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BLDC Motor-Driven Solar PV System Through MPPT

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ABSTRACT

The drastic reduction in the cost of power electronic devices and annihilation of fossil fuels in near future invite to use the solar photovoltaic (SPV) generated electrical energy for various applications as far as possible. The water pumping, a standalone application of the SPV array-generated electricity, is receiving wide attention nowadays for irrigation in the fields, household applications, and industrial use. SPV array-fed water pumping, combining various dc–dc converters and motor drives, the zeta converter in association with a permanent-magnet brushless dc (BLDC) motor is not explored precisely so far to develop such kind of system. However, the zeta converter has been used in some other SPV-based applications. The advantages and desirable features of both zeta converter and BLDC motor drive contribute to develop a simple, efficient, cost-effective, and reliable water pumping system based on solar PV energy.

KEY WORDS: BLDC motor, PV System, Zeta Converter and PWM based VSI.

1. INTRODUCTION

A BLDC Motor or Electronically Commutated Motor (ECM) are synchronous motor which are supplied by Direct Current (DC) through Inverter or Switching Power Supply producing AC through which each phase of the motor can be driven. Brushless motor are similar to permanent magnet synchronous motor in terms of construction but it can also be transformed into a switched reluctance motor. BLDC motors find numerous applications in the field of industrial engineering, consumer appliances, electric vehicles, motion control system, positioning and actuation system's aero modeling and many more [1]. BLDC motor has number of advantages over other motors which include high power-to-weight ratio, better speed, electronically controllable, reliable operation and require less maintenance [2].

Brushless motors typically have rotating permanent magnets and a fixed armature, which eliminates the challenges associated with supplying current to the moving armature. The brush/commutators unit of the brushed DC motor is replaced by an electronic controller, which continuously shifts the phase to the windings to keep the motor moving. Instead of the brush/commutators scheme, the controller uses a solid-state circuit to conduct similar timed power distribution [2]. In the no-load and low-load regions of the motor's performance curve, the increased efficiency is greatest. Brushless motors and high-quality brushed motors are comparable in efficiency under high mechanical loads. Environments and requirements in which brushless-type DC motors are used include maintenance-free operation, high speeds, and operation where sparking is hazardous (i.e. explosive environments) or could affect electronically sensitive equipment.

The brushless dc (BLDC) motor sensorless control system for an automotive fuel pump is developed by Chun et al (2014). It is recommended that sensorless techniques based on a hysteresis comparator and a potential start-up method with a high starting torque be used. The hysteresis comparator compensates for back EMF phase delay caused by a low-pass filter (LPF) while also preventing numerous output transitions caused by noise or ripple in the terminal voltages.

Il-oun Lee et al. (2012) proposed an interleaved buck converter (IBC) with low switching losses and increased step down conversion ratio, which is also appropriate for applications with high input voltage and low operational duty cycles. It indicates that before or after turn-on, the voltage across all switches is half of the input voltage, and that when the operating duty is less than 50%, the capacitive discharge and switching losses are also decreased.

2. MODELLING OF BRUSHLESS DC MOTOR

One of the types of permanent magnet synchronous motors is BLDC motors. Brushless DC motors, for example, do not experience the "slide" that is commonly noticed in induction motors since they have a permanent magnet rotor. Magnetism that is permanent Mechanical commutators and brushes are commonly used in DC motors to complete the commutation process. However, instead of mechanical commutators and brushes, BLDC motors use Hall Effect sensors. Brushless DC motors' stators are coils, and their rotors are permanent magnets [3]. Initially, the magnetic field is created by the stator winding of a brushless DC motor, and the rotor begins to rotate as a result of this field. And the Hall effects presents in this type of drive is used for sensing the position of rotor as in the form of commutating signals. The schematic diagram for the brushless dc motor is as shown in figure 1.

