THINK INDIA Journal

ISSN:0971-1260
Vol-22-Issue-16-August-2019

Optimization of Phasor Measurement Unit Using Hybrid Search Algorithm For IEEE-57 Bus System

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Abstract

For administering purposein future, control and protection of power system,Phasor Measurement Units (PMU) are considered as a very good tool, especially with the direction towards smart grid. The adequate supervision of the system requires all the nodal voltages and also the phase and magnitude of the current through all incident edges. In order to observe the entire power system, the PMU's needs to be placed at some of the nodes of the Power system. But the obstruction is optimised employment of PMU's, which covers the best location and minimum number of PMU placement. This paper presents the Generalised Global search algorithm (GGSA) for the optimal location of PMUs. This algorithm will provide the Planning Engineers to plan and placed the PMUs at the best nodes from where the entire power station can be monitored using and devoid of zero-injection effect in the system. For analysis standard IEEE 57-Bus system is investigated using GGSA and the practically relevant results with least PMUs essential and maximum System Obeservability Redundancy Index (SORI) are obtained.

Key words- Phasor measurement units (PMU), Global Search Algorithm (GSA), System Obeservability Redundancy Index (SORI). Electric power monitoring, energy management systems (EMSs).

1. Introduction

Electrical power system consists of transmission, distribution, setup of electrical devices for providing good quality of electrical power to loadi.e. a region, homes and industries etc. Being one of the maximumcomposite system it continuously observe numerousturmoil or faults during operating stages. These Faults thereby affectsfrequency of the system, lines voltages or flow ofpower. As power system performance are probabilistic in nature therefore it requires an optimal control system to control and maintained the system, such that it should stay in steady conditions during or after faults and there will be a continuous and non-variable power supply to the end-user [14]. The power system has one of the key problem that the real power consumed along with the losses has to be equal to the generated active power. There will be increase in frequency and voltage if the power generated is more than the demanded and in other way if the power generated is less than the demand than the voltage and frequency will be reduced. The alternators and the related equipment's can get damaged due to the fluctuations of the frequency and voltage levels.

Transmission system operator task is to maintain the frequency constant,thereby it is required to monitor these systems continuously so that the live status of the systems can be evaluated regularly, which will be helpful in minimizing the consequence of faults and problems and the system could be able to operate under stable condition. Also due to the increase in power system network growththe system has become progressively more complex and stressed. That's whycontinuousobserving and controlling of power system is must. The current energy management system needs to be accurately monitored continuously because of increase in power demand which leads the power system to operate on their critical limits.

So, for protection of electrical system and to prevent it from faults, continuous monitoring of it is very crutial i.e. the continuousevaluation of all electrical parameters at each bus is required [4]. The recent

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ISSN:0971-1260
Vol-22-Issue-16-August-2019

development in global positioning satellite (GPS) made the production of PMU commercial. Phasor Measurement Units are power system measuring devices proficient of measuring the phasors of coordinatedparameters. PMUs has come up ascrucial measuring device for future smart grid [3]. PMUs have become the noticeable interest in transmission lines.
The PMU is one of the device which is utilized to determine the voltage and current waveform that is harmonised with a signal which is taken constantly from GPS. ThePMUs are having inbuilt GPS receiver,synchronous data will be received continuously at a base station from every PMU continuously. These data will be utilised in finding theposition of unhealthy circuits or transmission lines if there is any unbalanced condition between different PMUs.
In this paper, the PMUs necessary in different scenarios has been broadlyevaluated. Few researchers utilised the Integer Linear Programming (ILP) framework to describe the zero injection constraints. In addition, the System Observability Redundancy Index (SORI) was also familiarised to expand the bus coverage in the minimal solution [13]. Some heuristic algorithms are also tested to decrease the PMU set for making the network fully observable.
This paper describes the improved method for PMU placement using Global search algorithm. Global search algorithm has applied to find the buses having most coverage until the network is fully observable [15].

