Design Aspects of Standalone PV System with Two Simulation Tools

Jeraldine Viji A., R. Rajendra Kumar, G.G. Muthu Kumar, R. Nakkeeran

Abstract: ***The conventional energy sources depleted day by date. Alternate energy requirement is necessitate for our daily life. Our energy demand is met by standalone PV based system. This paper explained the simulation of a standalone photovoltaic power system erected in Mailam with different simulation tools. Solar resources for the design of this system were taken from the National Aeronautics and Space Administration (NASA) Surface Meteorology at a location of 22° 59' S, 14° 29' E with annual average solar radiation of 5.14 kWh/m^2/d. PV planner and PV syst simulation tools were used to analyze the design of photovoltaic power system model. The entire model was designed based on an hour-by-hour data depend on energy availability and its demands. A detailed design of standalone PV system with two different simulation tools were presented in this paper.***

Index Terms**:** ***Stand alone PV system, PV SOL, PV syst, PV planner.***

I. INTRODUCTION

Generally standalone systems are needed the places where people who could not get supply from grid. To Provide grid electricity to such remote areas are required higher costs to the supply provider. The easier way is to transmit power through stand-alone systems. This system can fulfill the requirements of domestic appliances. Power demand is satisfied by various non conventional energy sources. Any one of the non conventional energy sources is chosen depending upon the load profile and the local availability of the supply options and its installation cost. Most of the isolated areas are far away from the grid it have a high potential of non conventional energy sources like solar. Stand alone PV system set up for home includes a photovoltaic (PV) module, a rechargeable battery, a charge controller, and a inverters. The sizing of the system determines the "light hours" needed to operate each appliance of home. Simulation of energy sources is very important to install any energy system. The main focus of work in this paper is to simulate standalone solar system with two different simulation tools, which will provide desired power to operate home appliances.

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II. METHODOLOGY

For designing a good power system, one has to know the information where to install stand alone PV system. The following parameters such as current demand, load profile, intensity of solar radiation, installation cost of each component and its life usage time is important.

A. References of home system

From the available data, a profile of the home system was developed. This following profile shows the load variations and its electrical usage patterns with in the home.

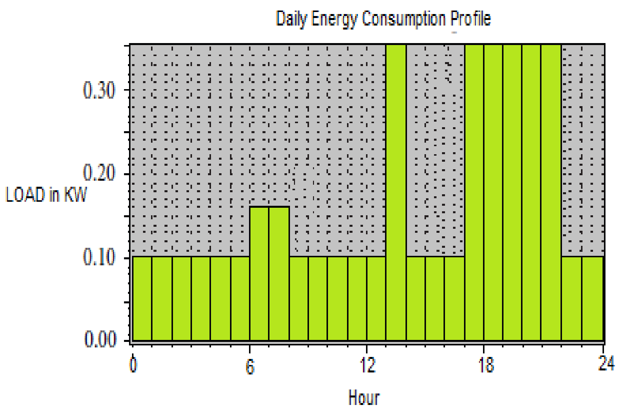

Fig 1 . Hour to hour of day profile and its electricity consumption in a home in Mailam (Tamil Nadu, India)

"Figure 1 shows the daily profile electricity consumption in a home in Mailam (Tamil Nadu, India) ".The homes in Mailam is are rural area and it is not require huge quantities of electrical energy for electrical appliances.

B. Pattern of Using of Electric Power within the Home

Table I:Estimation of every equipment's energy usage in a single day

Electrical appliances	Quantity	Load(power in Watts of one unit)	Total load power in watts)	Daily hours of actual utilization (hour.per day)
Television	1	80	80	2 hrs
Fan	3	20	60	6 hrs
Bulb	4	15	60	6 hrs
Refrigerator	1	150	150	24 hrs
Washing machine	1	250	250	1.30 hrs

Table 1. shows an estimation of each equipment's rated power. The lights are on in the homes of Mailam will always be from 6 am to 7 am By this time (6 am to 7 am) the home starts preparing for school. Majority of people leave from the home by 9 am and return back to home by 7 pm. Figure 2: shows the graphics of monthly solar radiation profile in Mailam. Day time [6 am–6 pm]. The lights are on at 6 pm to till 10 pm to do the daily work. At 10 pm, lights are off and they will go to bed, it is extended till 6am before the light comes in again. Day to date daily routines are washing clothes, watching TV, cooking etc.

