International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 04 Apr. 2024, pp: 1088-1096 www.ijaem.net ISSN: 2395-5252

Sustainable Water Supply with Solar PV Energy Storage and BLDC Technology for Efficient Water Pumping

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Date of Submission: 20-04-2024 Date of Acceptance: 30-04-2024

ABSTRACT: This paper presents the design and implementation of a water pump system driven by a Brushless Direct Current (BLDC) motor powered by solar photovoltaic (PV) panels. With increasing concerns about energy sustainability and environmental impact, the integration of renewable energy sources for water pumping applications has gained significant attention. The proposed system aims to provide an efficient and environmentally friendly solution for water pumping in remote areas where grid electricity is unavailable or unreliable.
The system comprises three main components: solar PV panels, a BLDC motor, and a water pump. The solar PV panels convert sunlight into electrical energy, which is then fed to a controller that regulates the power flow to the BLDC motor. The BLDC motor, known for its high efficiency and reliability, drives the water pump to lift water from a source such as a well, borehole, or reservoir. The system is designed to operate autonomously, utilizing energy stored in batteries for continuous operation during periods of low sunlight.
Keywords: BLDC Motor, Solar (PV) energy storage, dc/dcconverter, PICMicrocontroller.

I. INTRODUCTION

Access to clean water is a fundamental necessity for human well-being and sustainable development. However, in many remote or off-grid regions, the lack of reliable electricity infrastructure poses a significant challenge to water pumping systems. Conventional water pumps driven by diesel engines or grid-connected electric motors are often not viable due to high operating costs, logistical challenges, and environmental concerns associated with fossil fuel consumption.

To address these challenges, the integration of renewable energy sources such as solar photovoltaic (PV) technology with water pumping systems offers a promising solution. Solar PV-powered water pumps harness energy from sunlight, providing a sustainable and environmentally friendly alternative to conventional power sources. Among the various types of motors used in water pumping systems, Brushless Direct Current (BLDC) motors have emerged as a preferred choice due to their high efficiency, reliability, and suitability for solar PV applications.

By harnessing energy from the sun, solar PV-powered water pumping systems reduce reliance on fossil fuels. We will discuss the design considerations, system architecture,control algorithms, and performance evaluation of the proposed water pumping system. We will also present experimental results and case studies to demonstrate the feasibility and effectiveness of the system in real-world applications. Ultimately, the integration of BLDC motor technology with solar PV power holds great promise for improving access to clean water in off-grid areas while advancing sustainable development goals.

