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Grid Interactive Solar PV based Water Pumping System

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ABSTRACT: Grid Interactive Solar Photovoltaic (PV) based water pumping using Brush-Less Direct-Current (BLDC) motor drive focuses on the bi-directional power control of a grid interactive solar PV fed water pumping system. The rising energy demand requirement coupled with the possibility of reduction in supply of non-renewable fuels, evidenced by petroleum crisis, along with increasing concerns about ecological conservation, has driven study and enlargement of alternative energy sources that are cleaner, non-conventional, and leave little ecological impact. The alternative source, electrical energy from PV cells or solar cell now serves as a natural energy source that is more valuable, since it is free of cost, plentiful, fresh, and dispersed over the Earth and participates as a primary factor of all other processes of energy creation on Earth. A single-phase voltage source converter(VSC) with a unit vector template (UVT) generation technique accomplishes a bi-directional power control between the grid and the DC bus of voltage source inverter(VSI), which feeds a BLDC motor. The VSI is operated at fundamental frequency, which minimizes the switching loss.

KEYWORDS: Solar Photovoltaic, Unit Vector Template, Maximum Power Point

I.INTRODUCTION

The increasing carbon emission and diminishing of fossil fuels encourage the consumers to adopt renewable energy. Renewable energy resources are becoming popular due to gradual cost reduction alongside continuous technical advancements. Photovoltaic(PV) energy is oneamong the most importantplayers of renewable energy installations. Solar PV water pumps are pollution-free and require little maintenance compared to the diesel operated or AC operated pump sets. Solar PV water pumping system is designed to run water pump by utilizing the electrical current generated by solar PV array using solar energy efficiently.In the solar PV water pumping system, a solar PV array generates direct current from the sun's radiation. The solar water pumping is made reliable and energy efficient, in this work using Brush-Less Direct-Current (BLDC) motor, with an interface of PV array to the utility. A single phase voltage source inverter performs power sharing control to permit the flow of power from utility to the motor, when a low power is fed from PV array, to obtain a full water delivery. In the course of bad climatic conditions, water pumping would be severely interrupted. Moreover, unavailability of sunlight (at night) leads to shutdown of the water pumping system. These shortcomings are overcome by interfacing a PV generating unit which is installed for water pumping, into a utility grid.

In solar PV array, the efficiency of the system is optimized when the load characteristic changes to keep the power transfer at highest efficiency. Maximum power point tracking (MPPT) is the process of finding this point and keeping the load characteristic there. There are different algorithms that are used to control the MPPT. Thealgorithm used here is Perturb and Observe (P&O) algorithm due to its simplicity.

II.DESIGN AND COMPONENTS

A block diagram of the water pumping system is presented in Fig 1, wherein a Brush-Less Direct-Current (BLDC) motor runs a water pump. A Photo Voltaic (PV) array feeds a BLDC motor-pump via a boost converter and Voltage Source Inverter (VSI). The boost converter performs Maximum Power Point Tracking (MPPT) of PV array through Perturb and Observe (P&O) algorithm while the VSI performs an electronic commutation of BLDC motor. An inbuilt encoder generates three hall-effect signals to carry out an electronic commutation. The DC bus of VSI is supported by a single-phase utility grid. A voltage source converter (VSC) enables a bi-directional power transfer through a DC bus capacitor.The PV array feeds the grid only when water pumping is not required, otherwise it is a preferred objective.

