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Study on Design and Performance Analysis of Solar PV Rooftop Standalone and On Grid System Using PVSYST

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Abstract - *The actual system explores the opportunities to explore towards environmental friendly energy production. The environment effects and load demand of electricity are the main factor driving towards renewable energy. The main goal is to demonstrate the model based methods for a grid connected solar PV system for domestic & commercial application. Overall solar irradiation in Karnataka state is around 1266.52W/sq m. 1KWp solar rooftop plant will generate on an average over the year 5KWh of electricity per day (5-6 sunshine hours). For the generation of 1KW, carbondioxide emissions mitigated is 31tonnes.The installation is equivalent to planting 49 trees over the life span. Case study of 2.5KW solar PV plant installation on rooftop for home load consumption of 9.3kwh/day is analyzed using PVSYST software which gives solar radiation yield globally is 5.94kwh/m²/day, Available AC energy is 3713kwh/year, and used energy is 1504kwh/year excess energy generated to be fed to utility grid is 2045kwh/year. This method helps predict power interruption, the backup energy storage as they can use the energy stored from the batteries. Therefore, development of system model gives the clean energy for energy conservation and sustainable development of the society.*

Key Words: **Solar PV technologies, Grid connected, standalone, meteo data, PVSYST.**

1. INTRODUCTION

There are a number of factors behind the development of a nation, electricity is one of them. Nowadays, the main challenge for both developed and developing countries is to generate electricity continuously to meet the demand which is increasing tremendously day by day. The rising demand increases stress on power infrastructure as well [1]. As conventional sources of energy i.e fuel, oil, gas are depleting in nature day by day and are exhaustive due to increase in population and rise in electricity demand , they leaves harmful gases in environment causing global warming.

Hence we need to shift on non conventional energy sources i.e renewable energy such as solar, wind, rain, tide, hydro, geothermal which are abundant and in exhaustive in nature. Use of non conventional energy sources makes clean generation of energy, keep the environment clean. So in this project we are going to brief about renewable energy i.e solar photovoltaic cell, Types of solar modules, measuring instruments.

Mainly design and performance analysis of solar PV rooftop standalone and on grid system using PVSYST is designed in this project. Case study of 2.5KW solar PV plant installation on rooftop for home load consumption of 9.3kwh/day is analyzed using PVSYST software.

The installation of solar PV plant is calculated based on household consumption of electronics devices used in day to day life. The energy generated by plant is sufficient to meet the home load and excess energy or unused energy is fed to utility grid using net metering.

1.1 Objective

Design and performance analysis of solar PV rooftop standalone and ON grid system using PVSYST.

Using the meteo data available for site location where the solar PV pant has to be installed, performance analysis is made using PVSYST software for annual generation, solar irradiation and performance ratio is known by giving the technical specification details for residential purpose.

1.2 Methodology

Photovoltaic is a technology that reliably converts solar radiation into electricity. There are different types of modules depending on power ratings.

Every module has a number of solar cells. Solar cells are fabricated by means of semiconductors such as silicon. Photovoltaic cells generate electricity in clean and reliable manner which is the prime concern for today's environment.

The solar PV technologies are classified as follows.

	**1. Monocrystalline solar module** It consists of silicon in which the crystal lattice of the entire solid is continuous, unbroken to its edges, and free of any grain boundaries.Crystal latice of entire sample is continuous.
	**2. Polycrystalline solar module** Polycrystalline silicon is a material consisting of multiple small silicon crystals. It is composed of many crystallites of varying size and orientation.
	**3. Thin film solar cell** A thin-film solar cell is a solar cell that is made by depositing one or more thin layers, or thin film (TF) of photovoltaic material on a substrate, such as glass, plastic or metal.
	**4. Amorphous Silicon Solar Cell** Amorphous silicon (a-Si) is the non-crystalline form of silicon used for solar cells.
	**5. Concentrator Photovoltaic technology** It uses lenses and curved mirrors to focus sunlight onto small, but highly efficient, multi-junction (MJ) solar cells.

