IMPROVED POWER FLOW RESILIENCE IN GRID-CONNECTED PHOTOVOLTAIC SYSTEMS USING PV DESIGN SOFTWARE

Zeeshan Ahmad Arfeen[1*] – Syed Kamran Ali Shah[1] – Zeeshan Rashid[1] – Shahrin Md Ayub[2] – Sardi Salim[3] – Muhammad Rashid[1] – Zain-ul-Abiden Akhtar[4] – Saleh Masoud Abdallah Altbawi[2]

[1]Department of Electrical Engineering, The Islamia University of Bahawalpur (IUB), 63100 - Bahawalpur- Pakistan
[2]Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 JB Johor, Malaysia
[3]Faculty of Engineering Universitas Negeri Gorontalo, Indonesia
[4]Department of Information and Communication Engineering, The Islamia University of Bahawalpur (IUB), Bahawalpur- Pakistan

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Abstract:

Traditional electrical generation methods are expensive with disturbing ecological effects and excessive maintenance costs. So, combat with contemporary scenario, alternative sources of energy that are environmental friendly are adopted. This research is marked by an efficient, economical ON-Grid Photovoltaic (PV) system installation in Lodhran City, in the South Asian country Pakistan, to solve this forthcoming issue. Lodhran is a place where the intensity of the sun's power is quite high. The Global Diurnal Horizontal (GDH) sun insolation at the proposed location is 1828 kWh/m2, having gross sun insolation is 5 kWh per m2 per day whilst the gross temperature is 27.45° Centigrade. In this paper, the variant potential deficits, decrements prices in photo voltaic module, inverter efficiency, and temperature variation are given dire consideration and calculated by the PVSyst software. By the smart installation of solar panels, the industry can save 1003-ton coal per day i.e. equivalent to planting 50,000 trees over a whole lifespan. From the software, the numerical value of the performance ratio reaches 68.8%, and the total units generated per year is 1758 MWh. The performance parameters of the grid-tied system can be enhanced by the modeling, analysis, operation, and maintenance of grid-tied networks for different sites near the model city Lodhran in southern Punjab.

1 Introduction

Global energy demand is predicted to rise by over 25% by 2040, according to the 2018 World Energy Outlook [1]. Given the world's growing energy needs and the need to transition away from fossil fuels in order to fight climate change, solar cell technology is significant [2]. One of the most fundamental renewable energy sources that has rapidly evolved over the past ten years is solar energy. However, its erratic and intermittent nature may cause issues with the solar energy produced [3]. They are the power generation resource with the quickest rate of growth. Of all the renewable energy sources, they also exhibit the highest power density. In addition to this, they don't create any pollutants when in use and require no upkeep, making photovoltaic a crucial component of our energy future. The solar sector must drastically increase its installations and manufacturing capacity due to the global energy market's unpredictability, supply instability caused by weather and geopolitical events, and the pressing need to decarbonize. Administrative authorities must take the initiative to utilize renewable technology in light of the world's unavoidable growing demand for energy.

*Corresponding author:
zeeshan.arfeen@iub.edu.pk

Utilizing these renewable energy sources (RES) effectively is a strategic objective to lessen reliance on fossil fuels and to offer affordable, dependable, and high-quality services to the [4]. Because the whole world produces electricity around 49% of total energy production is from fossil fuels and only 5% from Solar Energy sources. This high use of fossil fuels will decrease our fossil fuel resources shortly. The generation of electricity of world from different resources is shown in Figure 1.

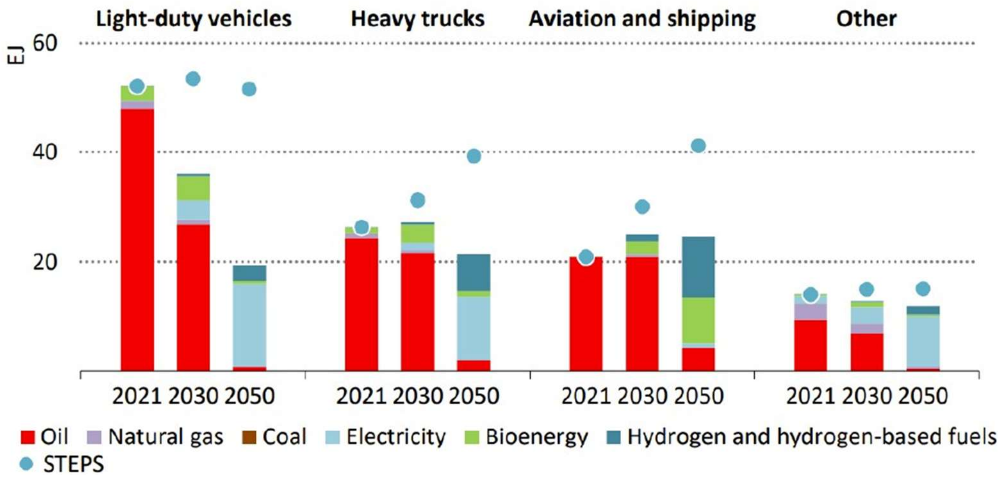


Figure 1. Energy consumption in transport by contemporary sources in the net zero emission EZE scenario, 2021-2050 [5]

In Pakistan, the region's power generation zone is not very abundant. The main root of this status of electricity dearth. Moreover, the country's major dependence mostly relies particularly in 10 decades on traditional energy [6]. The solution to this energy crisis is moving toward alternative energy resources. In this scenario, solar power is among the superb sources of energy that is abundantly available for countries like Pakistan which is located in the Asia continent rich in solar energy [7]. Throughout human history, solar energy has been essential for powering homes, businesses, and automobiles [8]. There are few doubt that now is the time for PV to shine. As the installation of solar PV is an environment-friendly, pollution-free, and cost-efficient power generation. Sun energy is universally available in abundant amounts of high intensity. Low-carbon parameters have frequently been added to the target function for carbon emission or carbon cost limitations in recent years [9].

