ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

OPTIMAL PLACEMENT OF PHASOR MEASUREMENT UNITS ON IEEE-24 BUS SYSTEM USING PSAT

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ABSTRACT

In the present era, with the expansion of power system the complexity and challenges in terms of grid stability, security and safety is increased. So more accurate, reliable monitoring and control systems are required. The present SCADA system is capable only to provide steady state view of the power system with high data latency whereas PMU can provide the dynamic view of power system. As PMU is a costly equipment so we can`t place PMUs on all buses of power system. Optimal placement of PMUs is necessary for complete observability of power system. In this paper Power System Analysis Toolbox (PSAT) is used for power system analysis and control. PSAT is used to solve the PMU placement problem using different methods such as Depth First, Annealing, Spanning Tree and Graph Theoretic procedure on IEEE-24 bus system. The Static report provides power flow through different methods and state variables, total P,Q and plots of theta, frequency, voltage magnitude are calculated for IEEE-24 bus system.An abstract of no more than 200 words (10pt Times New Roman, Justified).

KEYWORDS: PMU-Phasor measurement unit, PDC-Phase data concentrator, PSAT-Power System Analysis Toolbox,SCADA-Supervisory Control and Data Acquisition System, GPS-global positioning system, GUI-Graphical User Interface OPP-Optimal PMU Placement

INTRODUCTION

PMUs were first installed in 1980s. Phasor measurement units (PMUs) are power system devices that provide synchronized measurements of real-time phasors of voltages and currents. Synchronization is achieved by same-time sampling of voltage and current waveforms using timing signals from the Global Positioning System. The advantage of referring phase angle to a global reference time is helpful in capturing the wide area snap shot of the power system. The occurrence of major blackouts has given new impetus for large scale implementation of wide area measurement systems using PMUs and PDCs. Data provided by PMUs are very accurate and enable the system analyst to determine the exact sequence of events which have led to blackouts.[3]

PMU technology provides phasor information (both magnitude and phase angle). It is possible to obtain synchronized phasor measurements using PMU. Whenever any disturbance or fault occur the protection or control system has to be initiated for power system degradation, minimize the impact of disturbance, isolates the unhealthy part and restores the power system to normal healthy state.

It is neither economical nor necessary to install a PMU at each bus of wide area power network. As a result, the problem of optimal PMU placement (OPP) concerns with where and how many PMUs should be implemented on a power system to achieve full observability at a minimum number of PMUs[[4]]. The Optimal placement of PMU becomes an important problem to be solved in power system state estimation. PSAT is used for optimal placement of PMUs in this paper.

PSAT is a Matlab toolbox for electric power system analysis and control[2]. The command line version of PSAT is also GNU Octave compatible. PSAT includes power flow, continuation power flow, optimal power flow, small signal stability analysis and time domain simulation. All operations can be assessed by means of graphical user interfaces (GUIs) and a Simulink-based library provides an user friendly tool for network design. PSAT core is the power flow routine, which also takes care of state variable initialization. Once the power flow has been solved, further static and/or dynamic analysis can be performed. These routines are:

1. Continuation power flow;

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2. Optimal power flow;
3. Small signal stability analysis;
4. Time domain simulations;
5. Phasor measurement unit (PMU) placement [2]

MATERIALS AND METHODS

Pmu placement rules

The following PMU placement rules were proposed in [Baldwin et al. 1993] [1]:
Rule 1: Assign one voltage measurement to a bus where a PMU has been placed, including one current measurement to each branch connected to the bus itself.
Rule 2: Assign one voltage pseudo-measurement to each node reached by another equipped with a PMU.
Rule 3: Assign one current pseudo-measurement to each branch connecting two buses where voltages are known. This allows interconnecting observed zones.
Rule 4: Assign one current pseudo-measurement to each branch where current can be indirectly calculated by the Kirchhoff current law. This rule applies when the current balance at one node is known, i.e. if the node has no power injections (if N-1 currents incident to the node are known, the last current can be computed by difference).
Algorithms for different methods used are as follows[4]:-
Simulated Annealing-The code of the application of simulated annealing method for PMU optimal placement in a power system is in Nuqui (2001).

