Solar Energy Application in Indian Irrigation System

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Solar Energy Application in Indian Irrigation System

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Abstract. The electricity deficit and high diesel costs influence the pumping needs of urban water supply and irrigation; hence, the use of solar power for water pumping is a viable alternative to traditional water pumping systems dependent on grid power and diesel. In recent decades, attention has been given to clean and renewable energies from the vast majority of countries' priorities in the environmental and economic sectors. Agricultural sector is backbone of Indian economy as population increases demand of water also increases. Extract and transfer of water to agriculture and drinking is equals high-energy consumption. One of the best solutions is to use of an abundant and almost free solar energy to supply energy in all sectors, especially the irrigation sector. In the growth period of crops, when irrigation is often required, there are a high of solar radiation comes from the sun. This study shows that in India, like many other developing countries, the weakness of using this important source, the program of converting solar energy, and photovoltaic pumping systems use. This paper summarizes solar energy development and its application in the irrigation system and comparing them with the conventional diesel pumps. The expected results of this paper are to encourage the politicians, statesmen, and professionals to planning and policy-making the use of the green energy industry in the water sector that could pump water to the villages and agriculture and jump in the energy sector to the economic and Sustainable development.

1. Introduction
It is well known fact that Indian economy is one of the leading economies over the world. Among the various sectors in the Indian economy, agricultural sector provides the largest contribution to develop the nation. In order to achieve extreme manpower utilization and highest return in a given postulated it is required to promote different engineering methods which are recently used in today's global market [1]. Since there is a snowballing in usage of energy, the nonstop decrease in prevailing sources of fossil fuels and the rising issues in relation to the environment pollution, we have been pushed to discover renewable energy sources like solar energy, wind energy, etc. [2]. Solar energy is one of the greatest plentiful resources of energy in this universe. Besides being a solution to today's energy problem, Solar power also acts as a pollution free form of energy. Photovoltaic generation is an effective method for consuming the solar energy [3]. The solar energy projects in most of the developing countries of the world are diverse, such as rural power supply, communication services, water pumping, street lighting, cooling and heating of residential and commercial spaces, heating of water etc. that protected the environment [4]. Handling with the current situation of energy problems in India, irrigation system using solar power can be opted for farmers to manage their agricultural works. It is a finest technique to produce the energy in an eco-friendly manner after a primary investment [5]. One of the most significant usages of solar energy is providing drinking water for small communities which has the around thousand

members [6]. The World Bank estimates the number of people who live in remote rural areas and do not have safe drinking water in developing countries about one billion people [7].

According to the distant villages of the nationwide grid, supplying energy and drinking water to the rural population is very difficult and costly. For this reason, the policy of exploiting local energy sources, such as solar energy, has been recognized for many years as a useful solution. One can mention the benefits of using local energy, improving health and well-being, boosting agriculture through irrigation, access to safe drinking water and providing residential lighting and reducing urban migration. At present, more than 160,000 villages worldwide are based on solar energy [8]. Among the many uses of solar energy, photovoltaic pumping systems have been widely welcomed in the last two decades. According to World Bank reports, up to 1993, ten thousand photovoltaic pumps were installed and operated worldwide, and by the year 1998, there were 60,000 photovoltaic pumping systems [9]. Solar water pumps are very efficient in areas where the expansion of the power grid is not feasible. Even in areas where the connection to the national grid is possible, the use of photovoltaic pumps is preferable for several reasons [10]. Solar pumps can be used in numerous capacities according to the necessity of water [11].Today, the implementation and exploitation of photovoltaic pumps system in developing countries are growing faster than in developed countries. The reasons for this are as follows. restrictions on the distribution of the power grid, money restrictions for the import of oil and The Government's commitment towards rural population, providing electricity, health, and educational programs that have been guaranteed by international organizations [12]. Therefore, Governments in developing countries have decided to invest in the production of photovoltaic pumps system. Most of these studies began in 1979 and continue to this day [13]. The cost-effective economics of the photovoltaic pumps were fixed in comparison with the diesel pumps. In addition, during the survey of the inhabitants of the region, great reliability, and supply of water volume required by photovoltaic pumps were confirmed. Studies of photovoltaic pumps system in India confirm the economic justification and social benefits of these systems [14].

