To Study Performance Improvement of Solar Water Pumping System

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Abstract**—***Electricity is an essential part of our way of daily life. In the present scenario, most of the electricity is provided from the conventional thermal or hydro power stations. Irregular power supply and frequent grid failure are regular phenomenon in most Indian cities especially during peak summer and winter seasons. The use of photovoltaic array for water pumping system is one of the most promising techniques in solar energy applications. Deployment of PV based solar pumping system for domestic applications is an viable alternative to replace conventional grid electricity .The theoretical design, performance and simulation analysis of PV based water pumping system with the use of the computer software PVsyst is carried out. According to the analysis, the solar water pumping system has a system efficiency of 21.9% which is in fair agreement with the previous literature .Therefore SWPS is strongly recommended for both urban as well as rural water supply system.*

Keywords—Solar water Pump, PV Syst 6.4.3 Softwares

I. Introduction

Photovoltaic (PV) panels are often used for agricultural operations, especially in remote areas or where the use of an alternative energy source is desired. In particular, they have been demonstrated time and time again to reliably produce sufficient electricity directly from solar radiation (sunlight) to power livestock and irrigation watering systems.

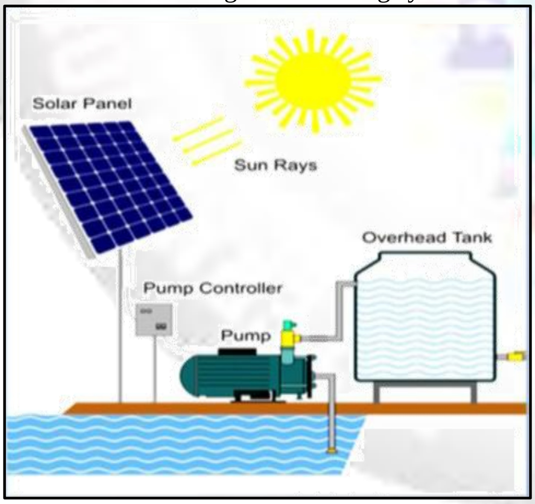


Fig. 1.1: A typical solar-powered water pump system, which includes a solar array, controller, pump, and storage tank

A benefit of using solar energy to power agricultural water pump systems is that increased water requirements for livestock and irrigation tend to coincide with the seasonal increase of incoming solar energy. When properly designed, these PV systems can also result in significant long-term cost savings and a smaller environmental footprint compared to conventional power systems.

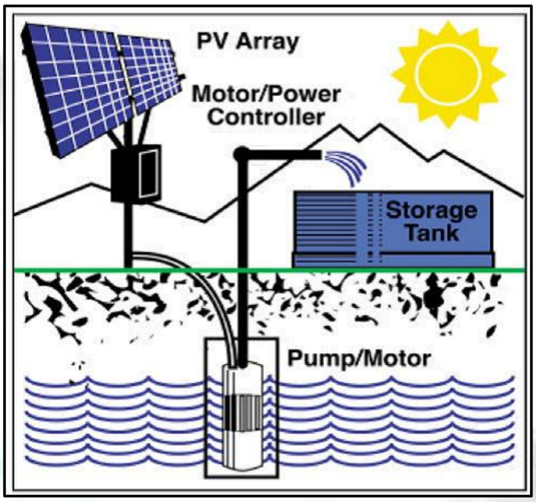


Fig. 1.2: Schematic diagram of solar Water pumping system

In residential areas ground water from bore well is being used, hence there is need for pumping water to overhead tanks. In the current situation water pumps in every household are driven by electric motors and these electric motors uses conventional electricity [2]. Also the Per capita energy consumption is high in residential areas of Chhattisgarh. Among all renewable sources of energy, solar photovoltaic energy is accepted as the most reliable and cleanest source of alternate energy. Solar water pumping system offers many advantages such as no fuel cost; require low maintenance, highly reliable, ease of operation and emissions. However, PV module still has relatively low conversion efficiency 15 to 19% depending on the type of PV cell [1-3]. Solar module constitutes 40 to 50% of the total cost of the solar PV system. Solar water pumping system is considered as viable and appropriate option especially in rural areas where grid connection is practically impossible [4]. In this context, this paper proposes a design and simulation of domestic solar pumping system for Chhattisgarh, India.

