Intelligent Solar Water Pumping Scheme with BLDC

Dnyaneshwar Walke, Dr. Paratwar P V, M.S.Tamboli, S.S.Bhosale, B.V.Anarase

Department of Electrical Engineering, Dattakala Group of Institutions Faculty of Engineering, Pune, India

Abstract:- Along with increased pumping system reliability, this also allows for the full usage of a PV array and motor-pump. A single-phase voltage source converter (VSC) uses a unit vector template (UVT) generation technique to achieve bidirectional power flow control between the grid and the voltage source's DC bus. A BLDC motor is fed by an inverter (VSI). Furthermore, a PI controller cannot achieve enhanced PQ features by regulating the DC capacitor voltage in the UVT controller to a desired level. However, the tuning concerns of the existing controller lead to its unpopularity; a revolutionary intelligent fuzzy-logic controller can resolve these issues and achieve good performance features. The suggested intelligent fuzzy control systems, which outperform the traditional PI controller, find widespread employment in various applications. In order to improve PQ, this study evaluates the efficiency of solar-PV and grid-integrated water pumping systems using traditional PI and intelligent fuzzy-logic controllers. Results are presented on how the Matlab/Simulink platform is used in this system to achieve the maximum power point (MPP) functioning of a PV array and power quality enhancements such power factor adjustment and reduction of the total harmonic distortion (THD) of the grid.

Keywords*: - VSI, BLDC Motor, Solar PV Array, Water Pump, Buck-boost Converter, FLC.*

1. Introduction

Due to the dwindling availability of traditional fossil fuels and the decreasing costs of solar PV technology, there has been a growing interest in utilizing solar PV technology for productive purposes. This has caught the attention of researchers and industrialists worldwide. A PV powered water pumping scheme seems to be quite fascinating. With its wide range of applications, solar PV energy has proven to be highly effective in areas like rural street watering, agricultural supply, and fish farms[4]. Water pumping for irrigation has become a significant concern for farmers. In this scenario, solar water pumping has emerged as the top alternative among all options. The water pumping is sporadic due to unfavorable weather conditions.Furthermore, since the pump is not operating at its full capacity, the system is not being fully utilized. Unlike during the day, when sunlight is abundant, the absence of sunshine at night results in the complete shutdown of the water pumping system. For optimal utilization of solar power, it is essential to have online monitoring of the complete power point of a PV array/module. Several techniques for MPPT have been developed. The techniques vary in terms of implementation complexity, sensed parameters, sensor quantity required, convergence speed, and cost. Ensuring a consistent and ample water supply is the top priority, no matter the time of day or working conditions. Furthermore, the SPV panel's performance is influenced by the level of solar radiance. The MPPT of the SPV array is often not achieved.One way to address this issue is by utilizing an MPPT, which helps keep the SPV arrays operating point closer to the MPPT. Two commonly used online algorithms for efficient execution and effective monitoring are the Perturb and Observe and Incremental conductance (InC). The InC algorithm performs better than the P&O algorithm, especially in quickly changing region conditions, where it has higher tracking performance. The advancement of society and the increasing reliance on electric motors have greatly amplified the need for electrical resources. Engines are responsible for over 40 percent of total electrical power expenditure. An engine is crucial in achieving efficient and affordable water pumping using solar PV technology. With the expertise of a specialist, a powerful motor can greatly reduce the number of solar modules needed and subsequently lower the capital cost for the required power demand. DC motors are commonly used in lesspower solar PV water pumping. This results in a more compact size and increased motor strength.This work presents a solution for enhancing water pumping efficiency by utilizing a solar PV-fed BLDC motor drive in conjunction with a PV-utility grid interface. For the MPPT of the PV series, a boost converter is used and an incremental conductance approach is implemented.Current sensor-less control is widely recognized for its effectiveness in regulating the speed of BLDC motors. Through an When it comes to the electronic commutation of the BLDC motor, the VSI operates using straightforward frequency pulses. This approach leads to reduced switching losses and improved conversion efficiency. Hardware models have been developed for a grid-interfaced solar PV-fed water pumping system. As an expert in the field, the remote agrarian required assistance with water siphoning for their domestic animals. The water siphoning system that operates the solar controller consists of two crucial components. There are PV boards and siphons available. The smallest component of the PV board is the solar cell. The PV board component, being the smallest, depends on sunlight for its functioning. Power is generated by the direct flow when each solar cell receives light through at least two layers in a semiconductor material.It is then supplied to a DC siphon, which siphons water whenever the sun shines, or stored in batteries for later use. The stored water can be pumped anytime the sun shines, or stored in batteries for later use.[10].