Moreover, as compared with other conventional sources the maintenance cost of solar Photovoltaic is very low. Various configurations of Photo Voltaic modules and network strategies were discussed that would help in the planning and modeling of solar plants [10]. The techno-economic feasibility study was conducted which helps in analyzing the performance of the most economical RES in Pakistan after a detailed comparison of the different solar systems in the country [11]. In ref [12], a comprehensive economic optimization for off-grid renewable energy systems was carried out for small loads. Pakistan, a developing country is facing a lack of generation of electricity due to high fuel prices. In this regard, the government has started the project to install solar plants at all educational and government buildings across the country.

As fossil fuels are depleting rapidly shortly, relying on renewable energy sources for the smooth availability of electricity is mandatory. By implementing renewable sources, one will protect the environment from pollution. Among all the RES- solar energy has the maximum potential to fulfill the demand. Monocrystalline panels have higher efficiency than polycrystalline. For a seamless output from solar panels Output from solar panels one should monitor the environmental factors continuously. There is some software like HOMER for designing and optimizing PV plants. Although HOMER software is used for optimization to find the optimal cost for PV plants. But PV Syst software has a cutting edge over HOMER because PV Syst software can design PV systems in three conditions ON-Grid, OFF-Grid, and DC system. Moreover, PV Sys also has all types of libraries of PV modules and inverter for optimizing the simulation of the PV system.
This work shows the simulation-based outcome of the southern Punjab region of Pakistan with actual data on location is plotted. The main purpose is to shift towards renewable PV energy for the Quaid-e-Azam Solar Park, Bahawalpur, Punjab. Thus, this paper will help these sorts of schemes in the Punjab province of Pakistan,

for meeting its load requirements instead of the conventional energy coming from Water and Power Development Authority (WAPDA). The modeling and simulation of a solar plant at a solar park were carried out by using PV Sys [12]. Furthermore, the growth of the modern financial circumstances and ecological operational conditions in an actual solar plant must be established and assessed. A comparison between the traditional WAPDA system and the proposed PV plant is conducted. The reliability along with efficiency of PV systems that connect to the grid faces difficulties because of temperature changes and power quality problems and equipment inefficiencies. Pakistan can maximize its solar resource potential by improving system designs and real-time performance evaluation and integration strategies despite its substantial solar resources.

The system performance is investigated with the following objectives:

- Modeling of Solar Plant
- Real-time simulation of solar installation at the model city Lodhran. The simulated temperature per month is 27.45C^0 and the practical temperature per month of the site is 32 ^{0}C which is quite near to the actual value. That's why the proposed plant will work efficiently.
- The per unit price is 0.11$/kWh which is quite good as compared to Quaid-e-Azam Solar Park (QASM) which has a per price is 0.13$/kWh.

The prime research contents of this research are as follows. Section-2 is about methodology and the system modeling. Section-3 contains the planned PV plant results, and a relative comparison of proposed system is embedded . Section-4 ended with a conclusion including future perspectives.

2 Experimental investigation

A PC program called PV SYST 7.2 is used for PV system sizing and data analysis. Along with comprehensive Mateo information and PV systems components databases, it covers grid-connected, stand-alone, pump, and DC-grid transportation with PV and systems. It also offers general solar energy tools.

In Figure 2, it is shown that the majority of countries shift toward renewable energy sources (RES) for energy generation. This is due to free and environmentally friendly particularly Solar. That’s why, South Asian countries also moving towards RES. It will save a lot of time and money for a country that is in developing. The Model City is situated in the town of Lodhran on the southern in Punjab, Pakistan. Longitude data and the Latitude of the Model City are 29.56° N and 71.65° E respectively. The site is 6 km away from Lodhran city, and the total area available for the Solar Power Plant is around 2.47 acres. Solar insolation data of Lodhran city was sourced from NASA’s Surface Meteorology and Solar Energy database [14], providing monthly averages for 15 years (January 2007–December 2022).

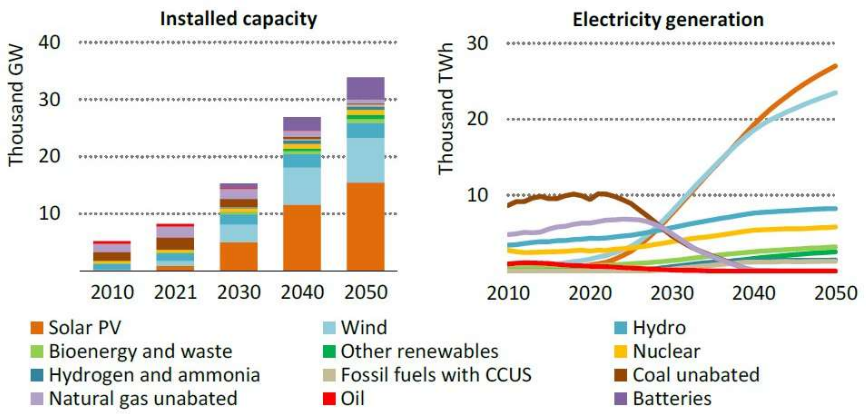


Figure 2. Installation capacity and generation of the electricity by source in NZE scenario [5]

Here from Figure 2 the gross electricity production is nearly three times in 2050, with a sharp rift far from unabated raw coal and gas to lower-emissions resources, coined by sun PV and wind.

As depicted in Figure 3, solar insolation peaks at 6.75 kWh/m² in May and drops to 2.5 kWh/m² in December, with an annual average of 4.93 kWh/m². Monthly solar energy output fluctuates due to variations in solar irradiation solar irradiation.

Figure 3. Average monthly insolation of model city, Lodhran

The installation and generation of energy from the proposed site are ideal due to its location at a deserted place which is the best place to meet load requirements and gain profits. The specified parameters were optimized to achieve maximum efficiency for the highlighted location, as illustrated in Figure 3. While in Figure 4 identifies the proposed site for PV Plant at model city Lodhran.

Figure 4. Proposed site of a photovoltaic plant

One natural resource that can be used for renewable energy is solar. Sunrays' scientific encounter is too convex, translate, store well, and take advantage of RES at a fair price. PV modules convert solar energy directly into electrical current. Photovoltaic (PV) cells, primarily made from crystalline silicon, form the core components. Converters are necessary to transform DC power into AC, ensuring compatibility with electrical grids. Digital energy meters monitor AC/DC voltage, current, and energy production to evaluate plant performance parameters [15].