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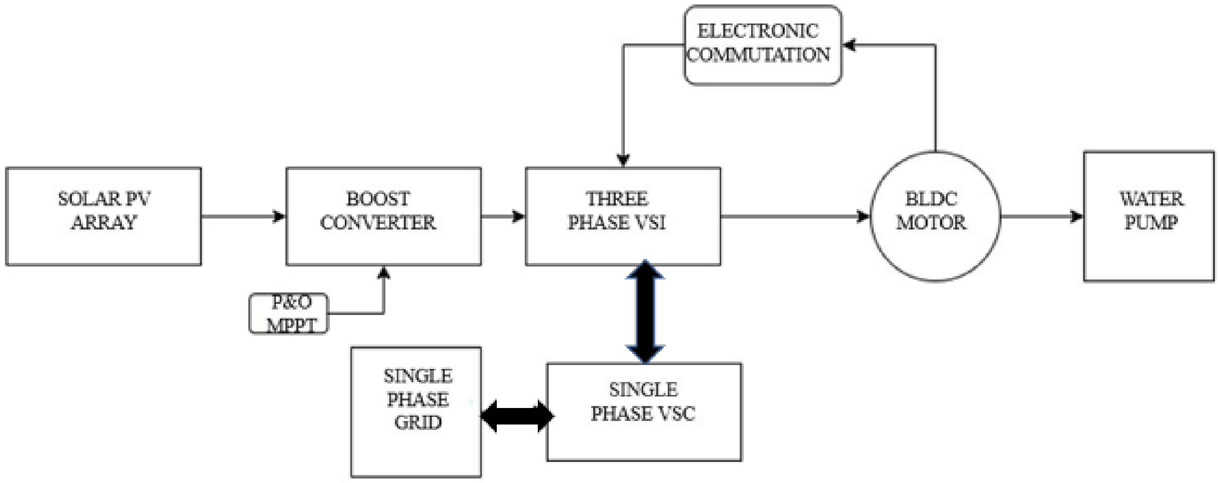

Fig 1:Block Diagram

An interfacing inductor is placed in the line to allow powerflow between the grid and VSC.The MPPT of PV array is achieved by a perturb and observe technique using a DC-DC boost converter. The magnitude of stator current of BLDC motor at starting is controlled by operating the VSI in PWM (Pulse Width Modulation) mode for a pre-defined duration. However, once the motor is started, the VSI is operated with the pulses of fundamental frequency resulting in a minimized switching loss and an enhanced conversion efficiency.

Water pump model number DC50E-24150S with rated voltage as 24V DC, rated current of 3.6A, power consumption of 86.4W, flow rate of 1560L/H, and weight of 650g is used for a PV solar panel of power rating 100W, maximum power point Voltage of 17V, open circuit voltage of 22V, close circuit currentof 7.3A, and maximum power point current of 5.8A.

III.MATLAB SIMULATION

Fig 2 shows the complete simulation circuit for grid interactive solar PV based water pumping system.The solar panelvoltage and current was measured and maximum power point was determined by Perturb and Observe algorithm. Duty ratio is determined after performing this algorithm and is given as the gate pulse to the mosfet of boost converter.

