Topic of PhD Thesis

Adaptive Control Strategies for Resilient Operation of Grid Interfaced Solar Energy Conversion System Enabling Power Quality Improvement

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Abstract

The usage of fossil fuels is responsible for environmental issues such as green-house gas, acid rain and deteriorates the ozone layer, which captures the world's attention towards non-conventional green energy sources. Of different non-conventional energy sources such as solar energy, wind energy, tidal and biomass energy, the solar photovoltaic system based technology has proved a breakthrough in the field of distributed power generation due to having technological advancement, ease of installation, low maintenance, clean nature, freely available, noiseless and non-polluting nature.

The grids of developing and underdeveloped countries are generally weak, unreliable, and have a poor power quality. Therefore, integration of solar energy conversion system (SECS) to the grid is facing extra challenges, apart from usual power quality challenges. Different challenges can identified as the system operation during weak distribution grids, operation during the shunt faults in grid side network, operation during sensor malfunctioning events, system capability to provide inertia to the grid and to eliminate the grid leakage currents. This research work is aimed at addressing the aforementioned challenges, without compromising the grid power quality.

Firstly, the performance of a SECS is analyzed under weak distribution grid scenarios such as distorted grid voltages, unbalanced grid voltages, voltage sags and voltage swells. An adaptive control strategy is presented to resolve these issues and compel the distribution grid to follow the IEEE-519-2014 and IEEE-1547 grid codes. Secondly, the problem of disconnection of SECS system from the grid under grid shunt-faults, voltage flickers, power outages is addressed, by derating the solar photovoltaic (PV) operating point and supplying the deficit reactive power as per the country grid-codes to the grid to assist the grid stability. The maximum permissible active power is curtailed and the peak current rating of the voltage source converter is inherently incorporated into the control strategy to keep the operating point within a safe operating region. Thirdly, the leakage currents caused due to large parasitic capacitance formed in solar PV array, are mitigated by controlling common-mode voltage of PV coupled voltage source converter (VSC) system. The typical value of leakage current is maintained within 300 mA as per VDE-00126 standard even under the presence of nonlinear load, without compromising with the grid harmonic current limits. Thus, the life-time of the solar PV panel is increased and mal-operation of the neutral current protection scheme is avoided. Fourthly, improvement in the frequency response of renewable energy based distribution system is contemplated, by providing virtual inertia to the system. A virtual induction generator concept is introduced to not only assist the grid by providing inertia, but also to eliminate the usage of phase locked loops during grid synchronization. Therefore, the solar PV coupled voltage source converter behaves as a virtual induction generator along with self-synchronizing capability. It is capable to operate under grid interfaced mode as well as islanded mode without control reconfiguration. The dependency on phase-locked loop and requirement of proportional-integral controller are totally waived-off. Finally, a robust solar PV system is proposed, which can withstand the malatious attacks caused in the system. As the attacker injects malicious data into the receiver, the system performance is degraded and leads to unstable operation of SECS. An adaptive control is proposed under malicious attacks in phase currents, such as false data injection, DC bias injection, replay attack and denial-of-service.

The proposed solution to the various challenges aforementioned, are implemented and tested in MATLAB/ Simulink software. These are further validated through different experiments, carried out on a developed laboratory protype using d-SPACE interface. This work is expected to provide a good acquaintance in developing multi-objective solar energy conversion systems with robust and reliable performance throughout the operation.