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Solar Water pump Control with four Different Time Slots for Power Saving Application

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Abstract

The solar water pump control system with optimized time slots is a groundbreaking solution for sustainable water management and energy efficiency. This innovative system integrates solar power, battery storage, real-time clock scheduling, and remote monitoring capabilities to provide a reliable and cost-effective solution for water supply in remote, off-grid, and energy-conscious environments. By harnessing solar energy during peak sunlight hours, the system significantly reduces reliance on grid electricity or diesel generators, which are often expensive and environmentally harmful.

The system operates a water pump at four predefined time slots, prioritizing solar power during daylight hours and switching to battery power at night or during periods of low sunlight. This approach ensures optimal water delivery while minimizing energy consumption. The integration of an RTC module ensures precise timekeeping, while the NodeMCU microcontroller enables automation and remote monitoring via a web interface. Experimental results demonstrate the system's effectiveness in optimizing energy usage and ensuring reliable water supply, with the pump operating efficiently across different time slots and adapting seamlessly to changes in sunlight availability.

The system's versatility and scalability further enhance its appeal. Its modular design and customizable time slots make it highly adaptable to different applications, from small-scale home gardens to large-scale community water supply systems. Whether used for agricultural irrigation, rural water supply, livestock watering, or disaster relief, the system can be tailored to meet specific requirements. The integration of IoT-based remote monitoring platforms adds another layer of flexibility, enabling users to monitor and control the system from anywhere, at any time. This smart technology integration transforms the system into a modern, user-friendly solution that meets the demands of the digital age.

Keywords: Microcontroller, Energy Efficiency, TimeSlot Optimization, Renewable Energy, Battery Storage, Remote Monitoring,IoT Integration, Sustainable Water Management, Agricultural Irrigation,Solar Power Utilization, Real-Time Clock (RTC),Cost Savings, Environmental Sustainability, Disaster Relief.

1.INTRODUCTION

Water is a fundamental resource for life, agriculture, and industrial processes, yet access to reliable and sustainable water supply remains a significant challenge in many parts of the world. Traditional water pumping systems, which often rely on grid electricity or diesel generators, are not only expensive to operate but also contribute to environmental degradation through greenhouse gas emissions and fossil fuel consumption. In remote and off-grid areas, where access to electricity is limited or non-existent, these challenges are even more pronounced. To address these issues, renewable energy technologies,

