

Economic Evaluation and Performance of PV Plant: An Investigation for Village Malo Bheel Tharparkar

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Abstract— Energy crises have never been a new issue for Pakistan. Pakistan is facing this problem since long time. Power Sectors have been investing so much but still country has been facing lot of challenges to overcome energy crises. According to recent report by International Renewable Energy Agency (IREA), Electrification rate of Pakistan is 74% which means 26% (51 million of population) still don't have access to electricity. The report also mentioned that 32500 villages are deprived of electricity. 40% of rural population lives far away from grid stations as reluctance that is shown by utility companies on not expanding their network due to various reasons such as financial and technical problems. It is need of hour to focus more on generation of electricity through renewable energies as traditional generation of electricity relies mostly on coal which is causing some serious consequences. There are two objectives of this paper. Economic Evaluation and examine of various parameters for performance prediction of 50 houses in Malo Bheel tharparker which is obtained using Software PVSYS 6.4.3. The Cost of energy obtained using PVSYS software is 0.10\$/kWh which is proved to be feasible considering no access of grid station to village.

Index Terms—Performance parameters, economic evaluation, pvsyst.

I. INTRODUCTION

Tharparkar is the largest district of sindh by area being enriched with solar energy. As per recent population census of tharparkar out of 163141 housing units only 11011 has access to electricity which makes just 6.75% of population. Village Malo Bheel is among those villages that don't have access to grid station as a result they are deprived from electricity. It is so important in modern age to develop and implement different renewable energy technologies especially in Pakistan where energy crisis has been major issue. Pakistan being so abundant with renewable potential should focus more on investing on solar technologies as it can have significant contribution in electrification of rural areas [1-4]. As demand of electricity has been increasing due to industrialization it is so important to focus to these renewable energy technologies [11]. For that solar technology is nowadays more popular technology and gaining support in research in different countries. Lot of research has been carried on different solar technologies to improve efficiency, improve its reliability and to make it cost effective. Over last few years it has major contribution in overcoming power crisis issues. Many Countries has already implemented solar promotion programs in their national

electrification plans [6]. Not only this, solar technology has other favourable aspects such as it require less maintenance compare to conventional generation technology. Since majority of population in Pakistan resides in rural areas so this aids an advantage especially in those villages where there is no access to national grids stations [7]. It is important due to these advantages to install standalone PV systems in order to satisfy electricity demands of those villages [2], [9]. In Baluchistan, some areas have solar radiation of 7 to 7.5 kWh/m²/day while in South Punjab and Sindh intensity of solar radiation is in range of 6 to 6.5 kWh/m²/day however rest of the country's ranges from 5.5 to 6 kWh/m²/day. This shows Pakistan is enriched with solar energy and is in Sun Belt [5, 8].

It is important to have knowledge about performance of PV system under various climatic conditions [3]. All the climatic data and solar resources used at latitude 24.6838N and longitude 70.2498E is taken from NASA-SSE (Surface Meteorology and Solar Energy). In this paper economic analysis and performance prediction has been examined of small village called Malo Bheel in Tharparker

II. DISCRPTION OF TECHNICAL SPECIFICATION OF SITE PLANT

For a PV System it is so important to collect weather data from authentic source. All the data of Climatic Conditions, Geographical locations, of village Malo Bheel is taken from NASA-SSE Satellite Data using PVSYST Software. Table 1 shows the details of site and Table 2 shows technical specification of plant..

TABLE I: Geographical site details.

Geographical Site:	Malo Bheel, Tharparker
Latitudes:	24.7°N
Longitudes:	70.2°E
Altitudes:	97m
Annual Solar Radiation:	5.20 kWh/m ² /day
Climate Zone:	0B (Extremely Hot)

TABLE II: Technical Specification

User Need:	House Hold
Hours of Operation:	3-18hours
Autonomy	2 days
Plane tilt:	27
Array Power:	6.41Kwp
Specification of Panel:	305Wp 31V
Maximum Power Current	8.97A
Module Type	Si-Poly
Module Area	40.3 m ²
Cell area	36.3 m ²
Number of Panels	21
Number of Series Modules	07
Number of Strings	3
Energy Usage	10w LED bulb 40w domestic appliance
Charge Controller	MPPT 48V, Max Charging Current: 28A Max Discharging Current: 23A
Battery Pack	2 strings of 24 in series Capacity 966Ah

