Abstract

Electric energy plays a significant role in the development of a nation. Today, there is a trend towards tremendous growth and phenomenal modernization of electric power systems throughout the world. To operate and control such systems, the importance of Dynamic State Estimation can not be over emphasized.

The dynamic state estimation consists of a filtering process based on power system measurements, followed by a prediction step utilizing the model of power system dynamics. The predictive data base is highly useful for all types of predictive analysis and control, preventive or corrective, for both the normal and emergency conditions. This thesis presents a number of novel dynamic state estimation algorithms, suitable for real-time applications.

The existing models of power system dynamics fail to depict the actual time evolution of the complex bus voltages. This not only degrades the predictive data base, but also affects the filtering performance. Accordingly, a new model of power system dynamics, utilizing the basic power system relations has been presented in this thesis.

At the filtering step, the state of the art is to use extended Kalman filter (EKF). But EKF is a far less precise, suboptimal filtering scheme, where the linear algorithm of optimal Kalman filter has been adapted in nonlinear environments. Consequently, use of optimal filter, realizing line flow measurements has been proposed in this thesis to enhance the filtering performance. The scheme utilizes a measurement model, which relies on the linear relationship between the complex bus voltage vector and the complex element voltage vector, derived from the line flow measurements. The performance of this filtering scheme is very much satisfactory, but degrades in presence of bad data in the in the measurements. This motivated to consider the problem of making Kalman filter robust, and two robust filtering schemes based on statistical approach, utilizing line flow measurements have been proposed in this thesis.

The performance of the above two robust filters are very much satisfactory not only in presence of Gaussian noise but also in presence of bad data in the measurements, characterized by heavier tails, called outliers. But the aforesaid robust filters utilize only the

active and reactive power flow measurements of the power system. In an actual power system, excepting active and reactive power flows, there are also measurements of active and reactive bus powers, voltage magnitudes etc., which bear useful information. Accordingly, one more robust filtering scheme, designated as 'Extended M-estimation' has been proposed, considering all types of power system measurements. Also, the suggested scheme of dynamic state estimation includes a simple but reliable method of detection and identification of anomalies, built from dynamic behaviour of the state and measurement vectors.

One major difficulty in real-time application of dynamic state estimation for large electric power system is the high computational burden at the filtering step. The computational time increases with the increase in the size of the power system. Thus, a novel two-level hierarchical dynamic state estimation has been suggested in this thesis.

In reality the power system dynamics are governed by the bus injections, as any change in bus loads and/or generations affect several bus voltages. So, the prediction step on the basis of nodal power injections rather than conventional state vector is more appropriate. Realizing this fact, the possibility of applying multilayered feed forward network, using back propagation algorithm for short term forecasting of bus loads has been investigated in this thesis and a new hierarchical dynamic state estimator based on artificial neural network has been proposed.

All the proposed schemes have been rigorously tested on IEEE 30-bus and 118-bus test systems under various simulated operating conditions and the results are presented in terms of various performance indices and statistical parameters.