DESIGN AND ANALYSIS OF CONVERTER FED BRUSHLESS DC (BLDC) MOTOR

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Abstract—The best alternative to the conventional energy sources is everlasting solar energy; it is one among the cheapest and widely used. This paper deals with the design and analysis of zeta DC-DC converters, it is been used as intermediate between voltage source inverter (VSI) and solar PV array. MPPT technique is been used for gaining maximum efficiency form solar PV array for proper control of permanent magnet brushless DC (BLDC). Compared to other methods of MPPT technique, Fuzzy logic based MPPT technique is best used because it provides better results for randomly varying atmospheric conditions. BLDC motor has higher efficiency and noiseless operation compared to induction motor. Maximum power locus of PV generator is well matched with the load characteristic of BLDC motor. Matlab based simulation is carried out for the different topology of the DC-DC converters and the results are analyzed and compared.

Keywords—PV array; Buck/Buck-Boost converter; voltage source inverter(VSI); Brushless Dc motor(BLDC).

I. INTRODUCTION

A continuous markdown in cost of PV panels and electronic devices has encouraged the industries and research institutes to utilize the PV array generated power for different application. A maximum efficiency of PV array is mostly gained through maximum power point tracking (MPPT) algorithm using a dc-dc converter. There are many dc-dc converters such as buck, boost, buck-boost, cuk, sepic for achieving MPPT in different PV array based application. Its utilization is initiated in order to extract the maximum power available from the solar PV array and soft starting of the BLDC motor. BLDC motor has the merits of high efficiency, high reliability, high ruggedness, low EMI problems and excellent performance over a wide range of speed. The ratings of the solar PV array and the BLDC motor are selected such that the proposed system operates successfully under all the variations in the atmospheric conditions. The various performances are analysed through the simulated results using MATLAB/Simulink environment.

Most of the industries used induction motor for various applications but nowadays induction motors are replaced by permanent magnet brushless DC (BLDC) motor because of its high speed-torque characteristic, reduced size and so on. BLDC motor is considered as DC motor but it runs on AC supply. BLDC motor is operated smoothly with a use of inverter whose gate pulses are given by feedback signal drawn from motor using hall sensors. In this paper, various environmental conditions is considered for extracting maximum power form the PV array, we require MPPT technique for this process. Fuzzy based MPPT technique is proved the best by providing better results for varying weather conditions. BLDC motor is driven by inverter interface.

II. PROPOSED SYSTEM

Fig1 shows block diagram of from right to left, the proposed system consist of brushless DC motor (BLDC), Voltage Source Inverter (VSI), battery, DC-DC converter and PV array. Fuzzy and Hall Effect blocks are used as control blocks.

![Figure1: Block diagram of the proposed system.](image)

Depending on the environmental condition, PV array generates electrical power and feeds boost DC-DC converter. MOSFET switch of dc-dc converter is worked through fuzzy based MPPT technique such that maximum power is tracked and feed to BLDC through Voltage Source Inverter (VSI) so that motor as smooth operation. Zeta converter is always operated in continuous conduction mood in order to reduce stress on semiconductor devices and components. Further the output energy of boost DC-DC converters stored in a battery, then feeds VSI, supplying BLDC motor. The electronic communication of Brushless DC motor (BLDC) provides switching sequence for MOSFET switches in VSI. The process of decoding hall signals generated by hall sensors according to the position of BLDC rotor is called electronic communication.

III. DESIGN OF PROPOSED SYSTEM

Design of solar based converters feed BLDC motor such as boost converter, PV array and motor is designed such that a stable operation is always
obtained in any kind of change in solar insulation levels. BLDC motor of 50W rated power is selected. Depending on the selected power ratings, each stages of the system are designed as follows.

A. Design of PV array
A PV array of 3KW power rating, which is more than the power required by the BLDC motor, is selected in order to compensate the losses associated by DC-DC converter, VSI and motors. Estimation of all the parameters of PV array is done using Standard Insulation level of 1000 W/m² PV module is formed by connecting [1]. Table I gives the information about the various parameters to design a PV array of appropriate size.

TABLE I: Parameters of PV array

<table>
<thead>
<tr>
<th>Number of cells/ module</th>
<th>36</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open circuit voltage , $V_{oc}$</td>
<td>22.099 V</td>
</tr>
<tr>
<td>Short circuit current , $I_{sc}$</td>
<td>8.3695 A</td>
</tr>
<tr>
<td>Voltage at MPP , $V_{mp}$</td>
<td>17.7 V</td>
</tr>
<tr>
<td>Current at MPP , $I_{mp}$</td>
<td>7.62959 A</td>
</tr>
<tr>
<td>Number of module connected in series</td>
<td>1</td>
</tr>
<tr>
<td>Number of module connected in parallel</td>
<td>50</td>
</tr>
</tbody>
</table>

B. Design of converters
The solar PV array voltage at MPP, $V_{IN} = 18$ V appears as the input voltage source whereas the DC link voltage of the VSI, $V_{OUT}$ appears as the output voltage of the zeta converter. The duty ratio, $D$ of the boost converter is estimated, using the input-output relationship as

$$D = \frac{V_{OUT}}{V_{IN} \cdot I_{IN}}$$  \hspace{1cm} (1)

Where $V_{OUT} = 26$ V is an average value of the DC link voltage of the voltage source inverter. Addition of the two currents, $I_{IN}$ and $I_{OUT}$ flows through the inductor, $L$.