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II. LITERATURE SURVEY

Compared with internal-rotor SRM motor external-rotor (ER) SRMs can appear distinctive vibration and acoustic clamor behavior due to the contrasts within the plans, e.g. thinner rotor back press to attain littler idleness, and longer stator post stature to improve the electromagnetic execution. This paper presents the contemplations within the modeling and examination of the acoustic clamor sources of an ER SRM stator and rotor. The consonant components of the stator digressive constrain thickness and rotor spiral drive thickness are analyzed and compared. The vibration modes, the vibration behavior, and acoustic clamor of the stator and rotor are too compared. A 12/16 external-rotor SRM planned for a direct-drive E-bike application is utilized for the modeling, investigation, and exploratory approval of vibration and acoustic commotion. It is concluded that both the stator extraneous vibration and the rotor outspread vibration can be sources of the acoustic clamor in an ER SRM[1]. The SRM, be that as it may, display a few known downsides, such as expanded torque swell and acoustic commotion generation, as well as a profoundly nonlinear behavior. Through the utilize of adequate control techniques, be that as it may, the most challenges of the machine can be overcome. Hence, this paper presents a state-of-the-art audit of the progressed control of SRMs, including current control procedures, torque control procedures and vibration concealment strategies. To begin with, two categories of current controllers are surveyed: model-independent and model-based. Another, circuitous and coordinate torque control strategies are investigated. At that point, three approaches to vibration concealment are talked about, specifically dynamic cancellation, current profiling and coordinate immediate constrain control. Finally, a rundown of each subject is displayed and proposals of future inquire about themes are recorded[2].This paper proposes an effective control system that utilizes dc-dc converters to realize adaptable control stream control in multiterminal dc (MTDC) lattices. The dc-dc converter utilized in this paper is associated in cascade with the dc transmission line, and is hence named cascaded control stream controller (CPFC). In this paper, a two-layer control procedure is created for the operation and control of voltage source converter stations and CPFC station in MTDC frameworks. At the essential control layer, a novel differential voltage hang control is created, whereas at the auxiliary control layer, adjusted dc control stream algorithmemploying the unused CPFC frameworkis executed [3]. In this paper, the three-phase inverter control effectiveness of a brushless DC (BLDC) engine drive is analyzed hypothetically and confirmed tentatively.A rearranged pulse width tweak driving plot has higher control productivity than an ordinary six-step driving plot, especially beneath moo rotor speed due to less diode conduction control misfortune of Adjust metal-oxide-semiconductor field-effect transistors (MOSFETs). Be that as it may, the distinction within the control proficiency diminishes as the rotor speed increments; for a rotor speed over 1000 r/min, the contrast within the control productivity is insignificant. In expansion, the control effectiveness of the rearranged driving plot drops advance than one for the ordinary six-step driving conspire with testing recurrence increment. It is due to the extra exchanging control misfortune of Adjust MOSFET. The hypothetical examination of control misfortune in a three-phase inverter confirms the exploratory comes about[4]. Lasting magnet (PM) brushless dc (BLDC) motor-based photovoltaic water pumps are getting to be prevalent in country zones due to their higher effectiveness and unwavering quality compared to acceptance motor-based pumps. The water table level in these country regions is ordinarily more than 15 m. Thus, profound bore-well submersible engines are utilized for extricating consumable water from the water table. The engine and controller are submerged within the water table, and have more temperature rise due to the destitute climate. In this way, control of a PM BLDC engine with hall-effect-based position sensors is questionable in these situations due to the temperature affectability of the hall-effect sensors. A position sensor less control conspire is executed to dispose of the utilize of lobby sensors, in this way making strides unwavering quality of the by and large framework. Furthermore, the challenges included within the control of a profound bore-well submersible ferrite PM BLDC engine are explained. The model of a 1.5-kW submersible BLDC engine drive is created and the test comes about are displayed[5].Ghastly lists can be characterized to characterize how the solar based range influences photovoltaic gadgets. The utilize of such lists is especially critical in innovations which are profoundly subordinate on unearthly varieties, such as couple, or multijunction (MJ), solar based cells. In this paper, we analyze the capability of three viable irradiance values, given by the photocurrents of the components of triple-junction solar based cells, and covering distinctive ghastly groups, to characterize the range condition.

