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Abstract: *The Islamic Republic of Pakistan is a federation of five provinces, and Baluchistan is the largest province. It covers almost 40% of the total area of Pakistan. The critical issue relating to local power generation through renewable energy is the absence of area-specific production capacity and economic viability data for the different renewable energy technologies. This paper addresses one of the issues by assessing the area potential and economic feasibility of external electrification of the vocational training school building by using an on-grid PV system with net metering for bidirectional energy transportation. The economic feasibility reveals that the electricity generated using solar PV costs Rs. 4.89 per kWh with a NEPRA feed-in tariff rate of Rs.8.64 per kWh to sell back electricity to the distributor company. It is considerably cheaper than conventional electricity, which is now Rs.22.65 per kWh for a sanctioned load above 5KW. Similarly, the current solar PV system is easy to install and environmentally friendly also reduced CO_2 emissions by 5030 kg, SO_2 by 21.8kg and NOx by 10.8 kg per year.*

Keywords: renewable, electrification, solar, PV, economic feasibility, Pakistan

1. INTRODUCTION

The electricity consumers in Pakistan are categorized as domestic, general services, commercial, industrial, agriculture, and others. The major portion of electricity is consumed by the domestic including general services, followed by the industrial sector. The continued growth of electric load with respect to current power generation has a supply-demand gap. Power generation capacity is, and the demand gap cannot reduce until we have some big power projects; they will take time and a huge amount of money. The available generation is based on coal-oil and LNG is affecting the country's economy due to high coal and oil imports. It is, therefore, essential to shift the current electric load to renewable energy sources like solar and wind which are easy to install and economical green energy solutions without any environmental impact. The current power generation is shown in fig. 1 here renewable energy share is very less, for wind power, it is nearly 1900 MW and solar is only 600MW [1].

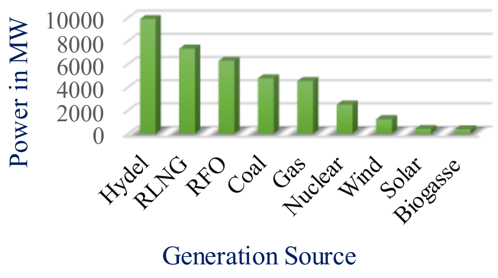

Fig. 1. Pakistan Present Power Generation

Baluchistan is one of the biggest provinces of Pakistan and its electricity demand is increasing for the last one decade. Currently, we are importing 75 MW of energy from IRAN, but due to international sanctions on Iran, energy import is very limited. Moreover, with fewer recoveries from consumers, lengthy lines with high power losses, and low voltage issues, it is not a feasible solution to extend the existing electricity network in highly remote areas, which is a waste of energy. In different research work, optimal configuration with an economically suitable hybrid RE system was tested and found as appropriate for rural areas, small towns, and commercial and educational buildings. So on-grid PV systems are a more suitable choice for the vocational training school located 10km away from the main city the purpose of this institute is to promote vocational and entrepreneurship training for local people.

A simulation-based PV system study is carried out with a load centre located 8 km away from the 132KV grid station connected with an 11kv feeder and 25KV distribution 11/400v step-down transformer.

Designed an on-grid PV-connected bidirectional model theoretically for VTS building. The main objective of the study is to find the optimized HRE combination to meet the VTS building demand reliably and sustainably and to reduce the energy cost by limiting the grid purchase up certain level with a feed-in tariff to export energy. Refer to fig 2 On-grid PV power system layout design.

2. METHODOLOGY

The VTS building's total area is 10890 Sq.ft with a covered area of 9800 sq.ft. Electrical load assessment is made according to the covered area is 18KW under National Electric Power Regulatory Authority (NEPRA) rules. The building is connected to a local 11KV distribution network with a 25KVA transformer and three-phase static energy meter that can record all the load parameters like instantaneous active, reactive power, loss of power, and daily, monthly, and yearly energy consumed. Average daily electricity consumption is recorded as 67kWh, and monthly average energy use is 2010.5Kwh. The cost of energy (CoE) calculated is Rs. 56473 per month, which is very high. So, to reduce the cost of energy and dependency on the local power distributor grid, this study was carried out.

The purpose of this work is to find an economically green energy solution with a suitable Bi-directional Solar Power Plant connected through net metering that can transport extra PV energy to the local distribution network. Data is collected from the local power distributor and the energy management information system (EMIS).