II. Proposed Methodology

This project includes the following elements

1) Establish a general model describing the electrical and hydraulic behaviour of a pump, valid for any running conditions encountered in a Photovoltaic system. In order to be useable in a general-purpose software, it should be possible to establish this model from usually available data in the manufacturer's datasheet. We have developed a phenomenological model, completely determined from different sets of parameters, ranging from very simple ones to very complete. The final accuracy of the model will be of course function of the completeness of the input parameter set.
2) Implement this pump model as component in the PVsyst software. We can mention that PVsyst is a

simulation software for Photovoltaic systems, widely used over the world (460 licensed companies and universities, more than 1'000 users in 55 countries). It is generally considered as the reference tool in the field.

3) Give to the user the opportunity of defining by himself the required parameters for the model (from manufacturer's datasheet), with a check of the coherence, and detailed (graphical) display of the global behaviour of this model as function of diverse parameter. Creation of an exhaustive specification sheet, describing the parameter and behaviour of the pump device.
4) Create a database of the main pump devices suited for photovoltaic systems, available on the market. This base may of course be completed by the user, and will be periodically updated as for all PVsyst components.

In collaboration with the CREDA which disposes of a specialised measuring facility, check of the accuracy of the modelling, using detailed measurements performed on several pumps of various technologies.

This model is included in a general simulation process of the whole pumping system (hourly steps simulation), taking the environmental conditions into account (meteo, pumping depth, user's needs), and various regulation/coupling technologies (direct coupling, direct with booster, power converters, batteries, pumps connected in cascade, reconfiguration of the PV field according to available solar power).

The coupling technology between the PV array and the pump(s) is specified in the software through the "Controller" component, which defines the detailed parameters of any possible control device (power limitation, efficiency, etc). The first simulations of a system may be conducted with a dummy, optimised device, without reference to really available devices.

III. PHOTOVOLTAIC (PV) PANELS

PV panels are made up of a series of solar cells, as shown in Figure 4.1, below. Each solar cell has two or more specially prepared layers of semiconductor material that produce DC electricity when exposed to sunlight. A single, typical solar cell can generate approximately 3 watts of energy in full sunlight. The semiconductor layers can be either crystalline or thin film. Crystalline solar cells are generally constructed out of silicon and have an efficiency of approximately 15%. Solar cells that are constructed out of thin films, which can consist of a variety of different metals, have efficiencies of approximately 8% to 11%. They are not as durable as silicon solar cells, but they are lighter and considerably less expensive.

PV panels may be arranged in arrays and connected by electrical wiring to deliver power to a pump (see Section 3.0 for more details).

PV panels must meet all NRCS required specifications, both for power production and structural integrity (including resistance to hail), as described in the following sections.

IV. PARAMETERS OF SOLAR CELL

The adequate performance of solar photovoltaic system can be analysed in terms of several parameters and these parameters are as follows:-

- Short circuit current of solar panel.
- Open circuit voltage of solar panel.
- Maximum power point.
- Value of current at maximum power point.
- Value of voltage at maximum power point.
- Fill Factor
- Efficiency

The solar modules are designed as per the Standard Test Condition which corresponds solar input of 1KW/sq.meter and operating temperature of 25◦C.

