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GRID CONNECTED SOLAR BASED WATER PUMPING SYSTEM USING BLDC MOTOR

[1]K.Girish Kumar,[2] P.Ramesh, [3]M.Divya, [4]TCM.Karthik,[5]A.Giridhar, [6]E.Kavya Priya
[1]Assistant Professor ,[2]Assistant Professor,[3,4,5,6]UG Scholar, Dept. Of E.E.E
[1,2,3,4,5,6]Sree Venkateswara College Of Engineering, North Rajupalem, Nellore ,A.P

ABSTRACT

This paper proposes a bidirectional power flow control of a grid interactive solar photovoltaic (PV) took care of water pumping framework. A brushless DC (BLDC) motor-drive without phase current sensors, is utilized to run a water siphon. A single phase voltage source converter (VSC) with a unit vector template (UVT) age method achieves a bidirectional power flow control between the grid and the DC transport of voltage source inverter (VSI), which takes care of a BLDC motor. The VSI is worked at basic recurrence, which limits the exchanging misfortune. The maximum power point (MPP) activity of a PV cluster, and power quality upgrades, for example, power factor revision and reduction of total harmonic distortion (THD) of grid are accomplished in this framework. Its pertinence and unwavering quality are shown by different recreated results utilizing MATLAB.

Keywords- Brushless DC motor; Unit vector template; Maximum power point; Total harmonic distortion.

INTRODUCTION

The ceaselessly expanding fossil fuel byproduct and decreasing of fossil fuels urge the moment buyers to take on the environmentally friendly power. A solar photovoltaic (PV) age is arising as the best option of regular sources for different machines [1]. Concerning this, the water pumping has acquired a wide consideration in most recent couple of a long time as a critical use of PV energy [2-3]. The DC motors have been utilized at first to siphon the water followed by an AC enlistment motor [4]. A countless explores have been completed on electric motor drives to work on the presentation and effectiveness of PV took care of pumping frameworks with money saving advantage. A permanent magnet brushless DC (BLDC) motor, because of its high proficiency, high power thickness, no upkeep, long help life, low electromagnetic impedance (EMI) issues and little size, is being picked from last ten years [5]. It has been resolved that presenting this motor decreases the expense and size of PV boards notwithstanding further developed execution and support free activity [6]. Being a grid-segregated or independent framework, the current BLDC motor driven water siphons took care of by a PV exhibit depend just on solar PV energy. Because of its irregularity, the solar PV age displays its significant disadvantages, which brings about a temperamental water pumping frameworks. Throughout awful climatic condition, water pumping is seriously interfered, and the framework is underutilized as the siphon isn't worked at its full limit. Besides, an inaccessibility of daylight (around evening time) prompts closure of the water pumping framework. These shortcomings are required to be overcome in order to acquire are liable PV based pumping system. Few attempts in this connection are found in [7-10], 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 [11-12]. A lead acid battery which is mostly used, has a useful life of only 2-3 years [13]. The previously mentioned demerits with the battery storage certainly stand out towards an other mechanical arrangement which might be the most ideal in each viewpoint for a solid water pumping in light of PV age. These as of late perceived advances, truly, interface a PV creating unit which is introduced for water pumping, into a utility grid. The superb consideration is to accomplish a continuous water pumping with its full limit paying little heed to working circumstances, whether day or night. A grid associated solar water pumping framework is accounted for in [14] wherein a power portion framework chooses whether to draw power from PV cluster or from the utility (when PV exhibit is deficient to power the siphon). A water siphon alongside a siphon controller is associated at the normal DC transport of PV exhibit and grid associated inverter. No battery storage is utilized, a help life of the framework is in this manner delayed, and the support and it are decreased to make cost. Notwithstanding, the created control empowers just a unidirectional power flow for example an abundance power or an unutilized power (while pumping isn't expected) of PV exhibit isn't gotten back to the utility grid. Thusly, the PV establishment isn't completely used and a shopper should take care of a power bill. Such another framework [13] initial feeds the PV energy into the utility grid through a grid inverter and a water siphon is then taken care of by that utility grid through a siphon inverter. In spite of the fact that being a grid associated PV pumping framework, it shows up as a framework worked by utility grid as it were. A sort of mixture PV water pumping is introduced in [15], wherein a battery is first charged by PV cluster through a charge controller and afterward it is released to take care of the water siphon by means of an inverter. The siphon is likewise upheld by a utility connection point through a choice switch. This framework becomes costly because of an additional assembling and support cost of the battery storage. A piece of the PV establishment is participated in water pumping and the leftover part in taking care of power to the grid in [16-17]. The framework isn't solid as the pumping is reliant just on the PV energy and no power is drawn from the utility. A grid communicated PV took care of BLDC motor driven water pumping with unidirectional power flow control is created in [18], wherein the excess power is drawn from the grid at whatever point required. The created framework neglects to use the PV power in the event that the water pumping isn't needed. All these aforementioned existing topologies of a PV based pumping systems present a unidirectional power flow control which either feeds the grid or draws power from the grid. A multifunctional system which may enable a bidirectional power flow depending on the operating circumstances such that both PV installation and pumping system are fully utilized, is yet to be developed. This work presents suchlike system employing first-time a BLDC motor drive. As mentioned, the proposed system deals with the development of a bi-directional power flow control, enabling the flow of power from PV array to the single phase utility grid in case a water pumping is not required, and from the grid to BLDC motorpump in case the PV array power is not sufficient (or at night) to run the pump at its full capacity. This practice offers a source of earning to the consumers by sale of electricity to the utility. A unit vector template (UVT) generation, due to its simplicity and ability to serve the objective, is applied to perform a bi-directional power transfer. The proposed system also meets the power quality standards required by a utility grid as per IEEE-519 standard [19]. A grid interfaced PV based water pumping system, incorporating some of the aforementioned features, has been reported in [20].

