Abstract

This thesis mainly concentrates on exploring the detection and analysis of the onset of lightly damped electromechanical oscillation as soon as they appear in the system response, and tools were developed to characterize the signal. Electromechanical oscillations of sustained nature were further investigated, and the source-effect relationship behind the event was established. Data-driven techniques to utilize electromechanical oscillation of the power system and ascertain the power system conditions were further discussed. Different mathematical formulations were used to support the theories and tools proposed in the thesis and validated by several measurement data obtained from the time-domain simulation as well as field phasor measurement units (PMUs) as discussed in detail as follows:

1) A novel signal processing technique, wavelet ridge technique (WRT), was introduced in this thesis to extract the slow varying feature of the power system response. The idea behind this WRT is that for electromechanical oscillation, there exists a unique time/curve called 'ridge' along which the dominant oscillating trend can be appropriately extracted. It was seen that the WRT showed superior performance when compared to empirical mode decomposition (EMD) to extract the low-frequency oscillation in the noisy signal. One can estimate the impact of the disturbance on a system by obtaining the dynamic trend from the noisy signal and determining its characteristics. The generalized wavelet used in this thesis was an analytic wavelet, and the extracted signal was in the analytic format. This feature was further used to characterize the oscillatory signal i.e., estimating amplitude, frequency, mode shape, damping parameter of the oscillation.
2) A well-damped electromechanical oscillations do not pose a threat to system security, whereas sustained oscillation has a detrimental effect on the power system. Sustained oscillation can persist in the system due to (*i*) small-signal disturbance to weakly damped power system or (*ii*) periodic forced disturbance to weakly/ well-damped power system. A new data-driven technique was proposed in this thesis to distinguish the sustained oscillation between the natural and forced oscillation. It uses the characteristics of the ambient noise, which gets affected differently in both types of disturbance to determine the nature of sustained oscillation.
3) A measurement-based technique has been suggested in this thesis to locate the source of

the disturbance. The methodology calculates the dissipating energy contribution of a generator into the system, and depending on the nature of it, the source of forced oscillation has been localized. Dissipating energy calculation uses the measurement data from the generator as well as the load buses. The discussed method was tested and verified for various scenarios such as single and multiple sources of disturbance present at single and multiple time instants.

4) A multidimensional approach, which utilizes the measurement data as well as system information to locate the source, was discussed in this thesis. In this approach, frequency response function (FRF) for a pair of input/ output has been utilized to define an index to quantify the contribution of a generator in the disturbance, and based on that generator numbers were ranked. Another index using the time measurement data was proposed to sort the generators depending on its participation in the forced disturbance. Then, both sequences were compared using a multidimensional search algorithm, and then, the source was revealed.
5) Electromechanical oscillation recorded in the power system may be used for various applications. Three different applications of utilizing power system scenarios were discussed in this thesis. In one application, the oscillating trend of the signals was utilized to determine the most potential candidate of controller location by processing multivariate signal. Therefore, a multidimensional signal processing technique was discussed to process multidimensional data and evaluate power system conditions following a disturbance. A data-driven technique to form a reduced area network for a large system utilizing electromechanical oscillatory signal was proposed in this thesis. Furthermore, in this thesis, measurement data recorded at the generator terminals were utilized to estimate key states and parameters of the synchronous generator represented in the classical form. Various time-domain simulations and field measurement data were used to verify the proposed methods.

Keywords: Electromechanical oscillation, Signal processing technique, wavelet ridge technique, transient stability, small-signal stability, forced disturbance, Dissipating energy, frequency response function, multivariate signal processing technique, State and Parameter Estimation, unscented Kalman filter.