2. Objectives

By incorporating BLDC technology, the solar water pumping system can significantly improve its overall efficiency in comparison to conventional systems. This leads to a more effective utilization of solar energy. By enabling grid connection, the solar pumping system's power management becomes more efficient, enabling the feeding of surplus power back into the grid or the drawing of power as needed. This ensures a continuous water supply without any interruptions. Advanced control and monitoring systems can significantly improve system performance. This allows for real time monitoring of water flow, pump operation, and energy utilization, leading to more efficient operations. This aids in maximizing system performance and promptly resolving any troubleshooting concerns. Enabling remote operation and management capabilities provides the convenience of monitoring and controlling the solar water pumping system from any location. This enhances operational flexibility and helps to reduce maintenance costs.
The scheme strives to improve the reliability and durability of the solar water pumping system by utilizing BLDC motor technology and intelligent control systems, resulting in reduced down time and maintenance needs. The scheme prioritizes the efficient operation of the solar water pumping system by taking into account factors such as solar irradiance, water demand, and grid conditions. This approach aims to minimize energy waste and promote sustainability. The scheme aims to reduce the overall costs associated with solar water pumping by utilizing cutting-edge technologies and improving system design. This will improve the technology's accessibility and affordability for agricultural and rural purposes.

3. Methods

3.1 Conventional Water Puming System:

As previously mentioned, the proposed BLDC motor drive eliminates the need for phase current sensors. The goal is to maintain the BLDC motor pump at its rated speed regardless of the weather conditions. We achieve this by consistently regulating the DC bus voltage of the VSI to match the rated DC voltage of the BLDC motor. The power flows in both directions. Flow control allows for precise regulation of the DC bus voltage, which in turn determines the operating speed. This guarantees the delivery of necessary power to pump water at its maximum capacity. Unfavorable weather conditions may prevent the DC bus voltage from maintaining the rated DC voltage of the BLDC motor if the grid is unavailable, leading to variable speed control. A one-phase PLL (Phase Locked Loop) is employed to synchronize the voltage and current of the utility grid. The system produces a sinusoidal unit vector of supply voltage, sin θ, at the fundamental frequency. However, the amplitude of the fundamental component of the supply current, Isp, is

