SOLAR PHOTOVOLTAIC ARRAY FED WATER PUMP RIVEN BY BRUSHLESS DC MOTOR USING KY CONVERTER

B.Dinesh,
Electrical and Electronics Engineering, University college of Engineering, Arni.
Mail Id: dineshtata911@gmail.com

M.k.Jaivinayagam,
Electrical and Electronics Engineering, University college of Engineering, Arni.
Mail Id: jaivimk5678@gmail.com

M.Udayakumar,
Electrical and Electronics Engineering, University college of Engineering, Arni.
Mail Id: mudayuk@gmail.com

S.Syedismail
Electrical and Electronics Engineering, University college of Engineering, Arni.
Mail Id: syedmail272@gmail.com

Mr. A. Sakthidasan, M.E.,
Assistant Professor, Electrical and Electronics Engineering, University college of Engineering, Arni.

Abstract-This study deals with the use of a KY converter for maximum power point tracking in solar photovoltaic (SPV) array-based water pump driven by a permanent magnet brushless DC (BLDC) motor. The primary function of a DC– DC KY converter is to optimise the power output of SPV array and it also provides the safe and soft starting of the BLDC motor with an appropriate control. Amongst various DC–DC converters, KY converter meets the desired performance of proposed water pumping system. The starting, dynamic and steady-state behaviours of the SPV array fed BLDC motor driven water pump are presented to demonstrate the novelty of the proposed system. The SPV fed water pumping system under study is simulated using MATLAB/SIMULINK environment and validated on a developed prototype of the system in order to manifest its performance under practical operating conditions.

Keywords-Solar photovoltaic array(SPV),Brushless DC motor(BLDC),Maximum Power Point Tracking (MPPT)

1. Introduction

Solar photovoltaic (SPV) array-based energy generation is receiving wide attention nowadays to supply the various loads such as water pumps. The water pumping system based on SPV array targets mainly the irrigation on the agricultural field, household and industrial water supply. In spite of such enormously developed water pumping systems and available literature till date, various challenges to come up with a cost-effective, simple, efficient and reliable system have motivated the researchers towards this green energy fed water pumping.

An electric motor plays a significant role to develop an energy efficient and economical water pumping system based on the SPV array. An efficient motor substantially reduces the size of SPV array and hence its cost. The majority of commercial systems use DC motors for water pump. Unfortunately, the DC motors have low efficiency and high-maintenance cost due to their commutator and brushes . To get over from the aforementioned problems associated with DC motors, the induction motor is employed to drive a water pump in , due to its robustness, low cost, high efficiency, availability in local markets and low-maintenance cost. Nevertheless, this motor is not adapted in this work owing to some of the limitations it possess which are notfavourable for SPV array-based water pumping, such as requirement of complicated control and prone to overheating.A permanent magnet brushless DC (BLDC) motor, incorporating the merits of higher efficiency than an induction motor, high reliability, high ruggedness, low Electromagnetic Interference (EMI) problems, simple control, compactness, easy-to-drive, capability to operate successfully at low voltage and excellent performance over a wide range of speed application.

The MPPT of SPV array is accomplished by introducing a DC–DC converter as an interface between the SPV array and voltage source inverter (VSI) feeding the BLDC motor. A DC–DC boost converter [1], buck–boost converter [2], Luo converter [3], canonical switching cell (CSC) converter [4], zeta converter [5] and Landsman converter [6] are already utilised with SPV array fed BLDC motor driven water pump. Investigating the various non-isolated DC–DC converters viz. buck, boost, buck– boost, Cuk and single-ended primary inductor converter for photovoltaic applications, although not based on water pumping, it is concluded in that the best selection of DC–DC converter in the PV system is buck–boost converter, allowing an unbounded region for MPPT. A KY converter, one of the topology of a DC–DC buck– boost converter, capable to overcome the aforementioned limitations of various previously used converters in SPV array fed water pumping, is adapted in this work.

The proposed water pumping system using a DC–DC KY converter is designed such that the operation is not deteriorated by variation in irradiance level and losses associated with the converters and motor pump. Moreover, the KY converter is designed to operate always in continuous conduction mode (CCM) irrespective of the variation in irradiance level, resulting in a reduced stress on its power devices and components. reduced switching loss. The starting inrush current of BLDC motor is restricted within the permissible range by appropriate control of Landsman converter through MPPT algorithm. The motor always attains the required speed to pump the water irrespective of the atmospheric variation. The various performances of the proposed water pumping system are analysed through simulated results in MATLAB/SIMULINK environment followed by the experimental validation on a developed system. Simulated and experimental results demonstrate the suitability of the proposed system for SPV-based water pumping.

