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ANFIS controlled BLDC Motor Drive for Agricultural Application with Solar System

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Abstract: In India, it is of utmost significance to ensure that the agricultural fields receive supplies of water. Agricultural applications are the focus of this paper, which depicts the implementation of an advanced BLDC motor connected drive that is controlled by an adaptive neuro fuzzy inference system (ANFIS). In this work, the implementation of the bidirectional power flow among the load and the renewable energy source (RES) is carried out. In order to power the water pump, renewable energy sources (RES) are generated through the use of solar photovoltaic (PV) cells. Additionally, a BLDC motor load is connected to the water pump through a single phase bi-directional converter and a voltage source inverter (VSI) inside the design. The PV system is able to get the maximum amount of power while simultaneously lowering the main grid and enabling consumers to run their motors and loads at their maximum efficiency throughout the entire day. This is made possible by the integration of fusing into the solar generating framework. Using the suggested controller, the PV system is able to reduce conversion costs and total harmonic content of the grid, all while maintaining the power factor, good quality in power, and stability of the system.

Keywords: Adaptive neuro fuzzy inference system, BLDC Motor, Power quality, PV system, DC/DC converter.

1. Introduction

As carbon emissions continue to rise and fossil resources become scarcer, it is of the utmost importance for customers of electrical services to make the switch to renewable energy sources. As a consequence of the fact that solar photovoltaic (PV) output is gradually replacing conventional energy sources, PV water propelling has garnered a great deal of consideration over the course of the last few decades [1]. First, direct current (DC) motors were recommended to deliver the water, and then an alternating current (AC) motor was used.

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In an effort to improve performance and efficiency while simultaneously lowering costs, numerous revisions have been conducted on electric drives for PV-fed pumping system. In recent years, BLDC motors have gained popularity due to their excellent performance, increased efficiency, lack of maintenance requirements, minimal electromagnetic interference concerns, extended operating life and compact size. The incorporation of this drive results in a reduction in the scope and cost of the PV system, as well as an improvement in performance and the loss of the requirement for maintenance [2]. BLDC drive water pumps that are not connected to the grid and are powered by a photovoltaic system are solely dependent on the energy produced by the PV system. Due to the intermittent nature of solar photovoltaic (PV) generation, it is evident that it has fundamental shortcomings, which ultimately lead to an unstable water pumping system. The water pumping process has been severely disrupted as a result of the extreme weather conditions and the low utilization of the pump [3]. However, if there is not enough sunlight during the night, the mechanism that pumps water will not function properly. There are a number of concerns that

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need to be addressed before a PV pumping system can be considered reliable. BLDC motor drives have not been the subject of any of the few attempts that have been made to use batteries as a means of energy storage in this context. This ensures that there is a continuous supply of water uniform when the sun is not shining because the batteries are discharged and charged in conjunction with a controller that only operates in one direction. The use of an energy storage system in photovoltaic crop irrigation not only results in an increase in the overall charge and maintenance costs, but it also has an impact on the pumping system's lifespan [4]. Only two to three years is the typical lifespan of a lead acid battery in terms of its operational life. According to what was mentioned earlier, the drawbacks of battery storage have shifted the focus to other technical options that might be more suitable for a dependable water pumping system that is entirely dependent on solar photovoltaic power. Using these recently recognized technologies, a photovoltaic (PV) generating unit that has been installed for the purpose of water pumping may be connected to the utility grid. Without regard to the operational conditions that may arise during the day or night, the primary objective is to ensure that water pumping is maintained at its highest possible level. First, a utility grid inverter is responsible for providing power to the main grid. Next, the inverter supplies the water pump with power through a pump that is part of the inverter [5]. On the other hand, it appears to be an arrangement that is solely powered by the infrastructure of the main grid. Using a voltage converter and an inverter, it is possible to charge and discharge a batteries, which can be used later to power a water pump. This is according to the information provided in [6]. Additionally, a utility interface is made available by means of an choice switch located on the pump. There is a requirement for the battery storage in order to maintain the system's affordability. [7] is an example of a PV arrangement that is recommended to pump water, while the other portion of the system is utilized to supply electricity to the utility. On account of the fact that the solar panels are the only source of power for the pumping, the design is unreliable. The remaining power is obtained from the utility as required in this grid-interfacing PV fed BLDC operated pumping system with directional power flow regulation. The system is designed to be grid-interfacing. In situations where there is no requirement for water pumping, the new technology wastes solar electricity [8]. It can be deduced from this that every single one of the aforementioned representations of a PV-connected pump scheme has a regulator of power that is only in one direction. It is still in the process of being designed, but a multifunctional arrangement that enables power flow in both directions is being developed in order to make the greatest of both the photovoltaic connection and the pumping structure. This is the first time that a BLDC engine has been utilized in this system. This scheme will permit for the transmission of energy from photovoltaic collections to single-phase grids, and vice versa, in the event that the yield of the PV system is insufficient during the night to operate a BLDC motor pump at its maximum capacity. If a water drive is not required, this scheme will allow for the transmission of electricity. Through this method, consumers have the potential to make a income from the sale of their additional power to the effectiveness.

The remaining paper is organized as follows. Section 2 about the test system, Section 3 about the proposed controller, Section 4 about the results and Section 5 presents the conclusion.

