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Comparison of HOMER Optimization Result with Stand Alone PV System for a Terrace Cabin

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Abstract—*This paper presents the Homer optimization procedure followed in setting up stand-alone PV system .Homer optimization is found to be effective in obtaining the power ratings of PV array. Further, it shows the efficacy of this method in obtaining a solution for a multiple varying loads for utilities like small cabin power supplies. PV system sizing is done based on radiation as well as load calculation. PV array with dual axis tracking was setup for required power rating. Homer optimization shows the power supply performance are highly depend on the inverter efficiency and depth of discharge of battery. The homer optimization results are compared with PV system operational data. It is found that the homer optimization results are in good agreement with operational data for days with the clear sky.*

Keywords: *Homer optimization, PV array, solar radiation, solar energy*

1. INTRODUCTION

Electrical powering of stand-alone and isolated sites/utilities requires optimised and cost effective solution for the power supply source. The technical solution for such configuration are discussed in detailed by Hongxing Yang [1]. However, the power load pattern for different equipment in these utility shows that the same tool of optimization used in hybrid multi load configuration can be used in simulating energy utilization. The present work is an attempt to use Homer optimization tool for obtaining cost effective energy utilization for a small facilities like terrace cabin. Homer software has been used for energy optimization problems in PV, hybrid, biomass wind energy systems [2] etc.These methods uses a mathematical model for PV panel is described by the equation [3]

$E\text{PV} = G(t) \times A \times P \times \eta_{\text{PV}}$,

Where (t) is the hourly irradiance in kWh/m2, A is thesurface area in m2, P is the PV penetration level factor, andη_{PV} is the efficiency of PV generator.

The battery stateof charge (SOC) is the cumulative sum of the dailycharge/discharge transfers. The battery serves as an energysource entity when discharging and a load when charging.At any hour $t$the state of the battery is related to theprevious state of charge and to the energy production andconsumption situation of the system during the time from$t-1$ to t.During the charging process, the mathematical model describing the battery operation is given by the equation [5-7]

$E\text{BAT}\ (t) = E\text{BAT}\ (t-1) - E\text{CC-OUT}\ (t) \times \eta\text{CHG}$, where $E\text{BAT}(t)$ is the energy stored in the battery at hour t,kWh, $E\text{BAT}(t-1)$ is the energy stored in the battery at hour$t-1$, kWh, and ηCHG is the battery charging efficiency.During discharging time the battery operation is described by the equation. [5-7]$E\text{BAT}\ (t) = E\text{BAT}\ (t-1) - E\text{Need}\ (t)$

Where$E\text{Need}\ (t)$ is the hourly load demand or energy needed at a particular period of time.

Let d be the difference between minimum allowable

SOC voltage limit and the maximum SOC voltage across the battery terminals when it is fully charged which is equal to $1 -$ DOD/100 and the depth of discharge is given by

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

The mathematical model for inverter [7] is described by the relation $E\text{PV-INV, BAT-INV}\ (t)$

$= (E\text{PV}\ (t) + E\text{BAT}\ (t-1) - E\text{LOAD}\ (t)\ \eta\text{INV} \times \eta\text{DCHG}) \times \eta\text{REC}$,

Where$E\text{PV-INV, BAT-INV}\ (t)$ is the hourly energy output from inverter kWh, $E\text{BAT}\ (t-1)$ is the energy stored in the battery.At hour $t-1$, kWh, $E\text{Load}\ (t)$ is the hourly energy consumed by the load side, kWh,INV is the efficiency of inverter, and ηDCHG is the battery discharging efficiency.

2. METHODOLOGY

2.1 Radiation Power Estimation

Sizing of stand-alone PV system starts by data collection of the available solar energy radiation of the selected location and estimating the energy consumption of the cabin. To get optimum design of PV system, it is important to collect meteorological data (solar radiation) of selected location.

Table 1.shows the monthly average values of global solar radiation over Hyderabad given by NREL [4]. Mathematically estimated and measured data is also shown in table 1. It is clear from the table that solar energy incident on the region is very high especially during summer months, with average daily radiation during March, April and May are 6.36,6.51 and 6.28 KWh/m2/day respectively.

Table 1: The Monthly Average Values of Daily Global Solar Radiation (KWh/m²/Day) In Hyderabad.

