Journal of Energy Research and Environmental Technology (JERET)
p-ISSN: 2394-1561; e-ISSN: 2394-157X; Volume 6, Issue 2; April-June, 2019, pp. 130-134

http://www.krishisanskriti.org/Publication.html

Optimum Design of Rooftop PV System for An Education Campus Using HOMER

Shilpa N[1] and Sridevi HR[2]

[1]PG Student (Renewable Energy) Department of Electrical and Electronics Engineering
Nitte Meenaskshi Institute Technology, Bengaluru, India
[2]Asst Professor, Department of Electrical and Electronics Engineering
Nitte Meenaskshi Institute Technology, Bengaluru, India
E-mail: [1]shilpapakumuda@gmail.com, [2]sridevi.hr@nmit.ac.in

Abstract— *The energy demand is extremely growing day by day. This calls for alternate sources of energy. Renewable energy is one among the most effective solutions in meeting the increasing energy demand. It helps in reducing global carbon emissions and thereby lowers negative impacts on the environment. It also reduces the stress on the grid and demand for fossil fuels. Solar energy is a developing segment of our energy generation mix, and it will play a very important role in the future of energy production. Producing energy with solar panels has massive advantage over fossil fuels and found cost-effective. A Grid interactive PV system feeds power into the grid and also generates power from the PV modules to meet their own needs. Educational institutes face energy crisis because of load shedding in the grid. This paper presents the design and economical aspects of grid interactive PV system configuration for an educational campus also a comparative study is carried out for an on-grid PV system and off-grid PV-DG (Diesel generator) system. For the proposed optimum design of the PV system HOMER (Hybrid Optimization of Multiple Electric Renewable) software tool is used.*

1. INTRODUCTION

Renewable energy is key to fight against the global warming and increasing fossil fuel cost. Subsequently there is a growing interest in the renewable energy technologies especially the photovoltaic (PV) technology. The role of grid connected power system has become increasingly substantial, attractive and cost-effective. An on-grid photovoltaic system will be interactive with the utility grid [1]. The main advantage of this system is that power can be drawn from the utility grid when power is not available from PV system [2]. As load demands are always changing with time, the changes in solar or grid power supply do not perpetually match with the time distribution of consumer's demand. Therefore, there is a necessity for additional battery storage or other components for providing continuous power supply to the load. It has been investigated that a solar PV/grid/battery system could be a secure source of electricity. As the battery bank is expensive, the initial investment and O&M costs of standalone/off grid will be very high. Therefore, it is an absolutely necessary to find an efficient solution to this problem. One of the solutions is a grid connected to power system with proper planning for storage of less capacity which in turn reduces the cost [4].

Hybrid Optimization Model for Electric Renewable (HOMER) software has been used as an optimization and sizing tool in this study. HOMER software has been founded by the U.S. National Renewable Energy Laboratory [3]. It compares the hourly electrical load demand to the hourly supply by the system components and calculates the flows of energy to and from each component [2]. The optimal system solution, determined by Homer software, satisfies specific constraints at the lowest total net present cost (NPC) and cost of energy (COE) [3].

2. PROPOSED SOLAR PV SYSTEM

Paper presents on-grid rooftop PV system model with a suitable battery bank as a backup power source is shown in Fig.1. The model is optimally designed using HOMER to evaluate and determine the Net Present Cost. HOMER simulation software requires suitable input data to evaluate the optimization results for different combinations [3].

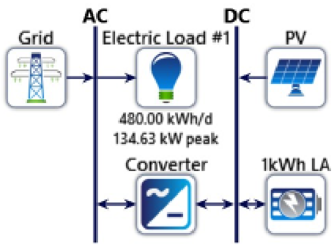


Fig. 1: Proposed on-grid rooftop PV system model

2.1 Load Assessment

The education campus for which the case study is carried out is Sri Jayachamarajendra (Govt) Polytechnic campus, Bengaluru. The latitude and longitude for this location is 12°58.5'N, 77°35.2'E.

