Abstract of Ph.D. Thesis
"Design and Control of Permanent Magnet Synchronous Motor Drive For Standalone and Grid Interfaced Solar Water Pumping Systems"
Mr. Mohd. Kashif (2016EEZ8501), Research Scholar

Abstract

Due to worldwide acceptance of net zero carbon emission policy and the subsequent necessity to minimize carbon footprints of energy infrastructure, there is an accelerated growth of solar photovoltaic (PV) array fed systems for several crucial applications like solar water pumping. The domains like irrigation, residential/commercial buildings, forest conservation, livestock, aquaculture and others are the potential beneficiary of solar water pumping systems. Besides, the declining cost of PV technology and the availability of low-cost digital signal processors have increased the number of installations of PV array fed water pumping systems. Meanwhile, permanent magnet synchronous motor (PMSM) has emerged as a potential candidate for driving solar water pumping systems due to its advantages like higher efficiency, higher torque density and unity power factor operation over induction motors. In this research work, various configurations of PMSM drive suitable for solar water pumping system.

In developed configurations of PMSM, the reverse-saliency is realized through introduction of flux barriers along q-axis in rotor to minimize permanent magnet demagnetization risk. While the developed topologies of PMSM operated solar water pumping system are broadly classified into standalone and grid interfaced systems. The PV array and battery energy storage (BES) are the two energy sources for standalone system. For such systems, a bidirectional power flow controller is developed for controlling battery power based on weather conditions. This enables delivery of constant water discharge for intermittent irradiation, thereby increasing utilization of the system. Whereas, the grid is available as another energy source in addition to PV array and BES for grid-interfaced system. Such a configuration facilitates on-demand water pumping irrespective of availability of irradiation. For this system, the fundamental component of grid voltage is extracted by using presented frequency locked loop (FLL). This enables the smooth operation of system even under abnormal grid conditions as the power quality at grid terminals is maintained in accordance to the IEEE-519 standard. Besides, a synchronization unit is added to the grid interfaced system for seamless synchronization of water pumping system with grid. For this purpose, the presented FLL based synchronizing controls are developed. Such a unit facilitates interconnection and interoperability between water pumping system and grid so that these two units work effectively, which thereby satisfies the IEEE 1547-2018 updated standard. Besides, mechanical position sensor is eliminated from PMSM drive by using presented rotor flux observer, which estimates speed and rotor position. The estimated speed and rotor position are then used for implementing field-oriented control of PMSM drive. The elimination of position sensor reduces cost and increases reliability of the solar water pumping system. Even a provision to supply power to local-loads of the system such as pressure boosters, cooling fans, lighting load, fan-load and others is included into the system. Such a load is necessary and unavoidable as it represents the auxiliary components of solar water pumping system, which are necessary for smooth operation of the system.

The performance of the presented configurations of solar water pumping system and the associated control techniques is analyzed by performing simulation on MATLAB/Simulink platform. Several simulation results are acquired and reported for each topology during starting, steady-state and dynamics under practical operating scenarios. Besides, an experimental validation of all the presented topologies is carried out on the laboratory prototype of the system, and the associated test results are reported.