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OPTIMIZED ENERGY EFFICIENT SOLUTION WITH STAND ALONE PV SYSTEM

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Abstract

Photovoltaic systems are presenting an alternative source for production of electricity in a sustainable way. PV systems are a form of renewable energy systems that are progressively being used for efficient production of electricity. PV systems in the form of Stand Alone systems offer a potential solution to generate clean electricity with minimization of all form of losses. This system consists of PV array, battery, inverter and load. Its performance depends on orientation of PV array, horizon, irradiance, shading, the local climate, wind speed and direction and inverter performance. The I-V characteristics of the system are affected by shading of module and varying irradiance levels. The simulation model of Stand Alone PV System design using PVsyst software to perform the full analysis of PV systems is presented in this paper. The *energy output throughout the year was simulated. The system loss diagram represents the efficiency of conversion and total energy output.*

Keywords

Renewable Energy Systems, Photovoltaic system, Batteries, Stand Alone PV system, PV Array, PVsyst software

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1. Introduction

Photovoltaic systems convert solar energy which is derived from radiant light and heat from the Sun, into Photovoltaic energy. PV systems consist of solar panels which are composed of solar cells electrically connected and mounted on a supporting structure. Due to increase in energy demand and fast depletion of available fossil fuels, renewable energy resources have to be used to meet the demand of power in future. At present in India solar energy contributes to nearly 5% of production of electrical energy. Solar energy is a unique prospective solution for energy crisis as it is a sustainable renewable energy source and environmental friendly with no emission of greenhouse gases. Technology enhancement of photovoltaic materials has made PV systems cheaper over a decade and has condensed environmental disorders.

PV systems with different battery storage techniques have helped in meeting user energy demands more efficiently. Orientation, module type and arrangement, placement of inverters and energy storage systems are the important parameters for PV technology. The design of Stand Alone system at Hyderabad city is simulated taking into account of all form of losses.

The characteristics of Stand Alone PV system are analyzed by using PVsyst software by predicting the energy production taking the amount of irradiance and shading effectsinto account. PVsyst software gives quick evaluation of potentials and possible constraints. It also involves the choice of meteorological data, system design, shading studies, losses determination, and economic evaluation. The simulation was performed over a period of one year in hourly steps to provide graphs and additional results. There is research paper on Quality of Performance Assessment of PV Plants Based on Irradiation Maps (A. Drews, 2008). A paper has been predicted on Long Term Performance Analysis of a Grid Connected Photovoltaic System in Northern Ireland (J. D. Mondol, 2006). Results and analysis have been performed on 3 kW Grid Connected PV Systems (J. H. So, 2007). Studying the Impact of Partial Shading on Solar PV Module Containing Series Connected Cells (R. Ramaprabha & Dr.B. L. Mathur, 2009). Studying an Evaluation Method of PV Systems (T. Oozeki, 2003). Measuring and analysis of residential PV Systems Which was carried out in Japanese Monitoring Program (T. Yamaguchi, 2006).

2. Stand Alone System

A Stand Alone PV system is also referred as off grid systems and used in remote areas where utility grid does not exist. This type of PV system includes electricity production by photovoltaic conversion, energy storage in form of batteries or fuel cells and regulation. The user can use energy which is stored in batteries produced by solar array at any point of time as per load demand. A regulator is used for proper regulation of generated voltage at the load end. A backup generator can be used in case of emergency purpose.

