Advancement in Solar Photovoltaic Water Pumping System - a Review

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December 14, 2022

Advancement In Solar Photovoltaic Water Pumping System - A Review

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1.ABSTRACT.

Energy received from sun is a capable substitute to conservative WPS for achieving the pumping requirements of community water supply as well as irrigation. The shortage of electricity as well as higher fuel expenses have effect on given requirements. PV technology is the basis of SWPS, which converts radiation received from sun into electrical energy to drive a water pump. The research's key objectives are to give a detailed estimation of the literature on solar water pumping systems and technologies, assess their economic viability, and pinpoint any research gaps or roadblocks to their wider adoption. Updates on SWPS, performance investigation, optimal sizing, the deterioration of PV generators used to drive the pumps, commercial and ecological considerations are the key topics of the research. This research brings an up to date on the development as well as application of SWPS. The performance of SWPS, the deterioration of PVA, and increasing efficiency SWPS are all factors that are highlighted. In compared to conventional water pumping systems for irrigation SWPS is proven to be cost-effectively viable. Some SWPS have an investment payback period of 4-6 years. Additionally, policy attempts for the upgradation of SWPS in underdeveloped nations are explored, as well as current incentives for SWPS in India. Areas for possible follow-up studies are also noted.

Keywords – Solar Energy, Solar Water pumping System, Photovoltaic Array, Solar Cell.

Nomenclature.

SWPS - Solar Water Pumping Systems
PV - Photovoltaic
PVA - Photovoltaic Array
MPP - Maximum Power Points
WPS - Water Pumping Systems
ROF - Rate of flow
TDH - Total Dynamic Head
HE - Hydraulic Energy
CFP - Centrifugal Pump
DC - Direct Current
AC - Alternating Current
SC - Solar Cell

2.INTRODUCTION.

The majority of the world's water pumping is based on conservative energy or power produced by diesel engines. SWPS reduces the need for electricity generated by coal, gas, or diesel. The usage of diesel or propane-powered water pumping systems results in the need for costly fuels, as well as noise and air pollution. A SWPS has 2-4 times the upfront cost, operating and repairs expenses, and standby costs of a diesel pump. SWPS are ecologically advantageous, negligible maintenance, and fuel-free. SWPS is among the most possible use of radiation received from sun , especially considering the absence of electricity in remote places in the majority of world[1]. With the exception of using radiation received from sun as its input. Despite lack of access to energy and the rising cost of diesel, SWPS has become more and more important in current times. The size of the PVA and incident solar radiation have effect on the ROF of pumped water. Comparing a correctly constructed PV system to traditional pumping systems, significant long-term cost reductions are achieved[2].

The availability of water during the summertime has a negative influence on agricultural production in underprivileged countries, which is heavily reliant on rainfall. Although summertime offers the most solar energy, more water will be impelled to fulfil rising demand for water. Towns' water supplying systems rely upon energy to impel water SWPS can be used for water supply in remote area, metropolitan area, community, industrial area as well as academic organisations.

A study of the condition of research and use of SWPS technology is provided in this work. The review concentrates on recent developments in SWPS technology, performance assessment, ideal sizing, demonstration, and simulation as well as the financial and ecological implications and the practicability of SWPS for irrigation and public water supplies in metropolitan, countryside and isolated areas. For additional follow-up research, the research results of various configurations of SWPS are presented. The study's major goal is to explain the state of current research, as well as to pinpoint knowledge gaps and roadblocks to the general adoption of SWPS technology. Also highlighted are the approach and strategy concerns for the advancement of SWPS. For additional follow-up research, the investigation results of various configurations of SWPS are presented. The study's major goal is to explain the state of current research, as well as to pinpoint knowledge gaps and roadblocks to the general adoption of SWPS.

3. LITERATURE SURVEY.

When compared to conventional energy sources, PV power for irrigational purpose is more affordable and can meet small-scale water pumping needs. Photovoltaic electricity is expected to become even more cost-effective in the future due to the ongoing rise in the price of fossil fuels and the decline in price of SC because of bulk manufacturing[3]. For agricultural uses in isolated areas having partial access to conservative energy, SWPS have grown in popularity[4]. Numerous research have been done on the financial and ecological aspects of SWPS, as well as the performance optimization, sizing approaches, performance enhancement, and factors impacting system performance.

