A Zeta Converter Fed Induction Motor Drive For Solar PV Array Based Water Pumping

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Abstract—The main objective of the proposed system is meant for designing zeta converter fed induction motor drive for solar PV array based water pumping. The best alternative method for the conventional energy sources is solar energy. Now a days PV fed water pumping have a wide attention due to available solar energy. Zeta converter is a DC-DC converter. The input voltage of the zeta converter is variable and the output voltage is constant. The DC ripple is variable and the output voltage is constant. The DC ripple currents are reduced while using Zeta converter. The DC voltage is converted to AC using PWM inverter and then induction motor was driven. IncCond MPPT algorithm is used for detecting the peak voltage from the solar cells. Simulation and experimental results are presented to verify zeta converter fed induction motor drive for solar PV array based water pumping using MATLAB-SIMULINK.

Keywords—Zeta-converter, MPPT, PV-array, Induction motor.

I. INTRODUCTION

For extracting as much energy as possible from photovoltaic (PV) modules, the energy utilization needs to be improved, as well as power conversion efficiency of converters. Renewable energy sources are becoming an alternative source for cleaned and for generating the sustainable electricity in which photovoltaic (PV) systems have gaining advantages mainly due to increasing the modules efficiency, reduction of cost and political incitement. PV modules have strong dependence on solar radiation and surface temperature hence it cannot have a specified voltage or current across its terminals. The Maximum Power Point (MPP) is used as operation point in order to avoid extreme PV output power oscillations and ensure its operation with the highest efficiency (given a solar radiation and temperature condition). For ensuring PV systems operation on the MPP, specific circuits named by Maximum Power Point Trackers (MPPT) are employed. In most of application, a MPPT is achieved thought a dc-dc converter (hardware block), a tracking algorithm (software block) and external sensors (usually voltage, current or both), as From the software point of view, the most commonly employed tracking algorithms are Perturb and Observe (P\&O) and Incremental conductance (IncCond). P\&O method is simple, however it failure to track the MPP under abrupt changes on solar radiation and present oscillations around the MPP on steady-state. IncCond technique is accurate, nevertheless, its implementation is more complex, and similarly to the P\&O method, it needs a voltage and a current sensor for properly work be capable of meeting the demanding reliability and performance criteria required. On the other hand, a zeta converter exhibits following advantages over the conventional buck, boost, buck-boost converters and Cuk converter. This property obviates a requirement of associated circuits for negative voltage sensing hence reduces the complexity and probability of slow down the system response. These merits of the zeta converter are favorable for proposed SPV array fed water pumping system.

II. CONFIGURATION OF PROPOSED SYSTEM

A zeta converter is utilized in order to extract the maximum power available from a SPV array, soft starting and speed control of Induction motor coupled to a water pump. Due to a single switch, this converter has very good efficiency and offers boundless region for MPPT. This converter is operated in continuous conduction mode reduces the stress on its power devices and components. Furthermore, the switching
loss of VSI is reduced by adopting fundamental frequency switching resulting in an additional power saving and hence an enhanced efficiency. The phase currents as well as the DC link voltage sensors are completely eliminated, offering simple and economical system without sacrificing its performance. The speed of Induction motor is controlled, without any additional control, through a variable DC link voltage of VSI. Moreover, a soft starting of Induction motor is achieved by proper initialization of MPPT algorithm of SPV array. These features offer an increased simplicity of proposed system.

III. OPERATION OF THE PROPOSED SYSTEM

The advantages and desirable features of converter and Induction motor drive contribute to develop a simple, efficient, cost-effective and reliable water pumping system based on solar PV energy. Simulation results using MATLAB/Simulink and experimental performances are examined to demonstrate the starting, dynamics and steady state behavior of proposed water pumping system subjected to practical operating conditions. The SPV array and Induction motor are designed such that proposed system always exhibits good performance regardless of solar irradiance level.

B. Design of Zeta Converter

The Zeta converter is the next design process consists of an estimation of input inductor, L1, output inductor, L2 and intermediate capacitor, C1. These components are designed such that the zeta converter always operates in CCM resulting in reduced stress on its components and devices. An estimation of the duty cycle, D, initiates the design of zeta converter which is estimated as

\[ D = \frac{V_{dc}}{V_{dc} + V_{in}} = \frac{200}{200 + 96.87} = 0.673 \]

TABLE-II

<table>
<thead>
<tr>
<th>Zeta converter</th>
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<tbody>
<tr>
<td>Input voltage</td>
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<tr>
<td>Output voltage</td>
</tr>
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</table>
The components used in the zeta converter are two inductors, two capacitors, two resistors and their values are tabulated below in the table.