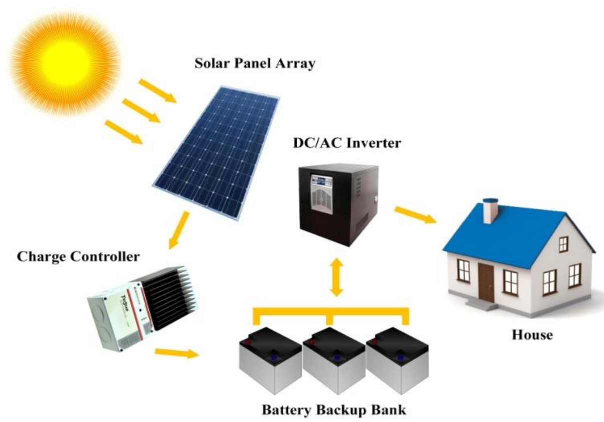

Figure 1: *Stand Alone System*

The batteries can be arranged in series or parallel connection or combination of both to obtain required voltage to meet the load demand by the user. The arrangement of solar cells in the panel should be done such that it satisfies the area available for mounting of the system. The performance analysis of Stand Alone system includes amount of energy available at array, energy at load, losses and unused energy. The main components of PV system are solar panel array, charge controller, battery storage, inverters and loads.

2.1 Solar Panel Array

The solar panel array uses photovoltaic effect to convert solar radiant energy to DC electricity to be stored in batteries in Stand Alone PV systems. The solar panel array should have voltage ratings synchronized with voltage capacity of batteries and system DC voltage. The rate of electricity generation depends on amount of irradiance.

2.2 Charge Controllers

The charge controllers are used to protect batteries from over charging as it may lead to damage. It regulates the voltage and current produced by solar panel that is stored in the battery. Charge controllers are being used for Stand Alone systems are either 3 stage PWM or MPPT controllers.

2.3 Batteries

The batteries are used to store energy and supply the load whenever required. This energy can be even used in absence of solar energy from the sun which can also be used to supply loads during the night. The batteries are to be used in Stand Alone system should be efficient and should have good performance. The price, capacity, size and type of installation are important features for selection of optimal battery.

2.4 Algorithm of the Proposed System

Step 1: Start Solar PV module

Step2: Select Project Design

Step 3: Select Stand Alone Project

Step 4: Select the details of Input side and meteorological parameters

Step5: Give Orientation Details which includes Tilt Angle and Azimuth Angle, Fill in user needs

Step 6: Select the Required Battery Set and Orientation Batteries

Step 7: Select the Required PV Module and Arrangement of Solar Cells

Step 8: If Oversized/Undersized again go to step 7

Step 9: Select Desired Regular (with/without back - up Generator)

Step 10: If requirement matched go to Step 9

Step 11: Simulate the PV System

Step 12: Enter the Economic Evaluation Details, Print Reports

Step 13: Stop

2.5 Inverters and Loads

For supplying lighting load, DC appliances as well as AC appliances the stand-alone systems can be used. The inverters are used to convert DC to AC. An appropriate rating should be selected as per energy generation and user requirement.

3. Proposed Stand Alone System

The figure 2 depicts a schematic diagram of the Proposed Stand-Alone System. The size of the system depends on the load considerations. The PV array sizing and arrangement of solar cells has to be done. The specifications of batteries and regulator are taken from the database. The back-up generator supplies power in case of emergency. The geographical locations of the site can be represented in Table I which gives meteorological data of the stand-alone PV system.