2.1 PV Modelling

Because of its sustainability and ease of use in producing power, photovoltaic energy is thought to be the most popular alternative production choice. However, the intermittent nature of the PV modules causes cut-off. Regardless of output power variations in PV inputs, energy storage systems like batteries, fuel cells, and super-capacitors are incorporated to ensure consistent power delivery to consumers [16]. Figure 5 shows the single-diode model of the PV Module.

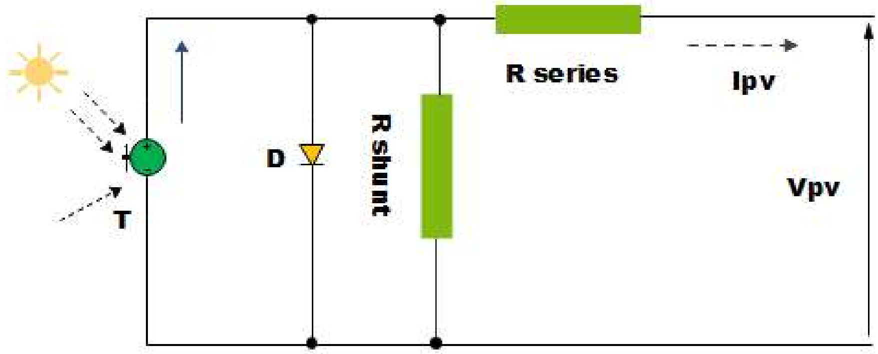


Figure 5. Schematic diagram containing a single diode

The most important factor in designing PV system is solar irradiance. Irradiance is stated as the quantity of power discharged via the sun and hits on the one-meter sq. every moment open-air environment of the globe. It refers to the energy striking a unit area within a specific time interval [10]. In the next section, it is discovered that the best spot for installation of solar panels and parameters for designing the SPV system for better production from solar plant. The insolation of the region is found by the formula given:

$$Irradiance = \frac{Average\ Isolation\ of\ area}{Average\ bright\ sun\ /hours} \tag{1}$$

The average insolation of the region divided by the average of the daily bright sun per hour. Lodhran is identified as a prime location for solar installation [17]. Prime metrics and parameters for this site are detailed in Table 1 as provided the site data to PV SYST software.

Table 1. PV Plant parameters of the proposed site.

Parameter	Value
Consideration area for Plant	2.47 acres
Long and Latitude	71.65 east, 29.56 north
Global Horizontal Insolation (GHI)	5kWh per m^2 per day
Diffuse Horizontal Insolation (DHI)	2.35 kWh per m^2 per day
Global Insolation for optimally Tilted surface (GTI)	5.54 kWh /m^2 / day
Direct Normal Insolation (DNI)	5.389 kWh /m^2 /day
Efficient Temperature	27.45 C^0

$$Irradiance\left(\frac{W}{m^2}\right) = irradiance * kWhr * \frac{1000}{hours} \tag{2}$$

Maximum Power -

$$P_{max} = V_{max} * I_{max} \tag{3}$$

The efficiency of PV module -

$$\eta_{max} = \frac{(P_{max})}{S.I * A} * 100 \tag{4}$$

The model and the apparatus of the plant are distributed into the given groups: DC energy, AC energy, and programmed governing of this apparatus using SCADA. The model and apparatus of the project are SCADA [18]. Figure 6 shows the block diagram of the project. All equipment has owned its worth in the process. The Components for working and supervising the system contain of SCADA, PLC and also contain weather monitoring systems and MPPT systems. The control system facilitates access to essential information at any time displayed with the help of an LCD. It also displays faults in any solar module so the fault can easily be fixed.

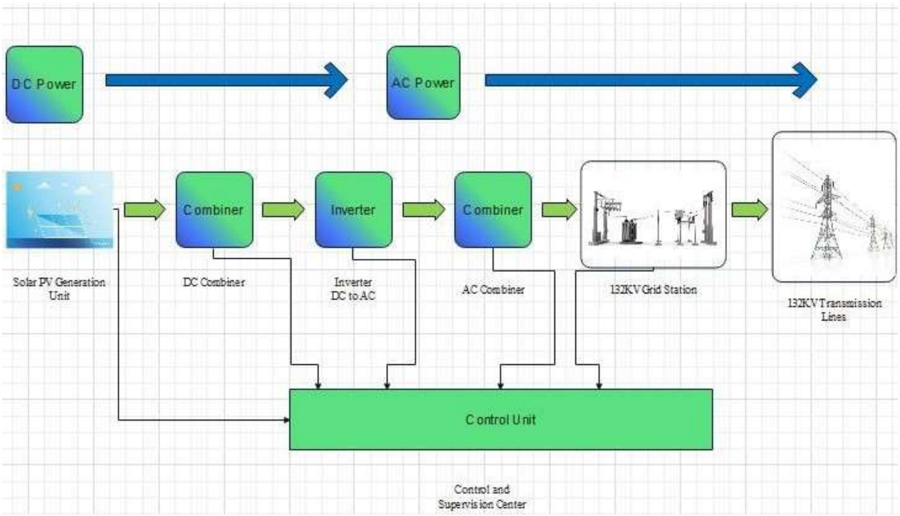


Figure 6. Schematic diagram of PV plant

2.2 Maximum power point tracking

Perturb and Observe P&O algorithm is frequently utilized in MPPT controllers as it is simple to implement. The fundamental idea of MPPT P&O is dependent on the power and voltage conditions [19]. If the output voltage of the PV network is distributed and the power demand absorbed from the PV network increases, this leads the algorithm to push the operating point of the voltage in the existing direction to be near the MPP point. Therefore, the operating point should be more than the perturbed voltage in a similar direction. Conversely, if the demand power decreases, and the operating point changed to be far away from MPP. To be close to MPP in this situation, the algorithm needs to run in the opposite direction of the perturb voltage [20]. It states that the power (P(k)) is computed when the current (I(k)) and voltage (V(k)) are measured following each perturb execution. The prior disrupt execution is then contrasted with this one. The algorithm maintains the operation in the same direction (C=0) if the errors of voltage (e(V)) and power (e(P)) are greater than zero. If not, the algorithm will attempt to move the operational point closer to MPP in the other direction. where C is the difference between the output voltages from the prior output (V_ref (k-1)) and the present output (V_ref (k)). In Figure 7, the traditional MPPT P&O is delineated below.