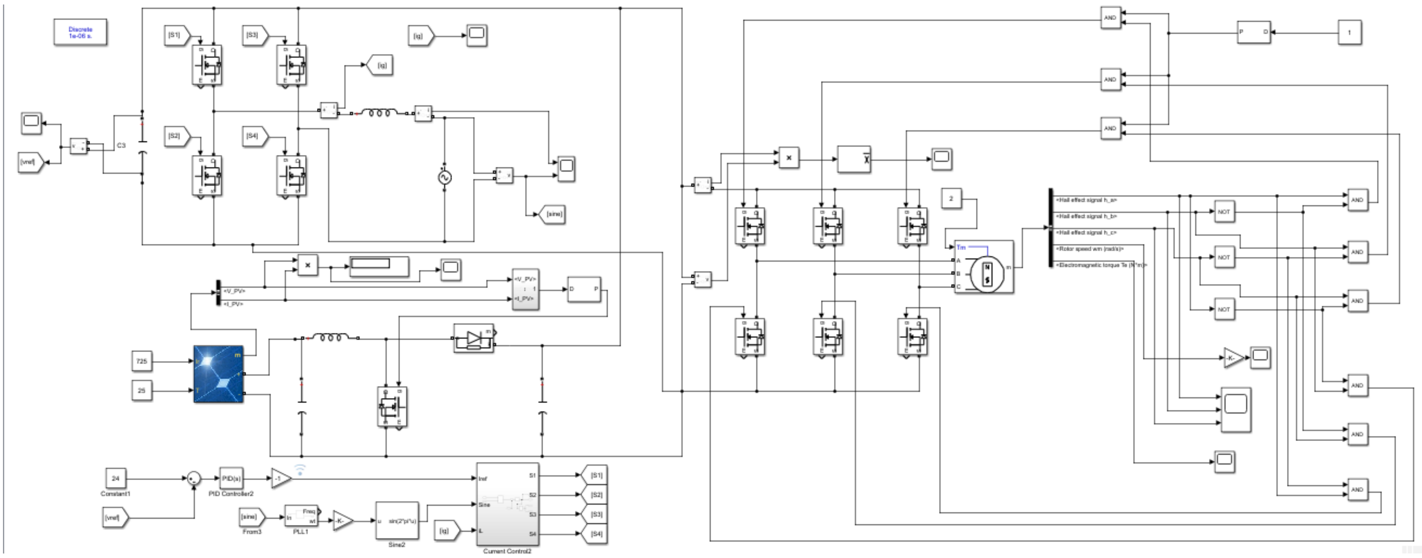

Fig 2: Grid Interactive Solar PV based Water Pumping System

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The variation of panel power, speed and busbar voltage with respect to time are shown below.

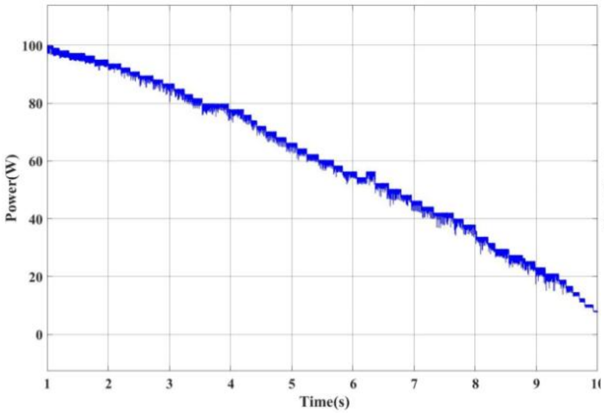

Fig 3: Power versus Time

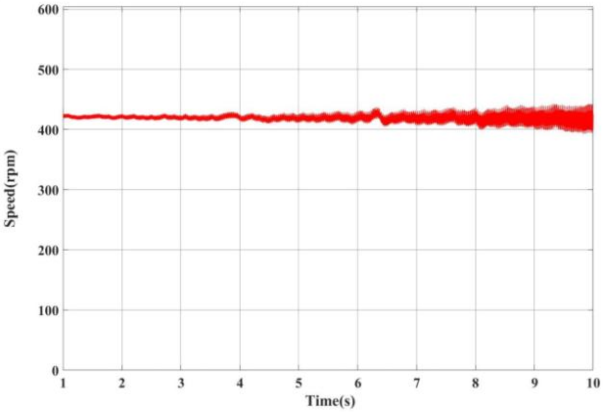

Fig 4:Speed versus Time

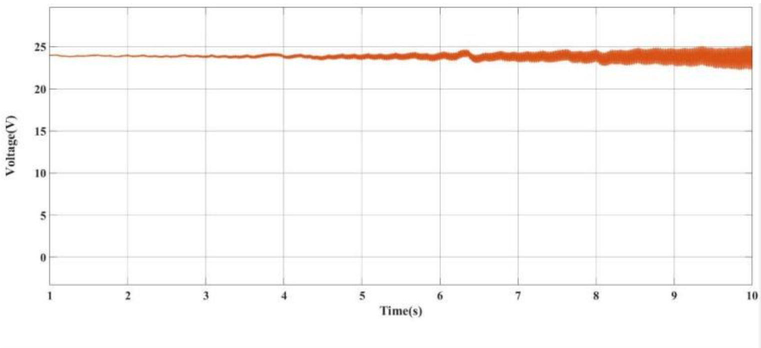

Fig 5:Voltage versus Time

The rated power of the solar panel at the maximum power point is 100W. As seen in the Fig 3, the power is reducing which indicates that the sunlight received during that time is lesser. Simultaneously, the speed of the motor as in Fig 4 and bus bar voltage as in Fig 5 remains constant, this implies that when there is a reduction in the power of the solar panel, the power is being compensated by the grid in order to maintain a continuous flow of water, maintaining maximum efficiency.

VI.CONCLUSION

Using bi-directional power flow technology and brushless direct current (BLDC) motor drive to make full utilization of grid interactive photovoltaic arrays and develop reliable water pumping mechanism used to run the water pump was developed. Solar water pumping system can be integrated to irrigation systems as it is feasible solution for longer period operation. The use of a power grid as an external power backup resolves the disruption in water pumping caused by the intermittent nature of PV power generation. If the PV array is unable to match the needed power demand, power is pulled from the grid; otherwise, the PV array is preferred.A bi-directional power flow control of voltage source converter(VSC) has enabled a full utilization of resources and water pumping with maximum capacity regardless of the climatic conditions. Another application of this project is a water purification system that can be driven by the same BLDC motor.

