MEASUREMENT CONFIGURATION FOR STATE ESTIMATION USING GRAPH THEORETIC APPROACH

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Abstract:

Calculations of power system conditions require a set of redundant measures. The problem with the measurement site involves choosing the quantity, nature and position of meters. The major purposes of configuring a measurement system is to meet the needs of costs, precision, observability and poor data processing for estimating the state of the electrical network. This article presents a method of graph theory for solving the complexity of placing meters for the estimation of state variables. The metering schemes for IEEE14 and IEEE30 bus system are presented. The proposed technique guarantees a reliable and accurate estimate of state variables at low cost.

Keywords: Graph theory, Meter placement, observability, State estimation.

Introduction:

State estimation is a significant function to form a real-time network model for power system operation and control. The state of the power supply system is defined by the amplitude vector and the bus angle of all buses in the network. The static state calculator is the data handling algorithm for altering redundant and less reliable real time measurements. The process involves collection data, gathering network topology, testing observability and estimation of state variables [1] - [4].

Topology processor detects energized and de energized sections of interconnected power system. Observability of the concern network is required to be tested before estimation to reach truthful state variable. Power system network of concern shall be observable for the computational needs of state estimator [24].

The estimates of the state of the electrical network requires instantaneous measurements, which are systematically selected depending on the nature, quantity and position in the monitored electrical network [13]. The important purpose of designing a measurement system is to meet requirements such as costs, precision, reliability and poor data processing of the electrical system condition calculator [11].

In 1990s, researchers began to attach importance to the development of an economical and dependable measurement system that can produce a precise estimate of the condition. Measurement data are usually voltages magnitudes and power at various locations on interconnected power system [19]. In 1996, a comprehensive method was developed and the configuration of measurement was presented on IEEE14 bus system [11]. In 2001, the method of simulated annealing (SA) was developed with the objectives to meet requirements such as observability, dependability and associated monetary costs was developed. The measurement configuration was presented on IEEE30 bus system [13].

Hybrid method of Genetic Algorithm and Simulated Annealing (GA / SA) was developed in 2006 and measurement configurations were presented on IEEE10 bus and IEEE14 bus system [43]. In 2011, measurement configuration for IEEE10, 14, 30 and 57 bus systems were presented. Biogeography Based Optimization technique was used to acquire measurement configurations [51]. In 2013, measurement configuration on IEEE10 and IEEE14 bus systems was presented using the Key Cutting Algorithm (KCA) [50].

Measurement Placement

Considering the cost of a voltage measurement, a power measurement and an RTU as 1, 4.5 and 100 monetary units (MU), respectively, Mesut E Baran et al. designed a measurement scheme on IEEE14 bus system [11]. The cost of the measurement system is 1112 MU. The measurement system has a redundancy of 1.92. The measurement system designed on IEEE30 bus with SA has a redundancy of 1.9 and the cost of measurement configuration is 3052 MU [13]. The measurement schemes designed with hybrid GA / SA [43] and KCA [50] give a redundancy of 1.04. The measurement scheme obtained through Biogeography Based Optimization [51] receives a redundancy of 1.02.

The measurement system obtained with GA / SA [43], KCA [50] and Biogeography Based Optimization [51] offers poor redundancy. Therefore, the cost of setting up the measurement system will be lower. However, the measurement configuration does not meet the requirement to recognise and removal of incorrect data because, after the loss of a few measurements, the redundancy will be less than 1. The quantities measured shall be greater than the minimal necessary to allow elimination of erroneous quantities to reach the correct estimation of state variables.

Proposed Process of Measurement Configuration

The suggested measurement location method is uses adjacency matrix of power system network of concern. The measurement configuration guarantees that all the lines of electrical system network are incident by injection or flow measurement at both the terminal nodes or by a flow measurement and an injection measurement at one of its end. Choice of meter places also confirms minimal necessity of RTUs.