2. Solar pumping system

Photovoltaic is being used for pumping for an extensive kind of processes, especially for water irrigation in agricultural area. It can be also used in refrigeration of fruits and vegetables, fencing, cattle lighting and insects controlling. The techniques which are being used in the PV system is applicable to only those activities that have need of slight power input. They are inappropriate when it comes to large power consuming areas like rice mills and high powered agricultural processing [15]. In current situation, under the hot sun, farmers find difficult to irrigate their plants to maintain their crops green. They suffer because they have no appropriate idea about obtainability of the power. The solar pumping system offers an idea to solve this problem. Generally, the solar pumping system has the following main parts: Electric solar panels pump controller, submersible pump, converter, storage tank and rechargeable battery. The illustration of solar pumping system is shown in figure 1.

2.1. Solar Panel

Solar panels are manufactured with solar cells which comprises of semiconductor materials. The main purpose of solar panels is to change solar power into DC electrical power. The rating of the load determines the number of cells needed and their size. The higher amount of electric power can be produced with the help of collecting solar cells. However, the solar panel should be placed accurately at precise angles towards the sun rays. The size of the pump is being decided in accordance with the photovoltaic cells. The solar submersible pumping system need to be operated along with a PV array of capability with the value ranging between 250 to 550 watt peak, and are being calculated through several typical test. Numerous modules in series & parallel can be utilized to acquire the adequate PV power output. When the PV modules are involved in typical test conditions, it should have a minimum of 74-watt peak.

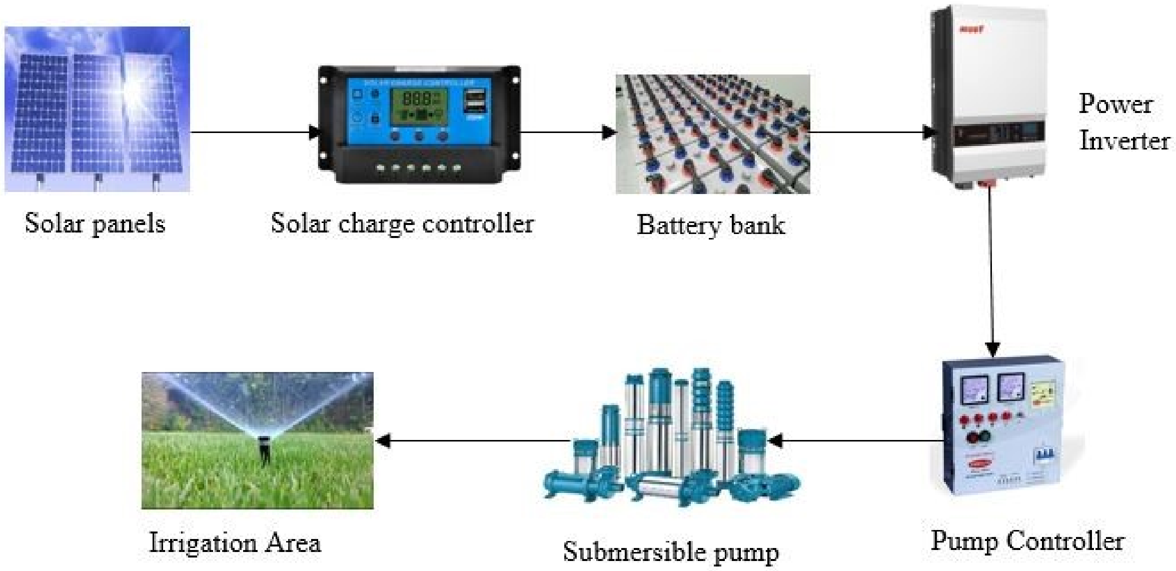

Figure 1. Solar pumping system

2.2. The Submersible Pump

The submersible pump is often placed in a stainless steel case, which is located in a well pit at the joint of the open channel and the natural stream course. The pump controller is used to pump water towards the water tank within a specific time period using the control unit. The size of the solar pumps is determined by the total depth of the well and the longitudinal and local losses of the piping system in pumping from the well and the required water flow.

2.3. Solar charge Controller

A charge controller is very significant electrical device in any solar-power system. It allows correct charging voltages to the batteries. The main purpose of charge controller is to regulate the current as well as voltage from the solar panel. It also used for charging the battery and protect the battery from over and undercharging conditions.

2.4. Battery

The battery is generally used for store current that is formed by the PV panel and delivered to the equivalent loads. The batteries requirement may be varied according to load requirement.