It is found that the average energy consumption is 430 kWh/day, from fig.2. the daily mean load profile the peak value of the demand can be obtained. This value helps in determining the size of the system. The annual mean consumption is assumed to be 480 kWh/day. Fig.3. represents the monthly mean load in the proposed location. The energy consumption in the month of July and December (college vacation period) is comparatively lesser.

Fig. 2: Mean load profile (daily)

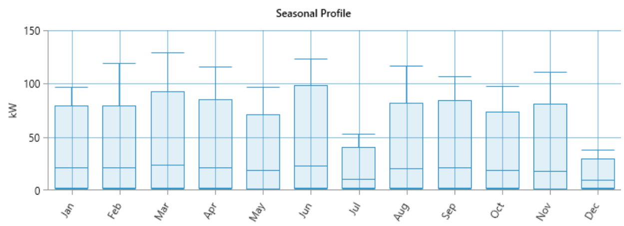


Fig. 3: Mean load for a complete year (monthly)

2.2 Solar Radiation:

Monthly mean solar radiation data available at Sri Jayachamarajendra (Govt) Polytechnic campus is as shown in fig. 4. The figure shows that the available solar insolation has a minimum value of 4 kWh/m2/day and maximum value of 6.602 kWh/m2/day for the months of August & March respectively with an average of 5.12 kWh/m2/day table 1.

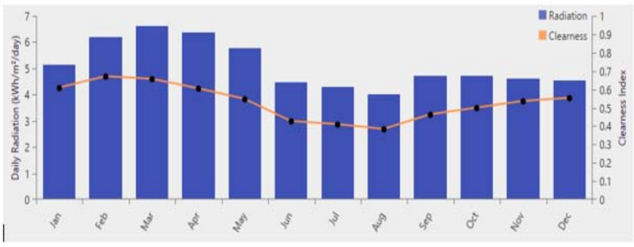


Fig. 4: Monthly average solar data and daily clearness index

Table 1: Bengaluru monthly solar data and clearness index

Month	clearness Index	Daily Solar Radiation ($kWh/m^2/day$)
January	0.606	5.15
February	0.669	6.199
March	0.655	6.602
April	0.603	6.362
May	0.546	5.781
June	0.425	4.467
July	0.408	4.287
August	0.382	4.009
September	0.461	4.699
October	0.497	4.709
November	0.534	4.614
December	0.552	4.529
Average		**5.12**

3. SYSTEM DESCRIPTION

3.1 Solar PV System

Total Energy (DC) Yield by the PV System is given in equation (1)

$$EY_{Dc} = N_{PV} \times V_{PV} \times I_{PV} \left[\frac{Sn_{hr}}{Sn_{Stc}}\right] \quad (1)$$

Where, EY – Energy Yield from the PV system, NPV – Number of the solar panels, VPV- Open circuit voltage (VOC) of the solar module, IPV - short circuit current (ISC) of the solar panel, Snhr - Solar insolation(kWh/m2/day), SnStc - At standard test condition incident solar radiation (1 kW/m2).

The efficiency of solar PV system considers all losses in a solar PV panel due to temperature variation, shadow on panel, dirt, and inverter losses.

Total Energy (AC) Yield by the PV System is given in equation (2).

$$EY_{Ac} = N_{PV} \times V_{PV} \times I_{PV} \times Df_{PV} \left[\frac{Sn_{hr}}{Sn_{Stc}}\right] \quad (2)$$

DfPV- Derating factor (PV) (%)

The photovoltaic derating factor is a factor that HOMER tool applies to the PV array power output to account for reduced output in real-world operating conditions compared to the conditions under which the PV panel is rated.

3.2 Converter

The Direct Current to Alternating Current ratio also known as the Inverter Load Ratio, (ILR) is an important parameter in designing a solar PV system sizing. ILR of 1.2 often results in minimal losses.

Batteries

A battery bank is employed as a backup source to supply the power in the emergency situations. Hence, size of the battery chosen is such that it can meet the load demands at some extent when both the sun and electric grid are not available.