- Short circuit current of solar panel:-It is the maximum value of current that can be produced from solar cell and denoted by Isc.The greater the value of Isc, more desirable is the cell. Sometimes the current density(Jsc) is mentioned in the panel instead of Isc and In that condition, the value of short circuit current can be obtained by dividing the current density by area of solar cell.
- Open Circuit voltage of solar panel:-It is the maximum value of voltage that can be produced from the solar cell. It is denoted by Vo.c.. The greater the value of Voc, more desirable is the cell.Operating temperature and Cell technology decides V.o.c. .
- Maximum power point of solar cell:- It is the maximum value of power that can be produced under Standard Test Condition.It is obtained at a particular value of voltage and current and it is generally occurred at a bent of curve and denoted by Pm.
- Value of current at maximum power point:-It is the value of current which is obtained when the solar cell operates at maximum power point. It is denoted by Im and the value of Im is always less than Isc.
- Value of voltage at maximum power point:- It is the value of voltage which is obtained when the solar cell operates at maximum power point. It is denoted by Vm and the value of Vm is always less than Voc.
- Fill Factor:-It is ratio of product of current and voltage at maximum power point to the product of short circuit current and open circuit voltage.It is generally provided in terms of percentage or it is the ratio of area formed by Im-Vm rectangle to the area covered by Isc-Voc rectangle.Solar cell with I-V curve in the shape of square is considered better.

$$\text{Fill Factor}=\frac{Im\ x\ Vm}{Isc\ x\ Vsc} \quad [1]$$

- Efficiency:- The efficiency of solar cell is the ratio of ouput power to the input power and generally provided in terms of percentage which describes the effective conversion of solar radation into electricity.It is denoted by η.

$$\text{Ƞ}=\frac{Pm}{Pin}=\frac{Isc\ x\ Voc\ x\ FF}{Pin\ x\ A} \quad [2]$$

Multiple panel arrays should be wired in a series and/or parallel so that the resulting voltage and current are compatible with the controller and pump motor requirements.

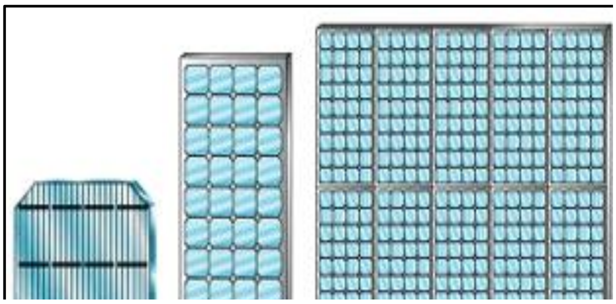


Fig. 4.1: Solar cell, PV solar panel, and PV panel array.

When multiple panels are wired in a series, the total output voltage is the sum of the individual panel output voltages; the total current stays the same. Conversely, when panels are wired in parallel, the voltage stays the same while the resultant total current is the sum of the individual panel current inputs. The total power output from a PV panel array is determined by multiplying the total output voltage by the total output current.

The power output from a PV panel can vary slightly from the panel's rated power, as noted by the "Power Tolerance" value in Table 3. Power output will also decline at about one percent per year due to environmental wear on the system. Oregon Construction Specification 68: Photovoltaic (PV) Power Supply for Pump specifies that the panel output shall be warranted against a degradation of power output in excess of 10 percent in a 10-year period following installation

V. Location & Load Demand Specifications

In this work, the optimal design of PV renewable system is done for a remote area situated at Chhattisgarh, India. The site under study has good level of solar radiation. It receives an annual average solar radiation between 900 to 1200 Wh/m2per day and the actual sunshine duration is about 9 hours per day. The amount of solar radiation in a typical year is presented as daily average solar radiation at horizontal surface (Wh/m2/day). The solar radiation data for the site under study are taken from department of CREDA in Chhattisgarh. The average solar radiation for each month data is shown in Figure. 4.2 June has the highest daily radiation (1200Wh/m2/day) while the lowest radiation occurs during December (500Wh/m2/day). The total average of the solar radiation per year is 850Wh/m2/day.

A. Radiation in Wh/m2

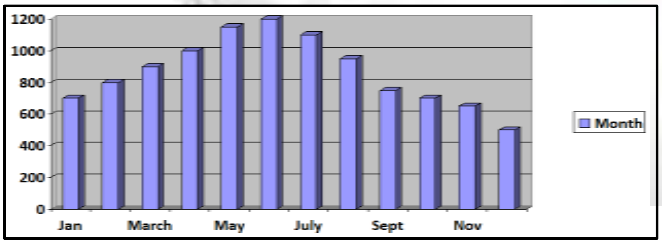


Fig. 4.2: Monthly solar radiation data for the site under study.

