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Simulation on Grid Interactive Solar PV-Based Water Pumping Using BLDC Motor Drive

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Abstract

This project introduces a bidirectional power flow control system for a grid-connected solar photovoltaic (PV)-powered water pumping setup. Employing a brushless DC (BLDC) motor drive without phase current sensors to run the water pump, the system ensures uninterrupted operation at full capacity for 24 hours, regardless of climatic conditions. Additionally, during periods of non-pumping, surplus energy is fed back into the single-phase utility grid. This approach maximizes the utilization of both the PV array and the motor pump, enhancing overall system reliability. To achieve bidirectional power flow control between the grid and the DC bus of the voltage source inverter (VSI), a single-phase voltage source converter utilizes a unit vector template generation technique. The VSI operates at the fundamental frequency, minimizing switching losses. The system incorporates maximum power point operation for the PV array and introduces power quality enhancements, including power factor correction and the reduction of total harmonic distortion in the grid. The effectiveness and reliability of the proposed system are demonstrated through various simulated results using the MATLAB/Simulink platform and hardware implementation

Keywords: Grid Interactive, Solar, PV-Based water pumping, BLDC motor.

1. Introduction

In a world grappling with the pressing challenges of increasing carbon emissions and depleting fossil fuels, the shift towards renewable energy sources has become imperative. Among these alternatives, solar photovoltaic (PV) generation stands out as a promising solution for various requests. Water pumping; in particular, has expanded significant consideration as a vital request of PV energy. Over the years, electric motor drives consume undergone extensive research to enhance the performance then efficiency of PV-fed impelling systems while minimizing costs. Among these motor types, the permanent magnet brushless DC (BLDC) motor consumes emerged as a preferred choice due to its numerous advantages. However, the intermittent nature of solar PV group poses challenges to the dependability of water pumping systems. Interruptions during bad weather and night-time operation limit the effectiveness of PV-based water pumps. While some systems have introduced battery storage solutions, they come with their own drawbacks, including increased costs and reduced service life. This chapter explores an innovative approach that integrates a PV producing component into a value grid, aiming to achieve uninterrupted water pumping regardless of effective situations, day or night. The proposed system introduces a bi-directional authority flow switch, addressing the limitations of existing PV-based pumping systems.

The persistent rise in carbon emissions then depletion of fossil oils is prompting clients to swiftly embrace renewable energy. Solar photovoltaic (PV) group is evolving as a superior different to conventional bases for numerous applications. In this context, water pumping has garnered significant attention in recent aeras as a crucial request of PV energy. Initially, DC engines were employed for water pumping, followed by the adoption of AC induction motors. Numerous research efforts have remained dedicated to enhancing the performance also competence of PV-fed pumping schemes through electric motor drives, considering cost-effectiveness. In the past decade, the enduring magnet brushless DC (BLDC) motor has become a preferred choice due to its notable attributes such as high effectiveness, elevated power thickness, low maintenance requirements, stretched service lifespan, nominal electromagnetic interference (EMI) matters, then condensed size.

While the use of permanent magnet BLDC motors has offered notable advantages in terms of efficiency and maintenance, the intermittent nature of solar energy has posed challenges to reliable water pumping systems. Existing solutions, such as battery storage and grid integration, have their limitations, including increased costs and reduced service life.

However, the proposed system, introduced in this chapter, represents a significant advancement in the field. By integrating a bi-directional power flow control, it ensures uninterrupted water pumping, harnessing solar energy during the day and seamlessly switching to grid power when needed. This innovation not only enhances system reliability but also offers the potential for income generation over the sale of excess energy to the effectiveness grid. Additionally, the scheme is considered to continue delivering water even during grid failures, depending on available solar radiation. Furthermore, the utilization of three-phase voltage source inverters (VSIs) operating at fundamental frequency reduces switching losses and contributes to improved efficiency. Moreover, the system adheres to power quality standards outlined in the IEEE-519 normal, irrespective of the way of authority movement.

Solar power generation

In this section lays the foundation for a novel and multifunctional PV-based aquatic pumping arrangement that promises to stunned the limitations of existing solutions. The integration of bi-directional power movement controller, coupled with the advantages of BLDC motors and adherence to power quality standards, positions this system as a potential game-changer in the field of renewable energy and water resource management.

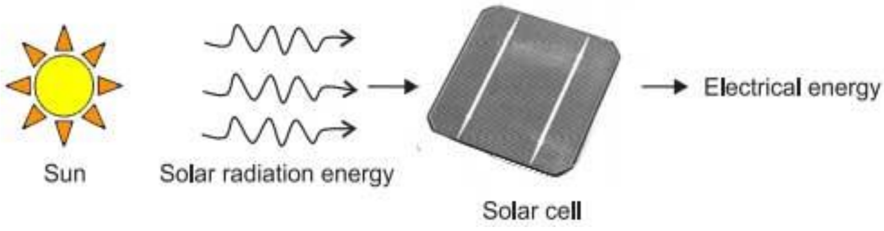

Figure: 1 Solar Power Generation

Methodology

discussing about the world of MATLAB and simulation results, where I analyze the presentation of a grid collaborative solar PV-based aquatic propelling system by means of a BLDC motor drive. This comprehensive study employs replicated consequences attained over the MATLAB/Simulink platform. The system, comprising a 1.5 kWp PV array, a 1.3 kW BLDC motor pump, also a one-phase 180 V, 50 Hz usefulness grid, is examined under various operational scenarios. These scenarios encompass situations where the BLDC motor pump is solely powered through the PV arrangement, the utility grid, otherwise a mixture of both, and instances when the pump is not in operation. The chapter aims to showcase the system's starting, steady-state, and dynamic presentation while emphasizing power quality aspects.