2. Considered test system

An example of the representation for the proposed BLDC drive that is fed by PV is depicted in figure 1. The BLDC motor is fed by the PV station, which is equipped with an incremental conductance-based MPPT based boost converter. The proposed drive is fed through three phase VSI. Additionally, the electronic commutation of the BLDC drive system is transferred to the VSI. This VSI makes it possible for the DC link and the two way power flow capacitor to function [9]. The suggested photovoltaic design will supply the utility with electricity whenever there is a need for water requirement. An inter connected inductor is connected among the utility and the single phase inverter in order to enhance the power quality by lowering the harmonics. Harmonics in the supply voltage are removed by the RC ripple filter; their presence is eliminated.

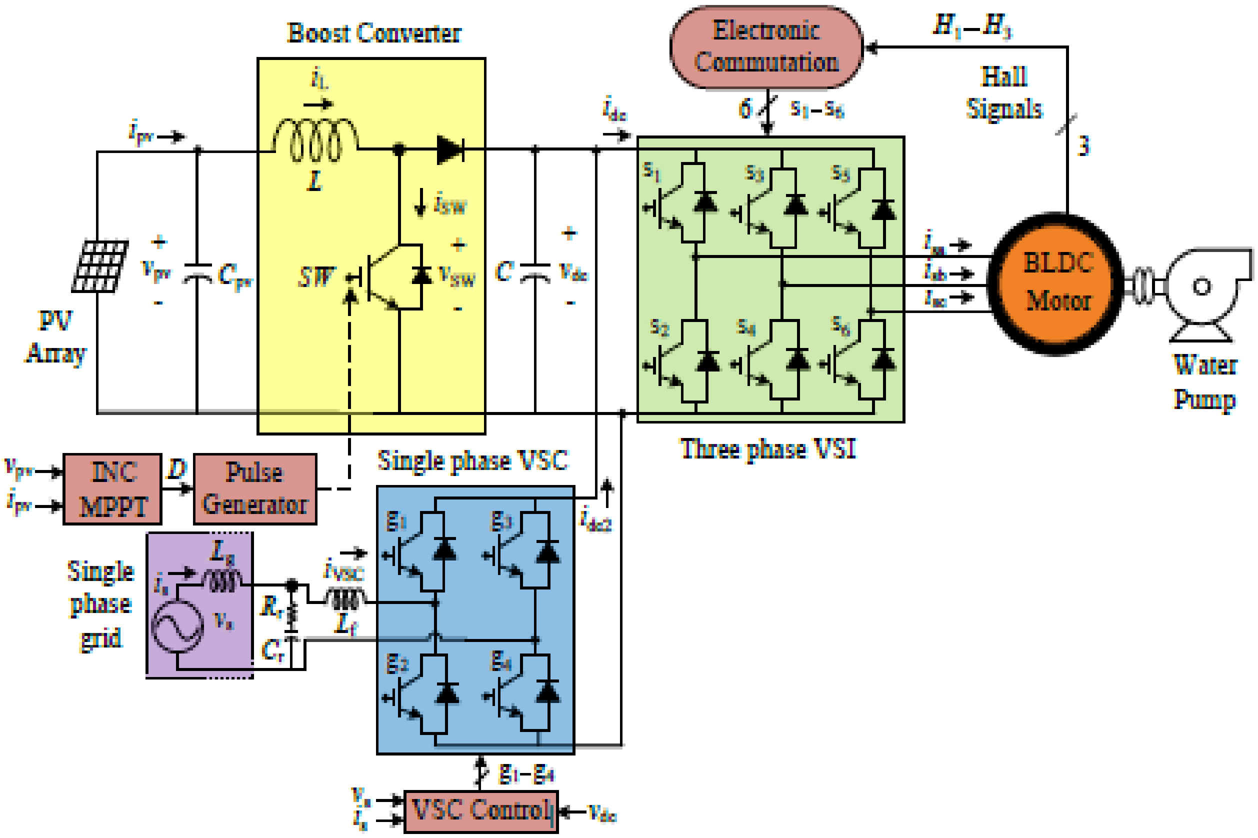

Fig. 1: Proposed system block diagram arrangement

3. Proposed controller

A photovoltaic (PV) system that is attached to the utility and has the capacity to generate dependable water pumping systems is able to bring about system reliability and maximize the utilization of available resources. Fig. 2(a) illustrates a voltage regulation that operates in both directions and is based on the generation of space vector modulation. This is the most straightforward method because it does not need a composite mathematical design or procedure to be implemented effectively. A single-stage Phase Locked Loop (PLL) is utilized in order to achieve synchronization between the grid's power voltage and current. It is at the fundamental frequency that the supply voltage, which is a sin sine wave, is generated. In addition, it is suggested to control the DC voltage in order to effectively receive the essential component of supply current. In order to maintain control over the voltage of the system, an ANFIS controller is recommended [10]. A reduction in the magnitude of the DC voltage signal is accomplished through the utilization of first-order low pass filters. In situations where it is necessary to draw electricity from the utility, the voltage converter produces a positive current. A supply current that is in phase is delivered to the grid as a consequence of this. In this way, an out of phase availability of resources is formed when a PV system supplies the grid [11]. This is because of the effect that this has. It is possible to achieve the desired direction of flow by switching the flow of power around within the system. The applied control approach also results in an increase in total harmonic distortion (THD) as well as voltage level. In the event that the grid is unavailable, the output direct current voltage is controlled. However, because the PV array is able to adjust to different climate conditions, it is still possible to operate the water pump without any external power source. An illustration of the configuration of the ANFIS controller can be found in Fig. 2(b).

