BLDC Motor Driven Solar PV Array Fed Water Pumping System Employing Zeta Converter

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Abstract – This paper deals with the usage of ZETA converter and a three-phase voltage source inverter for utilizing the power from a solar photovoltaic array to drive a Brushless DC motor. Here ZETA converter is used to maximize the power output from the solar photovoltaic system. The three-phase voltage source inverter (VSI) is implemented to obtain a maximum efficiency and to achieve a soft starting of BLDC motor for a smooth operation. The proposed algorithm for voltage source inverter (VSI) control utilizes fundamental frequency switching and the need for phase current sensors has been eliminated which results in reduced power losses at high switching frequencies. A variable DC link voltage of VSI controls the speed of BLDC motor and thus eliminating any usage of separate speed control units. The proposed system is implemented for water pumping system and designed to operate under any dynamic conditions without any change in performance which is demonstrated by the simulation in powersim software and through practical hardware verification.

Keywords: Zeta Converter, BLDC Motor, Solar PV Array, Pumping System, voltage source inverter, MPPT.

I. INTRODUCTION

A stand alone power generation system for water pumping plays an important role in irrigation systems of agriculture field of crops and also in various industrial and domestic applications. This combines the design of DC-DC converters along with inverters for driving a pump motor which are implemented in pumping systems [1]. The development of this kind of system was done basically using zeta converter and a VSI which drives a permanent magnet brushless DC (BLDC) motor based water pump.

II. EXISTING SYSTEM

Inverters based on a double stage architecture in which the first stage is a dc-dc converter that can be designed to match with the PV solar array voltages in need to meet with the required specifications of the dc-ac of the second stage inverter that can supply an ac voltage to the output loads or to inject some of the generated power flow to the grid [2]-[4]. Such type of configurations are effective in the featuring a controllability because of the first converter stage that can be adopted to track a maximum power from the PV panel array and then a next second stage will produce an output ac current of low Total Harmonic Distortion (THD) levels [5].

Drawbacks:

- There is no dynamic response
- High Total harmonic Distortion (THD)

III. PROPOSED SYSTEM

In this proposed system of Solar PV array fed water pumping system with an incremental conductance (INC) with MPPT algorithm is used to operate the zeta converter [6], [7]. Such that the Solar Photovoltaic array always operates at the starting current is reduced by the experience of MPP and BLDC motor. An electronic commutation of BLDC motor operated by fundamental frequency switching for the three phase voltage source inverter (VSI).

a) Block Diagram

In this system blocks consist of (left to right) a Solar Photovoltaic array, VSI, BLDC motor, zeta converter, and water pump. The Solar panel converts solar energy into electrical power that is fed to the ZETA DC-DC

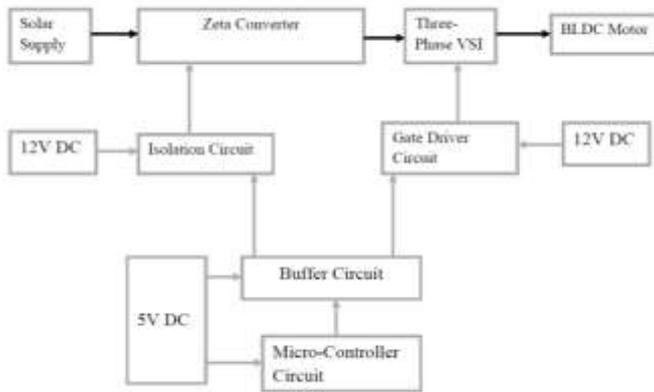converter. The power source for the zeta converter is SPV array.