2. Proposed system

Fig-1: solar PV grid connected system

The total amount of energy produced by the system will be used to meet the electric demand of the house load and the excess energy which is remaining will be feed back to the grid/battery bank as shown in Fig 1. The energy generated by the PV module is given to inverter for converting DC voltage to Ac voltage and feed to household requirement. Excess energy generated is sold back to grid using electric meter/ net metering.

There are two types of net metering, forward and backward net metering

For example, if the energy produced by PV module is 12.5units and the energy consumed by house hold requirement is 10units.Than the excess energy remaining 2.5units is feed to utility grid with forward net metering.

2.1 Components required

Main components required for design of rooftop standalone PV system is solar PV modules, Grid tie inverter, battery, net metering, utility grid & connected loads.

Solar PV modules

Fig–2: Solar PV modules placed on mounting structure

A solar photovoltaic (SPV) system converts incident solar radiation to electricity using semiconductor devices. Solar photovoltaic is a commercially available technology in India and solar PV system has been successfully installed in many buildings or site as shown in fig 2. Adoption of this technology will help in meeting the electricity demand to greater extent.

The best part is that they are modular in nature i.e depending upon the changing requirement of the consumers; the solar modules can be changed to meet the electricity demand. Components used in a system depend upon the type of system configuration, which in turn is dependent on the application.

Grid tie Inverter

Fig-3: Grid tie inverter

The selection of the inverter or selected technology should best fit the overall requirement of the plant. Should be reliable and easy to handle, install, operate and maintain. It should have longest life and deliver highest performance levels and should have low cost; however it should not pose performance risk over the long run.

Grid tied inverters as shown in fig 3. Battery backup inverters are special inverters which are designed to draw energy from a battery, manage the battery charge via an onboard charger and export excess energy to utility grid. These inverters are capable of supplying AC energy to selected loads during the utility outage, and are required to have anti-islanding protection. They tend to have features which are found in both grid tied and off the grid inverters.

Battery Banks

Fig-4: Battery

An electric battery is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices and store energy as shown in fig 4.

Net metering

Fig-5: Net metering

Net metering as shown in fig 5, allows residential and commercial customers who generate their own electricity from solar power to feed electricity they do not use back into the grid.Net metering is a billing mechanism that credits solar energy system owners for the electricity they add to the grid.

Utility grid

Fig-6: utility grid

Utility system is shown in fig 5. Also consist of metering panel and metering panel reads the energy fed to the grid. This meter is generally used by the utility authorities to know the amount of energy fed to the grid. The excess energy generated from the plant is fed to utility grid which is having 3phase, 440V, 60Hz. The net metering which is connected to utility grid can calculate import and export energy for home load.

2.2 Case study

Design of solar PV rooftop standalone system for home load consumption of 9.3units/day is considered.

Table – 1: Load consumption for home electronic devices

Sl.No.	Item	Power (watts)	No.'s	No. of hours of operation	Wh per day (Wh/day)	Hrs of operation (W/h)
1.	LED	10	10	6	600	100
2.	Fan	150	4	6	3600	600
3.	TV	100	1	4	400	100
4.	Refrigerator	200	1	8	1600	200
5.	Mixer	500	1	1	500	500
6.	Computer	300	1	4	1200	300
7.	Pump	400	1	1	400	400
8.	Iron box	1000	1	1	1000	1000
	Total	P=2,660W			Wh/day=9,300	W/h=3,200

Total energy consumption for daily load = 9300Wh/day
= 9.3KWh/day
= 9.3units/day

Hourly Load = 3200W/h
= 3.2KW/h = 4KW/h

Technical specification of solar PV module

SPV module capacity – 250Wp
Voc – 43V
Vmax – 35V
Isc – 7.62A
Imax – 7.15A

Selection of inverter

Inverter is selected based on **hourly load.**

1. As per table 1, hourly load is 3.2KW/h; hence range of 3-5KVA inverter is selected.
2. As per design 4KVA inverter is required.
3. DC input voltage =36/48V
   Output AC voltage = 1Ø, 230V, 50Hz

Selection and technical specification of battery

12V:20Ah, 40Ah, 100Ah
24V: upto 600Ah
As per MNRE for solar PV application it is recommended to go for **tubular lead acid battery**.