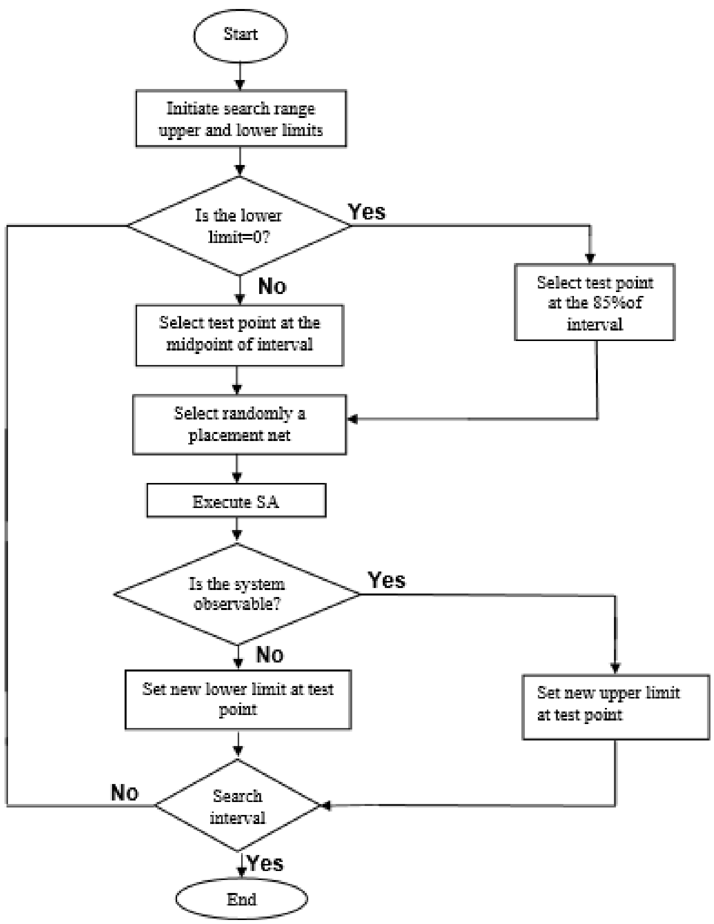

Figure 1 Simulated Annealing Method

Minimum Spanning Tree Method - Minimum Spanning Tree method (MST) is a modified depth first approach. (Farsadi et al., 2009):

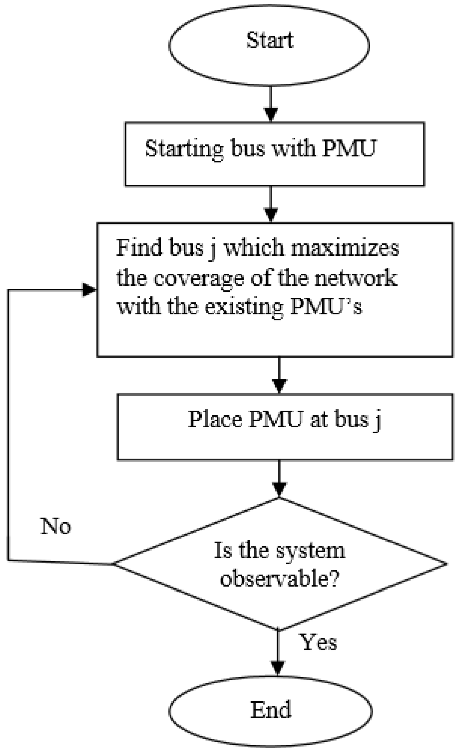

Figure 2 Spanning tree method

Graph theoratic technique:-The algorithm for Graph Theoratic is given below:-

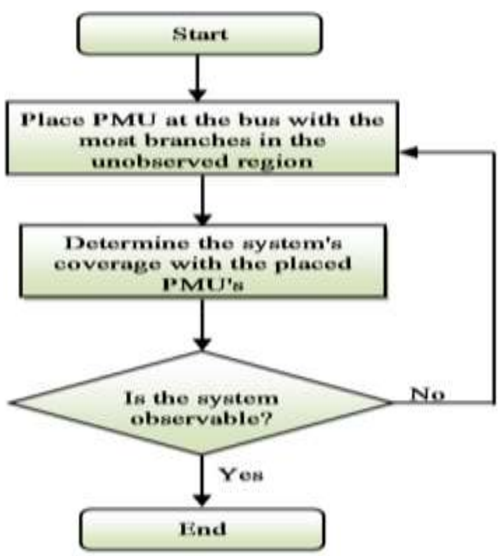

Figure 3 Graph Theoratic Method

IEEE-24 bus system is used in this paper.