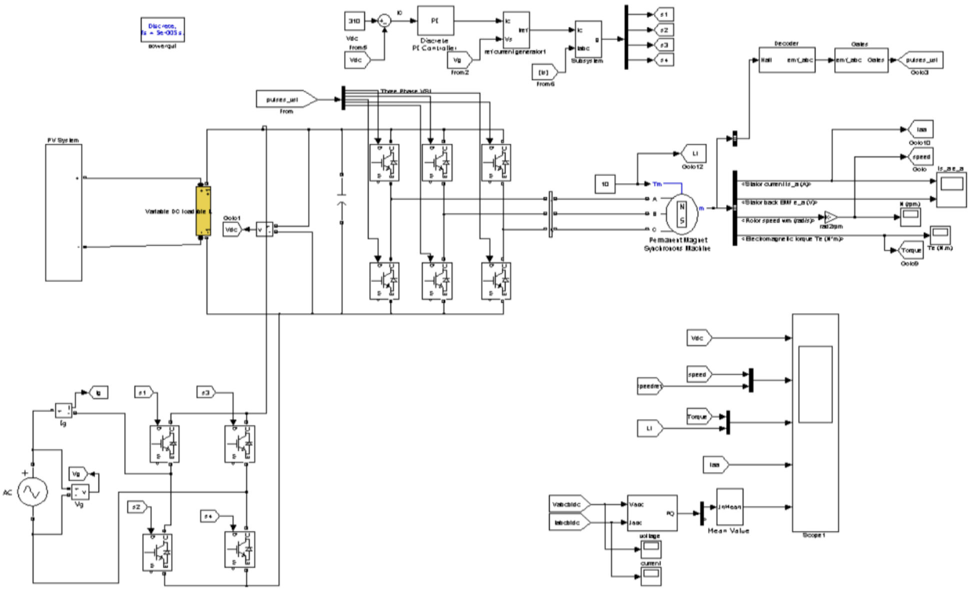

Figure:2 Simulation Model of grid collaborating solar PV founded water impelling using BLDC motor drive

