Best Assignment of PMU for Power System Observability

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Abstract

Phasor Measurement Unit (PMU) is a comparatively new knowledge that, when engaged in power networks, offers real-time corresponding measurements of the voltages at buses and currents all along the lines that unite them. This is proficient by using a GPS based monitoring scheme which facilitate time management of measurements and dissimilar SCADA, makes the calculated data accessible in Real-Time arrangement. SCADA is not capable to supply Real-time data due to the low speeds at which RTUs (Remote Terminal Units) supply data. Accessibility of time-stamped phasor measurements makes PMUs preferable for power system monitoring and organizes applications such as State assessment, Insecurity Prediction investigation, Real time monitoring of the system circumstances, Islanding uncovering, System Restoration and Bad Data discovery. Since PMUs are luxurious, their procurement and equipment needs to be planned both in terms of economy and usefulness. Frequently utilities like to see that the power network becomes completely apparent with minimum number of PMUs placed at calculated buses. Where full Observability refers to all the buses in the network is energetically monitored. Thus the difficulty of optimal placement of PMUs is formulated as an optimization problem where the number of PMUs is minimized theme to complete system Observability. This paper solves the optimal assignment of PMUs for power system Observability using Integer Linear Programming (ILP) method. The technique is tested on IEEE 14 Bus arrangement.

Keywords: *Integer Linear Programming, Phasor Measurement Units, Power System Observability.*

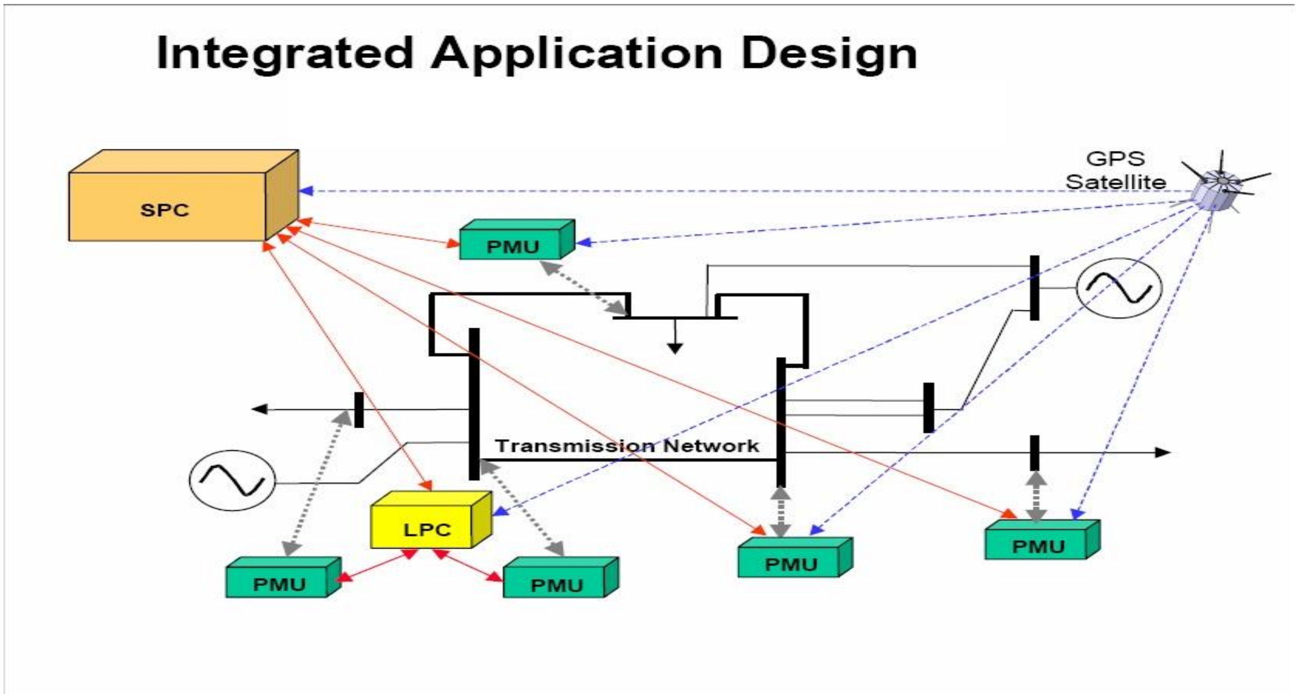
I. INTRODUCTION

A phasor measurement unit (PMU) is a device which procedures the electrical waves on an energy grid, using a common time foundation for organization. Time synchronization allows corresponding real-time measurements of numerous remote measurement points on the network. In power engineering, these are also frequently referred to as Synchrophasor and are measured one of the most significant measuring devices in the prospect of power systems. Synchrophasor knowledge provides a tool for scheme operators and planners to determine the state of the electrical system and supervise power excellence.