C. Study Area

This paper focuses on the simulation study of photovoltaic power generation system for an home sited in Mailam located in Tamil Nadu. It is geographically located at 14.5995° N, 120.9842° E with annual average solar radiation of 5.14 kWh/m^2/d. For simulation study, the solar PV technology was considered. In Mailam March is the hottest month of the year. During this month, the solar energy resource available is 5.14kWh/m^2/d but in October it is about 3.0 kWh/m^2/d [1]. The other month solar radiation is also taken into account while designing system sizing.

III. MODELING OF PV SYSTEM COMPONENTS

The general theoretical background is described below [2],[3], [4]

A .Model of PV system

The formula for calculating the output of the PV generator is
$E_{\mathrm{PV}} = \mathrm{y}(t) \times A \times P \times \eta_{\mathrm{PV}}$, (1)
where y(t) is the hourly irradiance in kWh/m^2
A is the surface area in m^2
P is the PV penetration level factor, and η_{PV} is the efficiency of PV generator.

B. Charge Controller

To Limit the battery from over charging a charge controller is used. Using this full charging of battery is identified, this decrease the amount of energy received from the energy source.

The model of the charge controller is presented below :

$E_{\mathrm{OUTPUT}}(t) = E_{\mathrm{INPUT}}(t) \times \eta_{\mathrm{Charge\ Con}}$ (1)

$E_{\mathrm{INPUT}}(t) = E_{\mathrm{SUR\text{-}E}}(t)$ (2)

where $E_{\mathrm{OUTPUT}}(t)$ is the hourly energy output from charge controller, kWh, $E_{\mathrm{INPUT}}(t)$ is the energy input to charge controller, kWh, $\eta_{\mathrm{Charge\ Con}}$ is the efficiency of a charge controller, and $E_{\mathrm{SUR\text{-}E}}(t)$ is the amount of surplus energy from DC sources, kWh.

C. Model of Battery Bank.

SOC(State of charge) is the property of battery which is the cumulative sum of the daily charge/discharge transfers. The battery acts as energy source at the time of discharge , act as a load when charging. At any time t the state of the battery is calculated from the previous state of charge and energy production and consumption during the time from $t - 1$ to t. [2], [5]-[7]

$E_{\mathrm{BATTERY}}(t) = E_{\mathrm{BATTERY}}(t-1) - E_{\mathrm{OUTPUT}}(t) \times \eta_{\mathrm{CHARGING}}$

where $E_{\mathrm{BATTERY}}(t)$ is the energy stored in the battery at hour t, kWh, $E_{\mathrm{BATTERY}}(t-1)$ is the energy stored in the battery at hour $t-1$, kWh, and η_{CHARGING} is the battery charging efficiency. when the load demand is > than the energy generated, the battery bank is in discharging state. Therefore, the available battery bank capacity at hour t can be expressed as [9] $E_{\mathrm{BATTERY}}(t) = E_{\mathrm{BATTERY}}(t-1) - E_{\mathrm{N}}(t)$ where $E_{\mathrm{N}}(t)$ is the hourly load demand or energy needed at a particular period of time. The difference between minimum allowable SOC voltage limit and the maximum SOC voltage across the battery terminals is noted by "d". when battery is fully charged which is equal to 1 − DOD/100. So, the depth of discharge (DOD) is as follows:

$\mathrm{DOD} = (1 - d) \times 100.$ (3)

The maximum value of SOC is 1, and the minimum value of SOC measured in percentage is :

$\mathrm{SOC_{Min}} = 1 - \mathrm{DOD}/100$ (4)