So, 20KW on a grid-connected PV system is simulated with component price parameters provided by NEPRA to local contractors. The NEPRA electricity tariff A-3 has applied Rs. 22.65/ Kwh with the sell-back price (feed-in tariff) as Rs. 8.640/kWh. Grid availability is assumed to be 100% as no load shedding is reported by the local distributor company [2].
The available building load, weather data, and prices of components, along with grid purchase energy tariffs, were added to Homer Energy Pro software, developed by NREL, used for the analysis of load forecasting and electricity generation business-related analysis. The VTS building renewable resource Solar radiation availability was also estimated based on geographical area parameters available online, and weather data is taken from NREL Homer pro. The investigation was based on the technical resources values and its Net present cost. The NPC is the flow of the initial capital cost, replacement cost, and operation and maintenance costs over the system's period of life.

3. Mathematical Modelling

The VTS-HRES is planned to operate in both grid-connected and stand-alone modes to supply VTS campus load demand. The schematic diagram in fig.2.

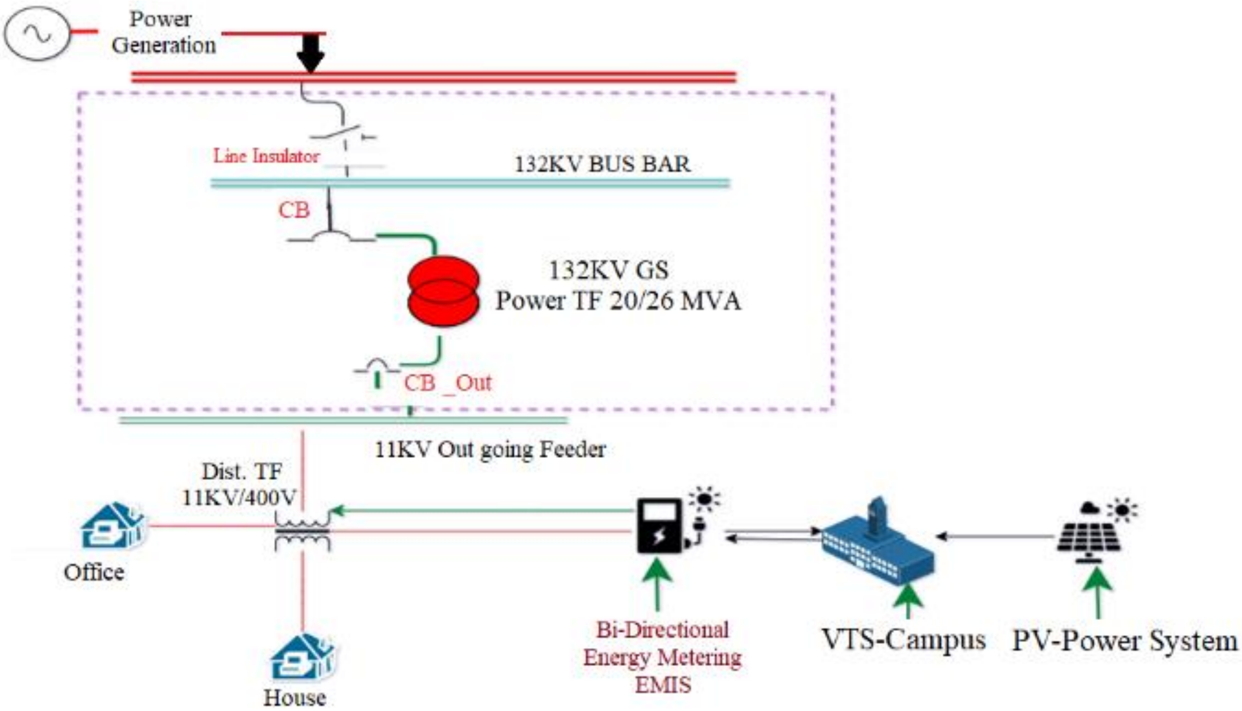

Fig. 2. Designed on-Grid PV Power System

3.1 Solar Power Generation

Power generation based on a PV system that depends on the GHI and temperature level can be obtained from equation (1) [4]:

$$P_{pv} = \mathrm{W_{pv} f_{pv}} \left(\frac{G_T}{G_{T.Test}}\right) \left[1 + \alpha_p (T_C - T_{c.Test})\right] \quad (1)$$