PMU is a monitoring device, which can make available synchronized quantity of voltage and current phasor in a power scheme. Synchronized signals are achieved from Global Positioning System (GPS) satellites. Synchronicity in PMU is achieved by time stamping of electrical energy and present waveforms using an ordinary synchronizing signal obtainable from the GPS. PMU measurements, in evaluate with SCADA system are in use at higher speed. Time stamping of each quantity; provides the precise view of the entire network interconnections. In recent years, due to towering cost of having PMU at every node of the network, several investigate activities have been performed to locate negligible set of PMUs in order to make the power system entirely apparent, with considering dissimilar operation conditions. A PMU is a measurement dispensation device which is associated to buses at substations. The PMU makes utilize of calculated currents and voltages beginning voltage and in development transformers. This is recognized in an analogue form and is processed by an anti-aliasing filter which removes all mechanism of the suggestion larger than half the Nyquist illustration speed.

The measurement signal is then put through an Analogue to Digital Converter (ADC). The digitized measurement is thereafter time-stamped by the GPS clock. The digital samples go through a microprocessor which converts the measurements into a phasor form of data. Now the calculated model is ready to be sent to the Phasor Data processor (PDC). The PDC can be compared to a mini-control centre; simply there may be several PDCs in a scheme. In other words, singular central control is not essential.

For systems of 60 to 70 Hz, 60 to 70 samples are provided per second correspondingly by the PMU. Figure 1 shows an illustration of control blocks of a PMU. The authentic phasor is consequent from the complex voltage and existing sinusoidal waveforms of the calculated buses. PMUs determine the voltage phasor of the occupant bus and current phasor in the lines concerning the adjacent buses.



A phasor network consists of phasor measurement units detached all through the electricity system, Phasor Data Concentrators to accumulate the information and an administrative Control and Data Acquisition (SCADA) system at the central control capability. Such a complex is worn in Wide Area quantity Systems (WAMS), the first of which was begun in 2000 by the Bonneville authority management. The complete network requires speedy data transfer surrounded by the occurrence of sampling of the phasor information. GPS time stamping can make available a theoretical accuracy of synchronization improved than 1 microsecond. PMUs often use phone lines to attach to PDCs, which then send data to the SCADA or Wide Area Measurement System (WAMS) attendant. Furthermore, PMUs can use ubiquitous portable (cellular) networks for data transmit (GPRS, UMTS), which allows possible investments in infrastructure and operation costs, at the expenditure of a larger data reporting latency. Nevertheless, the introduced data latency makes such systems more appropriate for R&D dimension campaigns and near real-time monitoring, and limits their use in real-time defensive systems.

Phasor Measurement Units (PMU) allows the viewer to get measurements of electrical energy phasor of all the bus as well as the phasor currents for all lines occurrence to that bus. PMU assignment at all substations allows direct quantity of the state of the system. Nevertheless, PMU placement on each bus of a scheme is complicated to achieve either due to cost factor or due to nonexistence of communication conveniences in some substations. Furthermore, as a consequence of Ohm's Law, when a PMU is placed at a bus, neighboring busses in addition happen to apparent. This implies that a system can be completed observable with a lesser number of PMUs than the numeral of busses.

Unified come up to be residential to find the minimum number and locations of PMUs such that the authority network is apparent. In adding together, it accounts for the accessible conventional measurements in the arithmetical model of the most advantageous PMU placement approach. An algorithm that avoids iterative adding up of measurements and allows simultaneous assignment of PMUs for Observability investigation. Technique to place PMUs in the power system optimally in the cases of loss of standard operating and in the case of any solitary PMU or single branch from the network. Comprehensive integer linear programming formulation for most favorable PMU placement beneath dissimilar cases.

II. PREJUDICED AND SUPPOSITION

PMU placement for Power System Observability is the main focal point of this manuscript. The algorithm must manufacture placement solutions that are cost effectual and either comparable to or better than placements of supplementary algorithms.

The following assumptions were made throughout the procedure of this paper:

- All PMUs cost the equivalent.
- There are satisfactory telecommunication facilities for PMU operations.

- The planned network does not utilize any obtainable conventional measurements and/or zero injections.

III. OBSERVABILITY ANALYSIS

Observability is and determine for how well interior states of a system can be incidental by knowledge of its peripheral outputs. The Observability and controllability of a system are arithmetic duals. Observability examination is a fundamental constituent of real time state inference. Observability investigation of electric power system is to study whether there is adequate measurement in system in order to estimation the state of electric power system together with the amplitude value and phase angle of the voltage. If the voltage of a node can be calculated directly or can be considered by other voltage phasor or current phasor, the node is apparent.

IV. PROBLEM FORMULATION

The least amount PMU placement difficulty is NP-complete, which can be solved by either arithmetical algorithm or heuristic algorithm. The integer of PMUs will have to be minimized due to cost and announcement line accessibility.

