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Experimental studies and performance evaluation of solar-powered water pumping system

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Abstract
Water pumping is an energy intensive activity and consumes a large amount diesel and electricity. Solar energy, which is abundantly available in India, can be used for pumping water via Solar-PV technology. In this study, we try to understand the performance of the already deployed solar PV water pumps in the SGSITS Campus and Indore area. The sites we visited included solar pumps installed under Govt. schemes such as the MNRE and installations by Shakti pump India private limited in both rural and urban areas. Along with the analysis of performance, various socio-economic aspects of the surrounding communities are also looked at. Based on our findings, we have come up with a list of recommendations mainly focused on development of community knowledge and greater accountability from the vendors. Along with these recommendations, future work should involve gathering of reliable data for analyzing the performance and operation of the pump and aizing mechanism as well as a pump-type selection framework. Irrigation is a well-established procedure on many farms and is practiced on various levels around the world. It allows diversification of crops, while increasing crop yields. However, typical irrigation systems consume a great amount of conventional energy through the use of electric motors and generators powered by fuel. Photovoltaic energy can find many applications in agriculture, providing electrical energy in various cases, particularly in areas without an electric grid. In this paper the description of reviews on a photovoltaic irrigation system, is presented. Photovoltaic water pumping system is one of the best alternative methods for irrigation. The variation of spatial and temporal distribution of available water for irrigation makes significant demand on water conservation techniques. Hence solar powered Automated Irrigation System provides a sustainable solution to enhance water use efficiency in the agricultural fields using renewable energy system removes workmanship that is needed for flooding irrigation. The use of this photo-irrigation system will be able to contribute to the socio-economic development. It is the proposed solution for the energy crisis for the Indian farmers. This system conserves electricity by reducing the usage of grid power and easy to implement and environment friendly solution for irrigating fields.

Keywords: photovoltaic cell, DC controller (3-5HP), solar submersible pump (3HP)

Introduction

The depletion of the fossil fuel reserves and the pollution caused by the conventional energy sources has made necessitous the exploitation of renewable energy sources in order to address the global challenges of clean energy, climate change and sustainable development. Those alternative energy production systems, such as photovoltaic (PV) systems are being supported by many governments and countries on a worldwide basis. Photovoltaic energy is one of the most promising emerging technologies. The cost of PV modules has been divided by five in the last six years; the cost of full PV systems has been divided by almost three. On the other hand, installations of PV systems around the world have been growing at an average annual rate of more than 44% during the period from 2000 to 2013. Since 2010, the world has added more solar photovoltaic capacity than in the previous four decades. New systems were installed in 2013 at a rate of 100 megawatts (MW) of capacity per day. Total global capacity overtook 150 GW in early 2014.

Photo voltaic is the field of technology and research related to the devices which directly convert sunlight into electricity. The solar cell made of semiconductor materials is the elementary building block of the photovoltaic technology. A number of solar cells electrically connected to each other and mounted in a single support structure or frame is called a 'photovoltaic module'. Several modules can be wired together to form an array. Photovoltaic modules and arrays produce direct-current electricity. They can be connected in both series and parallel electrical arrangements to produce any required voltage and current combination. To better understand the acting physical mechanisms within the solar generator (cell, module, array), several methods have been proposed for the identification of the different parameters that affect their According to the Indian government Portal, The energy deficit in India was evaluated in July 2016, at 2.8 Mtoe (million tonnes of oil equivalent) while production of oil has fluctuated between 6 and 7 Mtoe in the last two decades. In 2014, 98% of India's electricity generation came from fossil-fueled power stations, with hydroelectric and wind sources supplying only 2% of total generation. However, the Tunisian government aims to produce 11% of electricity from renewable sources by 2016, and 25% by 2030. Tunisia has also committed to be part of the DESERTEC "super-grid" that will connect African and European countries.

Renewable energy - wind, solar, geothermal, hydroelectric, and biomass- provides substantial benefits for our climate, our health, and our economy. Among renewable energy sources, solar energy is currently considered to be the most useful natural energy source because it is clean and silent. Because they do not use fuel other than sunshine, PV systems do not release any harmful air or water pollution into the environment, deplete natural resources, or endanger animal or human health.

