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NEW CONTROL STRATEGY BASED PHOTOVOLTAIC WATER PUMPING SYSTEM USING BLDC MOTOR DRIVE

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Abstract— **A simple and efficient solar photovoltaic (PV) water pumping system utilizing an BLDC motor drive is presented in this paper. This solar PV water pumping system comprises of two stages of power conversion. The first stage extracts the maximum power from a solar PV array by controlling the duty ratio of a DC-DC boost converter. The DC bus voltage is maintained by the controlling the motor speed. This regulation helps in reduction of motor losses because of reduction in motor currents at higher voltage for same power injection. To control the duty ratio, an incremental conductance (INC) based maximum power point tracking (MPPT) control technique is utilized. The proposed system is modeled and its performance is simulated in detail. The scalar control eliminates the requirement speed sensor/encoder. Precisely the need of motor current sensor is also eliminated. Moreover, the dynamics are improved by an additional speed feed forward term in the control scheme. The proposed control scheme makes the system inherently immune to the pump's constant variation. In our proposed system, BLDC motor which has higher efficiency and noise less operation is considered. Maximum power loss of PV generator is well matched with the load characteristic of BLDC motor. MATLAB/SIMULINK results carried out for the different topology of the DC-DC converters are analyzed.**

INDEX TERMS- *PHOTOVOLTAIC CELLS, MPPT, WATER PUMPING, SCALAR CONTROL, BLDC MOTOR DRIVES*

I.INTRODUCTION

In the modern era of development, renewable resources of energy, are being advocated by many countries to meet the increasing demand of electrical energy due to rapid depletion of non-renewable resources [1]-[2].The rising energy crises throughout the world and pollution of natural habitats, have been seeking attention from engineering and science fraternity since couple of decades. The knowledge for manifestation of renewable energy sources into useful form, has been maturing rapidly. The advent of fast switching power electronic devices and development in semiconductor technology, have majorly contributed to energy conversion methods. The renewable energy utilization, which started from converting the energy of running water, has travelled across to convert solar energy to electrical energy directly today. Solar photovoltaic (PV) energy converters earlier have been inefficient with the efficiency as low as 5-6 % and highly costly [1]. However, with increased technological research and advancements, the efficiency of PV array, at present, has reached 15-16%. Moreover, the prices have been reducing gradually. Today, PV energy conversion is viewed as one of the promising alternatives to fossil fuel based electricity generating systems, as there are no toxic emissions, no greenhouse gases emission, no fuel cost involvement, least maintenance cost, no water use etc. However, the technology is in developing phase and there are many challenges which need to be addressed such as, intermittency, high initial cost and low efficiency.

Solar PV based energy generation, has come up as an important alternative for many purposes [3]. The irrigation sector is one of the major sectors where solar PV power is extensively used for water pumping[4-5]. Solar PV water pumping has been initially realized using the DC motor. However, with all due virtues associated with the induction motor in terms of mechanical simplicity, ruggedness, reliability, low cost, higher efficiency and lower maintenance than the DC motors, it has replaced DC motors. Here, a solar PV array fed induction motor drive using vector control is used [6]-[7]. As one knows that solar PV power depends on solar insolation and temperature. The characteristic of PV module exhibits a single power peak. An extraction of maximum power is very important part of the PV system. Therefore, various MPPT (Maximum Power Point tracking) techniques have been developed and explained in the literature. These algorithms vary in their speed, range of effectiveness and complexities [8]. Here, an incremental conductance (InC)based MPPT algorithm is used to track MPPT. This algorithm is developed to overcome some drawbacks of perturb and observe (P&O) algorithm. In Calgorithm improves the tracking time and to produce increased energy on a vast irradiation changes. Moreover, it has advantage over P&O method, which increases losses in slow varying atmospheric condition as it oscillates around MPP [9]-[10].Most of the existing induction motor drives (IMDs)incorporate one DC-DC converter and a VSI (Voltage Source Inverter) for achieving MPPT and maximum efficiency of the motor [11]. Moreover, the DC link voltage regulation is achieved by VSI itself. However, the system requires at least seven power converter switches and hence switching losses are increased. This further includes a DC-AC conversion with a VSI feeding a vector-controlled three-phase IMD.

