Feasibility Analysis of Photovoltaic System for Green house using Energy Analysis Software

Swaroop R[1], Pradip kumar Sadhu[2]

[1]Asst Professor, Department of Electronics and Telecommunication Engineering, Amity University, Dubai Campus, Dubai.
[2]Professor, Department of Electrical and Electronics Engineering, Indian School of Mines, Dhanbad. India.

Abstract

The photovoltaic systems make possible to exploit the sun energy at various ends. They are highly reliable and constitute a nonpolluting source of electricity, which can be appropriate for many applications. Photovoltaic energy has an increased importance in electrical power applications, since it is considered as an essentially inexhaustible and broadly available energy resource. However, the output power provided via the photovoltaic conversion process depends on solar irradiation and temperature. Therefore, to maximize the efficiency of the photovoltaic energy system, it is necessary to design a system with optimum number of panels, tilt angles, battery storage and inverters. In this paper optimal photovoltaic system is designed using RET Screen software and SolDraft to get the maximum efficiency. The cash flow and risk analysis were also done to optimize the cost.

1.Introduction

Photovoltaic (PV) energy generating systems convert the sun's energy directly into electricity using state-of-the-art semiconductor materials. PV systems vary in complexity. Some are called a "stand-alone or off-grid" system, which means they are the sole source of power to a home. Stand-alone systems can be designed to run with or without battery backup. In contrast, stand-alone home power systems often store energy generated during the day in a battery bank for use at night. Stand-alone systems are often cost-effective when compared to alternatives such as utility line extensions. Other PV systems are called "grid-connected" systems. These work to supplement existing electric service from a utility company. When the amount of energy generated by a grid-connected PV system exceeds the customer's loads; excess energy is exported to the utility, turning the customer's electric meter backward. Conversely, the customer can draw needed power from the utility when energy from the PV system is insufficient to power the building's loads. Under this arrangement, the customer's monthly electric utility bill reflects only the net amount of energy received from the electric utility. Each type of system requires specific components besides the PV modules. Generating AC power requires inverter. Battery storage requires special batteries and a battery charge controller. The final cost of any PV system ultimately depends on the PV array size, the battery bank size, inverter and on the other components required for the specific application. This RETScreen is designed to generate an estimate for the PV array size, battery bank size, and total cost of a standalone PV system. This will help to decide to purchase a system. To obtain a more complete system design power needs, site location, local weather conditions, and equipment**s.** The worksheet presented here will help to estimate the size and cost of a PV system. The worksheet is adapted from a method developed by RETScreen and the analysis is conducted in two sections. In the first section, we derive the system specifications by determining the load, available sunlight, and the size of the PV array, inverter and battery bank needed. In the second section, we convert the system specification into a cost for the PV system. Besides PV modules and batteries, complete PV systems also use wire, switches, fuses, connectors and other miscellaneous parts. We use a factor of 20% to cover balance of system costs. The block diagram in figure 1 below shows that the panel is connected to the load through inverter.

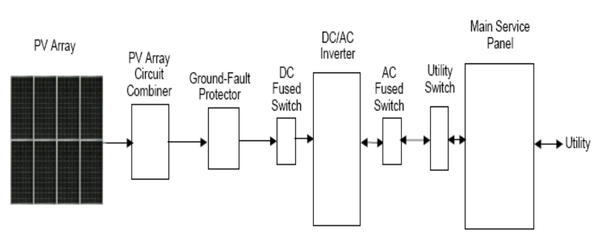

Fig 1: Schematic diagram for Photovoltaic System

2.Energy Modelling

2.1 Energy Calculation

It is calculated that the total load for the green house is 12.68KW.

The rated peak Load required for the photovoltaic system is 7.5 KW

The average hours of use per day = 7 Hrs.