Figure-1: Block Diagram of Proposed System
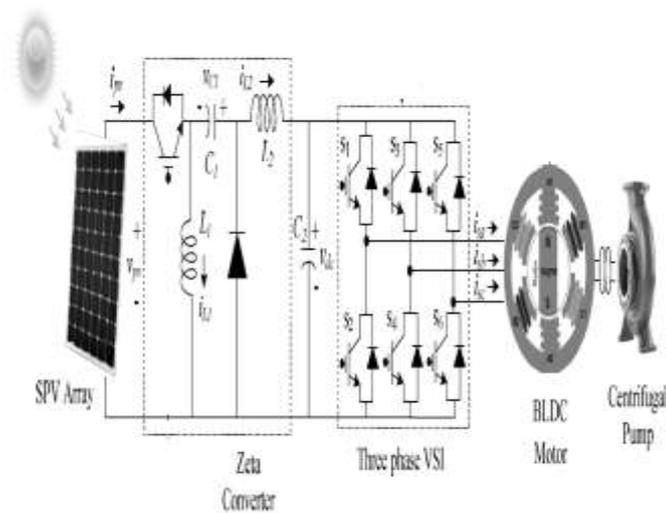
b) Overall Circuit Diagram

Figure-2: Circuit Diagram of Proposed System

c) Description of Proposed System

The voltage is boosted and power is transferred from the output of zeta converter which is the input source for the VSI. A maximum power point tracker (MPPT) is designed and tested to extract a maximum available power from the solar panel module and to transfer the power to the output load. The MPPT algorithm uses voltage and current as feedback from SPV array and generates an optimum value of duty cycle.

The pulse generator generates, through INC-MPPT algorithm, switching pulses for IGBT (Insulated Gate

Bipolar Transistor) switch of the zeta converter. The gate pulses used to operate the zeta converter is supplied by a microcontroller. Also it produces a accurate switching gate pulse by using a comparator to produce duty cycle of a high frequency carrier wave. The VSI is operated in fundamental frequency switching by sensing the speed of the BLDC motor with an inbuilt encoder. The high frequency switching losses were thus eliminated by contributing to an elevated efficiency in the proposed water pumping system. The BLDC motor to drive a water pump coupled to its shaft feeds AC from zeta converter its DC output from the voltage source inverter converting a into AC.

d) Zeta Converter

- A zeta converter is a fourth order non linear system.
- With regard to energy input, it can be seen as buck-boost-buck converter.
- With regard to the output, it can be seen as boost-buck-boost converter.
- Zeta converter is fourth order converter that can step down or step up the input voltage.
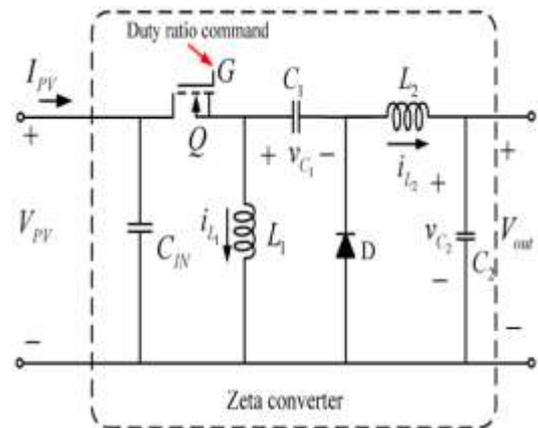
e) Zeta converter circuit

Figure-3: Zeta converter circuit

Mode-1:

The first operation mode is here by obtained during the turn ON of switch (closed) instantaneously while diode D is switched OFF. During this conduction period the inductor current of L1 and L2 were drawn by the voltage source Vs whose mode is the charging mode.
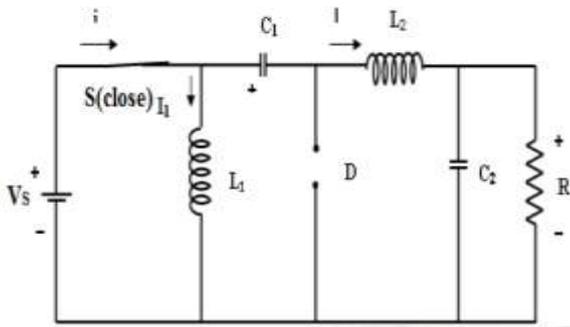
Figure-4: Equivalent circuit of converter (switch ON)

Mode-2:

The operating mode will be started with the switch is in OFF state and the diode D is in an ON position. This mode of operation in this stage is called as the discharging mode because of all of the energy is stored in inductor L2 is then transferred to the load R.
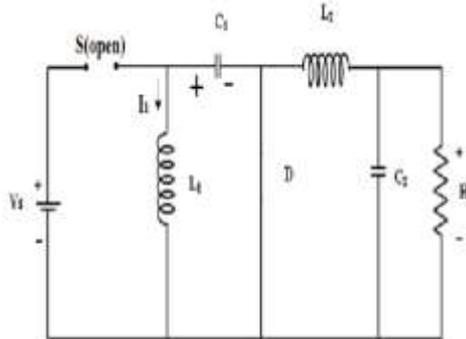

Figure-5: Equivalent circuit of converter (switch OFF)

f) Input outputs of Converter

The input voltage to zeta converter is DC voltage from solar PV array. The input voltage of zeta converter is 12V. The input voltage of zeta converter is variable and the output voltage is constant. The output voltage of the zeta converter is 24V. The input voltage from the SPV array is boosted and the output is increased. The VSI converts 24 DC voltage to 24 AC supply for driving the BLDC Motor.

g) Voltage Source Inverter

A voltage source inverter is one in which the dc input voltage is essentially constant and converts the dc into ac voltage of desired frequency. The VSI control circuit has direct control of output (ac) voltage levels in this type of inverter. A constant voltage source used here acts as

input to the bridge inverter circuit. The constant DC voltage source is done by implementing a large capacitor across the DC source grid.

IV. SIMULATION AND RESULT

a) PSIM Simulation Circuit

The circuit of the Zeta converter with 3-ph Voltage Source Inverter (VSI) has been simulated using PSIM software and waveforms of the PWM gate pulses along with 3-phase voltage and current waveforms are displayed in figures 7-10 and the simulated schematic diagram is shown in figure-6.
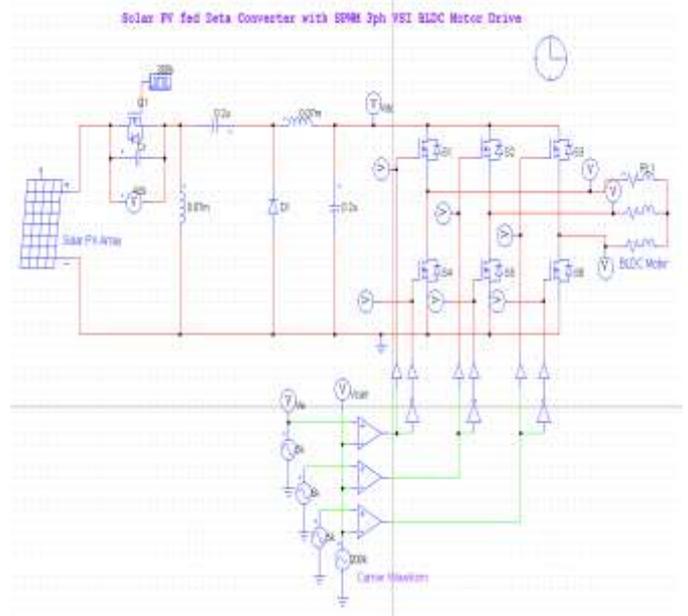

