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OPTIMAL PMU PLACEMENT ON EXTRA HIGH VOLTAGE BUS SYSTEM OF NORTHERN EASTERN REGION OF INDIAN POWER GRID USING PSAT

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ABSTRACT
Phasor measuring unit (PMU) is new advanced measuring technology installed in the power system for the implementation of smart grid. In India most of the energy is produced from fossil fuel which has appalling effect on environment. For developing countries like India effectively use of renewable sources is necessity for the development of the country. Which is only possible by implementation of smart grid. Absolute observability of the entire power system is the key feature of the smart grid that can be achieved by replacing tradional measuring system with new and advanced technology Phasor measurement unit. PMU is the time synchronized device provide real time measurement with time stamped. But it's very costly equipment so installation on every bus is not economical. Optimal placement of PMUs become prime need for the full observability with minimum no. of PMUs. In this paper four method is used for the placement depth first search, (N-1) minimum spanning tree, geographic theoretic, simulated annealing method on extra high voltage bus system of northern eastern region Indian power grid (NERIPG). Power system analysis toolbox (PSAT) is used for simulation and placement purpose.

KEYWORDS: PMU, optimal placement, PSAT.

1. INTRODUCTION
In this day and age, when everything has been modernized, traditional electrical systems are also improving to become modernized systems. Traditional grids are becoming more efficient and reliable through infrastructure improvements, the use of new technology, and independent monitoring. This new technology is referred to as a smart grid (SG). SG has the ability to observe and managed entire power system more efficiently. In comparison to traditional systems, SG provides greater dependability and efficiency, as well as real-time monitoring, two-way communication, smart metering, fault detection, and self-healing. Because of previous major blackouts, a better monitoring and measuring system has become necessary. According to various reports, previous blackouts could have been avoided if prompt and appropriate action was taken.

The phasor measuring unit (PMU) was developed in the 1980s as a cutting-edge technology. The PMU is a critical component of a wide area measuring system (WAMS). It measures data in real time and has a wide range of measurement options. PMUs are a one-of-a-kind combination of hardware and software tools used in power systems for security and control. PMU provides data that is synchronized. Because the global positioning system (GPS) is linked to provide time stamping on the data. It provides current and voltage phasor values that are synchronized. PMU is extremely expensive. It is not feasible or cost-effective to place it on every bus of the system. The implementation of PMUs is progressing slowly. The main reason for this has been the cost over the years. As a result, careful planning is required for the deployment of the PMUs.

1.2 Phasor Measuring Unit
PMUs are digital devices that use a microcontroller to calculate current, voltage, and phasor values in conjunction with the GPS time reference. By including a time stamp on data in the phasor concept, a synchronized phasor is

created. As a result, a synchronised phasor is defined as "cosine signal magnitude Measured in fixed time." As a time, reference, an extremely precise clock coordinated with universal time, such as the GPS clock, can be used.

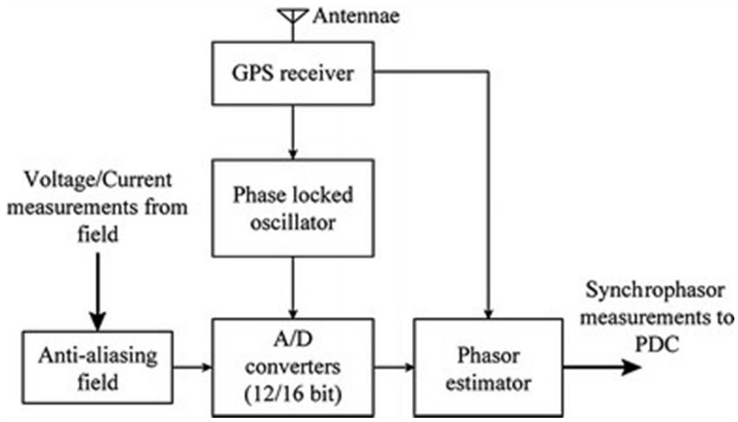

Figure 1 working internal model of PMU

All PMUs placed around the grid measure the phasor values using the precise time reference provided by GPS. The functional block diagram explains how PMUs work in detail. The analogue signals of current and voltage from the potential and current transformers are sent to anti-aliasing filters, which limit the frequency bandwidth of the signals to the standard band width of the ADC, as shown in the figure above. The filtered signals are converted to digital using analogue to digital converters (A/D converters). The phase lock keeps the sampling time synchronised with the GPS. The phasor microprocessor receives these digital signals and computes the phasor values using DFT. These phasor values are then sent to the modem, which serves as a means of communication with the phasor data concentrator (PDC)

1.3 PMU Placement Rules

In the literature, there are certain rules for phasor measuring units. (Baldwin et.al, 1993) put forward few rules for PMUs ideal placement

1. Assign one voltage measurement to each branch connected to the bus where the PMU is installed, as well as one current measurement to the bus itself.
2. Each junction reached by other with a PMU should be assigned one voltage pseudo-measurement.
3. Each branch linking two buses with known voltages should be assigned one current pseudo-measurement. This allows observed zones to be connected.
4. Set one pseudo-measurement of current to all branches on which the KCL can be used to calculate current indirectly. If the values are known at one node, i.e., there is no power injection on node, this rule applies.