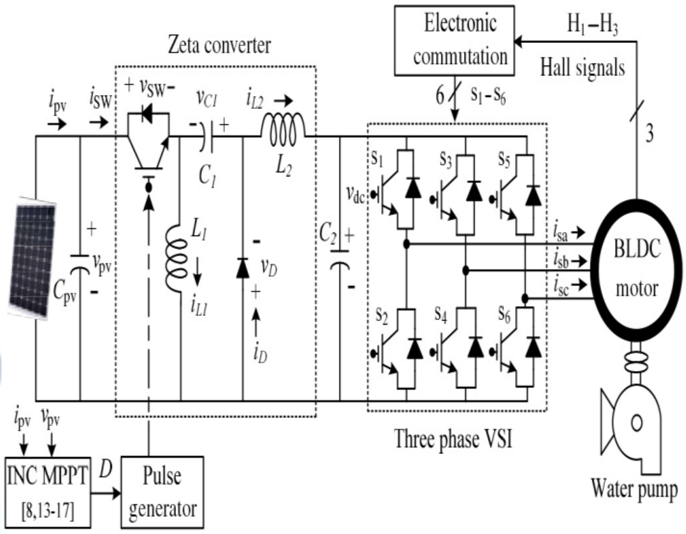

Figure 1: Basic schematic diagram for BLDC

To maintain synchronisation, a BLDC motor drive typically employs one or more positioning sensors. Due to sensor wiring and motor implementation, such a design results in a greater driving cost. Furthermore, sensors cannot be employed in applications where the rotor is enclosed in a closed housing and the number of electrical entry is limited, such as in a compressor, or in applications where the motor is submerged in a liquid, such as some pumps. Therefore, for cost and technical reasons, the BLDC sensorless drive is an essential capability of a brushless motor controller.

Since the neutral point of the BLDC motor is not offered, it is difficult to construct the equation for one phase. Therefore, the unknown input observer is considered by the following line-to-line equation:

PV Solar System:

Solar PV system play a key role in distribution energy systems in present scenario as its flexibility and reliable nature. The PV system converters sun irradiance to electrical energy by photon effect. In PV system the solar cells are arranged in series and parallel combination to meet the load requirement such as voltage and current. The main components in solar system is, PV panel which converters sun photon light to electrical current further it converted to dc voltage with the help of electrical equivalent circuit. To reach, the maximum power from the solar system an MPPT based DC-DC converter is implemented.

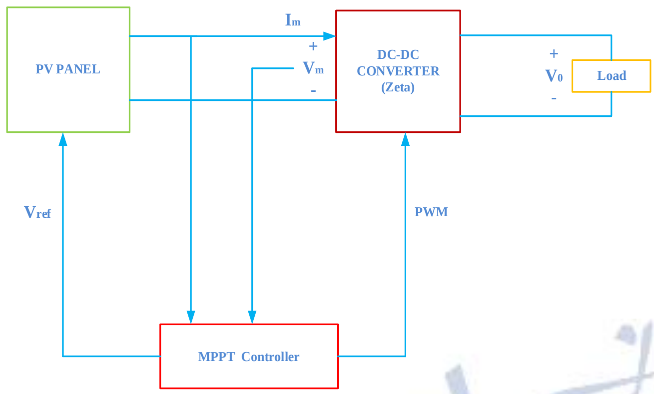

Figure 2: PV System with Power Converter

The purpose of MPPT technique is to track the power from the solar system. A maximum power point tracker is a basic DC to DC converter that synchronize between the PV system and PCC point. The purpose of this converter is to control the solar voltage and track the maximum power from the panels. The mathematical analysis and modelling of PV system is expressed in the following equation. The electrical equivalent circuit diagram for PV panel with single diode is shown in figure 3.

