Abstract of Ph.D. Thesis
"Design and Development of Induction Motor Drive for Grid Interactive and Standalone Based Solar PV Array Fed Water Pumping"
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ABSTRACT

This thesis deals with different topologies for water pumping system powered by solar PV array, utilizing an induction motor drive. It includes mechanical sensorless control of an induction motor drive to enable quick speed adjustments and a wide speed range. To enhance performance, this system utilizes maximum power point tracking (MPPT) for solar PV array. This is accomplished by placing a DC-DC boost converter between PV array and a voltage source inverter (VSI) that powers the motor. Additionally, this research explores a feasibility of a single-stage PV array-based system, eliminating a need for a DC-DC converter, and its application in long cable-fed submersible induction motor drive for water pumping. To mitigate potential disruptions in water pumping caused by the intermittent nature of solar PV array power generation, this study suggests employing a single-phase utility grid as an external power backup. A grid-interacted solar PV array, along with its control mechanisms, ensures consistent and reliable water pumping irrespective of solar PV array power intermittency. The power flow for unidirectional and bidirectional control strategies are employed for grid-connected PV array-powered induction motor-driven water pump. Bidirectional power flow control provides added benefit of feeding excess power to grid when water pumping is not required, thus maximizing resource utilization. The system adheres to maximum power point (MPP) operation of PV array and complies power quality (PQ) standard, such as power factor and total harmonics distortion (THD) of grid current, in accordance with the IEEE standard.

In remote locations, standalone solar PV pumping systems are installed because of absence of the grid. Main reason behind it is geographical remoteness as well as unavailability of continuous power since these places are not properly connected to the grid. However, despite having obvious benefits when it comes to lowering carbon emissions, solar PV array is not very reliable when it comes to continuous power for water pumping. Hence, a battery energy storage (BES) is utilised at DC link with bidirectional converter to resolve the intermittency issues. The advancement of solar photovoltaic array operated drives not only provides an economical solution but also reduces the strain on the grid. The functionality of the grid-integrated SPV system in different operating modes is discussed in a synchronization and desynchronisation logic with islanding identification technique to transition between standalone and grid-interactive modes and vice versa.

In grid-interactive mode, the system delivers power quality (PQ) solution such as elimination of harmonics, correction of PF and load compensation and grid currents balancing. In off-grid mode, control objectives focus on regulating voltage and frequency at point of common coupling (PCC). Primary goal of system is to ensure continuous power to emergency loads, even during a grid failure. Control algorithms for grid-side converter, are developed, with an extended phase-locked loop (EPLL) presented for improving power quality during integration with a weak grid. Unbalanced voltage dips are responded by the system by remaining connected at PCC while supplying residential and nonlinear loads and the main utility grid. To stabilize PCC voltage as per the IEEE standard 1547.4, reactive power is supplied by the system. To withstand fault conditions, a ride through technique is developed for the system, which avoids triggering of overcurrent protection by introducing a control for current limiting. Simulated and test results demonstrate balanced grid currents with sinusoidal profiles along with improved harmonic spectra even when the conditions are not favorable. Moreover, grid-side power factor is recorded nearly unity.

The grid-integrated system featuring multiple solar PV arrays and battery energy storage (BES) feeding multiple water pumping systems is designed and its performance is studied in detail. Main and ancillary grid-side converters are connected at DC links to individual solar PV arrays, each employing its own MPPT technique. Grid side converters (GSC) parallel connection at PCC, increases power rating of the system and expanding the system to supply surplus solar power to grid. The reliability of the system in standalone mode is also enhanced. When operating conditions are normal, then for main GSC, current control is used in grid-interactive mode and to maintain frequency and voltage at PCC, voltage control is employed during grid-disconnection. Performance of proposed configuration is studied during starting, dynamics and steady-state conditions. When analyzed in depth on basis of its simplicity, efficiency, performance and cost, the potential for commercial adoption and applicability of proposed systems are justified.