The photovoltaic system being large, needs the solar panel as its component in order to produce and deliver the electricity in rural and urban area's applications. The electric current produced by the photovoltaic panels is direct current (D.C). The voltages of these plates varying according to the variation of temperature and solar radiation. Solar cells are available in three types of monocrystals, polycrystals, and morphs. The pump controller adjusts the power exchanged between the solar panels and the pump. This controller protects the pump against current fluctuations and provides conditions for permanent output. In addition, if the pump is dry, the pump controller can automatically shut down the system, also the pump can be shut down by installing a floating switch connected to the controller when filling the tank. Control circuit permits the battery to charge. A converter circuit transforms DC supply from the battery to AC supply and it gives power to the water pump which is sunken into the well. Before discharging the water into the agricultural arena, the water is drove into an overhead tank for keeping save the water provisionally. The storage mechanism in the solar water pump system can be either water storage method or power storage method. The storage water method most economical way to save water and the most reliable method. Of course, the system can save the power for using the pump during cloudy days and at night with battery embedding. Although this method has high reliability, it also requires higher costs and more maintenance than the first method.

3. Comparison of energy consumption and solar pumps in India with other countries

The addition of solar power capacity into the electrical grids has been adopted by several countries and terrains to deliver a substitute to conventional energy resources. To take advantage of global experiences and compare the situation in India in terms of solar energy projects and consumption activities, especially in irrigation sector, according to a study of broad and wrap existing research and reports created. In this table of solar energy, development activities in various countries, especially in the solar water pumping for irrigation to farms, are summarized. The growth of photovoltaics over the universe is enormously vibrant and differs intensely by country. Nearly 37 countries in the world will generate more than one gigawatt cumulative solar power by 2020. By the end of 2019, a cumulative amount of 629 GW of solar power was installed throughout the world [16]. By early 2020, the leading country for solar power was China with 208 GW, [17] [18] accounting for one-third of global installed solar capacity. The cumulative photovoltaic capacity has been improved as 75 gigawatt (GW) and touched 303 GW, adequate to deliver around 1.8% of the world's entire electricity intake at the end of 2016. The China, the United States, and India were the leading PV panel installers in 2016 through 2019[19] [20]. The Honduras having its PV capacity is presently liable to deliver 12.5 percent of the country's electrical energy, at the same time, Italy, Greece and German is generating from 7 to 8 percent of the domestic electricity intake [21-23].

Table 1. The activities of the different countries in the field of the use of solar energy and pump

Country	Description	Description of activity	Data
China	The world's largest solar power plant construction program with the production capacity of the 200 gigawatts accounting for one-third of global installed capacity.	99% of the area under irrigation pump and photovoltaic systems are most cultures.	2020[24][25]
Japan	The program uses existing solar energy in space and sends to Earth by the year 2030 in Japan. By the end of 2017 cumulative capacity reached 50 gigawatts.	Solar energy production, increasing 1.2 times in one year.	Up to 2017[26]
Unite the States of America	The decision to install 10 million solar panels within a decade and 10% of the electricity needed by the year 2030.at the end of 2017 cumulative capacity touched 50 gigawatts.	Convert the Nevada desert (the location of the nuclear tests) is the world's largest solar laboratory.	Up to 2017[27]

Taiwan	Long-term goal of adding 6500 to 10000 MW for renewable energy sources in the next 20 years. By the end 2019, the capacity of solar energy production touched 4 gigawatts.	Construction of the largest solar power plant of Asia with an area of two hectares with a production capacity of one megawatt of energy.	2019[28]
Jordan	The fortunes of the public to make use of this technology have increased. Hit the number of pumps installed is exact at hand. By the end 2018, the capacity of solar energy production touched 1 gigawatts.	Promote the use of photovoltaic systems are the water pump and the expansion of research in this field.	2018[29]
Turkey	The program of the annual energy production of photovoltaic systems is 500 kW. By the end 2018, the capacity of solar energy production touched 6 gigawatts.	Solar energy collector plates increased from 8 million to 11 million square meters.	2018[30]
India	Installation and operation of photovoltaic water pump 10000 of the goals of the PM-Kusum in this country. . By the end 2019, the capacity of solar energy production touched 37.5 gigawatts.	Installed the 181000-water pump with photovoltaic systems for agricultural areas.	2019[31]