$$I = I_{ph1} - I_{D1} - I_{sh1}$$

$$I = I_{ph} - I_o[e^{(\frac{qV_D}{nKT})}] - (\frac{V_D}{R_s})$$

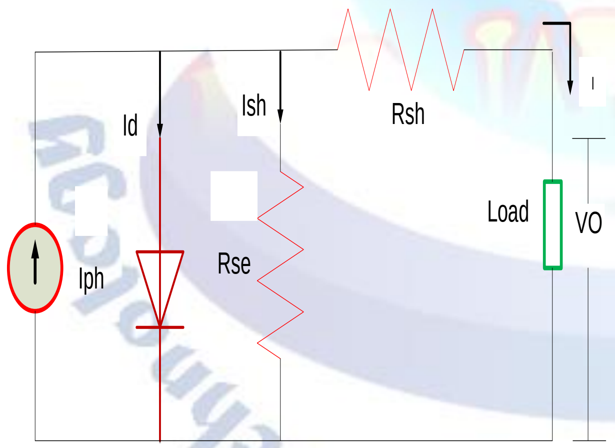

Figure 3: PV Electrical Equivalent circuit

The output power for the solar cell is calculated by using the following expression

P=VI

The performance of Solar Panel is measured by using characteristics between Power and Voltage, Voltage and Current parameters as shown in figure 4. From the characteristics, the point of maximum power is identified at a corresponding point where the voltage and current is maximum i.e at Voc and Isc.

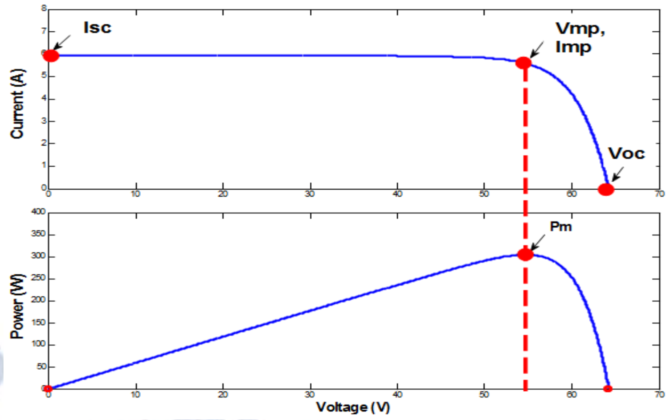

Figure 4: Response of output characteristics of PV Array

INC MPPT Technique:

This method consists in using the slope of the derivative of the current with respect to the voltage in order to reach the maximum power point [2].

What advantage does MPPT give in the real world that depends on the array, their climate, and their seasonal load pattern? It gives us an effective current boost only when the Vpp is more than about 1V higher than the battery voltage. In hot weather, this may not be the case unless the batteries are low in charge. In cold weather however, the Vpp can rise to 18V. If ther energy use is greatest in the winter (typical in most homes) and the have cold winter weather, then gain a substantial boost in energy when the need it the most.

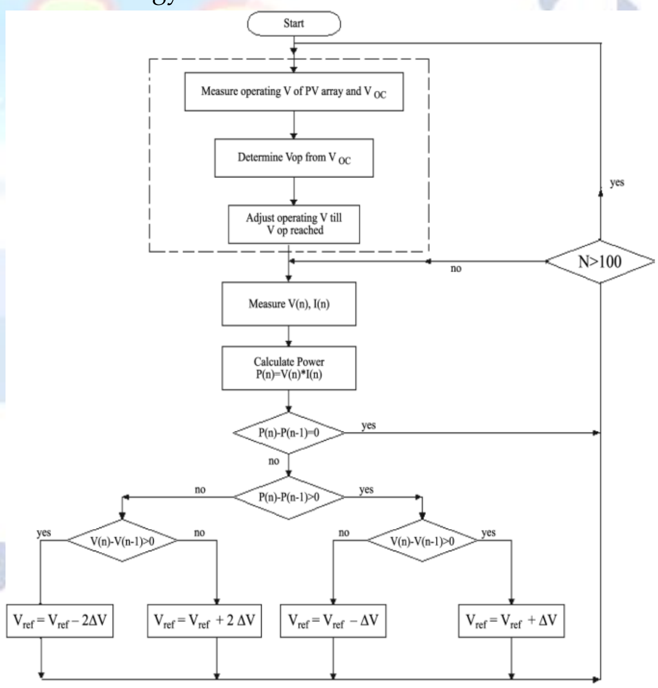

Figure 5: Incremental Conductance Method Algorithm

ZETA converters:

A zeta converter is a fourth order nonlinear system being that, with regard to energy input, it can seen as buck-boost-buck converter and with regard to the output, it can be seen as boost-buck-boost converter. The ideal switch-based realization of zeta converter is depicted. A non-isolated zeta converter circuit is shown in the figure 6.

