[Singh * *et al.*, 6(12): December, 2017]
IC™ Value: 3.00
ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

IMPLEMENTATION OF IEEE BUS SYSTEMS WITH OPTIMUM PLACEMENT OF PHASE MEASUREMENT UNIT (PMUS) USING PSAT TOOLBOX

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DOI: 10.5281/zenodo.1116734

ABSTRACT

In the recent years many of the world's powers has seen the days in which a major power outages has occurred. Even the world has seen the powerless days and nights. To overcome this blackout PMU is used. Phase Measurement Unit (PMU) emphasize on the synchronization of voltage & current. To find optimized location for placement of PMU is one of major requirement of an efficient network. In this paper, Depth First & Graph Theory algorithms are used to find the optimal placement of PMU. MATLAB 2016b is used for this purpose. PSAT toolbox in the MATLAB is used. IEEE 14 buses are used in this research.

KEYWORDS: Phase Measurement unit (PMUs), Power System Analysis Toolbox (PSAT).

I. INTRODUCTION

PMU basically works on the synchronization of voltages and currents with a continuously available clock frequency signal that may be received from a global network such as geo – satellite or GPS systems. Voltage is a vital characteristic to be looked after. Any variation of increase or decrease in voltage may lead to critical situations worsen to blackout. With the use of a precisely synchronized Phasor in real time environment, the detection of imbalances in voltage levels may be help in controlling the situation before it may become alarming. So voltage measurement plays a vital role in stabilizing a transmission system. Power is directly related to voltage. Any variation in voltage may lead to consecutive power flow variation in a system. In this concern, even SCADA systems may mislead the controller as it just indicate and don't measure the parameters. So power measurement is also vital for stable grid system.

In power distribution systems, generally frequency is same all over for example in India it is 50Hz. But due to some unavoidable circumstances such as heavy lightning or other natural or unnatural disturbances, there might be a recognizable variation in frequency of the power that flows in a system. This shifted frequency may be harmful for the end users as the supply might be connected to a major or expensive or even lifesaving equipment or machinery. In such a case, a measurement of frequency is one of a major requirement along with voltage or power measurement.

Integration of PMUs with GPS trans-receiver, the base station may be able to send and receive the data with synchronization from each PMU in real time. A system should be design so that the location of the breakdown or problem over transmission can be identified in a real time and detection of phase difference between different PMUs is incorporated. Phase angle between the voltage phase and current phase as the basic measuring function of PMU has been utilized to monitor the condition of power networks.

Theoretically, the active (real) power flow in a distribution line is proportional directly to the trigonometric sine of the angle difference between voltages that are at the two terminals of the line. In that case, the angle difference was deemed as a special consideration to manage and operate the power network. In the early 1980s, novel phase angle measurement equipment was introduced.

The communication channel that is based on LORAN-C, GOES satellite Communication system and the HBG radio trans-reception was intensively used to maintain the reference signal for the purpose of synchronization. Researchers established the local phase angle with respect to the time reference for resolving zero crossing of the phase voltage. The phase voltage was referred to the common reference signal and the differences between the phase angle between two sets were computed.

In a very large power distribution system, the placement of PMUs is done strategically so that they are dispersed all over the grid. As there are multiple data inputs from various PMUs, these data are guided to a Phasor Data Concentrator. It is also called PDC. A PDC is generally followed by a Master PDC. The data from Master PDC is further collected at Super PDC. Likewise the data from various PMUs is collected at a single place. Hence a database is compiled from data received from different PMUs at different locations in real time within a very less time span. Then this collective data can be utilized for various software applications to generate specific controls over the transmission system. This also helps the controller to decide necessary action to stabilize power system and maintain uninterrupted power flow. PMUs are numerically nomenclature to differentiate from one another so that the decision on data analyzed is vectored back to the respective network or Bus.

II. METHODOLOGY

The phase measurement units have a very vast area of application due to their accurate, precise and quick operation. But as discussed earlier, due to its high cost, phase measurement unit cannot be placed at each bus of transmission system. Hence it is very important to know the optimum position of placing phase measurement units over system which may use minimum number of units with maximum observability of distribution system estimating its state parameters within the permissible economical limits.