2. Existing Converter Method

In 2015,the detailed configuration and operation of the proposed SPV array-based BLDC motor driven water pumping system using the Landsman converter. The proposed system consists of an SPV array, Landsman converter, VSI and the BLDC motor with a water pump coupled to its shaft. The Landsman converter, acting as an interface between the SPV array and the VSI, is operated by the execution of INC-MPPT algorithm in order to extract the maximum power available from the SPV array. The VSI, operated through the electronic commutation, feeds the BLDC motor pump. The motor has three inbuilt low-cost Hall-effect position sensors, generate particular combination of three Hall signals according to the rotor position.

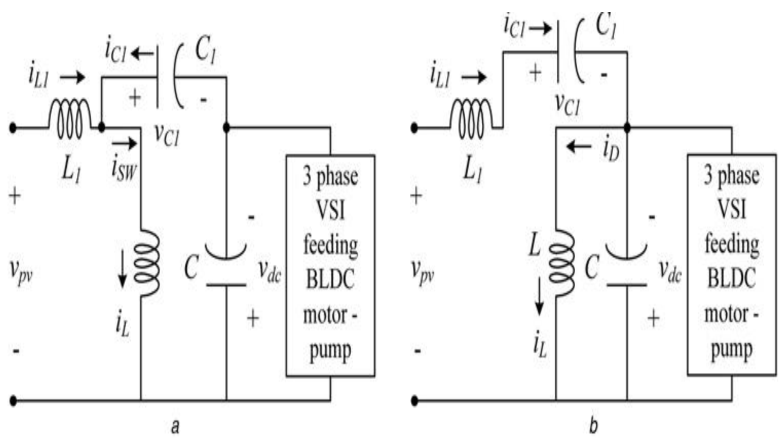


Fig.1 Circuit Diagram of Landsman converter

3. Configuration and operation of proposed converter system

In this paper, configuration and operation of the proposed SPV array-based BLDC motor driven water pumping system using the KY converter. The proposed system consists of an SPV array, KY converter, VSI and the BLDC motor with a water pump coupled to its shaft. The KY converter, acting as an interface between the SPV array and the VSI, is operated by the execution of INC-MPPT algorithm in order to extract the maximum power available from the SPV array. The VSI, operated through the electronic commutation, feeds the BLDC motor pump. The motor has three inbuilt low-cost Hall-effect position sensors, generating a particular combination of three Hall signals according to the rotor position.

KY converter named by the inventors Mr.KI .Hwu& Y.T. Yau. Has continuous in- put and output inductorcurrents, has a larger voltage conversion ratio. This converter is very suitable for low-ripple applications.This converter has the efficiency of 90%. This converter possesses fast load transient responses.It is a buck/ boost converter. It operates on low output ripples. It steps up the input voltage by varying the duty cycle. It operates on the non-pulsating mode and produces the positive output voltage.

The detailed comparisons between the proposed buck–boost converter and the KY converter are described as follows.

1) Both converters always operate in CCM. That is, the negative current can be allowed at light load, but the corresponding average current must be positive.
2) Both converters have individual output inductors, thereby causing the output currents to be non-pulsating.
3) The proposed converter has one additional inductor and one additional capacitor so as to execute voltage bucking/boosting as compared with the KY converter.
4) Both these converters can operate bidirectional. The proposed converter works with the backward voltage conversion ratio of 0.5/(1−D), whereas the KY converter works with the backward voltage conversion ratio of 1/(2−D).
It possesses non pulsating output current, thereby not only decreasing the current stress on the output capacitor butalso reducing the output voltage ripple strategies