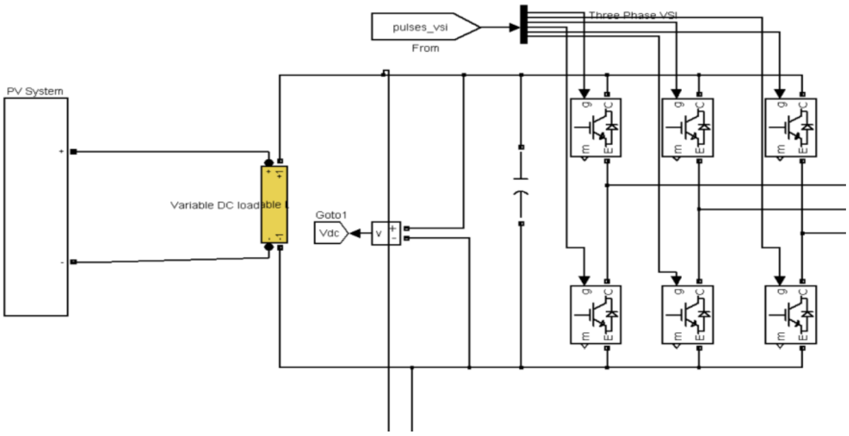

Figure 3 Represent PV system and voltage source inverter

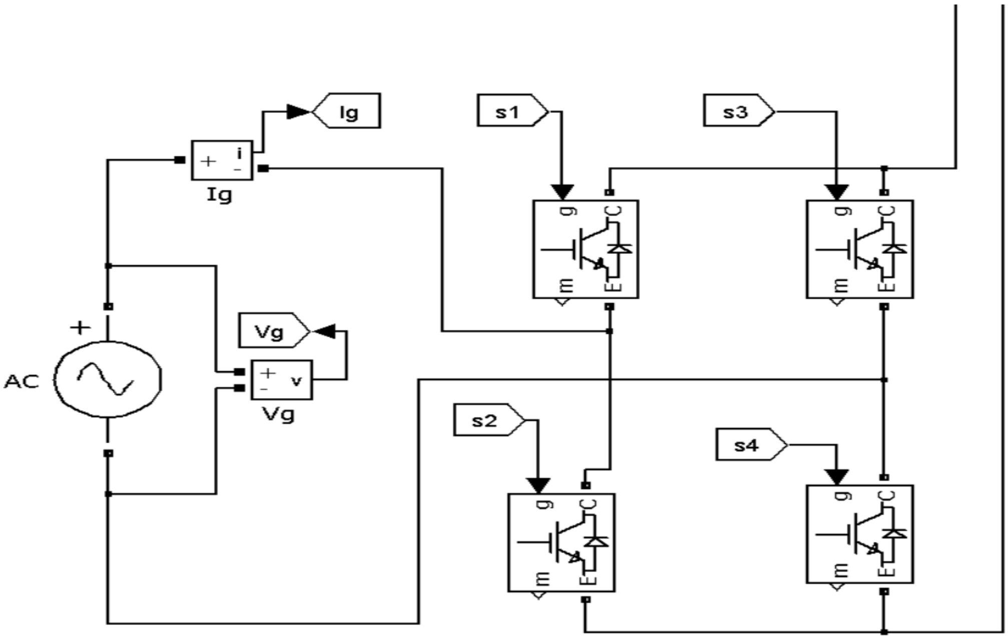

Figure 4: Represents Grid system

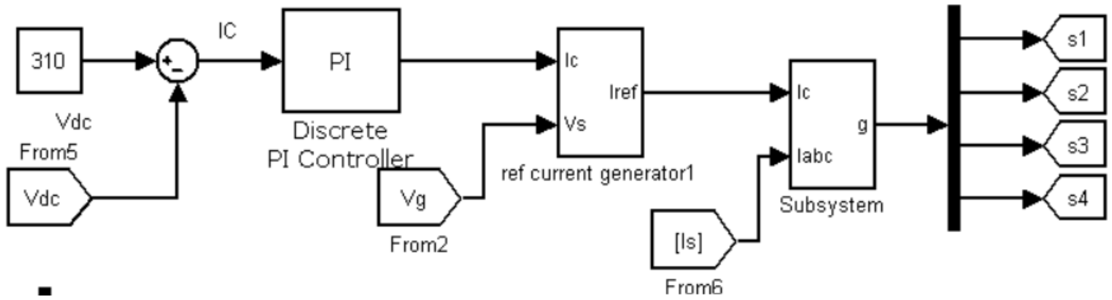

Figure 5 Temperature and Irradiation model

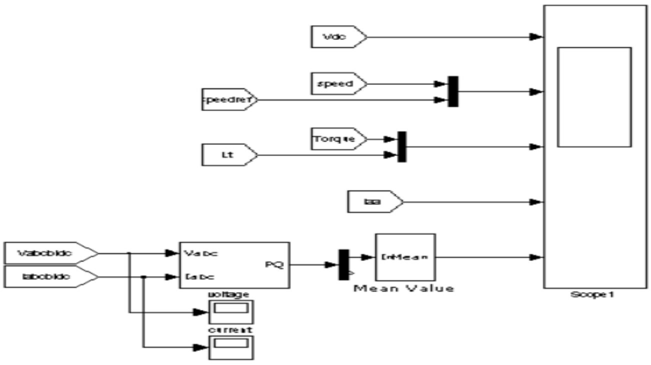

Figure 6 Scope for Voltage, speed and Torque

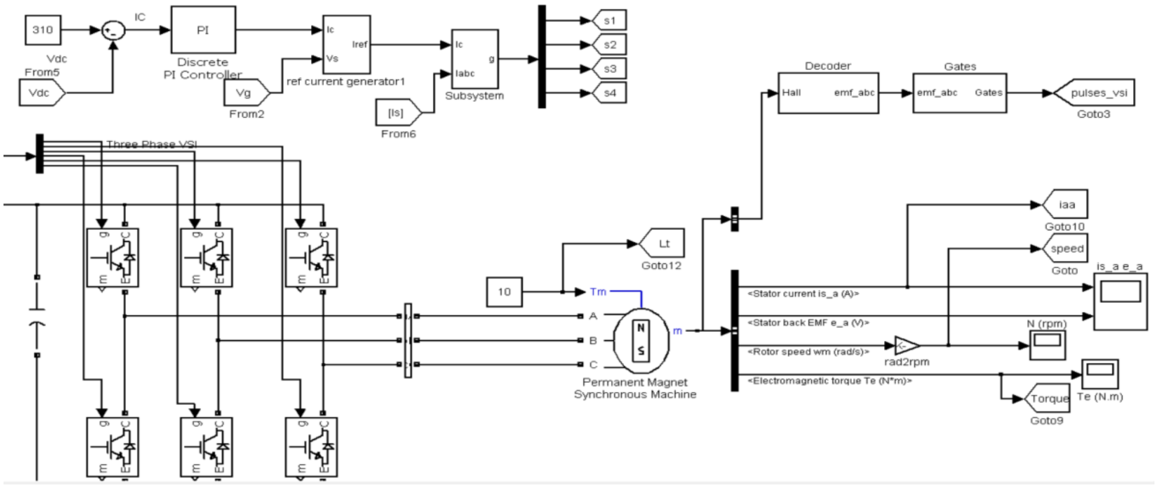

Figure 7 Represents VSI and BLDC motor drive

Via simulations on the MATLAB/Simulink platform, the suggested system is examined under various operational situations. Testing is done on the system to ensure that it operates in a steady-state, dynamic, and beginning manner. A single-phase 180 V, 50 Hz helpfulness grid and a 1.5 kWp PV array (beneath typical test conditions) operate a 4-pole, 1.3 kW motor pump operating at 3000 rpm @ 270 V (DC). The Appendices include the system's comprehensive specifications. The water pump can run just in conjunction with the PV array, individual in conjunction by the grid, in conjunction with mutually the PV array and the grid, or not at all. To illustrate the suggested system, all of these possible operational scenarios are taken into consideration.

