PV & Zeta Converter based Irrigation Pumping System using PMBLDC Motor

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Abstract: This paper proposes an idea of designing & implementing a simple, affordable, productive & pollution free water pumping system using the advantageous features of a zeta converter and PMBLDC motor for the irrigation which will help the farmers in minimizing their farming hurdles which in turn will improve the productivity as well as quality of life. It presents an outstanding system consisting of PMBLDC motor which is fed from a renewable source i.e, from PV array & to obtain the maximum power output from PV array via MPPT, a Zeta converter is used .This system eliminates the phase current sensors and acquires fundamental frequency switching of VSI,which contributes in avoiding the power loss due to high frequency switching. No circuitry is required to control the PMBLDC motor. It is controlled via variable DC link voltage of VSI. It also presents a new idea to completely remove the dc link capacitor which is bulky and also increase the cost of motor. But this elimination results in torque ripple to arise at the output of motor. A ceramic capacitor and switch are used in place of dc link capacitor to miminimise the torque ripple. Simulation is performed using MATLAB/SIMULINK software and the results are presented.

Keywords: Photovoltaic Array (PV), Zeta converter(ZC), Incremental conductance- Maximum Power Point Tracking (INC- MPPT), PMBLDC motor, Water pump.

1. Introduction

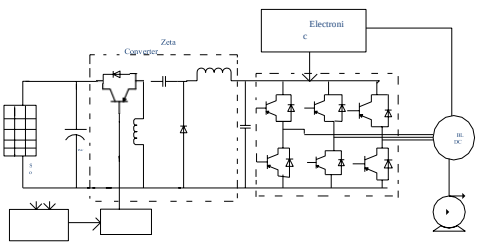
Today India is facing a huge energy crisis due to depletion of fossil fuels. Renewable energy can fix all of India's problems. Renewable sources will power our nation because renewable sources are unlimited. Wind will always blow and the sun will always shine, because that is what this earth is all about. we need something that stays for long i.e, sustainable sources of energy that will not end & continue to power India in the future. Renewable sources of energy are the basis & the future use of Non-conventional sources of energy replaces the energy sources consisting carbon incentives & minimize the global warming issues to large extent.

Maximum population around the world reside in remote and rural places with limited access to water. In many places, the Underground deep water is extracted via electric water pumps. But electricity is not available so the electric pumps have traditionally being powered by diesel generators. These generators require periodical servicing and maintenance which is costly & combusome. But it's necessary to do so to avoid breakdown. Generator runs on a fuel which is both expensive and emits carbon dioxide, polluting the environment so the best way to overcome this problem is by installing the solar powered pumps.

Water pumping system with use solar array, zeta converter & PMBLDC motor is a huge opportunity for rural & urban communities to reduce the cost of accessing water by using clean energy in the community for the next 30 years. The benefits of both zeta converter & PMBLDC motor results to invent a solar powered water pumping system capable of operating satisfactorily under various climates.

2. Proposed Topology

This topology is mainly composed of (a)SPV Array ,(b) Zeta converter,(c) a VSI (d)a BLDC motor (e) a water pump as shown in fig. (1) .



Water Pump

Fig.1.- Proposed Solar PV array and zeta converter based water pumping system using PMBLDC motor.

The electricity is generated by solar array which is required to run the water-pump. This generated energy is given to the water pump using a zeta converter and a VSI. Then for the zeta converter, photovoltaic array acts as the source of power. Zeta converter is operated through pulse generator .Switching pulse for the zeta converter IGBT Switches are generated through INC-MPPT algorithm using pulse generator. Voltage and current signals acts as the feedback from SPV array which is used by the INC-MPPT. Then actual switching pulse is generated by the comparison of duty cycle with a carrier wave of high frequency. This results in extraction of maximum power and hence increases the efficiency of the PV array. The DC output of a Zeta converter is converted into AC via VSI and this AC power is given to the PMBLDC motor to run the water pump which is connected to its shaft PMBLDC Motor has an inbuilt encoder. Electronic commutation of the PMBLDC motor is used to operate the VSI which is used to control the motor. The VSI is operated in fundamental Frequency switching. The high frequency switching losses are therefore eliminated which helps in increasing the efficiency of the proposed water pumping system.

