

BLDC MOTOR DRIVEN PV FED WATER PUMPING SYSTEM EMPLOYING CSC CONVERTER

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Abstract: This work proposes a photovoltaic (PV) fed water pumping system utilizing a canonical switching cell (CSC) converter as an intermediate DC-DC converter in order to extract the maximum available power from the PV array. Controlling the CSC converter in an intelligent manner through the perturb & observe maximum power point tracking (P&O-MPPT) algorithm offers the soft starting of the brushless DC (BLDC) motor. Soft starting i.e. the reduced current starting inhibits the harmful effect of the high starting current on the windings of the BLDC motor. A fundamental frequency switching of the voltage source inverter (VSI) is accomplished by the electronic commutation of the BLDC motor, thereby avoiding the VSI losses occurred owing to the high frequency switching and speed control.

Index Terms: BLDC motor, CSC converter, P&O MPPT, Solar photovoltaic array, Water pump.

1. Introduction

The photovoltaic (PV) energy is a clean energy, with a long lifespan and a high reliability. So, it can be considered as one of the most sustainable renewable energy. Photovoltaic (PV) modules based renewable energy generation systems is more suitable and prominent solution for both domestic as well as industrial applications. An efficient motor substantially reduces the size of Solar Photovoltaic (SPV) array and hence its cost. The Permanent Magnet Brushless DC (BLDC) motor incorporating the merits of higher efficiency, high reliability, high ruggedness, easy-to-drive, capability to operate successfully at low voltage and excellent performance over a wide range of speed. To optimise the operating point of the SPV array in order to get maximum possible power output by means of the superior maximum power point tracking (MPPT) technique. A converter acts as an interface between the SPV array and Voltage Source Inverter (VSI) feeding the BLDC motor. The starting inrush current of BLDC motor is restricted within the permissible range by appropriate control of CSC converter through MPPT algorithm.

It is mandatory to optimise the operating point of the SPV array in order to get maximum possible power output by means of the superior maximum power point tracking (MPPT) technique [1]. The P&O method is generally the most used because of its simplicity and ease of implementation [2]. As its name indicates, this method works by perturbing the system and observing the impact on output power of PVG. 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. 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 [3] that the best selection of DC-DC converter in the PV system is CSC converter, allowing an unbounded region for MPPT. On the other hand, any converter besides the buck-boost topology, for example buck and boost converter, is not recommended because of their inability to track MPP independent of the loading and atmospheric conditions. In the sepic and cuk converter fed BLDC motor drive the speed of the motor is controlled by controlling the DC link voltage, hence the switching losses associated with the VSI switches are reduced, but it has a problem of using two sensors, which increases the system cost. The CSC converter based system presents a single voltage sensor based BLDC motor drive system, capable to overcome the aforementioned limitations of various previously used converters in SPV array fed water pumping, is adapted in this work.[4].

2. Brushless DC Motor

Brushless dc motor is a permanent magnet synchronous motor, with permanent magnets on the rotor also with back EMF with trapezoidal shape. The rotor position determines the switching sequence. The [5] phase current of BLDC motor, is synchronized with the back EMF to produce constant torque at a constant speed. The electronic switches replaces the mechanical commutation of the brushed dc motor, which supply current to the motor windings which is a function of

the rotor position. This kind of ac motor is called brushless dc motor, because it has similar performance as that of the traditional dc motor with commutations. These motors are usually controlled using a three-phase inverter, which requires a rotor 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 [6, 7]. The BLDC motor has already superseded partially the DC and AC motors employed to drive the water pump using SPV array as the source of electricity [8–10] and continuously attracting the industrialist and customers.

3. Proposed System

The proposed system consists of two stages in its BLDC motor drive with water pump. First stage consists of a position sensor which is required for starting and providing the proper commutation sequence to control the inverter. Hall sensors can be used as these position sensors, resolvers, or absolute position sensors. BLDC motor, canonical switching cell converter which provides a variable dc output voltage from the available SPV array. Second stage consists of the VSI, is operated by the execution of P&O-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 configuration and operation of the proposed SPV array-based BLDC motor driven water pumping system using the CSC converter is presented in Fig.1