A. Initial and Consistent Performance

These presentation studies' main goals are to establish the BLDC motor's gentle start & the motor-pump's steady-state functioning under diverse operating scenarios.

I. When the BLDC Motor-Pump Is Fed Only by a PV Array:

Figure 6.2 shows a number of indices pertaining to the PV array & BLDC motor-pump. Under 1000 W/m² of radiation, the PV array runs at its Maximum Power Point (MPP). As a result, as seen in Fig. 6.6 (b), the BLDC motor-pump runs at its rated rapidity of 3000 rpm, operating at maximum capacity. Since the PV array offers sufficient electricity to run the pump at full volume, no grid power is needed. The back-EMF (ea), stator current (isa), load torque (TL), speed (N), and electromagnetic torque (Te) are among the indicators. These outcomes demonstrate a smooth starting procedure and effective motor-pump steady-state functioning.

II. When the BLDC Motor-Pump Is Fed Only by the Utility Grid:

When water impelling is compulsory after hours, this operational situation occurs. The DC bus energy is kept at 270 V while an in-phase sinusoidal supply current of 8.3 A (rms) is drawn, as shown in Fig. 6.1. As shown in Fig. 6.3, the motor receives enough power from the utility to run at maximum efficiency. This case study demonstrates how the pumping system may be fully utilised.

III. Non-Requirement for Water Pumping:

In this instance, the PV array's electricity is sent into the usefulness grid, while the pump stays dormant. The PV array's MPP functioning at 1000 W/m2 is displayed in Fig. 6.1. The helpfulness is fed by the PV array, as exposed by the out-of-phase sinusoidal source current shown in Fig. 6.3. Power flow is overturned although the DC voltage is kept at 270 V.

B. Adaptive Execution:

A energetic situation is defined as a rapid shift in the weather or the necessity for a sudden alteration in the way of electricity flow. To show that the suggested system operates successfully in these dynamic circumstances, it is put through testing.

1) Shift after Grid Feeding Pump to PV Array Feeding Grid: In the event that PV array electricity is not available, this study is predicated on the water pump operating initially via the effectiveness grid. Considering that PV array electricity is obtainable but water pumping is no longer necessary, the mode of operation is abruptly altered. Currently, powering the utility with the PV array is the main separated. The scheme's performance in this dynamic environment is shown in Fig. 6, where the mode of operation changes every 0.3 seconds. The usefulness grid, BLDC motor-pump, and PV array indices are shown. Within a half-cycle, the current flow direction flips, also the DC bus energy is controlled at 270 V.

2) Switch beginning PV Array Feeding Pump to Together PV Array then Grid Feeding Pump: In this case, it is thought that the pump is first receiving electricity only from the PV array, which is sufficient to run it at maximum capacity. At 0.3 s, there is a decrease in energy after 1000 W/m² to 500 W/m². The plan is to use the utilities to supply the remaining electricity because the PV array cannot run the water pump at 500 W/m². Fig. 6.4 shows how the system reacts to this scenario, with the maximum PV array power declining in accordance with a radioactivity intensity of 500 W/m². There is no power demand from the utility before 0.3 seconds. The lasting power is pulled from the helpfulness starting at 0.3 s, resulting in an in-phase supply current of 4.3 A (rms). Regardless of the weather, the motor-pump runs at maximum capacity, maintaining a speed of 3000 rpm while the DC bus energy is controlled at 270 V.

The suggested method focuses on power factor then total harmonic distortion (THD) in direction to expand power superiority on the utility grid. The system offers a graphic depiction of THD and the supply current's harmonic spectrum for various operating scenarios. The THD and harmonics spectrum of the supply present are shown when the water pump is motorized only through the efficacy grid, as shown in Fig. 6.4, and when extra influence is needed after the utility grid because of a radiation intensity of 600 W/m². The supply current's THD stays below 5% in both cases, adhering to IEEE 519 requirements. In addition, the system guarantees operation with unity power factor under diverse operating circumstances.

IV. When grid fed to BLDC motor: A Brushless DC (BLDC) motor can be operated using various control methods, including grid-fed operation. Grid-fed operation refers to the mode of operation where the BLDC motor is powered by an external power source, typically the electric grid (AC power supply), rather than a battery or other standalone power source. In this manner, the BLDC motor is linked to the grid through an inverter or controller that alters the grid's alternating current (AC) into the direct current (DC) required for BLDC motor operation.

Results and discussions

The PV array operates at 1000 W/m² of radiation, which is its Maximum Power Point (MPP). As a result, the BLDC motor pump runs at its rated rapidity of 3000 rpm, exerting all of its potential.

