TECHNOSCIENCE ARTICLE

Photovoltaic Pumping System Vs Livelihoods and Sustainability

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Abstract

Power consumption demand and hike of fossil fuel costs made everyone adopt sustainable energy for better electrification. Sustainable irrigation improves production, reduces susceptibility to changing rainfall patterns in the countries. Today a total of 25 million irrigation pumps are in use in India, out of which 40% are diesel engine-operated and the rest are powered by electricity. The present research approach is to design, develop and implement an efficient solar water pumping system for the replacement of the traditional pumping system in Odisha. The benefits comprise enhanced livelihoods, increased sustainability, reduced fossil fuel uses and centralised infrastructure. Solar PV based solutions in agriculture systems can deliver reliable, cost-effective and eco-friendly sustainable energy for the farmers. Solar radiation is converted into electricity for the operation of the DC/AC motor pump and it pulls water from the open well, bore well, pond, pond, canal etc. The concept and research gaps of solar-powered pumps used in irrigation and community water supply systems were examined elaborately using an action research approach. The current Indian government's KUSUM scheme is discussed for the installation of 2 million off-grid solar pumps by 2022. This will help future researchers and project developers for efficient designing and implementation of solar-powered irrigation systems in the country and world.

Introduction:

Electricity is a basic need for human beings. Without power, the people cannot endure on the earth. Each and every moment of their lives, they depend upon the power for smooth operations (ESMAP, 2019). Access to reliable electricity is one of the important factors to overcome the gap between energy generation and consumption in different sectors of the world (Campen, 2020). This also leads to improving the socio-economic development of a country. But in this 20th century, 1.2 billion people lack access to electricity and around 200 million are in India alone. According to the 15th report of Sustainable Development Goals (SDG), out of a total 7.7 billion in the globe, 2.6 billion people have their livelihood quenched from native agriculture as the source. The model results indicate that energy consumption will be increased by almost 55% by 2050 (IRENA, 2019 <https://www.irena.org>;

SDG, 2020). SDG indicator 2.4.1, indicates as "Sustainable Agriculture" with three main goals such as environmental health, economic profitability, and social equity. For the development of a country, the greatest challenge is to access reliable energy, food and water in a particular area and also to fulfil the requirement of SDG 7, recommended in the United Nations Conference (SDG, 2020). India has promised to place importance on renewable sources of energy to mitigate the energy gap and reduce greenhouse gas emissions (GHGs). The country's solar installed capacity was 40.09 GW by March 2021. The target is to install 175 GW capacity of renewable energy by 2022, which includes 100 GW from solar, 60 GW from wind, 10 GW from bio-power and 5 GW from small hydro-power (GOI, 2021-<https://mnre.gov.in>; Kumar, 2015).

India is an agricultural country. India ranks 2nd globally in agricultural products. More than 50% of the Indian workforce depends on it and contributed about 25%

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to the country's GDP (GOI, 2021; Census, 2011). Agricultural skill is changing speedily. Farm machinery, farm building and production services are continuously being improved (Samson, 2019). About 22 million irrigation pumps exist in the country, with about half of them utilising diesel-powered engines and the other half utilising electric-powered engines. Agricultural applications with photovoltaic (PV) solutions are more reliable than traditional fossil fuel-based power generation systems (Bano & Rao, 2016). The installation of solar water pumps helps in drinking water supply, livestock watering, irrigation, and other residential uses. Basically, four types of PV water pumps; submersible pumps, surface pumps, alternate current (AC) pumps, and direct current (DC) pumps. Among them, the DC water pumping system (off-grid type) is widely used in the country (Closas & Rap, 2017). In order to efficiently develop a solar PV water pumping system for the long-term demand of water for agriculture, Centurion University of Technology and Management, Odisha acted as the first mover. To increase agricultural productivity, the Odisha government is implementing the "SouraJalanidhi" – A Solar Micro Pump Scheme of 0.5 HP capacities (OREDA, 2019-20; <http://oredaodisha.com>). It is proposed to implement a Solar Micro Pumping System of 5000 numbers under the Soura Jalanidhi scheme and 2000 off-grid solar pump systems under the PM-KUSUM (Kisan Urja Suraksha Evam Uhaan Mahaabhiyan)scheme.

