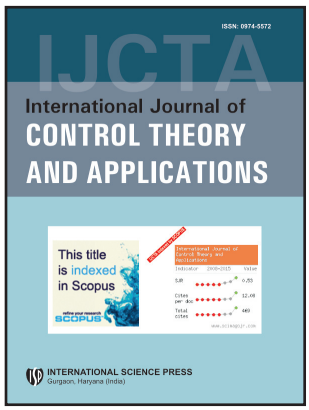

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BLDC Motor Driven Solar PV Array Fed Water Pumping System Employing Zeta Converter

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Abstract: A dc motor find wide application in industries and the speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of current in its field winding. The dc motors are used in propulsion electric vehicles, elevators, robot and hoists. To achieve the desired level of performance the motor requires suitable speed .the speed control is achieved by conventional PI- controller. Although conventional controllers are widely used in the industry due to their simple control structure and ease of implementation, these controllers pose difficulties. This project presents the optimized technique of particle swarm optimization and used to tune PI gain of the controller. For the purpose of comparison with conventional PI controller are considered from the simulation result, PSO technique offers an improvement in the quality of the speed response and better performance.

Keywords: Particle swarm optimization technique (PSO), Proportional-integral (PI) controller.

1. INTRODUCTION

Drastic reduction in the cost of power electronic devices and annihilation of the fossil fuels in near future invite to use the solar photovoltaic (SPV) generated electrical energy for various applications as far as possible. Water pumping, a standalone application of the SPV array generated electricity is receiving wide attention now a days for irrigation in the fields, household applications and industrial usage. Although the several researches have been carried out in the area of SPV array fed water pumping, combining various DC-DC converters and motor drives, the zeta converter in association with the permanent magnet brushless DC (BLDC) motor is still unexplored to develop such kind of system. However, the zeta converter has been used in some other SPV based applications. The merits of both the BLDC motor and zeta converter can contribute to develop a favorable SPV array fed water pumping system possessing the potential of operating satisfactorily under the dynamically changing atmospheric conditions. The BLDC motor has high reliability, high efficiency, and high torque/inertia ratio, improved cooling, low radio frequency interference and noise and requires practically no maintenance. On the other hand, a zeta converter exhibits following advantages over the conventional buck,

boost, buck-boost converter and Cuk converter when employed in SPV based applications. Belonging to the family of buck-boost converters, the zeta converter can be operated either to increase or to decrease the output voltage. This property offers a boundless region for maximum power point tracking (MPPT) of the SPV array. The MPPT can be performed with simple buck and boost converter if the MPP occurs within the prescribed limits. The aforementioned property also facilitates the soft starting of the BLDC motor unlike a boost converter which habitually step up the voltage level at its output, not ensuring the soft starting. Unlike a simple buck-boost converter, the zeta converter has a continuous output current. The output inductor makes the current continuous and ripple free. However, a small ripple filter may be required at the input to smoothen the input current. Although consisting of the same number of components as the Cuk converter, the zeta converter operates as non-inverting buck-boost converter unlike an inverting buck-boost and Cuk converter. This property obviates the requirement of associated circuits for negative voltage sensing hence reduces the complexity and probability of slow down the system response. The merits of the zeta converter mentioned above are favorable for the proposed SPV array fed water pumping system. An incremental conductance (INC) MPPT algorithm is used to operate the zeta converter such that the SPV array always operates at its MPP and the BLDC motor experience a reduced current at the starting. A three phase voltage source inverter (VSI) is operated by fundamental frequency switching for the electronic commutation of BLDC motor [6]. Simulation results using MATLAB/ Simulink software is examined to demonstrate the starting, dynamics and steady state behavior of the proposed water pumping system subjected to the random variation in the solar irradiance. The SPV array is designed such that the proposed system always exhibits satisfactory performance regardless of the solar irradiance level or its variation.