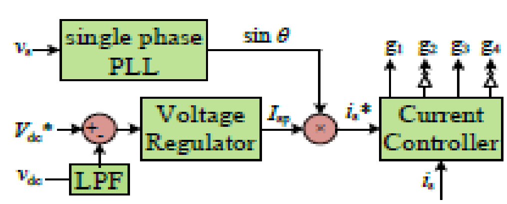

Fig. 2: (a) Two way bidirectional controller for VSI

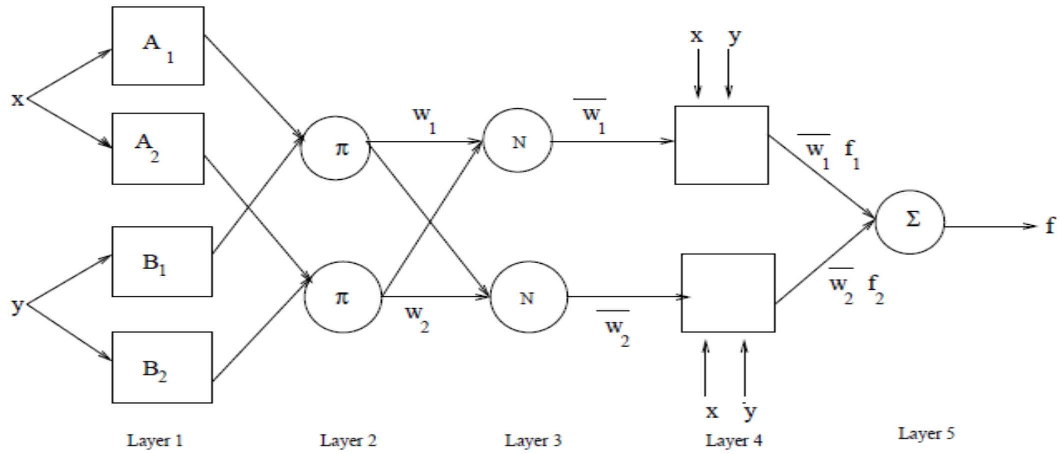

Fig. 2(b): Type-3 ANFIS Structure

4. Simulation results and Discussion

In order to test the suggested structure under a variety of operational conditions, the MATLAB/Simulation bench is utilized. The regulation of the test bench, as well as its starting, static, and steady state operations, are all put through comprehensive testing. A single-phase grid with 180 volts and 50 hertz and a photovoltaic array with 1.5 kilowatts supply the required power for a four-pole pump with a speed of three thousand revolutions per minute at 270 volts direct current. The water pump, for instance, might be fed by a PV system, the grid, or a mixture of the two different sources. For the purpose of putting the proposed system through its paces, we take into consideration each and every one of these potential organizational scenarios.

4.2 Starting and Steady-State Performance

Demonstrating the BLDC motor's ability to start quietly and maintain a steady state under different operating conditions is the primary focus of motor pump performance studies.

4.2.1 When only PV array feeds BLDC motor pump

As can be seen in Fig. 3, the photovoltaic (PV) system is operational at its MPPT under temperatures of 1000 W/m². That is why, as can be seen in Fig. 4, we operate the DC drive at the speed that is recommended for it, which is three thousand revolutions per minute. Consequently, there is no requirement for grid power because the photovoltaic array generates sufficient electricity to run the pump at its maximum capacity. The steady-state performance of the motor pump as well as its gentle starting behaviour are both demonstrated by these data.

4.1.2 When only utility grid feeds BLDC motor pump

This operational state is developed whenever there is a prerequisite for water production during the night. As can be seen in Fig. 5, a sinusoidal source current of 8.3 A (rms) is utilized, and the voltage output is obtained at 270 V. It is demonstrated in Fig. 6 that the motor is able to draw sufficient power from the grid in order to function at its maximum capacity. The pumping mechanism is being utilized to its full capacity in this scenario.

4.1.3 When water pumping is not required

In this scenario, the power generated by the photovoltaic array is fed into the utility grid, and there is no need for pumping to take place. The PV array MPP that is operating at 1000 W/m² is depicted in Fig. 7. In Figure 8, the presence of an out-of-phase supply current indicates that the utility is supplied by a photovoltaic array, and that the output current is reversed while the voltage remains at 270 volts. In addition, the power factor and total harmonic distortion (THD) of the main grid would be improved by the suggested system's improved power quality. The harmonic spectrum and total THD of the supply current are depicted in Fig. 7.