Solar photovoltaic (PV) directly converts solar energy into electricity using a PV cell; this is a semiconductor device. The global total of solar PV is now close to 140,000 megawatts, to be compared with just 1.5 GW in 2000. Over the past five years, solar PV has averaged an annual growth rate of over 50%. Growth has been mostly concentrated in a few countries, where PV generates today a few percent of total yearly electricity production.

Water pumps are driven by various types of motors. AC induction motors are cheaper and widely available worldwide. The system, however, needs an inverter to convert DC output power from PV to AC power, which is usually expensive. In general, DC motors are used because they are highly efficient and can be directly coupled with a PV module or array. Today the generation is heading towards ultra-technologies.

Water pumping has a long history; so many methods have been developed to pump water. People have used a variety of power sources, namely human energy, animal power, hydro power, wind, solar and fuels such a diesel for small generators. The most common pumps used in remote communities are:

a. Hand pumps
b. Direct drive diesel driven borehole pumps
c. Electric submersible pumps with diesel generator
d. Solar submersible pumps

1. Photovoltaic cells

Photovoltaic cells are devices which 'collect the light and convert it into electricity. The cells are wired in series, sealed between sheets of glass or plastic, and supported inside a metal frame. These frames are called solar modules or panels. They are used to power a variety of applications ranging from calculators and wrist-watches to complete home systems and large power plants. PV cells are made of thin silicon wafers; a semi-conducting material similar to that used in computer chips. When sunlight is absorbed by these materials, the solar energy knocks electrons loose from their atoms, allowing the electrons to flow through the material to produce electricity. This process of converting light (photons) to electricity (voltage) is called the "photovoltaic effect.

2. PV applications

Solar panels are used in a variety of applications. The applications vary from small simple lanterns to large elaborate power plants.

1. Rural and urban households for domestic purposes like lighting.
2. Communities, small industries and institutions like schools, for lighting as well as for powering television sets, computers, etc.
3. Water pumping systems.
4. Telecommunications, as these systems are often installed in isolated places with no other access to power.
5. Refrigeration of vaccines at health center in rural areas. Such solar refrigerators are also utilized to store blood plasma. WHO supports programmers that install solar power for medical purpose

System components

The whole system of solar pumping includes the panels, support structure with tracking mechanism, electronic parts for regulation, cables, pipes and the pump itself.

1. **Solar panels or modules:** Solar panels are the maincomponents used for driving the solar pump. Several solar panels connected together in arrays produce DC electricity, interconnections are made using series or parallel combinations to achieve desired voltage and power for the pump.
2. **Solar pump:** Centrifugal or submersible pumps areconnected directly to the solar array using DC power produced by the solar panels. Solar pumps are available in several capacities depending upon the requirement of water.
3. **Support structure and tracking mechanism:** Supportstructure provides stability to the mounted solar panels and protects them from theft or natural calamities. To obtain maximum output of water, a manual tracking device is fixed to the support structure. Tracking increases the output of water by allowing the panels to face the sun as it moves across the sky.
4. **Foundations (array and pump):** Foundations areprovided for support structures and pump.
5. **Electrical interconnections:** A set of cables of appropriatesize, junction boxes, connectors and switches are provided along with the installation.
6. **Earthing kit:** Earthing kit is provided for safety in case of lightning or short circuit.
7. **Plumbing:** Pipes and fittings required to connect the pump come as part of the installation.

3. How the solar pump system works

A 300-watt (300*10 Panels in series) photovoltaic solar panel can power a 12-volt pump, which can move 1,300 to 2,600 L/h. Standard plastic fittings and half-inch piping connect these elements to a water saving tank of 500 to 1,000 L. A sturdy stand should be built for the water tank to provide gravity flow, and a frame should also be constructed to provide the best angle for the solar panels. Multiple filters are needed to protect the life of the pump and minimize clogging in sprinkler emitters and tubes. A solar pump combined with affordable drip irrigation kits can be used with a wide variety of high-value crops to increase water efficiency, minimize fertilizer loss, and irrigate hilly terrains.