Odisha is a state located on the east coast of India. It is the 8th largest state by area and the 11th largest by population. Its coordinates are 20°56'27.3120" N and 84°48'12.4812" E. 420 million people inhabit the state (Census, 2011). Agriculture is the leading occupation in Odisha and major contributor to the state economics. About 75% of the total working population is engaged with agriculture and its industries (GOI, 2021). Some of the major agricultural hubs such as Cuttack, Balasore, Dhenkanal, Sambalpur and Koraput (Giri, 2021). The purpose of this study was to understand the role of agriculture in the Balasore and Kundera block in the Koraput district of Odisha. In Baliapal and Bhograi blocks of Balasore and Jeypur and Kundera blocks of Koraput, electric pumps and irrigation have been widely adopted in agriculture use.

The Government of India has started a new scheme named KUSUM to subsidise the farmers with solar irrigation pumps (SIPs) in their farms. Under this scheme, the government provide a 60% subsidy to a farmer for the installation of pump sets and tube wells on their land. According to the Ministry of New and Renewable Energy's (MNRE), solar-powered irrigation is an enormous prospect in India (GOI, 2021). At the end of the financial year 2019-20 a total of around 246,000 solar pumps were installed and only 8,900 of these were installed in the 12 months after the policy was launched in 2019 (GOI, 2020 <https://powermin.nic.in>), Fig.-1.

Figure-1: Solar irrigation pump installation in India (GOI-MNRE, 2020)

Methodology:

A solar water pumping system or photovoltaic system is an electrical pump system in which the electricity is provided by one or more solar panels. A standard solar-powered pumping system consists of solar panels, a DC/AC motor set, a charge controller, connecting cables, and a variety of ancillary electrical equipment, all put together (Fig.-2). When mounting the PV module/array, it should be done on a support structure in the southeast facing with manual or automatic tracking available (Giri *et al.*, 2020; Closas & Rap, 2017). Pumping water during the day and storing it in tanks or reservoirs for use during the day or night is an example of using stored water. The water tank serves as a storage reservoir and generally, batteries are not required for storage except for storing energy from the sun. The electricity can be stored in batteries, for particular purposes, which can be used during emergencies. This comes down to a desire to make sure all the mechanisms are standard with regard to international and national usage (Hariri *et al.*, 2020). The quality and capacity of a solar water pump is important aspect to be considered before buying or designing a solar water pump.

Figure-2: A typical block diagram of PV water pumping system

The technology used to harness solar energy and pump water with it is based on PV technology, which uses solar energy to generate electrical energy to power the pump. A motor that incorporates PV panels turns electrical energy into mechanical energy, and then hydraulic energy. This circuit uses a controller to regulate the flow of current in the system (Aliyu, 2018). The motor used DC power (off-grid) to pick up the water from the soil, where both the inverter and battery are integrated into the system (Awan *et al.*, 2020; Giri *et al.*, 2020), illustrated in Fig.-3. The motor used AC power to pick up the water from the soil, thus there is a need for an inverter to convert DC to AC power, given in Fig.-4.

Basically, a solar water pump does not need batteries. To save costs of the system, the popular solar water pumps

Figure-3: Block diagram of a PV DC water pumping system

Figure-4: Block diagram of a PV AC water pumping system

are running directly from the solar panels or arrays during the day. But for residential and drinking water use at night time, battery storage is very essential to provide a healthy operating voltage to the DC motor of the pump (Singh *et al.*, 2020; Narale *et al.*, 2013), illustrated in Fig.-5. The electric current generated by PV panels or arrays through sunlight will charge the batteries, and the batteries in turn supply power to the solar pump anytime water is required (Shahajahan & Mittal, 2020; Priyanka *et al.*, 2018).

