ABSTRACT

In recent years, photovoltaic (PV) power systems have been gaining importance in catering to the energy needs of villages and small towns for domestic purposes. In agriculture, these systems are mostly to drive the water pumps. While adequate financial input from global agencies is available, appropriate technological input is lacking. In view of these systems being eco-friendly and energy efficient, countries like India have made it a national mission to install a large number of PV operated pump sets to irrigate remote and rural areas. Using diesel pump to deliver water for the agricultural needs causes problems both in terms of profitability and environmental perspectives. Higher price of diesel increases the operation costs of diesel water pumping system thereby reducing the incomes of farmers. Electric motors such as permanent magnet dc motors (PMDC) and induction motors (IM) used for these purposes are low power motors with low torque loads, which need a complex drive control system having high maintenance cost. Since the system has to be installed in technically unattended zones, it must be robust, economical and maintenance free. The PMDC motors using mechanized commutators and brushes need regular maintenance and are prone to failure. The drawbacks of these motors can be improved by the use of permanent magnet brushless DC (PMBLDC) motor, which has a good speed response, high torque, higher efficiency and better reliability. PMBLDC motor drives have received considerable attention recently as their performance is superior to those of the brushed dc motors and ac motors for servo and constant/adjustable speed applications.
This doctoral thesis aims to bridge the current knowledge gaps particularly in the selection of motor that sustain the changes in irradiance level changes and provide required water for the agricultural use. The designing of the system is carried out for i) a pump to suit the needs based on the total dynamic head (TDH), ii) a controller to operate the system under constant and varying irradiance level, iii) appropriate sensors for control, iv) solar array to meet the energy requirement of the water pumping system, wiring, and pipe. Models for the dynamic simulation of the various components of the solar photovoltaic (SPV) system have been presented and integrated. Of the various maximum power point tracking (MPPT) techniques, the better MPPT algorithm namely the incremental conductance (IC) algorithm is selected to operate the system under the constant and varying irradiance levels. The three phase ac driving system connected to the pump is controlled by the space vector pulse modulation (SVPWM) technique to have better controllability and operability under open loop and closed loop conditions.

Economic analyses have been conducted to establish the most cost effective solution for irrigation and to evaluate the project profitability. The diesel operated water pumping system and the electrical motor operated solar water pumping are compared and the economic-beneficial system chosen. Three different solar water pumping system powered by induction motor (IM), permanent magnet synchronous motor (PMSM) and permanent magnet brushless dc motor (PMBLDC) has been analysed in economic terms and the most economically operable and reliable system highlighted. The systems are analysed for the life cycle cost (LCC) and LCC of the systems are compared with the traditional diesel water pumping system. The possible benefits generated by the solar photovoltaic water pumping system (SPVWPS) implementation have been highlighted. The results show that BLDC operated SPVWPS represents the best technical and economic solution for providing
water for irrigation among the three different motors and is a better solution compared to other traditional water pumping technologies.

The existing methods of ac motor operated SPVWPS mostly uses induction motor to pump water to the fields. Due to its complicated control, increased losses and maintenance problems, PMSM and BLDC motors are also tested in open loop condition to deliver the same throughput as that of the traditional water pumping system. Therefore, a detailed analysis of the operability of the solar water pumping system with the use of three different motors have been performed in the MATLAB/Simulink environment. The feasibility of the three different motors operated SPVWPS has been tested under constant and variable irradiance level. It is found that the BLDC operated SPVWPS shows better controllability and operability compared to the IM and PMSM operated SPVWPS. Evaluation results of three motors are presented to highlight the major differences to enable the selection of best operable motor for SPVWPS.

In this thesis, to verify the controllability of the SPVWPS to provide constant throughput under the constant and varying irradiance level, a closed loop control of the solar water pumping system has been carried out in the MATLAB/Simulink environment. The control has been implemented with SVPWM controlled three phase inverter to provide supply to the SPVWPS operated with IM, PMSM and BLDC. It is observed that BLDC operated SPVWPS shows better response to the constant and varying irradiance level and provides constant throughput. The analysis of these different SPVWPS is tabulated to highlight the potentials of the systems to be implemented in optimal locations where the environment is extremely sensitive.
From the financial analysis and simulation results of the IM, PMSM and BLDC operated SPVWPS, it is observed that the BLDC controlled SWPS has lower LCC over the other motors and the diesel operated water pumping system. It is also observed that the BLDC controlled SPVWPS has better operability and controllability under constant irradiance level of 1000 W/m² as well as variable irradiance level varying from 400 W/m² to 1000 W/m². To verify the hardware feasibility and implementation of the SPVWPS in the real hardware, a prototype hardware of the open loop system has been implemented and tested. The results of the BLDC operated SPVWPS in the period of 31st March to 3rd April shows that the amount of water pumped and delivered to one acre of rice field.