Aspects

In general, the investment required for a PV pumping system is Rs 250-300/Wp (where Rs is the Indian rupee and Wp is watts peak). For example, the cost of a 900 Wp unit would be Rs 225,000-270,000, but with subsidies, this will be reduced to Rs 50,000. To make the best use of solar energy, the PV system, the groundwater pump and the water distribution system have to be well matched. The PV power provided must cover the power demand of the pump adequately. This is determined by the relationship between the required discharge flow, the total head and the pump efficiency. This depends on the type of pump, which in turn depends on the depth of the available water source. Although positive displacement pumps are preferred for large heads, centrifugal pumps are most commonly used for this as shown in Figure 1. Photovoltaic (PV) panel electrical outputs are rated according to industry Standard Test Conditions (STC) of 1000 W m-2 incident solar radiation at an operating cell temperature of 25°C and under an absolute air mass of 1.5. Environmental conditions met outside the laboratory will cause a decrease in PV performance from the STC rating, the magnitude of which depends on the module technology. Many additional losses are incurred due to the inefficiencies in transferring energy from the PV panels to a load, such as a pump or battery bank, thus resulting in a secondary decline of performance. Though there have been studies measuring outdoor performance of PV modules, there is a great need for further field studies of complete PV systems. Another important aspect would be the ability to model the potential solar radiation, PV power output, and subsequent water output for the purpose of irrigation scheduling. Photovoltaic powered water pumping systems (photo-irrigation) have been studied by researchers for many years. Studies mostly concentrated on DC motors because energy obtained from solar panel is DC (*Lawrance et al.*, 1995; Dursun and Saygin., 2005). These are shown that better results were obtained for performance analysis (Kolhe *et al*., 2004; Kolhe *et al*., 2000). Photo-irrigation system has advantages over flood irrigation, for bringing efficient utilization of water sources, preventing erosion and growing of weeds (Cuadros *et al*.,2004), decreasing moisture stress (Pande *et al*., 2003), no operation cost, providing opportunity for local energy sources and exhibiting a parallel point of view with water requirement (Ghoneim, 2006). In terms of automation, developed wireless technologies, researches focused on automatic irrigation with sensors in agricultural systems (Kim and Evans, 2009; Stone *et al*., 1985).The advantages of using wireless sensor is to reduce wiring and piping costs, and easier to install and maintain especially over large areas (Dursun and Ozden, 2010).

Energy of pumps used for the agricultural irrigation is generally provided from electrical energy or fossil fuels. Solar energy that is sensitive to environment, clean and requiring no maintenance is an alternative renewable energy source especially for countries like Turkey having a high amount of annual solar irradiation rate. Means for requirement for irrigation PV pumping systems has advantage of water demand (Anis and Metwally, 1994). In summer months obtained solar energy increases and also naturally water requirement of trees increases. The cost of solar PV has come down and cost of diesel has been regularly increasing. At present the cost of solar PV is very much less than diesel, solar PV cost shall behalf of diesel within three to four years, since approaching towards grid parity. 400,000 telecom towers are associated with diesel generating sets having capacity 3 to 5 kW. 60% Telecom towers located in urban and semi urban areas and 100% located in the villages are run by diesel generating sets. In fact, off-grid potential is unlimited in India and is about 20 to 25% potential of the world (Arora, 2014). Solar water pumps are often thought of as being an expensive technology, which is not able to pump enough water and which is not durable. However, solar water pumps have come a long way in 25 years and today there are solar pumps on the market which have improved on previous technology, e.g.: Submersible pumps which can pump up to 200 m heads; pumps that are able to pump larger volumes of water, e.g.: At 100 m, about 10,000 L/day; At 50 m, about 20,000 L/day. Above performance can be doubled through dual systems (if the borehole allows this).

1. Low maintenance requirements (3 to 5 years);
2. Good performance which means fewer solar panels to pump the same amount of water;
3. Some of the pump models can be backed-up by a genset to pump additional water with the same pump during the night or during overcast days;
4. Good quality and reliability
5. Simple to install.