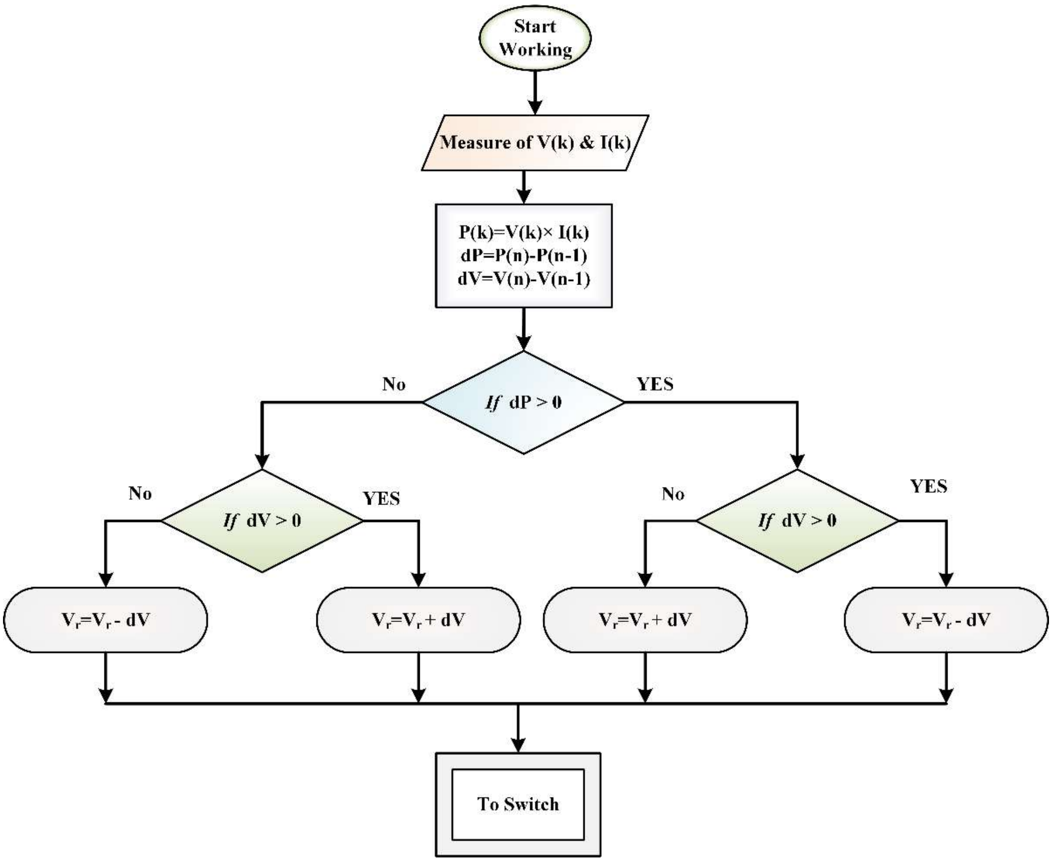


Figure 7. Flow diagram for MPPT P&O algorithm

2.3 DC System

This part handles the direct current generated from solar modules and also combines it. It came under the DC system, category. In any solar generation plant PV module is a very important part. The main purpose of the Photovoltaic module is to transform solar power into electrical power [21]. In the market, there are many types of PV modules available. Table 2. Shows the effectiveness of various solar panel types:

Table 2. Manufacture types of Solar panels [22].

Sr. #	Solar Plate Type	% Efficiency
1	Slim Film	7-10
2	Mono-crystalline	12-16
3	Amorphous Silicon	6-8
4	Polycrystalline	12-18

The Poly-Crystalline-Si module is used for plants located at sites like Lodhran because Si Module has high tendency to bear high temperatures and work efficiently at a very high temperature than its normal working temperature [23]. The next part is DC Combiner whose work is to sum direct current produced via PV modules.

Next part is the Inverter whose job is to convert DC from PV modules into AC for transmission because AC transmission is being used for transmitting electricity.

2.4 AC System

It handles each part which work with AC. The important elements of AC systems are examined here. AC combiner case whose job is to combine all alternating current from the inverters. If we choose an inverter for a project that has the in-built function of an AC combiner, so, there is no need for an external AC combiner. The environment is an important factor for a solar plant. For example, if irradiance increases then definitely output power increase, but if panel temperature exceeds the efficient temperature of the panel it will minimize the productivity of the plant [24]. On cloudy and humid days there is a hindrance to energy generation because the wavelength of the spectrum from the sun is starting to be absorbed by the atmosphere. Sun rays do not hit effectively solar panels. In brief, it will have short potential wavelengths that will touch the earth which is not enough to complete the energy band differences of the Photovoltaic panel [25].

The Components for working and supervising the system contain of SCADA, PLC and also contain weather monitoring systems and MPPT systems. The controlling system will enable us to require any information at any time displayed with the help of an LCD. It also displays faults in any solar module so the fault can easily be fixed.

2.5 Inverter

This study employs TC 630KH TBEA Xi'an Electric inverters to mitigate harmonics generated during DC to AC conversion. Two 630 kW inverters support the current module.

2.6 Solar PV Modules

There are many options for PV plates but for the proposed work use a PV plate of JA solar company rating 260W. By using the mathematical formula, it is easy to calculate the number of PV modules for designing of 1.7MW solar PV plant on-grid system [26]. No. of plates should be installed for 1.7 MW = 4860 PV plates (rating 260 W). The PV plates which have been chosen for this project are manufactured by JA Solar China. Table 3 shows the unit consumption of Model City, Lodhran in the years 2020 and 2021, by this it is easy to predict the load variation that comes shortly as indicated by the MEPCO bill.

Table 3. Energy Consumed by the Model City (kWh) in 2020-2021.