1. Modified Topology

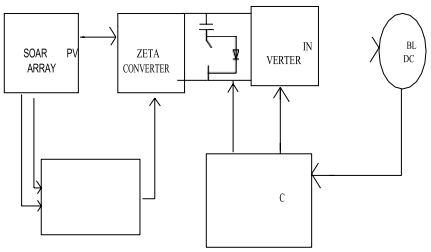


Fig.2.-Block diagram Solar PV array and zeta converter based water pumping system using PMBLDC motor with compensation of torque ripple.

As seen in earlier fig(2).,In between the zeta converter and the inverter to get a constant voltage at the input of inverter a DC link capacitor is connected, which makes the voltage free from ripple .The size of this connected DC link capacitor is large. The operating temperature of DC link capacitor has an intense effect on its life time. Also its cost is about 5-15% of the total cost of BLDC motor. Hence its an Endeavour to minimize the cost of motor by eliminating the DC link capacitor which gives rise to torque ripple to arise at the output of motor. A new method is introduced to reduce the torque ripple which comes up due to elimination of the DC link capacitor. This eradication helps to minimize the price and size of motor. The DC link capacitor between the zeta converter and Inverter has been replaced with a ceramic capacitor and a switch with ant parallel diode.

The working basis of each apparatus is as follows:

SOLAR PHOTOVOLTAIC ARRAY

The solar water pumping system must be run with solar irradiations with a capacity in range of 200 W/m2 and above. In this paper, we are considering till 1500W/m2, measured under standard test conditions. PV array consists an arrangement of several solar panels in a group to capture maximum amount of sunlight to convert it into usable electricity. The number of modules in series and parallel used must be sufficient to obtain the required power output from solar array.

ZETA CONVERTER

The zeta converter comes after the Solar array. A Zeta converter is a fourth-order DC-DC converter that cans step-up and step-down the output voltage. It is a type of Buck-Boost converter. It consist of two inductor and two capacitor as shown in fig.(3).

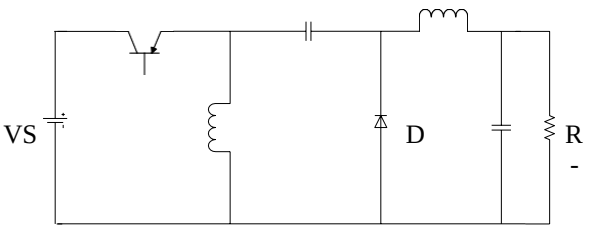


Fig.(3)-Zeta Converter

It is used to extract maximum power from the SPV array with minimum power losses. The output voltage depends on the duty ratio of the converter. This converter has following advantages over the conventional Buck, Boost , Buck-Boost, CUK and Sepic converter when they are used with SPV applications.

- It provides better efficiency and better voltage gain than regular buck-boost converter.
- It has wider range of duty ratio than any other converter.
- It has non-inverted output. This property eliminates the requirements of associated circuit for negative voltage sensing which reduces the complexity and probability of slow down of system response.
- It has improved power factor, low input current distortion, low output current ripple and wide output range.
- Its output current is continuous and ripples free. Its output efficiency is high and economical.

PMBLDC MOTOR

A PMBLDC motor is an electronically commutated DC motor which does not have brushes .It has three coil winding in the stator and a single pole pair in the rotor. The controller provides pulses of current to the motor windings which control the speed and torque of the motor. PMBLDC motor gives superior performance when it is preferred for solar based applications. I t has many advantages over their brushed counter parts like higher efficiency, lower maintenance ,high reliability, less noise, long operating life, high ruggedness, excellent performance over wide range of speed.