Furthermore, solar pumps are well known for having the following features:

a. Require minimal attention as they are self-starting;
b. solar pumps are “good” for boreholes over the whole day; c.Weak boreholes can be used effectively with a low volume pump due to pumping 8 to 10 h a day;
c. In most cases, a solar pump offers an ideal solution to the diesel option which requires operating funds (with uncertainty about future diesel prices), time investment for operating pump (manual starting etc.) and logistics for fuel, maintenance, installation and de-installation;
d. Tracking arrays can be used to increase daily water pumping rates;
e. Solar pumps offer clean solutions with no danger of borehole contamination.

Photovoltaic (PV) technology is used for generating electricity from the incoming solar radiation. Several attempts have been made to evaluate, monitor and improve the performance of different components of a PV system: a PV module (Abdallah, 2004; Vick and Clark, 2004; Huang and Sun, 2007; Hansen *et al*., 2000; Lorenzo, 1994), a controller (Hohm and Ropp, 2003), a battery (Copetti *et al*., 1993; Gergaud *et al*., 2003; Achaibou *et al*., 2012), a pump (Vick and Clark, 2011), and a pump motor (Bhat *et al*., 1987). These, and similar studies have been effective for improving the efficiency of the PV system components. However, several factors need to be considered for an optimal PV system design to achieve the desired reliability of the system in a given environment. This involves a detailed investigation of all interacting physical (plant and soil type, irrigation system specifications, PV system sizing, site attributes), meteorological (solar radiation, air temperature, relative humidity, wind speed, precipitation) and managerial (irrigation scheduling) variables with the aim of achieving the desired reliability of the PV system. Ultimately, a technique that combines the center pivot irrigation system characteristics, daily crop water requirements, soil moisture status, irrigation applications, PV array output, load demands, and energy storage is required for evaluating a solar-powered center pivot irrigation system in terms of its reliability. This sort of holistic approach could be very beneficial for effective sizing of the system. Environmental conditions met outside the laboratory will cause a decrease in PV performance. Important environmental conditions to consider are the insolation, ambient temperature, and wind speed (Van Dyk *et al*., 2005). The setup of a PV system is also very flexible. The most efficient use of solar energy is when the panels are directly connected to the load. In fact, the success of water pumping lies partly with the elimination of the intermediate phase, namely the battery bank, for energy storage. With a direct connection between the PV array and the pump, water can be pumped during sunlight hours. The most efficient form of direct-connect systems is when the water is being pumped to an elevated storage tank, thus the electrical energy from the panels is converted to potential energy of the elevated water, to be used on demand, often by gravity (Hamidat *et al*., 2003). The overall efficiency, from sunlight to water flow, has been recorded to exceed 3% (Daud and Mahmoud, 2005).

This system is easy to implement and environment friendly solution for irrigating fields. The system was found to be successful when implemented for bore holes as they pump over the whole day. Solar pumps also offer clean solutions with no danger of borehole contamination. The system requires minimal maintenance and attention as they are self-starting. To further enhance the daily pumping rates tracking arrays can be implemented. After economic analysing, it is shown that photovoltaic pumping system for irrigation in Bangladesh is more feasible than diesel engine pumping system.

Types of Pumps

1. Surface Centrifugal Pump

Surface pump are suitable for areas where the water level is within 7m below ground level. A surface or centrifugal pump is normally placed at ground level. The pump is suitable for pumping from shallow bore wells, open wells, reservoirs, lakes & canals. The solar pump driven by a permanent DC motor is connected directly to an array of solar panels. The pump has a total dynamic head (suction plus delivery) of 14m. The maximum suction head is 7m or 22 feet. The pump will not work if the water table is below 7m in depth. (Figure 2-2) It is possible to increase the delivery head if the suction head is less 7m. This enables one to pump water even from deep wells, by installing the pump inside the well; called 'cut-down'. (Figure 2-3) These pumps are designed for high flow rates and low heads. The permanent magnet DC motor driving the surface pump is powered by a matching solar array to maximize efficiency. An enclosed impeller design ensures smooth operation. Made of cast iron, these pumps are finished with anti-corrosive primer, followed by silver coloured polyutherene paint.

