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RESEARCH ARTICLE

Energetic and highly reliable photovoltaic power source assisted water pump control system design using IoT

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Abstract

The tools used in agriculture are evolving quickly. The advancement of farming technology, farm infrastructure, and manufacturing facilities is ongoing. Numerous photovoltaic (PV) systems may be used in agriculture. These use cases include both standalone installations and larger systems put in place by utilities when they determine that PV technology is the most cost-effective way to meet a specific remote agricultural demand, such water irrigation for fields or cattle. The heart and soul of a solar-powered water pumping system are two solar panels. The solar cell is the smallest component of a photovoltaic panel. Here, we connect the ESP module's outputs to those from sensors installed in the PV panels' controller and water pump. With the use of the GSM module, the main controller unit may show the status of each module, such as whether the motor is on or off, on the administrator's mobile phone. In the event of a motor failure, the malfunctioning component can be identified. Challenges to agricultural land development include transport and road conditions. In this study, we'll look at the numerous options open to the farmer. The primary goal of this study is to develop a solar-powered, Internet of Things (IoT) and GSM-controlled water pump. This reduces the need for human labor (from farmers) in outlying areas. The farmer's mobile device serves as the hub for all activities.

Keywords: Solar, Photovoltaic, Water pump, Internet of things, ESP module.

Introduction

In rural regions or anywhere the use of renewable energy is encouraged, photovoltaic or (PV) panels are a common sight powering farms and other agricultural endeavors. Especially, they are being shown to dependably generate enough energy from radiation from the sun to run agricultural and farm watering systems (Harish Kumar Varma Gadiraju, *et al.*, 2022). The increasing need for water for livestock and irrigation often coincides with the seasonal rise in incoming solar energy, which is a boon for solar-powered agricultural water pump systems. These PV systems may have a reduced environmental impact and lower long-term costs compared to traditional power systems when they are constructed appropriately. A solar-powered system can only pump a certain quantity of water in a particular time period, and that amount is proportional to the entire quantity of energy from the sun available during that time. The amount of solar power accessible and the dimension of the PV system utilized for transforming that solar radiation intodirect current (DC) power are the two main factors that affect the pumping rate of the water (Altimania, M. R., *et al.*, 2023) (Figure 1). Fundamental parts of an internet of things (IoT) assisted PV-assisted water pumping system is the rapidly expanding network of physically located objects that have been assigned an IP address to enable internet connectivity and subsequent communication among other Internet-enabled gadgets and structures. The term "things" refers to anything having embedded technology that can communicate with and interact with its external environment, including but not limited to computers, smartphones, and tablets. Solar energy has the potential to reduce reliance on foreign

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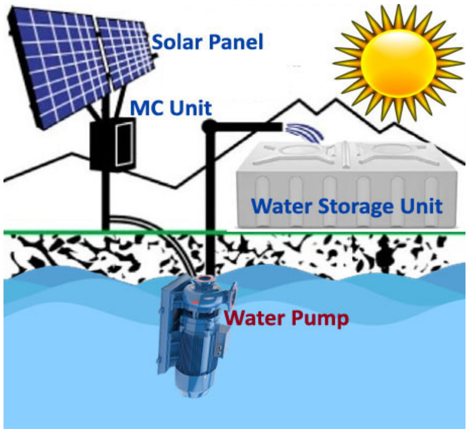

Figure 1: PV array, the controller, water pump and storage container make up a standard PV operated water pump unit

energy supplies because of its widespread availability. All of Earth's annual energy requirements can be met by the sunlight that hits the globe in only 90 minutes. During operation, solar PVs produce zero emissions of greenhouse gases (GHGs) and no other pollutants. Ventures in further adaptable resources, including demand-side assets, energy preservation, infrastructure for the grid, and flexible generation, is possible thanks to solar's internet-enabled, system-friendly deployment and improved operating strategies, such as progressed green energy predicting and improved organizing for energy plants (Amirthalakshmi, T. M., *et al.*, 2022).

