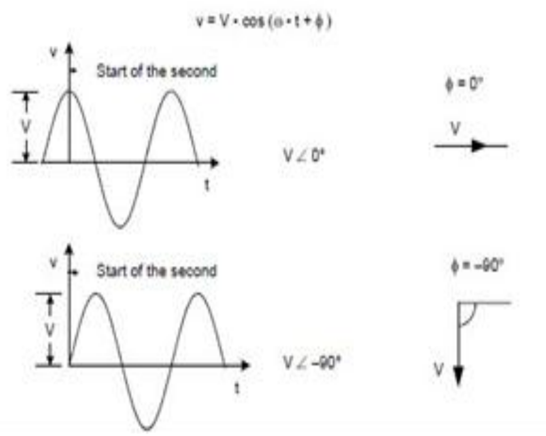


Fig. 3: Synchrophasor diagram and angle convention

The time reference can be given by a highly accurate clock with coordinate universal time, such as a Global Positioning System clock. From figure 1 above, the phase angle is calculated by the phase shift between the peaks of the sinusoidal and the angle at reporting time. In the top of the figure, the reporting time's phase is the peak of the sinusoid; therefore the angle of the synchronized phasor is 0. In the second diagram of Figure 2.1, positive zero synchronization with the second pulse; the phase angle is -90 degrees. With the synchronizing process, two different signals which might be thousands of kilo miles apart can be represented on one phasor diagram for analysis. If the source frequency keeps constant, the phase angle from the measurement will be constant all the time. However, in the real world, the system frequency will be an off-nominal frequency the signals will include noise, so the phase will vary at different times. The IEEE standard assumes the waveform in the steady-state with rated frequency. It has no requirement for phasor measurement values during transient conditions. However, the method for adjusting the measurements for off-nominal conditions will be introduced later2.1 Review Stage.Relay determines the direction of fault by comparing thephase angle relationship of phase currents to phase voltages In faulted conditions there will be an approximate 180 degree difference of calculated Z1, Z2 and Z0 for faults in forward direction and reverse direction from relay.

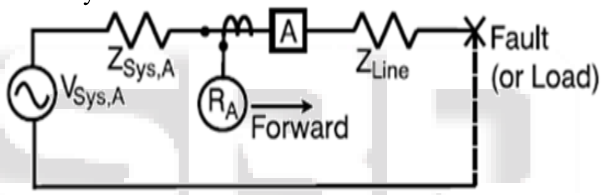


Fig. 4: The three phase voltage drop equation for a system voltages at two defined locations are VSys and Vfault

$$\begin{bmatrix} V_{A,Sys} \\ V_{B,Sys} \\ V_{C,Sys} \end{bmatrix} - \begin{bmatrix} V_{A,Fault} \\ V_{B,Fault} \\ V_{C,Fault} \end{bmatrix} = \begin{bmatrix} Z_{AA} & Z_{AB} & Z_{AC} \\ Z_{BA} & Z_{BB} & Z_{BC} \\ Z_{CA} & Z_{CB} & Z_{CC} \end{bmatrix} \begin{bmatrix} I_A \\ I_B \\ I_C \end{bmatrix}.$$

When the impedances are highly balanced

i.eZAA=ZBB=ZCC,

ZAB=ZAC=ZBA=ZBC=ZCA=ZCB=0

$$\begin{bmatrix} V_{0,Sys} \\ V_{1,Sys} \\ V_{2,Sys} \end{bmatrix} - \begin{bmatrix} V_{0,Fault} \\ V_{1,Fault} \\ V_{2,Fault} \end{bmatrix} = \begin{bmatrix} Z_0 & 0 & 0 \\ 0 & Z_1 & 0 \\ 0 & 0 & Z_2 \end{bmatrix} \begin{bmatrix} I_0 \\ I_1 \\ I_2 \end{bmatrix}.$$

At the remote system, V0 = V2=0 and V1 ≤ 1.