D. Modelling of Inverter

The output of PV panel is always Dc supply ,therefore an inverter is needed to connect electrical load to the PV panel. The inverter models for photovoltaic and battery bank are given below [8]:

$$E_{\mathrm{OUTPUT\ -\ INVERTER}}(t) = \mathrm{E_{PV}}(\mathrm{t}) + \left(\frac{\mathrm{E_{BATTERY}}(\mathrm{t}-1) - \mathrm{E_L}(\mathrm{t})}{\eta_{\mathrm{INV}} + \eta_{\mathrm{DCHG}}}\right)\eta_{\mathrm{DISCHG}} \quad (5)$$

where $E_{\mathrm{OUTPUT\ -\ INVERTER}}(t)$ is the hourly energy output from inverter kWh, $\mathrm{E_{BATTERY}}(\mathrm{t}-1)$ is the energy stored in the battery at hour t − 1, kWh, $\mathrm{E_L}(\mathrm{t})$ is the hourly energy consumed by the load kWh, $\mathrm{E_{INV}}$ is the efficiency of inverter, and η_{DISCHG} is the battery discharging efficiency.

E. Generated power (P GE)in PV Model

Total power generated at any time t is given by [9],[10]

$$P(t) = \sum_{1}^{N_p} P_{PV} \quad (6)$$

where N_p are number of PV cells. Generated power $\mathbf{P_{GE}}$ will feed to the connected loads. when this $\mathbf{P_{GE}}$ > load demand, then the $E_{\mathrm{SUR\text{-}E}}$ will be stored in the battery bank. The battery bank is to satisfy the constraint $\mathrm{SOC_{min}} \le \mathrm{SOC}(t) \le \mathrm{SOC_{max}}$. The $\mathrm{SOC_{min}}$ is at 30%, while that of $\mathrm{SOC_{max}}$ is at 90%. This selected SOC minimizes the cost function.

F. Cost Function Model (Economic and Environmental Costs) of Energy Systems

The following equations helps to estimate the level of optimization of photovoltaic energy solution [8]

$$C_{annual,tot.sol+bat} = \sum_{s=1}^{N_s}(C_{acap,sol} + C_{arep,sol} + C_{aop,sol} + C_{emission}) + \sum_{b=1}^{N_b}(C_{acap,bat} + C_{arep,bat} + C_{aop,bat} + C_{emission}) \quad (7)$$

where $C_{acap,sol}$ is annual capital cost of solar power, $C_{arep,sol}$ is annual replacement cost of solar power, $C_{aop,sol}$ is annual operating cost of solar power, $C_{emission}$ is cost of emissions, $C_{acap,bat}$ is annual capital cost of batteries power, $C_{arep,bat}$ is annual replacement cost of batteries power, and $C_{aop,bat}$ is annual operating cost of batteries power.

Table II: Simulation results of production, consumption, losses, and excess (kWh/yr).

Component	Quantity of Electricity(KWh/Yr)
PV array generation	2000
Battery losses	100
Inverter losses	200
cable losses	60
Ac load utilization energy	1400
Excess energy	250

G.Net Present Cost (NPC) for Energy Systems

The total net present cost (NPC) of a system is the present value is the all the component cost over its lifetime minus the present value of all the revenue during its lifetime. Revenues include grid sales revenue and salvage value. The net present cost (NPC) for each component is derived using [10,11]

$$C_{NPC} = \frac{C_{annual,tot}}{CRF(i,R_{proj})} \tag{8}$$

where the capital recovery factor is [12]

$$\text{CRF} = \frac{i.(1+i)^{N}}{(1+i)^{N}-1} \tag{9}$$

This method gives the economic optimization of standalone photo voltaic system.

IV. SIMULATION STUDY

The Simulation study is performed with two simulation tools such as PV sol and PV syst. The PV system with 5 MW installed capacity is located in Palaiyam, Mailam (22° 59' S, 14° 29' E). Based on the data availability and preliminary simulation value, the input parameters were adjusted according to it. In this simulation model, the size of the system is based on installed capacity. The system faced to south, i.e. azimuth angle is 0° or north, tilt angle should equal to latitude, i.e. 23°, inclination angle is 25° which gives 0 losses.

