Design and Cost Benefit Analysis of a 10KW Standalone Photovoltaic System in Krishna Milk Union

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Abstract*: *Day to day there is a drastic decrease in the availability of non-renewable energy sources such as coal, crude oil in the earth's Crust and also the massive utilization of fossil fuels severely effects the society and earth. So, there is need for alternative energy source energy to meet the energy demand and reducing the utilization of fossil fuels. In this paper the design process of standalone solar PV System for small scale industry is presented. Design process involved the estimation of load, sizing of battery, inverter PV array and area required for PV panel installation. The estimated size of PV system as per the company requirement is found to be 10KW.Finally Cost benefit analysis including payback period and life span of the PV system with the estimated configuration is checked with the System Advisor Model [11]. The design Specifications of the Solar PV system is reported.

Index Terms*: *design of solar PV system, cost benefit analysis, payback period, System Advisor Model (SAM).

I. INTRODUCTION

Power from renewable energy sources is getting to be well known nowadays because of government help what's more, investment from private endeavors. Among these energy sources sun based photovoltaic innovation is risen out in picking up intrigue particularly in nation like India, where sun-oriented vitality is bounteously accessible all through the year [1]. Some real facts which made a installer's to install PV system they are sudden rising of power cost and sudden changes in environments conditions these facts make into rapid growth of PV installation which will give ecofriendly to the environment, pollution less, noise free, maintenance free and with support of government, PV innovation coming into picture to answer for supply of energy. The efficiency of solar cell is more than 24 % [2]. The yearly generation is as of now more than 10000 MW in the world and today the PV energy source is rapidly growing technology because all the nations are coming forward to decreasing the using of fossil fuel generation to make the environment greenly [3]. So many states also building up a solar with support of government with aim of generation of power is based on fully solar technology. The installation of PV System takes less time compared to other generation plants and it has wide scope of utilization it can building up on surface of land or roof top of buildings without any testing of soil testing and strength of building because of the PV is weight less and ecofriendly. It is cost less freely available energy source in the universe The PV working on the principle of photovoltaic reaction. The sun energy converts into electrical energy by photovoltaic reaction. PV we can use two types grid connected PV system and standalone PV system. This paper work carried in a small-scale industry for design of standalone PV system in cost benefit method. Different points of interest for small scale industry by utilizing this innovation are [13]:

1. Decrease in customary power cost.
2. Carbon credits decrease.
3. Gives pollution less energy
4. Reduction of electricity bill.

This research work is carried out in Krishna Milk Union, Vijayawada, A.P. Krishna Milk Union produces 2.7laks liters of milk. For the process of milk production, the industry requires huge amount of electricity every day. So as per the record collected from Krishna Milk Union an average of 15,000units are consumed per day. Hence Krishna Milk Union requires 4.5 lakh units per month on an average. To reduce the monthly bill paid for the consumption to utility as to be cutdown. One of the alternative available in the process of reducing electricity bill is by relaying on alternative source of energy like solar. The paper organized as follows: Section II illustrates the methodology involved in the design of a 10KW standalone PV system. The estimated size of PV array, ratings of inverter, battery and payback period are reported in Section III. In this section, the estimated design specifications are compared with the results obtained from system advisory model (SAM). Finally, Section IV concludes the with key issues in the design process.

II. DESIGN METHODOLOGY

The framework estimating includes completely different advances that area unit as pursed:

A. Burden Evaluation
B. Array Tilt
C. Format of the planned framework
D. Load Estimation of the system
E. Battery Sizing
F. Inverter size
G. Restitution amount (Payback)

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a. BURDEN EVALUATION

Burden evaluation framework design relies upon the amount of load existed. The working voltage decided for a PV autonomous system is typically the voltage enforced by the vast loads [4]. Energy necessity is given by watt-hour of day by

$$D_e(\text{Wh}) = \sum_{i=0}^{n} N_i I_i V_i D_i \quad (1)$$

Where N_i no. of ith load, I_i and V_i are the voltage and current drawn by the i^{th} loads and D_i is the daily duty cycle of the i^{th} load in hrs./day.

