Phasor Measurement Unit placement optimization using breadth-first algorithm and greedy algorithm

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ABSTRACT

The current scenario of power demand of the world is increasing at a very fast rate due to modernization and the industrialization. And there are some problems with the approval of new transmission lines. In order to meet the demand of world we are using the power transmission lines to the limit of stability limits. So with the loss of sudden generation or transmission line stability may get disturbed there may be collapse in line voltages, may be frequency changes and may current get suddenly high due to short circuit. In order to meet the demand of load or continuous flow of power from source end to load end our system need to be stable at all the time. Main issue arises when there is fault accurse in the transmission line or distribution line or to the generation side then our system should remain stable. For above reason we need to stable the system at all the time for that we need to continually monitor the system at all the times for that in these days we are using Phasor Measurement Units. Phasor measurement unit system provide us the magnitude and phasor both of line current and line voltage unlike SCADA (supervisory control and data acquisition). With the help of phasor measurement unit we can continuously monitor our power system and can see where fault accurse and according to that we can generate the control signal or control action can be taken. Hence the power system stability can be enhanced. But these Phasor Measurement Units are not cheaper there are costlier so we cannot use them everywhere. The disposal investment of PMU device with the single price of $40,000 USD. So we do the optimization of the Phasor Measurement Unit. Which decreases the number of PMU used in system for monitoring and hence controlling cost will be less.

Keywords: Phasor Measurement Units, SCADA, Programmable Logic Controllers, Heuristic Method

INTRODUCTION

As we know electric power system is network of electrical devices, transmission and distribution and also component of electric system for use of good quality of power at the load end. Electric power system is network of electrical component that supply a region, homes and industries with power. Power system is a grid Electricity is associated with the presence of flow of electric charge. Electric power is product of two different quantities that is electric current and electric voltage. These both quantities varies with time and also kept at constant values in DC. Because most of our daily appliances use A.C. and some other like computer and digital equipment use D.C. power. A.C. power is a practical choice because it is easy to transform and generate. But D.C. remains practical choice for DC systems and it is more economical for transmit over high voltage. Electricity can be generated in different ways in different power plant like, solar energy system, hydroelectric energy plant, thermal power generation plant, wind power system, nuclear energy power plant etc.

In hydro power plant we use water for the production of electricity by making dams. In this kinetic energy is used to convert to electric energy.

In solar power plant we use solar energy to produce electric energy. In solar power generation we use solar cell to convert solar energy into electric energy. Solar cells are act as transducers. Which convert one form of energy into other. Solar cell produces DC output voltage at the end.

In wind power plants we convert wind energy into electric energy. For that we use wind turbines and then mechanical power generators for production of electricity. But there are some limitations with it that they are used at places where high speed of wind is present.

Thermal power plants are used to convert coal energy in electric energy. In this we burn the coal and generate steam from that and then that steam is used to rotate the turbine and that energy is converted into electric energy.

In nuclear power plant is we convert nuclear energy into electric energy. In these plants we generate heat to produce steam and then that steam is used to rotate the turbine system and then mechanical energy of turbine is converted into electric energy using generator.

In today's world most of the countries in the world have been effected by number of power failure, blackouts and faults. These are caused by lack of investment in protection equipment and controlling system infrastructure, improper maintenance and continuously increase in demand of electric power that overset the power transmission and distribution system limits. And due to these companies who invest in power system are suffering from losses of billions of dollars. To achieve batter reliability and for continuous operation of power system new technologies are used to prevent the blackouts. Today we are implementing state of then art technologies, to get the good

controllability and high reliability we do the state estimation from measurements obtain from PMUs. It is used to get the high controllability, high reliability and for real time monitoring of power system and to satisfy the consumers also by providing good quality of power. [1]

Network of electric system are very complex and are used to send or supply power to load end from generating stations. Electrical power system is the most complex system which continuously suffers from various disturbances or faults (switching or lightening etc.) all the time. Hence they are affecting system frequency, voltages of lines or power flow. Since power systems are dynamic in nature hence there is need of control system to so that system should remain in stable conditions during or after faults so that our power supply should be continue to the costumer or to the load end. One major difficulty in power system is that amount of active power consumed in addition to loss should always equal to active power product. If more and more power produce than demand then there is increase in voltage and frequency and also if there is less generation then there is decrease in voltage and frequency. And even small amount of deviation from frequency may become cause of damage to synchronous machines and loss of synchronization and other appliances. So we have to making sure that frequency is constant is work of transmission system operator.