Month	NREL[4] Radiation data in Kwh/m²/day	Calculated Daily Radiation in Kwh/m²/day	Measured Daily Radiation in Kwh/m2/day
January	5.06	5.2	NA
February	5.82	5.91	5.1
March	6.36	6.64	6.1
April	6.51	6.94	6.4
May	6.28	6.29	NA
June	4.84	5.48	4.6
July	4.26	5.41	4.3
August	4.18	5.22	4.2
September	4.52	5.07	NA
October	4.79	4.91	NA
November	4.85	4.89	NA
December	4.74	5.1	NA

*NA –Data Not Available

2.2 Load Estimation

The electrical loads for cabin which is going to be used through stand-alone PV system consist oflighting and cooling, one desktop, dual axis solar tracking motor and labinstruments. The total load is 360Watts as shown in table 2. Thecontinuous and short duration are used according to the requirement.

Table 2: Typical Electrical Appliances in aLab.

Appliance	Watts	Type
Lighting and cooling	150	continuous
PC(desktop)	120	continuous
Tracking motor	30	Short duration
Lab instrument	50	Short duration
Total Load	360	

Finally all the different loads need to be estimated on a typical day and sum them. Table 3 provides the calculations of the power and energy for the cabin. The daily load profiles were determined by calculating the power demand (Kwh/day) for all load during the three seasons (summer, monsoon and winter).The load duration in cabin is from morning 9AM to 5PM. The estimated daily energy consumption for the summer, monsoon and winter season are shown in Table 3, 4 and 5 respectively. For summer season three months are considered (March, April May).For monsoon season months from June to September are considered and winter season is considered from October to February. The daily and monthly load profiles are shown in Fig. 1 and 2.

Table 3: The Daily Load Energy Consumption for summer season.

Load type	Hours Used/ day	Load Wh/day
Lighting and cooling	8	1200
PC(desktop)	6	720
Tracking motor	2	80
Lab instruments	2	100
Total(kWh/day)		2.1

Table 4: The Daily Load Energy Consumption for monsoon season.

Load type	Hours Used/ day	Load Wh/day
Lighting and cooling	5	750
PC(desktop)	4	480
Tracking motor	2	80
Lab instruments	1	50
Total(kWh/day)		1.36

Table 5: The Daily Load Energy Consumption for winter season.

Load type	Hours Used/ day	load Wh/day
Lighting and cooling	5	750
PC(desktop)	5	600
Tracking motor	2	80
Lab instruments	3	150
Total(kWh/day)		1.58

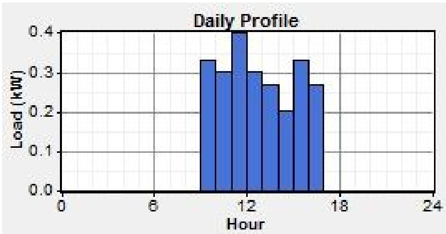

Fig. 1: Daily Load Profile during the Year.

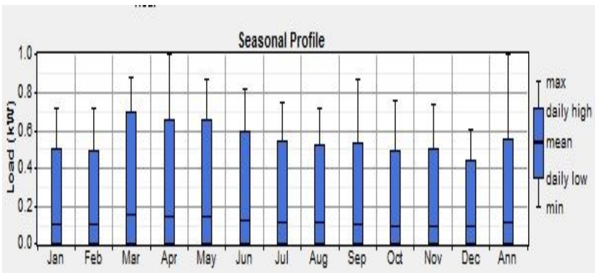

Fig. 2: Monthly Load Profile.

2.3 PV Array sizing

PV array sizing is done in conventional way [8]based on available battery bank rating, depth off discharge, insolation radiation power for a critical month and daily energy requirement based on load pattern. This procedure resulting a PV array of 540W approximately. This estimates are based on average value of radiation and daily energy demands.

3. SYSTEM ANALYSIS WITH HOMER

Homer software [9]is used for the analysis. A stand-alone PV system consists of PV array (converting solar energy), battery bank for energy storage and power inverter to maintain the flow of energy between the AC and DC sides. Fig. 3. shows the proposed scheme as implemented in the Homer simulation tool.

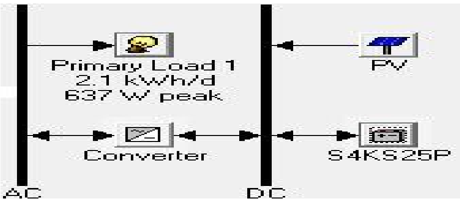

Fig. 3: HOMER Implementation of the Stand-Alone PV System.

Homer estimates the availability of solar radiation once the latitude and longitude are given as shown in the Fig. 4. Once the solar power source is selected for load pattern,the Homer generate the schedule of the solar power operation. For the remaining time periods the power is to be drawn from the connected grid or axillary power if any. Monthly average data of global solar radiation in Hyderabad are used as the solar energy resource. This is shown in Fig. 5.