The proposed meter placement method proceeds as follows:

- Read the bus file and initiate measurement set by power injections at all the zero injection buses.
- For n bus network, read line file and formulate n x n connection matrix A= [a_{ij}] where; a_{ij} =1, if i^{th} bus is connected to j^{th} bus and a_{ij} =0, if it is not. Revise the connection matrix by making all a_{ii} =0, as these components of matrix denote the bus itself.
- Calculate ones for every row of revised connection matrix. Detect nodes of highest (p) and lowest (q) connectivity. Place RTUs and measure the injection quantities at the buses of connectivity p, p-1, p-2 ……., till p, p-1, p-2 ……., = q+2.
- Recognize the lines having no injection quantity measured at one of its terminal ends, place RTU and add injection quantities at one of its end. Add injection quantities at the buses of q+1 connectivity and voltage measurements at all RTU positions till redundancy reaches $\geq$ 1.
- Reform line file by eliminating all the lines containing of injection measurements at both ends. Measure power flows through the remaining lines such that minimum number of RTUs are required to be placed. Measure voltages at additional RTU positions.

Test Result: IEEE14 bus

The simulation of suggested method is carried out to configure measurements on IEEE14 bus system. Figure 1 shows the measurement system configuration reached by the suggested process of measurement placement. Measurement arrangement uses 44 quantities out of 122 available measurements. The measurement system configuration yields redundancy of 1.63.

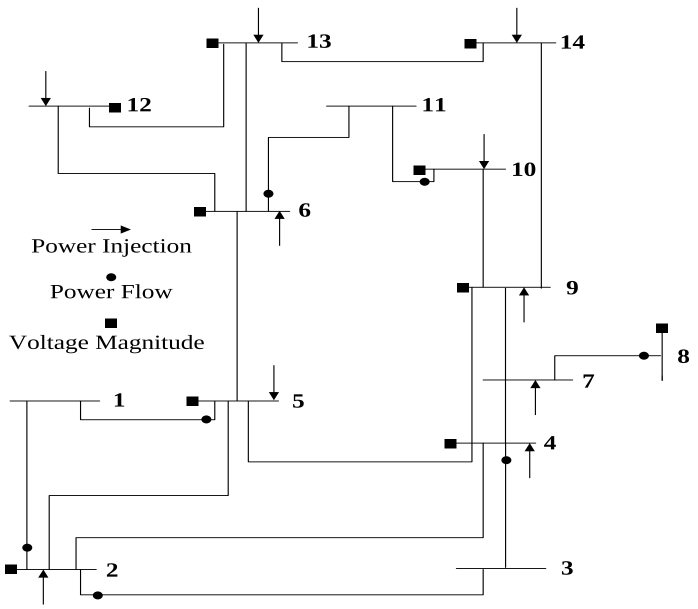

Figure1. Meter arrangement on IEEE14 bus using suggested method

Figure 2 and 3 shows the inaccuracies of estimations calculated using the proposed and all the methods of measurement placement discussed herein.