At the other end, i.e at the fault location,

Every type of fault will have differing values of V0, V1 and V2.

$$\begin{bmatrix} V_{0,Relay} \\ V_{1,Relay} \\ V_{2,Relay} \end{bmatrix} = \begin{bmatrix} 0 \\ V_{1,Sys} \\ 0 \end{bmatrix} - \begin{bmatrix} Z_{0,Sys} & 0 & 0 \\ 0 & Z_{1,Sys} & 0 \\ 0 & 0 & Z_{2,Sys} \end{bmatrix} \begin{bmatrix} I_{0,Relay} \\ I_{1,Relay} \\ I_{2,Relay} \end{bmatrix}.$$

If Z0, Z1, and Z2 are divided into two impedances as line impedance and source impedance, equation will become
As V2Sys=0 and V0Sys=0 ,

$$\begin{bmatrix} 0 \\ V_{1,System} \\ 0 \end{bmatrix} - \begin{bmatrix} V_{0,Fault} \\ V_{1,Fault} \\ V_{2,Fault} \end{bmatrix} = \begin{bmatrix} Z_0 & 0 & 0 \\ 0 & Z_1 & 0 \\ 0 & 0 & Z_2 \end{bmatrix} \begin{bmatrix} I_0 \\ I_1 \\ I_2 \end{bmatrix} .$$

The angle of Z0,Relay and Z2,Relay is the source of determining the direction to a fault. Z0 and Z2 at the relay to either match the source impedance angle or to be inverted by 180 degrees.

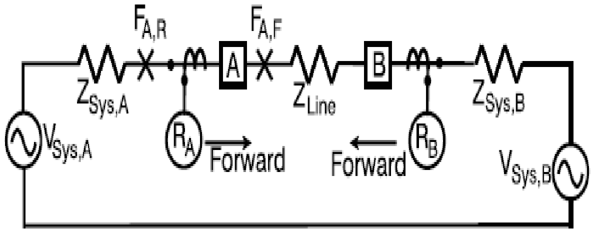


Fig. 5:

For fault FA,F and FA,R
The impedance seen by relay RA will be

$$Z_{0,Relay,Fault\ A,For} = -Z_{0,Sys,A}$$

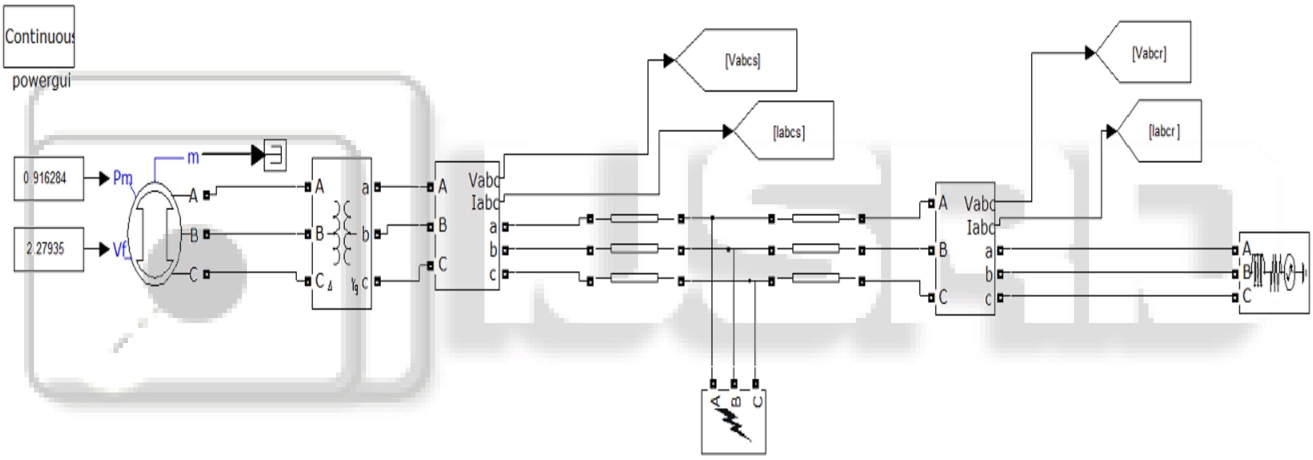
$$Z_{0,Relay,Fault\ A,Rev} = 1\angle 180^0 \left(-Z_{0,Sys,B} - Z_{0,Line}\right) = \left(Z_{0,Sys,B} + Z_{0,Line}\right)$$