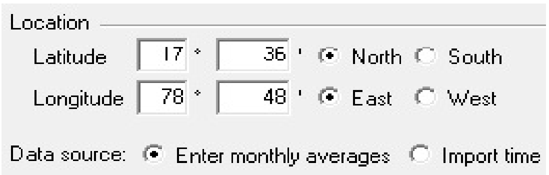

Fig. 4: Solar Location Data Entry.

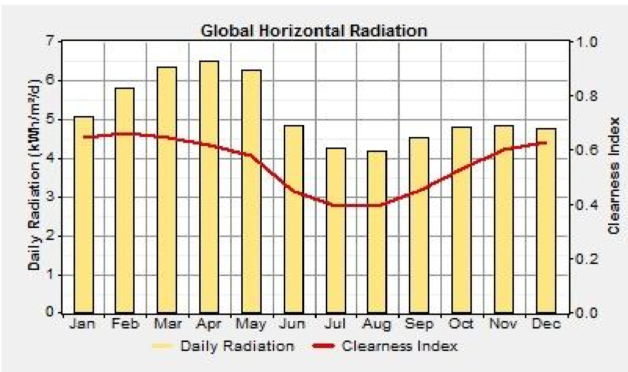

Fig. 5: Monthly Average Data of Global Solar Radiation in the Hyderabad.

3.1. Cost Analysis

The installation, replacement and maintenance cost of all components of PV system are shown in Fig. 6. From HOMER program, the net present cost consists of the installation, replacement and maintenance cost of the all components of the PV system. The life time used for PV arrays is 20 years.The net present cost with total investment is shown in table 5. andFig. 6.

Table 5: Net Present Cost

Compo-nent	Capital($)	Replacement ($)	Total ($)
PV	333	104	379
Su-Kam battery	333	248	510
Converter	300	125	432
other	1000	0	1000
System	1966	477	2290

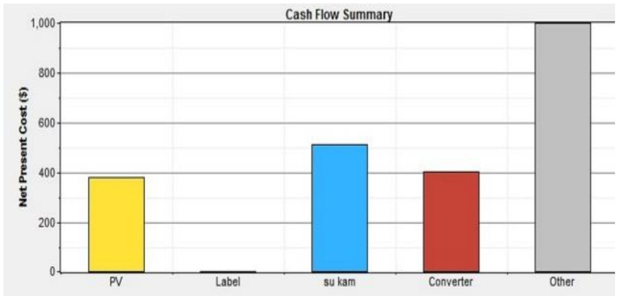

Fig. 6: The Net Present Cost.

3.2 Analysis for PV Array Rating

Table 6: The Analysis Result of HOMER.

PV rating(KW)	Renewable Fraction	COE($)	NPC($)
0.3	0.61	1.85	3850
0.4	0.78	0.653	2460
0.45	1	0.213	1940
0.5	1	0.245	2290
0.6	1	0.587	3160
0.7	1	1.25	3650

*COE- Cost of Electricity
*NPC- Net Present Cost

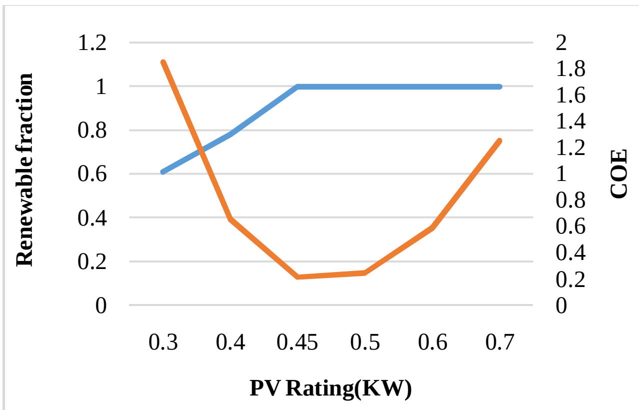

Fig. 7: PV rating versus Renewable fraction and COE.

The analysis is conducted for varying power rating of PV panels starts from 0.3 to 0.6KW, keeping same battery and inverter configuration. Simulation results are listed in table 6. The Fig. 7 shows the variation of renewable energy fraction generated versus increment in the rated power of PV array. Cost of electricity and net present cost are also tabulated. As the result shows the PV array rating of 0.45KW gives the minimum power cost and renewable energy fraction rating. There for 0.45KW is selected as the optimum power rating for the system. However the nearest standard panel available in the market is 0.5 KW rating. Therefore one has to conFig. the system for 0.5KW rating.