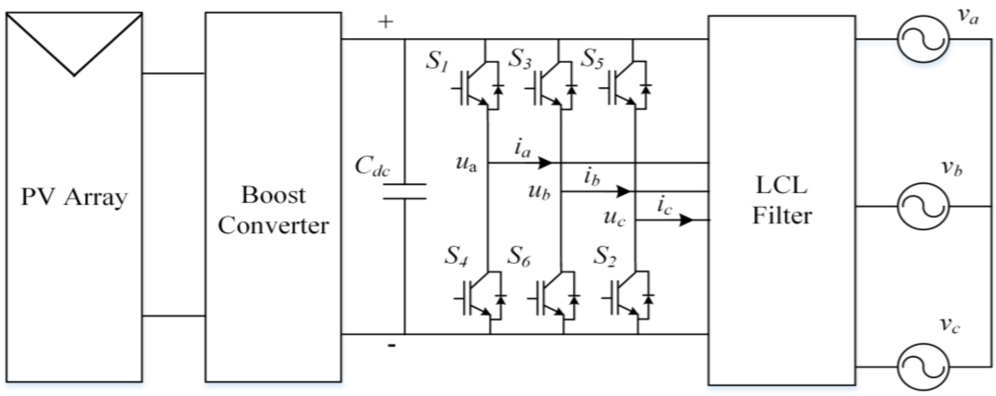

Fig.1 . Two-stage three-phase PV system configuration

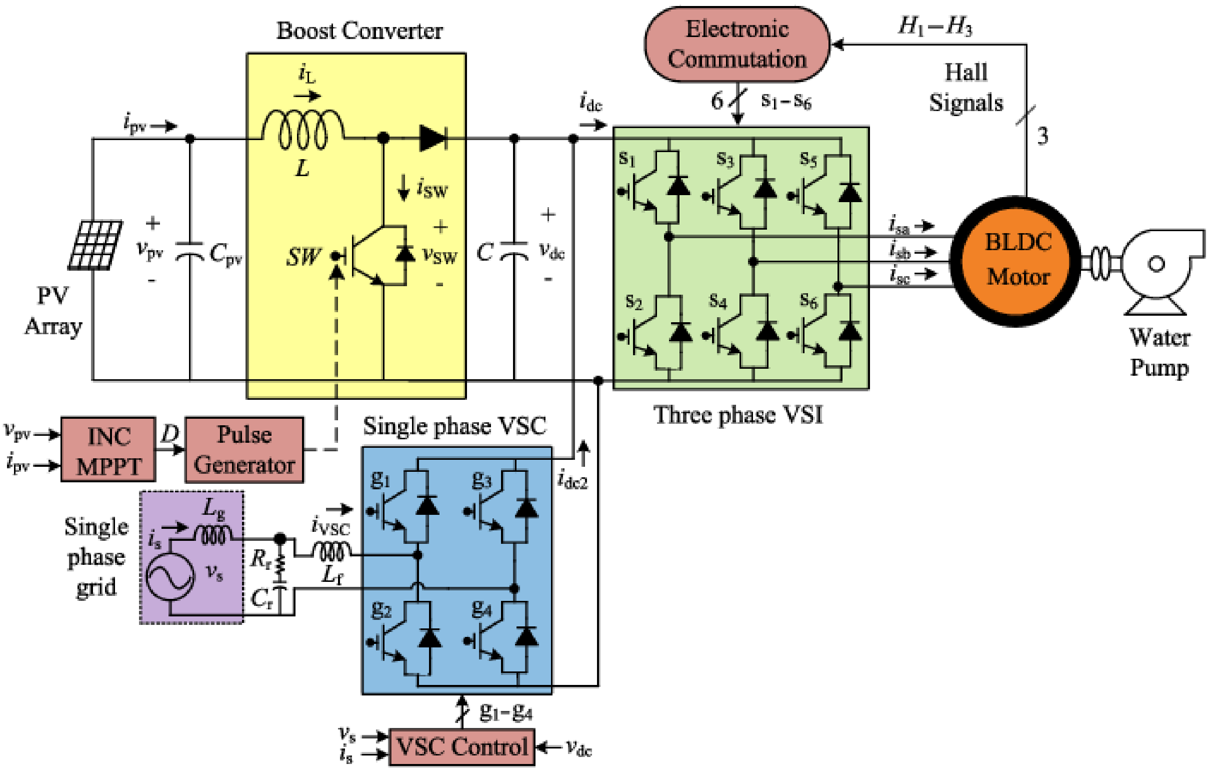

Fig 2 : Detailed Block Diagram

Controlled by adjusting the DC bus voltage, Vdc. We utilize a PI controller as a voltage regulator. The Vdc is sensed and then passed through a first-order low pass filter in order to suppress any ripple contents. We then compare the filtered Vdc to a predetermined value, Vdc*. The extraction of a crucial element of supply current involves the multiplication of Isp and sin θ. A current controller compares the measured supply current with a reference value and processes any deviation to generate the gating pulses for the VSC. The voltage regulator generates a positive Isp when the utility needs power. As a result, the grid draws a synchronized supply current. Similarly, when the utility is powered by a PV array, it produces a negative Isp, which causes the supply current to be out-of-phase. Therefore, we can adjust the power flow to the desired specifications by altering the current's direction. The applied control technique also ensures an enhanced power quality at the utility grid, with improvements in total harmonic distortion (THD) and power factor. If the grid is unavailable, it becomes impossible to regulate the DC bus voltage. However, the weather conditions affect the PV array's ability to power the water pump independently.