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Indeed, in spite of the fact that these parameters will be based on a specific sort of MJ solar oriented cell, they give sufficient data to precisely evaluate the unearthly effect on other sorts of MJ solar based cell advances with essentially distinctive ghastly reactions. Subsequently, component cells for each MJ Solar oriented cell innovation may not be fundamentally required and a reference innovation can be utilized for all of them, giving a way for end of the standardization of these gadgets as a cruel of characterizing the sun powered ghastly condition [6]. The multiplication of(PV) establishments over the globe has quickened drastically within the past decade covering domestic, rustic, versatile, mechanical, and utility-scale applications. In all these cases, progressing payback time and vitality production for PV establishments could be a exceptionally complex plan tradeoff that includes numerous factors such as irradiance vacillations, inverter productivity, working temperature variety, and PV board sort. In this paper, a nitty gritty multivariate think about of PV plant plan is displayed, coming about in an progressed strategy to extend the potential benefits of sun powered plants with lower capital costs. This modern approach incorporates point by point thought of the probabilistic hourly temperature and sun powered illumination profile of the establishment location, the efficiencies and working zones of diverse grid-tie inverters, and point by point models of diverse PV modules within the ideal plan handle. The gathered vitality, add up to costs, and payback time are the objective capacities in this approach, whereas the number of arrangement and parallel boards, the tilt point, and inverter topology and PV module sort are decided from a list of conceivable candidates [7].In this paper, the plan and testing of a PC-interfaced PIC-based control unit utilized to oversee an assimilation spectrophotometer, utilizing a white Driven as light source, are depicted. Driven innovation permits to perform the assimilation estimations lessening the analyte temperature varieties and hence clamor era, which happen on the off chance that a Xenon light source, often utilized, is utilized; moreover, much obliged to Driven innovation, the framework comes about low fetched, simple to utilize and with a moo control utilization. The realized spectrophotometer can be utilized for barometrical and mechanical toxin discovery or for indoor discuss checking (e.g., in clinic rooms), being able to distinguish particulate matter, pesticides, unstable natural compounds as well as contamination created by overwhelming metals [8].In this paper, a fluffy controller connected to variable-speed drive for the utilize in direct-coupled photovoltaic (PV) pumping frameworks is proposed. The fluffy rationale framework utilized is of the Mandani sort, inserted in a microcontroller, and compares to a proportional-derivative controller. A low-power PV module is utilized to recognized varieties within the irradiance occurrence on the PV cluster. Experimental tests are performed employing a motopump testing workbench, which is able to mimic water wells with diverse manometric statures. The comes about appear that the fluffy controller is able of working the framework ceaselessly all through the day, with a normal proficiency of 23% [9]. Right now, little islands are confronting an vitality supply deficiency, which has driven to significant concern. Setting up an island microgrid could be a moderately great arrangement to the issue. In any case, tall speculation costs limit its application. In this paper, small scale pumped capacity (MPS) is utilized as an vitality capacity framework (ESS) for islands with great topographical conditions, and deferrable machine is treated as the virtual power source which can be utilized within the arranging and operational forms. Family acknowledgment of request reaction (DR) is demonstrated by the request reaction support degree (DRPD), and a measuring optimization show for considering the request reaction of family apparatuses in an island microgrid is proposed. In expansion, the battery capacity (BS) plot is utilized as the control bunch. The comes about of case ponders illustrate that the proposed strategy is successful, and the DR of deferrable apparatuses and the application of MPS can altogether decrease island microgrid speculation. Affectability investigation on the whole stack of the island and the water head of the MPS are conducted [10].

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III. PROPOSED METHODOLOGY

1. Block Diagram

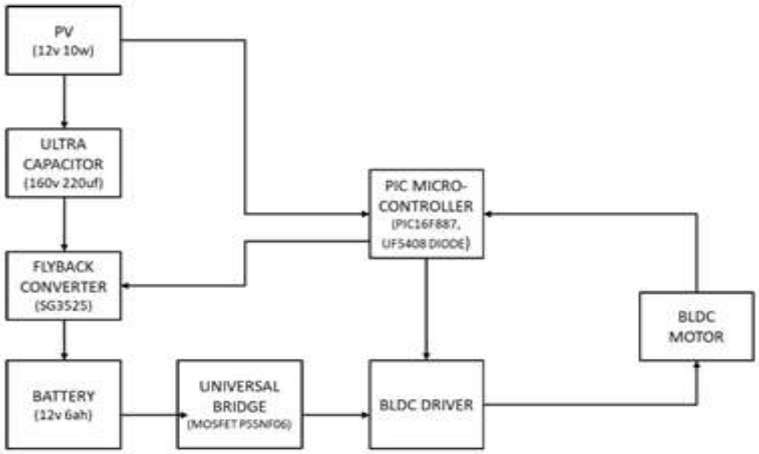

Fig. 1.Proposed Block Diagram

2. Working Methodology

As the name suggests, a BLDC motor-driven water pump is powered by a solar photovoltaic (PV) array. The solar PV-powered water pumping system operates by first harnessing solar energy through photovoltaic panels. These panels convert sunlight into direct current (DC) electricity. This DC electricity undergoes regulation by a DC/DC converter to match the system's requirements before being stored in a battery bank for continuous operation, even during periods of low sunlight.