3..1 Characteristics Of SWPS Performance.

The performance of a SWPS is mostly dependent on the ROF of water, which is controlled by local weather factors, particularly deviations in air temperature as well as sun irradiation. The water requirement, the dimensions of the water storage tank, the head (m) by which the water must be lifted, the amount of water to be pumped (m^3), the virtual energy of the PVA(kWh), the energy used at the pump (kWh), the unused PV energy (kWh), the pump efficiency (%), the system efficiency (%), and the variation in pump pressure due to changes in irradiance and pressure compensation all affect the performance of the solar pump. The effectiveness of the PV technology employed in the PV generator also has a significant impact. One of the crucial factors that affects a solar pump's performance in addition to PV panel degradation. The effectiveness of the PV technology employed in the PV generator also has a significant impact. Another crucial factor that affects how well a solar pump works is the degradation of PV panels.

The following variables affect the SWPS's performance:

- Availability Of Solar Radiation At The Site
- TDH
- ROF Of Water
- Requirement Of Total Quantity Of Water
- HE

3.2. Summary Of Performance Investigation Studies.

The performance estimation approaches employed in diverse studies are examined in this part to give the researcher more information.

Using a computer simulation tool, Gad [5] created a approach for performance forecast of a directly joined SWPS in South Sinai, Egypt. The software simulates the system's hourly performance throughout the year under various PVA angles. The system can pump 24.16 litres per day on summer solstices, 21.57 litres per day on equinoxes, and 12.22 litres per day on clear winter days, respectively. The predicted PVA efficiency varies from 13.76% in the winter to 13.81% in the summer.

When a MPPT and a sun-tracker are additional in the system, Katan et al.[6] discovered that the performance of the system is enhanced. The system comprises of a PVA, a sun-tracker, DC motor, and a helical rotor pump.

Using average monthly solar radiation input data and hourly simulation, Loxsom and Veroj[7] created and verified an algorithm to predict the durable monthly performance of a SWPS without any battery for 4 sites in the USA. A DC-DC buck converter was included in the design of a SWPS by Khan et al. [8] in order to augment the DC pump's current. In order to lower costs and maintainability, the system doesn't utilise a battery or an inverter. The fastest without load is between 3000 and 3200 revolutions per minute (rpm). The combination of the DC motor and the CFP has matched rather effortlessly, according to the findings of the no load test.

The effectiveness of a directly coupled DC driven SWPS was examined by Mokeddem et al. [9]. Without batteries or electrical controllers, the system works. Although a directly-coupled SWPS motor-pump efficiency did not reach 31%, this system is acceptable for lower head farming in isolated places. By choosing the PVA’s size, direction, and motor-pump system, the system's efficiency can be raised.

In Madinah, Saudi Arabia, Benghanem et al. [10] identified the best PVA layout for providing the best energy to a DC helical pump in outdoor circumstances.Six series three parallel modules, 24 modules in six series four parallel, 24 modules in eight series three parallel, and 24 modules in twelve series two parallel are the four alternative PV array configurations examined. Comparing the performance of four different SWPS designs (SWPS1, SWPS2, SWPS3, and SWPS4) reveals that SWPS3 is the best option for supplying the required 22 m^3 of water per day. According to a comparison of system efficacy, the SWPS3 is more suitable for this area. However, an effective utilisation of the SWPS design is necessary for this site in order to maximise energy exploitation.

3.3. Ideal Sizing Of SWPS.

A SWPS with "switched mode" was suggested by Wagdy et al. [11]. When the battery is charged to its full potential, this system couples the pump with the PVA directly with the aim of maximising solar radiation usage and minimising costs by taking into account three fundamental parameters: the size of the PVA, the battery, and the storage tank. The authors showed that adding battery storage without increasing array size has little impact on system performance and that the ideal option is one that reduces the PVA size because the array cost is the key component.

For the sizing of SWPS, Hamidat and Benyoucef [12] offered scientific models. These models relate the electrical operational power to the pump's ROF vs TDH. Two SWPS subsystem from various manufacturers and technological eras are investigated. One of them is a CFP, which combines a CFP with a three-phase AC engine. Other one is the PDP, which combines a PCP and a DC engine. The outcomes demonstrate that the displacement pump performs better than a CFP.