3.2 Fuzzy Logic Controller Implementation:

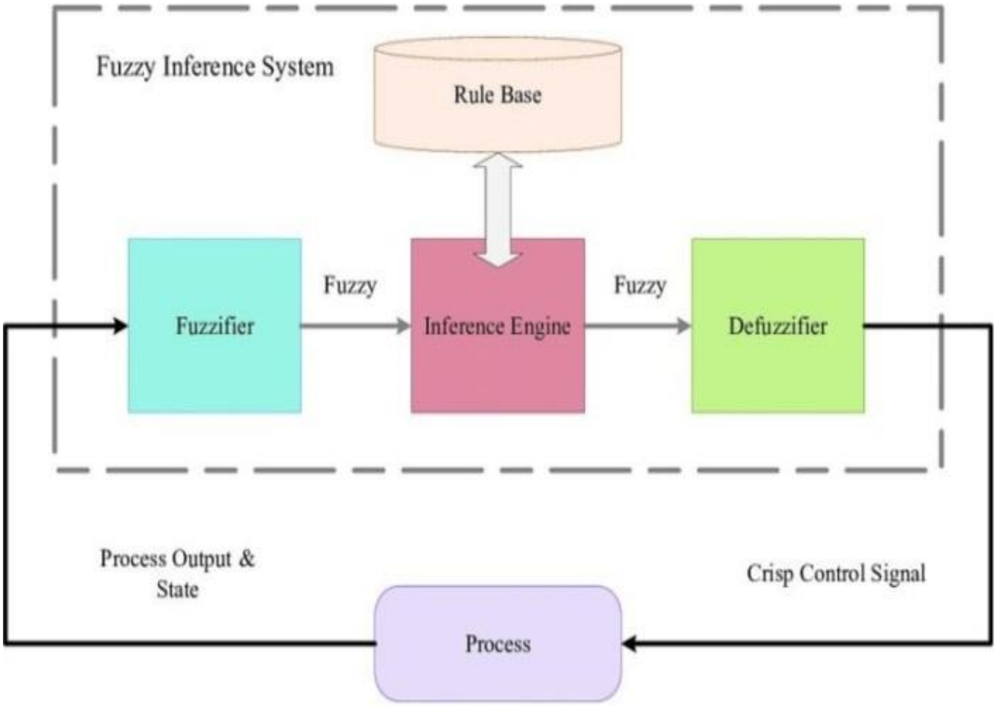

Fig.3. Structure of FLC

Many applications in control engineering and automation have widely used the proposed fuzzy controller, making it easily adaptable to associated challenges. The fuzzy evolution approach uses relative functions of attributes to build real-time control objectives. The fuzzy system within the control action of the design capabilities in both experience and intuition reflects the operation of the process or plant in a specific and precise manner. Typically, experts recommend the control system for its efficient mathematical representation of a plant model. The fuzzy control approach utilizes linguistic information, offering numerous advantages such as high robustness, increased strength, model-free operation, and the ability to achieve the universal approximation theorem with a rule-based algorithm. Figure 3 illustrates how the fuzzy scheme provides the input data for the fuzzy logic controller. The fuzzy process is executed by effective control action as part of the overall fuzzification process. The generation of input data uses the assessment of IF and THEN rules derived from various language logics. Once the fuzzification process is complete, the rule processing stage proceeds to the outcome summary stage, where the de-fuzzification procedure begins. The de-fuzzification procedure occurs at the point of the outcome summary and is initiated. Following the completion of the fuzzification process, the rule processing stage advances to the outcome summary stage, where the de-fuzzification process commences. During the final stage, a fuzzy enhancer converts the incoming inferences into actual data output, initiating the de-fuzzification process. Therefore, data is employed as an interface module to fulfill the processing requirement. The operational principles of the fuzzy logic control objective have been demonstrated by the distinction between language nature and mathematical notation. Despite linguistic terminology, the derived methodologies provide the most advanced and practical operational features. This objective of fuzzy logic control pertains to the control action of a symbolic type that is specific to a certain class.