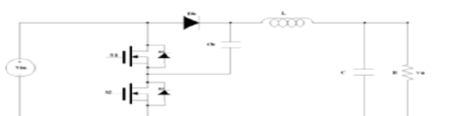
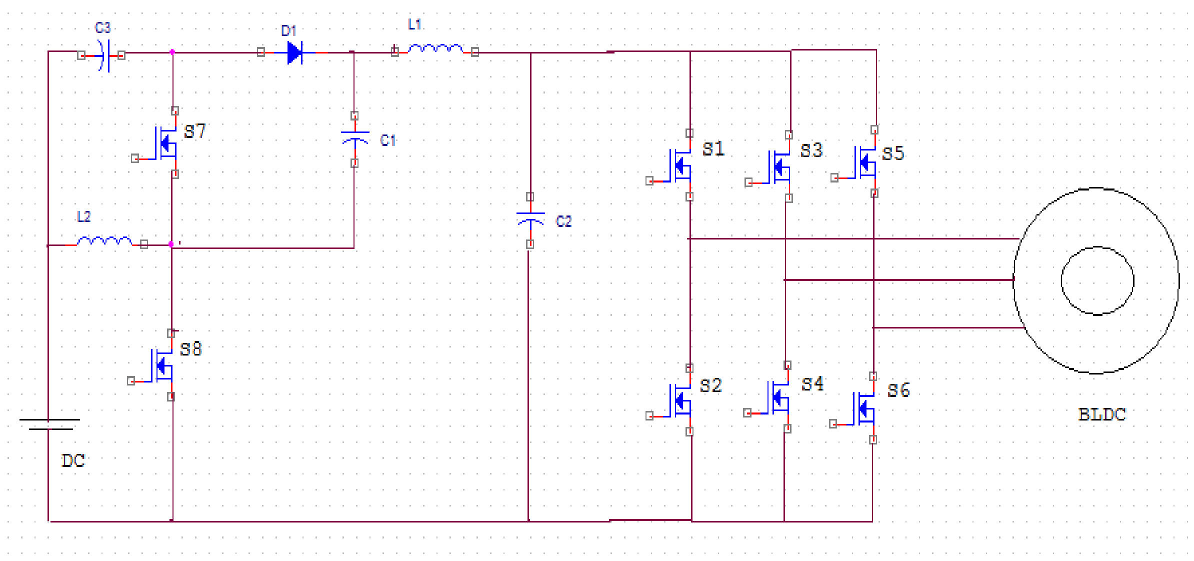
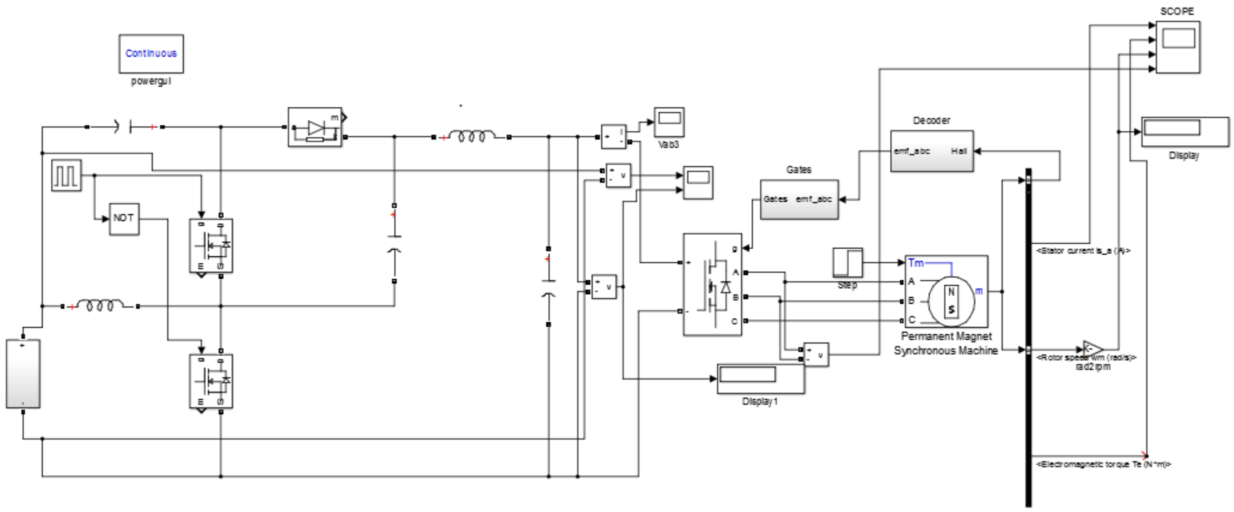