2. Basic Structure of PMU

In the continuouslychangingsituation of compositenetwork the presence of distribution generators demands for cumulativeaccuracy of measurementis growing,quickbroadcasting rate and sophisticated communication abilities [8]. PMU analyseddifferent parameters of the waveform and provide output which is utilizedfor determination of the unidentified components for continuous observation and control. PMU as shown in Figure: 1, comprises of three basic units

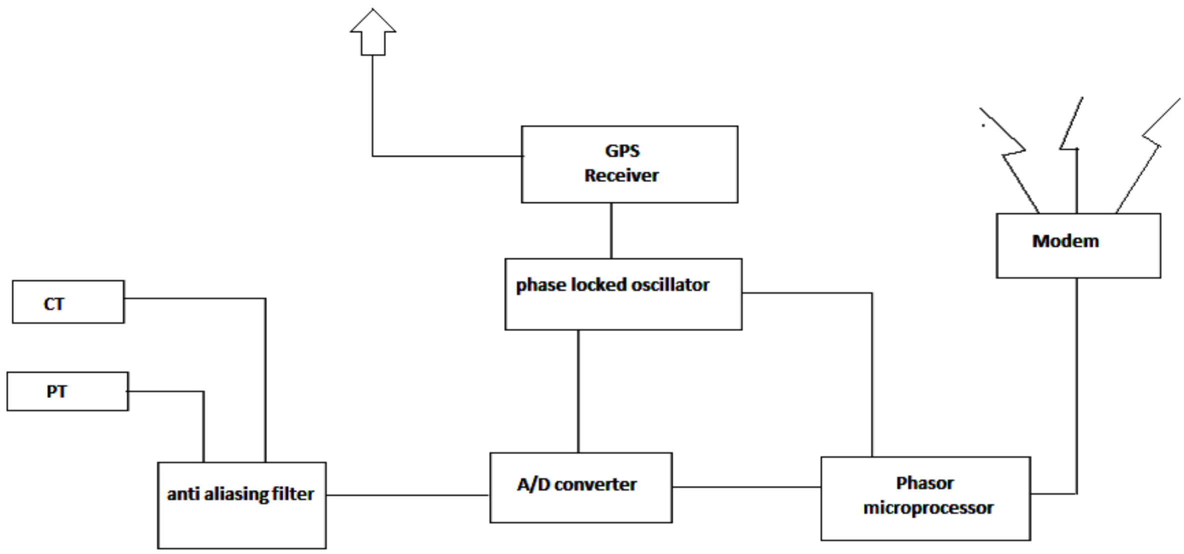

Figure: 1 PMUStructure
The main components of Clock Synchronization Unit are GPS receivers and phase-locked oscillators which providesignal to measurement unit after sampling. The accurate clock generates the one pulse per second which is received and detected by GPS receiver. In combination these provide high accuracy and high-speed sampling that is synchronized to 1 microsecond accuracy. In general PLL is an electronic circuitryconsisting ofadaptable frequency oscillator and a phase detector [6]. The comparison of the phase of standard signals with the measured signal phase is done by phase detector that will help in taking actions. If the phase difference is identified then there is a system change and if the phase signals are mapped then no action will be taken.

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ISSN:0971-1260
Vol-22-Issue-16-August-2019

3. Model Diagram of PMU

The PMU modelling isprepared in MATLABSimulink toolbox [7,9]. Actually PLL is electronic circuit that consist ofa phase detector and variable frequency oscillator. The phase of test signal is compared to the measured signal using phase detector if there is change in system. That signal is utilised for arithmetical computing, it also allows plotting of functions and data, interfacing with programs using languages such as C, C++.
The majorcomponents of PMU modelwhich are shown in Figure: 2 are described below: -

