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Tie-line constrained distributed state estimation

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ABSTRACT

This paper presents an implementable distributed state estimation method for online analysis of power systems having multiple, geographically separated areas. Distributed state estimation apart from giving a faster solution, also improves the condition number of the resultant gain matrices. The method proposed here uses the conventional WLS estimator (Gauss–Newton method) with equality constraints forcing the tie line flows as calculated by the adjacent areas to be equal. Based on the topology of the network, the system is partitioned into multiple areas and a processor is assigned to each of these areas for solving the local state estimation problem. Simulations carried out on the IEEE 14, 30 and 118 bus systems show good convergence properties and improvement on the condition number of the gain matrices when compared with centralized algorithms.

1. Introduction

State estimation is used in all Energy Management Systems (EMS) to identify the present operating state of a system [1–4]. Once the estimates of the state variables are known, proper actions, if required (during emergency, normal insecure states), can be taken to bring the system back to its normal secure state. For proper monitoring of the system, the intervals at which the telemetry data are collected and the estimates of the state variables made must be very less. At present state estimation in power system control centre is done every ten to fifteen minutes. As the size of a power system increases, collecting data and solving the state estimation problem in a very short time in one control centre, not only becomes very difficult, but also requires extra investment in setting up long telemetry and communication lines. Besides, policy and privacy considerations among companies operating in a transmission system also make centralized state estimation unsuitable.

Distributed state estimation (DSE) is one way of solving the above mentioned problems. Shahidehpour and Wang in [4], Tylavsky and Bose in [6] and Ramesh in [7] discuss the uses and issues concerning parallel and distributed computing in online power system analysis. In a distributed system, instead of having one control centre, the system has multiple control centres located in geographically separated areas. Each of these centres is equipped with tracking instruments and software to collect data and estimate the states of the buses local to it. Under such a distributed environment, the Remote Terminal Units (RTUs) collect data and sends it to the control centre that is local to it; instead of sending it to a central control centre located hundred kilometers away. The availability of advanced distributed computing technologies, both hardware and software makes this kind of real time analysis possible. Since the size of the local state estimation problem is much smaller than the very large master problem, the time taken to solve it and the number of iterations for it to converge is also less when compared to the master problem. Apart from saving in time and investment, distributed state estimation has certain numerical advantages as well. The gain matrix of a large state estimation problem is a severely ill-conditioned matrix. Gu et al. in [5] discusses about the solution of large ill-conditioned power system state estimation problems. Once the problem becomes smaller, the ill-conditioning of the gain matrix decreases and the state variables become less sensitive to errors in the measured values.

Distributed state estimation has been an area of research for quite sometime. Some of the proposed methods of solving a distributed state estimation problem are given in [8–15]. Wu and Falcao in [8], Carvalho and Barbosa in [9], and Ebrahimian and Baldick in [10] propose methods based on two adjacent areas sharing a boundary bus. Lin and Lin in [11] proposed a hierarchical, tier based state estimator [12]. In [13], Lin proposes a method based on the recursive quadratic programming on the dual (RQPD) method. In [14], Zhao and Abur propose a two level state estimator using synchronized phasor measurements. The method proposed here uses the conventional decoupled (P–θ and Q–V), Gauss–Newton method with equality constraints forcing the tie line flows as calculated by the adjacent areas to be equal. It follows [8] very closely because of its simplicity and effectiveness. However, in [8], two areas are made to share a bus and the equality constraints forces the state variables of the shared bus as calculated by the two areas to be equal. An important advantage of the proposed method is that the buses in one area are not referenced to a slack bus placed

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