Load demand in Ah computed by

$$D_i(Ah) = D_e(Wh) * V_{gsv} * n_{pce} \quad (2)$$

Where n_{pce} power conversion efficiency and V_{gsv} given system voltage.

Reformed Ampere hour load is given by

$$D_{rAh} = {D_i(AH)}/{n_w n_b} \quad (3)$$

Where n_w is the efficiency of wire and n_b is the efficiency of battery.

b. ARRAY TILT

To capture the maximum amount of solar insolation the PV array should be tilted perpendicular to the solar radiation. This requires dual axis tracking. But the advantage of dual axis tracking is due to its high maintains cost. So, it is reasonable to install fixed tilt solar PV panels. As the industry is located southern hemisphere the panel should be faced north. The suggested optimal tilt for PV panel is the location of latitude angle. Sometimes a tilt of latitude angle plus 15deg is also used fixed tilt of type of PV panels. [3]

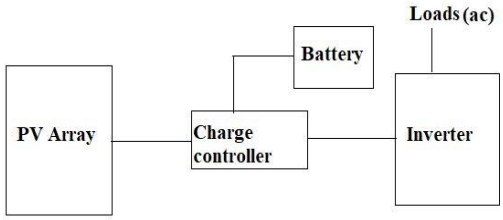

Fig 1: Layout of the Standalone PV system

c. FORMAT OF PLANNED FRAMEWORK

The steps to size the solar PV system required to meet the total demand for peak solar hours location on a day are given as below [5].

Step 1: Ascertain the mean day by day sun-based radiation accessible

Step 2: Mean daily PV output from $1m^2$ surface area is given by *{(Mean solar radiation) × (efficiency of module) × (accessible irradiance of cell from makers specification)}/ demand system voltage.*

Step 3: Array losses because of mismatch of module, blocking diodes, and earth's dirt examine multiplication with the above to get maximum output from $1m^2$ surface area.

Step 4: Number of Panels is *{total watt-hour rating (daily load)/ Daily energy produced by a panel}*

Step 5: Required PV modules is given by {(area of the region) / (area of the PV module)}

Step 6: Required roof area is given by {(*one panel area required + clearance) × (number of panels*)}

d. LOAD ESTIMATION OF THE SYSTEM

The estimated energy consumption by administrative building is 59.65kWh/day, the number of appliances and their power demand with their duty cycle, number of hours of operation and power rating of appliances are given in Table I. The design and standalone PV system is 10KW/day for to meet the daily load demand.

Table I: Load Estimation for the System

Load estimation for the system							
S.No	Appliance	Nos	Voltage (V)	Power Demand (W)	Duty Cycle (h/day)	Consumption per day (Wh /day)	Mean daily load (Ah/Day)
1	Tube lights	120	220	4080	8	32640	370.90
2	CFL	20	220	460	8	3680	41.818
3	Fans	12	220	888	8	5328	60.545
4	Exhaust fans	8	220	640	8	5120	58.18
5	Vacuum Cleaner	3	220	600	2	1200	13.63
6	Air conditioner	2	220	2172	4	8688	98.72
7	Water dispenser	2	220	1000	3	3000	34.09
Total				9840		59656	677.88

The system is associated with batteries through a control framework and an inverter along with the solar PV panels. The complete assessed burden for the whole framework is 9.8kwp nearly approximately 10kwp as appeared in the Table 1 above.

As shown in Fig 1, standalone PV system as the following components: 1. PV array, 2. Charge controller 3. Battery, 4. Inverter, 5. Loads(ac).