TABLE III: Balances and Main Results of Site

	GlobHor kWh/m'	T Amb	GlobInc kWh/m'	GlobEff kWh/m'	EArray kWh
January	1259	20.10	1737	1709	927.5
February	1299	22.40	164.4	161.1	852.3
March	1702	27.50	191.7	187.4	933.3
April	1923	30.70	1936	188.9	906.1
May	211.7	32.10	194.5	189.0	927.8
June	1959	31.30	1722	1670	882.6
July	1693	29.70	1526	1482	812.0
August	1603	29.00	156.0	151.7	829.4
September	157.5	29.80	1690	1650	863.7
October	147.3	29.70	1784	174.7	916.6
November	121.8	26.00	1636	1604	860.9
December	1159	21.89	1660	1629	892.2
Year	18880	27.54	2075.7	2027.2	10604.5

GlobHor: Horizontal global irradiation
GlobEff: Effective Global, corr. For IAM and shadings
T Amb: Ambient Temperature
Earray: Effective energy at the output of the array
GlobInc: Global incident in collector plane

LOAD DETAILS

Malo Bheel is 20km away from Islamkot. Population of Malo Bheel is 362 who live in 136 mud huts and village includes 1 school. The study is carried out for 50 homes with 10w bulb and 40w home appliance load. Each home has since Village has no access to grid station. PV plant can be best choice for electrification [4]. All the parameters are examined and economic evaluation has been done through software PVSYS.

III. OPERATION OF PV SYSTEM

As seen in Fig. 1, Plant consists of 3 sections PV array, System which includes power conditioning unit (controller, regulator) and batteries and Load section. Solar Panels and batteries fed load which are connected through PCU. The panel used is 72 cell panels Canadian Solar CS6X-305P because they are less expensive per watt compare to 36 cell panels (12V). In this system 3 strings of 7 modules has been used. We are using 48 units of concord (PVX-5340T) 2V 483Ah battery in parallel string of 2. We do not want to have more than 3 parallel strings of batteries. This can cause uneven charging and discharging of the batteries as a result shortening the life of batteries so we have connected 48 batteries in parallel string of 2.

During sunny hours loads are fed from solar energy while batteries are in charging phase but if the power produced by PV arrays isn't enough to feed the load then to balance power is taken from batteries as shown in figure 1. It is important to wire the solar panels in higher voltage strings. This allows us to have lower current in the wire from the array, so we can use smaller, less expensive wire, and we will have less voltage drop. Since Demand of village can be fulfilled from 48 units of batteries of pack voltage of 48V, 966A so we don't require backup generator at present but taking future consideration As there is no Grid Access to village Malo Bheel and if load demand is increased backup generator can be connected to fulfil the demand.

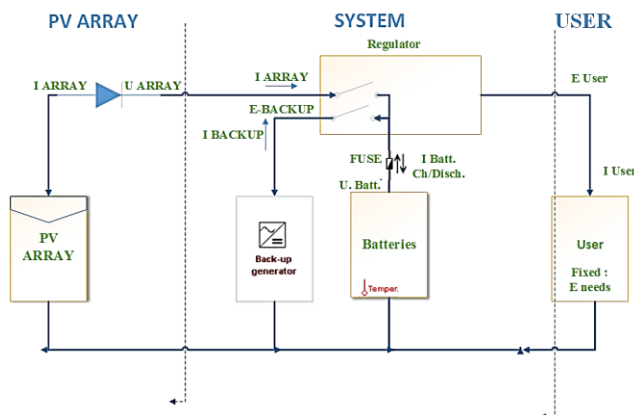


Fig. 1: Technical layout of plant.

IV. RESULTS AND DISCUSSION

Variation of PV Plant over the year is shown in the daily Input/out diagram in Fig. 1. Every dot in figure shows the output of array w.r.t Global incident solar energy in collector plane on every particular day. As seen in Fig. 2 concentration of dots is maximum above 30kwh which means minimum output of 30kwh is generated by this plant on most of the days of year. Under different climatic condition maximum 38 kWh may be obtained. However considering demand average demand which is 24.67 which indicates system is feasible at that site.

