Applied Sciences Research Periodicals
May 2023, Vol. 1, No. 2, pp. 31-37

Feasibility Study of Solar PV System for Backup Application: A Case in Dilla University Water Pump System

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Abstract:
Solar energy generation utilizes solar cells or photovoltaic cell devices to convert the energy of light directly into electricity. In recent, it has been proved that the population increased and the need for energy and its related services to satisfy human social and economic development and health is increasing. At this time, most institutions and business firms use backup generators for backup applications. This study focuses on renewable energy production as well as the storage system for running water pumps found in Dilla University, Odaya Campus. The use of this fuel generator has various economic, social, and environmental impacts. This includes the higher cost of fuel, air pollution for global warming, and maintenance costs. This research intends to design a Solar PV and study the feasibility of the system for backup applications. Finally, this potential contributes to fill the energy gap between the demand and supply of the country mainly at Dilla University. In designing and studying this hybrid system we have gained a payback period of four years. This implies that once investing the required initial capital, we can use the system for over fifteen years with only maintenance costs.

Keywords: Photovoltaic, Solar Energy, Radiation, Module

INTRODUCTION

Solar energy generation utilizes solar cells or photovoltaic cell devices to convert the energy of light directly into electricity. In recent, it has been proved that the population increased and the need for energy and its related services to satisfy human social and economic development and health is increasing. Most developing countries are poor in conventional fossil fuel resources and have to import them. One of the most versatile, renewable, and environment-free energy sources is the solar PV system. Since it has no moving parts in the system, it will have a low maintenance cost as compared to a fuel generator [1, 2]. So, a decentralized system of solar equipment installed at the village level is one of the technically feasible solutions. Solar power offers many advantages in the generation of electricity. Even though it has a high initial investment cost, it will pay back in a short time and it will be a feasible energy choice for the backup application [3, 4].

In Ethiopia, most of the critical infrastructure that communities depend on in universities, hospitals, and community shelters relies almost exclusively on diesel generators when the grid goes down. Unfortunately, diesel generators aren't always up to the task when called upon. Among these institutions, Dilla University is a former institution in Ethiopia that uses a diesel generator backup for grid downtime. This paper assesses a feasibility study for solar energy usage in Dilla University instead of a backup generator. This is achieved by taking the water pump generator which is on standby 24/7 and designing the solar power needed. The study aimed at finding and verifying a way that shows how the university can use solar energy sources efficiently to produce electricity, reducing its dependence on oil according to the collected data.

RELEVANT LITERATURE REVIEW

Photovoltaic (PV) technology is used for generating electricity from incoming solar radiation. Several attempts have been made to evaluate, monitor, and improve the performance of different components of a PV system [5].

The most efficient use of solar energy is when the panels are directly connected to the load. The success of water pumping lies partly in 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 the potential energy of the elevated water, to be used on-demand, often by gravity. The overall efficiency, from sunlight to water flow, has been recorded to exceed 3% [6, 7].

The system is an easy-to-implement and environment-friendly solution for irrigating fields. The system was found to be successful when implemented for boreholes 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. The main advantage of this project is optimizing power usage through water resource management and also saving the government's free subsidiary electricity. This proves an efficient and economical way of irrigation and this will automate the agriculture sector [8, 9].

On the other hand, the solar PV system is used in thermal pumping systems. Delgado-Torres (2007) reviewed the thermal energy of a water pumping system and the different types of solar thermal energy based on thermodynamic methods. While a simple solar thermal water pumping system usually has low effectiveness and low output power, there are two alternatives for thermo-mechanical conversion; conventional that the pump is moved by mechanical energy, and unconventional in which the specially designed system of water pumping is driven by mechanical energy [10].

Harishankar et al., (2014), this study demonstrates the feasibility study and demonstration of using a solar PV system to provide energy for the pumping requirements for Dilla University water consumption. Even though there is a high capital investment required for this system to be implemented, the overall benefits are high and in long run, this system is economical [11]. Mohammed M (2001), After economic analysis, it is shown that the Photovoltaic pumping system for the water pump is more feasible than a Diesel engine pumping system. From an economic viewpoint, the PV pumping system for only one season of irrigation is a little bit higher than the diesel engine pumping system due to the high cost of the PV modules and their components [12]. The automation of an irrigation system will largely reduce the gap between requirement and consumed energy and further conserve resources thereby reducing the wastage of resources.

MATERIALS AND METHODS

The method is a procedure or set of rules and principles of intellectual operations to analyze to achieve the result using scientific analysis. It is a set of principles leading all organized projects and research, allowing selection and coordination of the project. In this study, the methods implemented are listed in figure 1.