Semiconductor materials are used to create the solar cells that make up a PV module. Electrons in a substance are dislodged when subjected to a strong enough light pulse. By connecting electrical wires to the material's positive and negative sides, a direct current may be generated from the caught electrons. A load, such as an irrigation system, may be powered by this energy after it has been created, or the electricity can be kept within a storage device (Choudhary Piyush, *et al.*, 2018). Solar PV modules are only effective at producing energy during daylight; therefore PV systems need a backup power source to keep working after sunlight sets low. During the day, energy from the sun can be kept as the water in a reservoir and at night, when it is required, gravity can release the water to wherever it is required. A battery needs to keep the electric power produced during the day for use in electrical appliances at night (Pires, V. F., *et al.*, 2022). To make sure everything works as it should and that all the parts are compatible, it's crucial that the system be designed as a whole. Getting everything from the same place will guarantee that everything works together well. To create a pump that runs on solar energy, you'll need to know: The amount of sunlight accessible at a given location (also known as "solar isolation"). The quantity of water needed for animals, irrigation, and storage throughout a specific time period. It is advised that livestock operations have enough water stored for three days in case of emergency or gloomy weather. The accompanying chapters will begin with an overview of the fundamental ideas behind solar-powered pump systems, followed by detailed descriptions of the aforementioned specific system components and architectural considerations for each (Jayaudhaya, J., *et al.*, 2023).

PV System

PVs are a mature, tested technology supported by a sizable international market. PV is becoming more economical than both expanding the electricity grid and installing renewable sources in outlying areas. Today, a peak watt of PV electricity costs roughly 122 INR. Shipping fees and import taxes are only two examples of how local supply circumstances might affect pricing. PV systems are a cost-effective means of delivering energy to outlying areas of agricultural enterprises including farms, ranches, orchards, and other similar enterprises. Even if you're only 15 meters from a functioning power supply, you may technically call it a "remote" location. In electric fence, area or structure illumination, and water supply — for animal watering or agricultural irrigation — PV systems may be significantly more cost-effective than constructing electrical lines and transformers that step down (PM, A. S. 2021, December).

Related Study

Water pumping systems are only one example of the various industrial uses for PV systems, which are among the most promising renewable energy sources. The purpose of this research is to suggest a novel application of a PV system in combination with a three-phase induction motor for the purpose of water pumping; the goals are to optimize daily water output as well as the efficiency of the three-phase induction motor and the harvesting of the PV system. In order to do this harvesting, the PV system makes use of a technique known as maximum power point tracking (MPPT). The approach that has been suggested may be employed in any operating circumstance involving a PV-powered three-phase induction motor water pumping system (PV-IMWPS). First, an analytical method for determining the ideal firing pattern (V-F) of the inverter for the motor with the assistance of flux management is given. This is done by looking at the data. This flux control enables MPPT of the PV system, which results in the motor operating at its highest possible efficiency regardless of the irradiance or temperature. In order to evaluate the usefulness of the analytical optimum flux control that has been provided, a comparison is made with a conventional flux control. It has been shown that the optimum flux management that was presented may increase a number of metrics, some of which include the daily pumped volume, the power factor of the motor, and the overall efficiency of the system. Second, the outputs of the initial analytical phase are input into an adaptive neuro-fuzzy inference system to be transformed into a more intelligent approach. This system is trained offline utilizing the input, and the output is the inverter pattern, which is utilized to increase the efficiency of the proposed pumping system (Ramkumar, G., *et al.*, 2021).

The vast majority of the renewable water pumping systems discussed in the research literature are a single supplier system (often PV), whereas just a few multi-source systems are mentioned. This paper provides a comprehensive literature analysis on the topic of mixed sustainable technologies that are employed to water pumping, assessing the practicability and the multiple sources used as a foundation for subsequent research (Cruz Igor Souza, *et al.*, 2022) and it delivers a comprehensive literature review on the subject of mixed sustainable technologies that are applied to water pumping. In 86% of the articles talk about solar-PVs, whereas only 81% talk about wind energy and 53% talk about hydroelectric.