4. A review: usage of solar energy in agricultural area

Water pumps in most essential application in agricultural sector, the use of solar energy for lifting the water is a best option for agricultural development and efficient use of available water resources. There are various stages to implement the solar water pump to the irrigation system, and are as follows, (i) Determine the quantity of water requirement which includes climatic analysis. (ii) Calculate the power requirement for pumping water. (iii) Estimate the rate of energy production and climatic adaptation. The aim of the study was to estimate the rate of energy production and climate adaptation [24-36]. Water requirement for irrigation, which is completed by use CROPWAT8.0 software for two types' crops one is winter wheat it planting time in November and harvest time in July.So during the design stages of the required flow drip irrigation system 33.3m^3/h (25.9lit/s) and 7.5 hours and duration of irrigation in two

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turns. 27-meter system and the dynamic head static head are estimated to be 5 meters. The pump should be selected as the height of 32 metros of water [15].

The hydraulic energy (HE) requires pumping the 799.2 m^3/day water.

$$HE = \frac{Q \times TDH \times Dw \times Gr}{3.6 \times 10^6} \quad (1)$$

Where:

Q is flow requirement

TDH is a total dynamic head of well.

Dw is water density.

Gr is the gravity of earth.

HE= (799.2 x 32 x 1000 x 9.81)/ (3.6 x10^6)

HE= 69.69 kWh/day

$$\text{Pump capacity } = \frac{HE}{daily\ sun\ hours} \quad (2)$$

=69.69 /6.791=10.26kW=13 hp.

Pump capacity=13hp

4.1. Shaft power

The power which is provided by the motor to the pump shaft is named as the shaft power. The ratio of hydraulic pump to the efficiency of the pump determines the shaft power.

$$\text{Shaft power (Ps)} = \frac{\text{hydraulic power}}{\text{efficiency of pump } (\eta p)} \quad (3)$$

ηp = 80 % = 0.8

Shaft power (Ps) = 13/0.8 = 16 hp

4.2. Motor power

The power used up by the pump motor to change the pump shaft is called as the motor power. We can calculate the motor power by adding the shaft power and power loss that is made due to ineffectiveness in changing electric power into kinetic power [37-48]. It is better defined as the ratio of shaft power to the motor efficiency.

$$\text{Motor power } = \frac{\text{shaft power}}{\text{efficiency of motor } (\eta m)} \quad (4)$$

ηm = 90 % = 0.9

Motor capacity = 16/ 0.9 = 17 = 17 hp

Total energy requirement 12.66 kW capacity available solar submersible in bazar start 0.5 horse power (HP) up to 50 horsepower (HP).

5. Design of solar photovoltaic array

The solar photovoltaic array consists of several photovoltaic solar modules size basically to satisfy the energy needs of pumps has been designed. The connection of the PV modules in series and parallel, depending on the voltage and time required are made. The solar array installed in this field Fixed type can be either track one. The tracking system will considerably improve the efficiency although it adds an additional cost of tracking equipment.40 to 60% of the photovoltaic panels of the overall system costs. The power output of the PV array with respect to the difference in the location of the solar radiation and atmospheric factors, different temperatures, so the appropriate size according to the required page is very important and the process is difficult. The size of the PV array can be done regarding the need to lift the daily required an amount of hydraulic energy of water HE, Average daily radiation on photovoltaic array E and the daily subsystem efficiency. This method makes the system more accurate and reliable.
Peak watt module can be calculated with the equation

$$\text{Solar PV array power(kwp)} = \frac{\text{motor energy requirement}}{\text{F x E}} \tag{5}$$

Where:

F= array mismatch factor (0.85 on average)

E= daily subsystem efficiency (0.25 - 0.5 typically)

Solar array requirement (kW) = 12.66 kW/ (0.5*0.85) =37.23 kW

Table 2. Electrical characteristics of a multicrystalline solar panel.