Here W_{pv} = maximum power output (kW), f_{pv} = PV derating factor (80%), GT = solar irradiation incident (kW/m2), $G_{T\text{-}Test}$ = incident irradiation under STC (1kW/m2), α_p = temperature constants of power (%/◦C), T_C = PV cell temperature in the present time step (◦C) and T_{c_Tes}t = PV cell temperature Ambient (25 ◦C). The Energy generated can be calculated by equation (2)[3]

$$E = A * \eta_p * H * PR \quad (2)$$

E = Energy (kWh)
A = Total solar panel Area (m2)
η_p= solar panel yield or efficiency (%)
H = Annual average solar radiation
PR = Performance ratio, coefficient for losses (default value = 0.75)

$$\eta_p = \eta_r\left[1 - \beta_p (T_c - T_r)\right] \quad (3)$$

$$PR \frac{P \times I_{STC}}{GTI \times C} \quad (4)$$

I_{STC} = Irradiance at STC Ambient Conditions which is taken at 1000 W/m^2 and C = DC capacity of Plant in Watt. Solar irradiation on a horizontal surface in the atmosphere (*H*) and on the Earth's surface (H_o) could be calculated using the following equations [4]

$$H = H_o \times K_T \quad (5)$$

$$H_o = \frac{86{,}400}{\pi} \times G_{sc}\left\{1 + 0.033 \cos\left(\frac{2\pi n}{365}\right)\right\} [\cos\phi \cos\delta \sin\omega_s + \omega_s \sin\phi \sin\delta] \quad (6)$$

Where, G_{sc} is the solar constant, *n* is the day of the year, ω_s is the solar hourly angles, ϕ is the latitude angle of the place, and K_T is the sky clearness index which varies between 0.3 and 0.8 depending upon the location and time of the year. δ is the solar declination angle.

3.2 Grid Supply

Grid availability is assumed to be 100% during the whole year ($\infty \le P_{GRID(t)} \le \infty$), given by equation (7) as [5]

$$P_{GRID}(t) = \delta_{GRID}(t) \times P_{GRID}(t) \quad (7)$$

However, if Supply ON: $\delta_{GRID(t)} = 1$ and in case of Supply OFF: $\delta_{GRID(t)} = 0$.

3.3 Converter Power losses

Ac output could be calculated from equation (8), and after conversion losses (P_{AC}) is useful available power,[6][7]

$$P_{AC} = \left\{\left(\frac{P_{ACO}}{P_{DCO}-P_{SO}}\right) - C_0(P_{DCO} - P_{SO})\right\}(P_{DCO} - P_{SO}) + C_B(P_{DCO} - P_{SO})^2 \quad (8)$$

$$\text{Inverter power loses } \eta = f\left(\frac{P_{LN}}{P_{NOM}}, \frac{V_{DN}}{V_{NOM}}\right) \quad (9)$$

3.4 Economic Modeling for Cost of Energy

Cost of energy is the focus of this study, so to calculate the CoE of the project following set of equations are used. The total cost is estimated as follows:[8]

$$TC = \sum_{1}^{k}(IC + MC + CoR + CoF + CoG) \quad (10)$$

Where IC is the initial cost, MC is the maintenance cost, CoR is the cost of replacement, CoF is the cost of fuel in the case of generator and Cog is the cost grid including energy tariff.[8]

$$Cost\ of\ Maintenace = \left[\left(N_{PV}C_{M,PV}\right) + \left(N_{INV}C_{M,INV}\right)\right]\left(\frac{1+infR}{1+intR}\right) \quad (11)$$

$$NPC = (CT - SV) + \left(p_f \times LPS\right) \quad (12)$$

$$LPS = \sum_{t=1}^{T}\left[P_{load}(t) - (P_{IN})\right] \quad (13)$$

Equations 10 to 11 are used for the maintenance cost, including inflation and interest rate, net present cost, and loss of power supply penalty during normal operations of the PV system. The salvage value represents the remaining value of each component at the end of the project time. The salvage value (SV) can be obtained using equation (14) [9]

$$SV = \left(N_{PV}C_{PV}\right)\left(\frac{R_{T,PV}}{L_{T,PV}}\right) + \left(N_{INV}C_{INV}\right)\left(\frac{R_{T,INV}}{L_{T,INV}}\right) \quad (14)$$