Therefore there is need of live monitoring of these systems so that we can get the continuous status of system at all the times so that effect of problems and faults can be minimize and our system should remain in stable condition

Likewise as power system demand increases so power system network grow and become more and more complex as load increases our system become more and more stressed. So continuous monitoring as well as controlling of electric system is required.

PMU History

The origin of concept of Phasor Measurement Unit was from a particular relay i.e. symmetrical component distance relay (SCDR). This relay is used in dynamic relay technology. Calculation of voltage phase angle was first computed in 1983 by Dr. Phadke and Dr. Thorpe on theoretical basis. But PMUs comes in usage first time in field in the early 1990's. At that time there applications were very limited. They (PMUs) were used as a digital system disturbance recorders (DSDRs) only. [Modelling of PMU] at that point of time, PMUs usage for protection and control were any theoretical but not practical. But practically PMUs were continued to be used only DSRs. They came into practical use after the blackouts in 1996 and 2003. After that PMUs technology were highly encouraged for research for the use in protection and control system. In 1965 after the blackout in north east of America starts the large amount of research in the field of real time data on the state of power system was started. The first paper to determine the importance of positive sequence phasor measurement was published in year 1983[36 full text thesis]. At the same time all around the global positioning satellite system was beginning to develop or become the part of it. Moving on from Symmetrical Components Distance Relay (SCDR), Virginia tech were the first to develop the first prototype synchronised phasor measurement unit (PMU). In 1988 few Devices were installed in a few substations along the east cost of America, after it collaborate with Macrodyne in 1991 to produce the first commercial manufacture of PMUs. [2].

CONTROLLING TECHNIQUES

SCADA, Synchrophasor technology in accordance with IEEE C37.118 Standard, its applications and basic components of PMUs and their detail also phasor estimation techniques like zero crossing, recursive and non-recursive DFT and Sliding DFT also challenges in PMUs and limitations of PMUs has been explained.

Supervisory Control And Data Acquisition (SCADA) : Supervisory control and data acquisition is a control system architecture that uses computers, networks, data communications and graphic user interphase. For high level supervisory of power system. It also use other devices for measuring and controlling like programmable logic controller(PLC) and PID controller to interphase to the process plant. SCADA concept is like a remote access to a verity of a local control modules. The main attributes of SCADA is ability to perform supervisor operation over the wide area. It can be seen from the diagram that we have different levels in the SCADA system.

Level zero we have sensors such flow, temperature, flow, pressure sensors, and final control element like valves etc.

Level one contain industrial input and output module and electronic processers.

Level two contain the supervisory computer for supervision which collect all the information from processer nodes on system and provide the operator control. Level three contain the production control which is not directly control

the process it control the process with output of product requires that is production targets. Level four is the production scheduling levels.