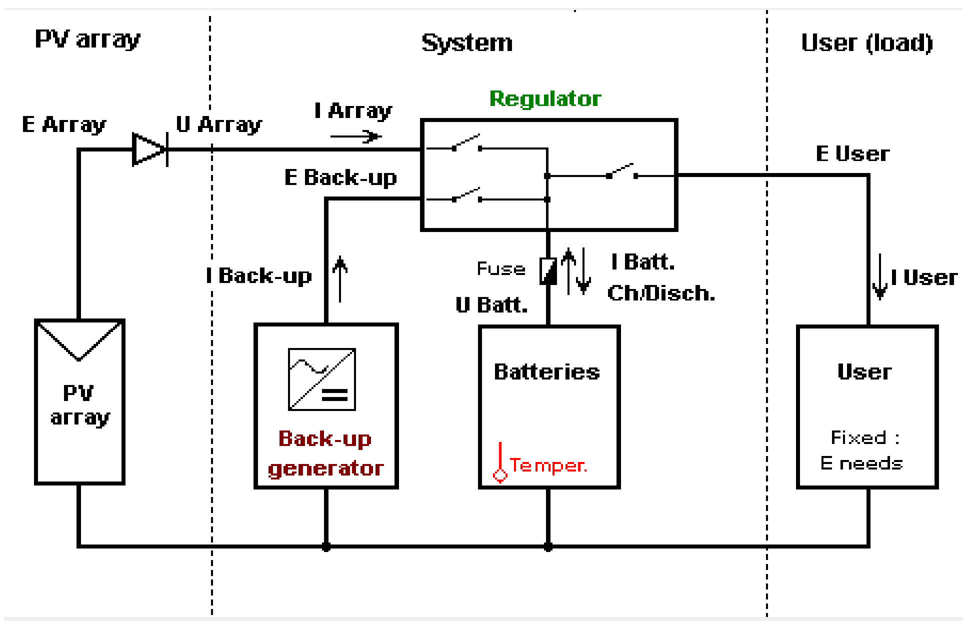

Figure 2: *Schematic Diagram of Proposed Stand-Alone System*

The proposed stand-alone system design depends on main parameters like meteorological data, system design, shading studies, losses determination, and economic evaluation. The meteorological data includes the latitude, longitude and altitude location of the site and irradiance data for different locations are to be stored in Meteonorm database in PVsyst software. The system design includes modeling of panel and inverter ratings and connection of batteries. The simulation is performed over a period of one year in hourly steps and provides graphs and additional results.

Table 1: *Geographical Parameters*

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Place	Latitude	Longitude	Altitude
Hyderabad	17° 37’	78° 48’	542 m

The azimuth angle indicates the orientation of the panel with respect to southern direction. The Tilt and azimuth angle are shown in figure 3. The azimuth angle for the proposed site was 166°.The horizon in figure 4 represents the amount of useful energy. The blue line indicates shading of cells in the plane. The red line indicates objects which cause the shading such as trees or partial shading by clouds.