In this research IEEE 14 bus test systems are taken for studying the various optimal PMU placement methods and comparing their results. Ideal number of PMUs & their location will be detected in the test bus system. To fulfill this purpose test IEEE- 14 bus system. The different systems are modeled & simulated using PSAT. Then different techniques and algorithms such as depth first method & annealing methods are applied. Optimal location of PMUs is found exercising the following methods. Algorithms for different methods are given below:-

1. Depth First Search

In this method zero injections are not taken into account. Steps are taken into account i.e. in the beginning PMU is employed at the bus having maximum number of coupled buses/branches and the process can be further repeated till the complete system becomes observable. The algorithm shown in the Fig1.

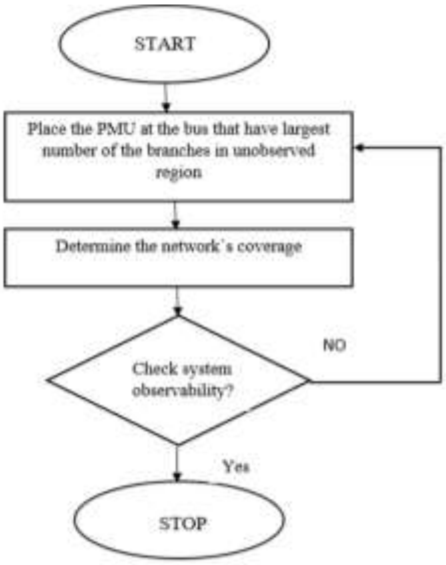

Fig1: Algorithm of Depth First Method

2. Graph Theoretic Procedure

Graph Theoretic method is similar to Depth First search method (DeFS), except that it takes into account zero injections. The process and flow of methods is very much similar to that of depth first method. The algorithm is shown in the Fig2.

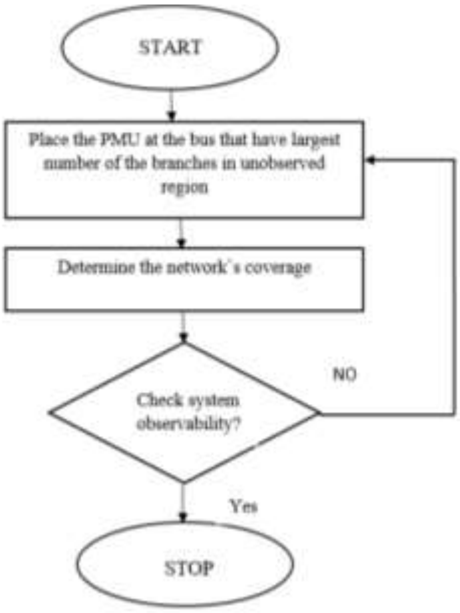

Fig2: Algorithm for the Graph theory method

MATLAB is a technical language that has extended the limits of researchers and researches. The calculations are performed at a higher speed and accuracy as compared to other computational software available. In this research, Matlab R2016b version is used. This research has been done using PSAT toolbox.

Power System Analysis Toolbox is a versatile tool of MATLAB for power system analysis of a design and controlling environment as per the measurements. Many of the operations are performed by a Graphical User Interface of the toolbox that provides its SIMULINK library of components for design. For performing the operations in PSAT, a Power flow of the system is firstly performed which can easily be done using GUI screen. The Fig. 3(a), (b) shown below is window of PSAT toolbox and the library of toolbox which used to be design the power system components.

Fig3 (a): Window of PSAT toolbox

Fig3 (b): Toolbox Components of PSAT

III. RESULTS

IEEE Bus systems of 14 Buses are designed in PSAT toolbox and the design was keenly observed along with voltage ratings. Fig.4 shows the mesh diagram of 14 Bus systems are design in Matlab, describe the complete observablity of the network. A repetitive and iterative analysis of the layouts is performed and results are recorded.

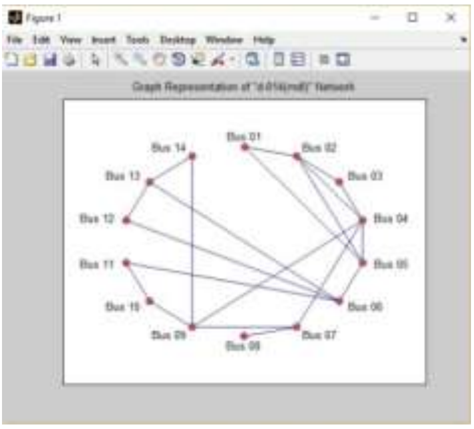

Fig4: IEEE 14 Bus Systems

The Table1, 2 is shown below describe the PMU placement by Depth First Search & Graph Theoretic Procedure with time taken for complete the process.