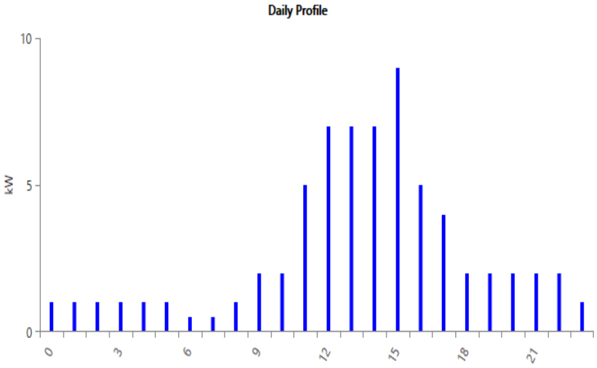

Fig. 3. Daily Energy Consumption Profile

Finally, CoE is estimated by using equation (15):

$$COE = \frac{NPC}{P_{year}}(\mathrm{Rs}/kWh) \quad (15)$$

Where P_{year} is power generated in one year by the PV plant.

The mathematical model is validated in excel to calculate the total energy generation for one year with a solar penal area of 100m^2, solar panel efficiency of 20% and annual irradiation for Table 1. represents the theoretical calculation of PV energy.

Table 1: PV-Energy per Year

E = Energy (kWh)	37209	kWh/y
A = Total solar panel Area (m²)	100	m²
r = solar panel yield (%)	20%	
H = Annual average irradiation on tilted panels	2301	kWh/m².an
PR = Performance ratio, coefficient for losses (default value = 0.75)	1.00	
Total power of the system	20.0	kW

3.5 Losses in Solar PV Systems

Before installing a solar PV system, calculating the losses associated with PV systems is necessary. These losses play an important role while system optimization, CoE reduction and energy export otherwise, it will not give a feasible solution. Table 2 shows losses in the PV system assumed for the optimal design.

Table 2: PV-Systems Losses

Inverter losses (6% to 15 %)	8.20%
Temperature losses (5% to 15%)	5%
DC cables losses (1 to 3 %)	1%
AC cables losses (1 to 3 %)	1%
Shadings 0 % to 40% (depends on site)	2%
Losses weak irradiation 3% to 7%	3%
Losses due to dust, snow... (2%)	2%
Other Losses	0%

4. Data Collection

The building energy consumption per day is arranged according to the electric appliances, their power in watts, and hourly time of use depicted in table 3.

The total power demand for the selected building is approximately 67 kWh/day (i.e., 67000Wh/day). The area of the building is 1080sqr. Feet and according to NEPRA Load criteria minimum load assessed is 18KW with 10 KW peak demand, taken from monthly billing data of the building.

Building load variation is seasonal and varies with temperature. Summer average temperature is taken near about 28.75 ºC. and winter average temperature 6ºC.

4.1 Monthly Energy Price (Grid-Purchase)

The cost of energy purchased from the local power distribution grid is shown in table 4, and fig. 4. is the tariff comparison with the slab rate price of electricity in Pakistani rupees, averaged into two slabs.[11]

Table 3: Connected Electrical Load and Hourly Use

	Power (watts)	Qty	Hrs	Total Wh
Lighting Load				
Energy Saver Lights	24	8	16	3072
LED Bulb	10	10	16	1600
LED light	18	5	16	1440
Total				4512
AC Load				
Inverter AC (1-ton unit)	900	2	8	14400
Inverter AC (1.5-ton unit)	1200	1	10	12000
Refrigerator	180	1	24	4320
Total				30720
Computer Lab Load				
Computers	200	12	8	19200
Laptop	40	10	10	4000
Laser Printer	450	1	1	450
Inkjet Printer	80	1	1	80
Total				23730
Inductive Load				
Ceiling Fan	80	6	8	3840
Exhaust Fan	60	2	8	960
Bracket Fan	60	1	12	720
Other Appliance				
Water Dispenser	100	1	2	200
Pump-motor (1 HP)	750	1	1	750
Energy Consumptions				KWh
Energy Consumed per Day				67.032
Energy Consumed per Month				2010.96

Table 4: Energy Pricing

Energy Price Calculation			
Units kWh	2010	Rs/kWh	Price (PKR)
Slab 1	1-700	19.55	13,685
Slab2	701-1310	22.65	29,671.5
Price Before Taxes			43,356.5
Other Charges GST, ED , Qtr, FPA			13,116.5
Total Price			56,473

4.2 On-Grid Supply

The bidirectional external electrification of VTS building from 132KVA grid station with 11KV Feeder having 220volt service connection agreement between consumer a local distributor. The continuity of supply depends upon the availability of electricity on the bus bar of 132KV grid Station feed from national grids connected with the National Transmission and Dispatch Network of Pakistan [12].