2.3 Design Calculation

Generation of 1KW is equal to 5units/day.

Table – 2: calculation steps for rooftop PV system

Total energy consumption per day	9.3KWh/day 9.3Units/day
Hourly load	3200W/hr 3.2KW/hr
Generation of power 1KW/day	5units/day Energy consumption
For requirement of home load	1.86KW/day
Normally we go for 25% more load, Hence the solar plant required is	2.4KW/day
Selected PV panel capacity	250Wp
No. Of PV modules required is	10modules
Total power generated by 10 PV modules	2.5KW/day
Hence, power generated by PV modules meets the home load and the excess power which is generated is feed to utility grid (ON GRID)	0.64KW/day
If we go for OFF GRID ,Battery is required	The selected battery capacity is 12V,150Ah
Total energy which can be stored in single battery is (P = V x I)	1.8KW
Therefore, to store 10units , no. Of batteries required is	6 battery
If we consider 60% discharge, No. Of battery required is 4 Extra	10battery

2.4 Economic analysis

Total PV Plant capacity = 2.5KW

Area required = 2.5 x 100 = 250 sq ft
Energy generation by PV plant = 12.5 units/day
= 4,562.5kwh/yr

Table – 3: From **MNRE** (ministry of new and renewable), solar rooftop calculator estimation.

Size of power plant	2.5KW
Cost of plant	Rs.70,000/-/KW
Without subsidy	Rs.1,75,000
With 30% subsidy	Rs.1,22,500
Total electricity generation from solar plant	3750kwh
Life-time (25years)	93750kwh
Financial savings: Traffic @ Rs.7.31/ kwh Monthly Annually Life –time (25 years)	 Rs.2284 Rs.27412.5 Rs.685312.5
Carbondioxide emissions mitigated is	77 tonnes
This installation will be equivalent to planting	123 teak trees over the life time

3. Software Requirements

PVSYST V5.0 is a PC software package for the study, sizing and data analysis of complete PV systems.

It deals with grid-connected, stand-alone, pumping and DC-grid (public transport) PV systems, and includes extensive meteo and PV systems components databases, as well as general solar energy tools.

Software version: PVSYST, V5.74
Operating system: windows 7

3.1 Software simulation steps of standalone System

This software is geared to the needs of architects, engineers, researchers. It is also very helpful for educational training.

PVSYST software is used for Evaluation as shown in fig 6, for project design of grid connected, standalone, and pumping and DC grid.

Fig - 6: Evaluation mode (PVSYST V5.74)

Case study:
Location: Gulbarga, Karnataka
Latitude: 17.3⁰N, **Longitude**: 76.8⁰ E, **Altitude**: 454 m, **Time zone**: 5

Fig - 7: Meteo details of location

As shown in fig 7, we need to enter details of site were the solar power plant need to be installed. Location details include latitude, longitude, altitude and time zone of particular place.

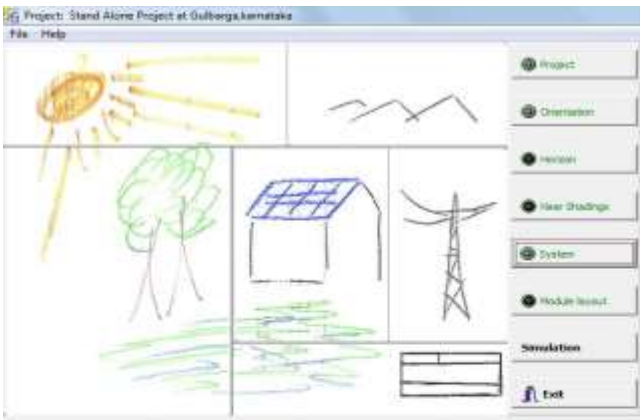

Fig - 8: Design of standalone system

Design of solar PV standalone system evaluation mode as shown in fig 8, can be analyzed by giving technical specification details of resources used in project.