The site under study contains fertile land for cultivation within the desert land with mainly flat terrain. This area floats over large amount of aquifers and has high quality underground water, which can be used for irrigation purposes. The farm under study consists of six land pieces with a total of 15 acres. The water demand ranges between 350 and 500 m3/day in hot seasons and between 200 and 250 m3/day in winter seasons. The bore well has the following characteristics; 100 m static water level, 150 m well depth and 120m3/hour well discharge rate. Irrigation based on drip systems are rapidly developing in rural area of Chhattisgarh. The water efficiency by these systems is extremely high. The combination of stand-alone renewable systems with drip systems is appropriate for isolated areas with no connection utility grid. Required water demand per unit area irrigated depends on the crop, weather conditions, and soil type. In general, the daily energy demand is 8 KWh with 10 Kw peak demand. A typical monthly daily load demand of a year is shown in Figure.4. 3

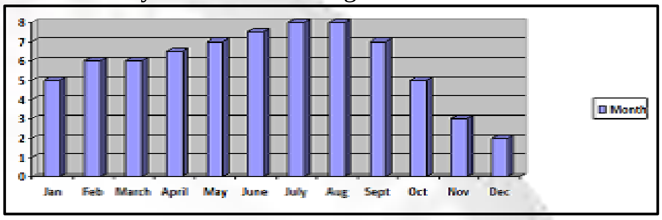


Fig. 4: 3Monthly daily average load demand.

VI. Performance Result Discussion

A. Pumping Systems Preliminary Design

For this study, the ENERGY PARK BILASPUR .The structure of solar system established

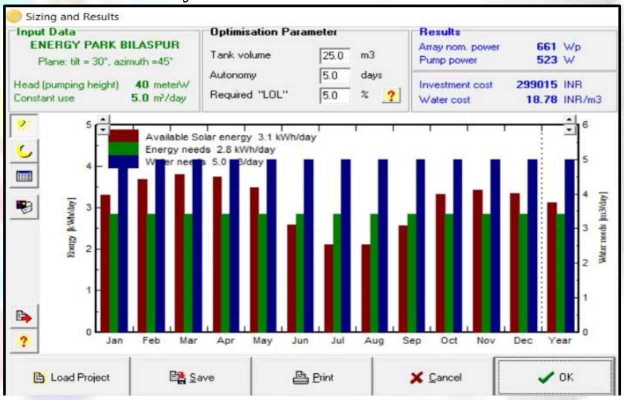


Fig. 5.1: Results of preliminary design

- The Water needs (in yearly, seasonal or monthly values).
- The nominal head at which it should be pumped (level difference between water outlet and source surface).
- The diameter and length of pipes (optional, for eventual friction losses).
- A pump technology (centrifugal for rather low heads, positive displacement for high heads).
- An array-pump coupling strategy, which strongly affects the system performances.

Now you can open the "Results" which asks for choosing: As shown in figure 5.1

- either the tank volume, or the autonomy of the system in days. These parameters are coupled, according to the daily needs of water.
- the "Loss of Load" probability (P LOL), i.e. the time fraction during which the operator will accept that the needs are not met (tank empty).

These parameters lead to the determination of the array nominal power (i.e. the installed STCpower according to the manufacturer specifications), and the pump nominal power required. These are very rough estimations, as the pumping system performances are strongly dependent on the pump technology, head, flowrate, as well as the electrical matching between pump and PV array. The first result graph shows the potentially available solar energy, along with the user's water and energy needs.