Therefore, there is a need to use single stage controlled drive for water pumping and thereby decreasing number of switches and losses. In single stage system, a VSI has to maintain the MPP as well as DC link voltage is also controlled by it. Therefore, variable DC link voltage cannot be achieved as explained in[12]-[13].The vector control strategy is superior to scalar control in terms of speed of response and accuracy as explained in [14]-[16]. In the vector control technique, an AC motor is operated in such a manner to behave dynamically as a DC motor by using feedback control [16]. Timely control of active power. This is due to the fact that the mechanical time constant of the motor pump system is much higher than that of aforementioned system. Under sudden fall in solar insolation, the PV array voltage tends to reduce drastically and consequently the level of flux in the motor falls rapidly. Once the flux has been fallen, the motor starts drawing higher current, which is limited by the short circuit current of the PV array in order to rebuild the flux.The operating point in the I vs V curves of PV array, shifts to current source region demonstrated by short circuit current and very low voltage. Due to insufficient power, the motor starts operating in an unstable zone of torque-speed characteristics near to a point where slip = 1. This particular condition is menacing for the motor health and once the motor enters this zone then there has to be a provision in the control, which can identify this condition and restart the motor from the standstill condition. The motor entering into such situations frequently, would reduce the overall duty of the pump, hence it's the responsibility of MPPT algorithm to take care of such events. To control the IMD tied VSI, a simple V/f (voltage/frequency) control approach is utilized in [14], [15]. The pumping system with a DC-DC converter and VSI is used for water pumping application in [16]-[18]. However, presented approach suffers from DC link voltage instability. V/f approach is simple, easy to implement and cost effective. Dual inverters are used to supply power to centrifugal pump with SAZEPWM technique [19]. Apart from V/f control, DTC (Direct Torque Control) and vector control techniques are complicated and they require extra current sensors for implementation [20]. In V/f control, only PV array current, voltage, and DC bus voltage are sensed. The proposed system tracks the MPP point by altering the modulation frequency so that the IMD is able to extract the maximum power from the solar PV array at sustained torque for different solar insolation levels.

2.1. CONFIGURATION OF PROPOSED SYSTEM

The structure of proposed SPV array-fed BLDC motor driven water pumping system employing a zeta converter is shown in Fig.2.1The proposed system consists of (left to right) an SPV array, a zeta converter, a VSI, a BLDC motor, and a water pump. The BLDC motor has an inbuilt encoder. The Fuzzy controller is generating pulses which are used to operate the zeta converter. The fuzzy controller sensing the power output and delivered duty cycle pulse.

2.2 OPERATION OF PROPOSED SYSTEM

The SPV array generates the electrical power demanded by the motor-pump. This electrical power is fed to the motor pump via a zeta converter and a VSI. The SPV array appears as a power source for the zeta converter as shown in Fig.2.2. Ideally, the same amount of power is transferred at the output of zeta converter which appears as an input source for the VSI. In practice, due to the various losses associated with a dc– dc converter [23], slightly less amount of power is transferred to feed the VSI. The pulse generator generates, through INCMPPT algorithm, switching pulses for insulated gate bipolar transistor (IGBT) switch of the zeta converter. The INC-MPPT algorithm uses voltage and current as feedback from SPV array and generates an optimum value of duty cycle. Further, it generates actual switching pulse by comparing the duty cycle with a high-frequency carrier wave. In this way, the maximum power extraction and hence the efficiency optimization of the SPV array is accomplished.

The VSI, converting dc output from a zeta converter into ac, feeds the BLDC motor to drive a water pump coupled to its shaft. The VSI is operated in fundamental frequency switching through an electronic commutation of BLDC motor assisted by its built-in encoder. The high frequency switching losses are thereby eliminated, contributing in an increased efficiency of proposed water pumping system.

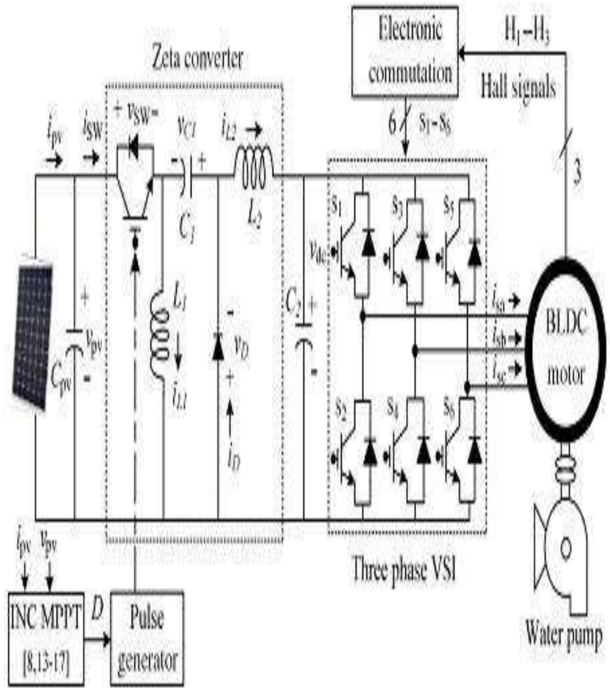
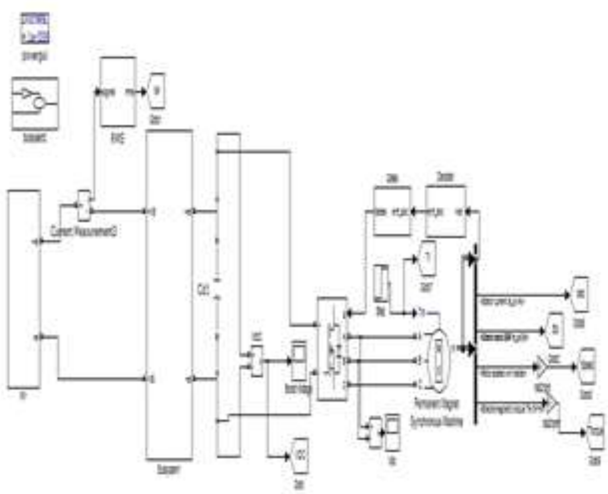