Number of PV panels needed to satisfy the estimated daily load:

The mixed efficiency of inverter and battery will be determined as:

Mixed efficiency = inverter efficiency × battery efficiency = 0.9×0.9 = 0.81

Available sunlight in a day = 6 hours/day (equivalent of peak radiation)

Rating of PV panel = 250Wp

Definite power of PV panel = Rating of PV panel× Operating Factor = 250 × 0.90 = 225

The expected power from PV panel = Definite power output of a panel × mixed efficiency

= 225 × 0.81= 182.25 Watts

= 182.25 watts (VA)

Energy originated by a 250Wp panel in a day

=Definite power output × 6 hours/day

= 182.5 × 6 = 1095 watts-hour

Number of Panels = *Total watt-hour rating (daily load)/ (Daily energy produced by a panel)*

= 59656/ 1095

= 54.48 = 55 (approx...)

From Table II the approximate roof calculated is $90m^2$ and from Table III calculated life cycle cost of PV system found to be Rs 5,13,000.

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Table II: Calculation of required roof Area for PV installation

Calculation of required roof Area required for installation of PV generation		
Module size for 250Wp	Length (mm)	Breadth (mm)
	1640	990
One panel Area Covered	$1,623,600 mm^2$	
Clearance	$25 mm^2$	
Clearance Covered by Area 55 panels (mm^2)	$1375 mm^2$	
Total Area Covered by 55 panels m^2	89.29(90 approx.) m^2	

Table III: Life Cycle cost of the PV System [6][7]:

Cost of the PV System	
Type	Monocrystalline
PV array per watt cost	Rs 47/wp
Cost of 10kWp Solar Photo- Voltaic	Rs 4,70,000
Auxiliaries cost and installation cost approx..	Rs 15,000
The life cycle of the system	25 Years
Charge controller cost	Rs 28,000
Total Cost PV	Rs 5,13,000

e. BATTERY SIZING

For a solar PV application, it is recommended to choose a deep discharge cycle type of batteries. Necessary battery limit in Ah is given by

$$B_{nl} = E_{c(Ah)} \times \frac{Ds}{(DoD)\,max} \times n_t \quad (4)$$

Where (DoD)max is the maximum depth of discharge, Ds is the autonomy and n_t is the temperature change factor.

Series Arrangement of Batteries is given by

$$B = V_{gsv} / V_{gbv} \quad (5)$$

Where Vgbv is the given battery voltage and Vgsv is the given system Voltage

Parallel Arrangement of Batteries is given by

$$B = B_{nl} / B_{rc} \quad (6)$$

Where Brc = Rated capacity battery (Ah)

Total battery

$$Tb = Bp \times Bs \quad (7)$$

The battery size can be estimated as below Table IV

Power consumption per day is 60kwh/day and power Generated by panels is 60Units/ day if we use Lead acid batteries of 24V and capacity 20Ah@20C if the DOD considered as to be 80%. The Number of batteries need is 40. Here we considered 40 for better connection.

Table IV: Cost calculation of Battery [12]:

Cost Parameters of Battery	
Battery Type	Lead Acid Flooded (LAF)
Capacity	12V,20Ah
Warranty	5years
Cost of each battery	Rs 3,250
Cost of 40 batteries	Rs 1,30,000
Total cost of Battery with Including Installation Charges approx.	Rs 1,30,000

f. Inverter Size to be determined as:

The Estimated load connected to PV system is approximately 10KW. In market, inverters with rating of 200VA, 500VA, 1KVA, 5KVA and 10KVA are readily available. Hence a inverter of 10KVA is chosen to meet the load requirements. The installation charges for chosen inverter accounts to Rs 1,05,000.

Saving in Power consumption Bill:

Once the PV system is installed with design specification suggested is saving of Rs 2,16,000 per month incurred.

g. PAY-BACK PERIOD

Pay Back period can be computed from the formula given as

$$\text{Pay- Back Period} = \frac{A}{B} \quad (8)$$

Where, A is the total expense of PV framework with helper hardware and B is the total yearly cost sparing after establishment of PV System. From Eqn (8), Payback period for the designed solar system is computed approximately 4Years.As we realize that helpful existence of PV is 25years and we determined the compensation back time of PV is 4 years so by subtracting valuable life to pay-back period and afterward the distinction in bill sum we can get the benefit of 5,44,32,000(Five Crores Forty-Four lakhs thirty-two thousand Rupees).