Design of standalone system includes details of orientation like tilt angle: 15⁰ and azimuth angle: 180⁰. Also the system specification like home load details for 2.3KW$_p$ plant installation. The energy consumed per day is 9300Wh/day, based on home load requirement.

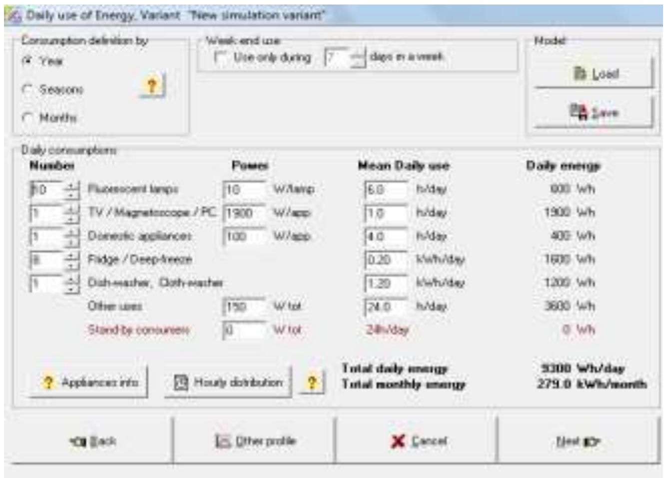

Fig - 9: Household load consumption

Daily use of Energy as shown in fig 9, gives the household load consumption per day. Power consumed by each electronic device is estimated as hourly load and daily load. As per energy consumption daily load is 9.3kwh/day and 279kwh/month whereas hourly load is 3.2kw.Hence inverter selection is based on hourly load whereas battery selection is done on daily load. Even solar PV module is specification is selected based on daily load calculation.

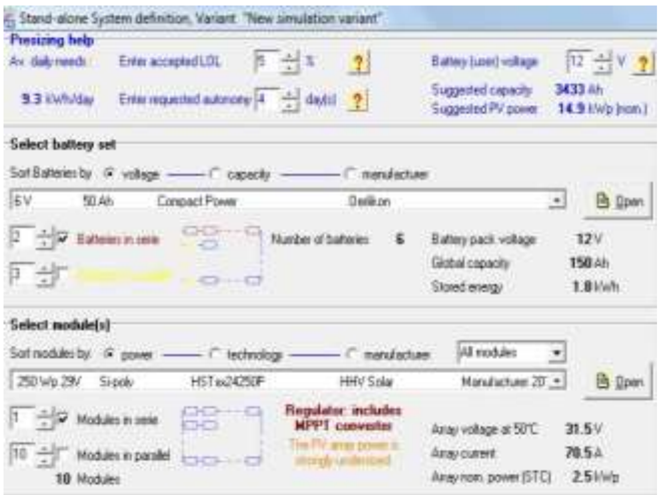

Fig - 10: PV module and battery selection

The above fig - 10 gives the PV module and battery specification for modeling of standalone system. As per technical specification battery used is 12V, 150Ah, which can store energy of 1.8Kwh and number of battery required is 6. The PV module selected is of 250Wp, 29V with array voltage 31.5V, array current 70.5A, Array power (STC) generated is 2.5Kwp .The number of modules required as per calculation is 10.