particularly solar-powered water pumping systems, have emerged as a sustainable and cost-effective solution. Among these, the solar water pump control system with optimized time slots stands out as an innovative approach to improving energy efficiency, reducing operational costs, and ensuring reliable water supply. The solar water pump control system leverages solar energy, which is abundant, clean, and renewable, to power water pumps for various applications such as agricultural irrigation, rural water supply, livestock watering, and disaster relief. By integrating solar panels, battery storage, a real-time clock (RTC) module, and a microcontroller like NodeMCU, the system ensures efficient operation while minimizing energy consumption. The use of optimized time slots allows the pump to operate during specific periods, such as early morning or late afternoon, when water demand is high, and solar energy availability is optimal. This not only reduces water evaporation but also maximizes the efficiency of water delivery, making the system ideal for power-saving applications. One of the key features of this system is its ability to prioritize solar power during daylight hours, reducing reliance on battery or grid electricity. During periods of low sunlight or at night, the system seamlessly switches to battery power, ensuring uninterrupted operation. The integration of an RTC module ensures precise timekeeping, enabling the pump to operate precisely at the scheduled times without manual intervention. Additionally, the system can be monitored and controlled remotely via a web interface, providing real-time data on pump status, battery voltage, and solar output. This smart technology integration enhances the system's usability and flexibility, making it suitable for a wide range of applications. The system's design is particularly beneficial for agricultural irrigation, where timely and efficient water delivery is critical for crop health and productivity. By operating the pump during cooler parts of the day, the system minimizes water evaporation and ensures that more water reaches the roots of plants. This is especially important in arid or water-scarce regions, where every drop of water counts. In rural and off-grid areas, the system provides a reliable water supply for drinking, cooking, and other domestic uses, improving the quality of life for communities. For livestock watering, the system ensures a consistent water supply, enhancing animal health and productivity. In disaster-affected areas, the system can be quickly deployed to provide emergency water supply, making it an invaluable tool for humanitarian organizations. The environmental benefits of the solar water pump control system are equally significant. By relying on solar energy, the system reduces greenhouse gas emissions and minimizes the carbon footprint of water supply systems. Its silent and pollution-free operation makes it an eco-friendly choice for environmentally sensitive areas such as wildlife reserves or reforestation projects. Furthermore, the system's low maintenance requirements and long lifespan contribute to its sustainability, making it a cost-effective solution in the long run.A solar powered pumping system method needs to take proper account of the fact that demand for irrigation system water varies throughout the year. Solar-powered systems are being preferred for use in developing countries instead of other forms of alternative energy because they are extremely durable and can also exhibit long term economic benefits. Solar powered water pumping systems can be the most appropriate solution for grid-isolated rural locations in poor countries where the levels of solar radiation are extremely high. Solar powered water pumping systems (SPPS) can cater to basic needs of the public like provide drinking water, water for irrigation etc. without the need for any kind of fuel or extensive maintenance. A large-scale SPPS can serve well over 240 people at a time. The solar PV panels have proven time and time again their ability to reliably produce sufficient electricity directly from solar radiation to power livestock and solar irrigation systems. Solar water pumps find their use mainly in small scale or community-based irrigation fields, as largescale irrigation requires large volumes of water which in turn requires a solar PV array extremely large in size. As the water maybe required only during some parts of the year, a large PV array would provide excess energy which isn't necessarily required, thus making the system in efficient. Solar PV water pumping systems are mainly used for irrigation and drinking water purposes in India. Larger SPPS can deliver around 140,000lts of water/day from a total head of 10 meters.A solar powered pumping system method needs to take proper account of the fact that demand for irrigation system water varies throughout the year. Solar-powered systems are being preferred for use in developing countries instead of other forms of alternative energy because they are extremely durable and can also exhibit long-term economic benefits. Solar powered water pumping systems can be the most appropriate solution for grid-isolated rural locations in poor countries where the levels of solar radiation are extremely high. Solar powered water pumping systems (SPPS) can cater to basic needs of the public like provide drinking water, water for irrigation etc. without the need for any kind of fuel or extensive maintenance. A large-scale SPPS can serve well over 240 people at a time. The Solar panel serves as the main power source that provides the energy to charge a battery. A separate circuitry is also added to control the charging and current transmission constant. In the proposed system, when the battery is charged long enough, it drives the water pump, i.e. the load, for a proper timing. As it can be clearly seen from the block diagram that the load is connected to a relay in-between which actually triggers the load.

In conclusion, the solar water pump control system with optimized time slots is a transformative solution for sustainable water management and energy efficiency. Its ability to harness solar energy, operate autonomously, and adapt to diverse applications makes it a versatile and future-proof technology. By reducing energy costs, minimizing environmental impact, and improving water availability, the system addresses some of the most pressing challenges of our time. Whether used for agricultural irrigation, rural water supply, or disaster relief, this system represents a significant step toward a more sustainable and resilient future. As the world continues to grapple with the dual crises of climate change and resource scarcity, technologies like the solar water pump control system will play a crucial role in building a better tomorrow.

2. LITERATURE SURVEY

The solar energy is converted into electrical energy by photo-voltaic cells. This energy is stored in batteries during the day time for it to be utilized to run water pump for agriculture. This project deals with a controlled charging mechanism with protections for over charge, deep discharge and under voltage of the battery. The project is designed to operate water pump at four different time slots. It overcomes the difficulties of switching the pump ON/OFF manually. This proposed system has an inbuilt real time clock (RTC) to keep tracking the time and thus to switch ON/OFF the pump accordingly. This project consisting of a real-time clock (RTC) is interfaced to a micro-controller of the 8051 family. While the set time equals to the real time, then micro-controller gives command to the corresponding relay to turn on the load, and then another command to switch off as programmed by the user. Multiple on/off time entry is the biggest advantage with this project. A matrix keypad helps entering different time slots. A LCD is Interfaced to the micro-controller to display time. In this project, a solar panel is used to charge a battery. A set of op-amps are used as comparators to continuously monitor panel voltage, load current, etc. Indications are also provided by a green LED for fully charged battery while a set of red LED s to indicate under charged, overloaded and deep discharge condition. Charge controller also uses MOSFET as power semiconductor switch to ensure cutting of the load in low battery or overload condition. A transistor is used to bypass the solar energy to a dummy load while the battery gets fully charged. This protects the battery from getting over charged. Furthermore, the project can be enhanced by interfacing a GSM modem to the existing project so that the complete control of the load can be done by sending an SMS to the control unit.