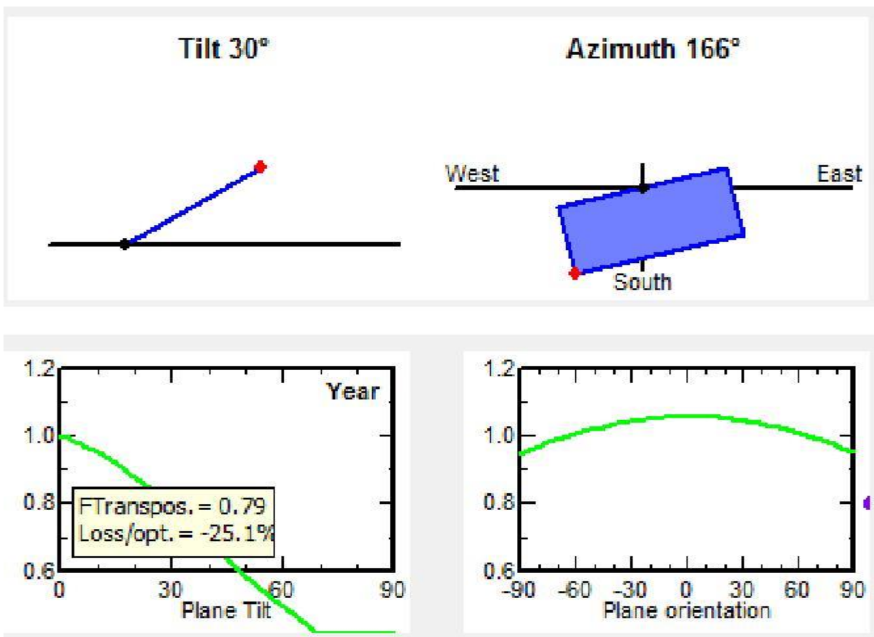

Figure 3: *Tilt angle and Orientation at Hyderabad site*

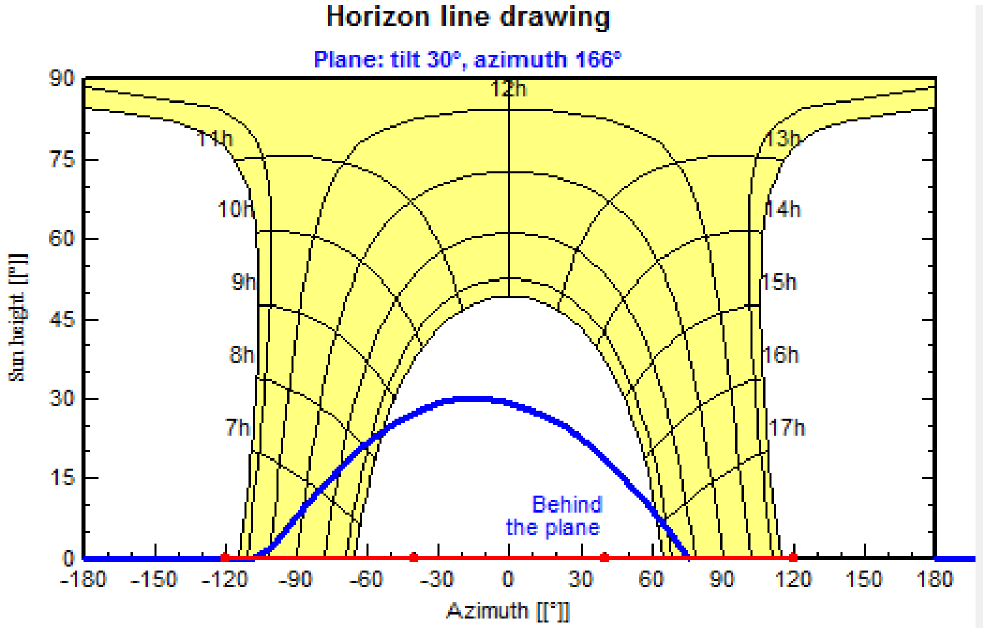

Figure 4: *Horizon at Hyderabad site*

The arrangement of batteries and PV cells are the inputs to the software for getting simulation results. The ratings of batteries are 12 V and a total of 48 batteries in 2 x 24 were used. The rating of PV module is of 60 Wp and 14 V and the arrangement consists of 100 cells in 10 x 10. The module layout describes the effect of shading on individual solar cell as well as the whole system. It also includes the 3-d view of whole panel for further analysis. The daily input output diagram was shown in figure 5 and displays the relationship between effective energy at the output of the array and global incident energy on collector plane. It represents system behavior at all instants throughout the year.

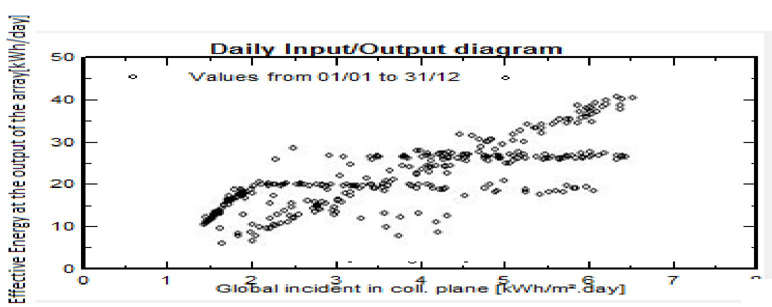

Figure 5: *Input-Output Simulation Diagram*

4. Simulation Results

The Optimized Output Parameters in the form of global irradiation, global effective energy, available energy, unused energy, energy demand by user, energy supplied to load and solar fraction obtained from simulation are presented in Table 2.The average values of global irradiation (Glob Hor) is 1973 kWh/m^2, global effective energy(Glob Eff) is 1313 kWh/m ^{2} , available energy(E Avail) is 13.42 MWh, unused energy (EUnused) is 7.035 MWh, energy demand by user (Euser) is 4.511 MWh, energy supplied to load (E_Load) is 4.511 MWh and solar fraction (SolFrac) is 0.999.