Selection of suitable location for installing PV arrays:

From the field visit of the industry suitable location for PV installations is selected on building of refrigeration and dairy maintenance blocks.

The conceivable place for establishment of PV modules are:

- Building's roof
- Stopping regions
- Path ways
- Open regions

By field work we noticed convincible place for PV installation project work finished on the top of the administrative and refrigeration building.

III. RESULT AND DISCUSSION

Following the steps proposed in Section II, a standalone PV system is designing to meet a 10KW load in Krishna Milk Union. The estimated ratings and cost analysis are given Table V.

Table V: Estimation and cost analysis for 10KW system

Estimation and Cost Analysis's for 10KW system		
Load Estimation for the System	Power Demand	9840Watts (10Kw approx..)
	Consumption per day	59656Wh
	Mean daily load per day (Ah)	832.64Ah

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Array Sizing	Type	Monocrystalline
	Number of Panels	55
	Watt cost	Rs 47Wp/watt
	Area for 55 Panels	$90m^2$
	Cost of 10Kwp PV	Rs 4,70,000
	Auxiliaries Cost and Installation cost approx..	Rs 15,000
	Charge controller	Rs 28,000
	Total Cost	Rs 5,13,000
Array Tilt	Latitude	16.54^oN
	Longitude	80.614^oE
Battery sizing	Type	Lead acid Flooded (LAF)
	Capacity	20Ah
	C-rate	20C
	Number of batteries in series	40
	Number of series in parallel	1
	Total batteries	40
	Energy Stored	9.6kwh
	Cost of Battery	Rs 1,30,000
Inverter Sizing	Estimated load generated from PV	10KW
	Size of Inverter	10KVA
	Cost of Inverter	Rs 1,05,000
Total Cost of the System	Rs 8,35,000	

Verification of estimated ratings of the PV system using System Advisory Model (SAM) [11]:

In this section the estimated PV system is verified with System advisory model (SAM) see below Table VI.

Table VI: Comparing with system Advisor Model

Design Standalone Solar PV System using System Advisory Model [11]		
Load Estimation	12.2KW	
Array Sizing	Type	Monocrystalline
	Total number of modules	54
	Number of strings	6
	Total module area	$90.7m^2$
	String Voc at reference condition	250.1V
	String Vamp at reference condition	267.3V
	Total cost includes fittings charges	Rs 5,25,000
Array Tilt (seasonal tilt)	16.442+15 deg	31.442deg
Battery Sizing	Type	Lead acid flooded
	Number of cells	40(12V,20A)
	Number of strings in parallel	1
	Max c-rate of charge	20
	Max c-rate of discharge	10
	Max charge power	32KW DC
	Max discharge power	16KWDC
	Total cost	Rs 1,38,400
Inverter Sizing	Type	SamilPower SolarRiver10000TL
	Max DC Voltage	480V
	Max DC Current	256.617A
	Max AC power	10000Wac
	Max DC Voltage	10268.7Wdc
	Nominal AC voltage	240Vac
	Nominal DC Voltage	400Vdc
	Max MPPT DC Voltage	480V
	Total Inverter DC capacity	10.269KWdc
	Total Cost	Rs 1,25,000
Installation labor	Rs15,785	
Total Cost of the Project	Rs 8,04,185(includes all charges)	

Even though Vijayawada is an Industrial area, it is keen on taking a functioning part in the improvement of new advance for misusing and using sustainable wellsprings of vitality. The most regular sustainable power source sources which are uninhibitedly accessible are wind and sun oriented. FigII&FigIII illustrates the monthly irradiance profile over the year. It can observe that high irradiance level persisted from March to May and comparatively lower from June to December [11].