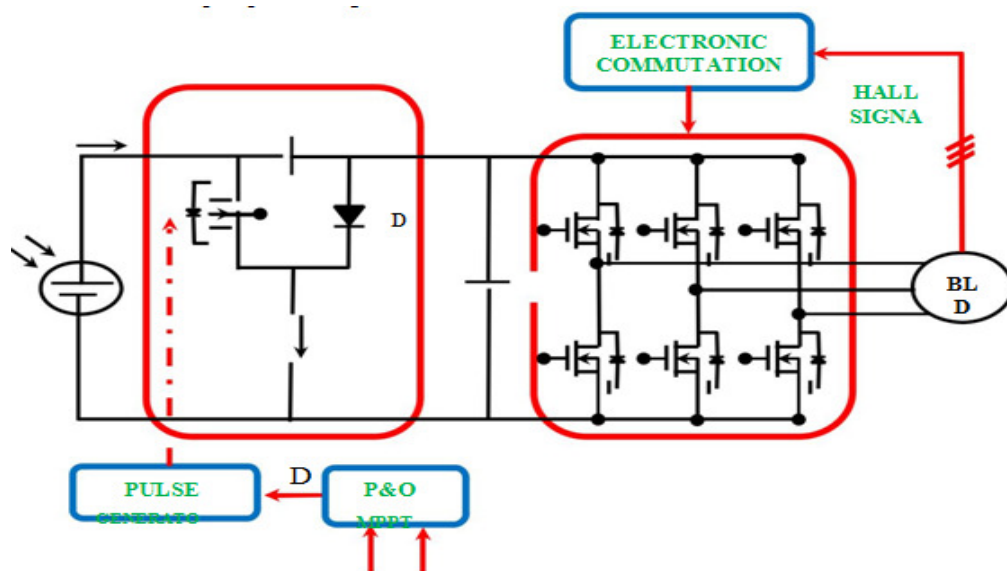


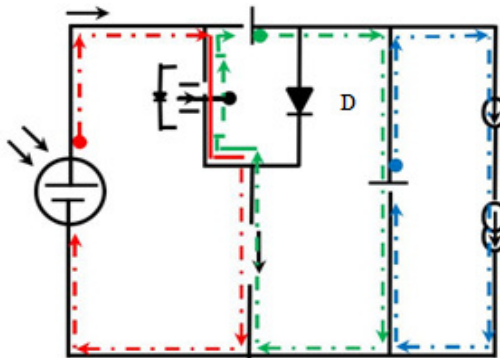
Figure 1. Proposed SPV array – CSC converter fed BLDC motor driven water pumping system

The VSI is operated with the pulses of fundamental frequency by means of electronic commutation, resulting in a reduced switching loss. The speed of BLDC motor is controlled by variation in the DC-link voltage. No need of additional phase current sensors, additional control or associated circuitry for the speed control. In addition, the DC-link voltage sensing is not required for control at any stage. Therefore, the resultant motor drive offers simplicity, compactness, cost effectiveness and easy-to-drive features without scarifying the performance. The starting inrush current of BLDC motor is restricted within the permissible range by appropriate control of

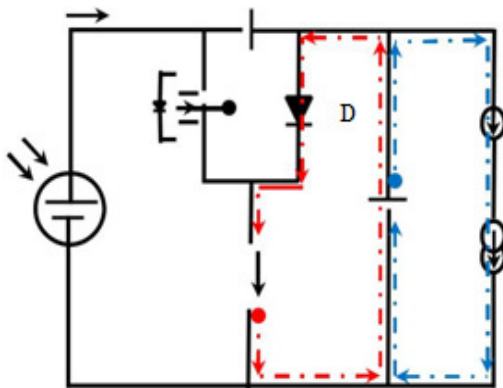
CSC converter through MPPT algorithm. The motor always attains the required speed to pump the water irrespective of the atmospheric variation.

4. Operating Principle of CSC Converter

The CSC converter is operated in discontinuous inductor current mode. The converter is operated in two different modes in every switching period, these as follows:

Mode I:**Figure 2.** Mode I of CSC converter

In this mode the CSC converter switch is ON, the inductor charges the input current and the capacitor C1 discharges the energy to the DC link capacitor, as shown in Figure 2(c). The DC link capacitor is charging as well as supplies a energy to the BLDC motor drive, so the DC link capacitor is fixes to the higher value for supplying a continuous energy to the motor drive.

Mode II:**Figure 3.** Mode II of CSC converter

In this mode the CSC converter switch is OFF state, then the inductor L discharges the stored energy to the DC link capacitor, as shown in Fig.3.