Table 2: *Optimized Output Parameters*

Year/ Month	Glob Hor (kWh/m^2)	Glob Eff (kWh/m^2)	E Avail (MWh)	EUnused (MWh)	Euser (MWh)	E_Load (MWh)	SolFrac
January	118.2	42.7	0.427	0.027	0.341	0.341	1.000
February	137.0	63.4	0.698	0.313	0.296	0.296	1.000
March	188.2	115.7	1.250	0.657	0.433	0.433	0.999
April	206.5	157.0	1.601	0.937	0.414	0.414	1.001
May	222.1	191.5	1.910	1.189	0.453	0.453	1.000
June	196.5	176.5	1.772	1.056	0.414	0.414	0.987
July	166.4	146.6	1.486	0.844	0.433	0.433	1.001
August	159.9	132.1	1.365	0.731	0.453	0.453	1.000
September	170.6	120.5	1.223	0.703	0.296	0.296	1.001
October	164.5	86.6	0.917	0.464	0.341	0.341	1.000
November	128.5	47.1	0.468	0.109	0.326	0.326	1.000
December	115.1	33.4	0.311	0.002	0.311	0.311	1.000
Average	1973	1313	13.42	7.035	4.511	4.511	0.999

The figure no. 6 represents the energy production. The unused energy is 1.61 kWh/kWp/day, the PV array losses are 0.65 kWh/kWp/day, the system losses and battery charging are 0.53 kWh/kWp/day and energy supplied to user is 1.03 kWh/kWp/day.

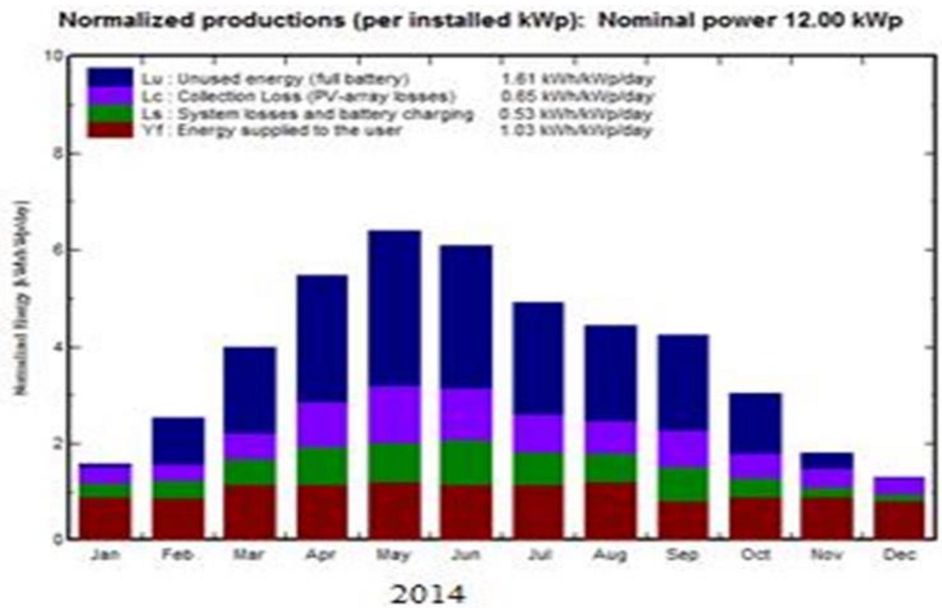

Figure 6: *Annual Energy Production*

Lu : Unused energy (full battery) 1.61 kWh/kWp/day
Lc : Collection losses (PV-array losses) 0.65 kWh/kWp/day
Ls : System losses and battery charging 0.53kWh/kWp/day
Yf : Energy Supplied to the user 1.03 kWh/kWp/day

Figure 7 signifies the overall system loss diagram for the proposed system at Hyderabad location. The horizontal global irradiation is 1974 kWh/m^2 and effective irradiation is 1313 kWh/m^2. So the loss in energy is 5.8%. The efficiency is 10.76%. The nominal energy at STC is 15.73 MWh. The effective energy is 6.85 MWh and stored energy is 6.39 MWh in batteries. The user demand is 4.51 MWh. All the values correspond to the ambient temperature of 25°C.