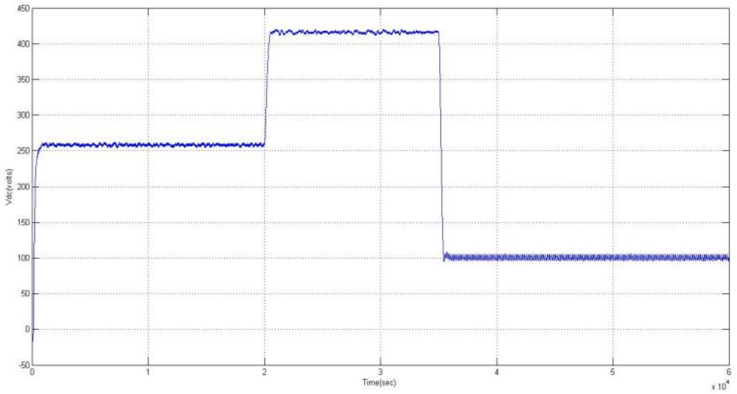

Figure:8 Relation between time and voltage when Solitary PV Array Feeds BLDC Motor-Pump

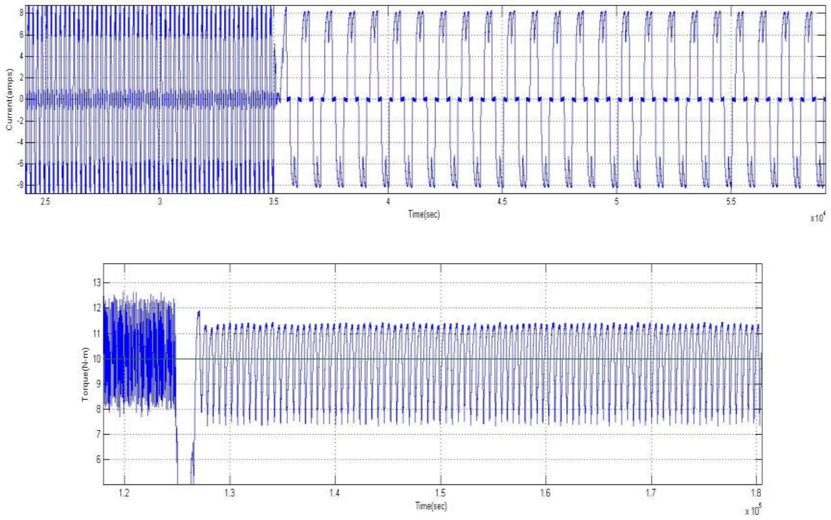

Figure: 9 Represents the relation between Time and Torque and current and time when PV array feeds BLDC motor

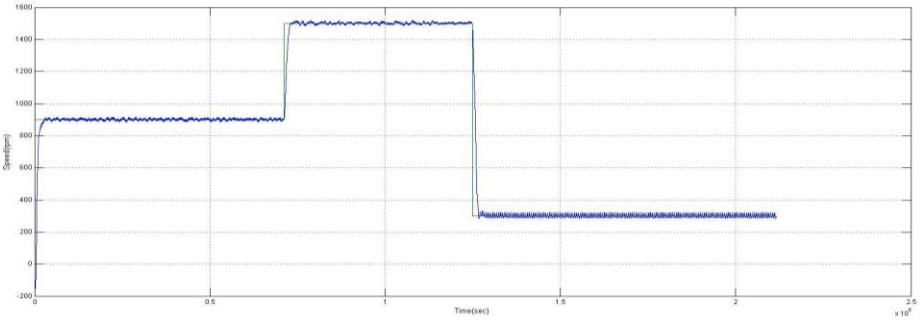

Figure: 10 Relation between speed and time of a BLDC motor

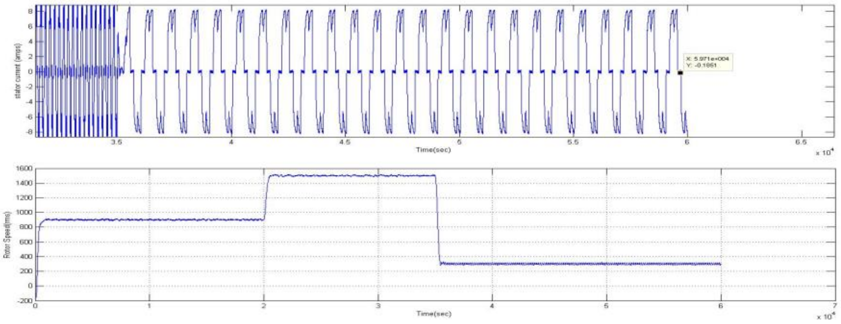

Figure: 11: Represents Stator current and rotor speed with respect to time

6.3.2. When PV array fed to Grid Steady State:

This circumstance develops when water pumping is essential during the night. The image shows the drawing of an 8.3 A in-phase sinusoidal supply current with the DC bus energy maintained at 270 V. In this case, the pumping system is fully used since the motor efficiently uses a sufficient amount of electricity from the utility to run at maximum capacity.