A solar-powered water-pumping system that makes use of a switching reluctance motor (SRM) is the subject of this study's primary emphasis, which is the use of computational modeling to the design and evaluation of the system's performance. SRM motor drives have a variety of advantages over conventional ac and dc motor drives. These advantages include a greater speed range, improved power density, less inertia, and a shorter reaction time. This system makes use of an upgraded SEPIC converter for its intermediate DC-DC converter. This kind of converter offers a significant voltage gain while undergoing very little stress. Monitoring the maximum power output of a PV panel may be done *via* the use of an incremental conductance method. The SRM uses a closed-loop control system, and the current and the velocity are used as feedback signals in this system. We are going to simulate and analyze a water pumping system that has a power output of 1.2 kilowatts (kW) using this particular configuration. According to the calculations, this particular site would be an excellent position for a solar-powered water pump. In simulation experiments carried out in a diverse set of circumstances, the static and dynamic performances have been shown to be satisfactory.

The pace of population growth that has been seen over the last several years has resulted in a significantly increased demand for agricultural goods. Irrigation is an essential component in the distribution of food all over the world. Electric field irrigation provides a challenge and an added expenditure for farmers because of the high cost of electricity and the need for continuous, uninterrupted service. Despite the fact that governments continue to subsidize energy production, global energy consumption is on the increase. In view of our increasing dependence on agriculture and the issues they confront on a daily basis, the current grid-linked strategy may result in high expenses, the need for additional acreage, and the need for regular maintenance. Moreover, this technique may also demand more frequent upkeep. DC pumps help farmers overcome these difficulties and open the way for more intensive farming. Three solar panels form the basis of this system, which also includes a 0.75 kW DC motor. Because DC motors can store energy generated by the system, they may be utilized at night or in an emergency to keep the lights on. The elimination of the need for fuel to power pumps is a major benefit to the environment provided by this method. The system's inherent independence and small footprint are two of its most appealing features. The panel array is strategically positioned to maximize its exposure to sunlight and, in turn, its power output. Power, power quality, and pumping rate have all been evaluated in different climates and over different time spans. This technology, then, offers a more effective means of harnessing solar energy and producing useful amounts of energy (A. Matheswaran, *et al.*, 2021).

The use of solar power as a major renewable energy source is expanding at a rapid rate (Boobalan, S *et al.*, 2021). The solar energy will be transformed into electricity and stored in batteries. The solar panel will charge the battery during the day using the sun's rays. The solar panel is equipped with light detecting resistors (LDRs) to monitor the peak brightness of the sun's rays. The most amount of energy can be generated from solar panels if they are kept pointed directly at the sun at all times. The solar panel is mounted on the stepped motor so that it may move in a tracking motion. A soil moisture sensor is buried beneath the surface of the ground. The humidity sensor readings control whether or not the water pump runs. Soil moisture sensors transmit signals to microcontrollers to activate solar-powered pumps when soil moisture levels drop too low. At the same time, a microcontroller employing the ZigBee method notifies the farmers' smartphones of the condition of the pumps. Soil moisture sensors send signals to the microcontroller, and the microcontroller uses those signals to carry out the tasks written into its read only memory (Puneeth Kumar, G.B. *et al.*, 2018).

Methodology

One of the easiest and best applications of PV is water pumping. Solar water pumps may be used for a variety of purposes, including supplying water for agriculture, livestock, and household usage. Most of these setups also have water storage for usage even when the sun isn't shining, simplifying operation and cutting down on expenses by doing away with the need for batteries. The high cost of constructing a solar water pumping system deters many potential buyers. However, the true cost may be seen more clearly when seen over a 10-year period. If you look at the whole cost of ownership over a 10-year period and include in the price of gasoline, electricity, and maintenance, solar may end up being the most cost-effective option. The cost of a new windmill is comparable to that of a solar-powered pumping system, although the former is typically more