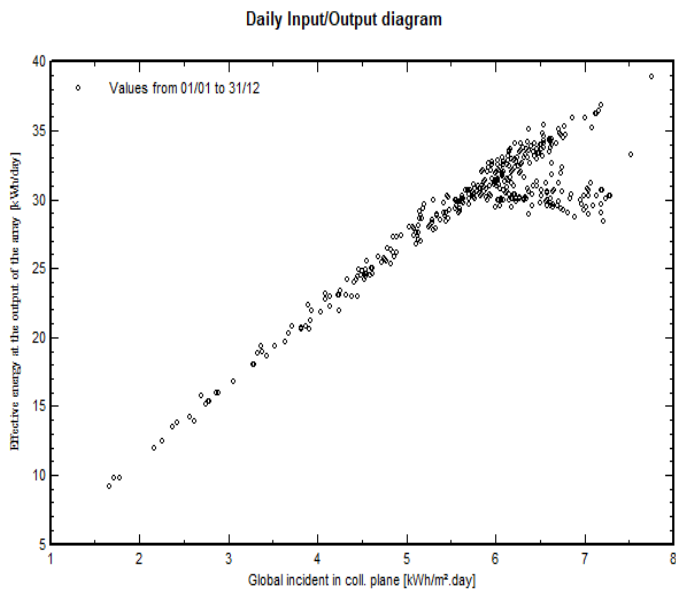


Fig. 2: the daily Input/output diagram of site.

V. VARIOUS LOSSES AND ENERGY FLOW PATTERN

Quality of this PV System design can be analysed by loss diagram shown below. The diagram consist of all loses that occurs from transfer stage to user end. Loses such as IAM factor loss (optical losses) which refers to weakening of irradiance while reaching at PV surface. w.r.t irradiance under normal condition.

As seen from Fig. 3 available energy of system is 1898 kWh/m² but actual energy available to collector plane is 12997 kwh. This decrease is due to losses considering IAM factor and 15.91% efficiency at STC.

Which means 6.84% of energy has been lost in conversion. Considering further loses such as irradiance losses, temperature losses, mismatch losses, energy available from the power plant is 10176 kWh [10]. Out of that energy 82.5% is used for storage taking in to account some other losses of batteries as well i.e electrolytic dissociation. and 17.5% of energy is directly supplied to load. Net energy supplied to user is 9486 kwh whereas energy required for location is 9855kwh Therefore this plant is capable of fulfilling 96.5% of that location.

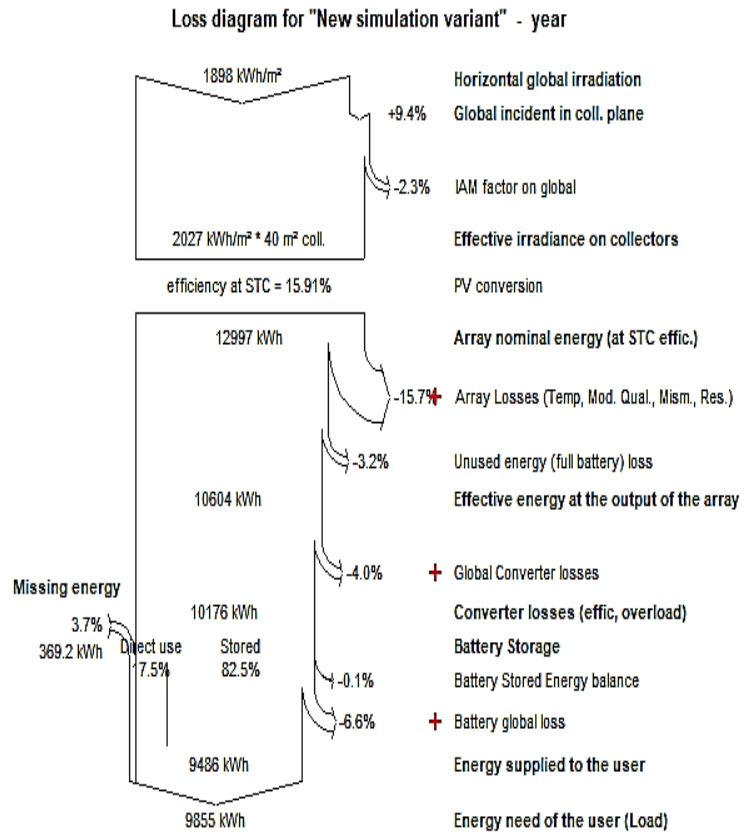


Fig. 3. Loss diagram

VI. NORMALIZED PERFORMANCE INDEX

In order to compare PV system with different installation and to have an idea how much system is reliable compare to other systems performance indexes are used. Different performance index as shown in Fig. 4 are obtained during simulation.

