Abstract

This dissertation primarily focuses on the mitigation of instabilities in the power system via novel auxiliary stabilizers and intelligently controlled energy storage systems. Improving the stability margins in a power system allows the higher flow of power through interties which translates into a measurable economic benefit. Dynamic state estimator using local measurements acts as a precursor for the auxiliary stabilizers as they utilize unmeasurable interior states of the machine in the control law. Further, bulk integration of renewable energy requires fast-acting energy sources/sinks at the time of the disturbance. In this context, intelligently controlled fast-acting energy storage systems have been suggested to mitigate intermittency, enhance transient and frequency stability margins. Several aspects investigated in this thesis are as follows-

1) A nonlinear dynamic state estimator has been recommended to estimate the unmeasurable states of the machine using analogue measurements from the generator (terminal) bus instrument transformers. This methodology is well suited for enhancing system control, assessing dynamic security and monitoring oscillatory modes to name a few.
2) A decentralized nonlinear excitation controller utilizing terminal bus voltage and frequency measurements as exogenous inputs and machine states (estimated locally) in the robust optimal control law for significant enhancement in the dynamic and transient stability margins has been proposed.
3) Grid integrated low inertia DFIG wind energy conversion system (WECS) exhibits prolonged oscillations following a network disturbance. A computationally adaptive optimal damping controller using DFIG-WECS interior states (estimated locally) has been suggested for the mitigation. Compared to its predecessors, proposed stabilizer being robust and cost effective improves the stability significantly.
4) Performance of auxiliary stabilizers is affected by the system nonlinearities like saturation limits, dead-bands, rate constraints etc. In this context, effective use of properly controlled fast acting storage facilities like flywheel energy storage system and ultrabattery storage is suggested. Modelling and control architecture of the new storage technology namely ultrabattery and flywheel storage has been introduced and discussed for subsequent use in power system stability enhancement.
5) The application of an intelligently controlled flywheel energy storage system (FESS), to

mitigate the intermittency in wind power injection, as well as enhance the transient stability of the connected multimachine power system has been investigated. The main contributions are – *a*) enhanced use of DFIM based FESS for transient stability improvement following a network disturbance, *b*) demonstrating the intelligent controller development and its application for the flexible operation of the FESS facility, and *c*) intermittency mitigation via FESS considering actual wind speed profile.

6) The use of intelligent virtual synchronous generator and constrained LQR based ultrabattery storage has been suggested for improved frequency control.

Keywords: Adaptive control, cubature-Kalman-filter (CKF), decentralized, dynamic state estimator, damping control, DFIG, linear quadratic regulator (LQR), neural networks (NNs), optimal control, phasor measurement unit (PMU), power systems, stability.