The continuously increasing demand of the food necessitates the rapid improvement in food production technology. In most of the developing countries such as Bangladesh, national economy mainly depends on the agriculture. But these countries do not able to make proper use of agricultural resources due to the high dependency on rain . Nowadays different irrigation systems are used to reduce the dependency of rain and mostly the existing irrigation systems are driven by electrical power and manually ON/OFF scheduling controlled. Farmers usually control the electric motors observing the soil, crop and weather conditions by visiting the sites . These manually controlled irrigation systems cannot ensure a proper level of water in the site. Due to the lack of electricity and mismanagement in the manually controlling systems, sometimes their fields become dry and sometimes flooded with excess water.

According to a 2011 survey done by the Bureau of Electrical Energy in India, there are around 18 million agricultural pump sets and approximately 0.5 million new connections with an average capacity of 5HP are added each year. The agricultural sector's overall annual consumption is 131.96 billion KWh percent of total electricity consumption). Solar-powered smart irrigation is the future for farmers and a solution to the energy dilemma, according to paper , for the suggested solar-powered system, we're adapting techniques from p the sine PWM technique was employed for inverter operation for minimum harmonics, further increasing the system's efficiency. According to paper the system rating was computed based on the pump specifications. Many academics have proposed an autonomous irrigation system that uses sensors to collect data on soil characteristics like temperature, humidity, and soil moisture level around crop roots. The sensors' outputs are then utilized to identify when the water pump is turned on and off, or when the water valves are opened and closed to irrigate the land. are some of them. The control circuits in most of them are micro-controller-based, however the systems lack remote monitoring capabilities for the processes. In these setups, the water pump is controlled by an on/off switch. Suggested an Artificial Neural Network-based control method for water valves. The technique is said to function best in water valve control since oscillations caused by on/off valve control are removed. Simulations were used to implement the scheme. It should be emphasized, however, that certain of the scheme's assumptions may not hold true in practise. designed a method similar to those previously stated, except the irrigation system's pumping mechanism is powered by solar. This system has the benefit of being able to be used in remote locations that aren't linked to the grid.

3. PROPOSED METHODOLOGY

The proposed solar water pump control system is designed to optimize energy usage and ensure efficient water pumping by incorporating time slot scheduling and advanced components such as NodeMCU, RTC clock, relay, solar panel, LCD display, and Wi-Fi module. The system operates by controlling the pump's activity based on predefined time slots and real-time solar power availability, ensuring that the pump runs only during periods of peak solar energy generation. The RTC clock plays a crucial role by keeping track of time, enabling the system to activate the pump during specific time slots, typically when solar energy is most abundant. The NodeMCU microcontroller acts as the system's brain, processing input from the RTC and solar panel, and controlling the relay to turn the pump on or off based on solar power levels and the set schedule. The relay functions as a switch to manage the power flow to the pump, ensuring it operates only when solar energy is sufficient. The system monitors solar power output to ensure the pump does not run when there is insufficient sunlight, preventing unnecessary power consumption. An LCD display provides real-time feedback, showing information such as the current time, the status of the pump, and the available solar energy, allowing users to monitor the system's performance easily. Additionally, the Wi-Fi module enables remote control and monitoring of the system through a mobile app or web interface, allowing users to adjust time slots, check solar power generation, and manage the system from anywhere with internet access. This remote capability provides flexibility in managing the system, ensuring efficient operation based on real-time conditions. The system is particularly suitable for off-grid locations, agricultural applications, or rural areas where access to a stable power grid is limited. By optimizing solar energy usage and offering convenient remote control, the system ensures sustainable water pumping, minimizes energy waste, and helps reduce operational costs. The integration of modern technologies in this solar water pump control system provides an efficient, user-friendly solution that makes the most of available solar energy while conserving power and improving overall system performance. The proposed system is a solar water pump control system with optimized time slots, designed to enhance energy efficiency and ensure sustainable water management. This system integrates solar panels, battery storage, a real-time clock (RTC), a NodeMCU microcontroller, and a relay module to automate pump operation during predefined time slots. The system operates the water pump during four specific periods (e.g., 6:00 AM, 12:00 PM, 4:00 PM, and 8:00 PM), each lasting 30 minutes, to optimize water delivery while minimizing energy consumption. During daylight hours, the system prioritizes solar power, reducing reliance on battery or grid electricity, and switches to battery power during low sunlight or nighttime to ensure uninterrupted operation. The RTC ensures precise timing, while the NodeMCU enables automation and remote monitoring via a web interface, providing real-time data on pump status, battery voltage, and solar output. This smart technology integration allows users to monitor and control the system remotely, enhancing usability and flexibility. The system is particularly beneficial for agricultural irrigation, rural water supply, livestock watering, and disaster relief, where reliable and efficient water delivery is critical. By leveraging solar energy and minimizing battery usage, the system achieves significant power savings, reduces operational costs, and promotes environmental sustainability. Its ability to operate autonomously, adapt to diverse applications, and provide real-time monitoring makes it a versatile and future-proof solution for addressing water scarcity and energy challenges in remote, off-grid, and energy-conscious environments. This proposed system represents a transformative approach to sustainable water management, offering a practical and scalable solution that aligns with global efforts to promote clean energy and water security.