Month	Energy Consumed in 2020, (kWh)	Energy Consumed in 2021, (kWh)
January	1,040	1,462
February	1,840	1,536
March	1,240	1,326
April	1,200	1,493
May	1,866	1,240
June	1,266	1,590
July	1,320	1,496
August	1,450	1,328
September	1,336	1,552
October	1,558	1,858

November	1,430	1,140
December	1,660	1,280
Total (kWh)	17,206	17,301
Average per year	1,434	1,442

2.7 Power quality and harmonics

When active power filters (APF) aren't operating properly, power pollution is one of the main reason of generated PV into the power grids. Power quality provision is a crucial concern for grid-connected photovoltaic systems. The introduced system's ability to maintain power quality is affected by nonlinear loads, power electronic inverters, and intermittent radiation [27]. The solution to this problem is the use of filters before injecting power into the grid. These filters will filter out harmonics to some extent. If power quality is not good it will cause a reactive loss in load because the load in industry and houses is inductive. In Figure 8 a conventional scheme to improving power quality in PV plant.

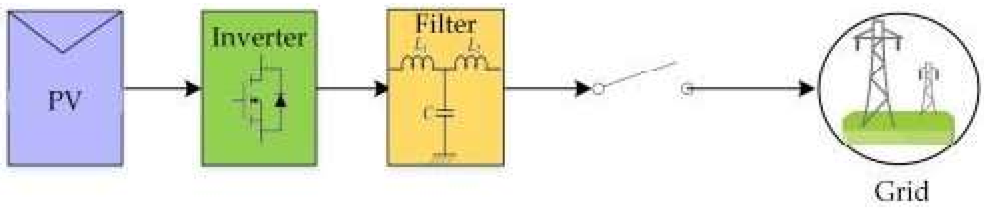


Figure 8. Power quality improvement scheme in PV plant

2.8 PV SYST

PVSyst is one of the trendiest and generally used software for the estimation of parameters & results for a solar PV plant (SPV). With extensive choices and in-built specifications, this software simulates outcomes that are very close to theoretical results. By using this software, it is easy to import Mateo and personal data for the plant sites which is the finest feature of this software. This software allows us design solar systems in three different categories Grid-connected, stand-alone, and DC grid systems [28].

The advantage of PV Software over other solar site software, it can haste 3D shading effects which have a resemblance to the actual scenarios. One can check the shading effect of different objects at the site on the solar plant and its generation. The advantage of PVSyst Software with other counterpart's software like PV Complete Solar, Homer Energy, and PVSOL, the sketch is enlisted as:

- Create a 3D shading scene that has a resemblance to the actual scenario.
- Can check the shading effect of different objects at the site on the solar plant and its generation.

Hence, the plant is modeled matching to the desired requirements. Figure 9 shows the design parameters of the system.

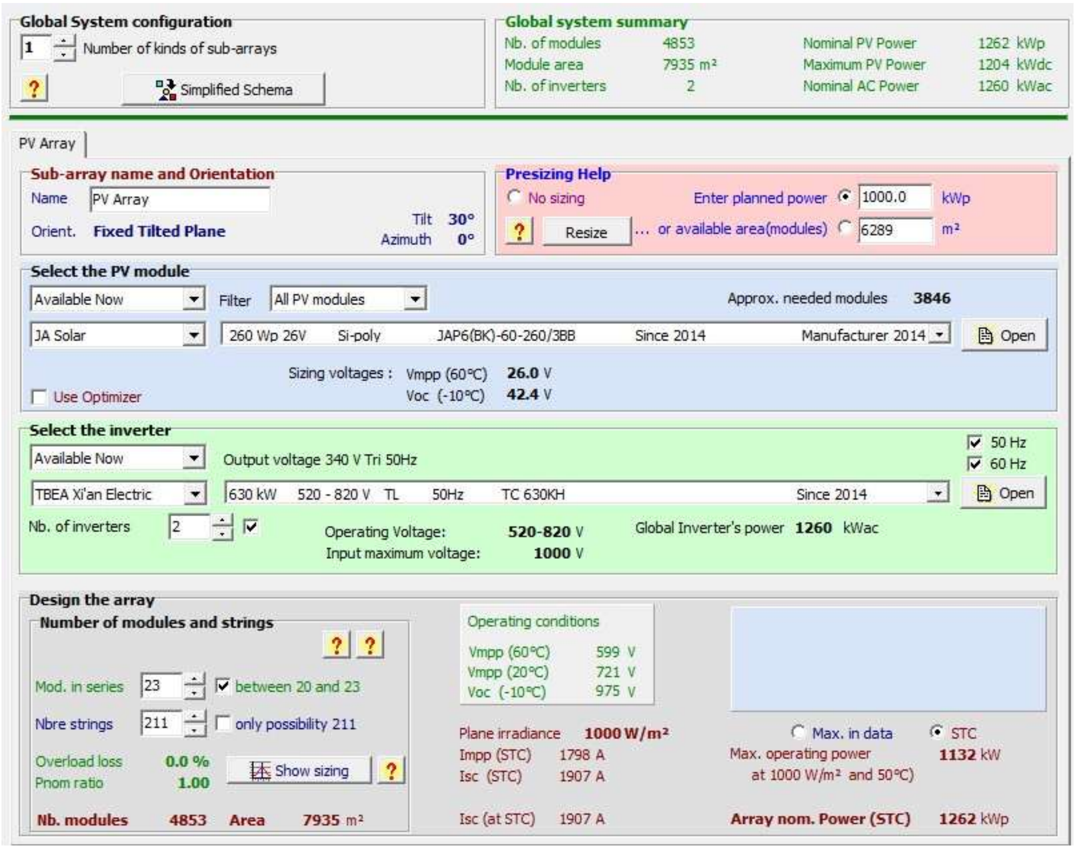


Figure 9. System modeling overview of 1.7 MW system

Further, this software (PV Syst) automatically computes the system production and different key factors by consuming hourly information. In this effort, the PVSyst is designed to calculate the yearly power generated by the 1.7 MW PV system considered for The Model City Lodhran grid-connected. Figure 10 shows the design parameters of the solar grid-connected system [29] and Figure 11 sites the location.