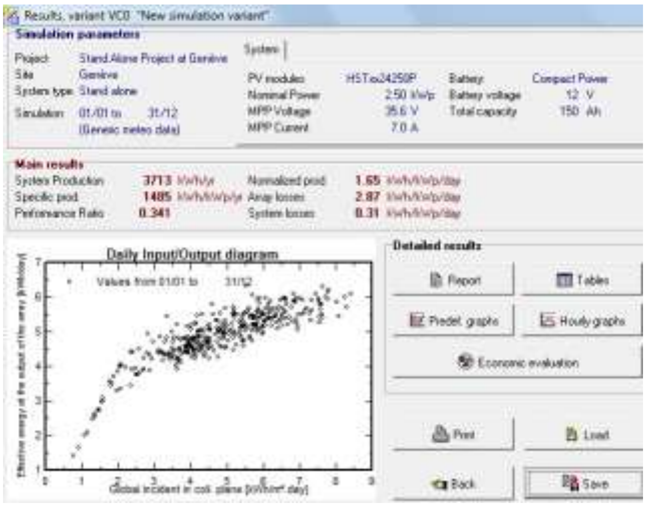

Fig 11: New simulation Variant

Than go for simulation, to get the output report of project details and also tables and graphs can be viewed for performance analysis of the system. The above fig 5.3.5 shows the new simulation variant, which yields system production of 3713kwh/year and specific production 1485 kwh/kwp/yr with performance ratio 34.1%. MPP voltage is 35.6V and MPP current 7A is required as per PV module selection.

4. RESULTS AND DISCUSSIONS

Table - 4: Main result of system production

Standalone system: Main results
Main simulation results **System production** : Available energy = 3713KWh/year Specific production = 1485KWh/Wp/year Used energy = 1504KWh/year Excess energy = 2045 KWh/year Performance ratio = 34.1%

From the Table - 4 , gives the main resut of system production i.e avaliable energy 3713kwh/year, used energy 1504kwh/year, excess(unused) 2045kwh/year which is fed to grid. Performance ratio (PR) is 34.1%.

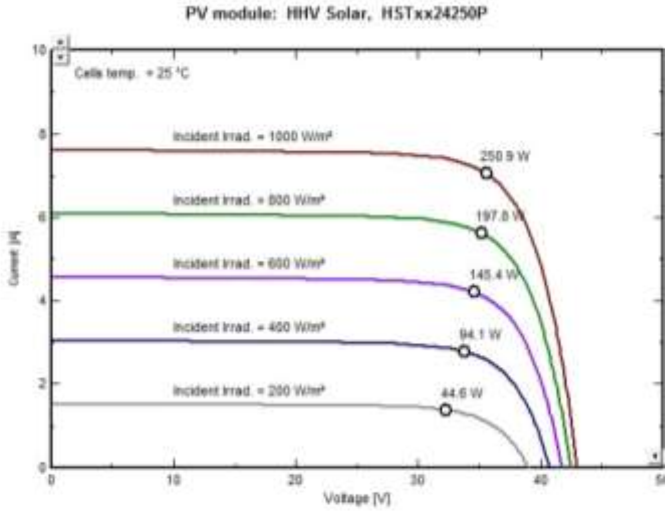

Chart -1 : Voltage verses current graph

From the chart-1, voltage verses current graph is given, cell temperature is 25^0C , power varies with respect to incident irradiation , if irradiation is 1000 w/m^2 maxmium power is 250W, if irradiation is 200w/m^2 than minium power is 44.6W.

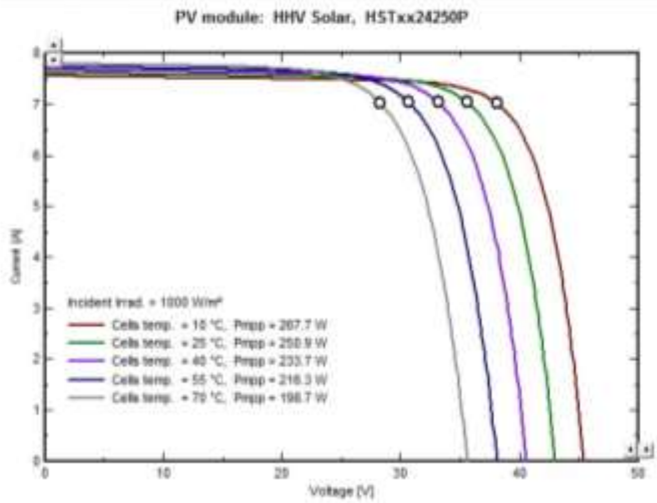

Chart-2: Voltage verses current with varing temperature

As shown in chart-2, voltage vereses current graph is drawn with varing temperature. If temperature increases voltage decreses, at cell temp 25^0C gives the maximum power of 250Wp. Temperature is inversely proportional to power due to negtive temperature coefficient of the material.

