Design and Development of Solar PV Fed BLDC Motor Drives for Water Pumping

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Abstract

The utilization of solar photovoltaic (PV) energy in water pumping is conservative particularly in isolated regions where the transmission of power is either impractical or exorbitant. In this research work, various topologies for solar PV array fed water pumping are developed using a brushless DC (BLDC) motor drive. A high efficiency BLDC motor substantially reduces the size of PV array and hence its installation cost. Moreover, its high power factor results in a reduced capacity of the used voltage source inverter (VSI). Besides these, unlike an induction motor, the speed of a BLDC motor is not limited by power frequency. This leads to a reduced size of the motor. A reduced sensor based simple, efficient and cost-effective BLDC motor drive is investigated with fast control of its speed. The voltage sensor at the DC bus of VSI and the motor phase current sensors are eliminated in the proposed drive. In addition, the speed control loop is not required, as the speed of BLDC motor-pump is adjusted by the DC bus voltage of VSI. The VSI is switched at fundamental frequency, which offers a high conversion efficiency by reducing the switching losses in VSI. The system possesses a maximum power point tracking (MPPT) of PV array by introducing a DC-DC converter between the PV array and a VSI, feeding the motor. The various DC-DC converters are placed for MPPT, and analyzed based on their performance, simplicity, design, cost and efficiency. The work is extended towards an elimination of DC-DC converter and a single stage PV array fed BLDC motor drive is also investigated for water pumping. This system is capable of operating the solar PV array at its optimum power using the same VSI, which is used for motor control. In order to make a PV water pumping further economical and compact, the position sensor-less BLDC motor drives are also developed for both two stage and single stage PV based water pumping. The sensorless control is the only reliable way to operate the BLDC motor for applications in submersible water pumping. A promising case of interruption in the water pumping due to the intermittency of PV power generation is resolved by using a single phase utility grid as an external power backup. A grid interacted PV array and its control are demonstrated to get a reliable and fully utilized water pumping with BLDC motor such that the pumping is not affected by an intermittency of PV generation. The power is drawn from the grid in case the PV array is unable to meet the required power demand. Both unidirectional and bidirectional power flow control are implemented for a grid interfaced PV fed BLDC motor driven water pump. The bidirectional power flow control based topology offers an additional merit of feeding power to the utility grid by the installed PV array, in case the water pumping is not required. This practice leads to a full utilization of installed resources. Moreover, it emerges as a source of earning by sale of electricity to the utility. The maximum power point (MPP) operation of PV array, and power quality (PQ) standards such as power factor and total harmonic distortion (THD) of grid current are met by this system as per IEEE-519 standard. All the proposed configurations are modeled and simulated using MATLAB/Simulink platform in order to demonstrate their performance during starting, dynamic and steady state conditions. Simulated results are verified through test results obtained from hardware implementation using a developed prototype in the laboratory. The applicability and commercial potential of proposed systems are justified by their in depth analysis based on efficiency, cost, simplicity and performance.