Energy supplied to user Y_f is 4.06 kwh/kwp/day. Collection losses (L_c) is 1 kwh/kwp/day. In this system System losses which refers to batteries inefficiency in PV standalone system are 0.48 kwh/kwp/day. This can be obtained from simulation or can be calculated from

$$\text{System Loss (Ls)} = Y_a - Y_f$$

where

Where Y_a is The array daily output energy,

And Y_f is energy supplied to user. With limited loads there is another performance index used here which is unused energy (Lu) that means the energy which is available potentially at the array output but which cannot be used because the system is saturated (i.e full battery).

Normalized production (per installed kWp): Normal power 6.41kWp

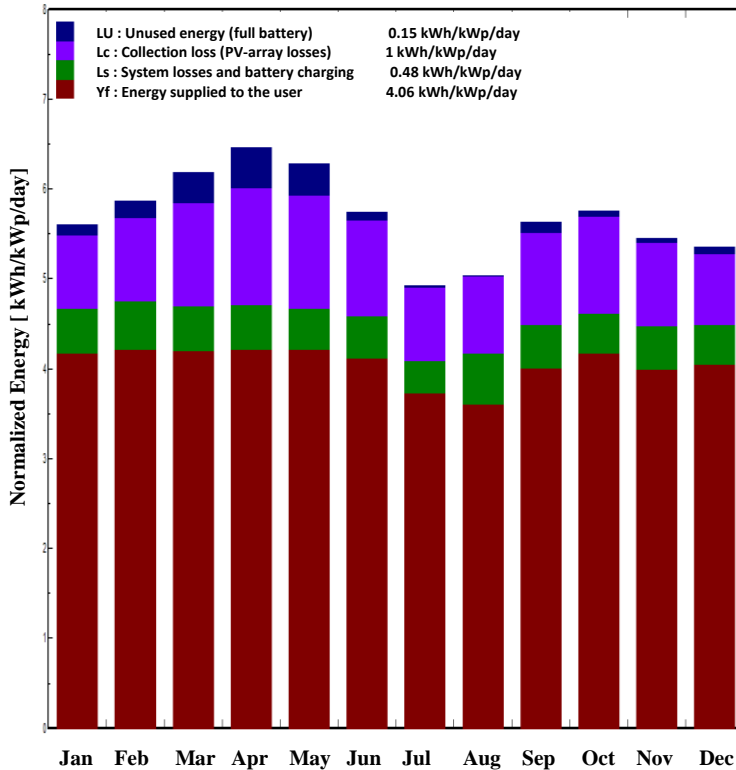


Fig. 4. Normalized Production

VII. SOLAR FRACTION

In order to examine how much system is efficient It is important to calculate the ratio between energy supplied to the user to demand of end consumer, i.e. what amount to demand is met from solar energy. The average solar fraction over the year for the plant is found to be 0.96. which means 96% of load demand is met from solar energy. From Simulation and Figure 5 as seen during months of Jan to May solar fraction is 1 and for months June Solar fraction is 0.997, July 0.884, August 0.855 and from Sep- Dec it is in between 0.95 to 0.96. That means during month of Jan to may as solar fraction is 1 PV plant can alone meet the demands in these months.

Performance Ratio PR and Solar Fraction SF

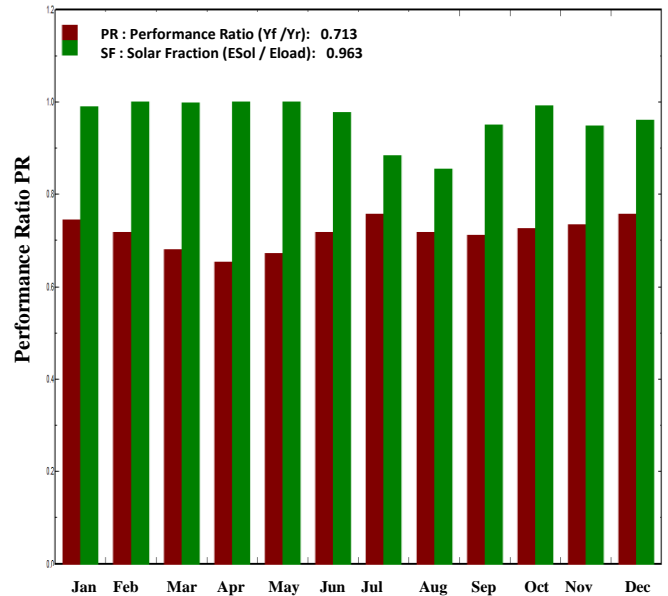


Fig. 5: Solar Fraction and Performance Ratio

One of most parameter to predict the efficiency of any PV plant is Performance Ratio (PR). Performance ratio is that ratio between actual and theoretical possible energy output. Orientation of pv plant and incident solar radiation isn't considered in this ratio. PV plant is said to be operated more efficiently when PR ratio is to 100%, though practically it isn't possible due to different losses mentioned earlier. In this system PR is 0.71 which means system is 71% efficient. In this study the highest performance ratio was obtained for month of July which is 0.75 as seen in Fig. 5.