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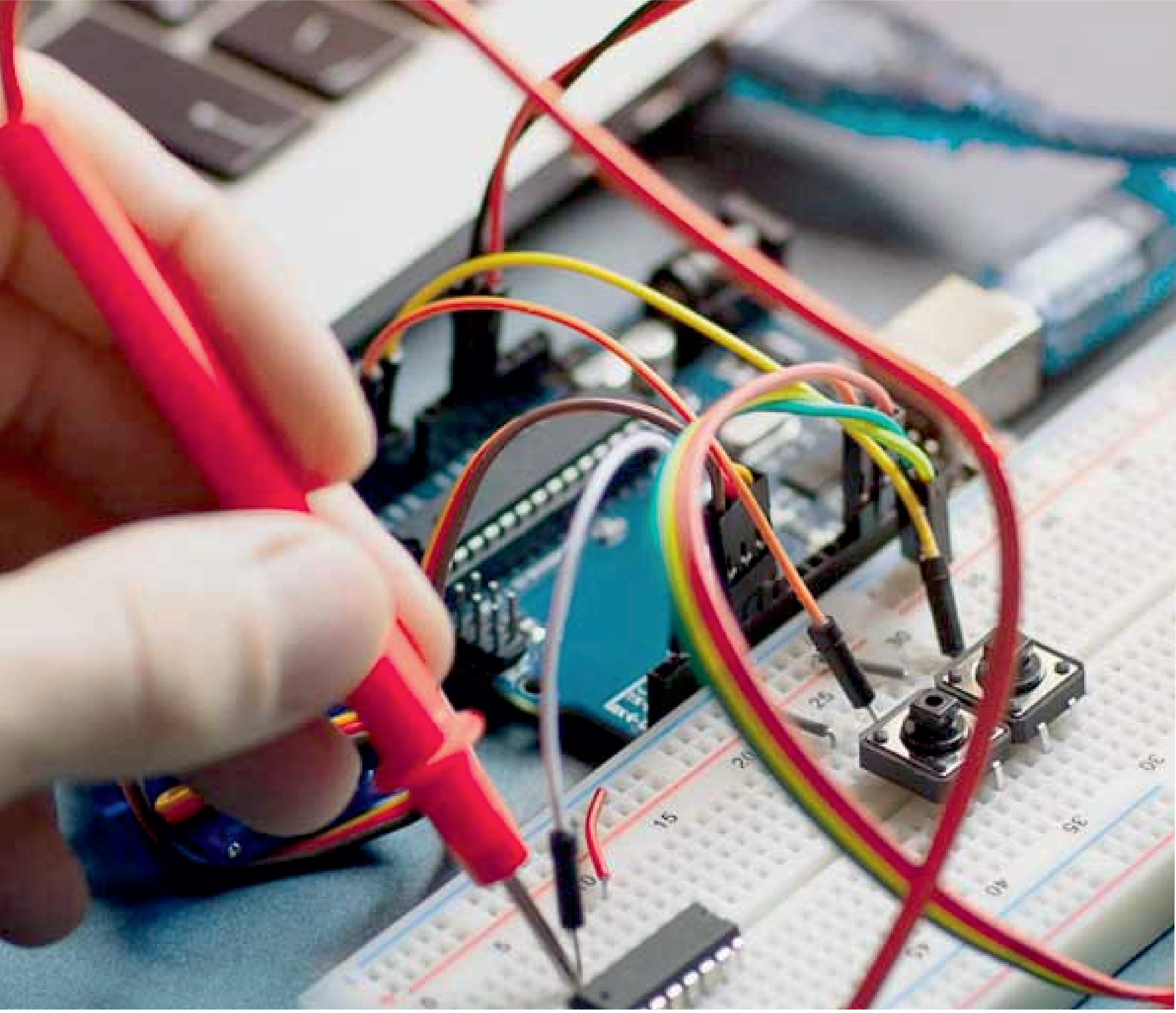

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