Abstract of Ph.D. Thesis
"Grid Interactive and Standalone Permanent Magnet Brushless DC Motor Drive For Solar PV Array Fed Water Pumping"
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Abstract

The integration of solar photovoltaic (SPV) array energy in irrigation as well as domestic water pumping is very much prudent specially in isolated zones where the utility grid is either impractical or exorbitant. Apart from this, utilization of solar PV array energy in the field of water pumping reduces the utility grid load, carbon footprint and also saves conventional energy. In this research work, different methodologies for solar PV array fed water pumping system are developed using a permanent magnet brushless DC (PMBLDC) motor drive. A highly efficient PMBLDC motor significantly reduces the size of the solar photovoltaic array and so the installation cost. Moreover, unlike an induction motor, the speed of the PMBLDC motor is not limited by frequency of the supply. This reduces the size of the motor. A high efficient compact size optimized PMBLDC motor is investigated and designed here. Efficiency and cost optimization are done in the designed motor in comparison with the available counterpart. Optimization of the magnetic volume in the designed motor leads to optimization of the cost of the designed motor. A prototype of the designed motor is manufactured using industrial manufacturing facility for validation of the design results.

A position sensorless, compact, efficient and cost-effective PMBLDC motor drive is investigated with sensorless speed control. The Hall Effect position sensors, for sensing, the voltage sensor at the DC bus of the VSI and the motor phase current sensors are eliminated in the developed PMBLDC motor drive. In addition, the sensorless speed control is done using virtual position estimation. The system consists of a maximum power point tracking (MPPT) of solar photovoltaic array using VSI, feeding the PMBLDC motor. This developed system is capable of operating the solar photovoltaic array at its maximum available power using the same VSI, which is used for sensorless commutation and speed control. In order to develop a solar photovoltaic array fed water pumping further, reliable and economical, the position sensorless PMBLDC motor drives are also developed for two-stage water pumping system. The position sensorless control is found the only way to use the PMBLDC motor for submersible water pumping. The work is further extended towards integration of DC-DC converter in the design system and a double stage solar PV array powered PMBLDC motor drive is also investigated for water pumping. Different DC-DC converters are placed for MPP and performances are analysed based on their simplicity, cost, design challenge and efficiency.

A challenging case of interaction in the solar PV array powered water pumping due to the intermittency of solar PV array power generation is resolved by using a battery integration and a single-phase grid as an external power backup. A battery integrated solar PV array and its control are evaluated to get a high reliable and fully utilised water pumping with PMBLDC motor. A grid interactive solar PV array and its control are demonstrated to get a well- engineered and fully utilised water pumping with PMBLDC motor such that the water pumping is not affected by the intermittency of the solar PV generation. The power is drawn from the single-phase grid in case the solar PV array is not able meet the power demand required by the water pumping system. Bi-directional power flow control is implemented for grid integrated water pumping system. The bi-directional power flow control gives an additional flexibility to feed the extra power to the utility grid by the installed solar PV array, which is not utilised for the water pumping system. This concept leads to a full utilization of the installed resources. Moreover, it is found as a source of earning by feeding electricity to the utility grid. The power quality (PQ) standard such as total harmonic distortion (THD) and power factor of grid current are mate by the developed system as per the IEEE-519 standard.

All the developed configurations are modelled and analysed using MATLAB/ Simulink tool in order to exhibit their performances under various operating conditions during steady state, starting and dynamic conditions. Simulated results are validated through experimental results obtained from the developed hardware laboratory prototype along with an industrial product prototype. The commercial viability of the developed system is justified from the developed industrial product prototype by their in-depth analysis considering cost, efficiency, size, reliability and performance.