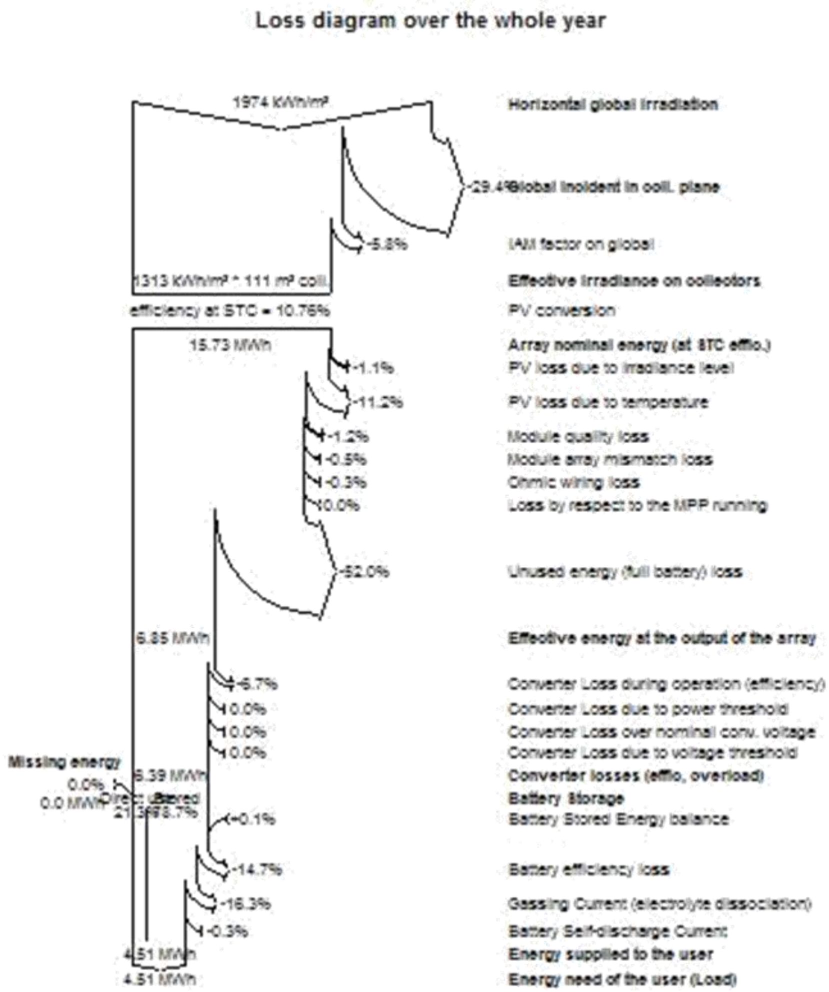

Figure 7: *System Loss Diagram*

5. Conclusion

The performance of PV systems mainly depend on orientation, meteorological location and system components. The PVsyst software analyzes the performance of Stand Alone systems along with effects of shading and losses that occur during operation. The losses in the form of wiring losses, temperature losses, and unused battery loss contribute to 5.9%. It providesmonthly energy production values and graphs. The losses are to be minimized by careful planning and optimization of system components.

6. Nomenclature

PV	:	Photo Voltaic
DC	:	Direct Current
AC	:	Alternating Current
PWM	:	Pulse Width Modulation
Earray	:	Effective Energy at the output of the array
Varray	:	Voltage on the array
Iarray	:	Current at the array
Euser	:	Energy at receiving end
Iuser	:	Current at load end
Ebackup	:	Energy generated by back- up generator
PWM	:	Pulse Width Modulation
MPPT	:	Maximum Power Point Tracking
V batt	:	Battery voltage
I batt	:	Battery current
Wp	:	Peak power rating of each solar cell
Glob Hor	:	Global Horizontal Irradiation in kWh/m^2
Glob Eff	:	Global Efficiency in %
E Avail	:	Available Energy in MWh
E Unused	:	Unused Energy in MWh
E User	:	Energy at User end in MWh
E_Load	:	Energy consumed by load in MWh
SolFr	:	Solar Fraction

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