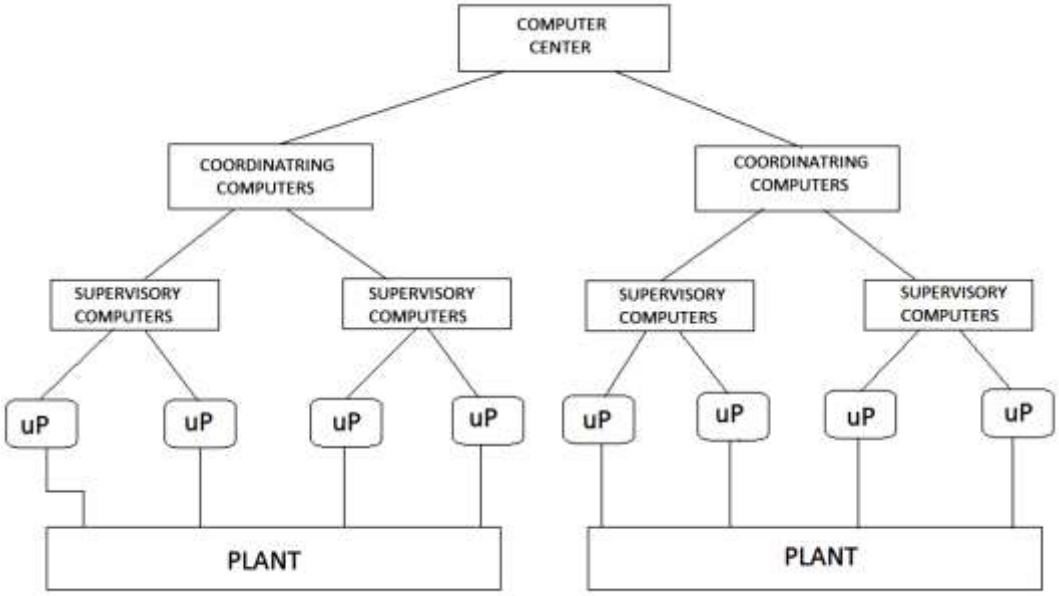
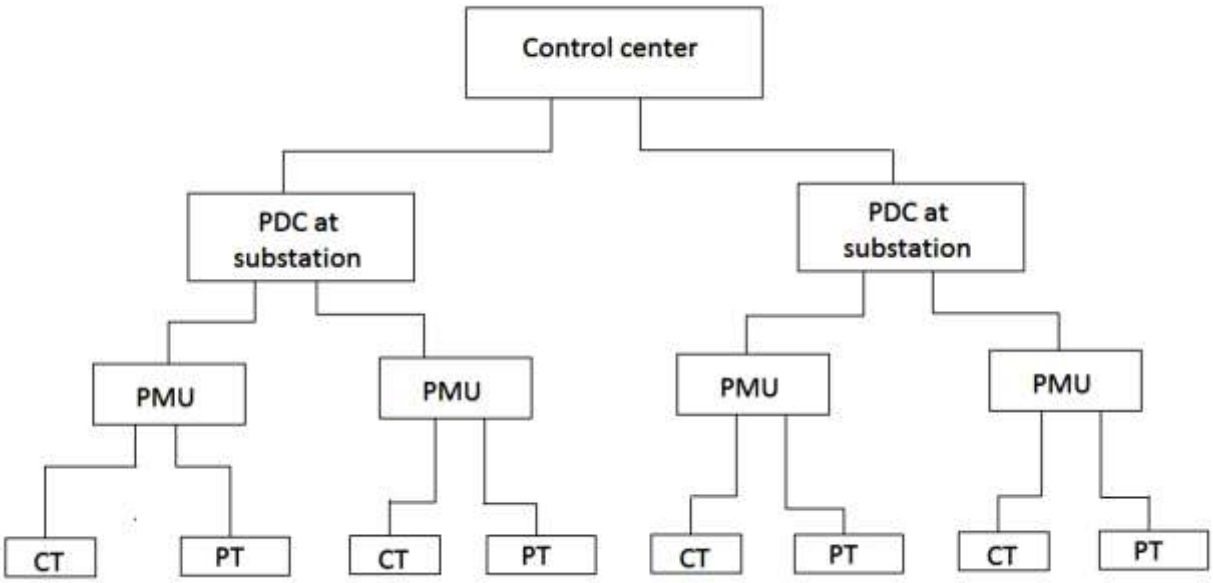


Fig : SCADA System

SCADA System Component

a. Supervisory computers
b. Remote terminal units
c. Programmable logic control
d. Communication infrastructure
e. Human machine interface

PMU Utilization In Power System



Phasor Data Concentrator (PDC)

Phasor data concentrator receives the time synchronized phasor data from multiple phasor measurement units to produce real time, time aligned output data stream. One Phasor data concentrator can exchange the phasor

data with other Phasor data concentrator at other location through the use multiple PDCs multiple layer of concentration can be implemented within an individual synchrophasor data system. A Phasor data concentrator is design to process streaming time series data with real time.