2. CONFIGURATION OF THE PROPOSED SYSTEM

The structure of the proposed SPV array fed BLDC motor driven water pumping system employing a zeta converter. The proposed system consists of (left to right) the SPV array, the zeta converter, the VSI, the BLDC motor and the centrifugal water pump. The BLDC motor has an inbuilt encoder. The pulse generator is used to operate the zeta converter. The step by step operation of the proposed system is reported in the following section in detail.

3. OPERATION OF THE PROPOSED SYSTEM

The SPV array generates the electrical power demanded by the motor-pump system. This electrical power is fed to the motor-pump system via the zeta converter and the VSI. SPV array appears as the power source for the zeta converte. Ideally, the same amount of power is transferred at the output of zeta converter which appears as the input source for the VSI. In practice, due to the various losses associated with a DC-DC converter , slightly less amount of the power is transferred to feed the VSI. The pulse generator generates, through INC-MPPT algorithm, the switching pulse for the IGBT (Insulated Gate Bipolar Transistor) switch of the zeta converter. The INC-MPPT algorithm takes the voltage and current variables as feedback from SPV array and returns an optimum value of duty cycle. Further, the pulse generator generates actual switching pulse by comparing the duty cycle with the high frequency carrier wave. In this way, the maximum power extraction and hence the efficiency optimization of the SPV array is accomplished.

On the other hand, VSI converting the DC power output from the zeta converter into the AC power feeds the BLDC motor to drive the centrifugal pump coupled to its shaft. The VSI is operated by the fundamental frequency switching availed by the so called electronic commutation of BLDC motor assisted by its built-in encoder. The high frequency switching losses are thereby eliminated, contributing in the effective and increased efficiency operation of the proposed water pumping system.

4. DESIGN OF THE PROPOSED SYSTEM

The various operating stages shown in Figure 1 are intellectually designed in order to develop an effective water pumping system, capable of operating under uncertain conditions. A BLDC motor of 2.89 kW power rating and the SPV array of 3.4 kW maximum power capacity under standard test conditions (STC) are selected to design the proposed system. The detailed design of the various stages such as the SPV array

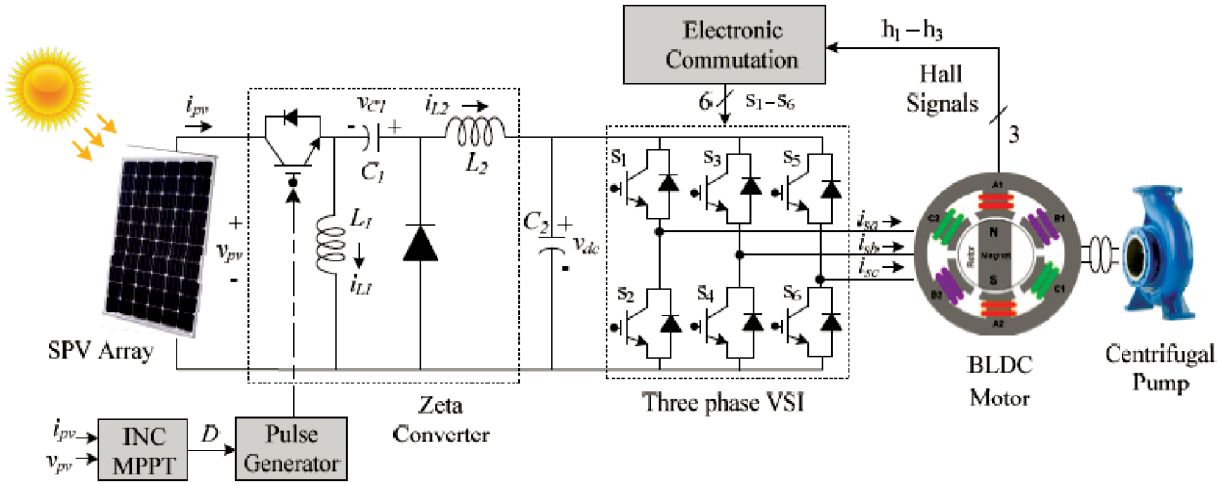

Figure 1: Configuration of proposed SPV array-Zeta converter fed BLDC motor drive for water pumping system

5. CONTROL OF THE PROPOSED SYSTEM

The proposed system is controlled at two stages. These two control techniques namely, MPPT and electronic commutation are discussed in brief as follows.