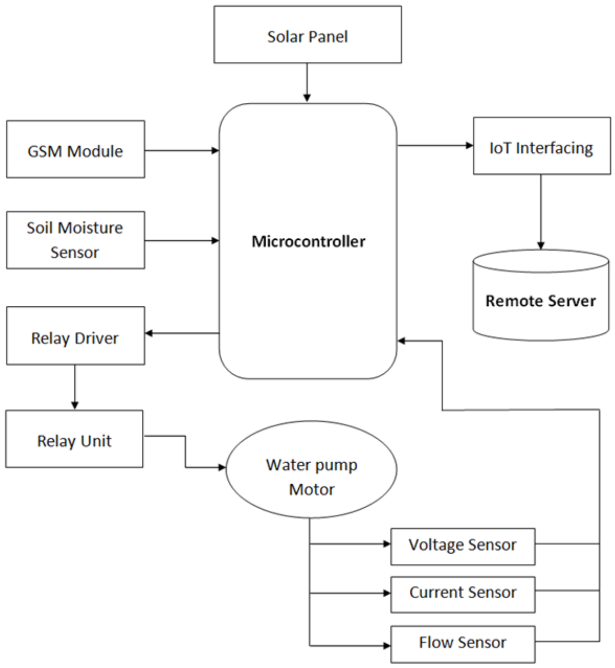

Figure 2: Block diagram

dependable and needs less maintenance. Again, the upfront investment for a solar-powered pumping system is more than that of a gas, diesel, or propane-powered generator, but the ongoing expenditures and effort are far lower.

The suggested system explains how to fix the aforementioned issue. Solar panels are used to generate electricity, which is then used to power the motor via an inverter or a battery bank. Motor control through text messages via a mobile device is feasible. The motor's ON/OFF status may be controlled remotely by text message. As the engine is powered by solar energy, whether or not there is access to electricity is less of a worry. Power can be provided to the motor straight from the inverter *via* the controller. By storing electrical energy in a battery and supplying it to the motor through an inverter, they can keep the motor running all night long. By inputting the IP address into any operating system, the user (farmer) may manage the water pump using the RF module, GSM module, and WI-FI module which are all connected to the DOL starter. The water pump may be controlled by the user (farmer) through a radio frequency module. As a result, the water pump system is controlled by an IoT platform and a GSM module. Figure 2 provides an understandable block representation of the suggested method.

Supporting Components

A PV array's mounting structure needs to be sturdy enough to endure the weight of the array as well as the elements for decades. These frameworks tilt the PV array at a predefined angle that takes into account local latitude, structural position and electrical power requirements. Components in the northern hemisphere are oriented so that their maximum yearly energy production is towards the south, and their tilt is equivalent to the local latitude. As it stands, rack mounting is the most popular option since it is reliable, flexible, and simple to build and install. There is constant progress towards more efficient and affordable techniques. Tracking systems mechanically shift panels on ground-mounted PV arrays so that they always face the sun for maximum energy production and financial returns. Typically, east-to-west tracking is the primary focus of one-axis trackers. Modules can stay oriented in the sun all day long with the help of two-axis trackers. There will always be more initial investment expenses associated with tracking, as well as ongoing maintenance costs associated with more complex tracking systems. Tracking for ground-based systems is becoming more economically viable as technology advances.

Power Inverters

Inverters take the DC power produced by solar PV modules and transform it into the AC electricity required for local transmission and by most household appliances. In PV systems, the power produced by the modules is either converted by a central inverter or by microinverters, which are mounted to each module. In most cases, a single inverter will save money and be easier to maintain. To account for the possibility of certain modules being shaded, the micro inverter enables individual control of each panel. Over the course of a PV array's estimated 25-year lifespan, at least one inverter will need to be replaced. Newer inverters, frequently referred to as "smart inverters," may exchange information with the utility provider in both directions. This may help keep supply and consumption in line electronically or by remote interaction with utility controllers. Utilities can save money, maintain a reliable infrastructure, and cut down on power outages if they are given this information.