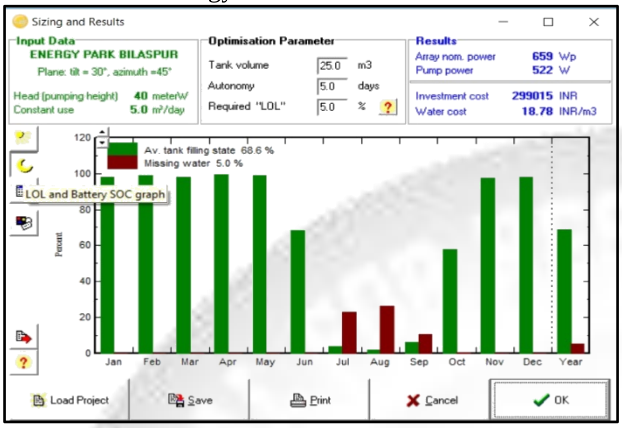
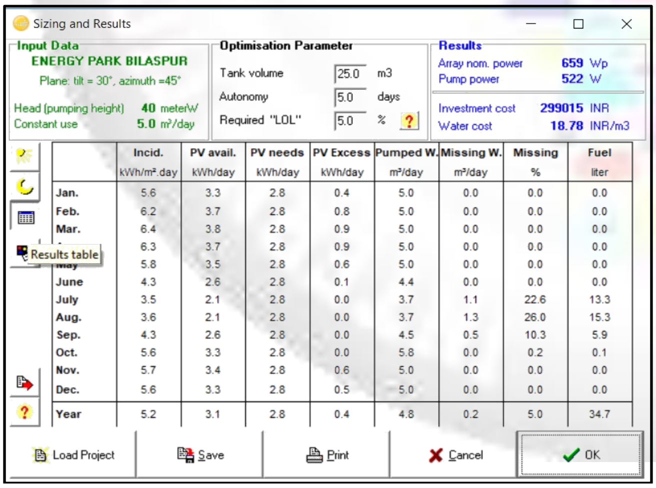


Fig. 5.2: Average filling state

The figure5.2 (available by the speed buttons on the left) gives the average filling state of the tank, and the missing water (P LOL) monthly distribution.

B. Computation

PV syst performs a very simplified simulation, which runs over one year in daily values. The evaluation of the available irradiance on the collector plane uses the Monthly Meteo tool algorithms, which calculate irradiation's monthly averages on the basis of instantaneous data for one day per month. This is not sufficient to manage the water storage balance evolution from day to day, and the effective use of solar incident energy. Therefore the program generates a random sequence of 365 days, according to the algorithms of Collares-Pereira, renormalized to the monthly sums, for calculating the daily balance from day to day, and the PLOL.


Sizing and Results

Input Data: ENERGY PARK BILASPUR; Plane: tilt = 30°, azimuth =45°; Head (pumping height) 40 meterW; Constant use 5.0 m³/day

Optimisation Parameter: Tank volume 25.0 m3; Autonomy 5.0 days; Required "LOL" 5.0 %

Results: Array nom. power 659 Wp; Pump power 522 W; Investment cost 299015 INR; Water cost 18.78 INR/m3

	Incid. kWh/m².day	PV avail. kWh/day	PV needs kWh/day	PV Excess kWh/day	Pumped W. m³/day	Missing W. m³/day	Missing %	Fuel liter
Jan.	5.6	3.3	2.8	0.4	5.0	0.0	0.0	0.0
Feb.	6.2	3.7	2.8	0.8	5.0	0.0	0.0	0.0
Mar.	6.4	3.8	2.8	0.9	5.0	0.0	0.0	0.0
[illegible]	6.3	3.7	2.8	0.9	5.0	0.0	0.0	0.0
[illegible]	5.8	3.5	2.8	0.6	5.0	0.0	0.0	0.0
June	4.3	2.6	2.8	0.1	4.4	0.0	0.0	0.0
July	3.5	2.1	2.8	0.0	3.7	1.1	22.6	13.3
Aug.	3.6	2.1	2.8	0.0	3.7	1.3	26.0	15.3
Sep.	4.3	2.6	2.8	0.0	4.5	0.5	10.3	5.9
Oct.	5.6	3.3	2.8	0.0	5.8	0.0	0.2	0.1
Nov.	5.7	3.4	2.8	0.6	5.0	0.0	0.0	0.0
Dec.	5.6	3.3	2.8	0.5	5.0	0.0	0.0	0.0
Year	5.2	3.1	2.8	0.4	4.8	0.2	5.0	34.7