PROPOSED TOPOLOGY CONTROL

The proposed topology is controlled in two ways:

(1)INC-MPPT Algorithm (2) Electronic Commutation

(1)INC-MPPT

Solar photovoltaic application uses the mostly used and an effective INC-MPPT technique to amend the available power & also to regulate the soft starting of BLDC motor i.e; the BLDC motor experiences reduced current at the starting. The incremental conductance method is based on the observation which states that at the MPP, change in power with respect to change in voltage is equal to zero? It was developed to overcome the drawbacks of perturb & observe the PPT technique. The incremental conductance method computes the MPP by comparing the incremental conductance of solar PV array. When these two are the same, the output voltage is the MPP voltage. The controller maintains this voltage until the irradiation changes and the process is repeated.

(2)ELECTRONIC COMMUTATION

Motion in PMBLDC Motor is generated through six-step commutation or trapezoidal control where the correct phases are accommodated every 60 degrees for continuous rotation of the motor. Depending on the rotor position, 3 Hall Effect signals are produced by inbuilt encoder in the motor. These 3 Hall Effect signals are converted into three EMF Signals. Then according to various combinations of three EMF signals, 6 switching pulses are generated which are further fed into six switches of VSI which results in control of the BLDC motor.

	Hall Signal			Switching Sequence					
	H1	H2	H3	S1	S2	S3	S4	S5	S6
	0	0	0	0	0	0	0	0	0
NA	0	-1	1	0	0	0	1	1	0
0-60	-1	1	0	0	1	1	0	0	0
60-120	-1	0	1	0	1	0	0	1	0
120-180	1	0	-1	1	0	0	0	0	1
180-240	1	-1	0	1	0	0	1	0	0
240-300	0	1	-1	0	0	1	0	0	1
300-360	0	0	0	0	0	0	0	0	0
NA									

Tab-1: Switching sequence for the electronic commutation of BLDC motor.

3. Simulation Model & Results

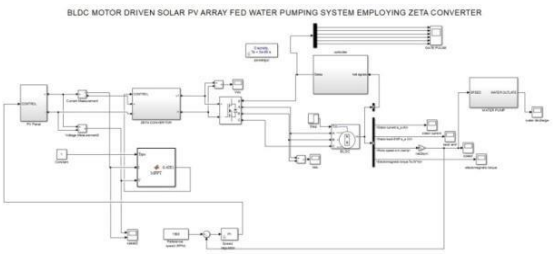


Fig.(4).- Simulation of PV array and zeta converter based water pumping system using PMBLDC motor.

The simulation model of PV array and zeta converter based water pumping system using PMBLDC motor is shown in fig.(4).The starting and steady state behavior of PV array, Zeta converter, PMBLDC motor,

water discharge at 1500W/m2 is shown in fig. given below.

Fig.4.(a)-Output waveform of SPV Array.

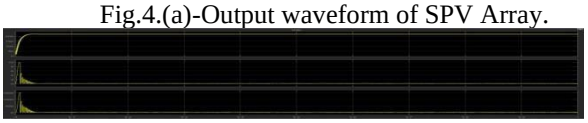


Fig.4.(b)-Output Waveform of Zeta Converter

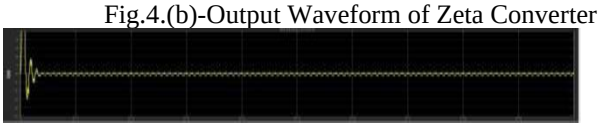


Fig.4.(c)-Output waveform of Stator Current.

Fig.4.(d)-Output waveform of Back EMF.

Fig.4.(e)-Output waveform of Rotor Speed.

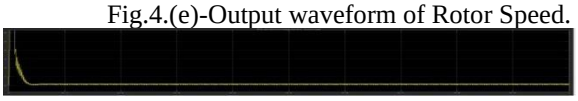


Fig.4.(f)-Output waveform of Electromagnetic Torque.