4. SIMULATION MODEL

Hybrid Optimization Model for Electric Renewable (HOMER) software tool developed by National Renewable Energy Laboratory (NREL) has been employed to carry out the present study. HOMER software is generally used for the design and analysis of PV power system. The information to be given to the homer software to carry out the analysis are- load data, solar radiation data, description of each component in the system.

The grid interactive PV system shown in Fig. 1 consists of Photo Voltaic array, battery, converter and grid connection.

For economic study, the following values are used.

4.1 System Configuration:

Proposed on-grid solar Photo-voltaic power system project life time has assumed as 25 years with the discount rate of 7% and inflation rate of 2% [5&6].

a. Solar PV Array: The capital cost of 1KW of solar panel is considered to be Rs. 55,000, Replacement Rs. 10000, and Operation & Maintenance cost have taken as 1000.Rs/year. Life time of a PV array is considered as 25 years with a derating factor of 80% [6].

b. **Battery:** The battery bank storage capacity is chosen to cover the energy load demands when both the sun and electric grid are not available. The capital cost of one battery is taken as Rs.5000, Replacement cost 2000 Rs/year and Operation & Maintenance cost have taken as 100 Rs/year. HOMER selects optimal configuration of number of batteries from the search space.

c. Converter: Power converter converts Photo-voltaic DC output energy into AC energy. Hence, for 1KW converter, the capital cost is around Rs. 20000. Replacement cost is assumed as 5000 Rs/year and the life time of converter is taken as 15 years.

5. OPTIMIZATION AND ECONOMIC ANALYSIS

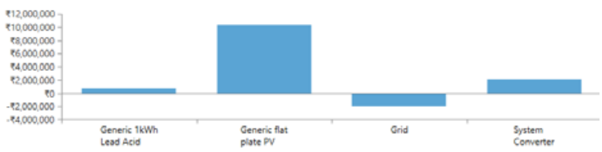
After carrying out the simulation the optimized results and the cost summary of the system of grid connected PV system is as show in fig. 5 & 6 respectively.

Optimization Results

Left Double Click on a particular system to see its detailed Simulation Results.

Architecture						Cost				System
	PV (kW)	1kWh LA	Grid (kW)	Converter (kW)	Dispatch	NPC (₹)	COE (₹)	Operating cost (₹/yr)	Initial capital (₹)	Ren Frac (%)
	150	100	999,999	99.9	LF	$11.4M	$3.10	$45,209	$10.7M	82.6

Fig. 5: Optimization Results



Component	Capital (₹)	Replacement (₹)	O&M (₹)	Fuel (₹)	Salvage (₹)	Total (₹)
Generic 1kWh Lead Acid	₹500,000.00	₹200,734.40	₹142,334.82	₹0.00	-₹30,228.03	₹812,841.19
Generic flat plate PV	₹8,250,000.00	₹0.00	₹2,135,022.27	₹0.00	₹0.00	₹10,385,022.27
Grid	₹0.00	₹0.00	-₹1,997,799.76	₹0.00	₹0.00	-₹1,997,799.76
System Converter	₹1,998,958.33	₹243,775.28	₹0.00	₹0.00	-₹50,353.81	₹2,192,379.80
System	₹10,748,958.33	₹444,509.68	₹279,557.32	₹0.00	-₹80,581.84	₹11,392,443.49

Fig. 6: Cost Summery

The month wise electrical power production by the PV and grid supply to the system is shown as in Fig.7.

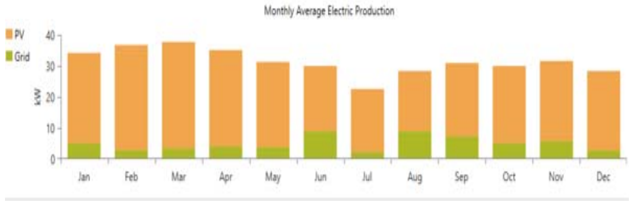


Fig. 7: Average electrical power production of system

The simulation results provide the most effective combination of the system with all parameters i.e., PV- 150KW, with 99.9kW converter with cost of the energy Rs 3.10. The net present cost of system is Rs.1,14,00,000 with a renewable fraction of 82.6% is as shown in Fig. 5, 8 & 9.

