CONSTANT MATRIX METHODS FOR STATE ESTIMATION, SECURITY ANALYSIS AND OPTIMIZATION IN POWER SYSTEMS

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M Y P A R E N T S

CERTIFICATE

Certified that this work, 'Constant Matrix Methods For State Estimation, Security Analysis And Optimization In Power Systems', by Mr. N. Srinivasan has been carried out under our supervision and that this work has not been submitted elsewhere for a degree.

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ABSTRACT

This thesis presents the results of the investigation on certain important aspects of real-time problems encountered in a power system. The problems considered are

- State estimation
- Simulation of the outage of a line or a transformer using a constant sensitivity matrix, and filtering and ranking of critical contingencies
- Line load alleviation using phase shifting transformers, generation rescheduling and/or load curtailment
- Economic dispatch and Inverse optimal power flow

The main contributions of this investigation include

- Development of three new state estimation algorithms
- Application of constant sensitivity approach for outage simulation, and development of an efficient and reliable method for filtering and ranking of critical contingencies
- Development of a simple approach for the computation of phase shifter distribution factors required for the alleviation of line overloads and application of constant sensitivity approach to the problem of load shedding
- Development of a simple method for the computation of penalty factors required for solving the coordination equations
- Formulation of load shedding problem as a nonlinear optimization problem.

To start with, a constant Jacobian load flow model is discussed. This method will be of considerable use for solving load flow problems for networks having large R/X ratios or systems having capacitive series branches. This method is more reliable than fast decoupled load flow method. The memory requirement of this method is less than the Newton-Raphson load flow method and is simple to program. Based on the constant Jacobian model all the other algorithms are developed. Three improved methods are developed to solve the static state estimation problem of power systems. The first method presents a modified decoupled estimator which is faster than the fast decoupled state estimator available in the literature. The second method is based on the constant Jacobian load flow model which is more reliable than the fast decoupled state estimator. The third method is based on a second order load flow model. The state of the system obtained from the estimator can be used to execute some sophisticated controls on the power system.

A simple and fast method for simulation of line and transformer outages based on a constant Jacobian load flow model is developed. Some of the elements of the constant sensitivity matrix are utilized in calculating the required changes in injections at the terminal buses of the outaged element during the simulation. The corrections for the state vector are computed using the triangular factors of the base case Jacobian and post-outaged state vector is obtained. This simulation technique is used to develop a reliable and simple method for filtering and ranking of critical contingencies. Infinite norm is used for filtering critical contingencies. Performance indices which reflect transmission line overloads,load voltage levels and generator reactive capabilities are used to rank the identified critical contingencies in a decreasing order of severity. Secondary outages are also included in the proposed method. Once the security assessment studies are carried out, it is necessary to take preventive and corrective actions to keep the system in a secure state. Since overloaded transmission lines in a system pose a major security problem, efficient methods have been developed for alleviating line overloads. One of the simplest ways of controlling the line flows is by adjusting the phase angles of the phase shifting transformers. Thus, a new method is developed for the computation of phase shifter distribution factors required for adjusting the phase angles of the phase shifters to control the line flows. These factors are computed from the triangular factors of the load flow Jacobian. Computation of these factors is carried out for both the base case system and the outaged system using the triangular factors of the base case Jacobian or the base case sensitivity matrix. The factors so computed are used to alleviate the line overloads leaving the economic generation schedules unaffected. In case the phase angle control does not reduce the line overloads completely, a method for generation rescheduling and/or load curtailment is proposed, thus ensuring a secure system operation.

However, under normal conditions of operation, economy being an important criterion, the cost of generation should be minimized. Two algorithms have been developed to suit two different conditions. In the first condition, when the available generation is more than the total load demand, a method for economic dispatch is proposed. In the second condition, when the load demand is greater than the available generation, an optimization technique for load shedding is proposed. The proposed economic dispatch method reduces involved calculations of penalty factors. In this method, penalty factors are generated using some of the columns of the sensitivity matrix. All the penalty factors can be obtained in one step. These penalty factors are then used to solve the coordination equations which result in economic dispatch. The optimization technique for load shedding gives the load demands at various buses for a given set of available generations in the system. The constant Jacobian load flow model again is used to obtain the load flow solutions. The objective function which is minimized in this case is the weighted sum of the squares of the differences between the actual load demands and the load demand that can be met at each bus. The gradient method is used for this purpose. This provides a systematic way of load curtailment under the conditions of generation shortage.

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