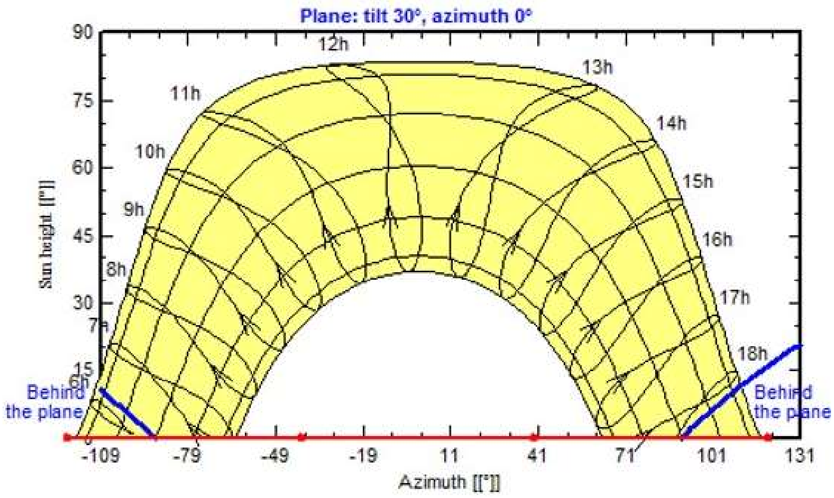
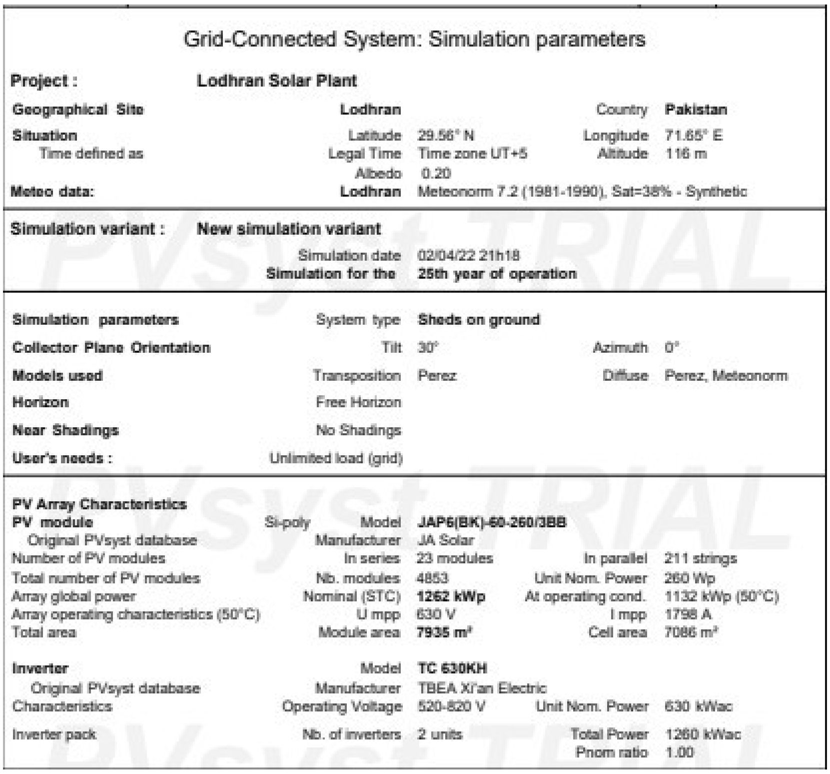


Figure 10. Obtained results after simulation



Grid-Connected System: Simulation parameters

Project :	**Lodhran Solar Plant**				
Geographical Site		**Lodhran**		Country	**Pakistan**
Situation		Latitude	29.56° N	Longitude	71.65° E
Time defined as		Legal Time	Time zone UT+5	Altitude	116 m
		Albedo	0.20		
Meteo data:		**Lodhran**	Meteonorm 7.2 (1981-1990), Sat=38% - Synthetic		
Simulation variant :	**New simulation variant**				
		Simulation date	02/04/22 21h18		
		Simulation for the	**25th year of operation**		
Simulation parameters		System type	**Sheds on ground**		
Collector Plane Orientation		Tilt	30°	Azimuth	0°
Models used		Transposition	Perez	Diffuse	Perez, Meteonorm
Horizon		Free Horizon			
Near Shadings		No Shadings			
User's needs :		Unlimited load (grid)			
PV Array Characteristics					
PV module	Si-poly	Model	**JAP6(BK)-60-260/3BB**		
Original PVsyst database		Manufacturer	JA Solar		
Number of PV modules		In series	23 modules	In parallel	211 strings
Total number of PV modules		Nb. modules	4853	Unit Nom. Power	260 Wp
Array global power		Nominal (STC)	**1262 kWp**	At operating cond.	1132 kWp (50°C)
Array operating characteristics (50°C)		U mpp	630 V	I mpp	1798 A
Total area		Module area	**7935 m²**	Cell area	7086 m²
Inverter		Model	**TC 630KH**		
Original PVsyst database		Manufacturer	TBEA Xi'an Electric		
Characteristics		Operating Voltage	520-820 V	Unit Nom. Power	630 kWac
Inverter pack		Nb. of inverters	2 units	Total Power	1260 kWac
				Pnom ratio	1.00

Figure. 11 Solar paths at Lodhran, latitude 29.56N and longitude 71.65E, altitude 116 meters

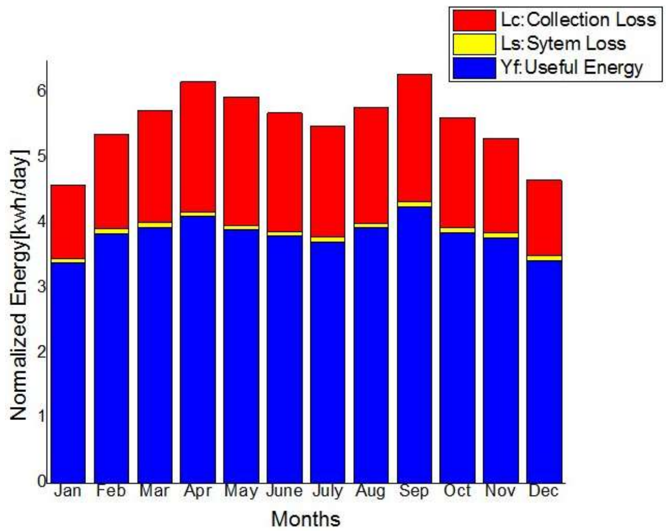


Figure 12. Output Production with all types of losses/day

Figure 12. shows the normalized energy losses for a whole year at the selected spot for the installation of the solar.

