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Pushpendra Kumar Chaturvedi
M. Tech Scholar, Department of Farm Machinery and Power Engineering, SHUATS, Prayagraj, Uttar Pradesh, India

Er. Babban Yadav
Assistant Professor, Department of Farm Machinery and Power Engineering, SHUATS, Prayagraj, Uttar Pradesh, India

Corresponding Author
Pushpendra Kumar Chaturvedi
M. Tech Scholar, Department of Farm Machinery and Power Engineering, SHUATS, Prayagraj, Uttar Pradesh, India

Design of an off-grid solar photovoltaic system to fulfil the electricity demand for Bijahi village

Pushpendra Kumar Chaturvedi and Er. Babban Yadav

Abstract
Energy is the basic unit that plays an important role in the socio-economic development of any region. It plays a vital role in meeting the domestic energy needs of rural households. The present study has been made to assess the utilization pattern of the households of Bijahi villages of Shahdol district, Madhya Pradesh. There are 100 families in which 359 person lives in the village. The required information and data were collected from the village with verbal discussion with the people of the village. To achieve sustainable development in these regions, access to clean and affordable (renewable) energy must be made available. And the electricity demand of each house is about 2.4kw/day for electrical purposes. The design of solar panels for electricity generation to fulfil the demand of the entire village needed 525 solar panels, each panel of 105watt. In this project, solar off-grid for the entire village as per the resources available in the village. Therefore, this study goals to determine efficient solar energy production and utilization for small-scale in a rural village. concludes that the advantages of the solar system are that it respects the environment by reducing greenhouse gas, it is also cheaper and less polluting. A community solar energy system can be the best option for the villagers.

Keywords: off-grid solar panel system, sustainable development, less pollution, reducing greenhouse gas

1. Introduction
Energy is one of the most important resources, which plays a major role in the economic growth of the world's nations. Several factors such as urbanization, modernization, and increasing human population lead to a sharp increase in the energy demand of the world. Energy is important to life and all alive organisms. Energy is one of the most essential needs of humans. a major problem that confronts mankind today is the inadequate availability of energy. Nowadays, all the world countries believe that renewable energy is the alternative solution instead of using the traditional energy types. Solar energy considers one of the most important types among all renewable energy types for the advantages which are clean, carbon-free, and available (Mohammad *et. al*. 2017) [1].

Nowadays, due to the decreasing amount of renewable energy resources, the last ten years have become more important for the per-watt cost of solar energy devices. It is set to become economical in the coming years and growing as better technology in terms of both cost and applications. Everyday earth receives sunlight above (1366W approx.) This is an unlimited source of energy that is available at no cost. The major benefit of solar energy over other conventional power generators is that the sunlight can be directly converted into solar energy with the use of the smallest photovoltaic (PV) solar cells. There has been a large number of research activities to combine the Sun's energy process by developing solar cells/panels/modules with high converting form. the most advantages of solar energy are that it is free reachable to common people and available in large quantities of supply compared to that of the price of various fossil fuels and oils in the past ten years. Moreover, solar energy requires considerably lower manpower expenses than conventional energy production technology (Rizwan *et. al.* 2017) [13].

The extended targets for 2030 include at least 27% of energy to be delivered from renewable sources together with a reduction in greenhouse gas (GHG) emissions of 40% compared to the levels in 1990 (Kryk *et. al.* 2021) [3]. Today, more than 1.4 billion individuals everywhere throughout the world need access to power. To enhance access to power to the next level in the rural areas on the planet, decentralized off-grid installations are considered in type of solar PV. Off-grid PV systems are systems that utilize photo-voltaic innovation. The systems utilize the DC yield of the PV modules to power DC loads, while a battery bank is utilized to store energy when there is demand.

Solar energy is the solar radiation that reaches the earth which is then being converted to electrical Power through several strategies. Solar buildings generally utilize solar PV panels to produce electricity. Solar PV panels produce DC electric power when exposed to sunlight, and a DC-AC inverter normally converts this to AC power, which is the conventional form of electric power in a typical building. Using DC electric power directly from solar PV panels is as most of the electric appliances are functioning using AC power. And the government gives subsidies for solar panel installation (Adesh p *et.al.* 2020) [8].

solar energy may be changed into electricity within a photovoltaic cell (PVC) and concentrated to provide heat for cooking [concerted solar cooker (CSC)] and electricity with a concentrated solar power (CSP) system. There are several advantages of using solar energy like low establishment period, no raw material expenses, non-polluting and renewable forms of energy, etc. Now day's conventional sources are rapidly depleting. Photovoltaic modules or panels are made of semiconductors that allow sunlight to be converted directly into electricity. These modules can provide you with a safe, reliable, maintenance-free, and environmentally friendly source of power for a very long time. most of the research on rural community energy attention on an off-grid electrical power system. The off-grid system term states the system not relating to the gird facility. Primarily, the system which is not connected to the main electrical grid is term an off-grid PV system (Raja, *et.al.* 2019) [4].

