International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Designing A Solar-Powered System for Submerged 3HP BLDC Motor

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ABSTRACT

Solar energy is abundantly available in the Indian subcontinent. To extract maximum power from solar panels there are effective methods and technologies that can be applied. This study deals with a position sensorless brushless DC (BLDC) motor-driven solar photovoltaic (PV) fed water pump. A technique based on the back electromotive force (back-EMF) zero crossing is proposed for sensorless operation of the BLDC motor. The back-EMF is derived from the difference of line voltages. Thus, a requirement of neutral potential is eliminated. In addition, the proposed drive avoids the use of phase current sensors. The speed is automatically adjusted according to the available peak power from the PV array. The devices of the voltage source inverter, used to feed the BLDC motor pump, are switched at fundamental frequency. This leads to minimizing switching losses. The responses of the PV fed pumping system with the proposed drive are observed under various operating conditions. The suitability of the proposed topology is demonstrated through the hardware implementation.

1. INTRODUCTION

The quick advancement in technology to extract power from renewable sources of electricity has discovered multiple ways to manage and reduce the use of fossil fuels. Solar energy is one of the best renewable sources of energy. For Maximum extraction of solar energy, there are various technologies which are being researched upon.

The said technology possesses several merits such as everlasting, no pollution and has a running cost nil. It is rapidly being applied in umpteen applications including water pumping. The irrigation, drinking and industrial water supply, and fountains are recently focused applications of solar PV based water pumping. Water pumping has been an attention-grabbing application of solar PV energy for the last two decades. The brushless DC (BLDC) motor, being an energy efficient motor, suits the said application of solar PV energy. It possesses a high power density and a high torque/inertia ratio. A BLDC motor needs rotor position information to feed a rectangular current in phase with the back electromotive force (back-EMF). This information is usually provided by a set of Hall-effect position sensors. The position sensors make the

motor costly and they require a precise mounting. Besides, Hall-effect sensors are very sensitive to the temperature,resulting in deterioration in the performance of the motor. Further, the system reliability is certainly reduced.

Towards finding a low-cost and energy-saving solution for water pumping, several topologies are proposed, using PV array fed BLDC motor drives. A conventional BLDC motor drive for PV-water pumping is reported in. The maximum power point tracking (MPPT) is achieved through a DC–DC converter. There is essentially a need of two-phase currents and a DC link voltage sensing for the drive. Additionally, the voltage source inverter (VSI) is switched at high frequency, resulting in a high switching loss. Another BLDC motor-water pump is proposed in, wherein the voltage and current sensors are absolutely eliminated. Moreover, VSI is switched at fundamental frequency. Such topologies are also proposed in, using various DC–DC converters for MPPT.

A Z-source inverter (ZSI) substitutes the DC–DC conversion stage in, affirming a single-stage PV-based topology. However, the DC-link voltage and phase current sensors are mandatory, similar to the schemes reported in. A high switching frequency of the VSI is also adopted in this topology. Furthermore, the ZSI is not suited to give a soft start to the motor, without current sensing. This issue necessitates the phase current sensing. Another single-stage PV-based topology for water pumping with BLDC motor drive is recently proposed in, wherein no intermediate converter is associated for the MPPT of PV array. A common VSI is used to achieve both control objectives viz. MPPT and motor control. Besides, a current sensorless based motor drive is used as in. In fact, the available peak power from a PV array governs the speed of the motor. The developed scheme also offers a soft starting to the motor.

All reported solutions to PV-BLDC motor-driven water pumping as of now are associated with the position sensor based BLDC motor drive. The main objectives of this work on a PV-fed water pumping are cost minimisation, simplification, energy saving and reliability enhancement. Thus, a position sensorless BLDC motor drive is developed here for PV-based water pumping. The sensorless drive is the only reliable solution for submersible water pumping.

The various methods for position sensorless control of BLDC motors are reported in. These methods mainly include the back-EMF-based method, inductance-based method, flux linkage-based method and artificial-intelligence-based method. Among the aforesaid methods, the back-EMF-based method is the most mature and extensively used one. Several techniques for the estimation of back-EMF are reported so far. In addition to the conventional approaches, the back-EMF is also estimated from the advanced techniques including the self-adaptive estimator and the adaptive sliding mode observer in order to increase the accuracy of estimation

2. METHODOLOGY

BLDC motors use the back EMF (Electromotive Force) produced by the motor windings to estimate the rotor position. The back EMF is generated when the rotor magnets pass by the stator windings and induce a voltage. By measuring the voltage pattern, the motor controller can determine the rotor's position and commutation timing.

