Design and Calculation of standalone system for Devon valley (TQ14 OEY) near Shaldon, England

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ABSTRACT - *Harnessing solar energy to run electric appliances begins with turning solar energy into electricity. The direct conversion of sunlight into electricity is called solar power. Energy from the sun can be used in almost any application using photovoltaic modules. Tackling sun-oriented energy for home use is a strategy for changing over the sun-based energy discharged by the sun into power most, if not all, homes and apartment appliances. Devon valley (TQ14 OEY) near shaldon, England. It is a small cottage house does not have grid connection, moreover it will run with diesel generator will produce more Co2 emission cause effect on environment and more expensive to overcome this effect the standalone solar roof system was installing. Building a photovoltaic framework is the process of planning, choosing and computing the rating of the hardware's utilized in the stream. This cycle relies upon various factors like topographical area, sun-oriented illumination and load necessities. In this report will focus on the design and calculation of solar standalone system by using PVGIS software from the previous Irradiation data. Moreover, calculation for inverter, solar panel design, charge controller and load calculation with respect to daily load consumption of the cottage house in Devon valley*.

Key Words: Standalone, Solar Irradiance, Load Consumption, Inverter and Panel Sizing

1.Introduction

The sun supplies the energy needed to support life in our solar system. The earth receives sufficient energy rays from the sun for an hour to sustain itself for nearly a year (Ventre, 2003). The immediate change of the daylight into power is called photovoltaics. It is an alluring option in contrast to customary power hotspots considering multiple factors, including it is protected, quiet & non-contaminating; it is likewise sustainable; it is exceptionally particular in that limit can be step by step expanded to oblige expanding loads: and solid, with negligible disappointments rates and anticipated existence of 20-30 years (R. W. Ritchie, 1999) & (Sonnenenergie, 2007). No special training is required to operate. -No moving parts. Extremely reliable and virtually maintenance free. Can be placed almost anywhere. Time of day, season, location and whether affect the amount of sun that breaches the earth. Irradiance, which represents total energy on a daily or yearly basis, represents the intensity of the sun. irradiance is measured in Watts per square meter per day or Wh.m-2 per day.

1.1 PVGIS software

PVGIS uses high-grade, high-structural & nuptial-resolution solar ray data from satellite imagery and ambient temperature and wind speed from climate reanalysis model. Measurements of commercial modules at the JRC's European solar test facility validated the PVGIS Energy yield model (ESTI). For all solar materials, ESTI is a photovoltaic calibration laboratory approved to ISO 17025.

1.2 Case Study: A Residence in Devon Valley, Shaldon, England (TQ14 0EY)

The Devon valley, Shaldon, England (TQ14 OEY) has latitude of 50.541 ° & longitude is a relatively sun-rich region with a yearly solar irradiation about 1284. 822kWh.m-2. This means that solar energy systems are efficient part of the world. Additionally, since this problem in a stand-alone system design that powers all energy consuming home appliances.

2. Literature Review

2.1 Paper 1

One of the best renewable energy systems that is not only economical but also environmentally good is the solar power system. Using an off-grid bus shelter as an example, these approaches for study are explained, along with how they might be relevant to other off-grid applications. These are commonly in regions with constrained get entry to grid infrastructure and are available numerous sizes. The off-grid bus safe has undertaking will totally rely upon sun energy, with sun photovoltaics producing energy to strength LED lighting, wi-fi network & billing for advertising. In the occasion of the worst weather, a battery backup might offer a regular strength source. This paper will concentrate on how off-grid systems/stand-alone systems technique can help to lessen our reliance on the grid and enable us to live independently of any public utility. To further illustrate the idea, a PV system will be created for an EIU bus shelter (Bai, 2018).

Paper 2

Many researchers have published various studies on the design of self-contained PV (Solar system) over the past decade. However, after reviewing several studies on solar systems, we earthed that some parameters were overlooked in the system's design. Variables such as geographical location, weather type, solar radiation, and, ultimately, power consumption have the greatest impact on the process. In this section, we look at a detailed description of the process, breaking down each step of a stand-alone photovoltaic system for all weather scenarios and typical energy requirements, furthermore, this white paper examines the installation and maintenance costs of photovoltaic modules over their lifetime. While the report will emphasis the high initial investment, it will also highlight the system's lifetime ROI and significant benefits. The resources provided are useful resources for developing and installing SPVs for rural and metropolitan areas (Adithya Ballaji, August 2022).

3. Block diagram of Standalone Systems

3.1 Standalone Systems

Standalone PV systems are ideal for remate rural areas and applications where other power sources are impractical or unavailable to power lighting, appliances, and other uses. The standalone system depicted in fig 1 is designed to operate independently of the power grid and it is generally designed and sized to supply certain DC & AC electrical load (K. Sopian, 2021).