PROPOSED CONFIGURATION

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 [5, 26]. 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 bidirectional 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.

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 bidirectional 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.

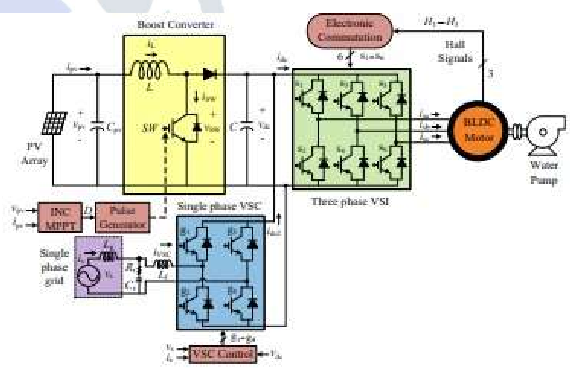


Fig.1 Schematic of the grid interactive PV array based water pumping system using a BLDC motor drive

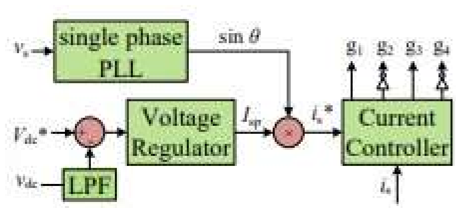


Fig. 2 UVT based bi-directional power flow control of VSC

BI-DIRECTIONAL POWER FLOW CONTROL

The development of a reliable water pumping system and full utilization of the resources are realized by a grid interactive PV generation. To allow the flow of power in either direction, a bidirectional power control based on a UVT generation [20, 27-28] is applied as shown in Fig. 2. This is the simplest technique and is easy to implement as it does not require any complex mathematical model or algorithm. A single phase PLL (Phase Locked Loop) is used to synchronize the utility grid voltage and current. It generates a sinusoidal unit vector of supply voltage, sin θ at fundamental frequency. On the other hand, an amplitude of fundamental component of supply current, Isp is extracted by regulating the DC bus voltage, vdc. A proportional-integral (PI) controller is used as a voltage regulator. vdc is sensed and passed through a first-order low pass filter to suppress the ripple contents. The filtered vdc is then compared with a set value, Vdc * . A fundamental component of supply current, is * is extracted by multiplying Isp and sin θ. The sensed supply current, is is compared with is * and error is processed through a current controller to generate the gating pulses for VSC. When it is required to draw power from utility, the voltage regulator generates a positive Isp. Therefore, an in-phase supply current is drawn from the grid. Likewise, when the utility is fed by PV array, a negative Isp is generated resulting in an out-of-phase supply current. Thus, by reversing the direction of current, direction of power flow is controlled as per the requirement. An improved power quality at the utility grid is also ensured by the applied control technique in terms of total harmonic distortion (THD) and power factor. In case the grid is not available, the DC bus voltage cannot be regulated. Nevertheless, the PV array is able to feed the water pump in standalone mode although being sensitive to the climatic condition.