$$Z_{2,Relay,Fault\ A,For} = -Z_{2,Sys,A}$$

$$Z_{2,Relay,Fault\ A,Rev} = 1\angle 180^0 \left(-Z_{2,Sys,B} - Z_{2,Line}\right) = \left(Z_{2,Sys,B} + Z_{2,Line}\right)$$

B. Simulated Work:

For the design of block which predicts the stability and instability of system we need a power system model on which we can implement phasor measurement units (PMU). So the following figure shows Power System Mode



The above model shows a single machine power system. It consisted of a synchronous machine of 500MVA connected to step up transformer (step up the voltage) then a Transmission (Distributed Parameter) and then to infinite bus (Three phase source) .We are mainly focused on protection of transmission line hence two voltage and current Measurement Blocks are placed at receiving and sending ends of transmission line, which symbolically represent PMU.

Fault is occurring at 5th cycle and getting cleared at 10th cycle of frequency 60Hz. That is at 0.0833sec fault occurred and cleared at 0.166 sec

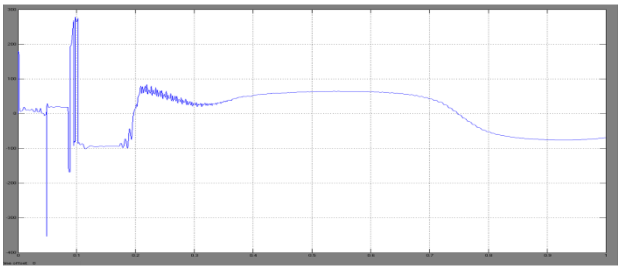


Fig. 6: Negative sequence sending end impedence phase angle for forward fault

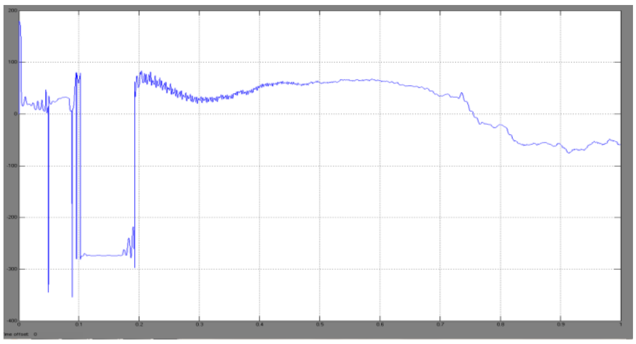


Fig. 7: Negative sequence sending end impedence phase angle for reverse fault

Phase Angle of negative sequence impedence for forward fault is -90 degree and for reverse fault -270 degree. There is exactly 180 degree difference for forward and reverse fault.

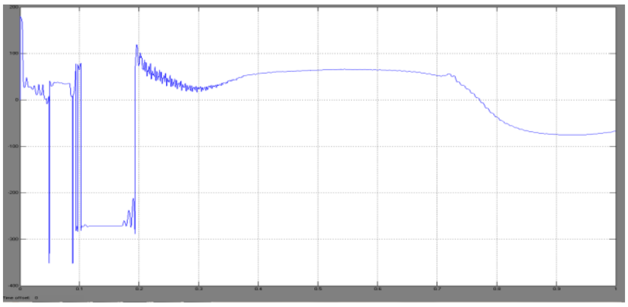


Fig. 8: Negative sequence receiving end impedence phase angle for forward fault

Negative sequence impedence phase angle of sending end and receiving end are same for reverse fault. Fault is occurring before for both the realays.

