Scenario of Solar Photovoltaic Water Pumping System

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Abstract. The need for agricultural and community water sources to be pumped is impacted by the high cost of diesel and the absence of electricity, particularly in rural areas. Thus, one alternative to conventional electricity and diesel- based pumping systems might be the use of solar energy for water pumping. Solar energy could therefore be a viable water pumping alternative to traditional electricity and diesel-based pumping systems. This review gives a glimpse of information on solar water pumping technology, and the research gaps for its wider adoption. The matching of characteristics between solar photovoltaic modules, controller, motor and pump is the great task to obtain optimum overall efficiency or solar pump efficiency.

Keywords: Photovoltaic, renewable energy, solar energy, solar pump, wire to water efficiency.

1 Introduction

Energy is essential to human life and to the ongoing growth of humanity. The sustainability of contemporary society depends on a reliable and easily available energy source. Almost all human activities, including those related to transportation, housing, industry, health, and other fields, now require energy. This will create an unsustainable situation in near future. Ecologically friendly, abundant, and never-ending are renewable energy sources like wind, solar, wave, biomass, and tidal energy. The Fig. 1 shows the power production potential in India as on July 2023 based on the sources of renewable energy, in that solar energy has been improved to 71 GW [1]. Out of other renewable source of energy solar contributes to 40%.

Figure 2 shows the average of Global Horizontal Irradiance (GHI) in India between the year 1999 to 2018 [2]. This gives an indication that, India can tap solar energy to a maximum extend.

Remarkable development in solar energy based technologies has been observed in last decades. The main concerns driving the usage of these technologies are the cost and availability of fossil fuels, as well as the effects of climate change. Figure 3 shows the state wise installed capacity of solar energy in MW [3]. It was observed that, Rajasthan is the first province followed by Gujarat and Karnataka. Same is reflected in GHI contour plot (refer Fig. 2).

Within India, there are different climates as shown in Table 1 [4]. It is clear that on a given operating day, a solar pumping system's performance will vary from province to provinces

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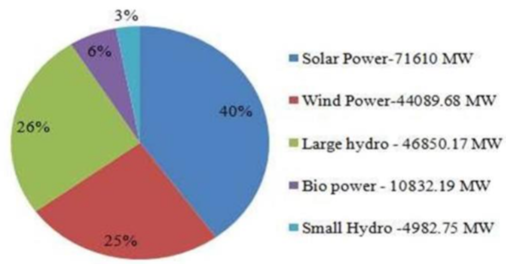

Fig. 1. Renewable power potential in India

Table 1: Table 1 Climate zone across India

Climate	Zones
Hot and Dry	Rajasthan, Gujarat, Western Madhya Pradhesh
Warm and Humid	Kerala, Tamil Nadu, Orissa
Temperate	Bangalore, Goa
Cold (Sunny/Cloudy)	Jammu & Kashmir, Ladakh, Himachal Pradesh, Sikkim
Composite	Uttar Pradesh, Haryana, Punjab, Bihar, Jharkhand, Chhattisgarh

2 SOLAR WATER PUMPING SYSTEM

Solar pump systems employ solar photovoltaic modules to convert irradiance into electricity, which in turn used to power AC or DC motors for driving surface or submersible pumps. Solar PV modules develop DC, It is eventually converted to an electrical current and voltage by a suitable solar pump controller (inverter) based on the amount of voltage required by the solar pump. Solar pump controller includes using Maximum Power Point Tracking (MPPT) technology; solar PV modules may produce their optimum amount of power, as well as overvoltage, under voltage, reverse polarity, and dry running protections. Figure 4 shows the schematic layout of solar water pumping.

Table 2 shows the classification of solar PV modules with efficiency [**?**]. It infers that still much more research is needed for enhancing the solar PV efficiency. The solar pump performance varies with reference to irradiance and ambient temperature; thereby the module temperature plays a vital role in solar panel efficiency.

The solar charge controller regulates the flow of energy from solar PV module to the pump, ensuring that the power does not exceed the capacity of pump and seeking toreduce waste energy. In general there are two methods. The first one is an analog signal is produced by digital devices like microcontrollers using a control technique called Pulse Width Modulation (PWM). Thesecond one is the MPPT, it is used with variable power source to maximize energy extraction as irradiation varies.