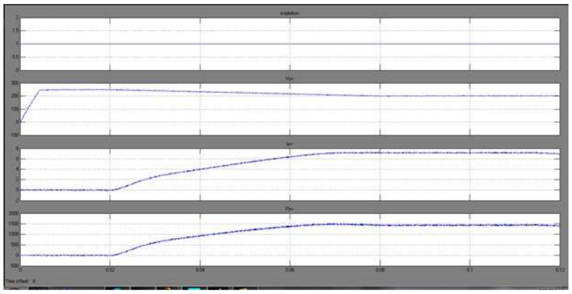
SIMULATION RESULTS

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 4pole, 3000 rpm @ 270 V (DC), 1.3 kW motor pump 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.

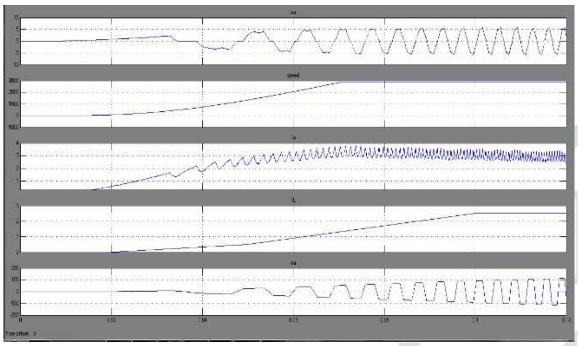
A. Starting and Steady State Performance

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 successfully steady state operation of the motor-pump.



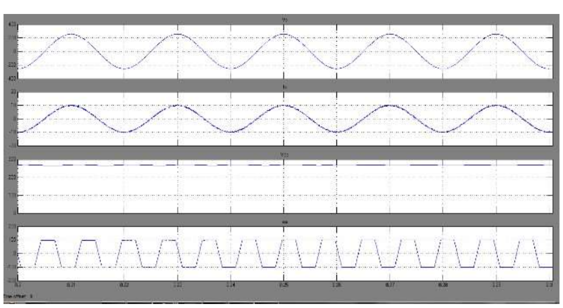
(a) PV array



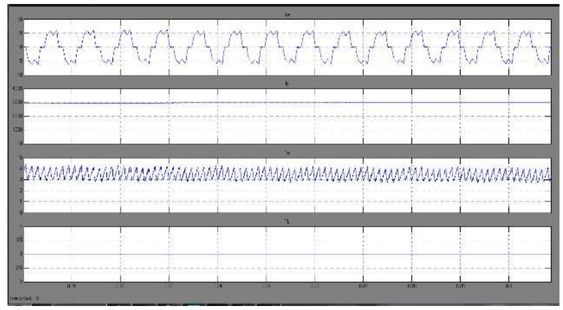
(b) BLDC motor-pump

Fig. 3 Steady state and starting performance. when only PV array feeds BLDC motor-pump

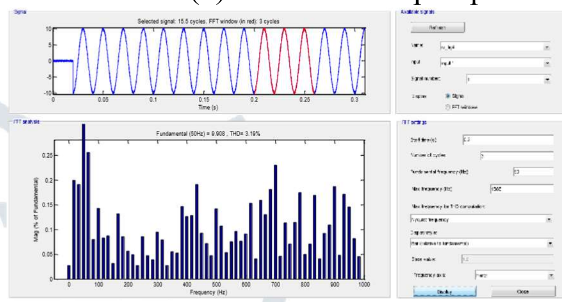
2) When Only Utility Grid Feeds BLDC MotorPump: This operating condition occurs when a water pumping is required at night. Fig. 4(a) depicts that an in-phase sinusoidal supply current of 8.3 A (rms) is drawn and DC bus voltage is maintained at 270 V. The motor draws a sufficient power from utility to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