Fig.2 KY converter

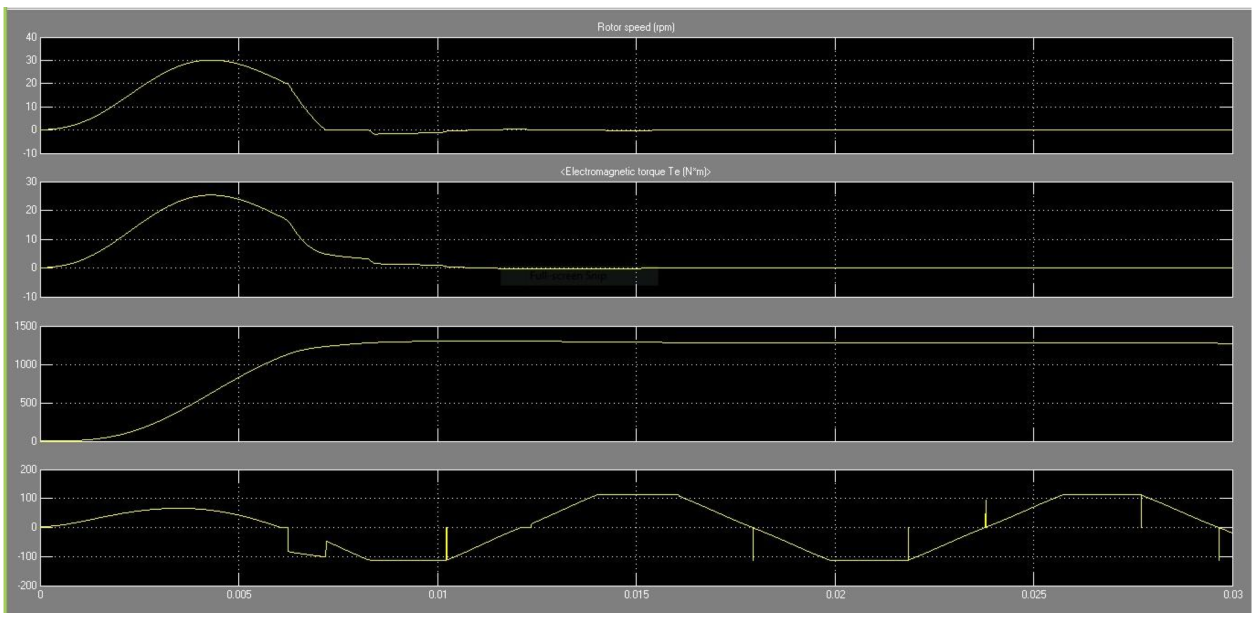
4. Circuit Diagram:



5. Simulation diagram:



6. Results :



7. Conclusion

A solar PV array based BLDC motor driven water pump employing a KY converter has been proposed,and its starting, dynamic and steady state behaviours have been analysed through simulation and implementation. The presented result have demonstrated the suitability of the proposed system for water pumping irrespective of the practical operating conditions. The utilization of KY converter has elimated external filtering requirement and has also contributed to damp the oscillations occurred in the module current due snubber elements .The speed control BLDC motor by variable DC-link voltage has completely eliminated additional phase current sensing,DC-link voltage sensing,additional control and associated circuitry.The distinct features of the proposed system include simplicity in the structure and control, cost effectiveness, compactness very good efficiency,unbounded MPPT operation,soft starting of the BLDC motor,operation of the KY converter in CCM resulting in a reduced stress on devices,fundamental frequency operation VLSI avoiding the high-frequency switching losses and successfuloperation upto the irradiation off 200 W/m^2. The KY converter with BLDC motor is hence proved has comfortable and suitablecombination for SPV array-based water pumping.

8. References

[1]. Singh, B., Bist, V.: ‘A BL-CSC converter-fed BLDC motor drive with power factor correction’, IEEE Trans. Ind. Electron., 2015, 62, (1), pp. 172–183.

[2]. Youssef, M.Z.: ‘Design and performance of a cost-effective BLDC drive for water pump application’, IEEE Trans. Ind. Electron., 2015, 62, (5), pp. 3277–3284.

[3]. Kumar, R., Singh, B.: ‘Buck–boost converter fed BLDC motor drive for solar PV array based water pumping’. IEEE Int. Conf. on Power Electronics, Drives and Energy Systems (PEDES), December 2014, vol. 16–19, pp. 1–6.

[4]. Kumar, R., Singh, B.: ‘Solar photovoltaic array fed Luo converter based BLDC motor driven water pumping system’. Ninth Int. Conf. on Industrial and Information Systems (ICIIS), December 2014, vol. 15–17, pp. 1–5.

[5]. Sera, D., Mathe, L., Kerekes, T., et al.: ‘On the perturb-and-observe and incremental conductance MPPT methods for PV systems’, IEEE J. Photovolt., 2013, 3, (3), pp. 1070–107.

[6]. Elgendy, M.A., Zahawi, B., Atkinson, D.J.: ‘Assessment of the incremental conductance maximum power point tracking algorithm’, IEEE Trans. Sustain.Energy, 2013, 4, (1), pp. 108–117.