When electricity is needed for water pumping, the stored DC power is converted into alternating current (AC) using a DC/AC converter (inverter). This AC power drives a Brushless Direct Current (BLDC) motor, which efficiently converts electrical energy into mechanical energy, powering the water pump.The system's operation is overseen by a PIC microcontroller, which acts as the central control unit. It regulates the BLDC motor's speed based on input signals from sensors and user commands, optimizing energy efficiency and pump performance. Additionally, the microcontroller monitors various parameters, such as water level and system voltage, to ensure smooth operation.

A control display provides a user-friendly interface for monitoring system status and adjusting. This allows users to view real-time data, set operating parameters, and receive alerts about any issues.In essence, the system operates autonomously, utilizing renewable solar energy to power the water pumping process. This integration of renewable energy technology with efficient water pumping mechanisms offers a reliable and sustainable solution for various applications, particularly in remote or off-grid areas.

IV. HARDWARE COMPONENTS

1. PV panel 12v 10w

A 12V, 10W solar photovoltaic (PV) panel is a compact and versatile energy solution commonly employed in various off-grid and low-power applications. Comprising multiple solar cells connected in series, this panel generates a voltage output of 12 volts and has a power output of 10 watts under standard test conditions. Despite its modest size, this panel is capable of efficiently converting sunlight into electrical energy, making it ideal for powering small-scale electronic devices and systems.In practical terms, this type of solar panel finds widespread use in remote or off-grid locations where access to traditional electricity sources is limited or non-existent. It is commonly utilized to charge batteries for portable devices such as smartphones, cameras, and GPS units, providing a reliable and renewable power source for outdoor activities, camping, or emergency situations. Additionally, it can be deployed to power LED lights, small water pumps for irrigation or livestock watering, and remote monitoring systems for environmental data collection or security purposes.Due to its compact size and ease of installation, the 12V, 10W solar PV panel offers a cost-effective and environmentally friendly alternative to conventional power sources in a wide range of applications. Its ability to harness solar energy efficiently makes it a valuable component in off-grid energy systems, contributing to sustainable energy solutions and reducing dependence on fossil fuels.

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Fig.2. PV panel 12v 10w

2. Dc/dc converter 12v5ah

A DC/DC converter rated for 12V, 5Ah is a crucial component in many electrical systems, particularly those requiring stable voltage regulation and efficient power conversion. This specification indicates that the converter is designed to step up or step-down DC voltage levels while delivering a maximum current of 5 amps.In practical terms, such a DC/DC converter serves various purposes in different applications. For instance, in automotive systems, it may be used to regulate the voltage supplied to sensitive electronic components, ensuring consistent operation despite fluctuations in the vehicle's electrical system. In renewable energy systems, it can be employed to efficiently transfer power between different voltage levels, optimizing energy harvesting from solar panels or wind turbines.The 12V, 5Ah rating implies that the converter can handle a load of up to 5 amps while maintaining a stable output voltage of 12 volts. This capacity makes it suitable for powering a wide range of devices and equipment, from small electronics to larger appliances, depending on their power requirements.Overall, a DC/DC converter with a 12V, 5Ah rating offers versatility, reliability, and efficiency in voltage conversion applications, contributing to the seamless operation of various electrical systems across different industries and sectors. Fig. 3. Shows the hardware for DC-DC converter.

