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# A VECTROR CONTROL THEORY APPLIED IN A GRID CONNECTED BLDC DRIVE WITH PV WITH ADVANCED MPPT SUPPORT

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ABSTRACT

A water pumping system powered by solar photovoltaics (PV) that is grid-interactive and has bidirectional power flow control. A brushless DC (BLDC) motor-drive without phase current meters drives a water pump. With this technique, a client can give a single phase power grid when it's not required to draw water and operate a water pump constantly for 24 hours, regardless of the weather. Complete use of a PV array and motor-pump is now possible, along with increased pumping system reliability. The Ann-based PV MPPT is used in this system to reduce voltage fluctuations and boost power output from the PV module operating in continuous mode. A single-phase voltage source converter (VSC) with a unit vector template (UVT) production technique feeds a BLDC motor through a voltage source inverter (VSI), which has a DC path that is regulated in both directions. Switching loss is minimized by running the VSI at fundamental frequency. This technology enables the operation of a PV array at its maximum power point (MPP), as well as power quality improvements like power factor correction and a reduction in total harmonic distortion (THD) of the grid. The utility and dependability of the MATLAB/Simulink program are demonstrated by a variety of produced results.

## INTRODUCTION

The dwindling supply of fossil fuels and rising carbon emissions are driving consumers to switch to renewable energy. A solar photovoltaic (PV) generation is quickly overtaking conventional sources as the best option for a variety of appliances. In light of this, the use of solar energy for water pumping has drawn considerable interest in recent years. The water was first pumped using DC motors, and then an AC induction motor. Many studies on electric motor drives have been conducted in an effort to increase the effectiveness and performance of PV-fed pumping systems while minimizing costs. Because to its high efficiency, high power density, lack of maintenance, lengthy lifespan, and low electromagnetic interference, a permanent magnet brushless DC (BLDC) motor (EMI) issues and small size, is being opted from last decade .

It has been determined that introducing this motor reduces the cost and size of PV panels in addition to improved performance and maintenance free operation. Being a grid-isolated or standalone system, the existing BLDC motor driven water pumps fed by a PV array rely only on solar PV energy. Due to its intermittency, the solar PV generation exhibits its major drawbacks, which results in an unreliable water pumping system. During bad climatic condition, water pumping is severely interrupted, and the system is underutilized as the pump is not operated at its full capacity. Moreover, an unavailability of sunlight (at night) leads to shutdown of the water pumping system. These shortcomings are required to be overcome in order to acquire a reliable PV based pumping system. Few attempts in this connection are found in, although not with BLDC motor drive, which deploy a battery as an energy storage.

Associated with a bidirectional control, the battery is charged and discharged during full and poor solar radiation (or no radiation) respectively, thus it ensures a full water delivery continuously. Contrary to it, introducing a battery energy storage in PV based water pumping not only increases the overall cost and maintenance but also reduces its service life. A lead acid battery which is mostly used, has a useful life of only 2-3 years. The demerits with the battery storage have turned the attention towards an alternate technological solution which may be best suited in every aspect for a reliable water pumping based on PV generation. Generation of electricity by using solar energy depends upon the photovoltaic effect in some specific materials. There are certain materials that produce electric current when these are exposed to direct sun light. This effect is seen in combination of two thin layers of semiconductor materials. One layer of this combination will have a depleted number of electrons. When sunlight strikes on this layer it absorbs the photons of sunlight ray and consequently the electrons are excited and jump to the other layer. This phenomenon creates a charge difference

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between the layers and resulting to a tiny potential difference between them.

The unit of such combination of two layers of semiconductor materials for producing electric potential difference in sunlight is called solar cell. Silicon is normally used as the semiconductor material for producing such solar cell. For building cell silicon material is cut into very thin wafers. Some of these wafers are doped with impurities. Then the un-doped and doped wafers are then sandwiched together to build solar cell. Metallic strip is then attached to two extreme layers to collect current. Conductive metal strips attached to the cells take the electrical current. One solar cell or photovoltaic cell is not capable of producing desired electricity instead it produces very tiny amount of electricity hence for extracting desired level of electricity desired number of such cells are connected together in both parallel and series to form a solar module or photovoltaic module.

Solar electric power generation system is useful for producing moderate amount of power. The system works as long as there is a good intensity of natural sunlight. The place where solar modules are installed should be free from obstacles such as trees and buildings otherwise there will be shade on the solar panel which affects the performance of the system. It is a general view that solar electricity is an impractical alternative of conventional source of electricity and should be used when there is no traditional alternative of conventional source of electricity available. But this is not the actual case. Often it is seem that solar electricity is more money saving alternative than other traditional alternatives of conventional electricity.