### Table III

<table>
<thead>
<tr>
<th>Zeta converter components value</th>
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<tbody>
<tr>
<td>$C_{in}$</td>
</tr>
<tr>
<td>$L_1$</td>
</tr>
<tr>
<td>$L_2$</td>
</tr>
<tr>
<td>$C_1$</td>
</tr>
<tr>
<td>$VC_2$</td>
</tr>
<tr>
<td>$VC_1$</td>
</tr>
</tbody>
</table>

C. Design of voltage source inverter

The voltage source inverter is designed next to zeta converter. A new design approach for estimation of DC link capacitor of VSI is presented here. This approach is based on the fact that 6th harmonic component of the supply (AC) voltage is reflected on the DC side as a dominant harmonic in the three phase supply system [3].

Here, the fundamental frequencies of output voltage of the VSI are estimated corresponding to the rated speed and the minimum speed of Induction motor essentially required to pump the water. These two frequencies are further used to estimate the values of their corresponding capacitors. Out of these two estimated capacitors, larger one is selected to assure a satisfactory operation of proposed system even under the minimum solar irradiance level.

The fundamental output frequency of VSI corresponding to the rated speed of Induction motor is estimated as is given as:

$$\omega_{\text{rated}} = \frac{2\pi f_{\text{rated}}}{\text{P}} = \frac{2\pi \times 1430}{120} = 449 \text{ rad/s}$$

D. Design of induction motor

The induction motor designed for coupling with the pump. The power rating, voltage, speed, frequency of the induction motor as shown in Table –IV. The 15 HP induction motor is used for coupling with the centrifugal pump. The torque value of the induction motor is constant. The frequency of the induction motor is 449 rad/sec. Induction motor RPM is given as 1430 rpm and the number of poles is 6. The rated frequency is 50 Hz.

### Table IV

<table>
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<tr>
<th>Induction motor rating</th>
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<tbody>
<tr>
<td>Power</td>
</tr>
<tr>
<td>Voltage</td>
</tr>
<tr>
<td>Frequency</td>
</tr>
<tr>
<td>Speed</td>
</tr>
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</table>

V. SIMULATION AND RESULTS

The FIG. (3) below, shows the simulated schematic diagram of the complete designing of zeta converter fed induction motor drive for solar PV array based water pumping. The modeling and simulation of the whole system has been done in MATLAB-SIMULINK.

A. Input voltage to zeta converter

The input voltage to zeta converter is DC voltage from solar PV array. The input voltage of zeta converter is 96.87 V. The input voltage of zeta converter is variable and the output voltage is constant.

![Fig.3. Simulink model of zeta converter fed IM drive for solar PV array based water pumping.](image-url)

![Fig.4. Input voltage to zeta converter](image-url)
B. Output voltage of zeta converter

The output voltage of the zeta converter is 415 V. The input voltage from the SPV array is boosted and the output is increased.

C. Voltage source inverter output

The VSI converts 415 DC voltage to 415.4 AC supply for driving the Induction Motor. PWM signals are given to gate terminal for PWM output voltage.

D. Output waveforms for induction motor

The output waveforms of induction motor are given below (a) Rotor Speed, (b) Electromagnetic Torque, (c) Stator Current and (d) Rotor current.

VI. CONCLUSION

The transient, dynamic and steady state behaviors of the proposed zeta converter fed induction motor drive for solar fed PV array have been validated for water pumping. The proposed system has been modeled, designed and simulated in MATLAB/Simulink environment. A DC-DC zeta converter provides the flexibility of increasing and decreasing the voltage level and hence does not possess a limited region of MPPT. Taking the advantages of very good conversion efficiency of zeta converter, the induction motor and centrifugal pump, a suitable water pumping system based on solar PV array has been developed. The proposed system is designed brilliantly, such that the performance is not affected by the weather condition and efficiency limitations of the converters and motors. Using the simulated results, a zeta converter with the Induction motor is proved as a suitable combination for solar PV based water pumping.

References