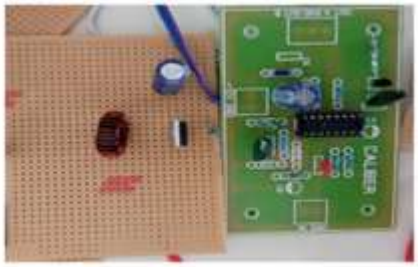

Fig. 3. Dc/dc converter 12v5ah

3. Battery 12v 6ah

A 12V, 6Ah battery is a compact yet capable power storage solution commonly utilized in a variety of applications, ranging from portable electronics to small-scale renewable energy systems. This specification indicates that the battery can deliver a constant current of 1 amp for approximately 6 hours before requiring recharging.In practical terms, this type of battery is often employed in off-grid or mobile scenarios where a reliable power source is needed. It can power a range of devices such as LED lighting systems, portable communication equipment, small appliances, and electronic gadgets. Additionally, it serves as a backup power source for critical systems like alarm systems, medical devices, and emergency lighting.The 12V voltage rating of the battery makes it compatible with many standard electrical devices and systems. Its 6Ah capacity provides sufficient energy storage for moderate power demands, allowing for extended operation without frequent recharging. This makes it suitable for use in remote locations, outdoor activities, and emergency situations where access to grid power may be limited or unavailable.Overall, a 12V, 6Ah battery offers a balance between compact size, capacity, and versatility, making it a valuable component in various power supply applications where reliability and portability are essential.

Fig. 4. Battery 12v 6ah

4. Pic16f887

The PIC16F887 is a popular microcontroller chip manufactured by Microchip Technology. It belongs to the PIC16 family of microcontrollers, which are widely used in embedded systems, consumer electronics, industrial automation, and many other applications. Here are some key features and characteristics of the PIC16F887Architecture:The PIC16F887 is based on a Harvard architecture with a reduced instruction set computer (RISC) design. It features an 8-bit CPU core with a relatively small instruction set, optimized for low-power and high-performance operation.Memory: It typically includes 14KB of flash program memory for storing user code, 368 bytes of RAM for data

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storage, and 256 bytes of Electrically Erasable Programmable Read-Only Memory (EEPROM) for non-volatile storage.Peripherals:The PIC16F887 offers a wide range of built-in peripherals, including analog-to-digital converters (ADC), serial communication modules (USART, SPI, I2C), timers/counters, pulse width modulation (PWM) modules, and capture/compare/PWM (CCP) modules. These peripherals provide flexible options for interfacing with external devices and sensors.Clock and Oscillator: It supports various clock sources and oscillator configurations, allowing for precise timing control and synchronization. The microcontroller can operate at speeds of up to 20 MHz, depending on the oscillator configuration.Power Management: The PIC16F887 features low-power modes and multiple power-saving features to optimize energy efficiency and extend battery life in portable applications.Development Tools: Microchip provides a comprehensive set of development tools for programming, debugging, and testing applications based on the PIC16F887 microcontroller. This includes integrated development environments (IDEs), compilers, debuggers, and programmers.Packaging: The PIC16F887 is available in various package options, including Dual In-Line Package (DIP), Thin Quad Flat Pack (TQFP), and Quad Flat Package (QFP), making it suitable for both through-hole and surface-mount applications.Overall,the PIC16F887 microcontroller offers a versatile and cost-effective solution for a wide range of embedded system designs.

Fig. 5. Pic16f887

5. MOSFET p55nf06

The P55NF06 is a popular power MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor) commonly used in various electronic circuits and applications. Here are some key features and characteristics of the P55NF06 MOSFET. Type: The P55NF06 is an N-channel MOSFET, meaning it conducts current when a positive voltage is applied to the gate relative to the source.Voltage Rating: It has a relatively high voltage rating, typically around 60 volts. This makes it suitable for applications requiring voltage levels beyond those handled by standard low-voltage MOSFETs.Current Handling: The P55NF06 can handle relatively high currents, often in the range of tens of amperes. This capability makes it suitable for power switching applications where significant current flows are involved.On-Resistance: It features a low on-resistance when fully enhanced, meaning it can conduct current with minimal voltage drop across the device. This low on-resistance results in reduced power dissipation and improved efficiency in power switching applications.Gate Threshold Voltage: The gate threshold voltage typically ranges from 2 to 4 volts. This is the voltage required to turn the MOSFET fully on and allow significant current flow from the drain to the source.Package: The P55NF06 is commonly available in TO-220 package, which provides good thermal performance and ease of mounting on a heatsink for applications requiring efficient heat dissipation.