Electronic motion control is a multi-billion-dollar industry. Servo motion is a fraction of that industry, sharing it with non-servo motion, such as stepper motors and variable-frequency systems. A servo system is defined here as the drive, motor, and feedback device that allow precise control of position, velocity, or torque using feed-back loops. Examples of servomotors include motors used in machine tools and automation robots. Stepper motors allow precise control of motion as well, but they are not servos because they are run "open-loop," without tuning and without the need for stability analysis.

The most easily recognized characteristic of servo motion is the ability to control position with rapid response to changing commands and disturbances. Servo applications commonly cycle a motor from one position to another at high rates. However, there are servo applications that do not need fast acceleration. For example, web-handling applications, which process rolled material such as tape, do not command large accelerations during normal operation; usually, they attempt to hold velocity constant in the presence of torque disturbances.

**CONFIGURATION OF PROPOSED SYSTEM**

A configuration of the proposed water pumping system is presented in Fig. 1, wherein a BLDC motor runs a water pump. A PV array feeds a BLDC motor-pump via a boost converter and VSI. The boost converter performs MPPT of PV array through InC 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 a water pumping is not required otherwise it is a preferred objective. An interfacing inductor is placed in the line to allow power flow between the grid and VSC, and to limit the harmonics current into the supply. A RC ripple filter is provided to limit the harmonics on supply voltage. An integrated mathematical modelling of the overall system is given in Appendices.

As discussed before, the proposed BLDC motor drive eliminates the phase current sensors. It is desired to operate the BLDC motor-pump at its rated speed irrespective of the climatic condition. This is achieved by continuously regulating the DC bus voltage of VSI at the rated DC voltage of BLDC motor. A bi-directional power flow control enables, by regulating the DC bus voltage and hence the operating speed, to deliver a full amount of power required to pump the water with full capacity. In case the grid is not available, the DC bus voltage is not maintained at the rated DC voltage of BLDC motor under bad climatic conditions, and the speed is governed by a variable DC bus voltage.

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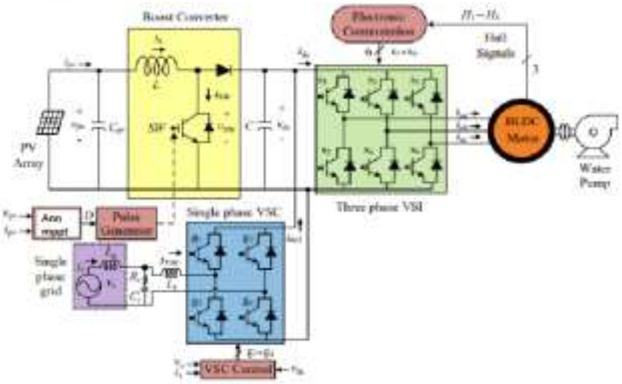


## SIMULATION RESULTS

An analysis of the proposed system under various operating conditions is carried out through the simulated results in MATLAB/Simulink platform. The developed system and its control are tested for starting, dynamic, and steady state operations. A 4-pole, 3000 rpm @ 270 V (DC), 1.3 kW motorpump is powered by a 1.5 kWp (under standard test conditions) PV array and a single phase 180 V, 50 Hz utility grid. Detailed specifications of the system are given in Appendices. The water pump is operated with a PV array only, with the grid only, with both PV array and grid, or may not be operated for instance. All these possible operating conditions are considered for the demonstration of proposed system.

A. Starting and Steady State Performance

The main objectives of these performance studies are to demonstrate the soft starting of BLDC motor and steady state operation of motor-pump under various operating conditions.

1) When Only PV Array Feeds BLDC Motor-Pump: Various PV array and BLDC motor-pump indices are presented in Fig. 3. As shown in Fig. 3(a), PV array is operated at its MPP under the radiation level of 1000 W/m2 . Therefore, the BLDC motor-pump is also operated at its full capacity and it runs at rated speed i.e. 3000 rpm, as shown in Fig. 3(b). No grid power is required as the PV array generates a sufficient power to run the pump at its full capacity. The various indices refer to back-EMF, ea , stator current, isa, speed, N, electromagnetic torque, Te , and load torque, TL. These results demonstrate a soft starting along with the successfull steady state operation of the motor-pump.

2) When Only Utility Grid Feeds BLDC Motor-Pump: This operating condition occures when a water pumping is required at night. Fig. 4(a) depicts that an in-phase sinusoidal supply current of 8.3 A (rms) is drawn and DC bus voltage is maintained at 270 V. The motor draws a sufficient power from utility to run at full capacity, as shown

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in Fig. 4(b). A full utilization of pumping system is demonstrated in this case.