Daily Power required = 7.5 x 7 = 52.5Kwh

If the Inverter efficiency = 0.95,

The power required is

$$p = \frac{52.5KWh}{0.95} = 55.26KWh$$

2.2 Calculation of the Number of Batteries

Battery Specification Considered

(12 V Battery, 170Ah,
Days of Autonomy =1
Depth of Discharge=0.5
Battery Temperature Coefficient=1.11)

The number of ampere hour per day is given as

$$= \frac{55.26KWh}{12} = 4.6KAh/day$$

If the Days of Autonomy is considered as 1 then the number of Ampere hour required is

$$= \frac{DailyLoad \times TempCoefficient \times DaysofAutonomy}{DepthofDischarge}$$

$$= \frac{4.6KAh \times 1.1 \times 1}{0.5} = 10.13KAh$$

The number of Batteries

is $= \frac{10130Ah}{170Ah} = 60Batteries$.

2.3 Calculation of the Number of Panels

The number of panels = 55.26 Kwh/day / 5 peak sun / 0.95 (Inverter Efficiency) / 0.83 (Temperature loss) / 0.9 (shading coefficient) / 0.85 (System derate) / 0.23KW = 80 Panels. Consequently two inverters are used. These two inverters are connected with the bank of 60 batteries to supply the required load with battery charge control. The figure 13 at the end of this document shows the inverter connection diagram.

3. Feasibility Analysis of Photovoltaic System Using RET Screen Software

3.1. Feasibility Analysis

In RET screen analysis the climate data of Nizwa is used for simulation. The climatic data can be seen from the figure 2 which gives the information on air temperature, humidity, daily solar radiation, latitude and longitude information. In this analysis an electrical appliances for an Ecohouse is considered which is 12.68KW as shown in figure 3. It is assumed that the photovoltaic system is used to supply power during the day time and the night. The figure 3 also gives the information on daily electrical energy consumption which is 71.48KW, which gives an annual electrical consumption of 26MW.

3.2 The Base Case Power System

The base case power system in figure 3 is the source normally used if it is not connected to the photovoltaic system. This is mainly for the cost analysis and green house gas emission analyisis.
It also required giving information on inverters and the battery backups as shown in figure 4 The total load is 13KW. But not all the loads will be used simultaneously. Hence it is assumed that 60% of the load will be used at a time and the peak load here is 7.5KW. The efficiency of Inverter is normally 95%. In this “days of Autonomy” for batteries is chosen as one day as the battery is connected to the solar panel for charging in the day times. It has been observed that the number of Ampere hour required for the battery is approximately 10000Ah which mean that it requires sixty 12V Batteries at the rate of 170Ah for each battery. The charge controller efficiency and the inverter efficiency are considered as 95% and the Depth of Discharge is considered as 65%.

3.3 Solar Tracking Mode and Azimuth

It has been observed from figure 4 that most of the time the sun is perpendicular to the house giving maximum efficiency. It has been observed that at 9^0 tilt angle the panels could give maximum efficiency. Hence the tilt angle is considered as 9 degree and the azimuth is considered as 180^0.

The figure 5 below shows the data required for photovoltaic panels. It has been observed that 80 panels are required to fulfill the load requirement. These 80 panels are used since the efficiency of the solar panel is 13.8% as shown below. It also depends on the nominal operating cell temperature and the temperature coefficient.

	Unit	Climate data location	Project location
Latitude	°N	22.9	22.9
Longitude	°E	57.5	57.5
Elevation	m	383	383
Heating design temperature	°C	13.4	
Cooling design temperature	°C	41.2	
Earth temperature amplitude	°C	22.5	

Month		Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January		19.2	48.4%	4.33	97.7	3.3	21.6	0	286
February		20.7	45.0%	5.12	97.5	3.5	23.4	0	299
March		24.3	37.7%	5.71	97.3	3.4	27.6	0	443
April		28.8	29.4%	6.70	97.0	3.3	32.7	0	564
May		32.8	23.9%	7.29	96.6	4.1	37.0	0	708
June		35.0	23.4%	7.09	96.1	4.6	39.4	0	751
July		35.2	30.4%	6.55	96.0	5.1	39.7	0	780
August		34.4	33.1%	6.42	96.2	4.6	39.2	0	758
September		32.0	33.0%	6.10	96.7	4.2	36.7	0	659
October		28.3	34.8%	5.48	97.2	3.0	31.9	0	566
November		24.1	42.4%	4.64	97.5	2.8	27.0	0	423
December		20.9	49.7%	4.14	97.7	3.2	23.2	0	339
Annual		28.0	35.9%	5.80	97.0	3.7	31.7	0	6,576
Measured at	m					10.0	0.0		