2. Material and Method

This chapter deals with the materials and methods adopted for the design of the solar panel hybrid energy generation system for Bijahi village. The survey was conducted from the year 2021.

2.1 Description of the study area:

Madhya Pradesh is the second-largest Indian State, covering 9.5% of the country's geographical area (308,000 sq.) and 6 percent of the nation's population (72.5 million). It has registered 20.3 percent of decadal growth (Census 2011), higher than the national average but population density in the state (236 per sq. km as against 382 of India) is lower than the national average. Bijahi village (24.0294° N, 81.4183° E) is situated in Tehsil Beohari, District Shahdol comes under Argo Climatic zone Northern hills of Chhattisgarh and in State of Madhya Pradesh, India. The village has a population of 359 as consistent with census information of 2011, in which the male population is 182 and the woman population is 177. The total geographical location of Bijahi village is 114.88 Hectares. The population density of Bijahi is 3 men and women according to Hectares. The total wide variety of residences maintain in the village is 100 [6].

2.2 Data collection and analysis

For the study the required information and data were collected from two sources:

2.2.1 Primary sources: The primary data was collected from the village with verbal discussion with the Sarpanch and the people of the village, there is a total of 100 houses in the village.

2.2.2 Secondary sources: The secondary data on solar energy was collected from the relevant energy-related govt., non-govt. and published report and other origination etc.

2.3 To calculate the energy demand for electricity purposes

The total population of the village was 359 in 100 families. These village energy demands for electrical purposes. The studies are made as electricity requirements since the shares of energy for electrical and appliances are to be analysed. Most of the households living in the rural village rely on the traditional use for some people use kerosene wick lamps for lighting. The household energy demand used in this study is made based on the demand estimation available in the relevant resources. The village energy demand is average electrical appliances use the assumptions are based on daily load per house are 4 LED bulbs of (9 watts each), Television (50 watts), 2 fans of (75 watts each) and a table fan of (55 watts), Mobile phone charger(10w), etc., for 8 hours daily. Calculation of the Load the total amount of power required.

Tables 2: Average number of electrical appliances are demand in a village

load	Power rating (Watt) (A)	Average quantity / House (B)	Power in Watt (A×B) =X	Hours used per day (C)	Energy / Day (Wh) (X×C) =Y	Total no. of houses (D)	Total energy/day (Wh) (Y×D) = Z
LED bulb	9	4	36	8	288	100	28800
Fan tables	55	1	55	8	440	100	44000
Ceiling fan	75	2	150	8	1200	100	120000
Television	50	1	50	8	400	100	40000
Mobile phone charger	10	1	10	8	80	100	8000
Other							
Total			301		2408		240800

The energy requirement for the average electrical appliances per house for 8 hours by power supply multiplied by the number of operating hours.

Total watt-hours rating of the system =
Total connected load (watts) × Operating hours

Per day electrical energy requirement of the entire village =
Energy per day(wh.) × total number of houses

The annual electrical energy requirement of the entire village =
Total energy per day(wh.) ×365(year)

The total energy required per day multiplied by the number of days in a year

2.4 Design Off-Grid Solar PV System for Electrification Rural Area

2.4.1 Photovoltaic Cells

The cells converted solar radiation directly into electricity. It consists of various kinds of semiconductor materials. It has two types: positive charge and negative charge. This cell technology is used to design solar cells with low cost as well as high conversion efficiency. When the cell absorbed photons from sunlight, electrons are knocked free from silicon atoms and are drawn off by a grid of metal conductors, which pressure a flow of electric direct current. Solar cell PV is made up of many chemicals (Saikh *et.al.* 2017) [10].

2.4.2 Off-Grid Solar PV System

Standalone or Off-Grid Systems the off-grid system term states the system not relating to the gird facility. Primarily, the system which is not connected to the main electrical grid is term an off-grid PV system. The off-grid system also called a standalone system or mini-grid which can generate the power and run the appliances by itself. Off-grid systems are suitable for the electrification of a small community. An off-grid electrification system is viable for the small areas in the countries where they do have little or no access to electricity because of the distinct living and spread population in the vast area. The off-grid system refers to the support that would be adequate for a living without depending on the grid or other systems. Electrical energy in the off-grid system produced through the Solar photovoltaic panels needs to be stored or saved because requirements from the load can be different from the solar panel output, battery bank is also used for the purpose generally (Rajeev *et.al.* 2013) [5].