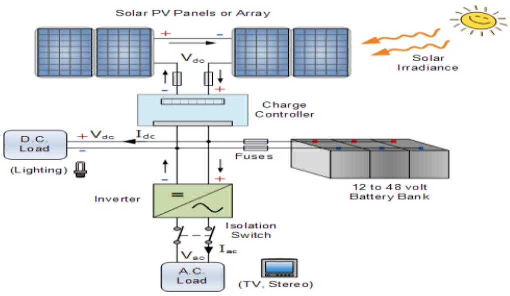

Fig1: Standalone System

3.2PV module

Sunlight is converted into electricity by the semiconductor device. Solar energy is converted into DC electricity by the PV. The most popular PV modules are made of amorphous silicon, single and polycrystalline silicon, and new materials are beginning to enter the market.

3.3 Battery

When required, the stored energy can be used to power electronic devices. A battery bank is a system component that provides energy during the night or autonomous days (also known as sunless o dark days) when the sun does not provide enough radiation. These batteries, which are typically lead-acid, are designed to be slowly discharge and recharge hundreds of times to 80 % capacity. Car batteries should be discharged to about 20% of their capacity before being used in PV systems.

3.4 Inverter

It will convert direct current (DC) power solar or wind energy sinusoidal AC power. It will be used I AC appliances or fed back into the grid. Solar panels generate direct current voltage and thus one of the fundamental components of the solar energy system. Inverter come in a variety of output waveforms, output power and installation configurations. Because it changes the form of electric power, it is known as power conditioner. When the load demand exceeds approximately 50% of the rated load, the efficiency of all inverters reaches its rated value, which is approximately 90%.

3.5 Load

It is electrical components that is connected to solar systems such as LED-light, LED T.V, laptop and others.

4 Methodologies for the PV systems designs

Step 1: Load analysis of the house

Step 2: Irradiation calculation by using PVGIS software tool

Step 3: Solar array sizing and design layout

Step 4: Specification of control charger

Step 5: Estimation of battery capacity

Step 6: Selection of inverter

Step 7: Analysis the result by using PVGIS software tool

4.1 Step 1: load analysis of the house:

As per the daily load consumption of electrical equipment, the load analysis has been calculated for the Respective house as shown in table 1

Equipment	Power (W)	Quality	Total power (w)	Duration in a day	Power consumption in Wh
LED light	9	7	63	7	441
LED TV	80	1	80	5	400
Laptop	80	2	160	4	640
Mobile Charger	5	4	20	5	100
Washing	250	1	250	2	500

machine					
Microwave	600	1	600	1	600
Room Heater 40sq.feet	500	5	2500	5	12500
Electric stove with Oven	1000	1	1000	3	3000
Fridge	150	1	150	24	3600
Miscellaneous	500	2	1000	5	5000
Total daily load in Wh					26781

4.2 Step 2: Monthly Irradiation Data using PVGIS Software Tool

By entering the postcode address or latitude/longitude, the solar irradiation data will be given in the monthly data by selecting the year from 2011 to 2020 as shown in the graphical prestation in below from this we can get the average irradiation data as shown table 2.

Latitude (Decimal Deg)	50.540			
Longitude (Decimal Deg)	-3.525			
Radiation database	PVGIS-SARAH2			
Optimal slope angle(deg.)	38			
Avg from 2011-2020				
month	H(h)_m	H(i_opt)_m	Hb(n)_m	Kd
JAN AVG	26.479	48.897	39.785	0.611
FEB AVG	43.227	67.742	53.881	0.58
MAR AVG	83.029	108.691	84.715	0.543
APR AVG	126.663	144.093	118.118	0.487
MAY AVG	159.878	161.736	136.454	0.489
JUN AVG	157.792	152.165	120.987	0.521
JUL AVG	167.475	164.991	138.398	0.495
AUG AVG	134.58	143.464	109.542	0.537
SEP AVG	97.092	118.95	91.686	0.547
OCT AVG	57.356	81.325	60.129	0.596
NOV AVG	30.635	51.836	39.77	0.637
DEC AVG	21.532	40.932	32.628	0.655

From the above tabular column, For the design of solar standalone system most prefers is the worst month i.e., the low solar power from the sun. In the above table the December is the worst irradiation month in a year with respect to location of weather.