3 Results and discussion

Table 4 shows the Mateo and global irradiance data of the PV plant site which is required for simulation. Mateo values are important for determining the potential of the site. Mateo's values show that the proposed site has enough potential for a solar plant.

Table 4. Mateo Values of Lodhran- Pakistan per month.

Month	T-Amb oC	Wind m/s	GloInc kWh/m2	DifSInc kWh/m2	AlbInc kWh/m2	Dif_Gl kWh/m2
January	15.58	0.9	142.1	53.31	1.358	0.000
February	19.83	1.2	150.1	57.87	1.567	0.000
March	25.99	1.3	177.1	75.11	2.073	0.000
April	30.81	1.5	184.9	79.19	2.409	0.000
May	35.64	2.2	184.1	91.11	2.610	0.000
June	34.85	2.3	170.6	92.21	2.519	0.000
July	33.61	2.0	178.6	92.88	2.479	0.000
August	32.44	1.8	188.6	96.22	2.429	0.000
September	31.29	1.3	174.0	76.50	2.291	0.000
October	28.94	0.8	158.7	71.50	1.900	0.000
November	22.84	0.7	144.4	54.33	1.513	0.000
December	17.44	0.7	144.4	52.96	1.351	0.000
Year	27.45	1.4	2023.4	893.19	24.427	0.000

Speed of Wind at site -
DifSInc- *Sky Diffuse Incident at collecting plane*
AlbInc- *Albedo Incident at collecting plane*
Dif Gl- *Incident Sky Diffuse/Global Ratio*
E-Array- *Effective Energy at output of Array*
Grid- *Energy Injected into Grid*

Table 5 shows the main results obtained after the simulation. The maximum energy produced in September is 161011 kWh and the minimum energy produced in January month which is 132179 kWh produced by the system. The prime outcomes are annual Global Horizontal irradiance, powers, energy output, and plant efficiency. The peak power produced by the system in September is 161011 kWh at an efficient temperature of 31.29 C^0 at a Performance Ratio of 67.7%. The total energy produced by the solar system is 179065 kWh per year. The productivity of the plant is 70% which is fairly good. The complete energy that hits on the collector region is 1828 kWh per m^2.

Table 5. Main results of 1.7 MW system.

	GloHor, kWh/m^2	DiffHor, kWh/m^2	T_Amb, C^0	GloInc, kWh/m^2	GlobEff, kWh/m^2	E_Array, kWh	E_Grid, kWh	PR
January	101.4	54.05	15.58	142.1	138.7	134866	**132179**	**0.737**
February	117.0	50.41	19.83	150.1	146.5	137798	135191	0.714
March	154.8	70.32	25.99	177.1	172.4	156452	153691	0.688
April	179.9	78.44	30.81	184.9	179.7	157938	155203	0.665
May	195.5	95.50	35.64	184.1	178.4	155000	152286	**0.656**
June	188.4	99.52	34.85	170.6	165.0	146266	143599	0.667
July	185.5	99.52	33.61	178.6	164.5	147685	145032	0.676
August	182.2	99.04	32.44	188.6	173.2	155942	153139	0.680
September	171.0	92.23	31.29	174.0	183.2	163797	**161011**	0.677
October	141.9	63.84	28.94	158.7	169.8	153217	150499	0.685
November	113.0	44.70	22.84	144.4	154.9	145098	142540	0.712
December	98.2	42.81	17.44	144.4	140.9	136594	133940	0.735
Year	1828.3	861.38	27.45	2023.4	1967.5	1790653	1758300	0.689

GloHor - *Horizontal Global Irradiance DiffHor-Diffuse Horizontal Irradiance*
GloInc - *Global Incident in Collected Plane*
GlobEff - *Global Effective*
E-Array - *Effective Energy at the output of Array*
E-Grid - *Energy Injected into Grid*

Figure 13 shows the average per-month temperature of the proposed location Model City. The maximum temperature in June with 41 ^{0}C and the minimum in December with 22 ^{0}C. The average temperature per year is 32 ^{0}C which is quite near to our simulated efficient temperature of 27.45 ^{0}C.

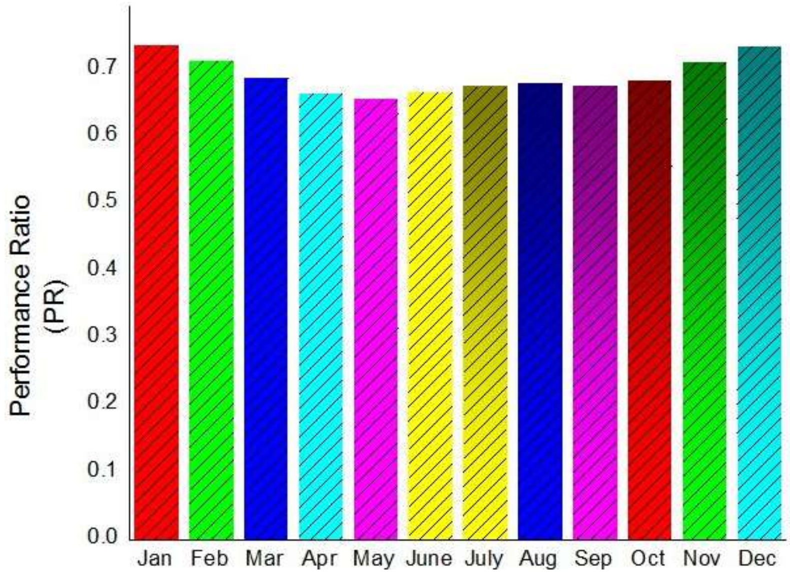


Figure 13. Performance ratio of 1.7MW system per month

Figure 13 shows the performance ratio of the plant per month whilst Figure 14 portrays the daily output of solar plants produced by solar arrays.