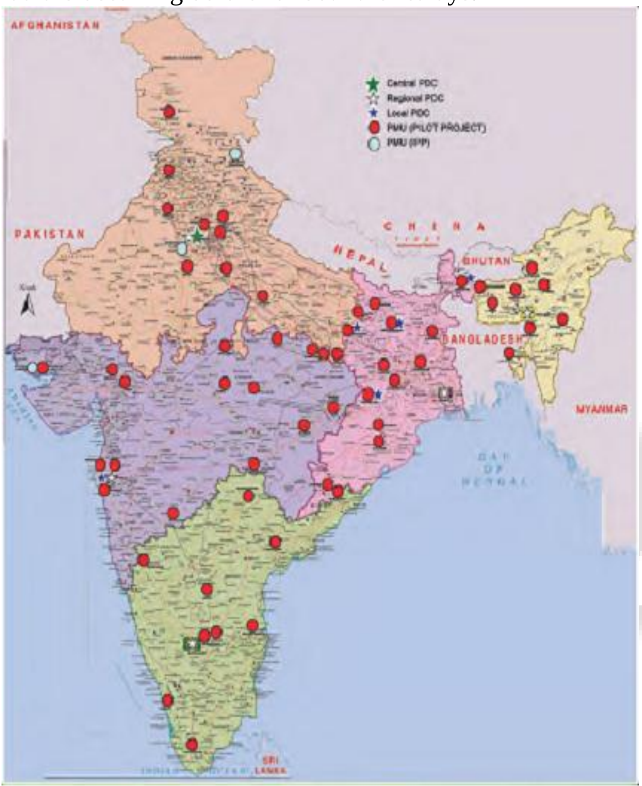


Fig. 9: Networked PMUs in India December 2013

III. CONCLUSION

Synchrophasors solve the problem of time incoherency required for wide-area power system control. With the ability to use time-synchronized measured values from across power systems, new protection and control schemes like these are being implemented today.

For monitoring purposes, it is advantageous to have PMUs at all critical locations. Time synchronized event records have been proven valuable in wide-area disturbances. Long-term disturbance recording using synchronized phasor measurements is improving power system analysis and operations. Low-speed and high-speed SCADA-based control is practical without the need for additional equipment. Conversion of standard synchrophasor or automated control systems is available and proven.

REFERENCE

[1] Role of Synchrophasor Technology in the Development of a Smarter Transmission Grid. By Navin B. Bhatt, Fellow, IEEE
[2] https://www.selinc.com/synchrophasors/
[3] An Adaptive PMU Based Fault Detection/Location Technique for Transmission Lines—Part II: PMU Implementation and Performance Evaluation. By Joe-Air Jiang, Ying-Hong Lin, Jun-Zhe Yang, Tong-Ming Too, and Chih-Wen Liu, Member, IEEE.
[4] A New Protection Scheme for Fault Detection, Direction Discrimination, Classification, and Location in Transmission Lines. By Joe-Air Jiang, Member, IEEE, Ching-Shan Chen, Student Member, IEEE, and Chih-Wen Liu, Member, IEEE.
[5] Directional Overcurrent Relaying (67) Concepts John Horak, Member, IEEE, and Walt Babic, Member, IEEE Basler Electric.
[6] Synchronized Phasor Measurement Applications in Power Systems – Jamie De La Ree, VirgilioCenteno, James S. Thorp and A.G.Phadke, IEEE Transactions on Smart Grid, Vol.1, No.1,JUNE 2010
[7] Exploring the IEEE Standard C37.118–2005Synchrophasors for Power Systems – K.E Martin,D.Hamai, M.G. Adamiak, D. Karlsson and E.Price
[8] Transient stability analysis with equal area criterion for out of step detection using phasor measurement units - A.Y.Abdelaziz, Amr M. Ibrahim , Zeinab G. Hassan , International Journal of Engineering, Science and Technology International Journal of Engineering, Science and Technology Vol. 5, No. 1, 2013, pp. 1-17
[9] Synchrophasorsinitiatives in India-Power System Operation Corporation Limited
[10] Synchronized Phasor Measurements and their Applications - A.G.Phadke andJ.S.Thorp, ISBN-978-0-387-76535-8

