Abstract

The thesis works pertain to the development of efficient and reliable power management schemes, optimal load dispatch based control, and robust stabilization of multiple voltage source inverter (VSI) interfaced distributed energy resources (DERs) operating in a standalone AC/DC system or a networked autonomous microgrid (MG).

Initially, a dynamic power management scheme (PMS) is developed for a standalone AC/DC system constituting of photovoltaic (PV) system, PEM fuel cell, and hybrid energy storage (HES) comprising battery energy storage (BES) and supercapacitor (SC) pack. The developed PMS uses a moving average filter (MAF) such that the generated current references to the DC-DC converters of PV, PEM fuel cell, BES, and SC are based on their different dynamic response characteristics. The PMS ensured stable operation of hybrid standalone AC/DC system even when the HES was subjected to the maximum and minimum state of charge (SoC) limits.

Further, the maximum penetration of PV systems in diesel generator (DG) based power system is limited in the range of 40% to 60%. When the PV capacity becomes comparable to DG capacity, the system suffers from stability and synchronization issues. A dc integration technique employing a dc droop-based hierarchical control was developed for the PV-BES-DG system integrated at a common dc bus to overcome these issues. Moreover, an optimal regulator-based secondary control is developed to ensure optimal load sharing among DG and BES while safeguarding BES life. Further, a PMS is designed to ensure the standalone system's reliable operation during source and load power imbalances and operation under the critical SoC limit condition of BES.

For the standalone operation of DERs interfaced to VSI, the VSI operates in grid forming mode to maintain a constant voltage and constant frequency (CVCF) across the load terminals. Under unbalanced and nonlinear loading, the output voltage waveform's power quality deteriorates, leading to increased voltage unbalance factor (VUF) and total harmonic distortion (THD). A multivariable nonlinear disturbance observer was developed to observe the SRF components of load current containing 2nd and 6k harmonic components. The observed SRF load currents were feed-forwarded to the outer voltage control loop, which minimizes the effect of load current as the grid forming VSI supplies reactive power current components for harmonic compensation.

The autonomous microgrid (MG) with multiple voltage source inverters (VSI) is operated in droop mode to share the load proportionally. These VSI controllers require higher droop constants if the feeder lines connecting the VSI to the microgrid have a low X/R ratio. The higher droop gains and large loading conditions in the microgrid may exhibit instability with the low-frequency power modes (LFPM). A systematic multivariable plant model of the MG using dynamic phasor modeling of power flow transfer functions is developed to analyze the LFPM. Further, a robust supplementary multivariable controller is developed to stabilize the developed plant model, damp LFPM, and improve transient power-sharing performance of VSIs without affecting their steady-state power-sharing. This stabilizer is developed based on Glover-McFarlane $H_\infty$ loop shaping robust stabilization technique with additional pole placement constraints formulated in linear matrix inequality framework.