Electrical characteristics	Values
Maximum power (Pmax)	170 W
Voltage at maximum power point (Vmax)	35.4 V
Current at maximum power point (Imax)	4.8 A
Short circuit current (Isc)	5 A
Open circuit voltage (Voc)	44.2 V
Temperature coefficient of short circuit current (Isc)	0.065± 0.015 (%/ºC)
Temperature coefficient of open circuit voltage (Vop)	-160± 20mV
Temperature coefficient of power	-0.5± 0.05 (%/ºC)
NOCT (ºC)	47 ± 2

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5.1. Number of series and parallel

Maximum power of the system W_{pa} = 37235W
The maximum voltage of the module V_{mp}=35.4V
The maximum current of the module I_{mp}= 4.8A
Boost converter input voltage it is the maximum voltage of the system V_{ma}=500V
The maximum current of the system I_{ma}= Maximum power of the system/ maximum voltage of the system
Maximum current of the system I_{ma}= W_{pa}/ V_{ma}=37235/500 = 74.47 A
Number of series module N_s = maximum voltage of the system/ Maximum voltage of the module= V_{ma}/ V_{mp} = 500/35.4 = 15
Number of module parallel = Maximum current of the system/ Maximum current of the module = I_{ma}/ I_{mp} =74.47/4.8 = 15
Total number of the PV panel = 15*15= 225

6. Solar water pump comparing with diesel water pump

In this section, a detailed analysis carried out between solar water pump and diesel water pump is the perspective of cost and reliability. Diesel water pumps, are usually cost effective at the initial time, though when it comes to operation and maintenance, they are costly. Unlikely, the solar water pumps are having maximum initial cost and little for operation and maintenance. In consistency, it is more liable to make use of solar water pumps rather than using diesel water pumps. From the environmental point of view, diesel driven water pump is produce various gases which change climate as well as health hazards. This is made possible where diesel water pump gets rusted when it is actually not in use, but solar pumps may survive for years, even if it is not used properly. The preliminary cost of the solar water pump is frequently unapproachable to the project executors to expanse their funds as extreme as possible to grasp the highest number of receivers with the use of a low primary optimum cost.

Table 3. Comparing the solar water pump and diesel water pump

Particulars	Solar water pump	Diesel water pump
Available capacity kW (hp)	0.5(0.75) to 75(100)	3.7(5) to 11(150)
Capital cost	High	Moderate
Running cost	No running cost	Very high
Maintenance cost	Negligible	High
Routine maintenance	Only panel cleaning once a week	Diesel lubrication minor &major servicing required, periodic overhauling must
Part replacement	Moderate	Worn out parts need to be replaced often
Operator	No operator required, auto start / stop possible	Operator required
Other utilization	PV array can be used for electricity generation when the pump is not running	No
Environmental aspect	Silent & pollution free green power	High air pollution and noise pollution
Limitation	Works on solar during day time only	High fuel & maintenance cost

Table 4: comparison of solar water pump and diesel water pump.

Years	Year 1	year 2	year 3	year 4	Year 5	year 10	year 15	year 20	Total USD
Solar water pump									
Initial cost	46644	0	0	0	0	0	0	0	46644
Servicing cost	0	0	0	0	0	574	0	673	1,247
Maintenance cost	0	0	0	0	0	32163	0	37684	69847
Cumulative total	46644	46644	46644	46644	46644	79381	79381	117738	117738
Diesel water pump									
Servicing cost	500	510	520	531	541	2,873	3,172	3,501	12148
Maintenance cost	0	0	3121	0	1624	8620	9668	6386	29419
Fuel	4380	5037	5793	6661	7661	59399	119472	240299	448702
Fuel delivery costs	2600	2652	2705	2759	2814	14939	16493	18210	63172
Cumulative total	7480	15679	27818	37769	50409	136240	285045	553441	553441

7. Conclusion

The solar power is suitable for agricultural applications such that electrical fencing, threshing, aeration, grinding, irrigation, purification etc. Nowadays the farmers from India are generally using the solar energy in the water sectors especially in irrigation sectors for their agricultural farms. However, farmers are thinking the solar water pump systems initial cost is higher than diesel water pump system but never thought generation and maintenance costs of both systems. One of the most importing things is the solar water pump system PV array can be used for electricity generation when the irrigation is not a requirement. Solar water pumping systems can easily meet the irrigation water requirement for landholding system marginal farmers. Due to facing regularly increasing fuel cost, pump sets is being deployed every year in India. Solar water pump system helps in the reduction of diesel consumption. The solar water pump is no novelty it has existed since three decades also solar water pump are available for different types. And despite being blue, uses up to 30% of the country's productive energy would devour precious resources continue to use most of the electrical energy production. it insists that many costs on society and the environment, based on the frequency in the electric sector and thermal power plants to the environment imposes. From the above, we conclude that, compared with diesel engine pumping system, the solar pumping system is more feasible for irrigating the farms in India. In economic basis, solar water pumps are not more expensive if the solar energy are used continuously, though their capital cost is high.

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