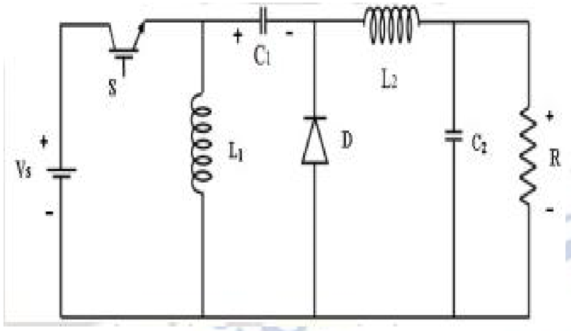

Figure 6: Structure of DC-DC Zeta Converter

Although several operating modes are possible for this converter depending on inductance value, load resistance and operating frequency, here only continuous inductor current, iL" analysed using the well-known state-space averaging method.

3-ɵ INVERTER:

The output of the zeta dc/dc converter is given to a conventional three phase inverter. The purpose of this inverter is produce required to operate the induction motor drive effectively. Here, this paper proposes a three-phase inverter. The advantage of this converter, the generated high power and high voltage have been effectively controlled. The unique nature of multilevel inverter is to generate high voltage levels. The increasing the voltage levels causes the decreases in harmonic content in output voltage. Figure 8, shows the closed loop control structure and diagram for BLDC VSI. This diagram consists of gate driver, IGBT based 6 pulse 3-phase converter.

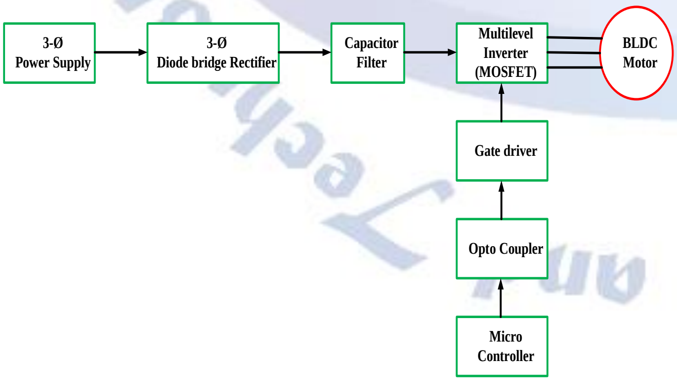

Figure 7: Basic block diagram.

Figure 7, shows the basic block diagram for inverter circuit. The main blocks in the system is a) control circuit and b) power converter. Here, the power converter consists of IGBT switches in three levels, filter capacitor which helps to minimize the harmonic content. And the control circuit is used to generate gate signal pattern i.e the switching signals required for IGBT switches in Power converter. In this, paper the control circuit for three phase inverter is based on pulse width modulation technique.

PULSE WIDTH MODULATION:

Pulse Width Modulation refers to a method of carrying information on a train of pulses, the information being encoded in the width of the pulses. The pulses have constant amplitude but their duration varies in direct proportion to the amplitude of analog signal. The amplitude and width of the pulse is kept constant in the system. The position of each pulse, in relation to the position of a recurrent reference pulse, is varied by each instantaneous sampled value of the modulating wave. PPM has the advantage of requiring constant transmitter power since the pulses are of constant amplitude and duration.

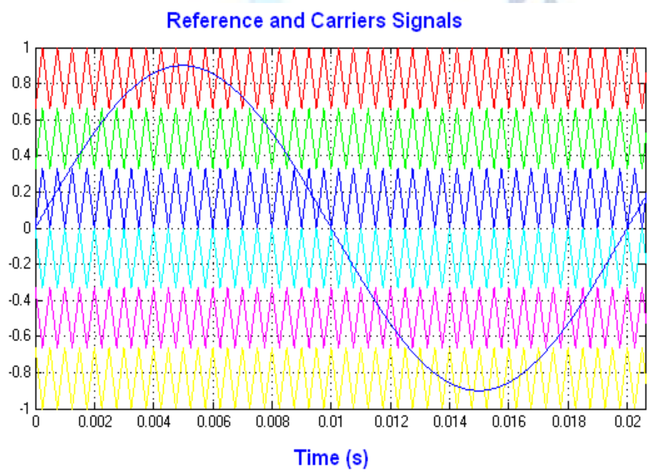

Figure 8: Reference and carriers signals for SHPWM technique.