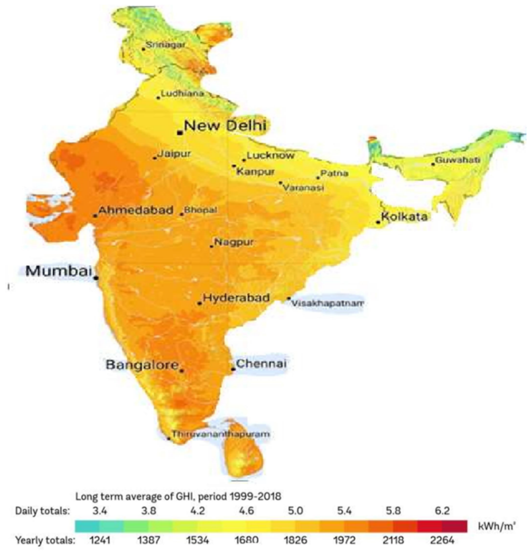

Fig. 2. Global Horizontal Irradiance (GHI)

As far as the motor is concern there are two major types AC (induction and synchronous motors) & DC (shunt, separately excited, series, permanent magnet, and compound motors). But in recent days because of material and technological advancement, it is further classified into various categories.A pump is a mechanical device that pumps water from one level to another level (mechanical energy into hydraulic energy). Pumping water from underground, wells, lakes, rivers, and other sources to buildings, residences, and other structures is a typical usage in residential, commercial, and industrial contexts. Pumps are classified as shown in Fig. 4.

The operation and maintenance of solar pumps should be fairly easy, since these units are typically located in remote places with limited professional labour [5]. In order to maximize the performance of solar powered water pumps, the electrical array reconfiguration controller introduced a novel strategy. It was accomplished by generating enough start up current to motor-pump at very low irradiance levels, giving the pump a wide operating range and more hours of pumping. [6]. An inductor and capacitor filter was introduced between PV array and it has been discovered that the inverter plays a key role in lowering fluctuations and smoothing the input power to the inverter [7]. To improve the efficiency of conversion from solar radiation to hydraulic energy while accounting for fluctuations in Total Dynamic Head (TDH) for a specific insolation was reported by Lujara et al. [8]. The load matching factor improves as solar radiation increases, and it was feasible to attain a larger load matching by carefully selection of appropriate array and the pump/motor subsystem [9]. It was determined that installing a PV-powered water pumping system to replace the current conventional AC powered one would be advantageous after testing the flow rate, output voltage, and current [10]. The Permanent Magnet Brushless (PMBL) DC motor has been shown to be effective

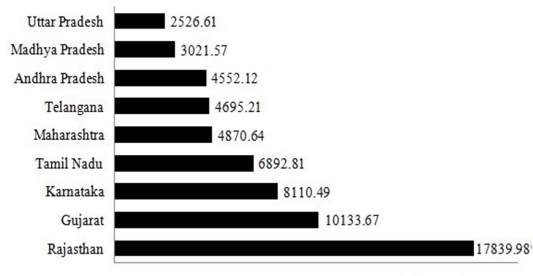

Fig. 3. State wise installed capacity of solar energy (MW)

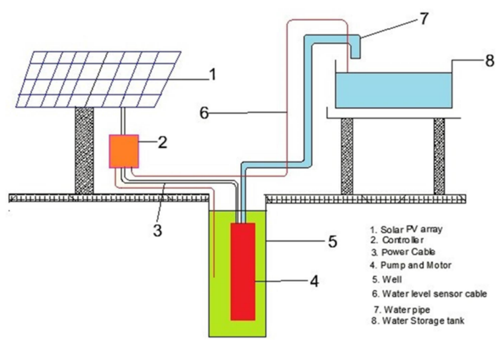

Fig. 4. Schematic of solar water pumping system

in analyzing the drive systems of pump [11]. A photovoltaic power system's long-term performance over any monthly or annual period can be developed and predicted using a simulation software programme that used weather data from two typical metrological years [12]. The dynamic model of a DC drive driven by a PV array through a boost converter was used to forecast the solar pumping system's performance using MATLAB [13].The SIMULINK programme is a simulation tool that is used to determine the response of a drive system by varying levels of light intensity [14]. Even under more complicated circumstances, the suggested approach for sizing the ideal PV pumping system for irrigation purposes was proven to produce good results [**?**]. The power output of boost converter was measured at various duty cycles for solar irradiance and temperature for solar pumping system [**?**]. The possibility in theory to create a solar pumping system considering solar radiation, water requirements, economic viability, and TDH features. This suggested system supplies more water than the required for the month [**?**]

