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Optimal placement of PMU and SCADA measurements for security constrained state estimation

K. Jamuna, K.S. Swarup *

Department of Electrical Engineering, IIT Madras, Chennai, India

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ABSTRACT

This paper presents a method for the use of Supervisory Control and Data Acquisition (SCADA) and synchronized measurements for complete observability of a power system. Under normal operation, both Node Phasor Measurement Unit (NPMU) and SCADA measurements are optimally placed using integer programming and Genetic Algorithm (GA) respectively. The minimum condition number of the Jacobian matrix is used as a criteria in conjunction with GA to obtain a completely determined condition. Next, a triangular factorization approach is used to search for the necessary candidates for single branch outage and single/multiple measurement loss. These candidate measurements are optimized by the binary integer programming method. Numerical results on the IEEE test systems are demonstrated. The results clearly show the robustness of the method to obtain reliable measurements under both normal and contingency conditions.

1. Introduction

In the deregulated environment, accurate monitoring of power system network is becoming most important function. State Estimator (SE) has been widely used as a vital tool for online monitoring, analysis and control of power systems. Entire power system measurements are obtained through Remote Terminal Unit (RTU) of SCADA systems which have both analog and logic measurements. SE uses a set of these measurements and it cannot be solved unless the system fully observable. Therefore the measurement placement becomes a significant problem in SE.

Network observability analysis determines whether the state vector of a whole system is able to calculate with available number and location of measurements. If so, the network is said to be observable, otherwise it is unobservable. Observability methods and Optimal Meter Placement (OMP) of state estimation for maintaining observability has been explained in detail by Clements [1]. In order to reduce the metering cost, meters are to be placed only at the essential location in the system. The meter placement method was first proposed in [2], which minimize the variance of estimated quantities. The same problem was addressed based on measurement reliability by Ariatti et al. [3]. Baran proposed a meter placement method for minimizing the meter cost based on state estimation accuracy [4]. Observability analysis can be solved by topological [5,6] and numerical [7,8] methods. Topological observability is found based on the graph theory. Maximal forests of full rank for a measured network are found in the topological observability algorithm. If the maximal forest of full rank is a spanning tree, then the network is topologically observable. Clements has contributed more works based on topological observability [6,9,10]. Numerical observability algorithm is based on the numerical determination of gain matrix. The network is observable, when the gain matrix is non singular and the rank is *N*, where *N* is the number of buses in the power system network. Gou and Abur have contributed an algorithm for meter placement using numerical observability [11,12]. In addition to the observability, bad data measurements have been done in [13]. Optimal meter placement during contingencies are also presented in [14]. The numerical observability method is complicated which requires iterative algorithms. Krumpholz et al. [6] explained algebraic observability where bus injection and line currents are considered as measurements.

The synchronized phasor measurements make significant improvements in control and protection functions of the entire power system and also improve the accuracy of state variables. The PMU is a device capable of measuring voltage and current phasor in a power system. Synchronism among phasor measurements is achieved using a common synchronizing signal from Global Positioning Satellite (GPS) [15]. Many researchers have focused on the optimal location of PMU for a system to be observable [16–20]. The general PMU placement criteria is presented in [21]. Bad data detection is done along with optimal PMU placement by Chen and Abur [22]. Gou [23] has proposed a new integer linear programming approach for optimal PMU placement with and without considering traditional SCADA measurements. The number of PMU requirements in a power network poses a problem to meet

* Corresponding author.
E-mail addresses: jamunakamaraj@gmail.com (K. Jamuna), swarup@ee.iitm.ac.in (K.S. Swarup).

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