4.3 Step 3: Standalone PV sizing

Typically, from the data sheet

Efficiency of inverter = 96 %; Efficiency of REG/ MPPT = 97%; Efficiency of battery = 80%

Energy required from the PV array = daily load (KWh)/Eff. Of Inverter, battery and MPPT/REG

Energy required from the PV array = 26.78/0.96*0.97*0.80 = 35.94 KWh/day

We are selecting 500 W Bifacial Dual Glass Monocrystalline Module:

Max power output: 500W (1 panel) +; Max eff: 21%

Module dimensions = 2.187×1.102 = 2.410 Module area.

High Reliability; Energy Yield; High Customer value.

500W = 2.410 module area

1000W= X

X= 1000×2.410/500 = 4.82 module area, kWh / kW

Nos of solar panel in a array = Daily load consumption in Wh/ selected solar panel i.e. 500W

Nos of solar panel in a array = 40932/500 = 54

Next process will be choosing the operating voltage Vdc, typically multiple of 12v. let's choose Vdc = 48 v

Nos of series module = Vdc / Vm = 48/12 = 4

Nos of parallel module = 28299/ 500×4 = 14

4.4 Step 4: Specification of control charger

From the 500W solar panel data sheet, short circuit current **Isc = 12.13A**

F-safe = 1.25 - The safety factor is used to ensure that the regulator can handle the maximum current generated by the arrangement that may exceed the table values. You can also use additional devices to handle higher than planned load currents, for example. In other words, this safety factor allows the system to be slightly expanded.

I = Isc × Np × Fsafe

I = 12.13×14×1.25

I = 212.75 A

N controller (no's of charge controllers) = Array short current in amps/ amps each controller

N controller = 212.75/80 = 3

4.5 Step 5: Estimation of battery capacity

For no city power areas, the battery pack can be charged by solar panels and used for night lighting; for the areas that city power is expensive, the battery pack can be charged during the electricity valley value period and used at the peak power period; for the areas which power off from time to time, the battery pack can be used as UPS, to avoid information loss caused by sudden power outage. The battery pack is applicable to commercial lighting, industrial lighting, industrial lighting, home lighting, outdoor lighting, camping tourism, farming, planting, the night market stalls, etc.

Battery = LiFePO4 Battery pack (cast aluminium version); standard capacity = 24v/200Ah; storage capacity= 5120 Wh; delay protection = 1000ms; warranty = 5 yrs.

Choose autonomy (n = 5 days) i.e., the battery will charge 5 days in a week. therefore, the capacity of battery formula is shown below

Cb = n × daily load consumption / depth of discharge permitted

Cb = 5 × 26781 / 0.8 = 167382 Wh

W, k,t , power (p) = voltage (v) × current (I) = 24 × 200 = 4800Wh

No of batteries = battery capacity in Wh/ selected battery in Wh

No of batteries= 167382/4800 = 36

No of batteries in series = 2

No of batteries in parallel = 18

4.6 step 6: Selection of Inverter

The first step, when sizing an inverter is to determine the actual power consumption of the loads operating simultaneously. The inverter cost is high for the safety purpose we are assuming the 25% extra power consumption is added as shown in below equations

Inverter = power consumption in a day / power factor × 25%

Inverter = 5823/0.8 × 1.25 9910 VA

In terms of Inverter watt = Inverter in VA × power factor

In terms of Inverter watt = 9910 × 0.8 = 8000W

4.7 Step 7: Analysis of the result by using PVGIS software tool

From all above calculations,

Installed peak power = selected PV panel (500W) × No of modules in PV array

Installed peak power = 500 × 50 = 2700 Wp

From the battery capacity,

Capacity of battery = 167382 Wh

Slope angle = 38 deg (obtained from the step 1)

Daily load = 26781 Wh

Enter the above respective values in PVGIS/ OFF grid, we get visualization data to built standalone system for location fig 2