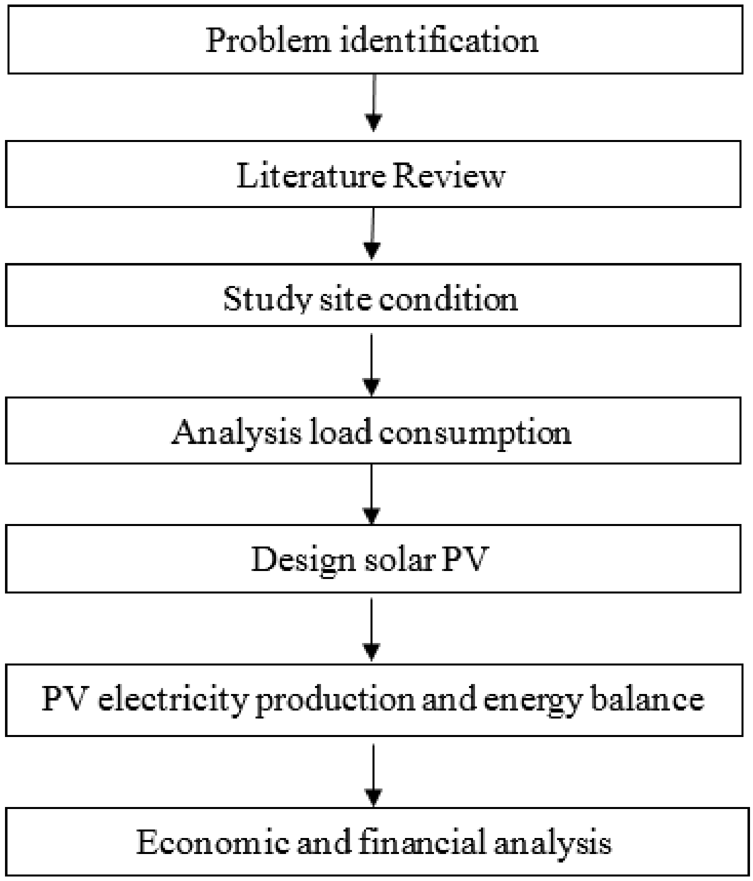

Fig. 1 Project Methodology

PV system design is the process of determining the size of each component of a standalone photovoltaic power system to meet the load requirement.

The designing is done through the following steps;
Step 1: Site inspection
Step 2: Determining load requirements
Step 3: PV module sizing
Step 4: Charge controller sizing
Step 5: Battery bank sizing
Step 6: Inverter Sizing
Step 7: Cable size

Site inspection is the most important in the design because it helps to determine whether a stand-alone system is viable or not. The factors influencing power generation from the PV system are irradiation and temperature. At constant temperature power generation from PV System increases with increasing irradiation so the site location should be inspected to know the number of sun day per year as shown in table 1.

Table 1. Geographical details.

Descriptions	Details	Units
Location	Dilla	
Longitude	6°24'30"N	
Latitude	38°18'30"E	
Elevation	1570	Meters
Solar radiation	5.55	$kWh/m^2/day$
Area	583.2	m^2
Ground mounting	Fixed	

The major components of solar PV systems are solar charge controllers, inverters, battery banks, auxiliary energy sources, and loads (appliances) [13]. Figure 2 shows the solar PV system components that are designed for the backup application in the case of the Dilla university water pump.