Fig 2: Climate data

RETScreen Energy Model - Power project

Power project

Base case power system

Grid type		Off-grid
Technology		Grid electricity
Fuel rate	$/kWh	0.130
Capacity	kW	12,680.00
Annual O&M cost	$	0
Electricity rate - base case	$/kWh	0.130
Total electricity cost	$	3,392

Description	AC/DC	Intermittent resource-load correlation	Base case load	Hours of use per day	Days of use per week
			W	h/d	d/w
Fan-10x100	AC	Zero	1,000.00	10.00	7
Exhaust Fan-5x30	AC	Zero	150.00	5.00	7
Lights-148x60	AC	Zero	8,880.00	5.00	7
Washing Machine-500	AC	Zero	500.00	1.00	3
TV-150x4	AC	Zero	600.00	5.00	7
Microwave Oven-600	AC	Zero	600.00	0.50	7
Refigerator-500	AC	Zero	500.00	24.00	7
Computer-150	AC	Zero	150.00	2.00	5
Miscallaneous-300	AC	Zero	300.00	2.00	7

	Unit	Base case	Proposed case
Electricity - daily - DC	kWh	0.00	0.00
Electricity - daily - AC	kWh	71.48	71.48

Percent of month used

		Base case	Proposed case	Energy saved
Electricity - annual - DC	MWh	0.000	0.000	
Electricity - annual - AC	MWh	26.090	26.090	0%
Peak load - annual	kW		7.50	

Fig 3: Load for Green House

Inverter		Peak load - annual - AC
Capacity	kW	7.5
Efficiency	%	95%
Miscellaneous losses	%	0%

Battery			
Days of autonomy	d	1.0	
Voltage	V	12.0	
Efficiency	%	95%	
Maximum depth of discharge	%	65%	
Charge controller efficiency	%	95%	
Temperature control method		Ambient	
Average battery temperature derating	%	-0.2%	
Capacity	Ah	10,000	9,920
Battery	kWh	120	

Technology		Photovoltaic

Resource assessment		
Solar tracking mode		Fixed
Slope	°	9.0
Azimuth	°	180.0

Annual solar radiation - horizontal	MWh/m²	2.12
Annual solar radiation - tilted	MWh/m²	2.01

Show data

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity delivered to load MWh
January	4.33	3.73	1.92
February	5.12	4.60	2.04
March	5.71	5.36	2.32
April	6.70	6.52	2.26
May	7.29	7.31	2.33
June	7.09	7.19	2.26
July	6.55	6.60	2.33
August	6.42	6.32	2.33
September	6.10	5.81	2.25
October	5.48	4.99	2.29
November	4.64	4.06	1.97
December	4.14	3.52	1.80
Annual	**5.80**	**5.50**	**26.09**

Fig 4: Design of Inverter/Batteries

Photovoltaic			
Type		poly-Si	
Power capacity	kW	18.40	245.3%
Manufacturer		BP Solar	
Model		poly-Si - BP 3 230W	80 unit(s)
Efficiency	%	13.8%	
Nominal operating cell temperature	°C	45	
Temperature coefficient	% / °C	0.40%	
Solar collector area	m²	133.3	
Control method		Maximum power point tracker	
Miscellaneous losses	%	0.0%	
Summary			
Capacity factor	%	20.5%	
Electricity delivered to load	MWh	26.09	100.0%
Peak load power system			
Technology		Not required	

Fig 5: Photovoltaic specifications

Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Initial costs	$	40,700	20%	32,560	48,840
O&M	$	100	20%	80	120
Fuel cost - base case	$	3,392	5%	3,222	3,561
Debt term	yr	0	0%	0	0