3.4.Enhancing the efficiency of PV water pumping systems.

Azadeh [13] conducted research on how a SWPS constructed in Kerman City, Iran is affected by an rise in Temprature of of the PV array and system head. The water used by the authors was pumped in and used to cover the surface of the array, cooling the PV modules. Results showed that an increase in system head and a drop in array nominal power increased the power produced by the array. As sufficient power can be provided with a lower array nominal power, using this technology lowers system costs.

The idea of enhancing the efficiency of a SWPS by misting water above the PV modules was examined by Abdolzadeh and Ameri [14]. According to the findings, water spraying can produce a mean PV efficiency of 12.5%. On the test day, the mean flow rate at 16 m head was around 479 l/h for a system without water spray over PV modules, while it reached 644 l/h for the system sprayed with water. By cooling the solar modules using water spraying, the system and subsystem efficiencies are increased.

A new converter was put out by Joao and Luis [15] SWPS without batteries. They created a converter that powers an induction motor with three phases. The results indicate that the suggested solution is a viable choice for greater dependability as they show a peak efficiency of 91.5% for the DC/DC converter with three-phase voltage source inverter (VSI) at the rated power of 230 W and a peak efficiency of 92.74% for the dc/dc converter.

3.5.Environmental And Economic Concerns.

SWPS are now more economically feasible than electricity or diesel-powered pumping systems because of the unavailability or scarcity of conservative electricity, the annual price increase of diesel, the continually falling cost of PV modules. Several academics have recently evaluated the financial practicability of PV systems. Based on actual data and the three-year operational experience of 8 installations, Odeh et al. [16] evaluated the economic viability of photovoltaic and diesel water pumping systems for various system sizes in the range of 3.86–16.6 kWp. By anticipating demand patterns, sizing storage tanks, and choosing wells with low pumping heads, it may be possible to lower the cost of a unit of water. According to the study, there is a noteworthy negative influence on the financial feasibility of SWPS when there is a gap between water demand and supply patterns.

Meah et al. [17] emphasised the necessity of employing SWPS in states that are prone to drought. Some states of USA of might employ SWPS to deliver water to animals in remote areas, and Wyoming suggested the idea of using SWPS. In addition to the benefit of reducing carbon emissions, the study's analysis of the performance of 75 operational systems revealed great performance and cost effectiveness.

4. Improvements in photovoltaic materials and efficiency.

The primary and most expensive part of a solar water pump, the PV generator, is why cost reduction and efficiency enhancement are crucial factors in the continued promotion of SWPS technology. In recent years, there have been significant developments in SC materials and efficiency, which is been covered in this part. Since the 1950s, SC have been employed in satellite and spacecraft applications; however, the early 1970s oil crisis and the expansion of the photovoltaic (PV) sector led to the use of SCs for water pumping and electricity supply in remote areas as well. First generation SC technology is based on wafers made of mono- and multi-crystalline silicon [18]. Silicium wafers, which are sliced from a single, cylindrical silicon ingot, are used to make mono-crystalline SC. These cells' high module efficiencies are their principal benefit. Making molten silicon into ingots, which then crystallise into a solid block of intergrown crystals, is the process used to create multicrystalline silicon SC. Although they have lower efficiency than monocrystalline cells, these cells are lesser expensive to construct than monocrystalline ones because of the simpler production method and lower pureness requirements for the initial material. More than 81% of the global PV industry is based on crystalline silicon wafer-based technologies, and the crystalline silicon PV technology is already well recognized. It accounts for about 91% of all PV installations worldwide.

The second generation of SC, known as thin-film cells, is based on polycrystalline or amorphous silicon/hydrogen alloys. PV cells composed of amorphous silicon are created by coating a rigid or flexible substrate with a thin layer of noncrystalline silicon. These can be produced reasonably easily and are lesser costly than crystalline SCs, although they are less effective.