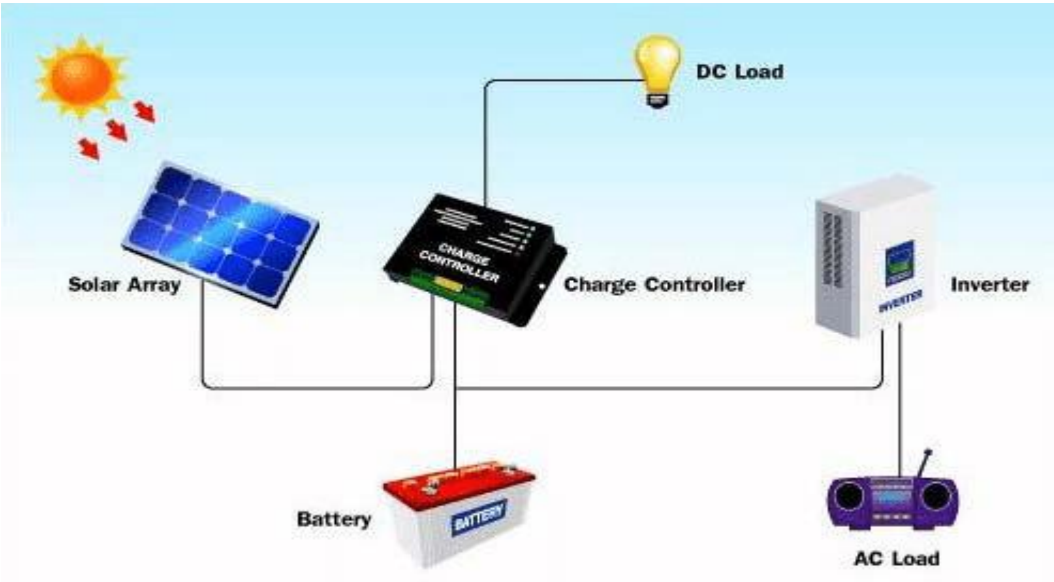

Fig. 2 Solar-powered water pump components

The first step in designing a solar system PV system is to find out the total power and energy consumption of all loads that need to be supplied by the solar PV system.

Total power use per day=Total appliances uses power in watt per day (1).

Total energy consumption per day=Total appliances use in watt-hours per day (2).

Now the total PV panels energy required=Total energy consumption per day x 1.3 (3) Where 1.3 is the loss factor of the system [14, 15].

In estimating the total watt-peak rating needed for the PV modules to operate the pump motor, the total watt-hours per day needed from the PV module is divided by the Panel Generating Factor (PGF) [15, 16].

Panel generating factor (PGF) = solar radiation × total correction factor on the solar panel

An inverter is needed in the solar home system to change the DC input signal from the battery to its appropriate AC signal for the power outlets. The input rating of the inverter should never be lower than the total watt of the appliances.

The inverter must have the same nominal voltage as your battery [13, 17, 18]. The input rating of the inverter should be 25-30% bigger than the watt of the pump.

$$\text{Inverter size} = \text{total watt} \times \frac{130\%}{100\%}$$

Solar battery sizing is one of the most important considerations when choosing the basic components of your stand-alone solar electric system.

The main objective when sizing a battery bank is to get one energy that can handle the load coming from your PV panel array and provide enough stored power for your needs when there is no sunshine [18, 19]. The battery capacity should be large enough to store sufficient energy to operate the appliances at night and cloud day.

$$\text{Size of battery} = \frac{\mathrm{C} \times \mathrm{n}}{0.85 \times 0.6 \times \mathrm{Vsystem}}$$

All the required components are designed and selected for this study. Table 2 shows the specification and the parameters designed to perform this plant in Dilla university for backup application.

Table 2 Results obtained from sizing the PV system

Component	Description of Component	Result
Load estimation	Total estimated load	384800Wh
PV array	Array capacity	8040 W
	Number of modules in series	2
	Number of modules in parallel	12
	Total number of modules	24
Battery Bank	Battery bank capacity	7859.47Ah
	Number of batteries in series	8
	Number of batteries in parallel	5
	Total number of batteries required	40
Voltage Regulator	The capacity of voltage regulators required	59A
	Number of voltage regulators required	1
Inverter	Capacity of inverter	60KVA
Wire	Between the PV module and batteries through the voltage regulator	59A 1.688mm^2
	Between the battery bank and inverter	236A, 34mm^2
	Between inverter and load	78A, 4mm^2

In designing the solar PV system for the backup application, it requires higher initial capital, but once the system is installed it is higher economical. So let us compare it with the fuel cost of the generator system to make sure if the PV system is relatively higher cost.

The PV system guarantee is 25 years this implies that there will be saving money for 22 years as well as the initial cost of the traditional generator system. From here it is well seen that a decentralized solar power system is one of the solutions for our future demand for energy for backup and standalone applications without environmental degradation and it will be at a lower cost as shown in table 3.

Table 3 Feasibility study.

Details	Qty in liter	Units	Cost in birr
Diesel Consumption			
Diesel consumption per hour	10	Liter	670
Diesel consumption per day	80	Liter	5360
Diesel consumption per month	2400	Liter	160,800
Diesel consumption per year	28800	Liter	1,929,600
Subtotal			13305560
Contingency (%5)	1,929,600×0.05		96,480
Total	1,929,600+96,480		2,026,080
Solar panel System Investment			
Total			6,684,493.2
Payback period /year			4 years

CONCLUSION

The location of the site at Dilla 6°24′30″N, 38°18′30″E was suitable for solar PV from the candidate locations. This is mainly due to it being the nearest, low slope, a short distance from roads, far from town, far from the forest, and far from the stream. This potential contributes to fill the energy gap between the demand and supply of the country. It is also used to bridge the energy gap between rural and urban communities if the country starts to use this high green solar potential to generate power needs. The Majority of areas fulfilled the suitability analysis criteria. Solar irradiance, slope, soil type, land use, land cover, and distance from roads, forests, towns, streams, and schools were the determinant factors for solar PV power site suitability analysis. This study focuses on renewable energy production as well as the storage system for running water pumps found in Dilla University, Odaya Campus. The use of this fuel generator has various economic, social, and environmental impacts. This includes the higher cost of fuel, air pollution for global warming, and maintenance costs. From this study it is clear that to conclude that, this potential contributes to fill the energy gap between the demand and supply of the country mainly at Dilla University. In designing and studying this hybrid system we have gained a payback period of four years. This implies that once we invest the required initial capital, we can use the system for over fifteen years with only maintenance costs.