The sensorless control of the BLDC motor is successfully integrated with the maximum power point control of the PV array. The said MPPT is properly controlled during sensorless starting.

The line voltages are used to estimate the back-EMFs for sensorless operation. Therefore, access to the neutral terminal is not required. The common mode noise is also rejected. The voltage drop on the devices would also not play any role.

The configuration of the proposed PV fed water pump using a position sensorless BLDC motor drive. It possesses a PV array, a DC–DC boost converter, a three-phase VSI and a water pump coupled to the BLDC motor. The MPPT of the PV array is realized by means of a boost converter. An incremental conductance (INC) based technique, which needs a feed-back of PV array voltage and current, is used to accomplish the MPPT.

On the other hand, electronic commutation and control of BLDC motors are performed through a back-

EMF zero-crossing based sensorless technique. The zero-crossings of the back-EMF are estimated indirectly from the line voltages. This technique does not need any integration. Further, the neutral potential is not required, as the terminal voltages are used. The common mode noise is also substantially reduced. The proposed position sensorless motor drive also avoids the motor current sensing and the DC link voltage sensing along with the Hall-effect position sensors. The speed is adjusted through the DC link voltage.

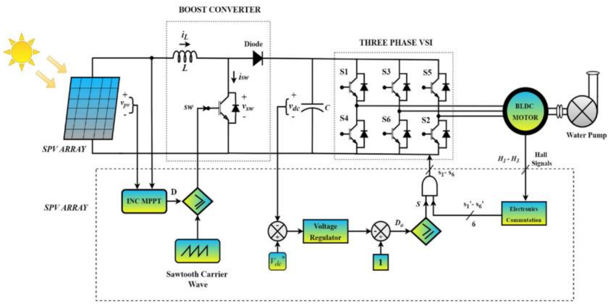

Figure 1. Block Diagram

Motor specifications:

- Power → 2300W
- Voltage → 48 V
- Current → 60 A.
- Torque → 7.3 Nm
- Speed → 3000rpm.

Selection of PV array:

A 2.2 kW SPV array has been chosen to supply the BLDC motor-water pump set having power rating of 1.8 kW. To overcome the losses of water pump and power converters, surplus power is required to be supplied from the SPV array. The voltage of the PV array is selected according to the DCDC boost converter design and rating of motor DC voltage. The parameter is selected such that at maximum power point the duty cycle should be at the minimum possible value resulting in decreased stress on semiconductor power devices due to current and voltage.

The efficiency of BLDC motors is around 86-90% and power converters have efficiency typically around 95%. Thus, the peak solar power output of array is calculated as:

$$P_{smpp} = P_{motor} / (\eta_{bldcm} \times \eta_{pconv})$$

$$P_{smpp} = 1.88/(0.9 \times 0.95) = 2.2\ \text{kWp}$$

Where η_{pconv} and η_{bldcm} is 95% and 90%

The SPV array parameters are calculated and estimated in the standard condition i.e Solar insolation at 1000 W/m2 and temperature at 25°C. To design PV arrays of required capacity, a PV module having MPP voltage of 17 V and 4.7 A is chosen. The other performance parameters are calculated as follows:

The current of module at maximum power:

$$I_{mp} = i_{pv} = \frac{P_{pv}}{V_{pv}} = \frac{2200}{238} = 9.3A$$

Series Module:

$$N_s = \frac{V_{mpp}}{V_m} = \frac{238}{17} = 14$$

Parallel Module:

$$N_p = \frac{I_{mpp}}{I_m} = \frac{9.3}{4.7} = 2$$

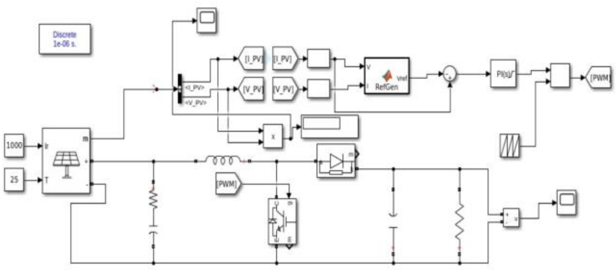

Fig 2: Matlab Simulink of MPPT controller

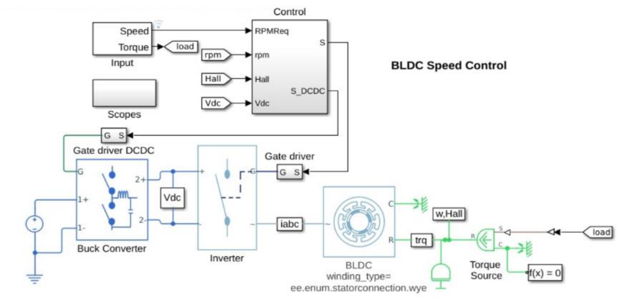

Fig 3: BLDC Speed Controller

3. RESULTS

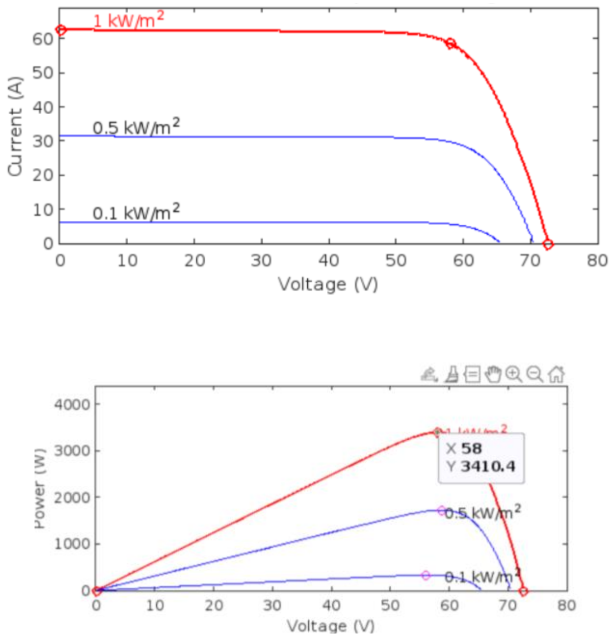

Figure 4. P V array performance at 25 degree C and irradiance 1000, 500 and 100 W/m2

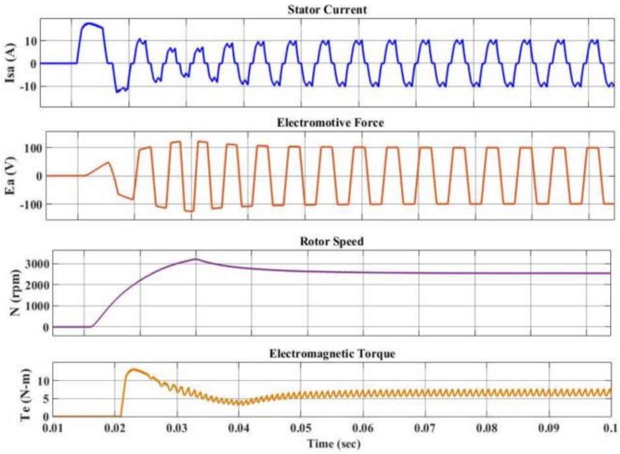

Figure 5. BLDC motor-pump characteristics in normal steady state mode

4. FUTURE SCOPE

This reference design is a Maximum Power Point Tracking (MPPT) solar charge controller for 12-V and 24-V batteries that can be used as a power optimizer in the future.

Fig 6: TIDA-010042

400-W GaN-based MPPT charge controller and power optimizer Design

This compact reference design targets small- and medium-power solar charger designs and is capable of operating with 15- to 60-V solar panel modules, 12-V or 24-V batteries, and providing upwards of 16-A output current. The design uses a buck converter to step down the panel voltage to the battery voltage. The half-bridge power stage with internal integrated drivers is controlled by a microcontroller unit (MCU), which calculates the maximum power point using the perturb and observe method. The solar MPPT charge controller is created with real-world considerations, including reverse battery protection, software programmable alarms and indications, and surge and ESD protection.

Specifications:

- 98.3% efficiency in 12-V systems and 98.5% efficiency in 24-V systems
- Wide input voltage range of 15 V to 60 V
- Flexible design supports 12-V and 24-V battery voltages
- High-rated output current of 16 A
- Battery reverse polarity, over-charge and over-discharge protections
- System over temperature and ambient light detection capabilities
- Small board form factor of 95 mm × 68.2 mm × 25 mm

5. INFERENCE

The Solar PV based water pumping system for agricultural irrigation purposes is studied and its various parameters and characteristics are analyzed using MATLAB simulation. With removal of the current sensing element used to sense current, it is the most economical and effective method for controlling motor speed. With proper selection of SPV array maximum power point tracking became easier irrespective of varying weather conditions.

Without any external controlling mechanism, the smooth start of the motor has been accomplished. This proposed system is independent from the utility grid and found to be greener and more useful for remote areas.

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