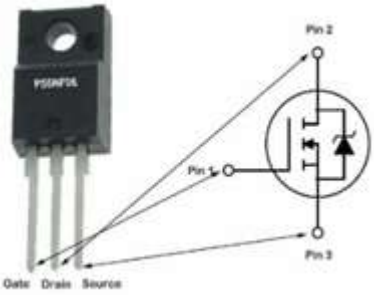

Fig. 6. MOSFET p55nf06

6. Sg3525

The SG3525 is a pulse width modulation (PWM) controller IC widely utilized in power electronics applications. It's adept at generating PWM signals to regulate the duty cycle of power transistors in devices like switching power supplies, inverters, and motor speed controllers. With a voltage operating range typically spanning 8V to 35V, it suits both low and high voltage systems. The SG3525 facilitates adjustable frequency control, often ranging from a few hundred Hz to several kHz, contingent on external components. Its soft-start function gradually ramps up output voltage, diminishing inrush current during startup. The IC also encompasses an error amplifier with a voltage reference for output regulation by comparing feedback with a reference voltage. Furthermore, it can synchronize with external clock signals. Protective features include overcurrent, overvoltage protection, and thermal shutdown. Packaged in dual in-line (DIP) or surface-mount options, the SG3525 is easy to integrate into electronic circuits. Its versatility, precise PWM signal control, adjustable frequency,

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and various protection features make it a cornerstone in power electronics design.

Fig. 7. Sg3525

7. UF5408 diode

The UF5408 diode is a high-speed switching diode designed for rectification and freewheeling applications. With a high reverse voltage rating typically around 1000 volts (1 kV), it can withstand high reverse voltage conditions. Its fast-switching speed and low forward voltage drop make it suitable for high-frequency switching applications like switch-mode power supplies and voltage multiplier circuits. Additionally, its capability to handle high surge currents and relatively low reverse recovery time further enhances its suitability for circuits with transient voltage spikes or high inrush currents. Packaged in axial lead package, it offers easy mounting and soldering onto printed circuit boards. Overall, the UF5408 diode is a versatile and reliable component widely used in power supply and rectification circuits where efficiency, speed, and high voltage capability is crucial.

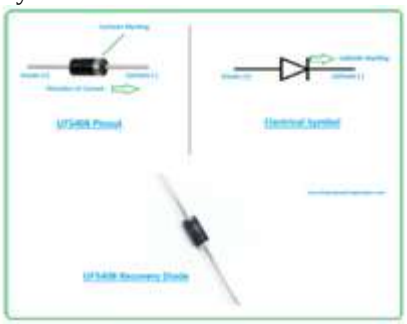

Fig. 8.UF5408 diode

8. LCD display 16 x 2

Fig. 9. Shows the picture A 16x2 LCD (Liquid Crystal Display) module is a common and widely used alphanumeric display in various electronic devices and systems. The "16x2" designation refers to the dimensions of the display, indicating that it can display 16 characters in each of its two rows. Each character position can typically display alphanumeric characters, symbols, or custom-defined characters.They provide a simple and cost-effective means of displaying information in a compact format, making them suitable for a wide range of applications, from consumer electronics to industrial control systems. The 16x2 LCD modules typically use parallel or serial communication interfaces for interfacing with microcontrollers, and they often include built-in character generator ROM for displaying standard alphanumeric characters.