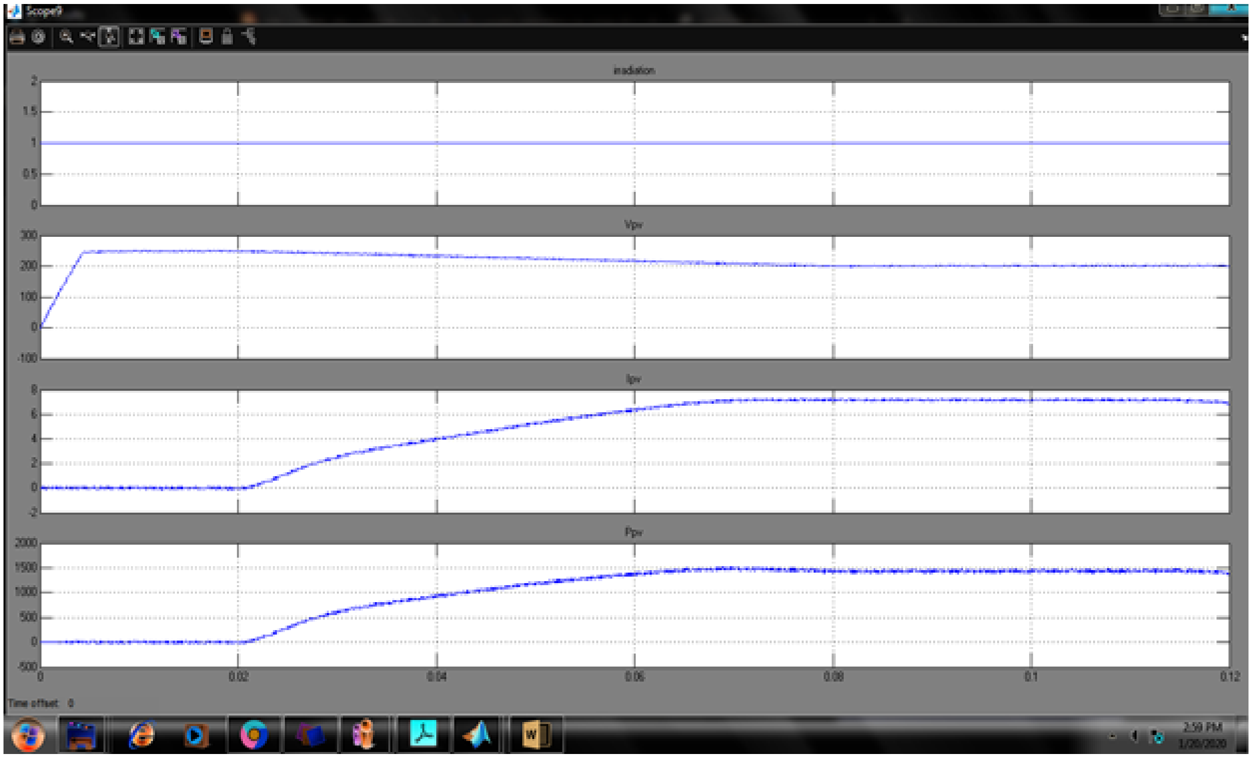

Fig. 3: PV system performance in starting and steady state

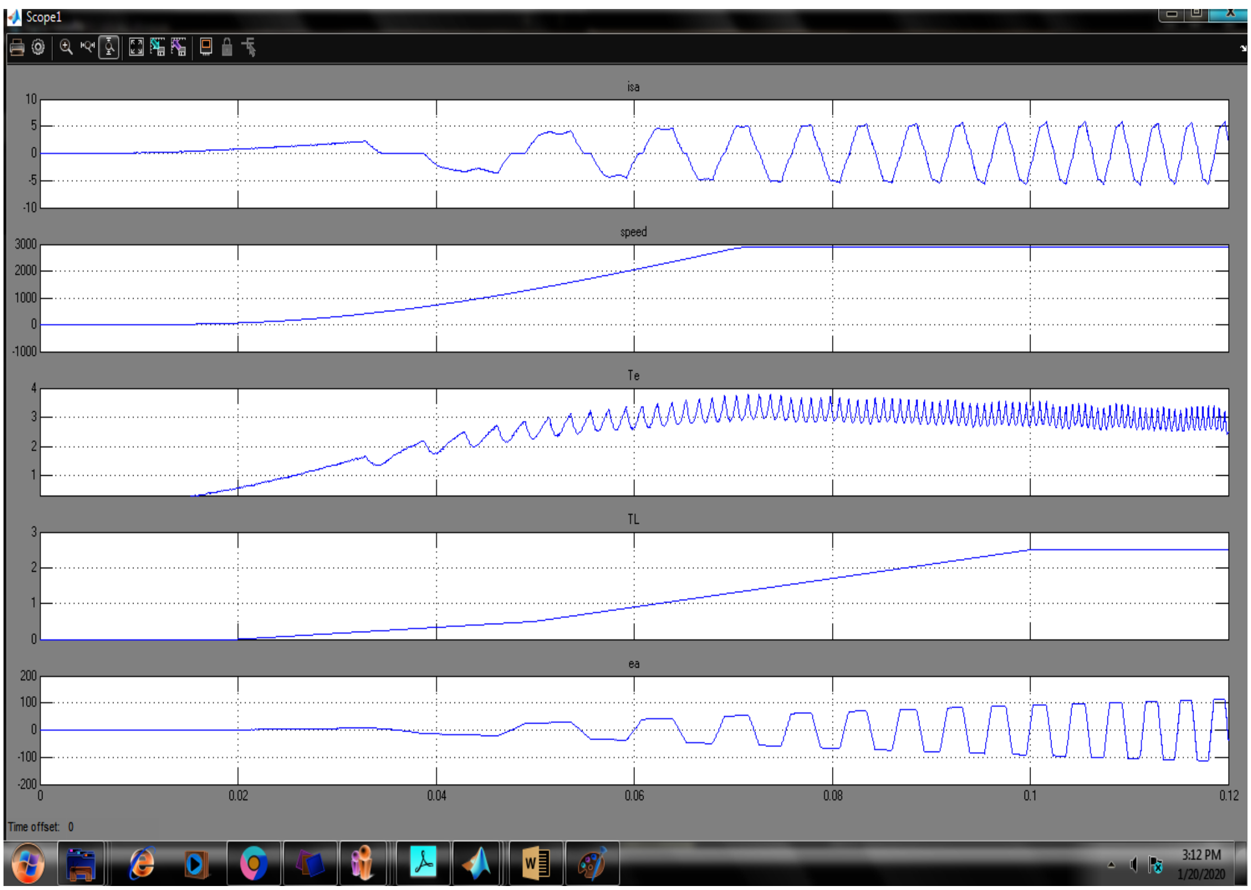

Fig. 4: BLDC drive presentation during steady state and starting