A. PV Planner Simulation

In PV Planner the user cannot see and adjust every step of simulation process. The input parameters are defined manually based on the parameters from PV syst simulation model, e.g. inverter's efficiency and DC/AC losses. The standalone PV Planner simulation is shown in Fig.2.The new simulation variant is shown in Fig.3.

Geographical Site		Madras	Country	India
Situation	Latitude	13.07° N	Longitude	80.25° E
Time defined as	Legal Time	Time zone UT+5.5	Altitude	10 m
	Albedo	0.20		
Meteo data:	mailam	NREL NSRDB Typ. Met. Year Suny_2000 to 2014 - TMY		
Simulation variant :	New simulation variant			
	Simulation date	20/03/19 14h28		
Simulation parameters	System type	No 3D scene defined, no shadings		
Collector Plane Orientation	Tilt	25°	Azimuth	20°
Models used	Transposition	Perez	Diffuse	Imported
Horizon	Free Horizon			
Near Shadings	No Shadings			
Storage	Kind	Self-consumption, No grid reinjection		
	Charging strategy	When excess solar power is available		
	Discharging strategy	As soon as power is needed		
User's needs :	Fixed constant load	1000 W	Global	8760 kWh/Year
PV Array Characteristics				
PV module Si-poly	Model	CS3K-275P-AG		
Original PVsyst database	Manufacturer	Canadian Solar Inc.		
Nb. of optimizers	In series	1	In parallel	1 strings
Total number of PV modules	Nb. modules	22	Unit Nom. Power	275 Wp
Array global power	Nominal (STC)	6.06 kWp	At operating cond.	5.48 kWp (50°C)
Array operating characteristics (50°C)	U mpp	619 V	I mpp	8.9 A
Total area	Module area	36.8 m²	Cell area	32.4 m²
Inverter	Model	SE 10KTL-D3		
Original PVsyst database	Manufacturer	Senergytec		
Characteristics	Operating Voltage	160-850 V	Unit Nom. Power	10.00 kWac
			Max. power (=>25°C)	11.00 kWac
Inverter pack	Nb. of inverters	1 * MPPT 50 %	Total Power	5.0 kWac
			Pnom ratio	1.21
Battery	Model	Open 12V / 100 Ah		
	Manufacturer	Generic		
Battery Pack Characteristics	Nb. of units	2 in series		
	Voltage	24 V	Nominal Capacity	100 Ah (C10)
	Discharging min. SOC	20.0 %	Stored energy	1.9 kWh
	Temperature	Fixed (20°C)		
Battery Input charger	Model	Generic		
	Max. charging power	0.1 kWdc	Max./ Euro efficiency	97.0/95.0 %
Battery to Grid Inverter	Model	Generic		
	Max. discharging power	0.1 kWac	Max./ Euro efficiency	97.0/95.0 %
PV Array loss factors				
Thermal Loss factor	Uc (const)	15.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	1163 mOhm	Loss Fraction	1.5 % at STC

Fig 2: Grid connected design.