Fig. 9.16 x 2 LCD display

9. BLDC driver

A BLDC (Brushless Direct Current) motor driver is an electronic circuit designed to control the operation of a BLDC motor by regulating the power supply to its windings. It typically consists of power transistors, gate drivers, and control logic. The driver generates the necessary commutation signals to energize the motor's phases in the correct sequence, enabling smooth rotation. Additionally, it may include features such as speed control, current limiting, and protection mechanisms to ensure safe and efficient motor operation. BLDC motor drivers are commonly used in various applications, including automotive systems, industrial automation, robotics, and consumer electronics, where precise speed control, high efficiency, and reliability are essential.

10. BLDC pump

A BLDC (Brushless Direct Current) pump is a type of electric pump driven by a BLDC motor, offering advantages such as higher efficiency, longer lifespan, and quieter operation compared to traditional brushed DC or AC motors. These pumps are widely used in various applications such as water circulation, HVAC systems, aquariums, and medical devices. The absence of brushes in the motor design reduces friction and wear, resulting in lower maintenance requirements and improved reliability over time.BLDC pumps are known for their precise control of flow rates and pressure, making them suitable for applications requiring accurate fluid delivery.

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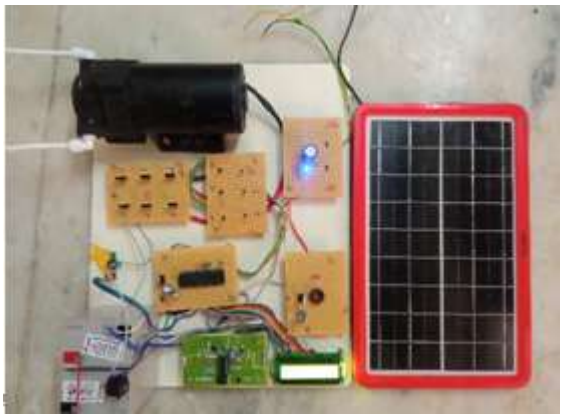

Fig. 10.Sustainable Water Supply with Solar PV Energy Storage and BLDC Technologyfor Efficient Water Pumping.

V. RESULTS AND DISCUSSION

Result and discussion of Sustainable Water Supply with Solar PV Energy Storage and BLDC Technology for Efficient Water Pumping with existing system. Here the difference can be valued by the input of the pic microcontroller. The values of this existing and proposed system were shown in Table. 1. Here we can get the appropriate values for both existing and proposed system power, input voltage, advantages etc.,

Table. 1.Difference BetweenExisting System and Proposed System

EXISTING SYSTEM	**PROPOSED SYSTEM**
Input Voltage by domestic supply is 100 V	Input Voltage by solar energy is 12 V to 48 V
Motor: Switched Reluctance Motor (SRM)	Motor: Brushless Direct Current Motor (BLDC)
PI Controller used	PIC Microcontroller used
Power: 2.2 KW	Power: 29.26 KW
High Noise	Lesser Noise
Efficiency is 88.8%	Efficiency is 97.55%
High Maintenance	Low Maintenance

VI. CONCLUSION AND FUTURE SCOPE

The integration of BLDC motors with solar PV power presents a promising solution for water pumping applications, offering high efficiency, reliability, and sustainability. The proposed system, comprising solar PV panels, a DC/DC converter, batteries, a DC/AC converter, a BLDC motor, and a PIC microcontroller, demonstrates the feasibility and effectiveness of harnessing renewable energy for water pumping in remote areas. By providing a reliable and environmentally friendly water pumping solution, the system contributes to improving access to clean water and promoting sustainable development.Moving forward, there are several avenues for further enhancement and optimization of the proposed system. Furthermore, research into alternative energy storage solutions, such as advanced battery technologies or hybrid energy storage systems, can improve the system's energy autonomy and reliability. Overall, continued innovation and research in these areas can lead to even more efficient and sustainable water pumping solutions for off-grid and remote communities.

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