Table 2: Classification of solar PV modules

Solar Cell Type	Efficiency	Merits	Demerits
Monocrystalline Panel	20%	High Rate of Efficiency	Costly
Polycrystalline Panel	15%	Low cost	Reduced Lifespan, less space-efficient
Thin film amorphous Silicon Solar Panels	7-10%	Easy to make reasonably, inexpensive and adaptable	Limited lifetime and warranty periods
Concentrated PV Cell	41%	Extremely high rate of effectiveness and performance	A cooling system and solar tracker are required

3 Characteristics of pumping system

The Fig. 5 shows the general characteristics of centrifugal pump with total head, power & efficiency curve with respect to flow rate at one particular speed. Tothat system curve is plotted to understand the operating point of pump. Based on operating and best efficiency points, pump user has control to run the pump near the Best Efficiency Point (BEP).

The Fig. 6 gives the typical solar pump characteristics for different TDH conditions. Flow rate (Q) and wire to water efficiency (Eta) are plotted with reference to solar power. Unlike pump performance characteristics the best efficiency zone will not be shown, since it is plotted with respect to irradiance power. This plot gives the information how the solar pump will operate at any particular TDH.

4 Conclusion

Solar based pumping system grows exponentially to meet the demand of irrigation purpose and so on. Hence it is necessary to contribute more insight for better enhancement of overall system. The general pump characteristics will give the best efficiency point to operate the pump within the allowable zone of operation. Whereas the solar pump characteristics does not give those range for optimum running of pump. Hence it is desired to find the allowable range for operation of solar pump with reference to wire to water efficiency, flow rate, and irradiance power corresponds to total dynamic head. Now a days, various technology enhancement are available to monitor the pump operation and to give appropriate signal for achieving the optimum efficiency. Using machine learning method, those problems will be sorted out to match the characteristics of solar photovoltaic, controller, motor, and pump. The best way is to control the speed of pump through variable frequency

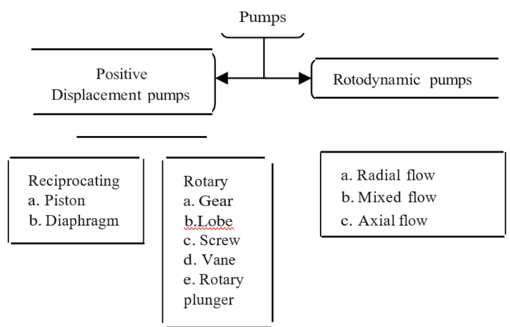

Fig. 5. Classification of pump

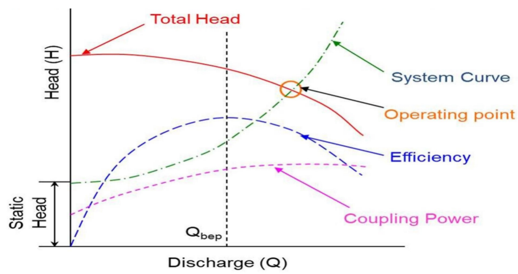

Fig. 6. Pump characteristics curve

drive.

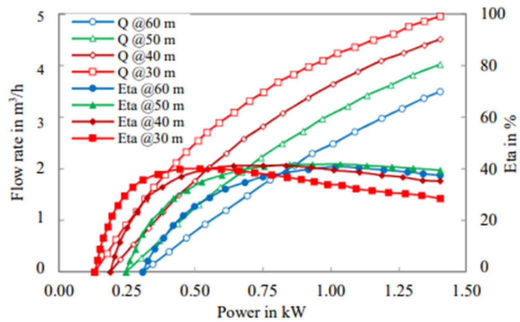

Fig. 7. Solar pump characteritics curve

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