2. NORTHERN EASTERN REGION INDIAN POWER GRID

The northern eastern region of India's power grid is made up of seven states: Arunachal Pradesh, Meghalaya, Mizoram, Assam, Nagaland, Manipur, and Tripura. 14 Extra high voltage NERIPG buses are tested in this paper.[2]

Table 1. bus details of NERIPG

Bus no.	Bus name	Bus no.	Bus name
1	Bongaigaon	8	Misa
2	BTPS	9	Kathalguri
3	Balipar	10	Mariani
4	Khupi	11	Silchar
5	B. Chairali	12	Imphal

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6	Ranganadi	13	Melriat
7	subansiri	14	Pallatana

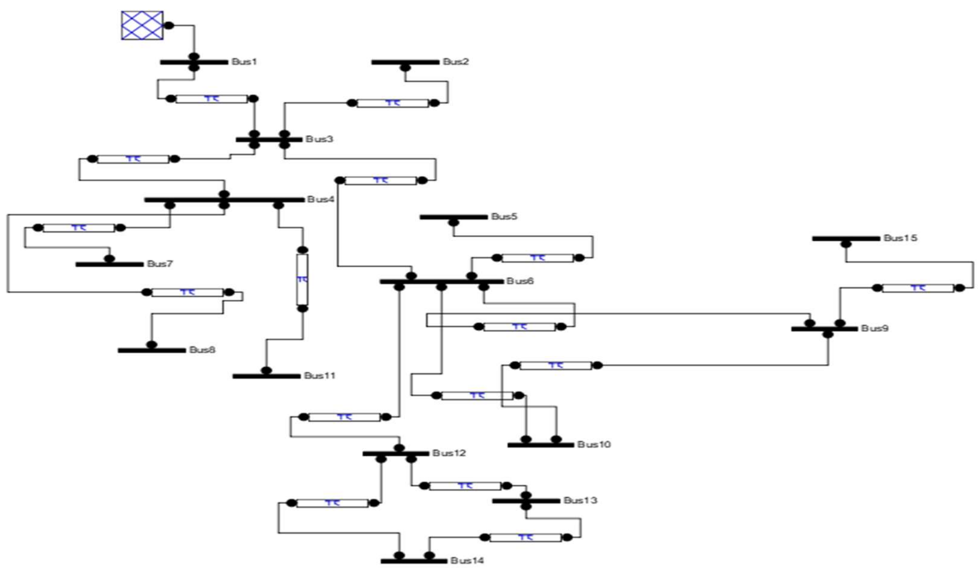

Figure 2 single line diagram of extra high voltage bus system of NERIPG

3. RESULT AND DISSCUSION

PSAT used for performing the test for optimal placement of PMU for absolute observability of the system. To find the best location for PMU in the mentioned region, four approaches are used: (N-1) minimum spanning tree, simulated annealing, graph theoretic, and depth first search. Ideal locations of PMUs for total observability with and without considering outage of one unit have been mentioned for this region. There is inbuilt algorithm of these four methods in PSAT called pmu placement tool. Results of the four-method mentioned in the table.

Table 2. Result obtained from different four methods

System name	Method	Elapsed Time	No. of PMUs required	PMU's location (bus no.)
Northern Eastern Region Indian Power Grid	Depth first search	0h 0m 0.02670sec	6	14, 13, 2, 6, 4, 1
	Graph theoretic	0h 0m 0.04155sec	4	14, 2, 4, 6
	Simulated annealing	0h 0m 0.0728sec	4	14, 2, 4, 6
	(N-1) spanning tree	0h 0m 0.0927sec	6	13, 14, 3,4,6, 9

3.1 Cost saving after optimal placement

In a standard installation, PMUs must be installed on all buses in the power grid. In optimum PMU placement, units are placed on some selected buses in accordance with the algorithm used, so that the grid can be observed with the fewest possible PMUs. Let us suppose the cost of one unit of pmu is approximately USD 30,000. The table below shows the overall cost for standard and optimal placement of pmu in the region.

Table 3 cost saving after optimal pmu placement

System name	Total no. of buses/per unit cost of PMU in USD	Total cost without optimal PMU placement	Method used for optimal placement	No. of PMUs required after optimal placement	Total cost after optimal placement
NERIPG	14 UHV buses/ USD 30000 (0.03million)	USD 0.45 million	Depth first search	6	USD 0.18 million
			Simulated annealing	4	USD 0.12 million
			Graph theoretic	4	USD 0.12 million
			(N-1) spanning tree	6	USD 0.18 million

4. CONCLUSION

The most important requirement for SG is that it be completely observable, which can be achieved by incorporating PMUs into the existing power grid. The results show that the placement location not only made the grid absolute observable, but it also kept it that way even when one pmu failed. We can conclude that the minimum (N-1) spanning tree method yields the greatest number of PMUs. In comparison to graph theoretic and annealing methods, the depth first search approach yields a higher number of PMUs. With graph theoretic we get lowest number of PMUs with good speed as well compare to simulated annealing method.

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