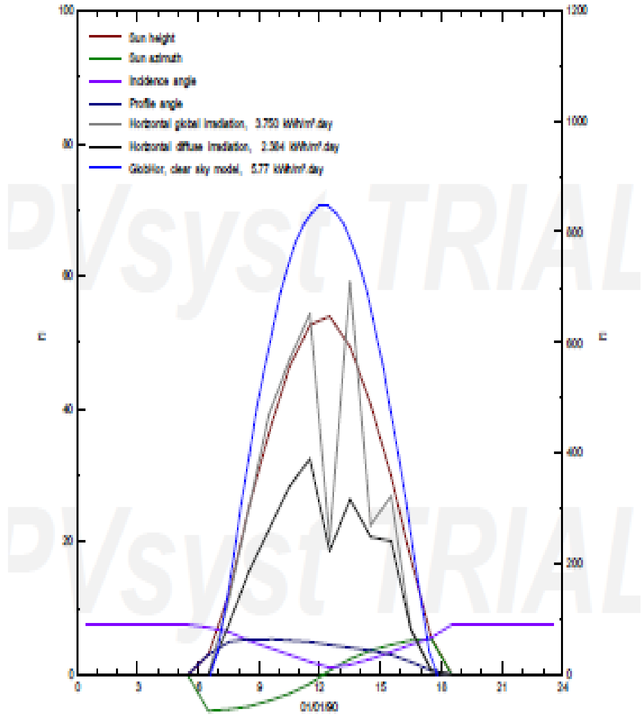

Fig.3. Simulation variant: New simulation variant

B. PVsyst 6.7.9 Simulation

PVsyst to be the most effective test tool for case study. To run simulation in PVsyst, series of steps to be performed with pre defined project location and their availability of solar data. The simulation is shown in fig.4

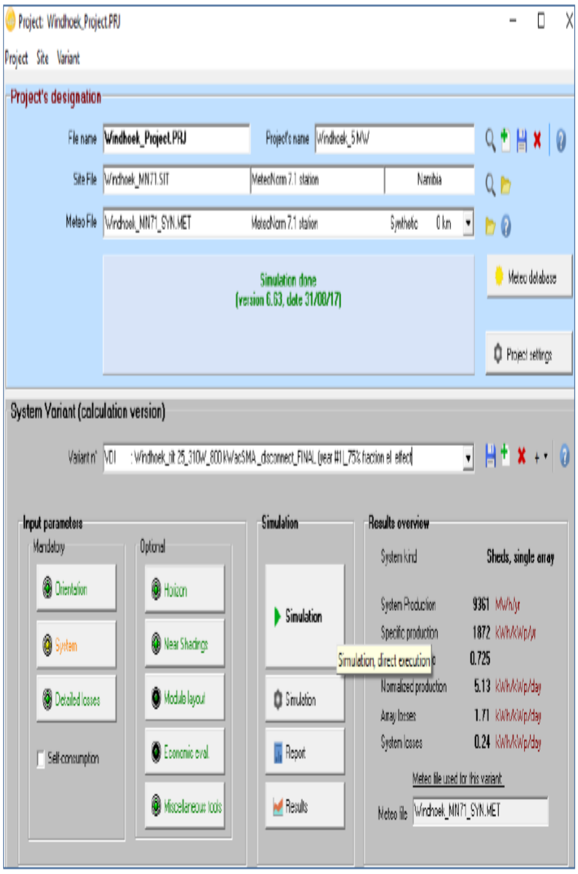

Fig.4. PV syst 6.7.9 Simulation

Orientation is fixed mounting system, tilt angle is 25° and azimuth angle is 0°, so that the loss by respect to optimum is to be 0.01 %. The number of modules to be taken as 18 which are connected in series. No of modules and its power, inverter power rating is chosen as the ratio of 1:2:1. Loss analysis includes the following : thermal parameters, resistance losses, aging factors, mismatch, module quality and LID degradation, soiling losses, efficiency of incidence angle and unavailability.

From measurements, thermal loss factor is based on a default value of 29 W/m²·k for constant loss factor. Losses with external transformer is 0.1 % and ohmic losses is 1.0% .The efficiency loss is 2%. LID factor loss is 1.0 % which refers to degradation of crystalline silicon. Soiling loss of 2% was applied.

Far and near shading effect was performed based on the positioned 3D shading scene .The exact height of nearby obstacles was not calculated properly therefore the shading scene should be considered as an assumption. The shading scene is done in 2 steps such that linear shading and shadings according to the module strings. The shading according to the strings can be performed with electrical effect. The electrical effect assumed as 60-80%. Let as assume the fraction for electrical effect resulted is 75 % means 75 % of a string will be inactive if it is affected by shade. Here this is applied to simulation study.

