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An Overview of Solar Water Pump towards Sustainable Development

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ABSTRACT

India has the second-largest accessible agricultural land in the world, and solar energy is a clean energy source. In order to reduce labour-intensive irrigation work in remote areas, this study examines agricultural irrigation solutions, including solarpowered water pumps that are managed by GSM modules. Solar energy is transformed into electrical energy by a solar panel and stored in a lead-acid battery. The switching of the motors is controlled by the embedded board LPC 2148, and the field can be divided into several slots depending on the needs of the user. Solar panels produce the energy necessary to extract water from a storage so that it can be used to irrigate crops. PV panels and pumps are the two main parts of solar-powered water pumping systems. When exposed to light, the solar cells generate direct current (DC) electricity, which is fed to a DC pump. After then, batteries serve to store this DC current for subsequent usage by the pump. This article describes the operation of a solar-powered water pumping system and various components of a solar powered pumping system.

KEYWORDS: Solar energy, PV panel, Motor, Water pump

1. INTRODUCTION

In India, the two main energy sources for powering water pumps for domestic and agricultural use are grid electricity and diesel. The community and scientists have shifted to renewable energy sources like solar, wind, biogas, and hybrid systems due to the usage of fossil fuels and their detrimental effects on the environment. The most potential power-generating resources for local power generation are solar and wind because they are available almost everywhere and may be used directly without a permit. Water is essential for survival because it is used for drinking, daily domestic tasks, and major projects like irrigation, the construction industry, and the production of hydropower. Although there is a lot of freshwater, it is not readily accessible where it can be utilised. According to the WHO's Global Water Supply and Sanitation Assessment Report, 3 billion people would be living without access to clean drinking water by 2025, up from the current projection of 1.1 billion. Solar energy is gaining popularity because of its accessibility in rural areas, which reduces reliance on the grid and diesel for pumping. Compared to conventional pumping systems, solar PV water pumps (SPWPS) provide a number of benefits, such as being environmentally friendly and requiring no additional fuel for operation.[1] SPWPS have the potential to transform rural communities through socioeconomic development in addition to water provision.[25]

Conventional water pumps relies on grid power hence their operation has limitations, on the other hand solar operated pumps have their own PV generated power enhancing it's reliability.[20] Also by feeding the excess solar energy we can enhance the performance of grid.[23]

2. SOLAR WATER PUMP TECHNOLOGY

Due to its independence from conventional energy sources like grid power and diesel, solar-powered water pumping systems (SPWPS) have grown in popularity as power outages in rural and isolated locations have become more frequent. Although there are many different designs for SPWPS development, PV panel-powered water pumping is typically used. The generalised representation of SPWPS is shown in Fig. 1 [3]. This includes a storage tank, a hydraulic water pump, and a solar power conversion system integrated with a power conditioning unit. PV panels with a tracking system for increased efficiency make up a solar power conversion systemthat gathers solar energy and turns it into electrical energy. The output energy must be converted to AC by the inverter since the generated energy is primarily in DC and the pump is primarily accessible in AC. A water pump can be positioned on land or submerged in water (submersible pump). In order to benefit from gravity flow, it pumps water from the reservoir to a tank that is positioned at a certain height. The head of the pump is the height between the tank and the level of the water reservoir. When choosing a pump to pump water from the reservoir into the tank, the head is crucial consideration. The major goal of recent SPWPS research has been to maximise SPWPS effectiveness.

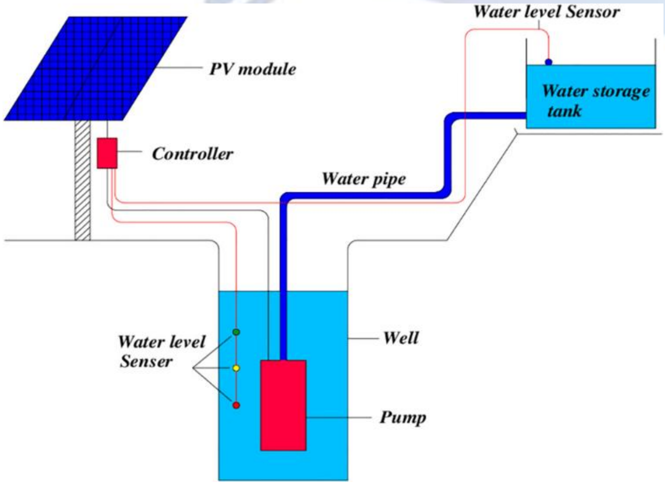

Fig 1. Typical representation of solar water pump[3]

2.1 TYPES OF CONFIGURATIONS

Figures 2 to 4 depict the many styles of DC/AC-linked water pumping systems that are in use across the world, both with and without battery backup systems.