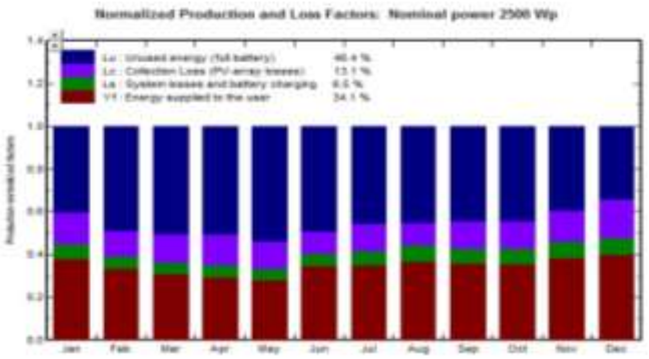

Chart-3: Normalized production and loss factors

From chart-3, gives the normalized power production and loss factor which is yield annually. Normalized power is 2500Wp. System loss is 6.5%. Energy supplied to the user is 34.1% and unused energy is 46.4%. collection loss (PV-array losses) is 13.1%.

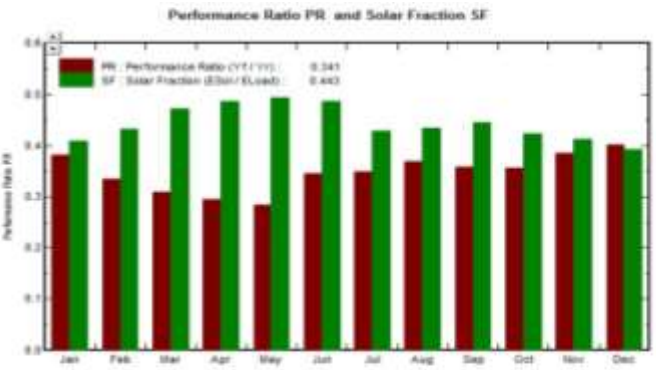

Chart-4: PR (34.1%) and solar fraction (0.443)

From the chart-4, gives the annual solar fraction 0.443 and performance ratio of 34.1%, solar fraction (Esol / Eload) i.e energy generated by solar module with respect to energy fed to load.

Table - 5: Balance and main result

New simulation variant

Balances and main results

	GlobHor kWh/m²	GlobEff kWh/m²	E Avail kWh	EUnused kWh	E Miss kWh	E User kWh	E Load kWh	SolFrac
January	160.9	115.8	253.6	123.6	170.6	117.7	288.3	0.408
February	164.4	128.2	269.6	165.1	147.8	112.6	260.4	0.432
March	197.2	168.4	372.6	222.1	152.2	136.1	288.3	0.472
April	192.3	178.6	386.8	233.8	143.1	135.9	279.0	0.487
May	200.0	196.5	427.4	268.7	146.1	142.2	288.3	0.493
June	154.8	152.2	341.6	193.8	143.4	135.8	279.0	0.486
July	140.7	137.0	297.3	161.5	164.7	123.6	288.3	0.429
August	138.9	131.3	294.8	154.3	163.1	125.2	288.3	0.434
September	147.6	133.5	292.0	163.5	154.9	124.1	279.0	0.445
October	157.5	131.6	288.4	153.1	166.1	122.2	288.3	0.424
November	150.6	113.0	248.1	118.0	163.9	115.1	279.0	0.413
December	150.4	105.4	222.0	96.3	175.1	113.2	288.3	0.393
Year	1954.8	1681.7	3713.3	2044.9	1890.9	1503.7	3394.5	0.443

Legends:
GlobHor Horizontal global irradiation
GlobEff Effective Global, corr. for IAM and shadings
E Avail Available Solar Energy
EUnused Unused energy (full battery) loss
E Miss Missing energy
E User Energy supplied to the user
E Load Energy need of the user (Load)
SolFrac Solar fraction (EUsed / ELoad)

From Table 5, gives the balance and main result sheet, gives the annual global horizon is 1954.8, avaliable solar energy is 3713.3, unused energy is 2044.9, load connected is 3394.5 and also having avaliable solar energy 3713.3, solar fraction 0.443.