Storage Unit

Batteries make it possible to maintain using electricity generated by solar PV panels even when the sun isn't shining or when clouds obscure the panels. Batteries are becoming increasingly crucial for utilities, and they are also useful in the household. Batteries can store excess solar energy generated by users and send it back into the grid. Increasing battery utilization will contribute to grid modernization and reliability.

Result and Discussions

DC water pumps typically consume 1/3 to 1/2 as much energy as their alternating current (AC) counterparts. Submersible and surface DC pumps are divided into the displacement and centrifugal categories, respectively. Diaphragms, vanes, or pistons in a displacement pump create a closed chamber that is then used to propel water out of the pump's outlet.

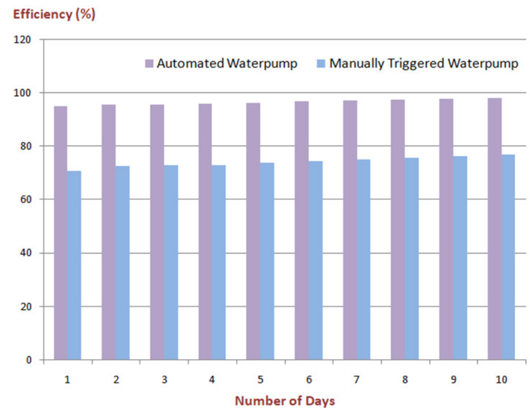

Figure 3: Water pump operating efficiency

Figure 4: Battery consumption analysis

Like a water wheel, the rotating impeller in a centrifugal pump imparts energy to the water, causing it to push into the system. When submersible pumps are installed in a well or sump, they are protected from freezing temperatures, the weather, and the need for priming, so they have a long lifespan and are very dependable. The primary function of surface pumps, which are often situated at or near the water's surface, is to propel liquid through a conduit. When it comes to transporting water over great distances or to high heights, some surface pumps can create large heads. In low-light situations, the pump controller can increase the volume of water pushed while protecting it from over- or under-voltage. An inverter, a piece of electrical equipment, is needed to power an AC pump from the DC electricity generated by solar panels.

System Planning and Implementation

When it comes to stock watering and pumping, every circumstance is different. Sizing and building a solar pumping system might be daunting for the typical customer, who would likely benefit from working with an experienced solar retailer. In most cases, shops are happy to assist customers. It only takes a few minutes on the phone to get a free estimate from several businesses. You may simply acquire offers from other sellers if you think the price is too high. The following details will help the supplier to determine the best configuration that suits your framework:

- To what extent do you need water?
- When do you need water, exactly?
- Where does your water come from: a lake, a spring, a well, or a creek?
- How many liters of water can be used per minute?
- What's the depth of your well?
- How much of an elevation rise is there, and how long the water has to be pumped?
- How likely is it that the pump will break if the water quality drops?
- What is the total capacity of the tanks and how are they laid out?

A solar pump system calls for electrical wiring, plumbing, and some serious building. However, not all written guides provide sufficient detail. Using a backhoe or loader with the user interface load is practically necessary for certain bigger projects. Figures 3 and 4 illustrate the performance measurements of the proposed scheme, in which Figure 3 portrays the efficiency of the water pump operations in a clear manner, in which it is cross-validated with the general human-operated pumps to prove the efficiency of the system. Figure 4 portrays the battery consumption analysis of the proposed approach clearly.

Conclusion and Future Scope

Renewable energy from the sun is cheaper to produce while the irrigation system that it drives has a low overall adjustable flow. This is because the cost for rise in unit power output of a solar system is greater than that of a gasoline, diesel, or electric system. When compared to a conventional sprinkler system installed above, a micro-irrigation system that is driven by the sun might end up saving you money in the long run. If the whole system design and use schedule is thoroughly examined and managed to make the most of solar energy, then PV electricity for agriculture may be affordable with traditional sources of energy for modest, far-off applications. This is because PV power can convert sunlight directly into electricity. Solar power will increasingly common and affordable in the future as a result of the economic benefits of mass production. This is because the price of fossil fuels will continue to climb, while the cost per peak watt of a solar cell will continue to decrease.

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