Results table

Load Project | Save | Print | Cancel | OK

Fig. 5.3:PVsyst one year daily value

VII. SOFTWARE SIMULATION

PV SYST V6.43 is a PC software package for study sizing and data analysis of complete PV system. It deals with grid connected, stand-alone, and pumping, DC-grid PV systems, and includes extensive meteo and PV system components databases, as well as general solar energy tools. The software is geared to the needs of architects, engineers, researchers. It is also very useful for educational training.

PVSyst V6.43 offers 3 levels of PV System study, roughly corresponding to the different stages in the development of the real projects. As shown in figure 6.1

For grid connected systems, and especially for building integration, this level will be architect-oriented, requiring information on available area, PV technology (colors, transparency etc.), and power required for desired investment.

For stand-alone systems this tools allows to size the required PV power and battery capacity, given the load profile and the probability that the user will not be satisfied ("loss of load" probability, or equivalently the desired "solar fraction").

For Pumping systems, given water requirements and a depth of pumping, and specifying some general technical options, this tool evaluates the pump power and PV array size needed. As for stand-alone systems, the sizing may be performed according to a specified probability that the water needs are not met over the year.

Project Design: it aims to perform a through system design using detailed hourly simulations. Within the framework of a "project", the user can perform different system simulation runs and compare them. He has to define the plane orientation (with the possibility of tracking planes of shed mounting), and to choose the specific system components. He assisted in designing the PV array (number of PV modules in series and parallel), given a chosen inverter model, battery pack or pump.

In second step, the user can specify more detailed parameters and analyze fine effects like thermal behavior, wiring, module quality, mismatch and incidence angle losses, horizon (far shading), or partial shading of near objects on the array and so on.

For pumping systems, several systems designs may be tested and compared to each other, with a detailed analysis of the behaviour and efficiencies.

Results include several dozens of simulation variables, which may be displayed in monthly, daily or hourly values, and even transferred to other software. The "Loss Diagram" is particularly useful for identifying the weaknesses of the system design. An engineer report may be printed for each simulation run, including all parameters used for simulation, and the main result.

A detailed economic evaluation can be performed using real component prices, any additional costs and investment conditions.

A. Databases:

The database management for meteorological data and PV components. Creation and management of geographical sites, generation and visualization of hourly meteorological data from several predefined sources or from custom ASCII files. Database management of manufacturers and PV components, including PV modules, Inverters, Regulators, Generators, Pumps etc.Measured data analysis: when a PV system is running and carefully monitored, this part (located in the "Tools" part) permits the import of measured data (in almost any ASCII format), to display tables and graphs of the actual performances, and to perform close comparisons with the simulated variables. This gives the means of analysing the real running parameters of the system, and identifies even very small irregularities. Included also some specific tools useful when dealing with solar energy systems. Tables and graphs of meteo data or solar geometry parameters, irradiation under a clear day model, PV array behavior under partial shading, or module mismatch, optimizing tools for orientation of voltage, etc.

VIII. Conclusion

A detailed analytical investigation of a typical Solar Water Pumping System is carried out in order to realistically estimate the solar PV sizing for the proposed installation. PVsyst software is used to design and perform simulation of water pumping system.

- The solar water pumping system is used to provide 5m3water per day.
- The simulation results have shown the pump efficiency of the water pumping system is 68.6% and System efficiency of the water pumping system is 5.9%. The energy performance of the SWPS(Solar Water Pumping System)
- 0 is satisfactory and may significantly contribute to the urban and rural water consumption needs.
- SWPS are already widely adopted in several rural areas where the vital need for water cannot be always supported by a local electricity network and the respective PV-application
- Thus, it is quite reasonable that SWPS may be used for covering both irrigation needs and potable water supply

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