SIMULATION BLOCK DIAGRAM

In this a fixed voltage source has been given to the whole system. A optimization technique has been used in this model to find the appropriate parameters for the PI controllers i.e., Kp and Ki, which helps in controlling the speed of the BLDC motor through a 3-ϕ inverter. With the increasing dependency on renewable sources of energy, supply from a grid or a fixed voltage source has some sort of disadvantages. A solar PV array has been connected to the system to power the whole system. Maximum efficiency from the array can be extracted using MPPT technique. A dc-dc converter has also been used to get desired output for the 3-ϕ inverter.

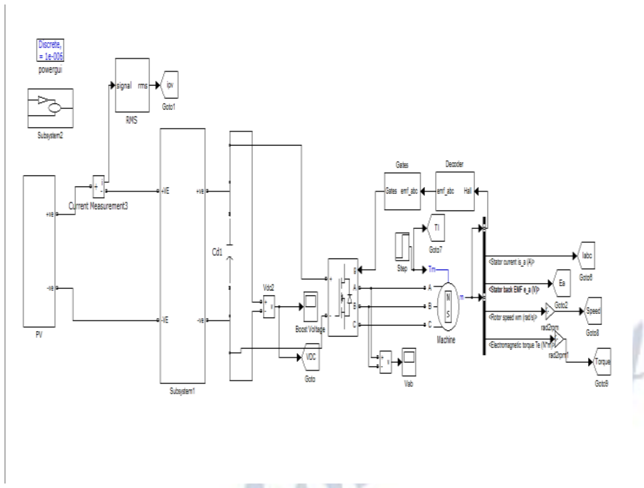

Figure 9: Simulation Circuit for Porposed BLDC motor

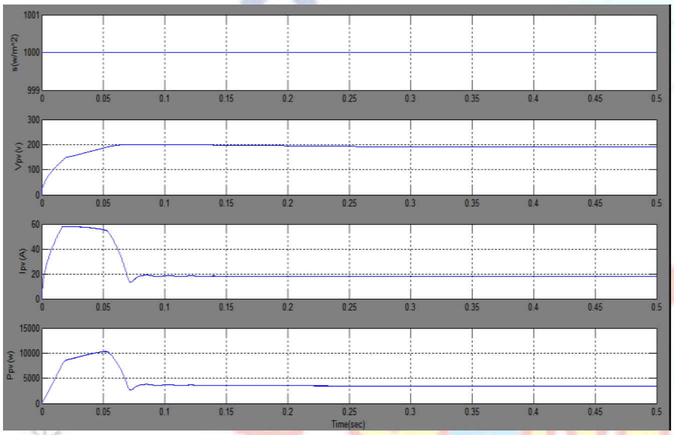

Figure 10: SPV array variables of Starting and steady-state performances of the proposed SPV array-based zeta converter-fed BLDC motor drive for water pump