Consider the IEEE 14 Bus System and its quantity configuration shown in Figure 3.

The task of most advantageous PMU placement can be solved by using a binary integer linear programming move toward.

The objective function is given below:

To define a vector $X = [x_1+x_2+x_3 \ldots x_{Nbus}]^T$, $x_i \in \{0, 1\}$;

Where xi is the PMU placement variable.

Xi represents the vector of the buses.

The constraints are thus given as equation $AX \geq b\_L$

Where b_L is a vector: $[1\ 1\ 1\ .\ .\ .\ 1]^T$, which generates the constraint that each bus must be observed by at least one PMU. The algorithm for Integer Linear Programming is shown in Figure 2.

V. SIMULATION RESULT

The accessible method in this dissertation is programmed on MATLAB and binary integer linear programming predicament has been solved in order to find the best PMU placement with absolute Power System Observability and minimum setting up cost. In order to inspect the validity of the proposed algorithm, it has been experienced on IEEE 14-bus as shown in Figure 3.

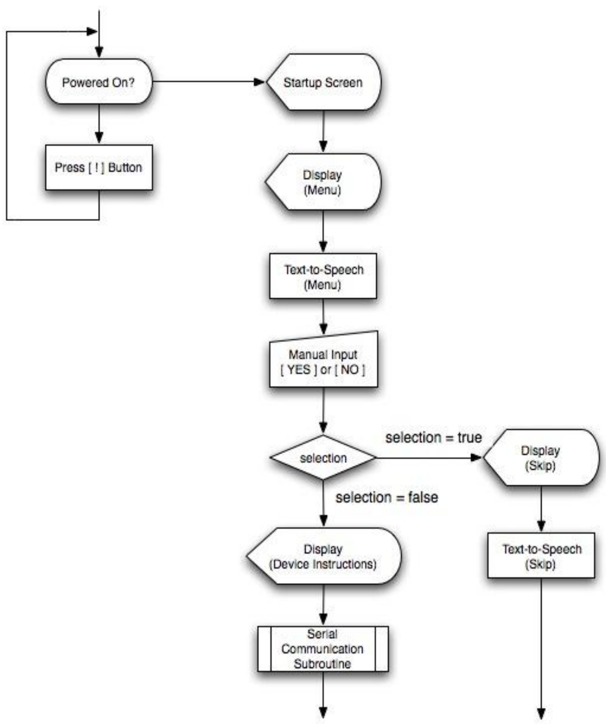


Figure 2 Algorithms for Integer Linear Programming

The technical specifications of the computer used for these simulations are given in Table I.

