Abstract of PhD Thesis

“Control Of AC/DC Microgrids With DFIG Based Wind Energy Conversion and Solar PV Generation”

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The decentralization of electricity generation has initiated a paradigm shift in the power sector. Decentralized generation, in the form of solar photovoltaics (SPVs), wind energy conversion systems (WECSs), etc., when aggregated with local loads, forms a self-sufficient entity, commonly termed a microgrid. Hybrid AC/DC microgrids are rapidly evolving into the preferred microgrid architecture due their minimized power converter redundancy when interfacing the DC-based generation sources or loads. The doubly fed induction generator (DFIG) shares a large portion of current market share among various variable speed WECSs. This is primarily due to its permanent magnet-free constructional benefits and reduced rating generator-side power converter. When integrated along with the SPV array-based solar energy conversion system (SECS), it provides an effective means of meeting the load power requirement. The DFIG-SPV based AC/DC microgrids may either operate as a grid-integrated entity that enables the import or export of the net power with the utility grid or operate as a standalone system, wherein, the deficit/excess generated power is exchanged with an energy storage system.

This work initially deals with the operation and control of DFIG-SPV based standalone AC/DC microgrid. The preliminary requirement of the standalone system is the effective amplitude and frequency regulations. Moreover, power quality aspects of the standalone voltages and currents amidst the presence of unbalanced and nonlinear AC loads cannot be undermined. This becomes increasingly prominent in case of DFIG-SPV based AC/DC microgrids due to the direct inter-connection of DFIG stator terminals with these abnormal AC loads. Any unregulated operation in such circumstances results in unsymmetrical and harmonics currents in the DFIG. Another major concern in the standalone DFIG-SPV based microgrids pertains to the availability and connection status of the DFIG-based WECS. The disconnection/reconnections instants of the DFIG is required to be smooth, while, the standalone AC as well as DC loads are required to be fed uninterruptedly.

In case of grid-integrated DFIG-SPV based AC/DC microgrids, three major issues are dealt in this thesis. The first issue relates to the uncertainty in the grid, especially in AC/DC microgrids located in rural and remote areas. Although many of the rural areas are declared electrified, the grid continuity in such regions is still a major concern. The need for ensuring a seamless transition between grid-integrated and system islanding operating modes is quite apparent. Furthermore, the uninterrupted operation of the system during these transitions is also a necessity. The second issue relates to the vulnerability of the grid to sudden power changes in the system. The large ramp-rate power changes in the system may impact the grid voltage amplitude and frequency, especially in the remote and secluded regions, where, the grid-interconnection is through long and weak distribution feeders. Grid-assistive power smoothening approaches need to be supplemented within the microgrid control to minimize the risk of grid instability. The third issue that is addressed, relates to the operation of the DFIG-SPV system amidst the presence of unbalance and distortions in the grid voltages. The non-idealities in the voltages culminate into oscillations in the DFIG torque, DFIG stator power, and injected grid power. Meanwhile, it degrades the power quality of DFIG rotor currents, DFIG stator currents, and injected grid currents. Both control-related and topology-related approaches are required to ensure enhanced operation of the system with the non-ideal grid voltage scenario.

After effectively mitigating the three major issues in the grid-integrated operation of the DFIG-SPV system, this thesis deals with the self-sustainability aspect of the microgrid during prolonged grid outage scenarios. Normally, the energy storage integrated to the microgrid provides sufficient back-up during islanding conditions. However, the energy storage cannot be designed to sustain prolonged periods of grid-outage. Therefore, to maintain the self-sufficiency of the system, the framework for operation of a dispatchable diesel generator system working alongside the WECS and SECS is required. The uninterrupted operation and seamless mode transition are also inculcated in this thesis through the control scheme of diesel generator (DG)-equipped microgrid.

Upon devising the methodology for control and operation of DFIG-SPV-DG based AC/DC microgrid, the focus of the research work shift towards devising generalized methodologies with uninterrupted feature and seamless mode transition for systems with multiple DFIGs and multiple SPV arrays integrated within a well-structured AC/DC microgrid architecture with separate AC and DC subgrids. Initially, control and operation of standalone multiple-source AC/DC microgrids are investigated, which are followed by implementation of grid-integrated multiple-source AC/DC microgrids.

Performance of all the microgrids is examined through simulation and experimental analyses. The obtained results showcase satisfactory control performance for all the features in the AC/DC microgrids comprising of DFIG-based wind energy conversion and solar photovoltaic generation.