Table1: PMU placement by Depth First Search method

Buses	14
Lines	20
PMU	6
PMU Sets	1
Meas. Current	16
Pseudo meas. Current	0
Elapsed Time: 0H 0m 0.02669s	

Table 2: PMU placement by Graph Theoretic Procedure method

Buses	14
Lines	20
PMU	5
PMU Sets	1
Meas. Current	15
Pseudo Meas. current	5
Elapsed Time: 0H 0m 0.030596s	

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

The values and measurements of **Real Power (P), Reactive Power (Q), Voltage Magnitude (V), and Voltage Phase (Θ)** are plotted for each bus and the results of 14 Bus systems are shown below

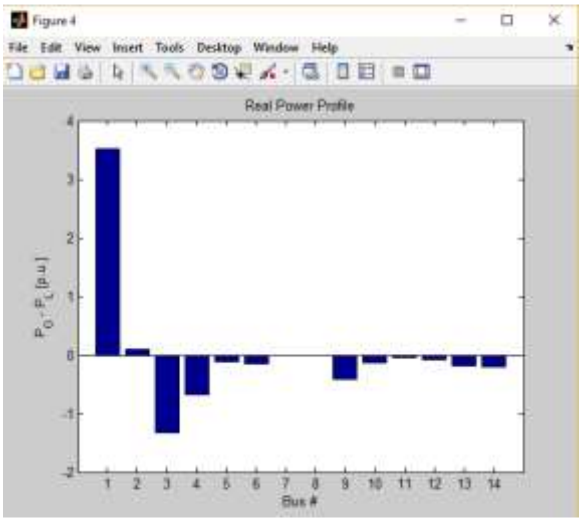

Fig5: Graphical Representation of Real Power (P)

Power in an electric circuit is the rate of flow of energy past a given point of the circuit. The portion of power that averaged over a complete cycle of the AC waveform, results in net transfer of energy in one direction is known as active power (more commonly called real power to avoid ambiguity especially). The portion of power due to stored energy, which returns to the source in each cycle, is known as reactive power. Fig5. show the graphical representative real power of individual buses of IEEE 14 Bus system. In this graph the active power is active power above the 3 per unit & reactive power is negative 1 per unit

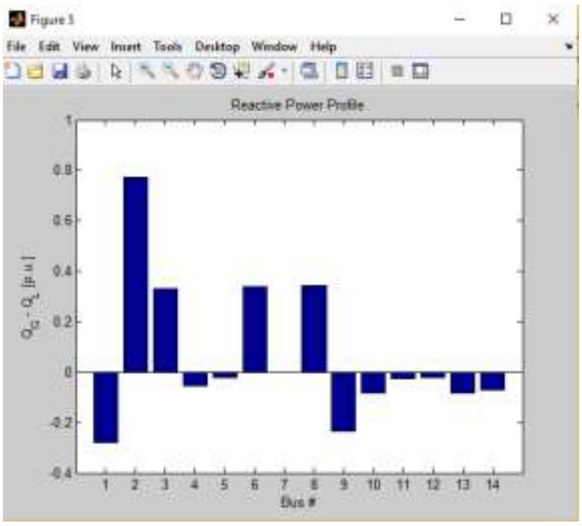

Fig6: Graphical Representation of Reactive Power (Q)

Fig6. show the representation of Reactive power at individual buses for an IEEE 14 Bus system. Reactive power **Q**, (Sometimes called the wattles power) is the power consumed in an AC circuit that does not perform any useful work but has a big effect on the phase shift between the voltage and current waveforms. Reactive power is an AC circuit when the current waveform is out of phase with the waveform of the voltage. The graph describe the current waveform is out of phase in positive direction approximately 0.8 & in negative direction is above 0.2.

The voltage magnitude, (is also called the amplitude) of an AC quantity is to measure the peak height on waveform graph. Fig.7 represents the voltage magnitude that has been induced in the individual bus for an IEEE 14 Bus system. The graph shows that voltage magnitude is equal to 1.