A. INC-MPPT Algorithm

An efficient and commonly used INC-MPPT technique [9] in various SPV array based applications is utilized in order to optimize the power available from the SPV array and to facilitate the soft starting of the BLDC motor. Selecting an optimum value of perturbation size ($\Delta D = 0.001$) not only avoids the oscillations around the MPP but provides the soft starting of the BLDC motor also. An intellectual agreement between the tracking time and the perturbation size is held to fulfill the objectives.

B. Electronic Commutation

The BLDC motor is controlled by the VSI operated through the electronic commutation of BLDC motor. 6 switching pulses are generated as per the various possible combinations of 3 Hall-effect signals. These 3 Hall-effect signals are produced by the inbuilt encoder according to the rotor position. A particular combination of the Hall-effect signal is produced for specific range of rotor position [6]. The electronic commutation provides fundamental frequency switching of the VSI, hence the losses associated with the high frequency switching is completely eliminated.

6. RESULTS AND DISCUSSION

Performance evaluation of the proposed SPV array fed BLDC motor driven water pumping system employing zeta converter is carried out using simulated results in MATLAB/Simulink. The proposed system is designed,

modelled and simulated considering the random and instant variation in solar irradiance level and its suitability is demonstrated by testing the starting, steady state and dynamic behaviour.