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4. **Results**

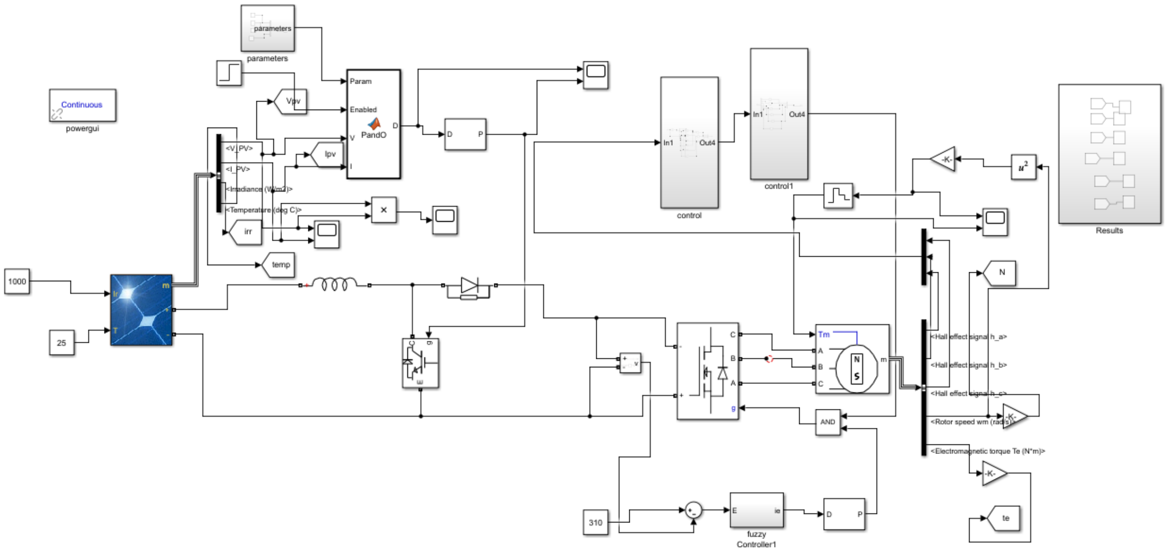

Fig. 4. Simulation of system with FLC

The Matlab/Simulink modelling is carried based on various cases and the proposed models are developed by using described system specifications illustrated in Table 1.

Table 1: System Parametrs with ratings

Sr. No	Parameters	Ratings
1	Input Source Voltage	Vrms-78, Fs-50Hz
2	Solar-PV System	Peak power = 1.5 kW; PV voltage = 29 V; PV current = 7.5 A.
3	DC-Link Capacitor	Vdc=78V, Cdc-1000 µF Interfacing inductor = 3.3 mH, R-C filter = 5 Ω, 5 µF
4	Switching Frequency	5KHz
5	BLDC Motor	V-78V, Speed = 1500 rpm; Stator resistance = 3.58 Ω; Stator inductance = 9.13 mH