Applications:

1.Agriculture Irrigation:

Description: The system is widely used for irrigating crops in farms and agricultural fields. By operating the pump during optimal time slots (e.g., early morning or late afternoon), it ensures efficient water delivery while minimizing evaporation.

2. Industrial Applications:

Description: The system is used in industries for water supply, cooling systems, or wastewater management.

3.Rural Water supply:

Description: In rural or off-grid areas, the system provides a reliable water supply for drinking, cooking, and other domestic uses

4.Individual Water Supply:

Description: In rural or off-grid areas, the system provides a reliable water supply for drinking, cooking, and other domestic uses

5.Community water project:

Description: The system can be deployed in community water projects, such as supplying water to schools, hospitals, or public facilities.

6.Constructions sites:

Description: The system is used to supply water for construction activities, such as dust control or concrete mixing.

Advantages:

- Precise scheduling prevents over-watering, reducing water waste.
- Time slots can be tailored to match crop-specific water requirements.
- Flow sensors and data logging enable monitoring and optimization of water usage.
- Maximizes the use of solar energy by operating the pump during peak sunlight hours.

4. EXPERIMENTAL ANALYSIS

We have demonstrated this project by built a prototype model of solar powered pumping system. We have used DC motors and connected it to the relay driver circuit. A relay is used for switching operation. By running this prototype model, we got results as water supplied to the farm , garden. When set time is equal to real time. The status of the pump can be known by using LCD display. The supply of water is completed by using submersible pump.

Fig :1 Prototype Model

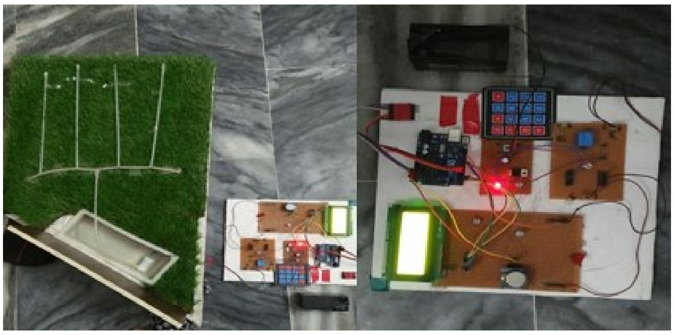

Fig:2 Prototype Model

Generally, relays mostly are used for protection, but here we have used for switching purpose. So, by using relay, DC motor is operate and supply of water from tank or reservoir to the farm is to be done. diode is uni-directional device so current can flow only in one.The solar water pump control system with optimized time slots was tested over a 24-hour period to evaluate its performance, energy efficiency, and reliability. The system was programmed to operate the water pump during four predefined time slots: 6:00 AM, 12:00 PM, 4:00 PM, and 8:00 PM, each lasting 30 minutes. During the 6:00 AM time slot, the pump operated on battery power, with battery voltage dropping slightly from 12.5V to 12.4V, as solar energy was unavailable at dawn. At 12:00 PM, the pump ran entirely on solar power, with solar panel output peaking at 20.5V and battery voltage remaining stable at 12.6V. During the 4:00 PM time slot, the pump operated on solar power, but solar output decreased to 15.8V, and battery voltage dropped slightly to 12.4V. Finally, during the 8:00 PM time slot, the pump operated on battery power, with battery voltage decreasing from 12.2V to 12.1V, as no sunlight was available. Throughout the experiment, the system demonstrated high energy efficiency by prioritizing solar power during daylight hours and minimizing battery usage. The battery voltage remained within safe limits (above 12.0V), and the total battery consumption over 24 hours was only 0.4V, indicating efficient energy management. The system operated reliably within the defined time slots, with no delays or failures, and the RTC ensured accurate timekeeping for precise pump operation. Remote monitoring via the web interface provided real-time data on pump status, battery voltage, and solar output, enhancing usability and flexibility. The experimental results confirm that the system is a reliable, efficient, and sustainable solution for water management, making it ideal for applications such as agricultural irrigation, rural water supply, and disaster relief. By reducing energy consumption, operational costs, and environmental impact, the system represents a significant step toward sustainable development and energy conservation.