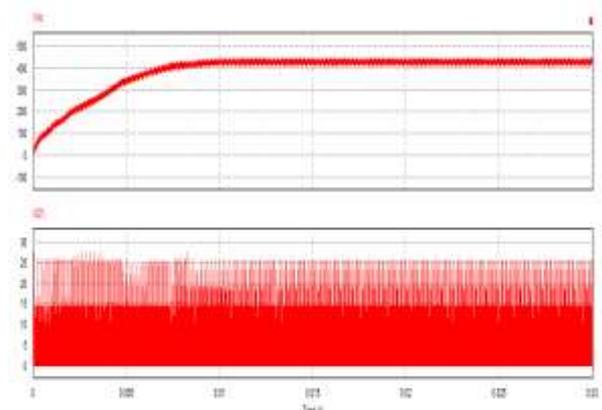
Figure-6: PSIM Simulation Circuit

b) Output Waveforms

Figure-7: Zeta Converter

Figure-8: PWM Gate Pulses

Figure-9: 3 Phase VSI Output Voltage

Figure-10: 3 Phase VSI Output Voltage

V. CONCLUSION

A solar photovoltaic array power source with a zeta converter based DC-DC converter is designed for boosting the output DC voltages and to supply a stable DC supply to the grid has been designed. A three-phase VSI also been designed to operate under PWM fundamental switching technique which converters DC voltage supplied to the grid to a variable frequency three-phase AC supply for deriving a BLDC motor pump. The usage of IGBT reduces switching losses and the power levels are improved by the continuous conduction mode of the Zeta converter. Hence the proposed system operated under a maximum power output levels under minimum solar irradiance. So by using these types of power generation, we can produce a electrical power with lower production cost and low energy consumption for pump motor with a high speed and smooth response of the system.

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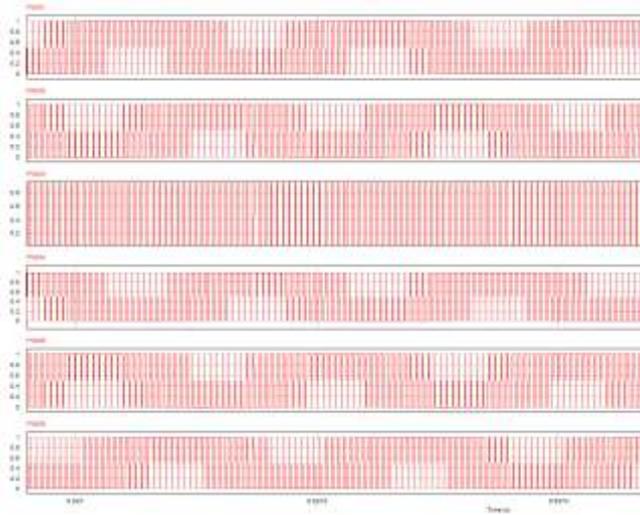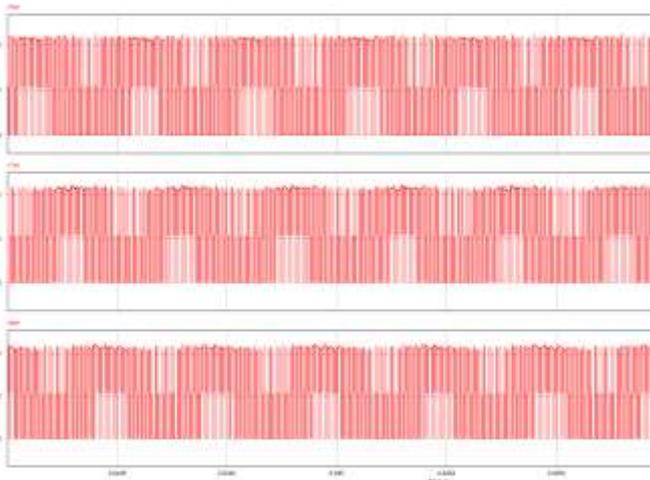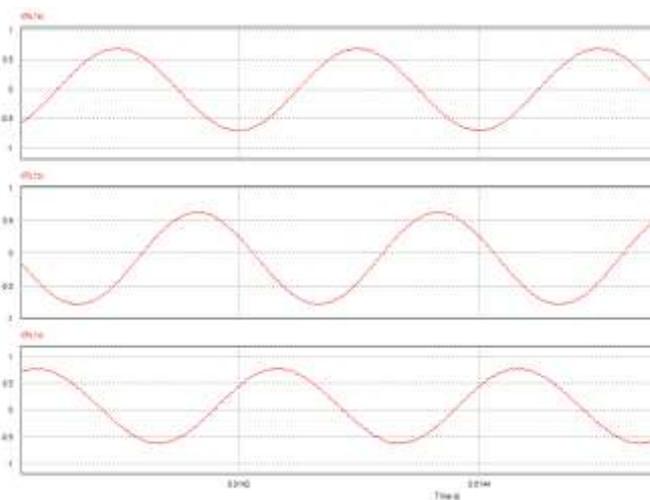
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