C. Sizing of standalone system

Geographical Site		**Palaiyam**	**Country**	**India**
Situation	Latitude	12.12° N	Longitude	79.62° E
Time defined as	Legal Time	Time zone UT+5.5	Altitude	47 m
Collector Plane Orientation	Tilt	24°	Azimuth	18°
System pre-sizing evaluation				
Average use of energy	Daily	6.6 kWh/day	Yearly	2423 kWh
Autonomy		4.0 days		
Loss-of-Load	Time fraction	4.9 %	Missing energy	30 kWh
Battery system	Voltage	24 V	Capacity	1302 Ah
PV array	Nominal power	1772 Wp	Nominal Current	57 A
Economic gross evaluation	Investment	2541165 INR	Energy price	69.61 INR/kWh

Fig.5 Presizing of standalone system

Simulation of a PV system in desired location was performed in using PV planner. PV syst allows the user to import the data, models based on the solar data from PVSOL Premium and PV Planner were run in PV syst. The missing input data is wind speeds but it is required by PV syst simulation model. The pre sizing of standalone system is shown in Fig.5.

V. RESULTS AND DISCUSSION

The simulation is carried out based on synthesized data without actual measurements from the site, PVsyst produce more conservative simulation results for the system output. The PVSOL Premium simulation model was not produce good result due to lesser capacity.

The energy loss in PVsyst is less compare to PV planner and PV SOL. Simulation results from PVsyst with PVSOL data and with inbuilt data shows 9.49 GWh and 9.36 GWh of annual electricity production respectively. The difference is almost only 1.6%. The PVsyst solar data gives the lowest value of global in-plane radiation resulting in the most of the conservative output.

VI. CONCLUSION

In the modern era the non-conventional energy system like standalone pv system is essential to met daily energy requirement in rural area.This paper mainly focusing on erecting solar power system in mailam area.The two different simulation tools such as PV planner and PV syst are used to analyze the design of photovoltaic power system model. The detailed design aspects of standalone PV system which is more appropriate is discussed so this paper is vert useful to the beginners to start solar project in rular area like mailam.

REFERENCES

1. NASA, 2013, https://eosweb.larc.nasa.gov/.
2. Ani V. A., "*Optimal energy system for single household in Nigeria,"* International Journal of Energy Optimization and Engineering,2013, vol. 2(3), pp.16-41.
3. Ashok S, "*Optimised model for community-based hybrid energy system*," Renewable Energy, 2007,vol. 32, no. 7,pp. 1155–1164.
4. Gupta A, Saini R P Sharma M P, "*Steady-state modelling of hybrid energy system for off grid electrification of cluster of villages*," Renewable Energy, 2010,vol. 35, no. 2, pp. 520–535.
5. Lal D K, Dash B B Akella A K., "*Optimization of PV/Wind/Micro-Hydro/diesel hybrid power system in homer for the study area*," International Journal on Electrical Engineering and Informatics, 2011,vol. 3, no. 3, pp. 307–325.
6. Sopian K Zaharim A Ali Y, Nopiah Z M, Razak J. A, and. Muhammad N S, "*Optimal operational strategy for hybrid 8 Journal of Renewable Energy renewable energy system using genetic algorithms*," WSEAS Transactions on Mathematics, 2008,vol. 4, no. 7, pp. 130–140.
7. Abdolrahimi H Karegar H K, "*Optimization and sensitivity analysis of a hybrid system for a reliable load supply in Kish Iran*," International Journal of Advanced Renewable Energy Research, 2012,vol. 1, no. 4, pp. 33–41.
8. Ani V A , *Energy optimization at telecommunication base station sites [Ph.D. dissertation]*,University of Nigeria, Nsukka, Nigeria, 2013.
9. Ani V A Nzeako A N, "*Energy optimization at GSM base station sites located in rural areas*," International Journal of Energy Optimization and Engineering, 2012, vol. 1, no. 3, 31 pages.
10. V. A. Ani and A. N. Nzeako, "*Energy optimization at GSM base station sites located in rural areas*," International Journal of Energy Optimization and Engineering, vol. 1, no. 3, 31 pages, 2012.
11. Lambert T.,"HOMER: "*The Hybrid Optimization Model for Electrical Renewables*," 2009, http://www.nrel.gov/

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