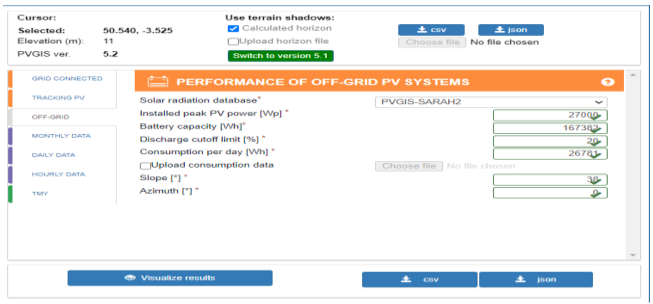

Fig 2: Solar electricity generation using PVGIS tool

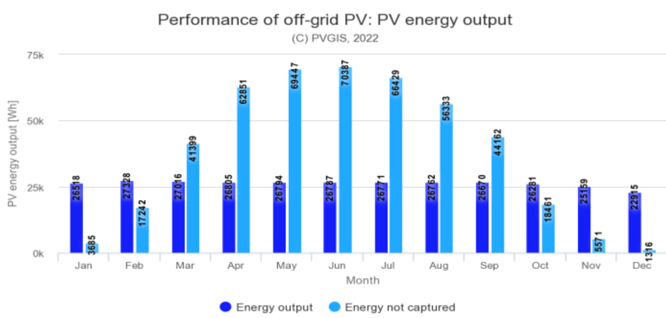

Fig:3 Energy output analysis

The above graph analysis is about the power production estimation for the OFF-Grid PV systems. The purple bar indicates that, the output energy is the energy required for the battery meet the load demand from the solar power. The blue bar chart indicates the amount of PV power obtained from the sun at the location shaldon, England. According to the graph above, the amount of sunlight available to charge the battery to meet the load is low from November to January. Aside from that, the energy power supply (from, March to October) will meet the load.

For the PV calculation and design, we are considering the month of December i.e., worth month.

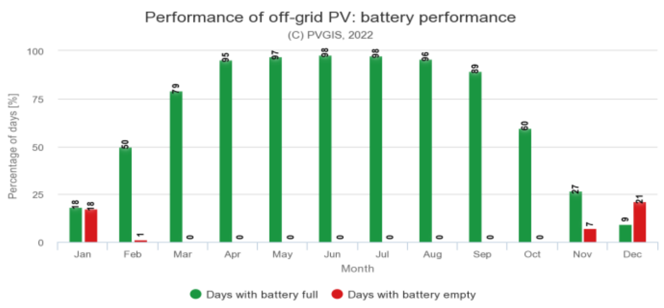

Fig 4: Battery performance analysis

The graph will talk about the battery performance in the off-grid PV system. The red bar indicates the number of days in a month that the battery is not charged. The green indicates that the respective month has a full charge. As mentioned above, the sunlight is very low in the months of November, December, January, and February. In other months, with enough sunlight, the battery will charge completely in 5 days.

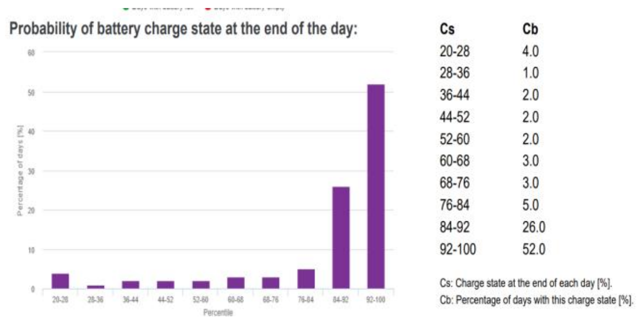

Fig5: probability of battery-charge state

The above will represents the probabilty of batery charge at the end of the day. In a day the state of battery percenatge is 92 – 100 (i.e the battrey will charge upto this perenatge in a day. Cb will be the 52% means the percenatge of days in a month the battery will be in charge state. The lowest charge state at the end of the day is 20-28 % and 4% days in a month the battery will be in charge state as shown in the above fig respectively.

From this, the average percernatge of battery with full charge is 68.15% and average percernatge of battery with empty charge is 3.98%. As a Engineer, I will suggest to install the standlone system in the devon valley cottage house to overcome the desiel generation expenses and become enviromental friendly.

5 Future scope

From the analysis, we can see that from the Novemeber to Febuary the low solar energy so, still the cottage required deisel genration in this month . furthermore, the solar energy is not captured during the months of march to october. To overcome this it will required some methods to include for future endevours.

1. We can see the fig 4&5 from the month of march to october the battery will fulfilled the energy with respect to load demand remaing solar energy will be wasted to overcome this they can add more battery banks to store the energy or connect the neighbour house load and utilze for the following month to avoid the deisel genrator.

2. Hybrid Energy

Fig6 : Hybrid Technology

During the month of December, the insufficient solar irradiation the battery is 21 days empty in a month by installing the small wind turbine with solar with respect to house as shown in fig 6. From this implementation of hybrid technology, we can solve this issue during the low irradiation at location. Moreover, the average wind speed in Devon is 14.1mph. This hybrid technology will have more economic benefits and less cost.

Conclusion:

The geographic location of England's (TQ14 OEY) Devon valley is a relatively Sunny area with annual solar radiation exceeding 1284. 822kWh.m-2. There is a proneness for the use of Standalone photovoltaic stations distributed in remote areas due to the known benefits of this source of energy. The selection of battery is economical cheap and 90% is recyclable with full charge efficiency of 68.15%. Advanced inverter is implemented that will check the battery voltage and supply via smartphone. Moreover, from this standalone installation in the location will reduce the use of diesel generator and sustainable energy with system lifespan of around 15-25 years.

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BIOGRAPHIES

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