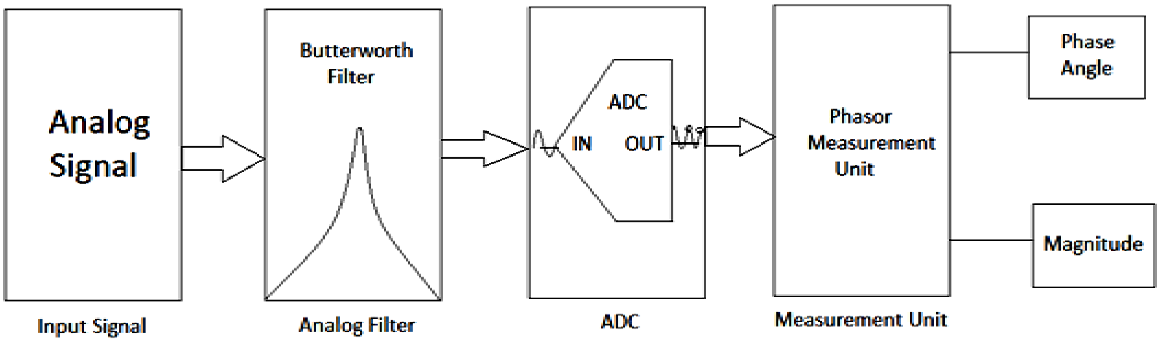

Figure: 2 PMU Model

4. Phasor Measurement Unit Components

To find out the current and voltage signals from the field, current transformer and potential transformers are utilised. After gathering the electrical signals, the signals are given to the anti-aliasing filters. Whichpick up the specific bandwidth of signal to whollyplacate the sampling theorem above the assured band. To transformanalog to digital signal ADC is utilised, basically in A/D converter test group of the signal obtained from CT and PT is accomplished. And sampling is carried out according to the sampling theorem.
As PMUs devices are controlled by time with signal obtained fromGPS therefore all of them contain GPS receivers which collect signal from satellite. There are over-allof 32 satellitesand every GPS receiver is associatedfrom four satellites every time as earth revolveson its axis then first GPS satellite getsdisengaged from the GPS receiver and the fifth GPS satellite is get connected at the same instant. All 32 satellites have covered five continents of earth. Every PMU is associated with four GPS satellites at singleinstant and repeatedly they harmonisedwith all PMUs coupled in varied areas. Phase lock oscillators are presented to cover the frequency range of 110GHz using high performance FET oscillators. Further signal filtering is done by phasor microprocessor to getting the desired output from the provided signal. Essentialmaterial is directed via wirelesslyto the PDCs after processing signals from every block of PMU [10,12].

4.1 MeasuringElement

Measuring element is there to measure voltage signal'sphase angle and its magnitude. Different phasor estimation techniques are utilised for this measurement like zero crossing, DFT (Recursive and Non-recursive) and sliding DFT. For improving the accuracy and reliability different techniques are utilised. The Efficiency of power system can be increased if the data obtained from PMU is correct which can be further utilised for creating the controlling and monitoring of power system better.

4.2 Phasor Data Concentrator (PDC)

From different PMU's the time synchronized phasordata is received by PDC that can be utilised to produce actual output data. One PDCmayprovide-and-receive the phasor data with differentPDC at

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ISSN:0971-1260
Vol-22-Issue-16-August-2019

otherpositionusingseveral PDCs numerouslevel of application can be realisedinside a singlesynchrophasor data system [5]. A PDC is plan to routerunning time series outputalong with actual data. The positive sequence of voltage and current of eachbusses that are monitoredusing the PMUs that areplaced at the substations. For diagnostic purpose these data goes in storage device which can bereachable to the remote locations. The function of PDC is that they collect data usingdifferent PMUs and discard the incorrect data. The received records is then aligned in time stamped and record is created.

4.3 Techniques for State Estimation ofPhasor

Phasor are helpful in explaining the performance of the system even though the system isn't in steady state. There are severalmechanism that are utilised for state estimation [5] like Zero Crossing, DFT, Sliding DFT, Least Error Squares, Kalman Filters, Demodulation, Phasor measurement angle changing. From these techniques Zero crossing, DFT and Sliding DFT phasor estimation techniques aregenerally used.

State estimation in PMUis donefor eradicating the inaccuracies and determine the position of the system which can be practical as possible as in PMU many transducers are havingspecific error boundswhich leads to incorrect estimation of the system position and that candirectto incorrect generation of control signal and lead toincorrectopening of system [1]. Therefore to end the generatedcomplications or monitoring and control of the system effectively these errors needs to be removed and regulate the actualposition of the electric system.