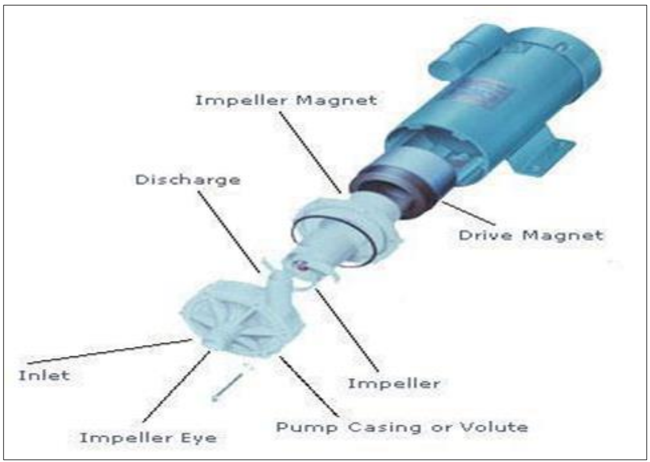

Fig 1: Surface centrifugal pump

Fig 2: A typical cut-down pump

Submersible Pump

A submersible pump is one that is immersed in water. It pumps water by displacement. Submersible pumps are suited both to deep well and to surface water sources. Most deep wells use submersible pumps. These pumps are costlier but have a longer life and greater reliability than surface pumps. These pumps are designed for high head and medium flow application. They multi-stage pump and high efficiency micro-controller based inverter. The inverter optimizes the power input and thus enhances the overall system efficiency.

Choice of Pump: A comparison

Positive displacement pumps have a better daily delivery than centrifugal pumps when driven by a solar PV system with its characteristic variable power supply. This is due to the considerable drop in efficiency of the centrifugal pump when operating away from its design speed. This is the case in the morning and the afternoon of a centrifugal pump driven by a PV array, unless that array tracks the sun (which is why centrifugal PVPs effectiveness improves more with a tracking array than a positive displacement PVP). The efficiency curve of a positive displacement pump is flatter over a range of speeds. However the efficiency of positive displacement pumps decreases with the shallowness of the borehole (the constant fixed friction losses become a more significant part of the power it takes to lift water).

2. The current scenario

For stand-alone (no utility interconnection) water pumping-systems there have been papers published comparing diesel powered water pumping systems to solar-PV water pumping systems [4-5]. There are also papers on modeling and field testing of solar pumps in different locations in the world [6-8]. Several papers have been written on the performance of PV s water pumping systems including the following:

1. Performance of PV powered diaphragm pump.
2. Fixed versus passive tracking PV panels.
3. Performance of PV powered centrifugal pump.
4. Performance of a PV powered helical pump.

Based on the case studies available through field testing done in multiple locations around the world, the advantages and limitations of solar pumping systems can be summarised as:

Submersible Pump Selection

A submersible pump consists of the following basic elements:

1. Bowl Assembly
2. Motor
3. Cable
4. Drop Pipe
5. Surface Plate (with)(without) discharge elbow

Data required for selection

1. Capacity in GPM
2. Static and Pumping Levels in Well
3. Setting Required (drop pipe)
4. Well I.D. Diameter
5. Electric Characteristics

Determination of Total Head

$$\text{Total head} = H + P + F$$

Where: H = Distance from surface to water level when pumping P = Pressure (head) at pump discharge
F = Drop pipe friction (+) check valve(s) loss

Advantages

1. **Low operating cost:** One of the important advantages is the negligible operating cost of the pump. Since there is no fuel required for the pump like electricity or diesel, the operating cost is minimal.
2. **Low maintenance:** A well-designed solar system requires little maintenance beyond cleaning of the panels once a week. Most vendors provide the post-installation service through trained technicians for every clusters.so that the farmers doesn't need to worry about availability of spares or other related problems.
3. **Harmonious with nature:** Another important advantage is that it gives maximum water output when it is most needed i.e. in hot and dry months. Slow solar pumping allows us to utilize low-yield water sources.
4. **Flexibility:** The panels need not be right beside the well. They can be anywhere up to 20 meters! 60 feet away from the well, or anywhere you need the water. So, it offers freedom regarding the placement of panels. These pumps can also be turned on and off as per the requirement, provided the period between two operations is more than 30 seconds.