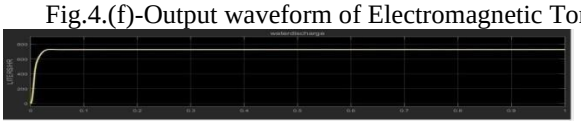


Fig.4.(g)-Water Discharge.

The simulation model of PMBLDC Motor driven PV array fed water pumping system employing zeta converter with torque ripple compensation is shown in fig.(5).

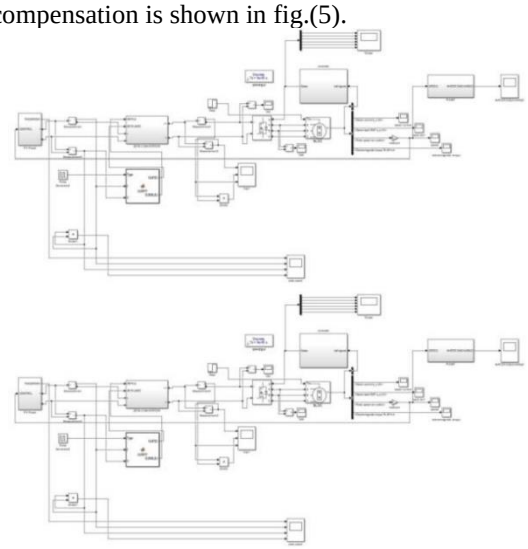


Fig.(5)-. Simulation model of Solar PV array and zeta converter based water pumping system using BLDC motor with compensation of torque ripple. The dynamic behavior of PV array, zeta converter, PMBLDC motor, water discharge at 1500W/m2 is shown in fig. below.

Fig.5.(a)-Output waveform of SPV Array.

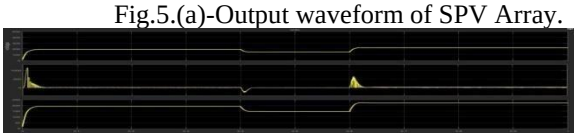


Fig.5.(b)-Zeta Converter Waveforms.

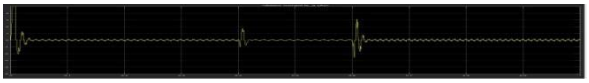


Fig.5.(c)-Output waveform of Stator Current.

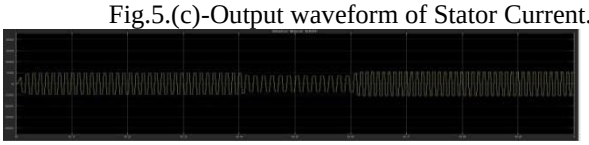


Fig.5.(d)-Output waveform of Back EMF.

Fig.5.(e)-Output waveform of Rotor Speed.

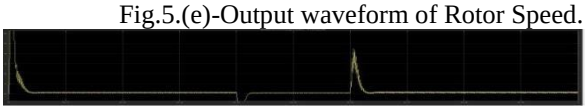


Fig.5.(f)-Output waveform of Electromagnetic Torque.

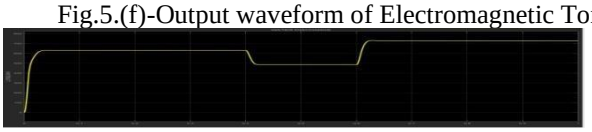


Fig.5.(g)-Output waveform of water discharge.

4. Conclusion

This paper gives an economical result about the idea of designing and implementation of a simple, fruitful and proficient method for water pumping which can be useful in various applications like irrigation household drinking water etc. with the use of zeta converter and PMBLDC motor. Here, the system is designed and simulated considering the random and instant variations in solar irradiance level. Suitability of system will be demonstrated by testing the starting, steady state and dynamic behavior of system. This system will prove to be a boon to the mankind especially for the farmers as it will provide a bundle of benefits to them like

a. No fuel costs & minimal maintenance cost.
b. Saves time and labour.
c. Improves agricultural productivity.
d. Highly reliable & durable.
e. Eco-friendly
f. Improves general quality of life with higher level of income.

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