4.3 Selling Electricity to Grid

Selling electricity to the Grid means adding energy to national grid networks. It is not a simple process. Every consumer in Pakistan who want to become a seller must have a license from NEPRA (National Electric Power Regulatory Authority) act as the regulator of the Power sector of Pakistan, responsible for controlling the generation and dispatch regulation. Power tariff is calculated based on the energy mix. A uniform Power tariff was implemented throughout Pakistan implemented by NEPRA.

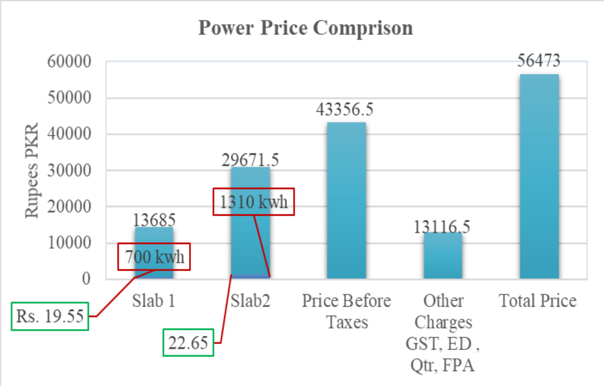

Fig. 4. Total Energy Pricing (Pkr)

After getting permission and tariff agreements under NEPRA net metering act, a consumer becomes Independent Power Producers (IPP) and can sell extra energy to area power distributor on certain terms and conditions that may not violate the safety and the PV plant will not cause any interruption to smooth running current distribution system. A synchronized mechanism and bidirectional metering panel complete system is called an energy-condenser, a device that can easily send and receive energy to and from the grid. A bidirectional meter can record the different parameters like active and reactive power, running a load of consumer, maximum demand indications, and energy sent and received from the grid[12]. A back-end network monitoring (NMC) terminal is used to check all the parameters, including energy transport, consumer running load and faults during operations by NMC.

So, the inverter is the most common and commercially available device when combined with sync operation to become a condenser for bidirectional energy transport. Table 4 shows the cost of electrical energy purchased from the grid is Rs. 22.65 per kWh and Rs. 8.64 per kWh for sale back to the grid, reference to NEPRA Tariff Guide[11][12].

Table 5: Electricity Tariff

Grid Purchase (Rs/kWh)	Sellback Tariff (Rs/kWh)
22.65	8.64

4.4 Proposed on-Grid PV Model

The proposed system model comprises of solar PV array of 20KW, and a grid-connected inverter of 18 kW capacity fig. 1. The simulation model in HOMER of the proposed system is shown below. The PV array assumed is Generic Flat Polycrystalline PV with an efficiency of 20 %. A minimum loss inverter is selected with 90 % efficiency. The installation cost of the solar inverter was considered the best available in the local market as Rs.19800 per kW with a replacement cost of Rs.19800 kW and operation and maintenance costs were assumed as zero, invertor is taken as life15 years as device data sheet inverter table 5. The system is considered to have a lifetime of 25 years.

Table 06: PV System Component Pricing

Market Available PV System Price in Rs.				
1 Watt	1kW	10kW	20kW	**PV System**
65	65000	650000	1300000	
Grid Tied Inverter Price in Rs.				
1Watt	1kW	10kW	18kW	**Invertor**
19.8	19800	198000	356000	

Table 07:Annual PV Energy Production

	Energy Production	
	kWh/Year	%
PV Energy	37576	82.5
Grid Purchase	7959	17.5
Total	45536	100

5. Result of Simulation

The optimization was performed on Homer Pro, and the best model was selected out of 148 iterations. The most suitable configuration of PV systems fulfilled the projected demand in a reliable way at the cost of Rs.4.89 /kWh. Thus, the main question that is solved from this study was that the PV energy mix-up reduced energy cost by 67% and dependability on the local distributor grid. So, it is an improved energy model as PV energy penetration is 82.5%. Moreover, it is CO_2 free hybrid green energy generation. The study under consideration has analyzed the best configuration of a hybrid RE system is meeting demand in a realistic manner. Simulation results are given in table (8).