3) When Water Pumping is not required: In this case, the pump is not operated and power generated by the PV array is fed to the utility grid. Fig. 5(a) shows the MPP operation of PV array at 1000 W/m2 . Fig. 5(b) exhibits an out-of-phase sinusoidal supply current which indicates that the utility is fed by a PV array and the power flow is reversed while maintaining the DC voltage at 270 V.

B. Dynamic Performance A sudden variation in climatic condition or requirement of sudden change in the direction of power flow, is considered as a dynamic condition. The proposed system is tested to operate successfully under the considered dynamics.

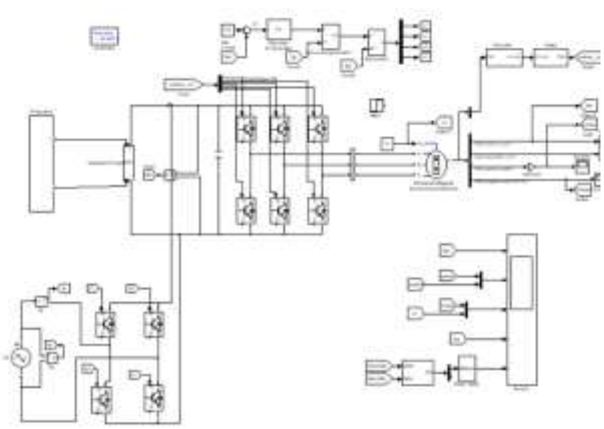

Fig 1 simulation circuit

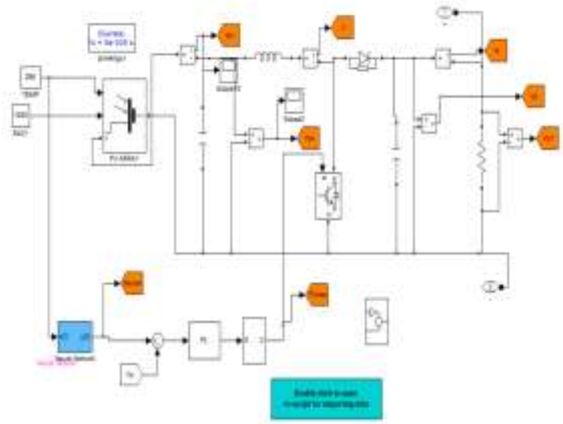

Fig Ann based mppt for pv

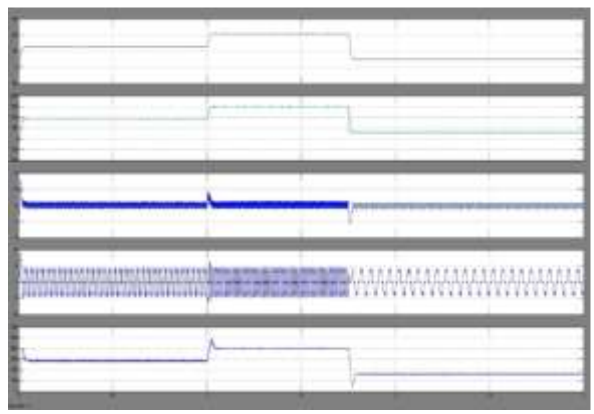

Fig 2 performance of the system with variable pv source

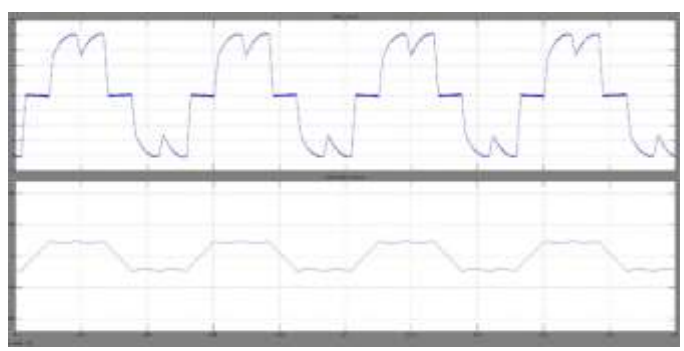

Fig 3 . current and voltage at grid

## CONCLUSION

A single phase grid interactive PV array based water pumping system using a BLDC motor drive has been proposed and demonstrated. A bi-directional power flow control of VSC has enabled a full utilization of resources and water pumping with maximum capacity regardless of the climatic conditions. A simple UVT generation technique has been applied to control the power flow as desired. All the power quality aspects have been met as per the IEEE-519 standard. The speed control of BLDC motor-pump has been achieved without any current sensing elements. A fundamental frequency switching of VSI has contributed to enhance the efficiency of overall system by reducing the switching losses. The proposed solution has emerged as a reliable water pumping system, and as a source of earning by sale of electricity to the utility when water pumping is not required.

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