(a) Utility grid



(b) BLDC motor-pump

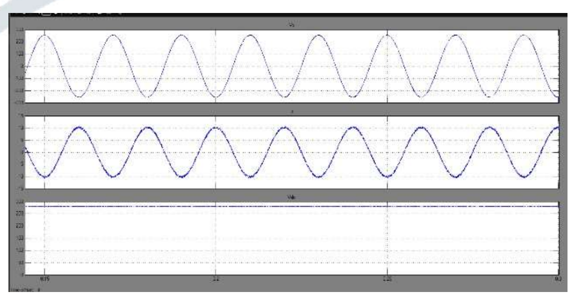


Total Harmonic Distortion (THD)

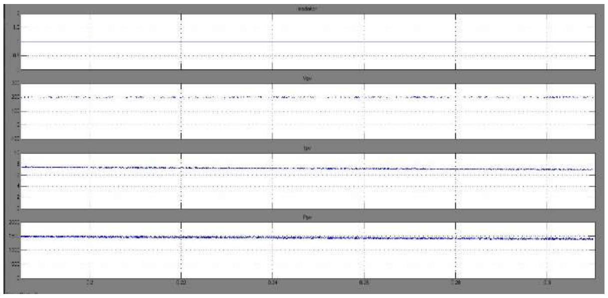
Fig. 4 Starting and steady state performance. when only utility grid feeds water pump

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.

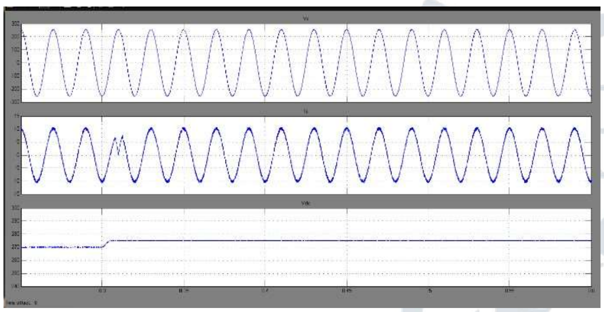


(a) PV array

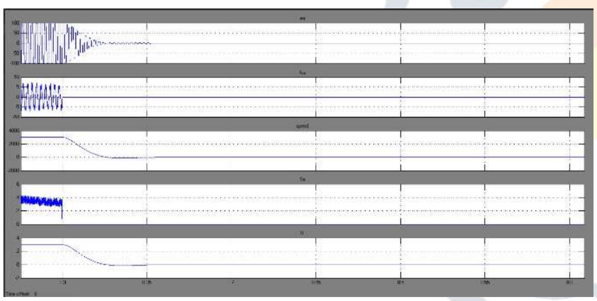


(b) Utility grid

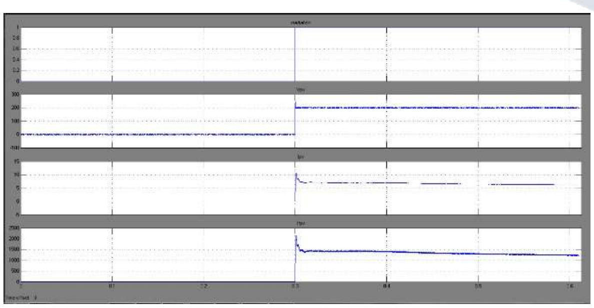
Fig. 5 Steady state response when water pumping is not required