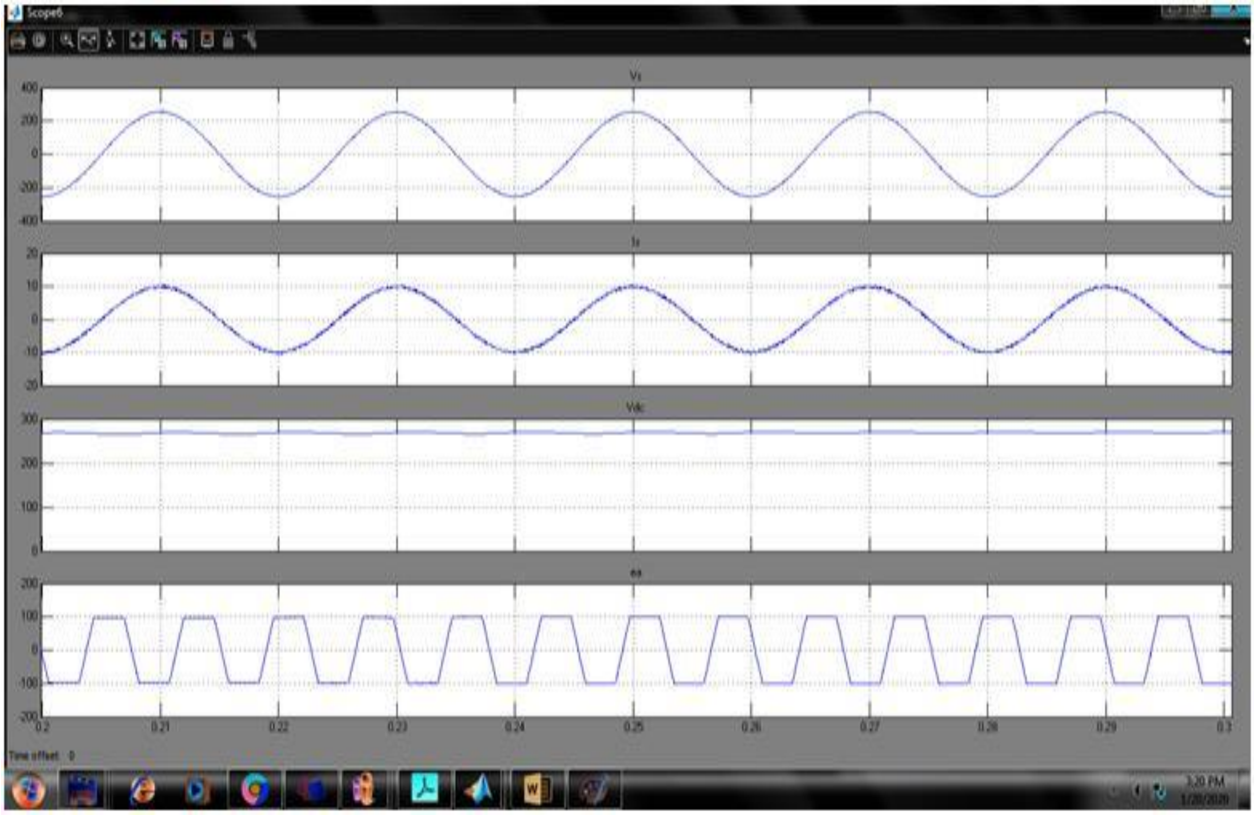

Fig. 5: When PV feeds the pump, the starting and steady characteristics of drive

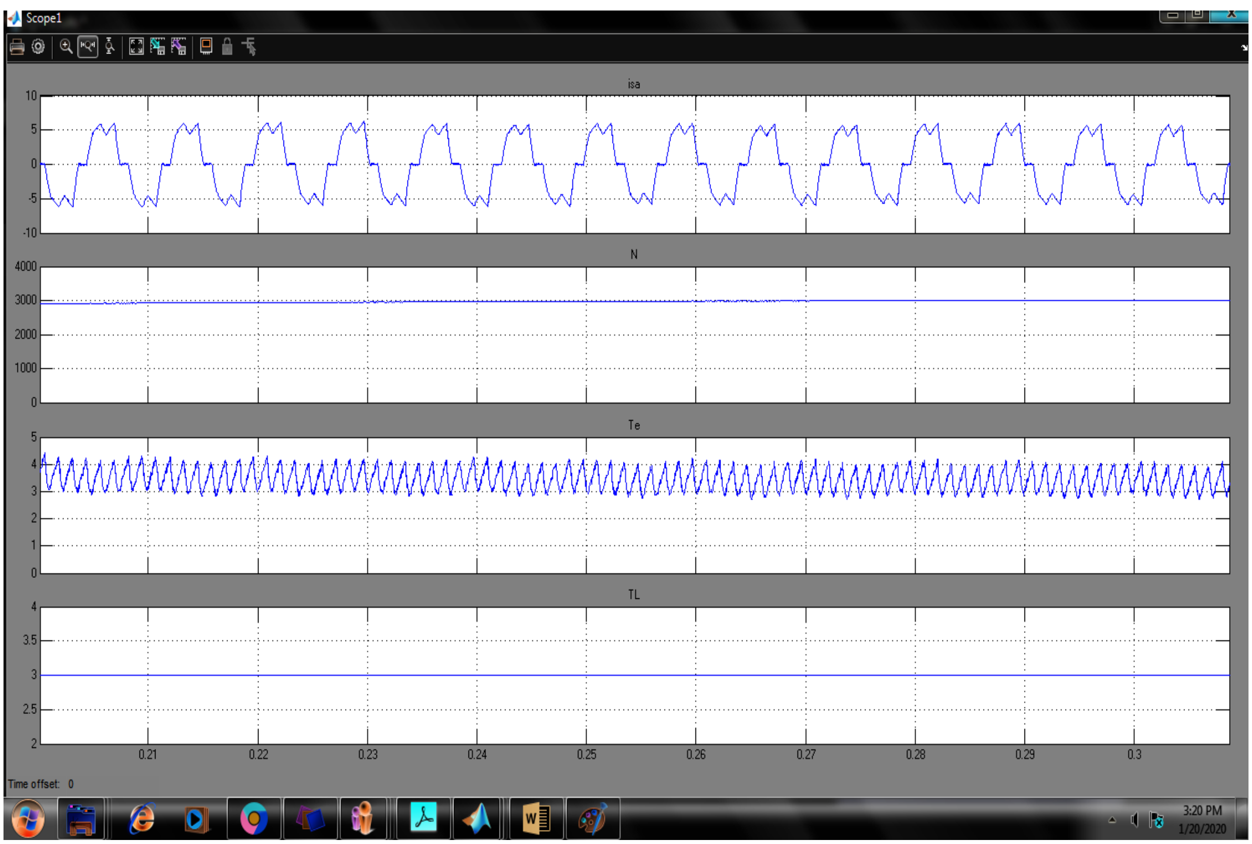