REFERENCE

1. Muluken Zegeye, Tassew Tadiwos, Abdulkadir Aman, Optimal sizing of solar water pumping system for small scale irrigation: A case study of Dangila. International Journal of Renewable and Sustainable Energy, 3(5): 99-107, (2014).

2. A. Castillo and D. F. Gayme, "Grid-scale energy storage applications in renewable energy integration: A survey," Energy Conversion and Management, vol. 87, pp. 885-894, 2014.

3. Kumarasamy, S., Tulika, S., Guddy, S. and Manicam, P. Modeling and Estimation of Photosynthetic ally Active Incident Radiation Based on Global Irradiance in Indian Latitudes. IJEEE. 4, 21 (2013).

4. Idowu, O.S., Olarenwaju, O.M. & Ifedayo, O.I. Determination of optimum tilt angles for solar collectors in a low-latitude tropical region. Int J Energy Environ Eng 4, 29 (2013).

5. Glasnovic, Z, Margeta, J., A model for optimal sizing of photovoltaic irrigation water pumping systems. Solar Energy, 81(2007).

6. Turlough Guerin, A case study identifying and mitigating the environmental and community impacts from construction of a utility-scale solar photovoltaic power plant in eastern Australia. Solar Energy, Volume 146, April 2017, Pages 94-104.

7. Grid-connected PV systems design guidelines for accredited designers, clean energy council l (CEC), Issue 3 July 2007, updated November 2009.

8. Esan Ayodele Benjamin, Egbune Dickson, Estimating the solar home system sizing for rural residential apartments using a panel tilt angle of 82 degrees. Ilorin, Kwara State as Case Study American Journal of Electrical and Computer Engineering Volume 1, Issue 2, December 2017, Pages: 90-96.

9. Wudil, Kano State, M. Ishaq, U. H Ibrahim, H abubakar, Design of an off-grid photovoltaic system: a case study of government technical college. International journal of scientific and technology research volume 2, Issue 12, 2013.

10. Delgado-Torres AM. Solar thermal heat engines for water pumping: an update. Renewable and Sustainable Energy Reviews 2009;13(2):462–72.

11. Harishankar S., Sathish Kumar R., Sudharsan K.P., Vignesh U., and Viveknath T., Solar Powered Smart Irrigation System. Advance in Electronic and Electric Engineering, Vol. 4(4), pp.341-346, 2014.

12. Mohammed Mozammel Haque, Photovoltaic Water Pumping System for Irrigation. 4th International Conference on Mechanical Engineering, December 26-28, 2001, Dhaka, Bangladesh/pp. I 21-26.

13. Ewnetu Tefera,Velmurugan Paramasivam, Eneyw Gardie , Habtamu Dubale, Senthil Kumaran Selvaraj, Experimental investigation of suitable thin layer drying curve to solar maize dryer assisted for biomass back-up heater, Materials Today: Proceedings Volume 46, Part 17, 2021, Pp 7389-7395.

14. Abdallah S., The effect of using sun-tracking systems on the voltage-current characteristics and power generation of flat-plate photovoltaics. energy conversion and management, Vol. 45, pp. 1671-1979, 2004.

15. M. N. Lakhoua, et al., "System Analysis of a Hybrid Renewable Energy System," International Journal of Electrical and Computer Engineering (IJECE), vol. 4, no. 3, pp. 343-350, 2014.

16. Sravankumar Jogunuri, Ravish Kumar, Deepak Kumar, Sizing an off-Grid Photovoltaic System. International conference on energy, communication, data analytics, and soft computing (ICECDS) 2017.

17. Kumar, Jerry & Ram, Nanik & Panjwani, Manoj & Khan, Danish. (2021). Design and performance analysis of PV grid-tied system with the energy storage system. International Journal of Electrical and Computer Engineering. 11. 1077-1085.

18. M. K. Panjwani, et al., "Hybrid concentrated photovoltaic thermal technology for domestic water heating," Indonesian Journal of Electrical Engineering and Computer Science (IJEECS), vol. 16, no. 3, pp. 1136-1143, 2019.

19. Mohammad Baqir, Harpreet Kaur Channi, Analysis and design of solar PV system using PVsyst software, Materials Today, Volume 48, Part 5, 2022, Pages 1332-1338.