2.4.3 Main Components of Solar Power System

The requirements of the solar power system are:

1. PV array
2. PV array circuit combiner
3. PV Array switch
4. Charge controller
5. Ground-Fault protector
6. Battery
7. Inverter
8. AC Fused Switch
9. Utility Switch
10. Wire

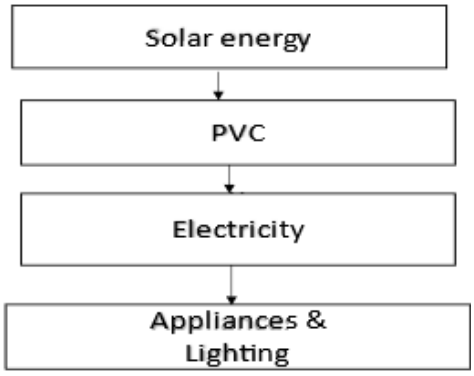

Fig 1: solar energy conversion into electricity

2.5 Design of solar panel off-grid system:

A solar PV system design can be done in four steps:

1. Load estimation
2. Estimation of the number of PV panels
3. Estimation of a battery bank
4. Cost estimation of the system
5. Base condition: 4LEDs (9 watts each), 2 fans (75 watts each), 1led tv (50watt), 1tablesfans(55watt), Mobile phone charger (10w) for 8hrs a day.

I. The total energy requirement of the system (total load) i.e.
Total connected load to PV panel system = **No. of units × rating of equipment** =
4 × 9 + 2 × 75+1×50+1×55+1×10 = 301watts

II. Total watt-hours rating of the system = Total connected load (watts) × Operating hours = 301 × 8 = 2408 watt-hours

III. Actual power output of a PV panel = Peak power rating × operating factor = 105 × 0.75 = 78.75 watt

IV. The power used at the end-use is less (due to lower combined efficiency of the system = Actual power output of a panel × combined efficiency =78.75 × 0.81 = 63.78 watts (VA) = 63.78 watts.

V. The energy produced by one 105 Wp panel in a day = Actual power output × 8 hours/day (peak equivalent) = 63.78 × 8 = 510.24 watts-hour.

VI. number of solar panels required to satisfy given estimated daily load: = (Total watt-hour rating (daily load)/ (Daily energy produced by a panel) = 2408/510.24 = 4.719 = 5 panels (round figure)/house

VII. For the entire village (100 houses) = 5×100=500 panels and 25 solar panel extra, Total= 525 solar panel

VIII. The average power output of solar grid in 8 hours =525×510.24 = 267876, watts

Per day excess energy = The average output of solar grid Per day - energy requirement of entire village per day

267876-240800=27076 watt/day=0.097436GJ/day
35.551GJ/year

One KW solar panel required area =10m^2
Therefore, 240.8 KW solar panel required area
10×240.8 = 2408m^2
0.595-acre area required to install a solar panel system,

2.6 Assumptions Taken For Design

i. Inverter converts DC into AC power with an efficiency of about 90%.
ii. Battery voltage used for operation = 12 volts
iii. The combined efficiency of inverter and battery will be calculated as:

Combined efficiency = inverter efficiency × battery efficiency
= 0.9 × 0.9 = 0.81 = 81%.

iv. Sunlight available in a day = 8 hours/day (the equivalent of peak radiation. Operation of lights and fan = 8 hours/day of PV panels.
v. PV panel power rating = 105 Wp (Wp, meaning, watt (peak), gives an only peak power output of a PV panel).

= A factor called „ operating factor‟ is used to estimate the actual output from a PV module. [The operating factor between 0.60 and 0.90 (implying the output power is 60 to 80% lower than rated output power) in normal operating conditions, depending on temperature, dust on module, etc. [11].

3. Result

This survey was conducted in a Bijahi village to evaluate the alternative energy resource to reduce the dependence of a villager on electricity and partially fulfil the requirement of a villager by alternate energy in a Bijahi village. Based on the survey, the daily requirement of a house is electricity 2.4KW per day per house required.

Tables 2: Annually average (GJ) electricity required in the village:

Load	Power rating (Watt) (A)	Average quantity /House (B)	Power in watt (A×B) =X	Hours used per day(C)	Energy /Day (Wh) (X×C) =Y	Total no. of houses (D)	Total energy/ day (Wh) (Y×D) = Z	Total energy/ Annually (Wh) = (Z×365)	Giga Joule/ annually
LED bulb	9	4	36	8	288	100	28800	10512000	37.8432
Fan tables	55	1	55	8	440	100	44000	16060000	57.816
Ceiling fan	75	2	150	8	1200	100	120000	43800000	157.68
Television	50	1	50	8	400	100	40000	14600000	52.56
Mobil phone charger	10	1	10	8	80	100	8000	2920000	10.52
Other									
Total			301		2408		240800	87892000	316.42

shown in fig 1. The assumptions are based on the daily use of 8hours 4LED of 9 W for lighting, 50 W for TV, and 10 W each for mobile charger, ceiling fan 2(each fan is 75 watt), and tables fan1(55watt) serving for about 8hours. This provides an equivalent annual village energy total consumption of about 316.42 GJ of useful energy, for lighting purposes annually 37.8432 GJ required, and tables fan57.816GJ required, Ceiling fan157.68 GJ, Television 52.56GJ, mobile charger 10.52GJ, required. Bijahi village for electrical energy is required to fulfil by solar power generation.