Limitations

1. **Low yield:** Solar pumping is not suitable where the requirement is very high. The maximum capacity available with solar is very low. However, the output of the solar DC pump is more than a normal pump.
2. **Variable yield:** The water yield of the solar pump changes according to the sunlight. It is highest around noon and least in the early morning and evening. This variability should be taken into consideration while planning the irrigation.
3. **Dry operation:** The submersible pump has an in-built protection against dry run. However, the surface pumps are very sensitive to dry run. A dry run of 15 minutes or more can cause considerable damage to a surface pump.
4. **Water quality:** As with any other pump, solar pumps work best if the water is clean, devoid of sand or mud. However, if the water is not so clean, it is advisable to clean the well before installation or use a good filter at the end of the immersed pipe.
5. **Theft:** Theft of solar panels can be a problem in some areas. So the farmers need to take necessary recautions. Ideally, the solar system should insured against theft as well as natural hazards like lightning.

All-in-one package

The solar drive is used as a solution for specific pumping requirements of the solar pumping system using shakti components, our technical expertise in groundwater pumping, and innovative thinking based on global market inputs, we have developed a rugged, high-output system which tackles the challenges of remote and harsh environments. No other system delivers the features, benefits, and reliability of solar driven in just one packages.

The Solar water pumping system includes

1. Shakti high efficient Submersible motor
2. Shakti Submersible pump
3. Solar Panel and its mounting structure
4. Solar Drive controller
5. Cable
6. Pipes
7. Variety of flow rates available in: 5 to 2500Ipm.(1.3 to 661.3US GPM)
8. Motor and drive rating available in: .5 to 50 HP(.37 to 41.5Kw)

DCSSP Series (DSSP-3000-50-30)

Type designation

DCSSP: Solar Submersible pump
3000: Input power (Watts)
50: Head (Meter)
30: Flow (Ltr. Per Watt)

Note: 1. Input power at Motor End
2. Do not operate pump above its recommended duty head.

Solar water pumping in India

Around 40% of world's population depend upon agriculture directly or indirectly. While 44% of the 140 million sown hectares depend on irrigation, the rest relies on the monsoons. Irrigation, therefore, is essential for good crop yield [3]. Most electrical consumption in this sector goes towards operating pump sets for irrigation. In 2006 accounted for 22% of the total electricity consumption, up from 10% in the 1970s. There are about 21 million irrigation pump sets in India, of which about 9 million are run on diesel and the rest are grid-based. Grid electricity for agriculture in India is provided at very low tariffs in most cases flat rates are charged based on the ratings of the pump. This is largely due to logistical difficulties faced with metering and charge collection. But this practice of providing electricity to farmers at highly subsidized rates has led to increasingly high consumption patterns and widespread use of inefficient pumps across the nation. Also, pumps of lower ratings are used to power applications requiring higher power. These factors, among others, have led to an invidious irrigation energy nexus. Apart from this, limited and unreliable supply of grid in addressing this challenge, the efforts of the Gujarat government are noteworthy. They introduced the Jyotigram Yojana, a programme that seeks to provide a reliable supply of power for agricultural and domestic purposes in rural areas. The MNRE has a programme for the deployment of various solar PV applications, including water pumping systems. However, the deployment has been sparse thus far, with only 7,334 solar PV water pumps having been installed across the country as of March 2010 [3]. Water demand for irrigation is correlated to bright sunny days. Hence, solar-based pumps make sense. Even so, small buffer storage might be needed to replace diesel satisfactorily. A solar PV water pumping system consists of a PV array, motor pump and power conditioning equipment, if needed. The power conditioning equipment is used to stabilize the fluctuating electrical energy output of the array. Depending on the total dynamic head and the required flow rate of water, the pumping system can either be on the surface or submersible and the motor can run on either alternating current (AC) or direct current (DC). For AC pumping systems an inverter is required. Ratings of pump sets are chosen depending on the water requirements, size of field, total dynamic head, type of irrigation (drip irrigation, use of sprinklers), etc. The key barrier to the large-scale dissemination of solar PV water pumps is the high capital cost incurred by farmers compared to the much lower capital cost of conventional pumps. Solar PV is a competitive option in the face of diesel, its adoption being contingent on the ease of access to subsidies. Another factor to be considered is the space requirement for the installation of a solar PV pump set. This factor limits adoption by small-scale farmers to whom land availability is a major fact.