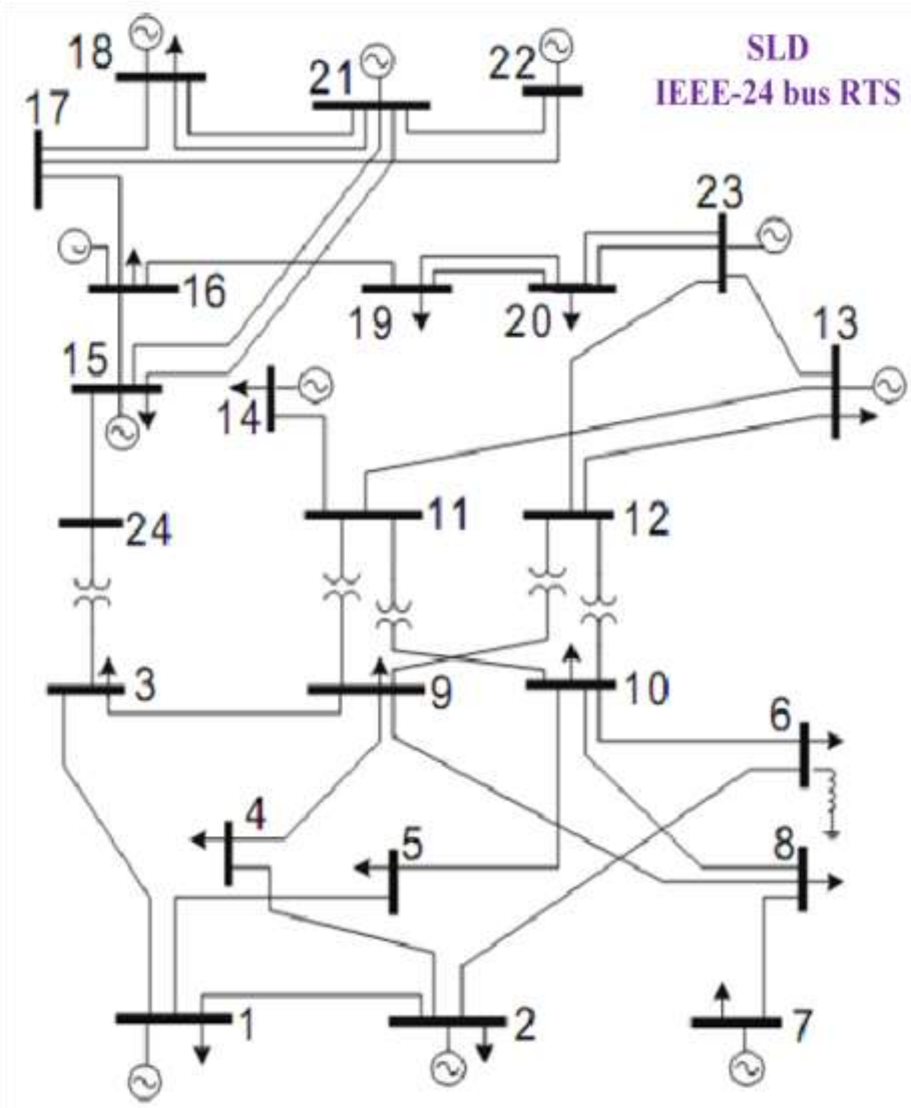

Figure. 4. IEEE 24 bus system

RESULTS AND DISCUSSION

POWER FLOW RESULTS

Bus	V [kV]	phase [rad]	P gen [MW]	Q gen [MVar]	P load [MW]	Q load [MVar]
Bus01	142.83	-0.23771	137.96	39.2321	108	22
Bus02	142.83	-0.23911	137.96	30.6427	97	20
Bus03	135.5351	-0.18962	0	0	180	37
Bus04	137.0992	-0.25462	0	0	74	15

ISSN: 2277-9655
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Bus05	139.8598	-0.26206	0	0	71	14
Bus06	138.6033	-0.29265	0	0	136	128.87
Bus07	141.45	-0.14648	272.31	53.3769	125	25
Bus08	136.3688	-0.23129	0	0	171	35
Bus09	137.1535	-0.19333	0	0	175	36
Bus10	140.4713	-0.2297	0	0	195	40
Bus11	225.6426	-0.09748	0	0	0	0
Bus12	227.7955	-0.06737	0	0	0	0
Bus13	230	0	464.44	34.36	265	54
Bus14	225.4	-0.06935	0	0.81783	194	39
Bus15	233.22	0.086	140.69	-9.785	317	64
Bus16	233.91	0.082	140.69	7.2707	100	20
Bus17	238.9532	0.14443	0	0	0	0
Bus18	241.5	0.161	363.07	138.87	333	68
Bus19	235.333	0.06857	0	0	181	37
Bus20	238.8132	0.09013	0	0	128	26
Bus21	241.5	0.1747	363.07	107.5573	0	0
Bus22	241.5	0.26588	272.28	-29.547	0	0
Bus23	241.5	0.11411	599.07	164.065	0	0
Bus24	226.0053	-0.01534	0	0	0	0