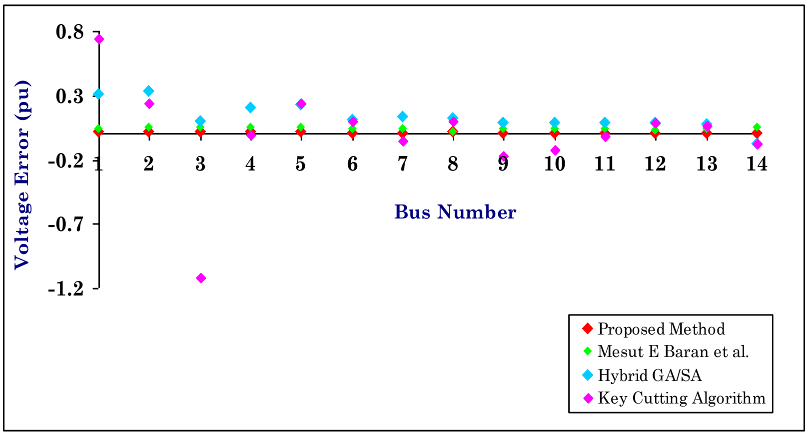

Figure2. Voltage Magnitude Errors: IEEE14 Bus

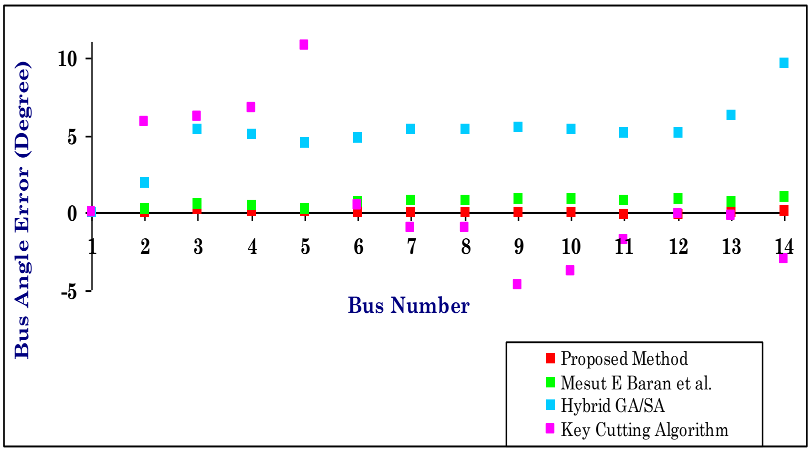

Figure3. Bus Angle Errors: IEEE14 Bus

Test Result: IEEE30 bus

The simulation of suggested method is carried out to configure measurements on IEEE30 bus system. Figure 4 shows the measurement system configuration reached by the suggested process of measurement placement. Measurement arrangement uses 90 quantities out of 254 available measurements. The measurement system configuration yields redundancy of 1.52.

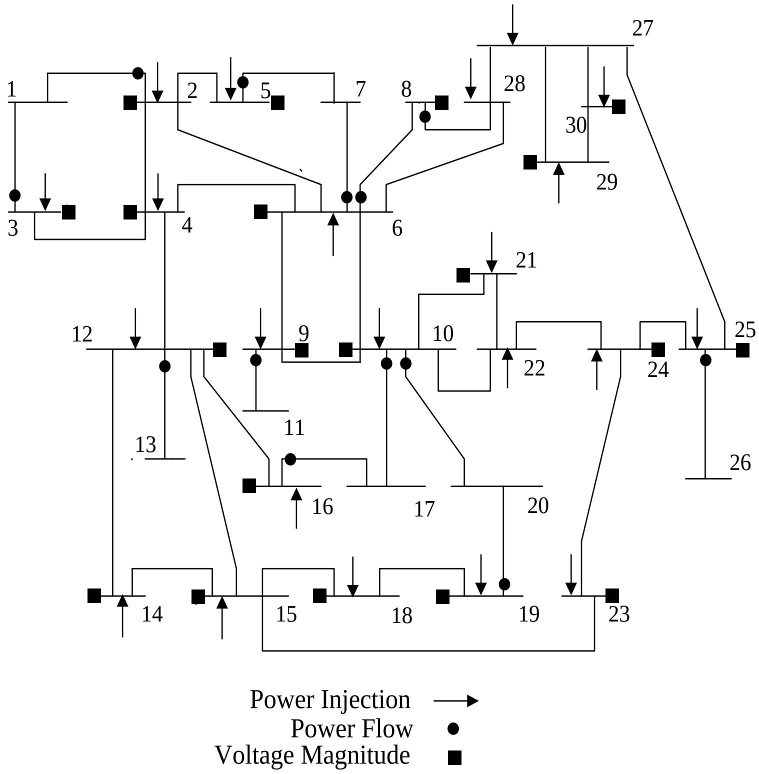

Figure 4. Meter arrangement on IEEE30 bus using suggested method

Figure 5 and 6 shows the inaccuracies of estimations calculated using the proposed and both the methods of measurement placement discussed herein.