Field Visits

Shakti Pump (India) Private Limited Pithampur

The Groundwater Surveys and Development Agency (GSDA) of the Water Supply and Sanitation Department of the Government of India and MNRE Programme have come up with an innovative drinking water supply scheme called Dual Pump Scheme in order to overcome the drawbacks of the existing bore well – hand pump based schemes in rural Madhya pradesh**.** In order to ensure the sustainability of the scheme in terms of maintaining ground water levels, rainwater harvesting structures are made mandatory on the site of installation. Hence this scheme intends to reduce drudgery for women by providing for water through taps closer to homes. Due to the rain water harvesting component of the scheme and focus on source, it gets funded by National Rural Drinking Water Programme (NRDWP). Around 1000 such schemes were implemented across MP during the year 2013-14. During the initial stages of implementation of this scheme, the 'solar power' component was not a part of it; rather grid electricity was used to operate the pumps. Later it was observed that there is no electricity available in economically backward habitations and in hilly, difficult terrains of the state. Hence, GSDA modified the scheme and developed a Dual Pump Scheme based on Solar Energy. Within our field visits, we look at both the installations made through the GSDA and private installations done by clubs or other administrative agencies.

Fig 3

Fig 4

Solar Panel Specifications

Table 1

Maximum Power	300Wp-+3%
Open circuit voltage(V_{OC})	44.45V
Short circuit current(I_{SC})	8.55A
Voltage at maximum power(V_{MP})	37.10V
Current at maximum power(I_{MP})	8.09A
Maximum system voltage	DC 1000V
Normal operating cell temp.	44.6^{0C}
Temperature cofficient	-1.036W/degree centigrate

DC Solar Controller

Fig 5

Table 2

Model	Max.input voltage of Solar Arrays(V_{dc})	Range of MPPT(V_{dc})	Controller current(Amp)
DCSHAKTI-01P-9A	300	30-260	9
DCSHAKTI-01P-10A	400	90-360	10
DCSHAKTI-03P-13A	780	320-700	13
DCSHAKTI-03P-17A	780	320-700	17
DCSHAKTI-03P-25A	780	320-700	25
DCSHAKT-03P-38A	780	320-700	38
DCSHAKTI-03P-45A	780	320-700	45
Solar Submersible Pump			
(Shakti Pump-Dcssp Series)			

Fig 6

High efficient System (3HP)

Table 7

Input Power(Watts)	3000W
Head(Meter)	50m
Flow(Ltr. per Wat)	30
Discharge	40% greater than other pump
Efficiency (%)	80-85%

SGSITS Campus (Biomedical Engineering department) Indore

The site refers to the SGSITS (biomedical engg. department), Electronics department in Indore. As such, this is also an example of an installation in an urban setting. Since the concerned authorities were a little reluctant in sharing all the details of the project, the exact nature of the origins of this set- up are unknown. The pump was installed oughly around May 2016, to run a 3HP DC water pumping system. The new pump installed was a submersible pump being run on solar panels that have been placed on the terrace of the biomedical engg department building. The pump is used to drive the water from the underground water tank tank. The technicians working there have no role to play in the functioning of the solar pump as it completely automated. Although it was noticed that even cleaning of the solar panel was not being done, as the layers of dust were visible. The authorities claimed that the pump is able to fill up the tank in roughly 5-6 hours. The pump is driven directly by the solar panel and has no being done, as the layers of dust were visible. The authorities claimed that the pump is able to fill up the tank in roughly 5-6 hours. The pump is driven directly by the solar panel and has no battery system.

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