VIII. REDUCTION OF CO2

Production of 1kwh requires 0.75kg of coal and during that generation process the CO2 produced by 0.7 kg coal is 1.486 kg thus it is very much important to take these facts in mind. 1.486kg emission of CO2 can be reduced by generating 1 kwh of solar energy. Thus it was observed that by System Production of 10528 kwh/year 110.356 ton of CO2 canbe avoided.

IX. ECONOMIC EVALUATION OF SYSTEM

Economic Evaluation for this Standalone System is given in Fig. 6. And as a result, energy per kwh for this system is 0.10\$ which is economical considering for site where there is no access to electricity.

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Stand Alone System: Economic evaluation			
Project : Stand Alone Project at Malo Bheel,			
Simulation variant : New simulation variant			
Main system parameters			
PV Field Orientation	System type	Stand alone	
PV modules	tilt	27°	azimuth 0°
PV Array	Model	CS6X - 305P	Pnom 305 Wp
Battery	Nb. of modules	21	Pnom total 6.41 kWp
battery Pack	Model	PVX-5340T	Technology sealed, AGM
User's needs	Nb. of units	48	Voltage / Capacity 48 V / 966 Ah
	Daily household consumers	Constant over the year	global 9855 kWh/year
Investment			
PV modules (Pnom = 305 Wp)	21 units	395 US\$ / unit	8285 US\$
Supports / Integration		15 US\$ / module	317 US\$
Batteries (2 V / 483 Ah)	48 units	40 US\$ / unit	1923 US\$
regulator / converter			57 US\$
Settings, wiring, ...			57 US\$
Substitution underworth			0 US\$
Gross investment (without taxes)			10638 US\$
Financing			
Gross investment (without taxes)			10638 US\$
Taxes on investment (VAT)	Rate 15.0 %		1596 US\$
Gross investment (including VAT)			12234 US\$
Subsidies			0 US\$
Net investment (all taxes included)			12234 US\$
Annuities	(Loan 3.0 % over 20 years)		822 US\$/year
Maintenance			113 US\$/year
insurance, annual taxes			0 US\$/year
Provision for battery replacement	(lifetime 3.4 years)		19 US\$/year
Total yearly cost			955 US\$/year
Energy cost			
Used solar energy			9486 kWh / year
Excess energy (battery full)			352 kWh / year
Used energy cost			0.10 US\$ / kWh

Fig. 6. Economic Evaluation for Standalone System

X. PERFORMANCE OF PV SYSTEM

Table 4 shows overall performance of PV system for village malo bheel. As seen average PR of system is 0.713 which indicates that system is feasible at this site.

TABLE IV: Performance of PV System

Energy Available at site	10528 kwh
Energy Supplied to user:	9485.8 kwh
Energy Needed to user:	9855 kwh
Average Solar Fraction over the year	0.963
Average PR over the year	0.713
System Yields:	4.06 kWh/kwp/day
Collection Loss:	1 kWh/kwp/day
System Loss	0.48 kWh/kwp/day
Unused Energy	0.15 kWh/kwp/day

XI. CONCLUSION

World has been investing a lot on solar energy not only climatic point of view to avoid greenhouse effect but also to supply electricity economically to those remote areas where supply of electricity become so costly due to inaccessibility of grid stations. Solar Energy is key technology not only to minimize the generation via those fuel which harm climate but also through standalone pv system lot of village can be facilitated with electricity. In context of village Malo Bheel various factors contributing to performance of PV system such as Normalized Performance Index, average daily energy generated by, the plant solar fraction, PR and emission reduction has been discussed in this paper. With this simulation and analysis using PVSyst it was found that PV System is not only cost effective in Malo Bheel but also it will work efficiently and is feasible technically. Hence it was predicted with help of these parameters that Electricity canbe supplied to areas like Malo bheel with lowest cost due to enrichment of solar energy at those areas. And results clearly indicate that plant is feasible both economically and by satisfying the demand of that area. Hence it is so important that these type of solar projects must be installed in villages like Malo Bheel.

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