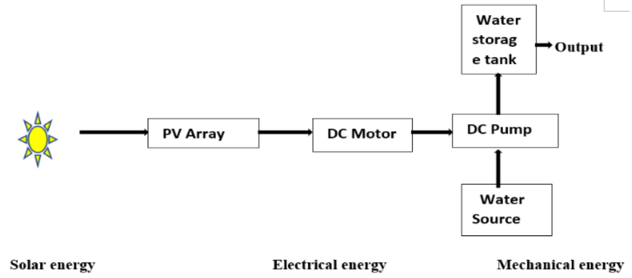

Fig 2. Block diagram of SPWPS with DC-coupled

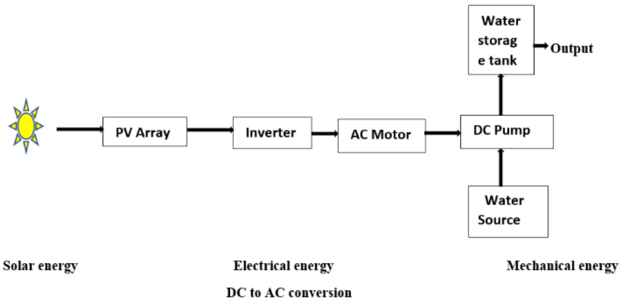

Fig 3. Block diagram of SPWPS with AC-coupled.

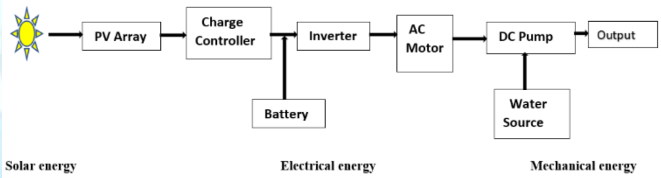

Fig 4. SPWPS with AC-coupled and battery backup.

3. TYPES OF MOTORS AND PUMPS

The experiments include a variety of SPWPS motor and pump types. Tables 1 and 2 provide an overview of the various motor and pump types.

3.1. MOTOR

Several types of AC motors (induction and synchronous) and DC motors (brush and brushless permanent magnet type, SRM) are employed in applications for SPWPS. The right motor should be chosen based on the system's size, efficiency, cost, power input, availability, and maintenance status. DC motors are common since they don't require an inverter or controller to convert the DC output of a PV array because the motor can use the power directly. For large applications (rated at or exceeding 9 hp), DC motors are effective, but an AC motor needs an inverter to convert the DC output from a PV array to AC. The use of an inverter increases energy and cost and, to some extent, reduces system efficiency. Submersible motors in deep wells must be removed for maintenance and repair purposes, which raises operating costs and decreases dependability and lifespan. The DC motor frequently used in SPWPS is described in Table 1.[3]

3.2. SOLAR PUMP

The output and head of the water are taken into account while choosing the pump.[4] In order for solar pumps to operate well, accessories including filters, float valves, and switches are installed. Solar pumps are made of low-lead marine-grade bronze and stainless steel, and they are rust- and maintenance-free, so they may operate in a tough environment for a very long time. According to their intended use, solar pumps may be divided into three categories: submersible, floating and surface water pumps. Surface water pumps pull water from shallow wells, ponds, rivers, or lakes, and floating water pumps alter their height in accordance with the level of the water in the reservoir. Submersible water pumps are put in deep bore wells. With submersible and floating water pumps, the engine and pump are both combined into a single unit. In contrast, both are picked out independently for surface water pumps based on the performance of the PV system, including the controller and PV array.

4. PV GENERATOR

A solar pump's PV generator is made up of PV modules that are wired in parallel and series in accordance with the voltage and current needed to power the water pump and drive motor. PV modules are made up of PV cells, which convert solar radiation directly into energy [6]. The current-voltage relationship for a single solar cell at a given irradiation is given by[5]:

$$\mathrm{I} = Ipv - Io\left\{\exp\left(\frac{V + RsI}{V_t a}\right) - 1\right\} - \frac{V + RsI}{Rp}$$

Ipv and Io are its photovoltaic and saturation currents, respectively, Rs and Rp are series and parallel resistances of cell. Vt is thermal voltage of array and a is its diode ideality constant. The amount of electricity a PV cell can produce depends on the weather. The maximum operating point (MPP), which is based on the irradiance level, is the PV array's ideal operating circumstance. A DC-DC converter is used to match the resistance of the source and a cell in order to drive maximum power. It also integrates with an inverter to convert DC to AC under the supervision of an MPP tracker. Even at low irradiance levels in the morning, evening, overcast, and winter months, a linear current booster is employed to match the motor's current level. Circuit breakers are fitted to turn off the pump when it is not in use or in the event that the system has to be maintained. To supply a particular volume of water at the needed head and flow rate, a pump has to have a certain level of power. To capture the necessary quantity of energy, the PV array size must be adequate. The pump will start earlier in the day and with greater power at low irradiance if the PV array has a bigger capacity. A larger setup, however, necessitates a significant initial expenditure. To capture the necessary quantity of energy, the PV array size must be adequate. The pump will start earlier in the day and with greater power at low irradiance if the PV array has a bigger capacity. A larger setup, however, necessitates a significant initial expenditure.