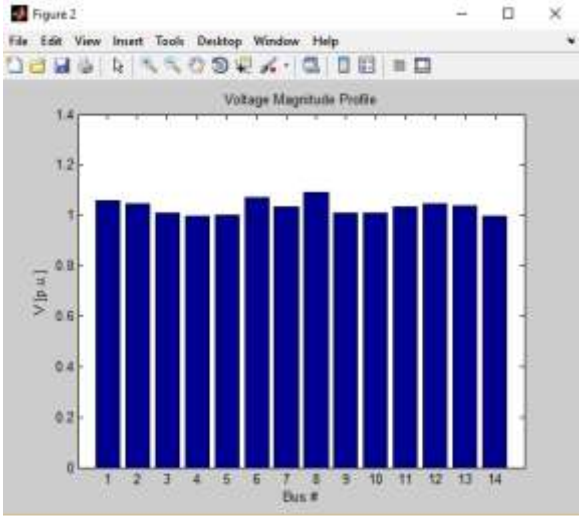

Fig7: Graphical Representation of Voltage Magnitude (V)

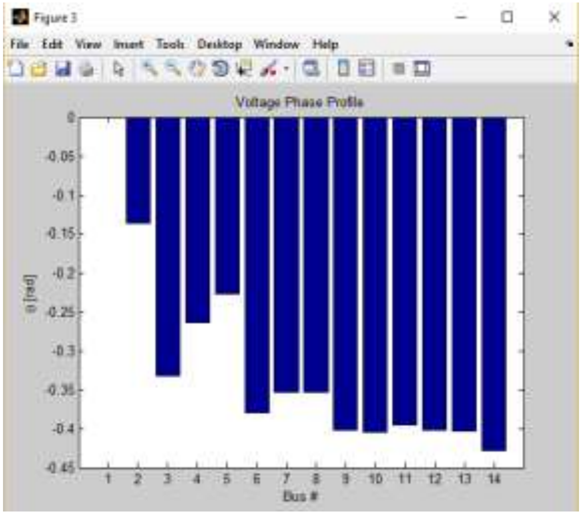

Fig8: Graphical Profile of Voltage Phase (θ)

The phase difference is <= 90 degrees. It is customary to use the angle by which the voltage leads the current. This leads to a positive phase for inductive circuits since current lags the voltage in an inductive circuit. The phase is negative for a capacitive circuit since the current leads the voltage. The graphical profile of Voltage phase of IEEE14 BUS systems is shown in the Fig8.

The results of IEEE 14 BUS systems were compared with the literature. It is found that by carefully choosing the voltage magnitude of each BUS in the system, the phase differences from different sources may be minimized such that the number of Phase Measurement Units (PMU) that may be used for efficient transmission are reduced hence reducing the installation cost.

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ISSN: 2277-9655
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Table 3: Number of PMU to be place in IEEE 14 BUS System

BUS System	Number of PMU to be place
IEEE 14	5

Above is of the power flow detail of 14 BUS systems. These values shown are of Real Power, Reactive Power, Voltage and Phase profile of each bus in the system. These values are calculated for error free transmission of the power and hence in real time, these values are helpful in maintaining minimum phase difference at each bus to avoid blackout.

TOTAL GENERATION			
REAL POWER [p.u.]			3.1964
REACTIVE POWER [p.u.]			0.2284
TOTAL LOAD			
REAL POWER [p.u.]			3.15
REACTIVE POWER [p.u.]			1.15
TOTAL LOSSES			
REAL POWER [p.u.]			0.04641
REACTIVE POWER [p.u.]			0.9216

IV. CONCLUSION

As per the results obtained after application of different algorithms, it is concluded that highest number of PMUs are to be implemented minimum when Graph Theoretic method is used. But It is also seen that the Graph Theory method has take more time to implement the PMU placement. Thus it is concluded that for a cost effective implementation of PMUs, Graph Theory and Depth First Search methods provide good deal of stability in system. However, it is seen while simulation that the ability to observe overall flow of power is better using Depth First Search method. Hence it is further concluded that the best method for placement of PMU is Graph Theoretic method.

A dire need of a system is a PMU to be present in it that certainly avoids the chances of complete blackout. Using PSAT the methods were used to find minimum number of PMUs because this equipment is of a very high cost. Further the research can be extended to find other algorithms that may provide a better solution against PSAT algorithms

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CITE AN ARTICLE

Singh, S., & Kaur, P. K. (n.d.). IMPLEMENTATION OF IEEE BUS SYSTEMS WITH OPTIMUM PLACEMENT OF PHASE MEASUREMENT UNIT (PMUS) USING PSAT TOOLBOX. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY*, *6*(12), 369-376.