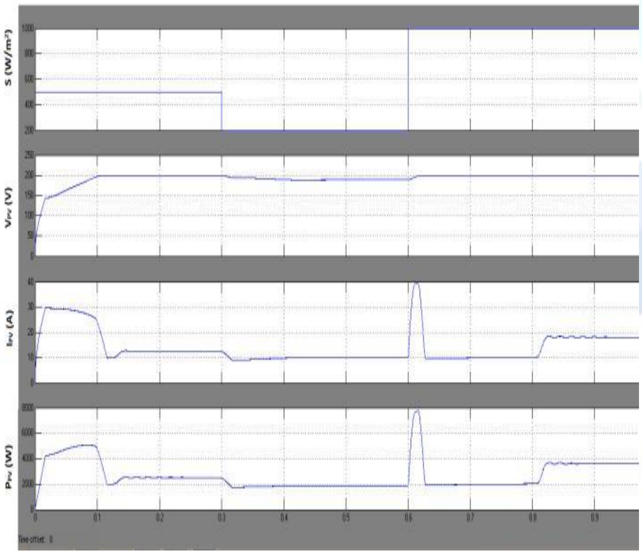

Figure 11: SPV array variables of dynamic performances of the proposed SPV array-based zeta converter-fed BLDC motor drive for water pump

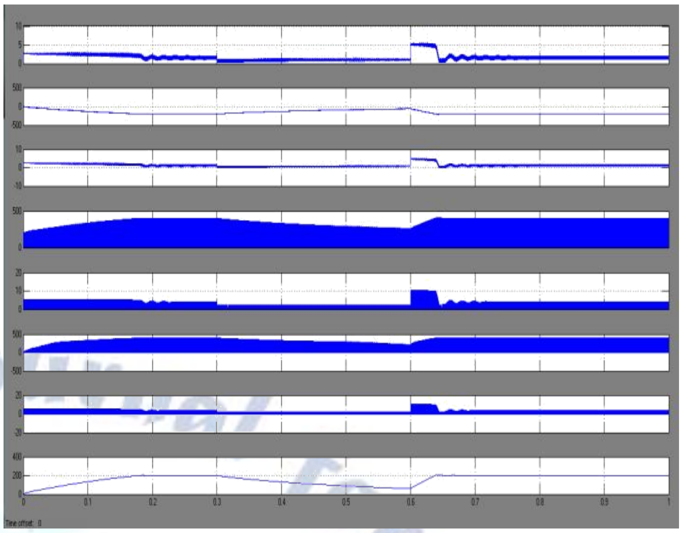

Figure 12: Zeta converter variables of dynamic performances of the proposed SPV array-based zeta converter-fed BLDC motor drives for water pump

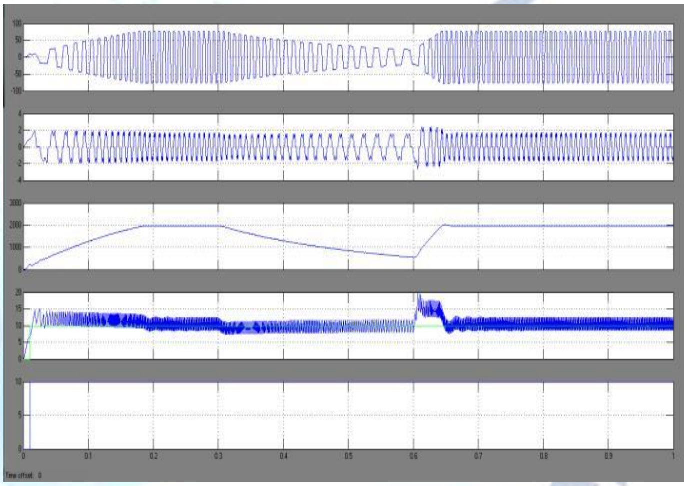

Figure 13: BLDC motor-pump variables of dynamic performances of the proposed SPV array-based zeta converter-fed BLDC motor drives for water pump

4. CONCLUSION

The SPV array-zeta converter-fed VSI–BLDC motor-pump has been proposed and its suitability has been demonstrated through simulated results. The proposed system has been designed and modelled appropriately to accomplish the desired objectives and validated to examine various performances under starting, dynamic, and steady-state conditions. The performance evaluation has justified the combination of zeta converter and BLDC motor for SPV array-based water pumping. The system under study has shown various desired functions such as maximum power extraction of the SPV array, soft starting of BLDC motor, fundamental frequency switching of VSI resulting in a reduced switching loss, speed control of BLDC motor without any additional control, and an elimination of phase current and dc-link voltage sensing, resulting in the reduced cost and complexity. The proposed system has operated successfully even under minimum solar irradiance.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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