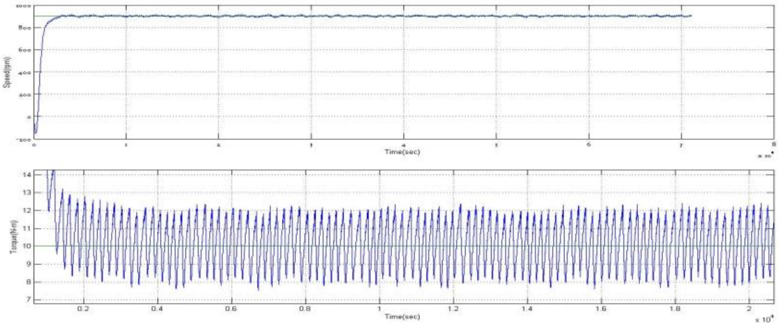

Figure:12: Represents Speed and Torque with respect to time When PV array feeds to Grid Steady State

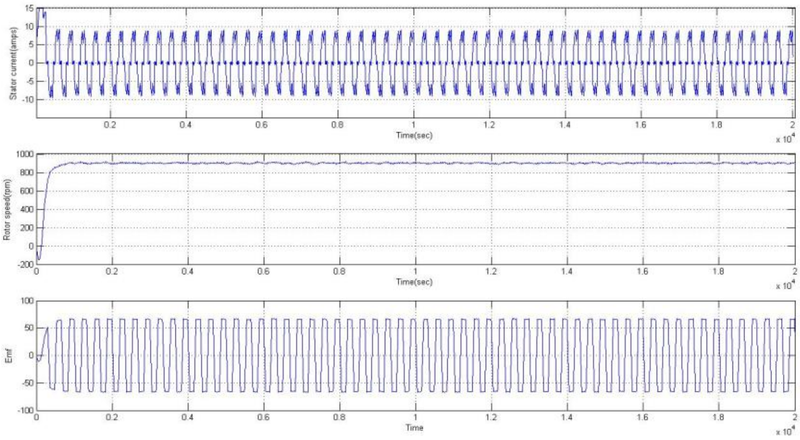

Figure:13: Represents Rotor speed and EMF with respect to time When PV array feeds to Grid Steady State

6.3.3. When Water pumping is not required (No load):

Under this situation, the PV array's electricity is sent into the utility grid, while the pump stays dormant. When exposed to 1000 W/m² of radiation, the PV array performs at its maximum power point (MPP). The utility is powered by the PV array, as evidenced by the out-of-phase sinusoidal supply current that is visible. The power movement is upturned, but the DC energy remains at 270 V.

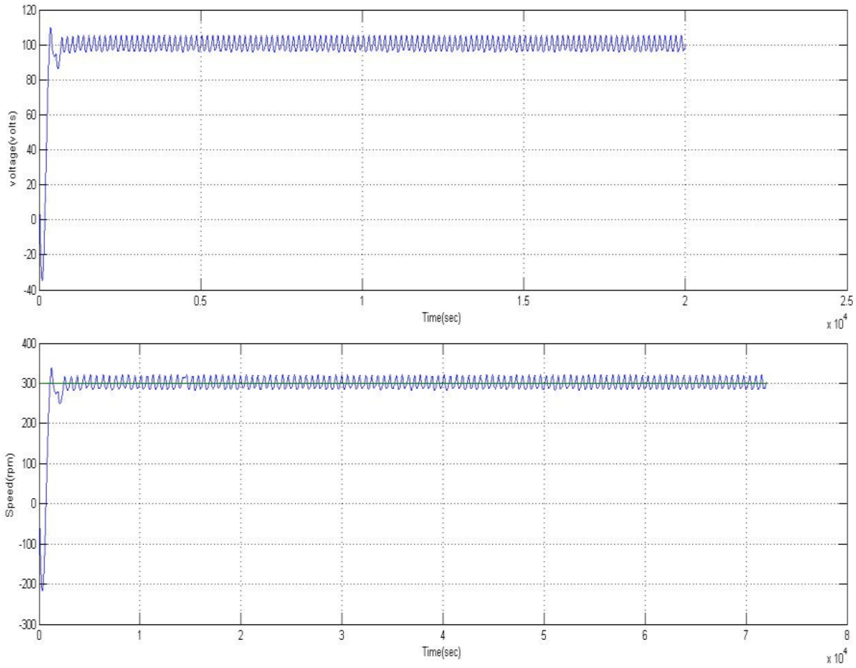

Figure 14: Represents Voltage and Rapidity by means of respect to time beneath no load condition

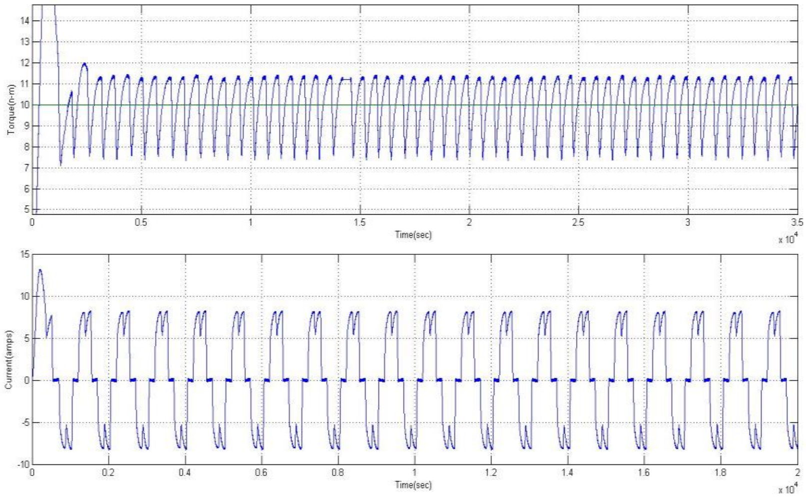

Figure:15: Represents Voltage and Speed by respect to period beneath no load disorder