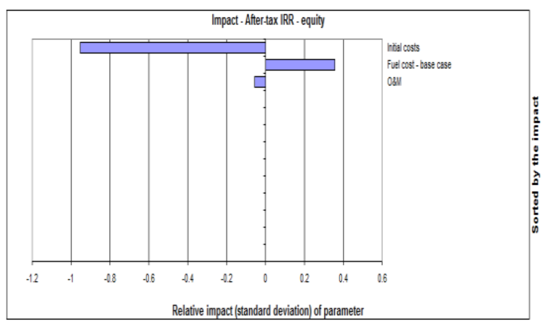

Fig 6: Risk Analysis

The figure 6 shows the carbon dioxide emission that would have generated if the project is not executed. It is clearly seen that the co2 emission is 5.1 tons/year. A final step in an economic feasibility study which is to compare estimated costs of the PV system to other alternatives. It is observed from the table below that the initial cost is 40700$ (15670 O.R) and the annual savings is 3392$. (1306 O.R). The most common alternative to off-grid PV is a line extension from an electric utility company The data in figure 7 gives the risk analysis on each investments made, especially on the initial costs, operation and maintenance, costs etc. It has been observed that the initial cost is at high risk and the operation and maintenance cost is comparatively low. It also shows that the fluctuation can be from 32560$ (12536 O.R) to 48840$. (18800 O.R) It has also been observed that the operation and maintenance cost is less that 20% of the initial costs. It is also been observed from the software that the distribution of Internal Rate of Return (IRR) and the frequency of the cost fluctuation these are shown in figure 8. This means that, given the *5% **Level of risk*** as specified above, you can be 95% sure that the outcome will be between 0.9% and 3.6%. Perhaps a more useful way of looking at this is to say that you will have a 2.5% chance of getting a return less than 0.9% (97.5% chance of greater than 3.6%).

4. Cash Flow Analysis

The figure 9 gives the cash flow analysis which gives the idea on the breakeven point for the investments made on the project. It also considers the inflation rate, fuel escalation rate. It has been observed that the initial cost is around 40700$ (15670 O.R) and reach the break even point at 18.5 years.

Base case system GHG summary (Baseline)

Fuel type	Fuel mix %	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Electricity	100.0%	26	0.196	5.1
Total	100.0%	26	0.196	5.1

Proposed case system GHG summary (Power project)

Fuel type	Fuel mix %	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Solar	100.0%	26	0.000	0.0
Total	100.0%	26	0.000	0.0

GHG emission reduction summary

	Base case GHG emission tCO2	Proposed case GHG emission tCO2	Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission reduction tCO2
Power project	5.1	0.0	5.1		5.1

Fig 7: GHG Emission

Median	%	2.1%
Level of risk	%	5.0%
Minimum within level of confidence	%	0.9%
Maximum within level of confidence	%	3.6%

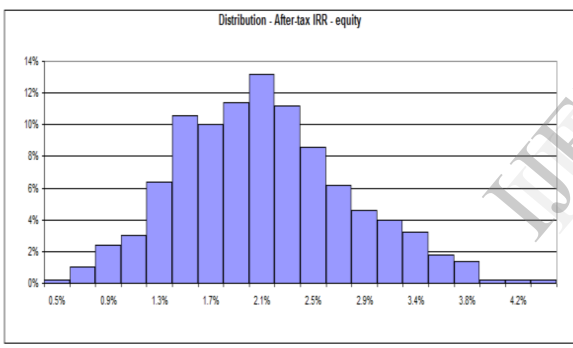

Fig 8: Risk Analysis (Level of Confidence)