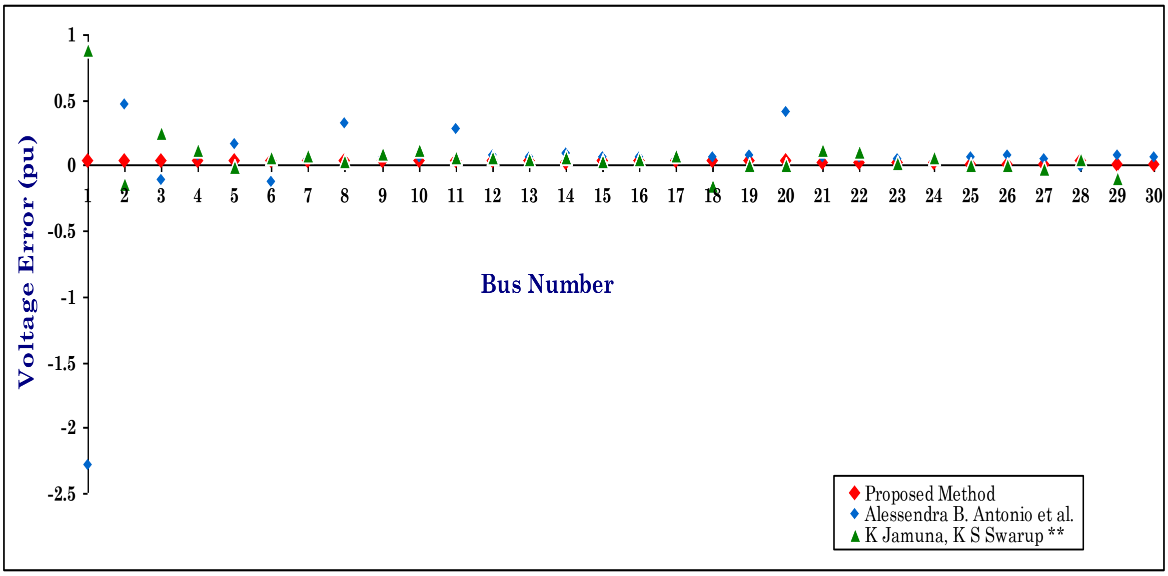

Figure5. Voltage Magnitude Errors: IEEE30 Bus

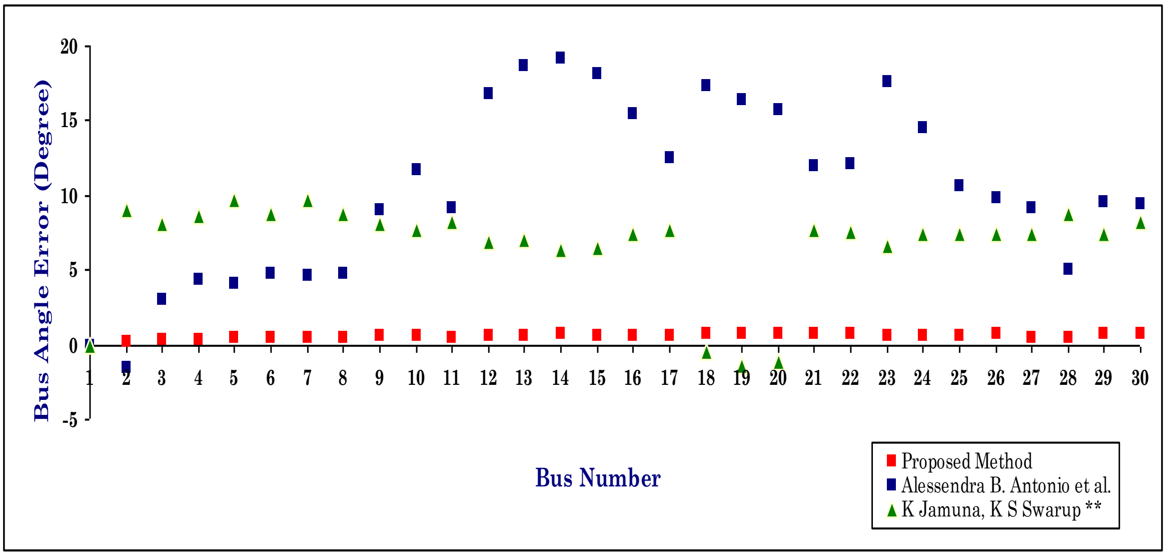

Figure6. Bus Angle Errors: IEEE30 Bus

Conclusion

The proposed measurement configurations provide a more accurate state than all the metering schemes discussed. The proposed method obtains a cost-effective measurement scheme compared with the measurement scheme acquired through comprehensive method. The monetary cost of the measurement system acquired with GA / SA, KCA and Biogeography Based Optimization is lower than the proposed method, but the proposed measurement system provides better reliability and yields much accurate state of power system.

It is expected that the suggested technique of measurement placement will be advantageous to present state estimators as an offline measurement system preparation instrument.

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