5. Control of Proposed System

The perturb and observe(P&O), as the name itself states that the algorithm is based on the observation of the array output power and on the perturbation (increment

or decrement) of the power based on increments of the array voltage or current. The operating voltage of the PV system is perturbed by a small increment of ΔV , and this resulting change in ΔP . If ΔP is positive, the perturbation of the operating voltage needs to be in the same direction of the increment. On the contrary, if ΔP is negative, the obtained system operating point moves away from the MPPT and the operating voltage needs to move in the opposite direction of the increment. An excellent tracking performance under dynamic condition with negligible oscillations around optimum operating point is achieved. Optimally selecting the initial value of duty ratio and its perturbation size offer soft starting of BLDC motor by slowly increasing the DC-link voltage of VSI.

6. Electronic commutation of BLDC motor

An electronic commutation of BLDC motor stands for commutating the currents flowing through windings of BLDC motor in a predefined sequence using a decoder circuit. Three inbuilt low-cost Hall sensors generate three Hall signals according to the rotor position at an interval of 60° . These Hall signals are then converted, using a decoder circuit, into the six switching pulses to operate the VSI feeding a BLDC motor. In this manner, fundamental frequency switching of VSI is obtained, resulting in a reduced switching loss. Table 1 shows the switching states of VSI for each particular combination of Hall signal states. It is perceptible that only two switches conduct at a time, resulting in 120° conduction mode of operation of VSI and hence the reduced conduction losses.

Table 1. Switching States For Electronic Commutation of Bldc Motor Based On Hall-Effect Position Signals

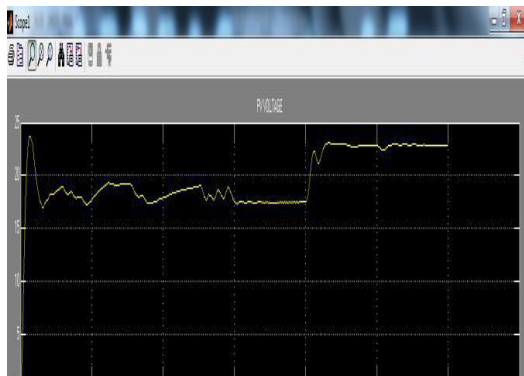
	Hall Signals			Switching States					
	H_a	H_b	H_c	Q_1	Q_2	Q_3	Q_4	Q_5	Q_6
NA	0	0	0	0	0	0	0	0	0
0-60	0	0	1	1	0	0	0	0	1
60-120	0	1	0	0	1	1	0	0	0
120-180	0	1	1	0	0	1	0	0	1
180-240	1	0	0	0	0	0	1	1	0
240-300	1	0	1	1	0	0	1	0	0

300-	1	1	0	0	1	0	0	1	0
360	1	1	1	0	0	0	0	0	0

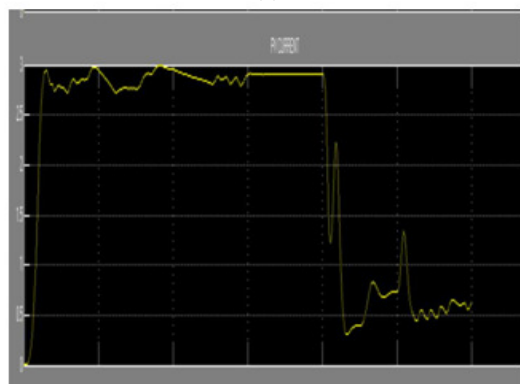
7. Simulated Performance of Proposed System

The various starting, dynamic and steady-state performances of the proposed SPV array fed BLDC motor driven water pump using a CSC converter are evaluated in MATLAB/SIMULINK environment A. State Performances.

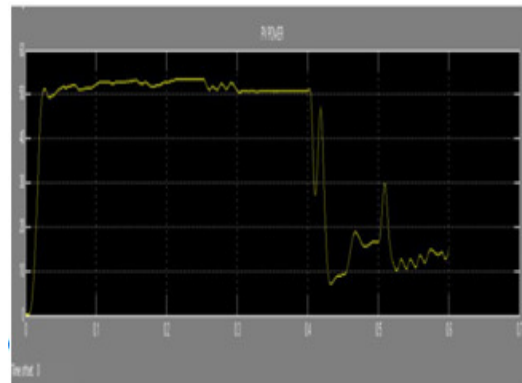
- (i) **Performances of P&O-MPPT:** Figure 4 depicts the responses of voltage, current and power SPV array for irradiance level. These indices express that MPP is tracked properly with negligible oscillation around the peak power point by applying the P&O-MPPT technique. The initial duty ratio and its perturbation are selected appropriately (0 and 0.001, respectively) in order to achieve the soft starting of the BLDC motor.
- (ii) **Operation of CSC converter:** Figure 5 depicts mean power, stator current, stator voltage, rotor speed, torque of BLDC motor. These responses demonstrate the operation of converter in CCM with reduced stress on power devices.