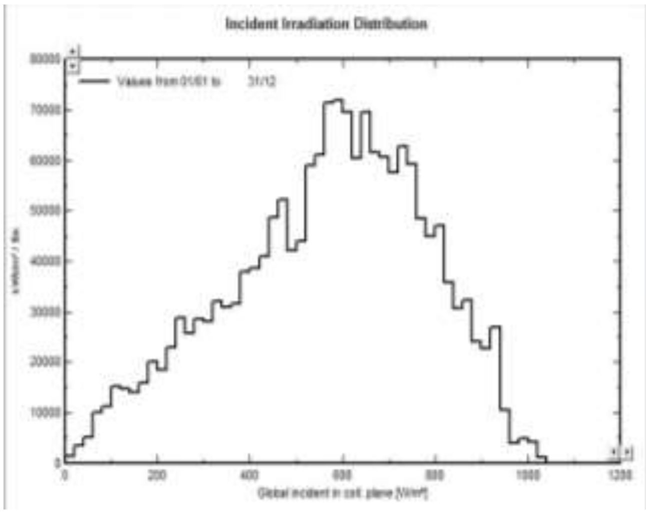

Chart-6: Incident irradiation distribution

From chart-6, gives the incident irradiation distribution of global incident collection plane generated annually.

5. CONCLUSION

Design and performance analysis of solar PV rooftop installed capacity 2.5KWp standalone system, location at Gulbarga Karnataka having latitude 17.32N, longitude 76.83E has choose for case study to analysis the home load consumption and fulfill the energy consumption using solar PV modules, inverter and battery and excess energy generated to be fed to utility grid using net metering with the help of PVSYST software. Considering as per case study, load consumption per day is 9.3units/day and hourly load consumption is 3200W/H, respectively inverter, battery and solar PV module selection is made.

Hence the performance analysis is done using PVSYST software which gives solar radiation yield globally is 5.94kwh/m^2/day, Available AC energy is 3713kwh/year, used energy is 1504kwh/year excess energy generated to be fed to utility grid is 2045kwh/year having inverter efficiency 96% and DC to AC size ratio is 1.2, performance ratio 34.1%, capacity utilization factor is 17.7%.

5.1 ADVANTAGES

1. They consume no fuel to operate, as the sun's energy is free. Rapid response in output to input radiation.
2. They can be used with or without sun tracking making possible wide range of applications possibilities.

3. Maintenance cost is low, as they are easy to operate. Wider power handling capabilities and easy to fabricate.

4. It is environmentally clean source of energy. Free and available in adequate quantity in almost all the parts of the world where people live.

5.2 DISADVANTAGES

1. The solar radian flux availability is a low value 1kw/m^2 for technological utilization and large collecting area required.
2. Cost is more and availability varies with time.
3. In many applications, energy storage is required because of insolation of light.
4. The relatively poor conversion efficiency.

5.3 APPLICATIONS

1. Water pumping, Radio beacons for ship navigation at ports, community radio and television sets, and cathodic protection of oil pipe lines.

2. Weather monitoring, Railway signalling equipment, battery charging and telecommunication.

3. Cooking: solar cookers are commercially available and can be used for the purpose of cooking food.

4. Heating: solar water heaters and air heaters are being used for a variety of applications both in industrial sector and domestic sector.

5. Lighting: solar photovoltaic lighting system can be effectively used in remote rural areas for both domestic lighting and street lighting.

6. Process heating: cylindrical parabolic collectors can be used for the production of low pressure stream for industrial application.

7. Refrigeration: solar energy can be used for the purpose of cold storage as well as air conditioning application. Vapour compressor system using PV panels and vapour absorption system using thermal collectors can be used for these purposes.

6. FUTURE SCOPE

Most of the commercially used Canadian solar panel has 72cells with different power ratings like 250Wp, 275Wp, 325Wp, 350Wp etc.

TwinPeak technologies has overcome with new invention which has 144 cells and are bigger in size, gives even higher power output per m^2, and are ideally suited for commercial and industrial applications across the world.

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