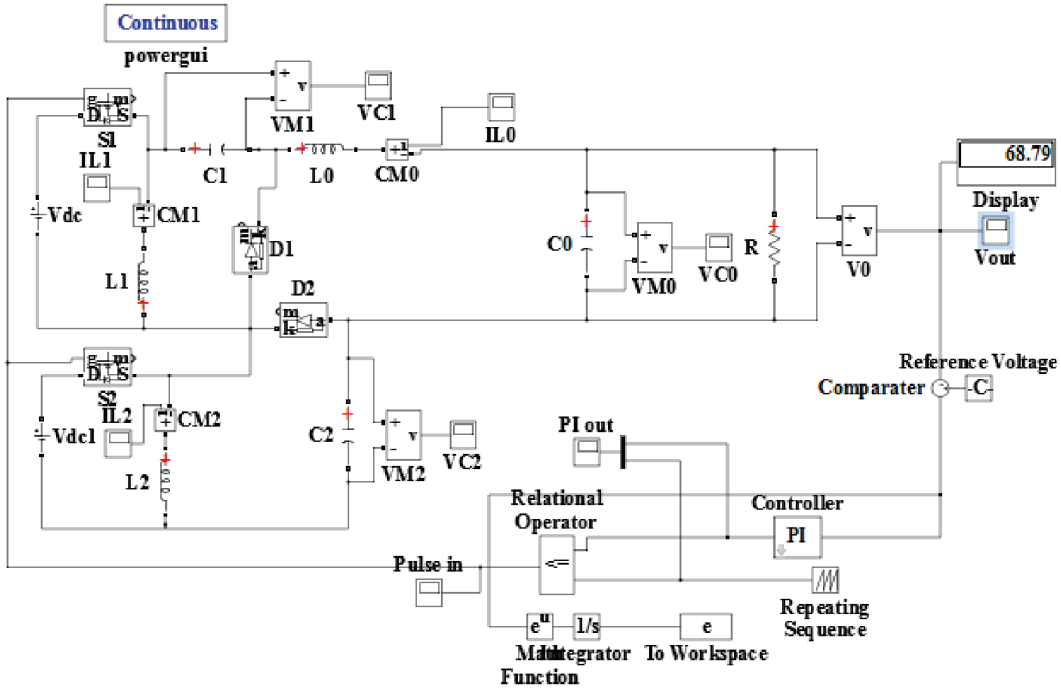

Figure 2: Simulation diagram

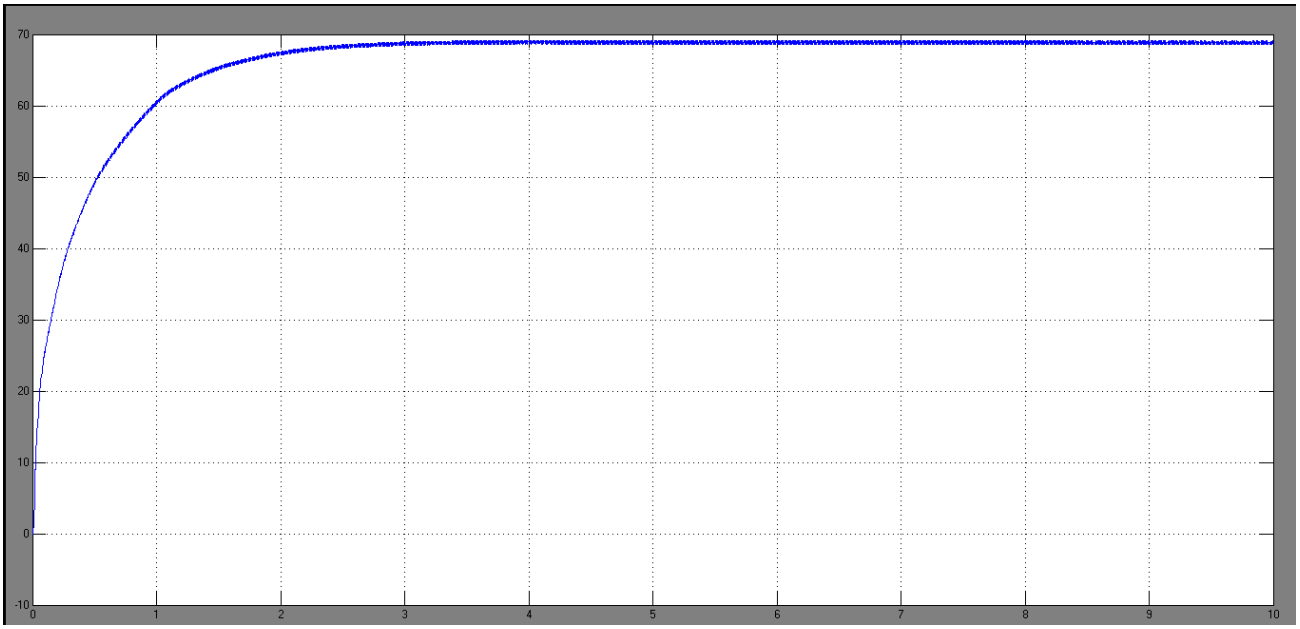

Figure 3: Simulation result

7. CONCLUSION

The SPV array-zeta converter fed VSI-BLDC motor-pump for water pumping has been proposed and its suitability has been demonstrated by simulated results using MATLAB/Simulink and its sim-power-system toolbox. First,

the proposed system has been designed logically to fulfill the various desired objectives and then modeled and simulated to examine the various performances under starting, dynamic and steady state conditions. The performance evaluation has justified the combination of zeta converter and BLDC motor drive for SPV array based water pumping. The system under study availed the various desired functions such as MPP extraction of the SPV array, soft starting of the BLDC motor, fundamental frequency switching of the VSI resulting in a reduced switching losses, reduced stress on IGBT switch and the components of zeta converter by operating it in continuous conduction mode and stable operation. Moreover, the proposed system has operated successfully even under the minimum solar irradiance.

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