PMUs are located at the substations and they will provide the time stamped positive sequence of voltage and current of all monitoring busses. These measurements go in small measurement data storage device which is accessible to the remote locations for diagnostic purpose. The device next to hierarchy are commonly known as phasor data concentrators. PDC has a typical function like they gather data from several PMUs and reject the bad data. Than alien the data in time stamped and make a record.

Phasor State Estimation Techniques

Phasor are primarily used for ac circuit analysis that is introduced as a mean of illustration of steady state curving signal of power frequency. Activity these voltage phasor in real time permits operators to ascertain and reply to approaching grid stability issues. Phasor are untypically helpful in describing the behaviour of the facility system although the facility system isn't in steady state. As an example, throughout power swings once the facility system is undergoing mechanical device oscillations, the voltages and currents signal area unit neither in steady state neither is the frequency of the facility system at its face value. underneath these reasonably conditions the variations within the voltages and currents area unit comparatively slow, phasor is also accustomed describe the performance of the network and also the variations being treat as a sequence of steady state conditions.

There are different type of methods that are used for state estimation as listed below [5].

i. Zero Crossing

ii. DFT

iii. Sliding DFT

iv. Least Error Squares

v. Kalman Filters

vi. Demodulation

vii. Phasor measurement angle changing

But we don’t use all of them because they all are not accurate and not easy to use. Out of above given techniques Zero crossing, DFT and Sliding DFT phasor estimation techniques have been used generally.

Depth-First Algorithm Flow Chart

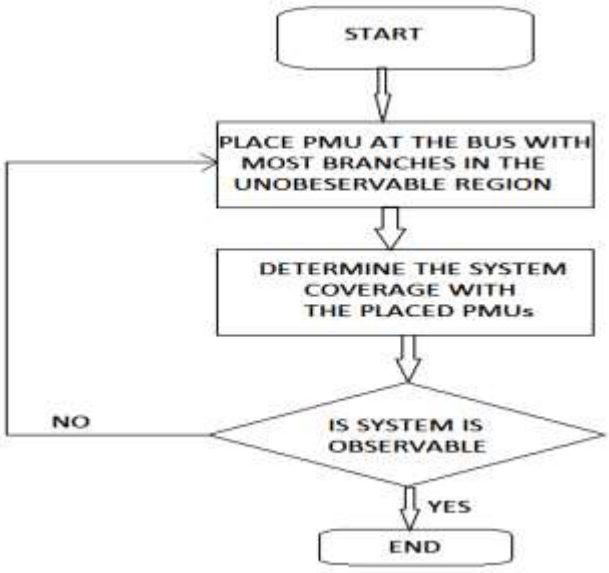


Fig.: Depth-First Algorithm Flow Chart

Advantage of Depth-First Algorithm DFS are
1) DFS is high efficient computationally.
2) DFS has high convergent speed as compare to other algorithms such as Simulated Annealing Method (SA)
3) And DFS use Minimum Spanning Tree Method (MST).
But there is one problem that this algorithm is failed in considering network, so it is not sure the result will be best optimal result.

Greedy Algorithm

Greedy algorithmic rules are used to find out the smallest number of PMUs required to get the fully observable network.
Basically, Greedy algorithmic rule give choices in step with one rule and that is at every stage, opt for and place the PMU to the bus which covers the highest variety of uncovered buses,
X=S_i1, S_i2…S_ik. Whereas X wasn't empty.

RESULTS AND CONCLUSIONS

The problem of optimal PMU placement in power network observability was investigated. A new PMU placement optimization method was introduced base on breadth-first algorithm and greedy algorithm. By employing the MatLAB. Simulation results on IEEE standard 57-bus test systems were presented to demonstrate the effectiveness of hierarchical algorithm. Large-scale network will be implemented in the future work.
Result for Global search algorithms are shown below with and without zero injection busses

- **Without Zero Injection Buses**

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 we can see that with zero injection we can find the results of PMUs optimization precise and network can be observed with less number of PMUs.
As from results without zero injection total number of PMUs required are 18 to observe the complete 57 bus system network but if we use the zero injection method the quantity of PMUs decrease considerably and total number of PMUs required are 11 only.

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