Many state estimation techniques can be utilized for the process, generally 2 or 3 techniques are used that are,weighted least squares criterion,minimum variance criterion,maximum likelihood criterion.

4.4 Installationproblems in PMU

In PMU installation there are different challenges. PMU's are needed to be installed at particular location using optimisation process due to its cost, and to perform this there are different optimisation techniques. The major problem with PMUs which leads to the selection of location of installation of PMUis cost problem. To install one PMU the cost of installation is high therefore to reduce that costthe quantity of PMUs in the system is minimized. It is tedious to predict after installation that obtained wave is unique or it is inaccurate which makes the computation large enough.

4.5 PMU Calibration

In order to reduce errors in sensors of station the calibration of PMU is must for harmonisation accuracy and forelimination of in-built error in the PMU'sdevelopedat different stages. This test signal willgenerate the GPS related synchronized signal. The PMUs is required to be testedbefore installation in the field for their correct working. The errors in any PMU set iseliminated by calibrating the device. In the course of testing of PMU's certain difficulties can be encountered likeHarmonic distortion, which are required to be analysed for the harmonics of the system for the range of 50th harmonic, however in practical processthis is tedious to generate for testing. A few problems are realised during the testing of out of band problems. Few problemsare analysed duringcommunication andevaluation of communication in network control andfor thata lot data is requiredto evaluate the communication network reliability.

5. Proposed PMU Placement Method

The position of the leastquantity of PMUs can be obtained usingGlobal Search algorithm after checking all the combination. Large number of combinations are produced in this process

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ISSN:0971-1260
Vol-22-Issue-16-August-2019

thatindicates to the ingestion of much time for computationand takes a lot memory space in computer,particularly in the complex network. Electric network are the most complex network and there are infinite number of busses can be present over there, which leads to more computational time to find the optimal location of PMUs [11]. As a solution a combination of new steps are provided to find and reduce the number of combinations with abetter way. For finding the leastquantity of PMUs require a theory is utilised i.e. domination set theory and the binary search algorithm. Mentioned methodescape the unnecessary groupingcreated by Global Search Algorithm. Also the operation with zero injection effect i.e. simply at non zero-injection buses phasor measurement devices mountingreducesthesignificant number of PMUs in the system [2]. Conversely the total number of PMU for the electrical system will come down throughreducing the quantity of zero-injection buses, which increases the calculation. A ‘brute-force attack’ which is an exhaustive Search also a part of the GSAwhich isused to find all the potential combinations. Afterevaluating each single grouping, the optimum PMU location will be calculated if the grouping is capable to find the whole network by means of the minimumquantity of PMUs necessary.