(a) PV array

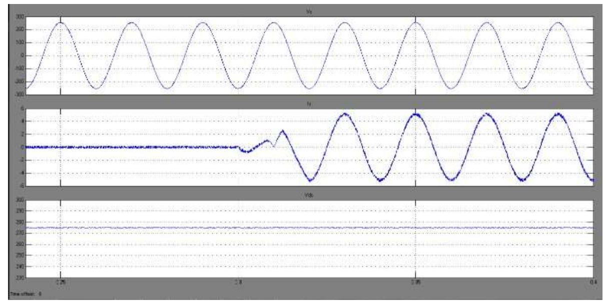


(b) utility grid

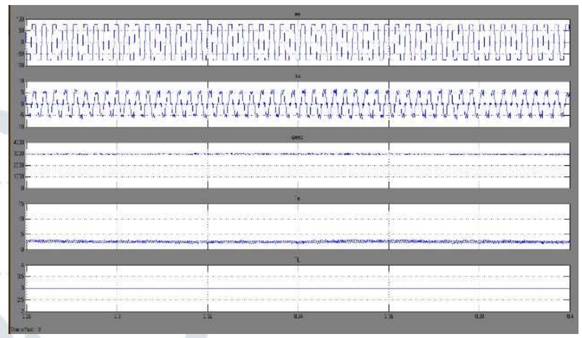


(c) BLDC motor

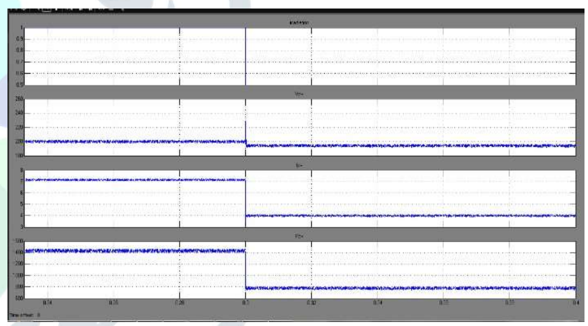
Fig. 6 Dynamic response under a transition from grid feeding pump to PV array feeding grid



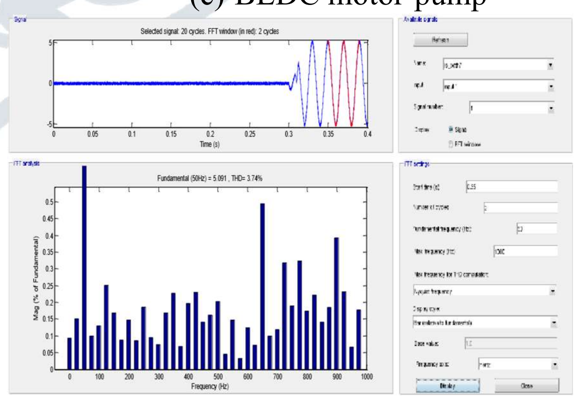
(a) PV array



(b) utility grid



(c) BLDC motor-pump



Total Harmonic Distortion (THD)

Fig. 7 Dynamic performance under a transition from PV array feeding pump to both PV array and grid feeding pump.

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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Author's Profile:

Mr.K. Girish Kumar received B. Tech Degree in Electrical & Electronics Engineering from J.N.T.U, Anantapur, and M. Tech Degree in Power Electronics from J.N.T.U, Anantapur. Currently working as Assistant Professor at Sree Venkateswara College of Engineering, North Rajupalem, Nellore, A.P.

Mr.P.Ramesh, received graduate degree in electrical and electronics engineering from JNTUA, Ananthapuram and post-graduation degree specialization of electrical power systems from JNTUA, ANANTHAPURAM and presently working as assistant professor in EEE Department At Sree Venkateswara College of Engineering, North Rajupalem, S.P.S.R Nellore,A.P .

M.Divya is currently pursuing B. Tech Degree in Electrical & Electronics Engineering from Sree Venkateswara College Of Engineering, North Rajupalem, Nellore,A.P.

TCM.Karthik is currently pursuing B. Tech Degree in Electrical & Electronics Engineering from Sree Venkateswara College Of Engineering, North Rajupalem, Nellore, A.P.

A.Giridhar is currently pursuing B. Tech Degree in Electrical & Electronics Engineering from Sree Venkateswara College Of Engineering, North Rajupalem, Nellore, A.P.

E.Kavya Priya is currently pursuing B. Tech Degree in Electrical & Electronics Engineering from Sree Venkateswara College Of Engineering, North Rajupalem, Nellore,A.P.