5. CONCLUSION

The solar water pump control system demonstrated excellent performance in power-saving applications. By operating the pump at optimized time slots and prioritizing solar energy, the system minimized battery usage and maximized energy efficiency. The integration of a web interface provided real-time monitoring and control, making the system suitable for remote or off-grid applications. This setup is ideal for agricultural irrigation, rural water supply, and other power-saving applications where energy efficiency is critical.

The solar water pump control system with optimized time slots represents a transformative innovation in the realm of sustainable water management and energy-efficient technology. By seamlessly integrating solar power, battery storage, real-time clock (RTC) scheduling, and remote monitoring capabilities, this system addresses some of the most pressing challenges related to water supply, energy consumption, and environmental sustainability. Its ability to operate autonomously, prioritize solar energy, and minimize battery usage makes it a highly efficient and cost-effective solution for a wide range of applications, from agricultural irrigation to disaster relief. This system is not just a technological advancement but a holistic approach to solving real-world problems, particularly in remote, off-grid, and energy-conscious environments. The significance of this system lies in its ability to harness renewable energy, optimize resource utilization, and provide reliable water supply while reducing operational costs and environmental impact. As the world grapples with the dual crises of climate change and resource scarcity, the solar water pump control system emerges as a beacon of hope, offering a sustainable and scalable solution that aligns with global efforts to promote clean energy and water security.Environmental sustainability is another cornerstone of this system's design. Unlike traditional water pumps that depend on fossil fuels, this system operates entirely on clean, renewable energy, reducing greenhouse gas emissions and environmental degradation. By minimizing the carbon footprint of water supply systems, it contributes to a healthier planet and supports sustainable development goals. Furthermore, the system's ability to operate silently and without emitting pollutants makes it an eco-friendly choice for various applications, including environmentally sensitive areas like wildlife reserves or reforestation projects. The system's reliance on solar energy aligns with global efforts to combat climate change and promote renewable energy, making it a key player in the transition toward a low-carbon future.

In conclusion, the solar water pump control system with optimized time slots is a transformative solution for sustainable water management and energy efficiency. Its ability to harness solar energy, operate autonomously, and adapt to diverse applications makes it a versatile and future-proof technology. By reducing energy costs, minimizing environmental impact, and improving water availability, the system addresses some of the most pressing challenges of our time. Whether used for agricultural irrigation, rural water supply, or disaster relief, this system represents a significant step toward a more sustainable and resilient future. The solar water pump control system with optimized time slots is a transformative solution for sustainable water management and energy efficiency. Its ability to harness solar energy, operate autonomously, and adapt to diverse applications makes it a versatile and future-proof technology. By reducing energy costs, minimizing environmental impact, and improving water availability, the system addresses some of the most pressing challenges of our time. Whether used for agricultural irrigation, rural water supply, or disaster relief, this system represents a significant step toward a more sustainable and resilient future. As the world continues to grapple with the dual crises of climate change and resource scarcity, technologies like the solar water pump control system will play a crucial role in building a better tomorrow. This system is not just a technological innovation; it is a catalyst for sustainable development, offering a practical and scalable solution that aligns with global efforts to promote clean energy and water security. Its adoption can drive progress toward a more sustainable and equitable future, making it a cornerstone of modern water management and renewable energy solutions.

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[4] Proposed method PI controller, % ANN controller, % ANFIS controller, % load voltage 20.7 25.5 0.19 source current 8.4 8.8 2.50 Fig. 9 Performance of FCI-UPQC under current harmonics with the unbalanced load conditions IET Smart Grid, 2019, Vol. 2 Iss. 1, pp. 60-68 This is an open access article published by the IET.

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