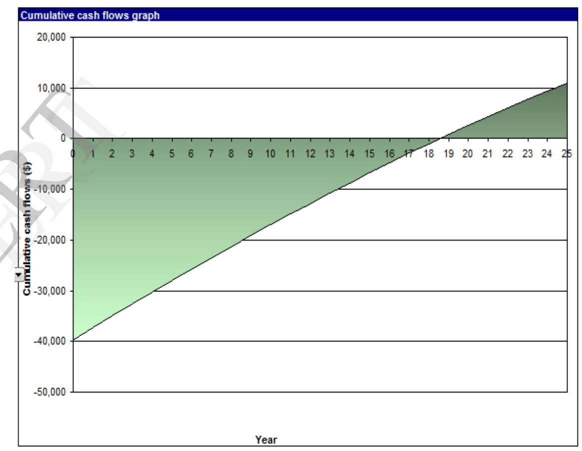

Fig 9: Cash Flow Analysis

5. Placement of Panels

The roof area available for the placement of panels is 21 X 6.5 m as two rows. The panels can be placed as shown in the figure 10 below. It can be seen that the initial row can accommodate 40 panels and the second row can accommodate 40 panels totaling to 80 panels. It can be seen that the specification below that a normal dimension of the panel is 990mm x 1660mm.

Company Name: BP Solar
Power: 230 Wp
Width: 990 mm
Length: 1660 mm
Thickness: 50 mm

6. Inverter Connection

The figure 11 above shows the connection of inverter. It requires two 10KW inverters. Each inverter are connected to a combination of 10 panels in series as arrays and then 4 arrays are connected in parallel as shown in the figure above.

7. String Connection

It can be observed from the string connection Figure 11 that 8 set of connections are there with ten panels in series.

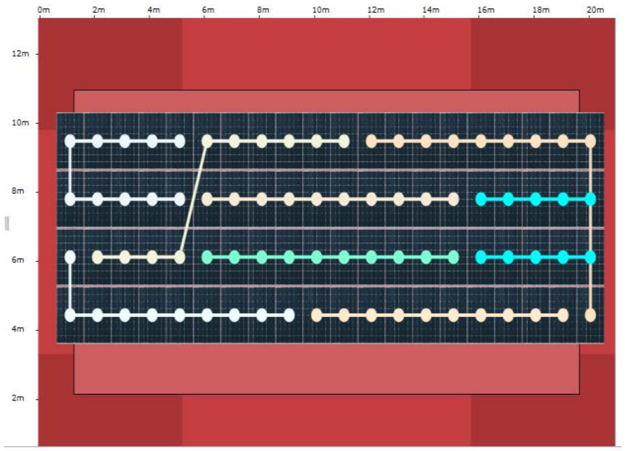

Fig10: Roof Area and String Connections

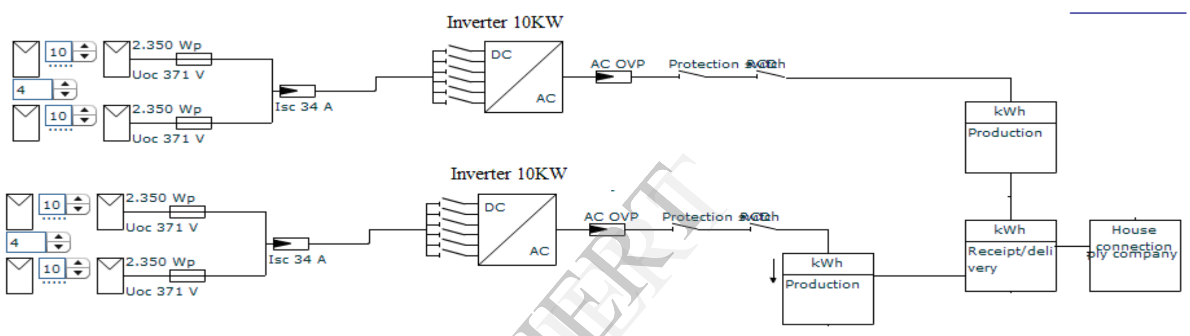

Fig 11: Inverter Connections

8. Conclusion

In this paper the design of photovoltaic system for an ecohouse is implemented. Optimum number of panels, bank of batteries, inverters are designed. The connection of inverter to the panels were also discussed. The cost analysis, risk analysis were also done using the RET Screen software.

10. References

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