Table 8: PV Sizing and Optimized CoE

Grid (kW)	PV (kW)	Converter (kW)	COE (Rs/kWh)	RE Fraction %
1000	20	18	4.89	80.9

Table 9**:** Energy Import and Export to the Grid

Grid Purchase kWh/Year	Sale to Grid kWh/Year	Demand kWh/Year	PV Production kWh/Year
7959	17232	24455	37576

The result of the total 80.9 % renewable energy fraction with the cost of energy of Rs. 4.89 per kWh is listed below in table 8.

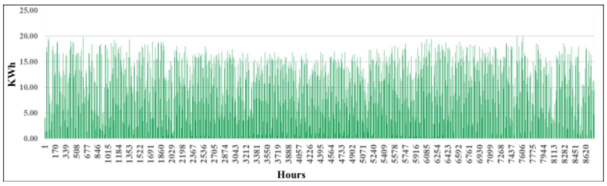

Fig. 4. Total PV output energy

Fig. 4. shows the plot of energy (kWh) produced per hour by a solar power plant as a function of time so for 8766 hours for a year. The value of the power was recorded every hour, a discrete set of points showing hourly energy production. From the results, highest hourly energy production was 20kWh and for one year, it is 37576kWh against the demanded energy 24455KWh.

Fig. 5 gives the hourly stable electric load served by the PV plant with a maximum up to 18kWh and a minimum of 1kWh for one year as per available solar irradiations.

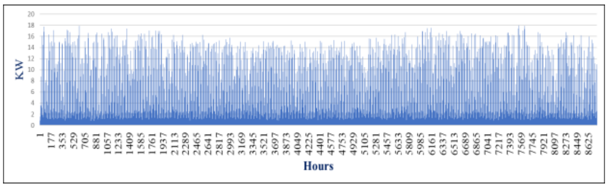

Fig. 5. Yearly AC load served

For the economic viability of the PV plant, it is very important to know how much power is served to the load, saved, and sent back to the grid, benefit to cost assessment. Fig. 6 shows the power (watts) import/export to the distributor grid. For minimum building load, the plant exported a maximum of 14kW in one hour to the grid in months July-August.

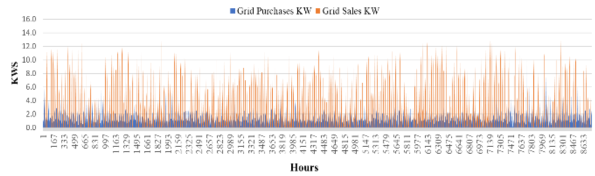

Fig. 6. Yearly energy import and export to the grid

Table 10: Project Emission Reduction Data

Emissions		
Contents	Kg/years	Total Project Life (25Years) Kgs
CO2	5030	125,750
SO2	21.8	545
NOx	10.7	267.5

Economic projection was assessed with total of 67% energy savings per year, amounting to Rs. 3712250. Project net present cost estimated as 2.21 million (Pkr), return on investment is 26%, internal rate of return is 31% and payback period is 3.3 years. So, project is feasible as cost of energy reduced significantly.

6. Emissions Reductions

Projcet second objective was to reduce CO_2 and other GHGs, table 10 shows that this project will reduce the CO_2 factor by 125,750 Kgs , SO_2, 545Kgs including NOx 267.5Kgs at the completeion of project life 25 years.

7. Conclusion

Pakistan's current energy scenario gives a vital importance to develop a sustainable energy system to resolve the energy crisis and mitigate greenhouse emissions. Techno-economic analysis for implemention of on-grid PV system revealed that the project is feasible with an entire PV electricity generation of 82.5% and grid purchase of 17.5%. Total renewable peneteration was 80.9% with the estimated cost of energy Rs.4.89 per kWh. Saves 67% enegry expenses per year by serving the 58.5

% of VTS building elctrical load from PV generated energy. The Project finacial achivements are, IRR is 26%, RoI is 31% and pay back period is 3.3 year. Finaly the CO2 emission reduction for complete project life. Over all project main objective are achived.the proposed model can also be implemented for simmilar educational schools near about VTS Baluchistan and area with the same climate conditions.

Acknowledgement

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