Fig. 6: When only grid feeds the pump the starting and running characteristics of drive

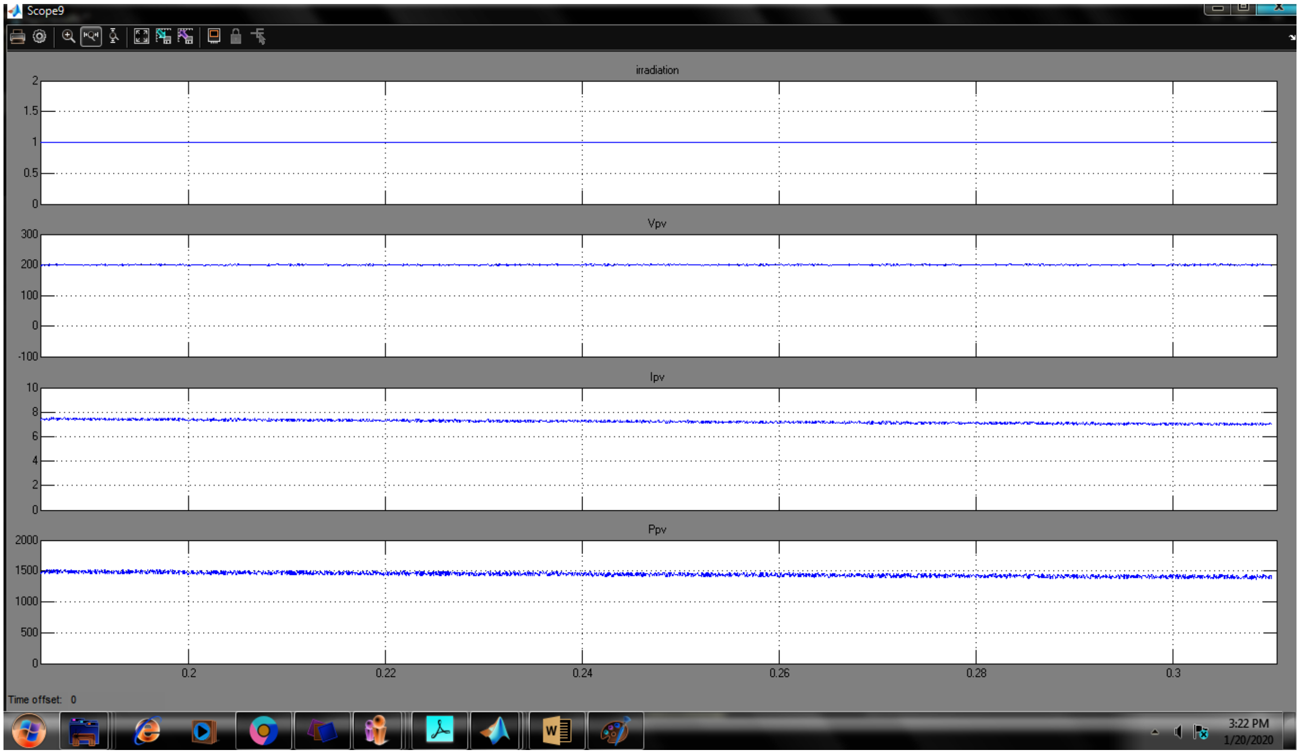

Fig. 7: Under no pumping requirement PV characteristics in steady state condition