Renewable Fraction

The amount of energy delivered to the load that originated from renewable power sources is named as renewable fraction.

The renewable fraction is calculated by using equation (3), and renewable fraction of the grid-connected PV system shown in fig. 8.

$$f_{ren=1-\frac{E_{nonren}+H_{nonren}}{E_{served}+H_{served}}} \qquad (3)$$

Where, $E_{nonren-}$ Electrical production by Non-renewable (kWh/year), $E_{grid,\ sales-}$ Energy export to the grid (kWh/year), H_{nonren} - Thermal production by Non-renewable (kWh/year), $E_{served-}$ overall electrical served (kWh/day), H_{served}- thermal load served (kWh/year).

Production	kWh/yr	%
Generic flat plate PV	230,177	83.7
Grid Purchases	44,921	16.3
Total	275,098	100

Consumption	kWh/yr	%
AC Primary Load	175,200	67.9
DC Primary Load	0	0
Deferrable Load	0	0
Grid Sales	82,727	32.1
Total	257,927	100

Quantity	Value	Units
Renewable Fraction	82.6	%
Max. Renew. Penetration	220	%

Fig. 8: Yearly electrical production of system, grid purchase and sale and renewable fraction

Fig. 8 from the simulation results it is seen that the total yearly production of the proposed model is 230,177 kWh/year, and fig 9 shows the excess power sold to the grid during the college holidays (vacation) and power purchased from the grid during the peak hours.

Grid	
Energy Purchased (kWh)	Energy Sold (kWh)
44,921	82,727

Fig. 9. Yearly grid electrical energy purchased and sold

Fig 10. the simulation results show the payback period is 5.92 years.

Metric	Value
Present worth (₹)	₹982,432
Annual worth (₹/yr)	₹69,023
Return on investment (%)	13.6
Internal rate of return (%)	17.4
Simple payback (yr)	5.92
Discounted payback (yr)	6.41

Fig. 10: On-grid system payback period

6. COMPARING THE GRID CONNECTED PV SYSTEM WITH OFF-GRID (PV-DG)

Analyzing the presented on-grid PV system with off-grid Photo-voltaic-Diesel Generator system for the cost-effective configuration. The main objective is to compare two systems to minimize the cost and carbon emissions to achieve the optimum design for an education campus. Comparative analysis broadly made on different criteria like cost, renewable fraction, cost of energy, fuel consumption related to carbon emissions.

On-grid PV system and off-grid PV-DG system design model using HOMER tool as shown in fig. 11 a & b.

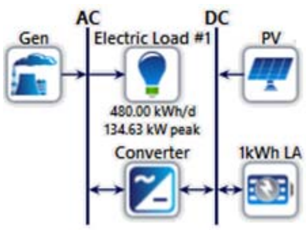


Fig. 11a. Off-grid PV-DG system

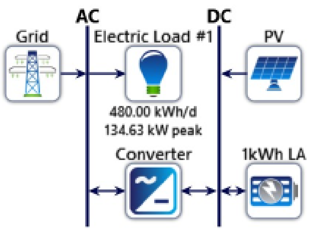


Fig. 11b. Grid connected PV system

Optimization result and simulation results of the off-grid PV-DG system as shown in fig.12&13. As shown in the fig. 12&13 cost of the off-grid PV-Dg system NPC (Net Present Cost) is Rs. 37100000 and COE (Cost of energy) is Rs 14.8. From table 2. can see the comparison of both systems that the off-grid system NPC and COE is 3-4 times more than grid connected system with more renewable fraction and zero fuel consumption with green energy.

Optimization Results
Left Double Click on a particular system to see its detailed Simulation Results.