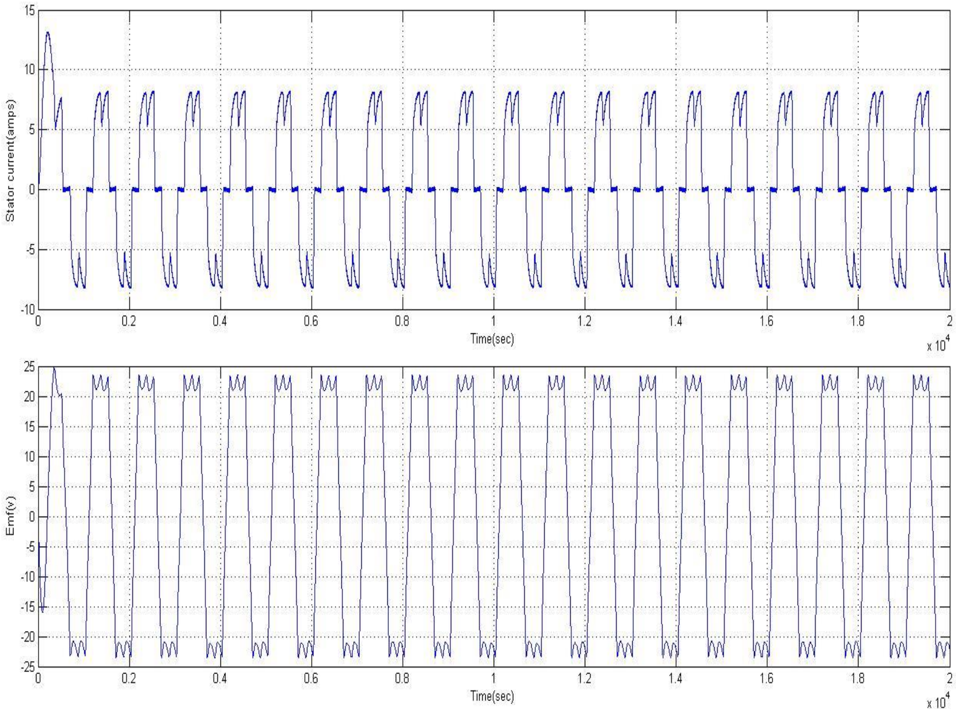

Figure: 16: Represents Stator current and EMF through respect to time below no load situation

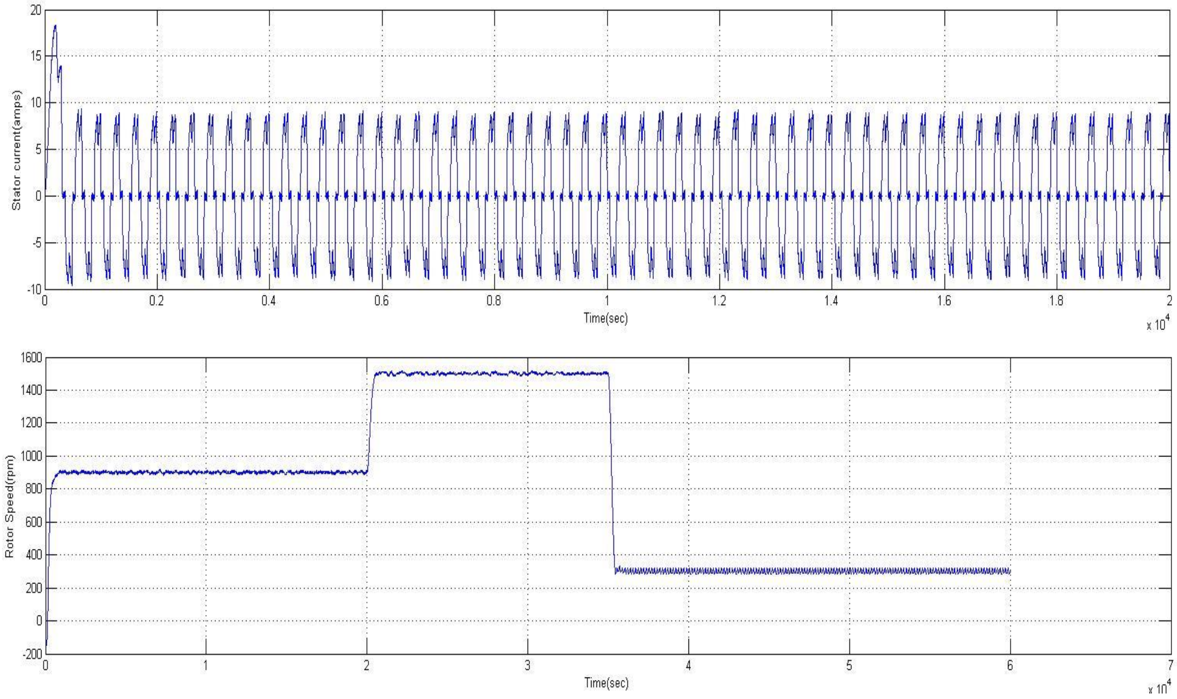

Figure:17 : Represents Stator current and Rotor Speed with respect to time when grid fed to BLDC