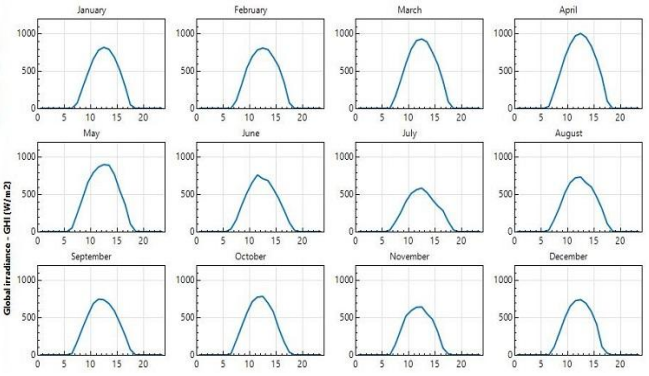

Fig II. monthly average irradiance profile

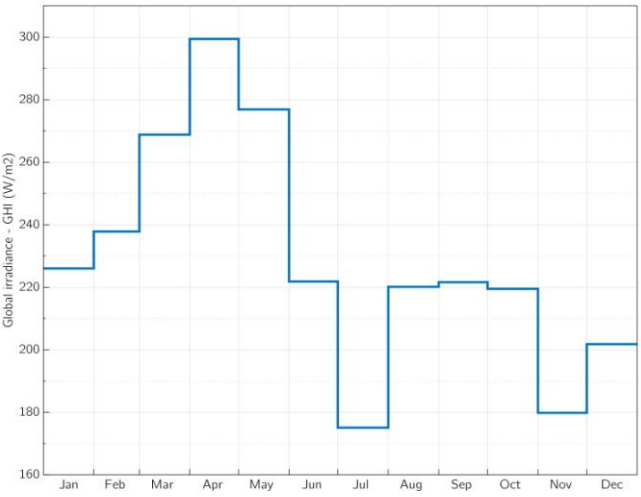

Fig III: annually average of irradiance profile

The estimated cost approximately Rs 8,35,000. Fig IV shows payback cash flow for the designed standalone PV system. From the graph it can be observed that the payback period for installed PV system approximately 4.7 years. As the payback is very fast, the estimated design reliable and aids in profit once the payback period is completed.

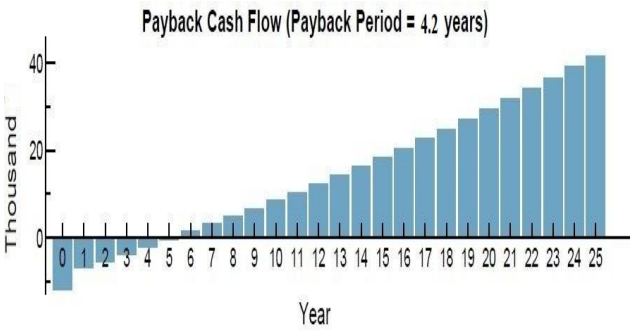

Fig IV: Payback cash flow

IV. CONCLUSION

In this paper a 10KW standalone PV system is designed for Krishna Milk Union Vijayawada, Andhra Pradesh [13]. The overall design of PV system is based on the geographical location and available area for PV panel installations. The estimated sizing of the system and cost benefit analysis is carried out and compared with the System Advisory Model (SAM). The comparative results show the authenticity of estimated design. The Solar PV system is capable of supplying power to load throughout day there by reducing the consumption value of electricity with battery back-up, it provides reliable supply at night time. Finally, the estimation and cost analysis of 10KW PV system carried out by Rs8,35,000 according to present scenario prices and area required for roof top taken approximately $90 m^2$. In future the standalone PV system can be grid connected. Then, whenever load is less than the generation from solar the excess power fed into grid and the consumer benefit from the utility. Whenever load is greater than the generation from solar the required power drawn from the grid.

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