(a)

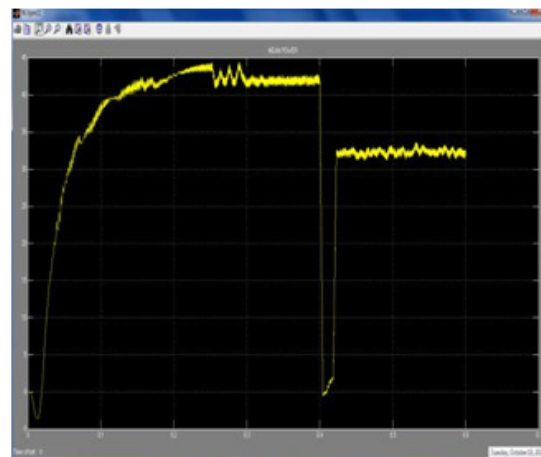


(b)

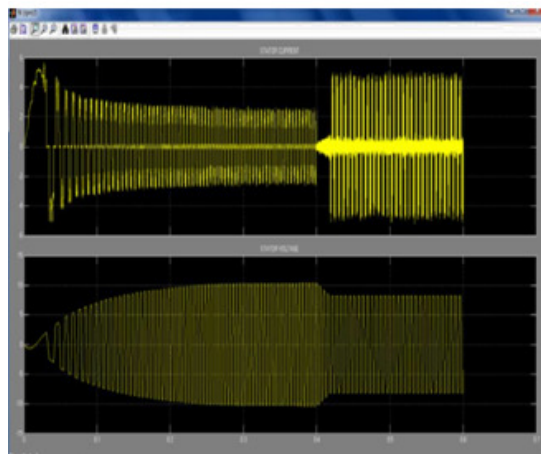


(c)

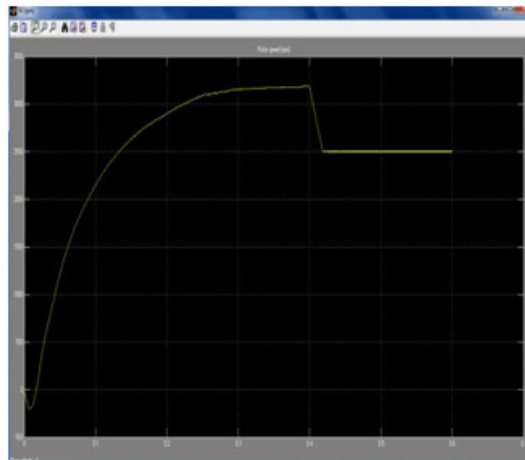
Figure 4. SPV array voltage, current and power for irradiance level



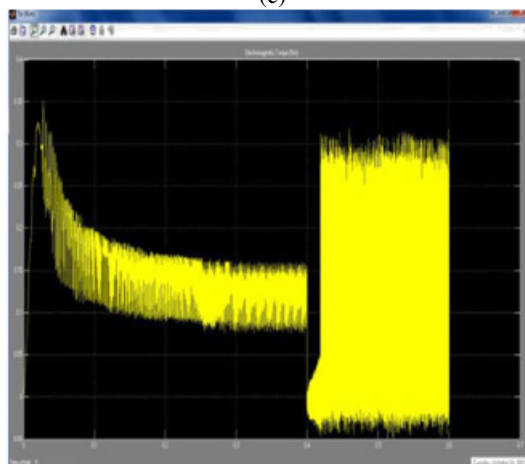
(a)



(b)



(c)



(d)

Figure 5. Depicts Mean Power, Stator Current, Stator Voltage, Rotor Speed, Torque of BLDC Motor

8. Conclusion

The SPV array-CSC converter fed VSI-BLDC motor-pump for water pumping has been proposed and its suitability has been demonstrated by simulated results using MATLAB/Simulink and its sim-power-system toolbox. First, the proposed system has been designed logically to fulfil the various desired objectives and then modelled and simulated to examine the various performances under starting, dynamic and steady state conditions. The performance evaluation has justified the combination of CSC converter and BLDC motor drive for SPV array based water pumping. The system under study availed the various desired functions such as MPP extraction of the SPV array, soft starting of the BLDC motor, fundamental frequency switching of the VSI resulting in a reduced switching losses, reduced switch stress and the components of CSC converter by

operating it in continuous conduction mode and stable operation. Moreover, the proposed system has operated successfully even under the minimum solar irradiance.

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