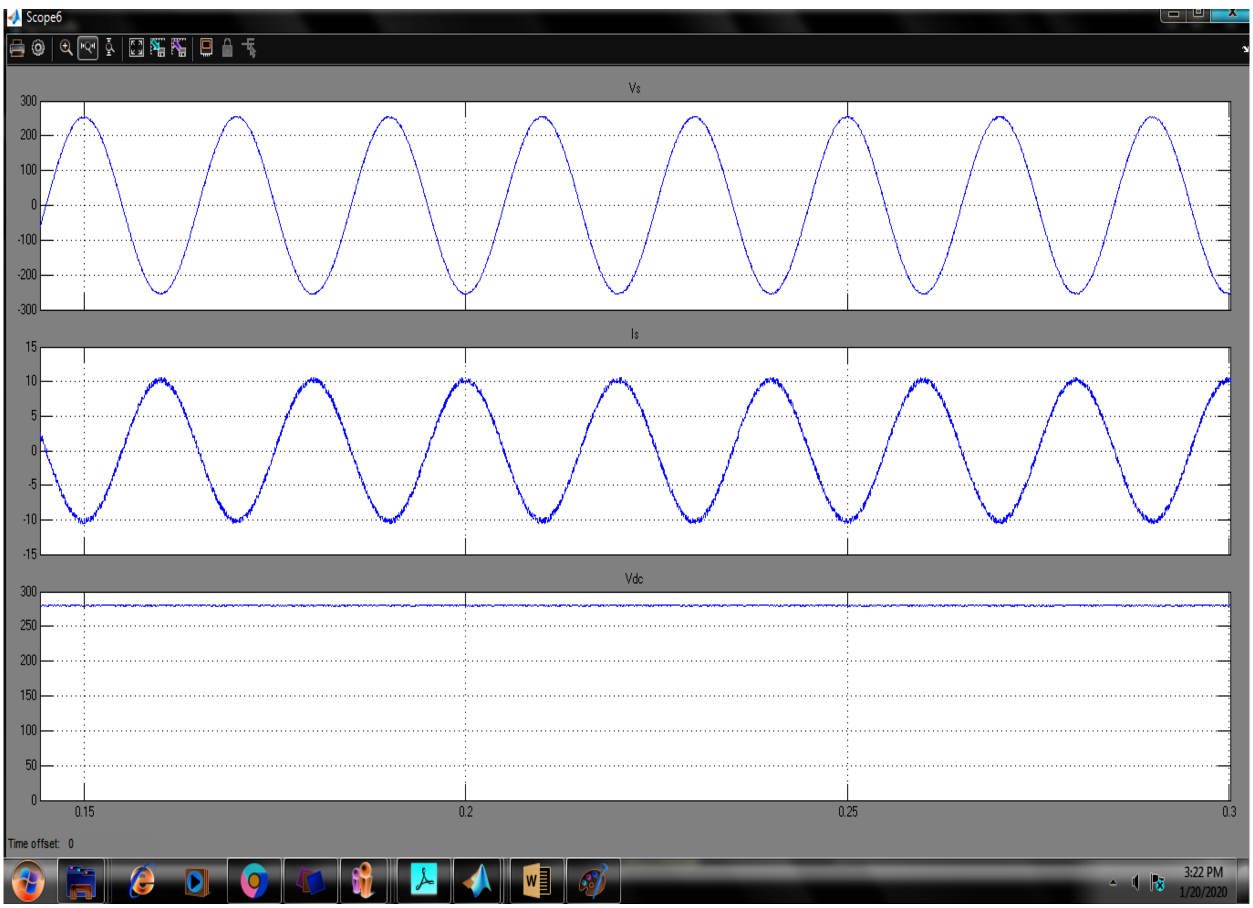

Fig. 8: When water not required grid performance in steady state condition

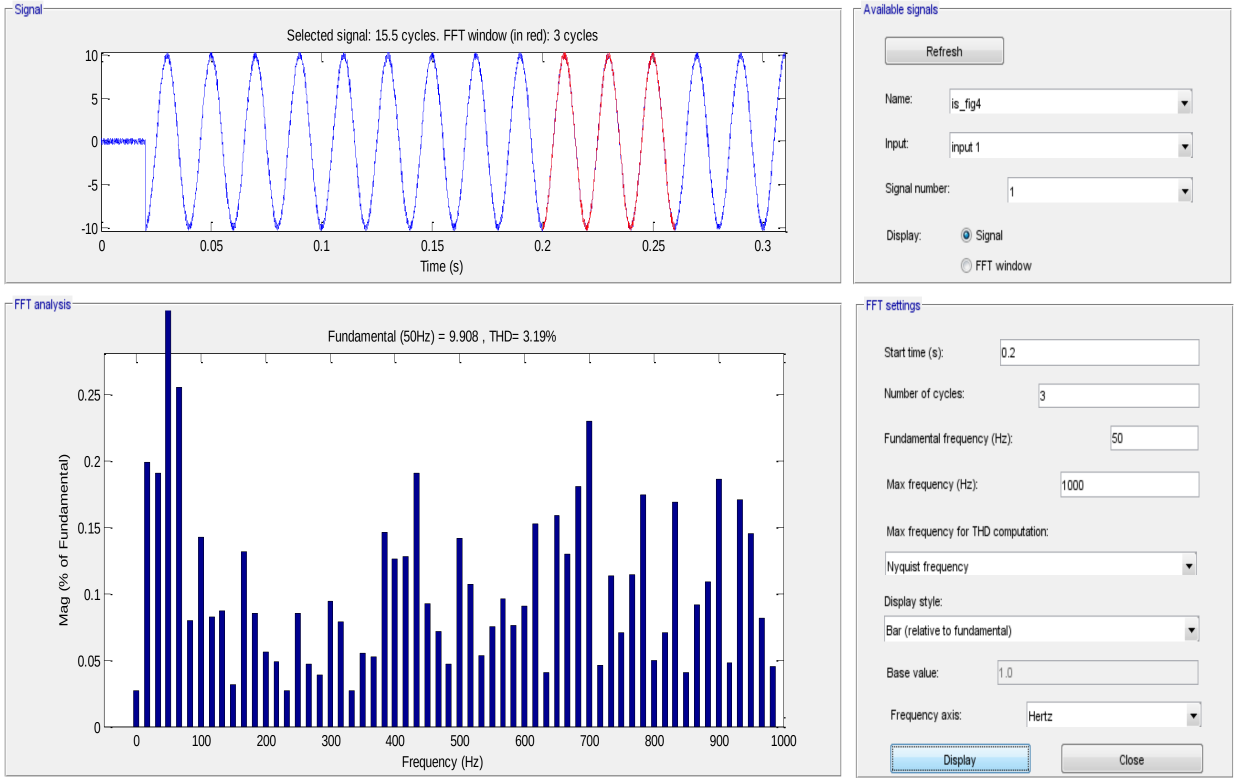

Fig. 9: Supply THD analysis when pump is fed by grid

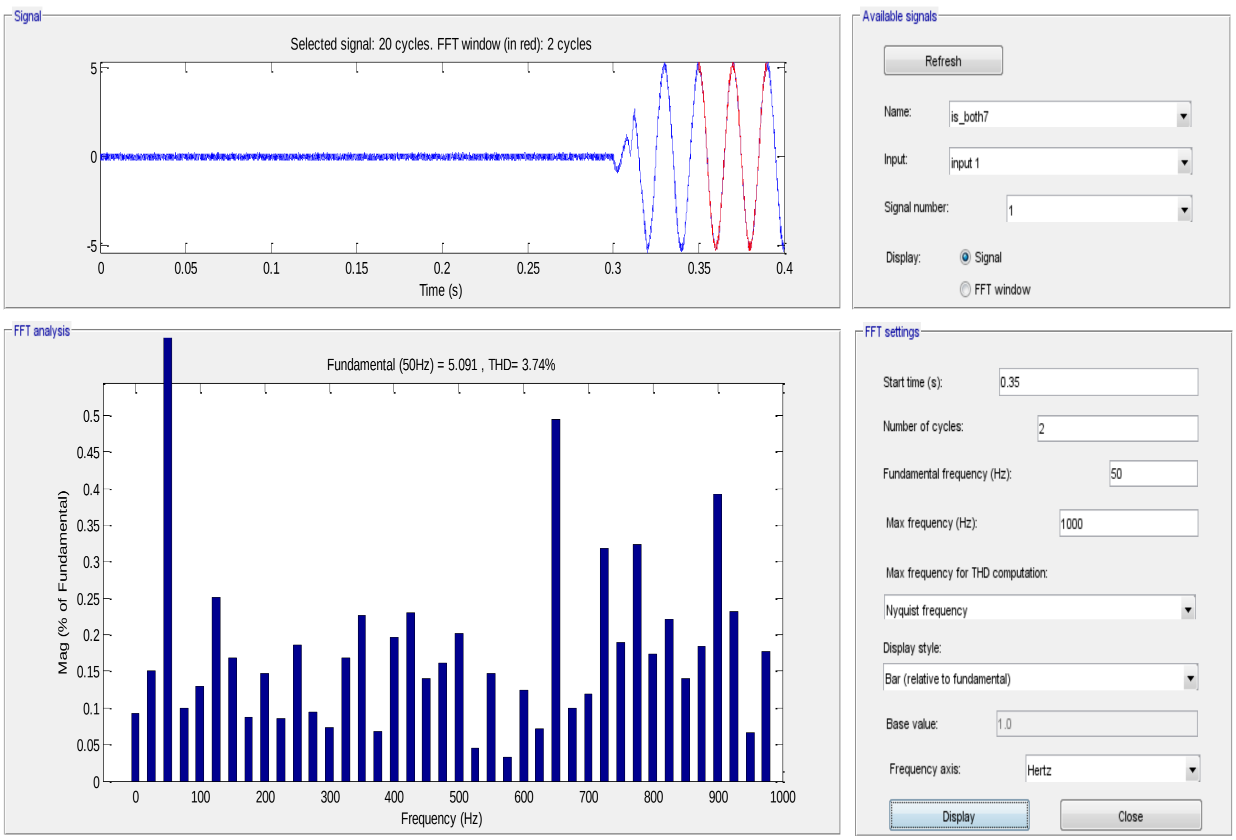

Fig. 10: THD analysis of supply when pump is fed by grid and PV system

This is because the water pump is only powered by the utility grid. As an illustration, the THD and distortion spectrum are depicted in Fig. 8 in the event that the radiation intensity is 600 W/m2 and there is a requirement for the utility grid to supply any residual power. According to the standards established by IEEE-519, the THD of the supply current is lower than 5% in both instances. Fig. 9 and Fig. 10 shows the THD analysis of supply voltage when the drive is fed by grid and PV system.

5. Conclusion

An ANFIS controller-based single-phase grid interactive photovoltaic system based water pumping technology has been proposed as a result of this research. The BLDC drive is also required. The utilization of resources for water pumping at maximum capacity has been made possible by the VSC bi-directional power flow regulation, which has enabled this to occur regardless of the weather. A fundamental UVT generating strategy has been implemented in order to facilitate the management of the flow of electricity. Every one of the requirements for power quality that were outlined in the IEEE-519 standard has been realized. It has been demonstrated that BLDC motor-pump speed control can be achieved without the utilization of current sensors. Since a fundamental switching frequency of VSI has been implemented, switching losses have been reduced, which has resulted in an improvement in the overall efficiency of the system. Up to this point, the water pumping system that was suggested has demonstrated that it is not only dependable but also profitable for the utility company especially in situations where groundwater is not required.

Conflict of interest: The authors declared “No conflict of interest”

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