Figure-5: Block diagram of a battery operated SPV water

Applications

The installation of solar water pumps helps in drinking water supply, livestock watering, irrigation, and other residential uses. There are four types of PV water pumps; submersible pumps, surface pumps, alternate current (AC) pumps, and direct current (DC) pumps.

A submersible pump is a device that has a waterproof motor close-joined to the pump body. The whole gathering is immersed in the fluid to be pumped, which is illustrated in Plate-1a.

Surface pumps are designed to pump water from surface sources like canals, ponds, tanks, or shallow wells. The concept is to produce liquid movement or flow in the system, illustrated in Plate-1b. The cycle mounted solar PV water pumping system of capacity 0.5 HP is illustrated in

Plate-1: a) Submersible pump (5 HP) for agriculture irrigation @ Karaput; b) Surface pump (3 HP) for agriculture irrigation @ Balasore; c) Cycle mounted solar PV water pump (DC) for irrigation and drinking water use @ Karaput; d) AC water pumping (1 HP) system

Plate-1c,d. This concept is used to make pump installation portable for easier operation in any agricultural land. The installed solar AC water pumping system (1 HP) at Centurion University campus is illustrated in the Plate-1d.

Result and Discussion

The empirical collection data of different types of water pumping systems have been analysed to develop and better implementation in any suitable agricultural site. A comparative study has been carried out to decide the optimal use of the solar water pumping system in Odisha. As per the farmer's requirement and references, four types of solar water pumping systems are investigated for further better applications. The apparatus used in this project and performance analysis are illustrated in Table-1.

The performance of a solar water pumping system depends on; solar radiation availability, system design, total dynamic head, and Stefan Boltzmann law (Tiwari & Kalamkar, 2016).

Table-1: Performance and specifications of photovoltaic water pumps

Item/Capacity	0.5 HP	1 HP	3 HP	5 HP
Solar Panel	0.5 kWp	1 kWp	3 kWp	4.8-5 kWp
Controller (MPPT)	12/24V 6A	12/24V 10A	12/24V 30A	12/24V 50A
Pump Head	10-40 m	30-45 m	40-75 m	70-100 m
Max. Current	5 Amps	8.2 Amps	24 Amps	40 Amps
Output Vage	30-85 V	30-85 V	30-85 V	30-85 V
Input Power	500Watt	1000Watt	3000Watt	4800Watt
Discharge (Lt/day)	6,200-12,000	10,000-39,000	39,000-96,000	62,000-1,00,000
Avg. Cost (Rs.)	45,000	85,000	2,00,000	3,00,000

Finally, the policymaking on "solar energy options for irrigation" lies at the core of the water, energy and food interconnection. The study's purpose is to investigate various aspects of photovoltaic pumping systems and their suitable applications. This can be fixed, portable or a tracking type of installation. Among all the four

configurations of Table-1 (Column-1) and (Column-3) give better results for the farmers. Although DC pumps have a benefit over AC pumps in terms of greater efficiency, avoid inverter for operation and maintenance. It can be concluded from the study that the 0.5 HP pump is the best configuration for portable and the 3 HP pump is best for surface configuration in drinking and irrigation purposes.

Implication:

From this study, the possible recommendations would be:

- The PV system configuration needs to be improved in order to raise the overall efficiency and reduce the cost of the system.
- Regular maintenance is required to prevent failure of the water supply due to an unexpected system shutdown.
- The energy payback period for solar water pumps need to be in the range of 5 to 8 years, compared with the usual system lifetimes of around 25 years.
- All pumps need to be protected from direct sunlight. This can be done using a sheet metal cover or by submerging.

The above data will help in future analysis, design and implementation of efficient solar-powered irrigation systems to fulfil the government targets. Thus, a sustainable photovoltaic pumping system is a crucial matter for enhancing livelihoods in the applications of drinking and irrigation systems of the World.

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Important Links:

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- Sustainable Development Goal (SDG) 7, Affordable and clean energy. <https://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-7-affordable-and-clean-energy.html>