Fig.2.2 Conventional SPV-zeta converter-fed BLDC motor drive for water pump

3. RESULTS AND ANALYSIS

MATLAB/ Simulink is used to develop and design the PV array system equipped with the MPPT controller to drive a water pump.



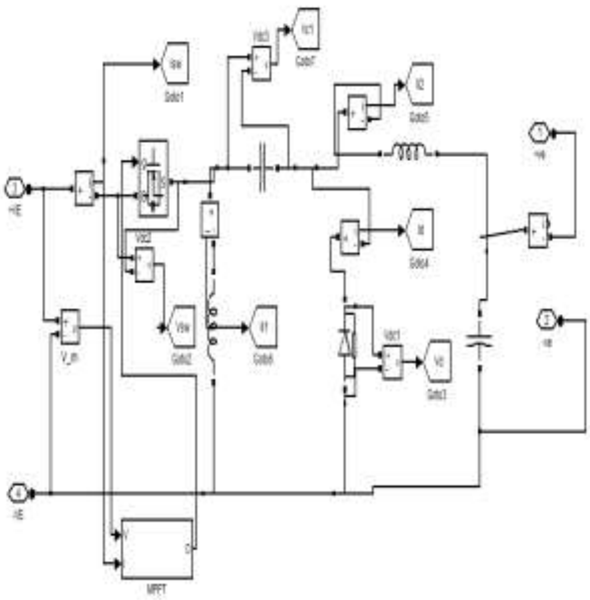


Fig 3.2 Sub system: Zeta converter

A zeta converter has been used in our simulation. It finds applications in various real life scenarios like charging of battery bank, running of dc motors, solar water pumping etc.

3.2 Case I: Running the system with Steady state performance:

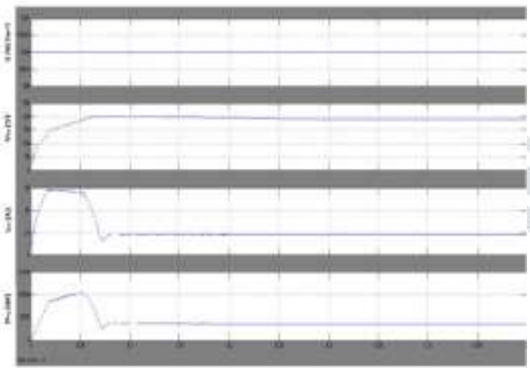


Fig 3.3 SPV array variables of Starting and steady-state performances of the proposed SPV array based zeta converter-fed BLDC motor drive for water pump.

3.2 Case II: Running the system with PI controller:

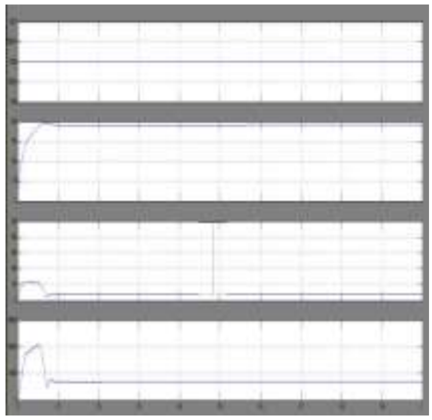


Fig 3.4 SPV array variables of dynamic performances of the proposed system.

CONCLUSION

The Solar Photo Voltaic array-zeta converter-fed VSI–BLDC motor-pump has been proposed and its suitability has been demonstrated through simulated results with PI Maximum power point tracking (MPPT) technique. The proposed system has been designed and modeled to accomplish the desired objectives and validated to examine various performances under starting, dynamic, and steady-state conditions of BLDC motor. 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, speed control of BLDC motor without any additional control and 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.

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