5. CONTROL SYSTEM

An important and crucial factor in determining how well the water pumping system performs is the efficient and accurate model of the control system.[24] Numerous techniques of control that researchers throughout the world have utilised to manage the water pumping system are: Novel control system, Fuzzy optimization, Intelligent algorithm, Proportional controller and fuzzy logic speed controller.[21]

Table 1

Types of motors used in solar water pump:

Type of Motor	Type of Pump	Features	References
Switched reluctance motor	Centrifugal Pump	SRM are more affordable and more efficient than DC or induction motors. The system efficiency is up to 95%, and the motor efficiency is up to 85%. Major losses were contained in the pump and pipe system, which consumed one-third of the total energy available.	16
DC shunt motor	Centrifugal Pump	A mathematical model is developed, and a study of its steady-state dynamics is performed. The majority of the day, the motor's speed remains steady, with an efficiency of over 75%. Voltage and current overshoots only last for a very short duration.	15
Brushless DC motor	Helical Rotor Pump	High efficiency (80–90%), a high torque-to-weight ratio, and inexpensive maintenance are all features of BDCM. The PSI/e programme was used to model the entire system. and achieved a system	17

		efficiency, excluding the array system, of between 30 and 50%.	
Induction motor	Centrifugal Pump	Although it is suggested to run at a nominal frequency, IM have superior system efficiency that is attained at a higher frequency. The simulation findings were closely matched with the experimental data from the system that was deployed in Jordan's desert area.	18

Table 2. Various Pumps in Solar water pump:

Type of pump	Features	References
Helical and diaphragm pump	A helical pump has a longer lifespan than a diaphragm pump and can pump at greater depths. Efficiency for helical pumps may reach 60%, while that for diaphragm pumps can reach 48%; overall system efficiency was 7% and 5%, respectively.	19
Centrifugal and positive displacement pump	Positive displacement pumps are more efficient than centrifugal pumps because they incur fewer losses and move more water. An Algerian pumping test facility uses experimental data to confirm a mathematical model.	3

6. APPLICATION OF SOLAR WATER PUMP

Solar water pumping is used in many different applications, and research has shown that it not only improves socioeconomic growth but also the ecological balance. Two primary PV systems were planned and built by Alajlan and Smiai [7], one for water pumping and the other for desalinating raw water using the reverse osmosis process. Each system is combined with a battery backup that lasts for five days. The desalination process is intended to produce 600 litres per hour. For slate mines in Spain with 131 Ah battery backup, Paredes and Villica [8] created and ran simulations using PVsyst software, with a final cost of €1310 for the solar water system. A drinking water pump system with a capacity of 130 m3 was built, installed, and tested for a year in a remote area along the Iraqi-Syrian border by Munir et al. [10]. A solar-powered system was created by Manfrida and Secchi [9] to pump seawater into a basin and store potential energy for the production of electricity. Two distinct types of motors, one with variable speed and the other with constant speed, were used for the analysis. The energy produced can be sent to grid after proper conditioning as it’s done in distributed solar and wind generation power plants.[22]

7. INDIAN SCENARIO

The Indian government has recently launched a new scheme named Pradhan Mantri Kisan Urja Suraksha evamUtthanMahabhiyan (PM KUSUM), which aims to install an off-grid solar pump and replace the existing grid-connected agriculture pumps. PM KUSUM started with a target to install 17.5 lakh standalone solar pumps by the year 2022[12]. The main objective of this scheme is to boost agricultural yields and decrease the dependency on diesel and grid electricity for water pumping set in Uttar Pradesh, Rajasthan, Punjab, Tamil Nadu, Andhra Pradesh, Bihar, Punjab, Haryana, Madhya Pradesh, and Himachal Pradesh. The farmers will have to pay 10% of the total cost of the setup of SPWPS, the government provides a 60% subsidy, and the rest is financed by the bank. The Indian government has set up certain guidelines to the manufacture of the PV panels as per the international standards with all modern testing procedures, to consider a quality product with high-efficiency performance and long life cycle. The efficiency of the PV must be greater than 13% with fill factor to be more than 70%.

8. CONCLUSION

A study of solar water pumping systems shows the state of system research and implementation at the moment. The study focuses on various water pumping system configurations, various motor and pump types used for various applications, PV systems, control systems for managing the entire pumping system and it’s applications. Following conclusions are made based on the study:

Given the high initial setup costs and the lack of knowledge among farmers, the government must widely publicise this technology and explain why it is a superior option to diesel and grid-operated water pumps in the future.

When used as an irrigation and drinking water supply instead of diesel and grid power, PV water pumping system are dependable and environmentally benign with a 30% loan from the government, a 60% government subsidy, and 10% from the farmer. According to the volume of water pumped for various categories of users, MNRE has certified a number of models. Emerging countries like India, Africa and Asian countries. The majority of the places have sufficient sun irradiation levels all year round. The ideal way to use locally available resources is with a PV-based water pumping system, which also contributes to environmental protection by lowering CO2 levels.

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Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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