3.3 Effect of inverter efficiency and depth of discharge

The analysis is conducted by varying the inverter efficiency from 60% to 80% .In this analysis the PV array output are kept to be constant and the depth of discharge is remain sameits value is considered as 70%.Table 7. Shows the variation of Renewable fraction with the inverter efficiency.

Table 7: Inverter Efficiencyversus Renewable Fraction.

Inverter efficiency (%)	Renewable Fraction
60	0.67
65	0.71
70	.79
75	0.92
80	1.00

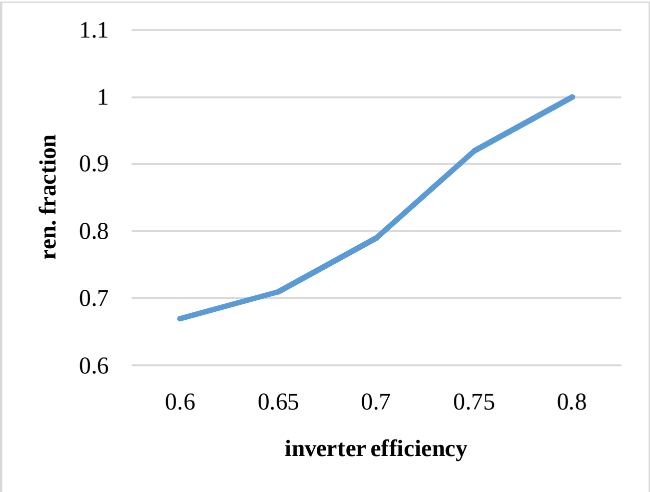

Fig. 8: Inverter Efficiencyversus Renewable Fraction.

As it is shown in Fig. 8, the renewable energy fraction is reducing drastically with thedecrease in inverter efficiency.

Further,the analysis is conducted by varying the depth of discharge from 50% to 70%.In this analysis the PV array output are kept to be constant the inverter efficiency is remain same and it is considered as 70%.

Table 8. Shows the variation of Renewable fraction with the depth of discharge.

Table 8: Depth of Dischargeversus Renewable fraction.

Depth of discharge (%)	Renewable Fraction
50	0.73
55	0.78
60	0.84
65	0.92
70	1.00

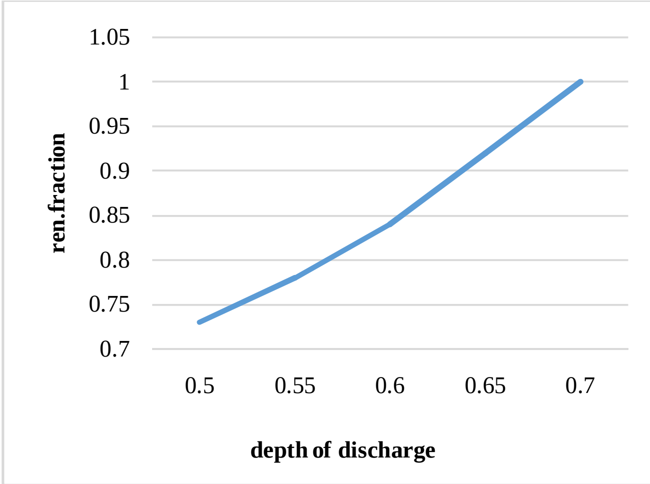

Fig. 9: Depth of Discharge versus Renewable fraction.

As it is shown in Fig. 9, the renewable energy fraction is reducing drastically with the decrease in depth of discharge.

3.4 Electrical Energy production

The monthly average electric production is shown in Fig. 10. The annual output energy production of PV array is 1150 KWh/year. The annual electrical load consumption is 730 KWh/year. The excess electricity is 387 KWh/year about 33.7% of the total PV energy production.

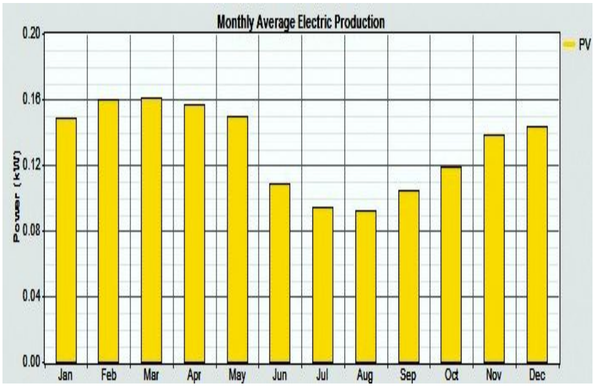

Fig. 10: Monthly Average Electric Production.