PV (kW)	Gen (kW)	1kWh LA	Converter (kW)	Dispatch	NPC (₹)	COE (₹)	Operating cost (₹/yr)	Initial capital (₹)	Ren Frac (%)	Total Fuel (L/yr)
150	150	100	100	CC	$37.1B	$14,888	$2.61B	$12.0M	73.5	23,712

Fig. 12. Optimization result of the off-grid PV-DG system

Fig. 13. Simulation result of the off-grid PV-DG system

Table 2: Comparison of off-grid and grid connected system

	Off-grid PV-DG System	Grid-connected PV System
NPC (Net Project Cost)	Rs. 3,71,00,000	Rs. 1,14,00,000
COE (Cost of Energy)	Rs. 14.8	Rs. 3.1
Renewable Fraction	73.50%	82.60%
Fuel	23712 L/year	0

Exhaust emission and fuel consumption both are directly related. Higher the fuel consumption more is the emission of CO and HC and NOx gases. Comparison of emission of on-grid and off-grid PV-DG system is shown in fig.13.

Off-grid PV-DG System

Quantity	Value	Units
Carbon Dioxide	62,070	kg/yr
Carbon Monoxide	391	kg/yr
Unburned Hydrocarbons	17.1	kg/yr
Particulate Matter	2.37	kg/yr
Sulfur Dioxide	152	kg/yr
Nitrogen Oxides	368	kg/yr

On-Grid PV System

Quantity	Value	Units
Carbon Dioxide	28,390	kg/yr
Carbon Monoxide	0	kg/yr
Unburned Hydrocarbons	0	kg/yr
Particulate Matter	0	kg/yr
Sulfur Dioxide	123	kg/yr
Nitrogen Oxides	60.2	kg/yr

Fig. 14. Emissions production comparison of off-grid and grid connected system

7. CONCLUSION

This paper presents an on-grid rooftop PV system for an education campus in Bangalore. The optimal result shows that the on-grid PV system with proper capacity of the battery bank is more efficient and economic compared to the off-grid PV-DG for the identical load. From the simulation results, it is also compared that the Net Present Cost of the proposed model is less than the off-grid PV-DG model. Although off-grid system uses complete renewable energy it needs an extra battery bank or diesel generator as a back-up for storage of electricity which costs very high and as well as it produces more emissions (greenhouse effect). The excess output power of off-grid system which is unused during vacation period can be exported to the grid. Therefore, present proposed on-grid solar PV power system is mostoptimum and cost effective because it offers more benefits.

REFERENCES

[1] MadhuriNamjoshi ,Anubha, "Study of Grid tied Smart Solar Photovoltaic system: A review" International Journal of Scientific & Engineering Research, Volume 4, Issue 10, October-2013, ISSN 2229-5518

[2] Homer Guide by Homer Tool.

[3] K. E. OKEDU, UHUNMWANGHO ROLAND, "OPTIMIZATION OF RENEWABLE ENERGY EFFICIENCY USING HOMER", INTERNATIONAL JOURNAL OF RENEWABLE ENERGY RESEARCH 4(2):421-427 · JUNE 2014.

[4] MOIEN A. OMAR AND MARWAN M. MAHMOU, 'DESIGN AND SIMULATION OF A PV SYSTEM PPERATING IN GRID-CONNECTED AND STAND-ALONE MODES FOR AREAS OF DAILY GRID BLACKOUTS", HINDAWI, INTERNATIONAL JOURNAL OF PHOTOENERGY, VOLUME 2019.

[5] MORAD, M., NAYEL, M., ELBASET, A. A., & GALAL, A. I. A. (2018). "SIZING AND ANALYSIS OF GRID-CONNECTED MICROGRID SYSTEM FOR ASSIUT UNIVERSITY USING HOMER SOFTWARE", 2018 TWENTIETH INTERNATIONAL MIDDLE EAST POWER SYSTEMS CONFERENCE (MEPCON).

[6] NURUNNABI, M., & ROY, N. K. (2015). "GRID CONNECTED HYBRID POWER SYSTEM DESIGN USING HOMER". 2015 INTERNATIONAL CONFERENCE ON ADVANCES IN ELECTRICAL ENGINEERING (ICAEE).