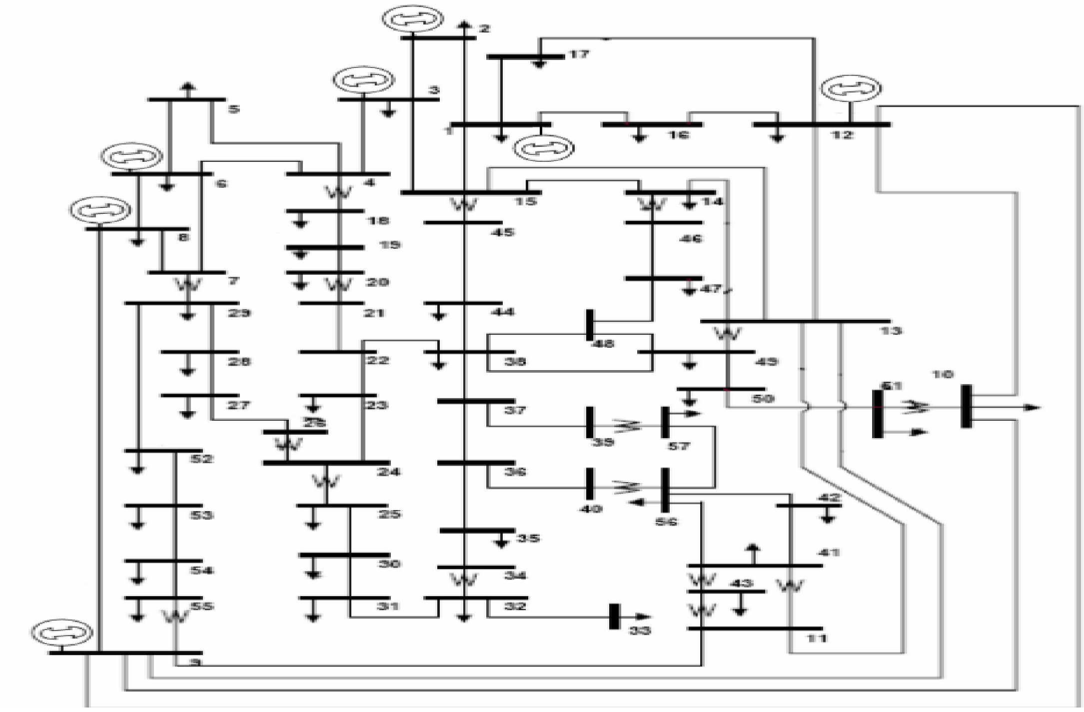

Figure: 3 IEEE 57-Bus system

To decrease the number of combination like we use the different methods like placing PMU on adjutant bus of single connected bus.

Datas for IEEE 57 bus systemshown above in Figure: 3 are given below.

Bus with single connection is bus number 33

Bus which is linked to 33 bus system is32,

The results obtain from the optimization of 57 bus system are given bellow without using the zero injection method.

Sol = 1 3 9 10 12 16 18 19 20 28 31 32 38 42 49 53 56 57

Global search algorithm use total of busses to create the complete system noticeable.

First this technique make the combinations of PMUs and make the system observable after that one PMU is decreased to check weather our system is observable or not but with 18 PMUs system become observable.

The results considering zero injection busses the quantity of PMUs essential are 11.

And the busses on which PMUs are installed are

Zsol= 1 3 13 15 25 26 32 38 42 52 56

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ISSN:0971-1260
Vol-22-Issue-16-August-2019

As from results without zero injection total number of PMUs required are 18 to observe the complete 57 bus network but if we use the zero injection method the quantity of PMUs decrease considerably and total number of PMUs required are 11 only.

6. Results

The investigation has been done for placement of PMU in electrical network optimally. Animprovedoptimization method for PMU placement ispresenteddepending ongreedy search and breadth-first search algorithm. Results on IEEE standard 57-bus test systems were presented using the MATLAB simulation,in order topresent the usefulness of hierarchical algorithm.
Global search algorithms results are provided below with and without zero injection busses

- Without Zero Injection Busses

Total number of PMUs require are 18
And the busses at which PMU is placed
Sol = 1 3 9 10 12 16 18 19 20 28 31 32 38 42 49 53 56 57

- With Zero Injection Buses

Total number of PMUs required are 11
And the busses which are installed with PMUs are given as
Zsol= 1 3 13 15 25 26 32 38 42 52 56
From the above results it can be seen that using zero injection the results of PMUs optimization precise and network can be observed with less number of PMUs.
As from results without zero injection actualquantity of PMUs required are 18 to monitor the complete 57 bus network but if we use the zero injection method the quantity of PMUs decrease considerably and total number of PMUs required are 11 only.

7. Conclusion

The proposed method is better for the optimization and in this method there are lot more scopes to improvise the work. Because ofcumulativegrowth of power system networks the controlling and protection necessitiesbecomes complicated. In few years, the synchronized phase angle measurement theory hasconfirmed that it take alonginherentbenefit for the protectionof the network.Also, consideringPMU, these uses will increase in totality, the monitoringof power system their control and protection. From thispaper it has been targeted to guarantee that quantity of PMUs essential for administeringelectricalsystem is negligible. For making thelocation observable, installation using few PMUs can be relocated in totaldifficulties related tooptimization. But the time for identifying the optimal location of PMUs is extra which can be further considered in future developments.

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