Conclusion

A single-phase PV array coupled with a BLDC motor drive is used in a grid-interactive water pumping scheme that has been introduced and verified. Regardless of the weather, the VSC's bidirectional power flow control enables maximum water pumping and efficient use of available resources. In order to comply with IEEE-519 power quality regulations, a simple UVT generating approach has been put into place to control power flow as needed. The speed switch of the BLDC motor-pump has remained attained deprived of the need of current sensing components. By reducing switching losses, the VSI's use of fundamental frequency switching has significantly raised system efficiency as a whole. In the event that water pumping is not operating, this suggested solution functions as a dependable water pumping system that may also generate power to be sold to the utility.

References

[1] M. T. A. Khan, G. Norris, R. Chattopadhyay, I. Husain, and S. Bhattacharya, “Autoinspection and permitting with a PV utility interface (PUI) for residential plug-and-play solar photovoltaic unit,” IEEE Trans. Ind. Appl., vol. 53, no. 2, pp. 1337–1346, Mar./Apr. 2017.

[2] M. Montorfano, D. Sbarbaro, and L. Morán, “Economic and technical evaluation of solar assisted water pump stations for mining applications: A case of study,” IEEE Trans. Ind. Appl., vol. 52, no. 5, pp. 44544459, Sep./Oct. 2016.

[3] B. Talbi, F. Krim, T. Rekioua, S. Mekhilef, A. Laib, and A. Belaout, “A high-performance control scheme for photovoltaic pumping system under sudden irradiance and load changes,” Solar Energy, vol. 159, pp. 353–368, 2018.

[4] P. Periasamy, N. K. Jain, and I. P. Singh, “A review on development of photovoltaic water pumping system,” Renewable Sustain. Energy Rev., vol. 43, pp. 918–925, Mar. 2015.

[5] R. Kumar and B. Singh, “BLDC motor driven solar PV array fed water pumping system employing zeta converter,” IEEE Trans. Ind. Appl., vol. 52, no. 3, pp. 2315–2322,

May/Jun. 2016. B. ingh and R. Kumar, “Solar PV array fed water pump driven by BLDC motor using landsman converter,” IET Renewable Power Gener., vol. 10, no. 4, pp. 474–484, Apr. 2016. [7] K. Rahrah, D. R

[6] kioua, T. Rekioua, and S. Bacha, “Photovoltaic pumping system in Bejaia climate with battery storage,” Int. J. Hydrogen Energy, vol. 40, no. 39, pp. 13665–13675, Oct. 2015. A. Khiareddine, C. B. Salah, and M. F. Mimouni, “Power management of a photovoltaic/battery pumping system in agricultural experiment station,” Solar Energy, vol. 112, pp. 319–338, Feb.

[7] S. G. Sigarchian, A. Malmquist, and T. Fransson, “Modeling and control strategy of a hybrid PV/wind/engine/battery system to provide electricity and drinkable water for remote applications,” Energy Procedia, vol. 57, pp. 1401–1410, 2014.

[8] A. Khiareddine, C. Ben Salah, and M. F. Mimouni, “Strategy of energy control in PVP/battery water pumping system,” in Proc. Int. Conf. Green Energy, Sfax, Tunisia, 2014, pp. 49–54.J. H. Ugale and M. S. Panse, “Single phase ac drive for isolated solar photovoltaic water p

[9] umping system,” in Proc. Int. Conf. Green Comput. Internet Things, Noida, India, 2015, pp. 1285–1287.

[10] A. Boussaibo, M. Kamta, J. Kayem, D. Toader, S. Haragus, and A. Maghet, “of photovoltaic pumping system model without battery storage by MATLAB/Simulink,” in Proc. 9th Int. Symp. Adv. Topics Elect. Eng., Bucharest, Romania, 2015, pp. 774–780.

[11] Z. Yan, “Photovoltaic pumping system using power grid as energy storage device,” Chinese Patent CN 202455296 U, Sep. 26, 2012.

[12] Huang, “Photovoltaic water pumping and residual electricity grid-connected system,” Chinese Patent CN 204131142 U, Jan. 28, 2015.

[13] W. Xing, “High-efficiency photovoltaic pump system,” Chinese Patent CN 203884338 U, Oct. 22, 2014.

[14] C. Steel, A. Fang, S. Weilong, G. Jing, and Z. Xiong, “Photovoltaic agricultural power generating unit,” Chinese Patent CN 203859717 U, Oct. 1, 2014.