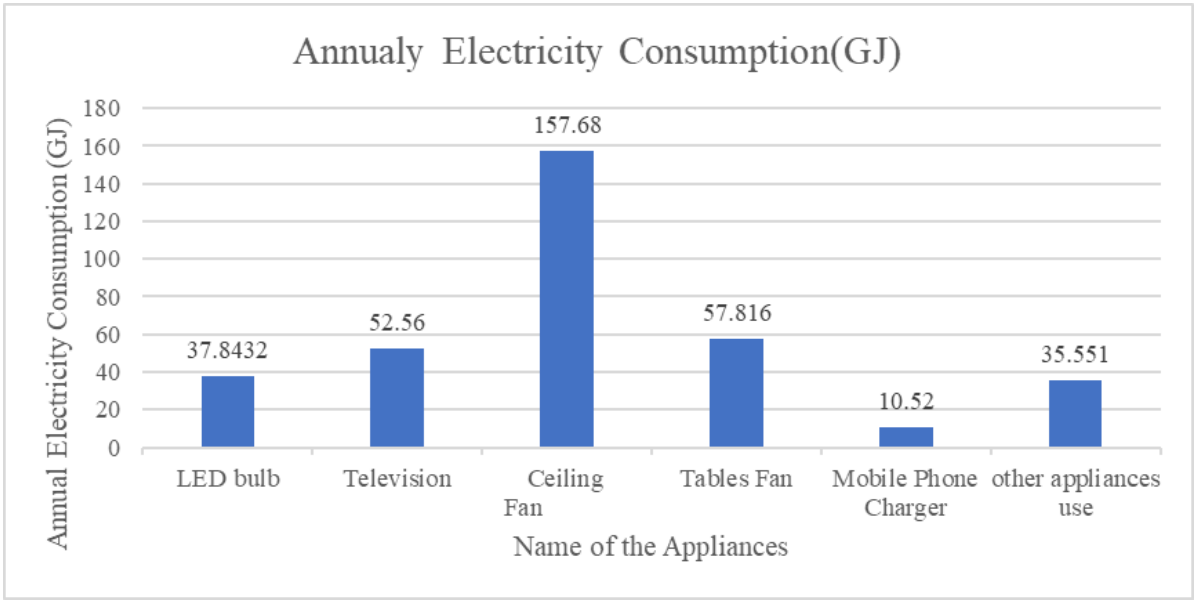

Fig 2: Annually electricity consumption in electricity appliances (GJ) of Bijahi village

For house 2408W/day electrical energy is required for electricity purposes per house per day. The average daily electricity requirement for each house is 2408 watts or 2.4kW. The 525 solar panels of 105Watt are required to install to fulfil the electricity demand of the village. Solar Conversion to electricity appliance demand requires annually about 316.42 GJ of gross solar energy. The result is presented in Table No 2. shows the amount of energy obtained with different appliances. It is the maximum amount of energy the resources available in the village. The available resources are sufficient when the difference between supply and demand is positive. electricity is a demand fulfil by solar energy. In that case, electricity from the off-grid can be used alternatively for electrical appliances. The size of solar collectors required to meet the demand depends on the local irradiation and device conversion efficiencies. With this estimate off-grid solar system is used.

4. Conclusion

Energy is an indispensable part of modern society and can serve as one of the most important indicators of socio-economic development. To achieve sustainable development in these regions, access to clean and affordable (renewable) energy must be made available. Within this study (solar energy) have the unique potential to provide clean and reliable energy, while simultaneously preserving the local and global environment. The Houses in the village require a combination of electricity for their energy requirement. Only with the most useful resource use, solar energy calls for electricity can be met. In this area is needed for solar Photo-

voltaic panels electricity generation for the electrical appliances. A very substantial PV collector area would be needed to generate enough electricity for electrical appliances. Solar energy technologies are easily adaptable to local electricity requirements. Electric energy provides better performances quality of energy for domestic appliances but is economically less likely to be an option in rural areas with the presently available resources and technologies. In general, with appropriate and efficient production and conversion, the available resources of the village are sufficient to meet their energy demands. 2408W/day electrical energy is required for electrical purposes per house per day. For the fulfilment of this energy by 525 solar panels, and each solar panel 105W for villages are required. Madhya Pradesh government gives a 30% subsidy for the installation of solar panels. A community solar energy system can be the best option for the villagers. In general, with appropriate and efficient production and conversion, the available resources of the village are sufficient to meet their energy demands.

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