The efficiency of dye-sensitized SCs, sometimes referred to as dye-sensitized nanostructured SCs and mesoscopic injection SCs, has reached up to 13% for tiny cells and 11% for mini-modules. Lead halide, which is a mixture of organic and inorganic elements As a result of their excellent power conversion efficiency[19-20], perovskite materials have lately become a promising next-generation material for solar applications. The mineral discovered in the Ural Mountains is the source of the name for perovskite cells. Despite the fact that dye-sensitized SCs with only 3.9% power transformation efficiency were used to make the first SC found in 2009, perovskite materials have long been known. Perovskite cells are now claimed to be 18% efficient. The best reported efficiencies for Perovskite SCs to far have been mostly attained with materials containing methyl ammonium lead halide.

In the past ten years, typical commercial wafer-based silicon module efficiency rose from 12.5% to 16.5%, while CdTe module efficiency rose from 9.5% to 13.5%. When using multicrystalline silicon wafer-based technology, the laboratory cell efficiency is 20.8% and 25.6%, respectively. The maximum efficiency in thin film technology under laboratory settings is 21.6% for CdTe SCs and 20.6% for CIGS SCs, demonstrating that there is still room for improvement at the level of commercial manufacturing. SCs with III-V multijunction have a 40.5% efficiency level[21].

5. Results And Analysis.

The conclusions of the research on many features of solar pumping technology conducted by various writers are compiled in the corresponding sections. However, the following are some of the significant findings that are included in this section:

- Similar to other SWPS, the performance of PV pumps is impacted by variations in solar irradiation, dust deposition on PV generators, and higher temperature of modules. When water is sprayed over solar panels, the dust is cleaned off and the modules are cooled, which increases efficiency of module and, in turn, flow rate of water. These guidelines must be followed in order to boost performance.

- The solar water pump's primary component is a PV generator.Therefore, choosing an appropriate PV technology is crucial for the efficiency and dependability of SWPS. When compared with price of energy generated from fossil fuels, solar power is less expensive since fewer modules are needed, installation costs are lower, and less land is needed for installation. As a result, even costlier PV cell technologies with better performance may cost less per module than those based on cells with low efficiency.

- By using the right size, incorporating MPPT, and controllers, PV water pumping systems can operate more efficiently. Another crucial factor for improving the effectiveness of fixed PV generators is the optimal PVA tilt angle. The system's PV panels' output power is increased when the maximum solar energy is directed toward panels tilted at their ideal angle.

- Some systems producing paybacks in half that time, the capital recovery for SWPS is determined to be between 4-6 years. PV modules nowadays are easily accessible from multiple reputable PV companies in a variety of sizes. Due to the durability of PV, manufacturers offer 15 to 20 year of warranty. The payback period will be shortened further by falling PV module costs, a 25-year warranty, and incentives offered in some nations, like India, for installing SWPS.

The biggest barriers to the widespread adoption of SWPS technology are their higher early investment costs and the general absense of user awareness. According to findings of a GIZ study [22] conducted in India, a 750 W diesel pumping system has a life cycle cost that is 35.89% higher over ten years than a SWPS with the equal capability. A fuel-free SWPS levelized cost of energy (LCOE) is discovered to be Rs. 8.65 (USD 0.143) as opposed to Rs. 13.95 (USD 0.230) for a diesel pumping system. Diesel pumps typically last 10 years, whereas PV modules have a 25-year normal guarantee duration. As a result, PV can be used as a very dependable and lower maintenance system, particularly for applications involving water pumping. It has been discovered that PV panels with a power output of 60 Wp to 500 Wp are adequate for household water pumping needs in residential structures.

6. Conclusions.

- For irrigation of agricultural crops, PV water pumping technique provides a dependable and practical substitute for electric as well as diesel water pumps.
- Another viable industry that is still underutilised is PV water pumping for municipal, rural, and institutional water supply. Remote, inaccessible areas without connection to the electrical grid also require special consideration. These industries continue to rely on out dated electrical or diesel pumping systems, which raises on going expenses for consumers.
- Considering the high capital costs of SWPS, particularly for big irrigational supplies, further government incentives are needed to make the technology an even more compelling substitute to diesel and electrical water pumping.
- Further study is desirable to decrease costs, improve performance, and lengthen the lifespan of pumping systems. These areas include factors impacting performance and effectiveness improving approaches, usage of super-efficient PVA.

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