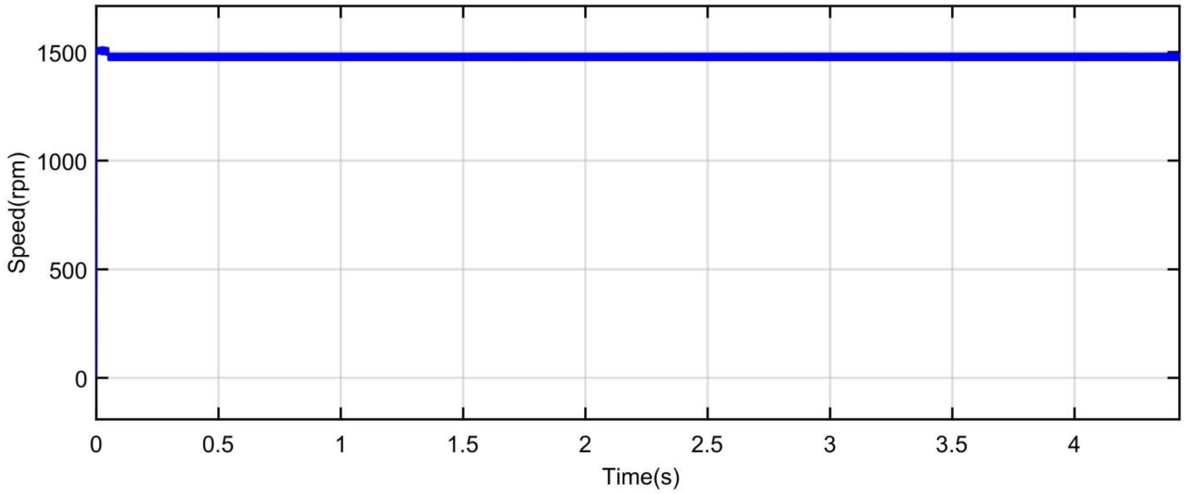

Fig. 5. Speed of BLDC with PI

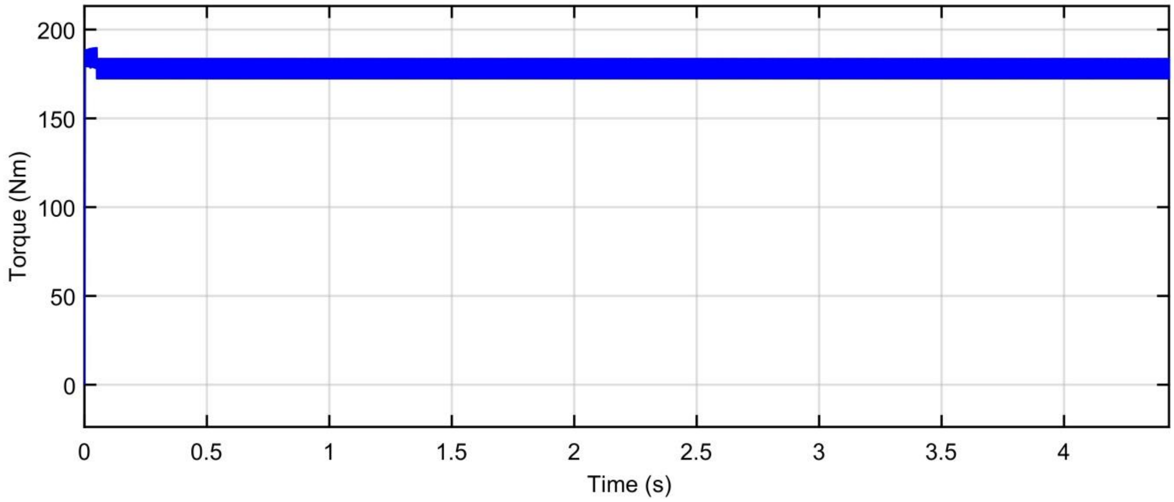

Fig. 6. Torque of BLDC with PI

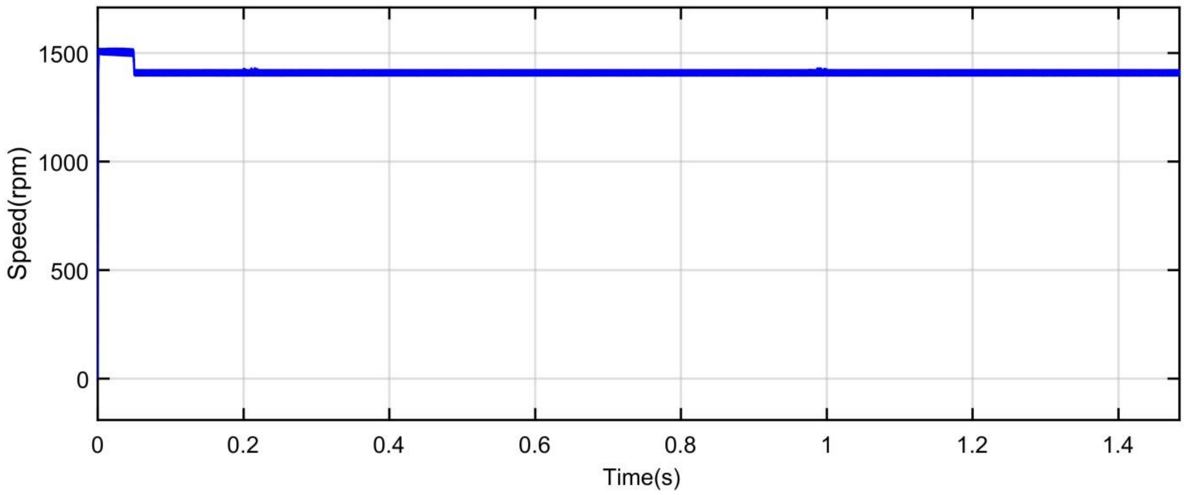

Fig.7 Speed of BLDC with FLC

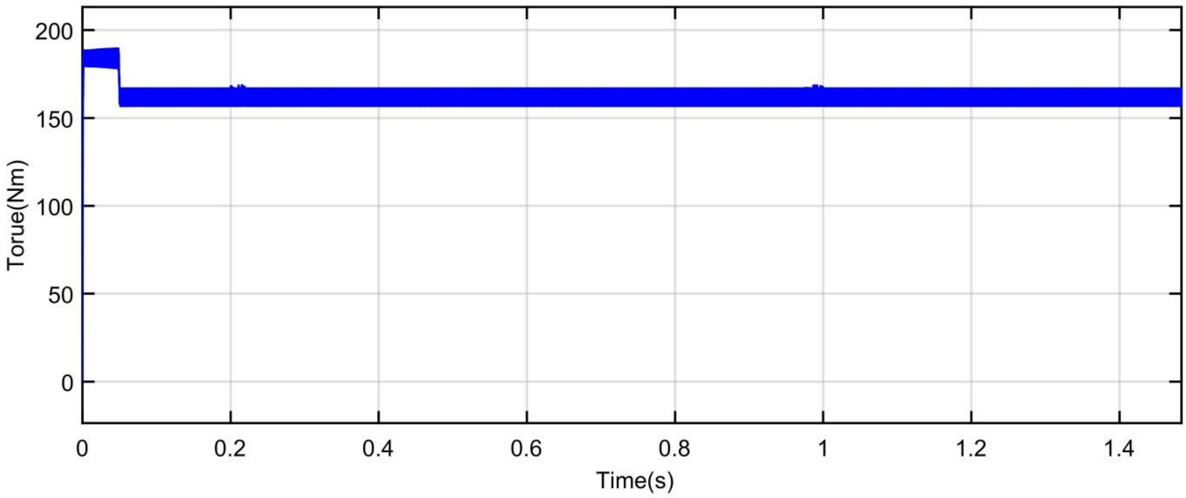

Fig. 8. Torque of BLDC with FLC

After simulating model with PI controller and fuzzy logic controller it can be observed that the FLC ggives better results than PI controller. Fig. 5 and Fig 7 shows the speed response of BLDC motor for PI controller and FLC controller. Where it can be observed that the amplitude of oscillations present in results is reduced with implementation of FLC. And FLC gives quik and accurate response to changes implied. Whereas fig 6 and Fig. 8 shows the response of torque for PI and FLC controller.

Table 2: THD Comparison for PI and FLC with current signal

Sr.No.	Method	THD %
1	PI	5.87
2	FLC	5.84

It can be observed from table 2 that THD get reduced with fuzzy logic controller implementation.

5. Discussion

An appealing control strategy has been used to present a single phase grid interactive solar-PV array based water pumping system that uses a BLDC motor drive. Regardless of the weather, the bi-directional power flow regulation of the VSC has made it possible to fully utilize resources and pump water at maximum capacity. We've implemented a basic UVT generation approach to achieve the necessary power flow control. Every element of power quality has satisfied the requirements of IEEE 519. Without the need for any current sensing components, the BLDC motor-pump's speed control has been accomplished. By lowering the switching losses, the VSI's basic frequency switching has improved the system's overall efficiency. The suggested technique has proven to be a dependable method of water pumping, while also generating revenue by selling energy to the utility. However, incorrect selection of PI control gains leads to a decline in the system's stability, a problem that the suggested intelligent fuzzy-logic controller can prevent. It reduces abrupt swings and maintains a steady DC-link voltage while adding new functionality.

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