3.5 System Hardware

Based on Homer optimization and results a 0.5KW PV array, 150Ah battery bank, 1KW converter was set up. This system is having dual axis solar tracking system as shown in Fig. 11. The distance between the PV array and the cabin is less than 10 meters.

Fig. 11: 500 Watts PV Panels with Dual Axis Tracking.

4. OPERATIONAL DATA OF PV SYSTEM AND COMPARISON WITH HOMER RESULT

After the installation of PV system comprising of 500Watt PV, 1KW inverter and battery bank, trial were conducted for several days on generating solar power and operating the cabin equipment. Load, current and insolation solar radiation are measured for an interval of one hour from morning 9AM to 5 PM.The measured radiation and the corresponding power generated are listed in table 9.

Table 9: Calculated and Simulated Result of 12nd April.

Time	Radiation (simulated) in W/m2	Radiation (measured) in W/m2	Power (simulated) in W	Power (measured) in W
9	591	543	300	274
10	643	612	324	286
11	765	625	376	302
12	810	767	405	368
13	784	736	384	352
14	687	654	336	315
15	636	610	318	286
16	572	547	302	258
17	472	442	276	234

The measured power data shows approximately 10 % variation of the simulated result. This may due to the losses in the system. Large variation in data are mainly due to the reduction in incident radiation caused by climatic conditions. The simulated power which are higher than the actual measured data can be mainly attributed to the sensitive parameter chosen for this simulation. The value of inverter efficiency and depth of discharge has higher influence on system performance of the homer simulation as described in section 3.2 For example at 11 AM of 12th April the measured radiation is 756.45W/m^{2}which has large variation with corresponding simulated value.For the month of April the results of daily measurement are averaged and listedin table 10.

Table 10: Calculated and Simulated Result of 12 days of April Month.

date	average radiation in W/m2 (simulated)	average radiation in W/m2 (measured)	average power in Watts (simulated)	average power in Watts (measured)	variation
2nd April	763.33	749.73	387	365.4	5.581395
3rd April	815.77	785.02	390	372.96	4.369231
4th April	805.36	765.28	402.58	375.28	6.781261
6th April	792.45	742.38	396.6	364.68	8.048411
7th April	782.17	728.46	396.52	347.26	12.42308
8th April	812.54	751.28	410.58	358.27	12.74051
9th April	768.25	712.36	371.25	338.46	8.832323
11th April	786.84	735.58	391.84	354.76	9.463046
12th April	805.24	761.25	402.48	361.58	10.162
13th April	754.85	625.84	372.84	310.58	16.69885
14th April	787.48	684.84	387.68	338.48	12.69088
15th April	748.51	728.29	372.28	352.28	5.3723

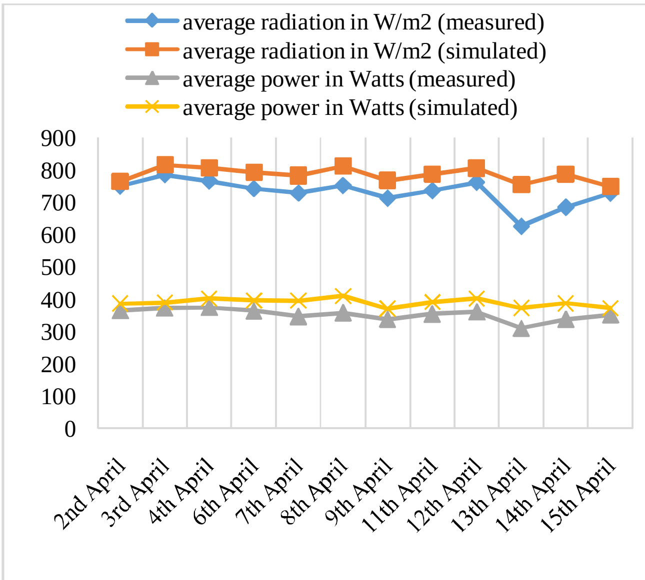

Fig. 12: Measured and Simulated Result of 12 days of April Month.

5. CONCLUSION

Load pattern for stand-alone terrace cabin is estimated, based on that Homer optimization analysis is conducted which yield the optimum power rating for the PV panel array. PV system is commissioned with 500Watt configuration .The operational data of this system is found to be in good agreement with the homer data. Homer optimization results are highly sensitive to the system parameters such as inverter efficiency and depth of discharge. Homer optimization technique can be used effectively for setting up stand-alone PV system for small cabin and utilises.

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