![Figure 2: Simulation model of zeta converter](image)

C. Design of zeta converter
$V_{IN}$, $V_{OUT}$, $I_{out}$ represent input voltage, output Voltage and output current of the converter respectively. $L_1$ is the intermediate inductor, $L_2$ is the output filter inductor, $C_1$ is the intermediate capacitor and $C_{DC}$ is the DC link capacitor. The switching frequency is indicated as $f_s$ and the duty ratio as $D$. figure2 shown the Simulink model of zeta converter. The input inductor current ripple $I_{L1} = 0.2 \times I_{out}$, filter inductor ripple $I_{L2} = I_{out}$, ripple in the DC link voltage $V_{OUT}$ = 0.02$V_{OUT}$, ripple in intermediate capacitor $V_{CC} = V_{IN}$.

The converter is designed using the equations (2) to (6) [8].

$$V_{OUT} = \frac{V_{IN} \cdot D}{1 - D}$$  \hspace{1cm} (2)

$$L_1 = \frac{f_s \cdot D \cdot C_1}{I_{OUT}}$$  \hspace{1cm} (3)

$$C_1 = \frac{V_{OUT}(1 - D)}{f_s \cdot I_{OUT}}$$  \hspace{1cm} (4)

$$L_2 = \frac{f_s \cdot D \cdot C_{DC}}{I_{OUT}}$$  \hspace{1cm} (5)

$$C_{DC} = \frac{2 \cdot f_s \cdot L_2}{I_{OUT}}$$  \hspace{1cm} (6)

IV. CONTROL OF THE PROPOSED SYSTEM
The controls of the proposed system with MPPT and Electronic commutation of BLDC motor are elaborated in the following sections.

A. Maximum power point tracking (MPPT)
The MPPT technique is mostly used to optimize the efficiency in solar PV based applications. A fuzzy type of MPPT technique [1-2] is used in this paper because of its high precision of tracking maximum power even under the rapid change in the atmospheric conditions. The soft starting of the BLDC motor is ensured under all the possible variation in the solar insolation level.

B. Electronic Commutation
The switching signals for the VSI are generated through the electronics commutation of the BLDC motor [3]. According to the angular position of the rotor, the encoder provides 3 Hall Effect signals. These Hall Effect signals are logically converted into 6 switching pulses used to operate the 6 IGBT switches of the VSI.

V. RESULTS AND DISCUSSION
The performance of the proposed solar PV powered dc-dc converter fed VSI-BLDC motor-pump system is simulated in the MATLAB/Simulink environment using the Sim-power-system toolbox.

A. Performance of buck-boost converter

![Figure 3: buck-boost converter](image)
Efficiency of buck-boost converter is 90% and the voltage ripple is 0.16. Below Simulink waveform shows the efficiency and output voltage of buck-boost converter.

![Figure 4: a) output voltage b) efficiency of buck-boost converter](image)

**B. Performance of sepic converter**

Efficiency of sepic converter is 97% and the voltage ripple is 0.15. Below Simulink waveform shows the efficiency and output voltage of sepic converter.

![Figure 5: sepic converter](image)

![Figure 6: a) output voltage b) efficiency of sepic converter](image)

**C. Performance of zeta converter**

Efficiency of sepic converter is 98.7% and the voltage ripple is 0.05. Below Simulink waveform shows the efficiency and output voltage of zeta converter.

![Figure 7: zeta converter](image)

![Figure 8: a) output voltage b) efficiency of zeta converter](image)

The comparison of buck-boost converter, sepic converter and zeta converter is summarized in table II. From table II we come to a conclusion that zeta converter is the best converter among the three converters.

**D. Zeta converter – BLDC motor**

The below figure shows the Simulink model of zeta converter which is used to fed BLDC motor.

![Figure 9: zeta converter-BLDC motor](image)
As the solar insolation level alters, the various BLDC motor indices such as the back EMF, $e_a$, the stator current, $i_{sa}$, the speed, $N$, the electro-magnetic torque developed, $Te$ is shown in Figure 4.

<table>
<thead>
<tr>
<th>Converters</th>
<th>Voltage Ripple $\Delta V$</th>
<th>Efficiency (In %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buck-boost</td>
<td>0.16</td>
<td>90</td>
</tr>
<tr>
<td>Sepic</td>
<td>0.15</td>
<td>97</td>
</tr>
<tr>
<td>Zeta</td>
<td>0.05</td>
<td>98.7</td>
</tr>
</tbody>
</table>

As the solar insolation level alters, the various BLDC motor–pump indices such as the back EMF, $e_a$, the stator current, $i_{sa}$, the speed, $N$, the electro-magnetic torque developed, $Te$ vary in proportion to the solar insolation level as shown in Figure Two important facts are observed from the simulated results. First, the stator current, $i_{sa}$ at the starting is controlled such that it takes time to reach its steady state value and hence the BLDC motor has a soft starting. Second, the BLDC motor develops electromagnetic torque, $Te$ which manifests the stable operation of the proposed system regardless of the weather condition.

VI. SIMULATION WAVEFORMS

Input voltage is maintained constant by the use of fuzzy controller, which is as shown in below waveform

Output voltage of zeta converter is a constant voltage, which is shown in figure below.

The electromagnetic stator current, rotor speed and torque are shown in figure. From the torque curve we can infer that the PV module was not able to drive the motor constantly without fluctuations.

CONCLUSION

The simulation of a PV based Brushless DC Motor was done. In order to extract the maximum possible power from the PV module, a Fuzzy based MPPT technique along with zeta converters was modeled and evaluated. The BLDC motor was driven by a Voltage source Inverter with switching signals generated by the Hall Effect sensors. The overall system was found to behave similar to any normal operation of the motor. The current simulated system will be able to act as a constant speed motor. The only mode of powering remote areas for applications such as pumping, grinding, etc. can be achieved by solar power, so it is better to use a buck-boost converter fed BLDC motor owing to their losses.

REFERENCES


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