CPU	LEVEL 2 CATCHE	SYSTEM MEMORY
AMD C-50 Processor 1.00 GHz	512 kB	2 GB RAM

Table 1 Computer Configuration

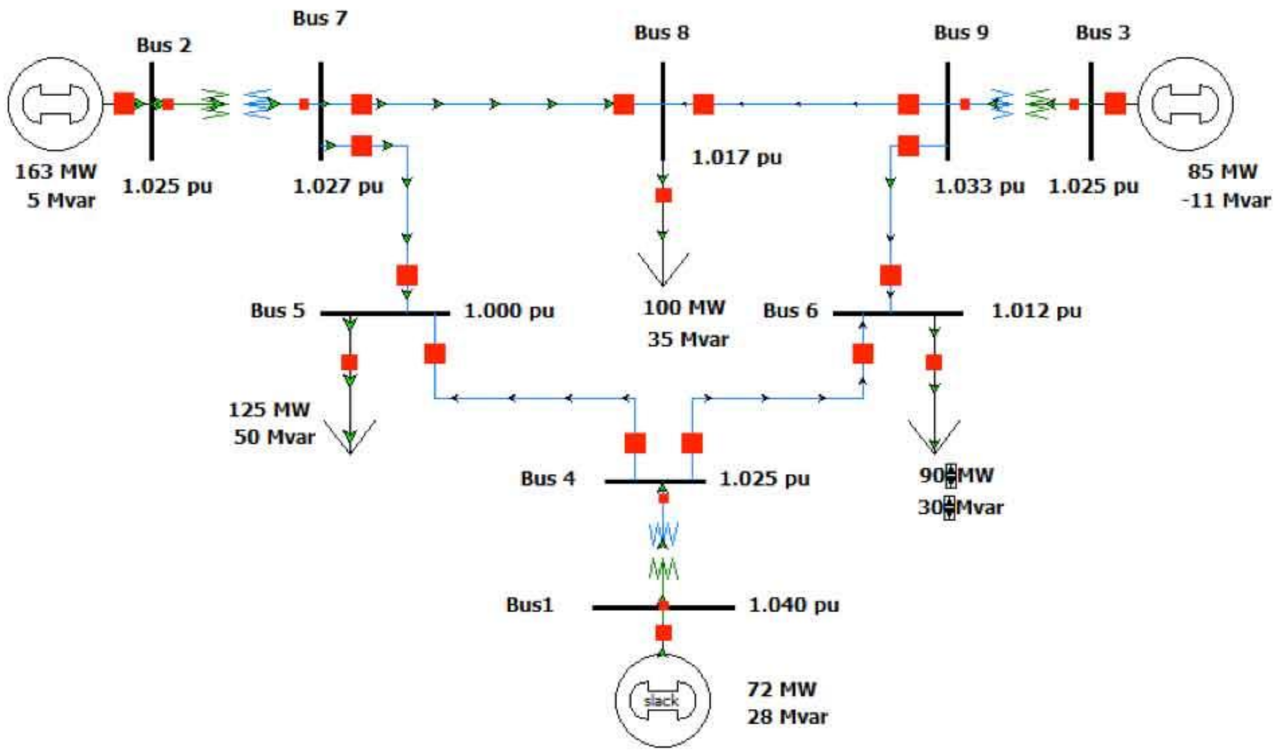


Figure 3 IEEE 14 Bus Systems

Integer Linear programming predicament is solved in MATLAB using the TOMLAB Optimization Toolbox. Table 2 shows the results of optimal PMU assignment for the IEEE 14-bus system, which has no other predictable power flow or injection measurements.

Sr. No.	Power System	No. of PMU Required	PMU Locations	CPU Time
1	IEEE 14 Bus	4	Bus 2, Bus 7, Bus 10, Bus 13	0.046800

Table 2 Simulation Results

The graphical demonstration is shown in Figure 4. The four PMUs installed at bus 2, bus 7 and bus 10, and bus 13 can construct the whole arrangement apparent.

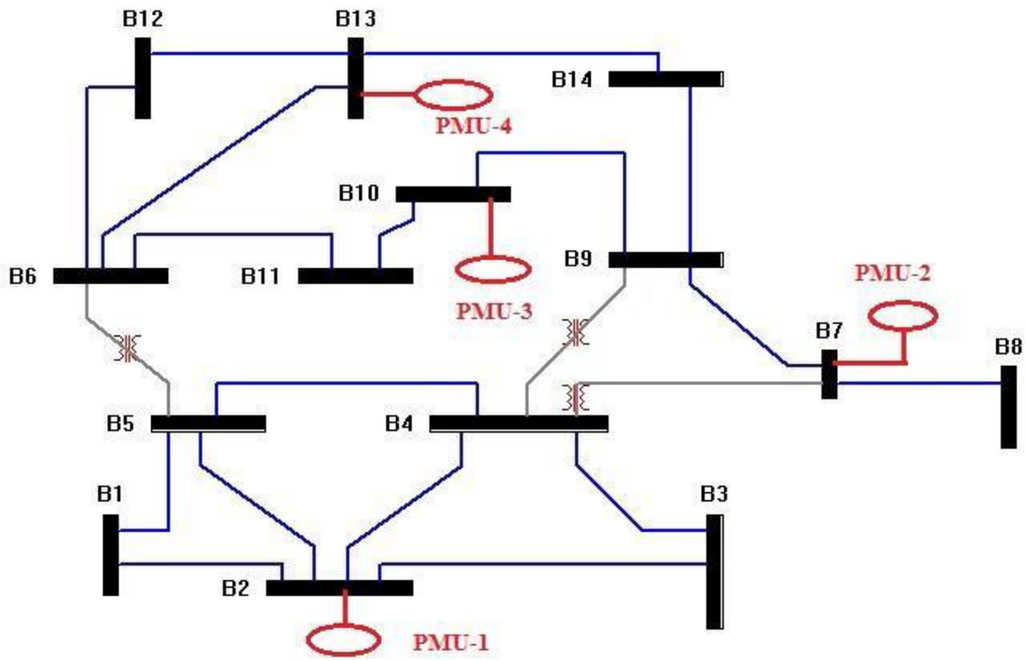


Figure 4 the Graphical Representation of Simulation Results

VI. CONCLUSION

A comprehensive method based on binary integer linear programming is worn to find the optimal number and position of PMUs, to make whole system entirely discernible. Keeping entire system apparent in case of any contingencies and minimizing total equipment cost are the major aims of this paper. Frequently utilities like to see that the power network becomes completely apparent with minimum number of PMUs placed at calculated buses. Where full Observability refers to all the buses in the network is energetically monitored. Thus the difficulty of optimal placement of PMUs is formulated as an optimization problem where the number of PMUs is minimized theme to complete system Observability. This paper solves the optimal assignment of PMUs for power system Observability using Integer Linear Programming (ILP) method. The technique is tested on IEEE 14 Bus arrangement.

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