GLOBAL SUMMARY REPORT

TOTAL GENERATION

Real power [MW]	2891.543
Reactive power [MVar]	536.8718

TOTAL LOAD

Real power [MW]	2850
Reactive power [MVar]	680.8763

TOTAL LOSSES

Real power [MW]	41.543
Reactive power [MVar]	-144.0045

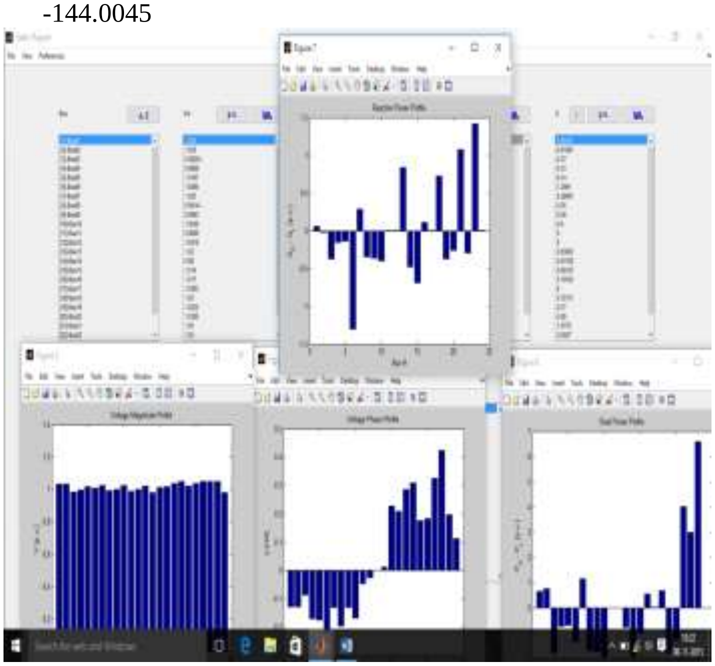

Figure 5 Graphs of P, Q, V, Ɵ

CONCLUSION

Number of PMUs and optimal placement of PMUs using different methods is shown below

Algorithm method	No. of PMU	Optimal Location
Depth first	8	2,7,9,10,16,21,23,24
Graph theory proc	8	2,7,9,10,16,21,23,24
Annealing	7	2, 8, 10, 17,20,21,24
Rec. spanning Tree	6	2,8,10,15,17,20

We can see that minimum no of PMUs are obtained using Rec. spanning Tree method. The Depth First search gives the highest number of PMUs. The optimal PMU placement decreases the no of PMUs which reduces the cost and obtains better power network operation and monitoring [5]. The OPP problem is an NP-hard problem. During the last many years, numerous optimization techniques have been developed to solve the problem. The proposed techniques can be classified into three main categories: conventional, heuristic, and metaheuristic [6]. It can be observed that the required number of PMUs for complete system observability is ranged from 21 to 25 percent. However it should be noted that the number of required PMUs for complete system observability is strictly dependent on network topology and the number of zero-injection buses[4]

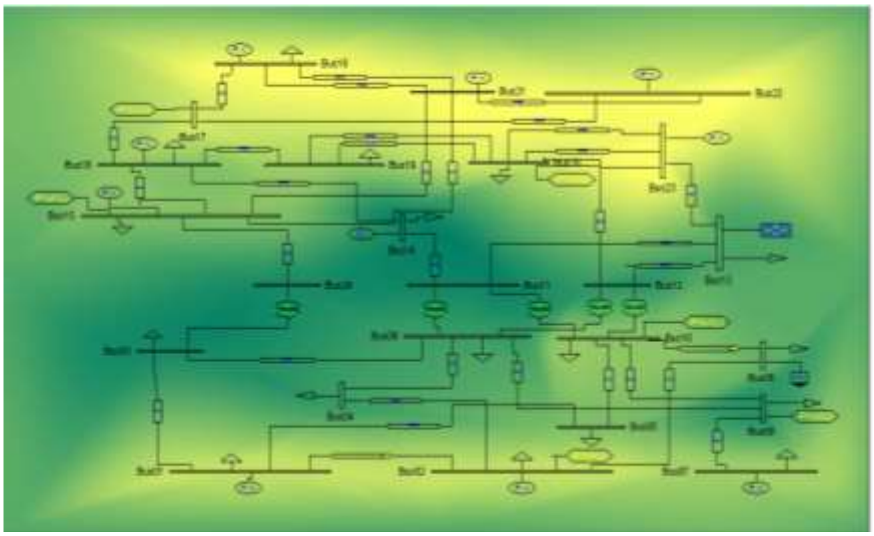

Figure 6 Optimal PMU placement

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