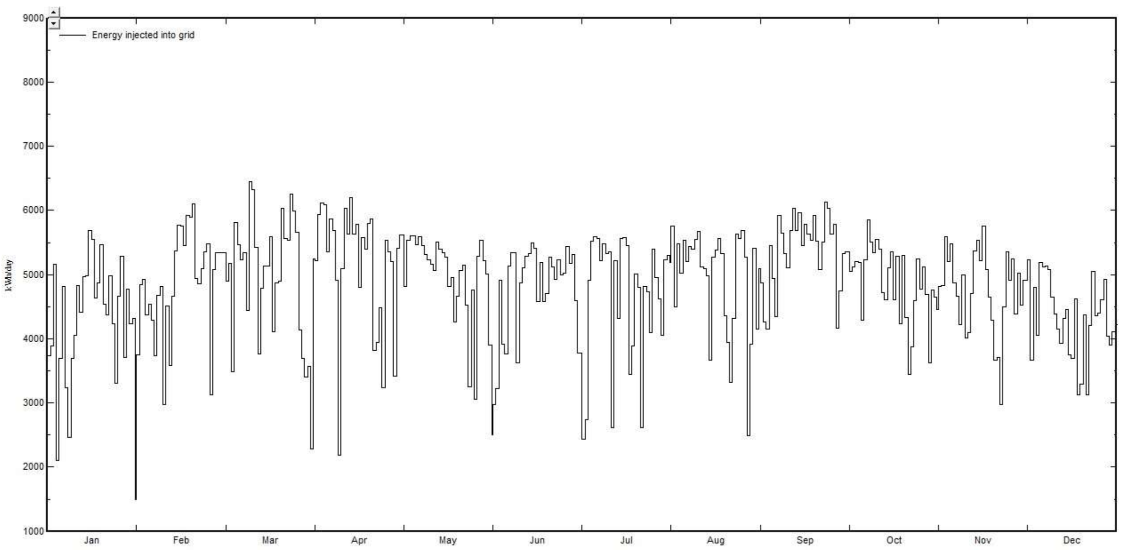


Figure 14. Daily system output energy injected into the transmission system

3.1 Comparative Study

A comprehensive analysis and implementation of the 1.7 MW solar plant at Model City, Lodhran, and a few results are drawn from a comparative study.
1. The overall energy produced from the PV array is 1790653 kWh per year at an efficiency of 70%.
2. The average yearly performance ratio is 68.9% with a minimum performance ratio of 65.6% in May and a maximum performance ratio of 73.3% in January at Model City, Lodhran.

From the Simulation Results, the average performance ratio obtained is 68.9% which is quite satisfactory. By implementing the solar plant, we will be able to save around 2000 kg of trees per day from burning. Energy from renewable sources has a positive environmental impact, unlike thermal power plants (TPPs), which emit significant greenhouse gases (GHGs) such as CO_2, SO_2, NO_x, SO_x, and ash. The environmental footprint of the selected plant has been similarly evaluated [30]. In this way, the environment becomes protected from pollution [31]. The current research will help in installing an efficient solar plant near Model City, Lodhran location.

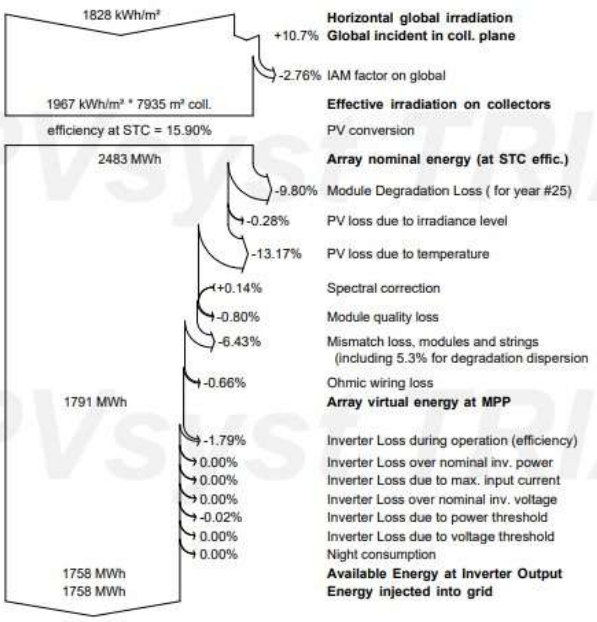


Figure 15. Delineated losses of the system in different sections, such as inverter and array losses

The most prime factor that should be undertaken cautiously whilst designing is power is network losses. It shows a key role in the computation of power output. Here in the proposed system, the above mentioned Table shows that GHI is 1828.3 kWh/m2, and the efficient irradiation which falls in the day time on the collector plane is almost 2023.4 kWh/m2. So, inevitably, gross system loss in the energy is (0.7- 1) %. Figure 15 shows the loss diagram over the whole year. Albeit, several unpredictable losses incurred in the network that may not be precisely measured in the simulation findings in real sense.

The proposed solar plant is compared with the Quaid-e-Azam solar plant QASP. The PR, rate of power, and transfer losses in contrast with QASP are tabulated in Table 6.

Table 6. Comparison between Proposed 1.7 MW Plant & QASP.

Solar Plants	PR	Efficiency	Energy Output, MWh	Cost of Energy, $/kWh	Maximum Energy, generated, kWh	Minimum Energy, Generated, kWh

Lodhran City	68.8%	70%	1790	0.11	161011	132179
QASP	65.5%	12%	100	0.13	8000000	13000000

The PR of the proposed plant is 68.8% while QASP has a PR of 65.5%. The cost of generation of the proposed plant is 0.11 $ per kWh and QASP has a cost of generation is 0.07 $ per kWh which is quite near to the obtained results. But proposed is more efficient than QASP in the manner of performance ratio (PR).

Table 7 provides a comparative analysis between the proposed 1.7 MW solar PV plant, and a traditional fossil fuel power plant in terms of efficiency, energy output, costs, and environmental impact.

Table 7. Comparison of the Proposed 1.7 MW Solar PV Plant with Traditional Fossil Fuel

Parameter	1.7 MW, Solar PV Plant	1.7 MW, Fossil Fuel Plant
Capital Cost	~$1.02M	~$1.5M–$2M
O&M Cost/Year	~$15,300	~$100,000+
Fuel Cost	$0 (Sunlight is free)	$300,000+ per year
Lifespan	~25 years	~20–30 years
Payback Period	~5.2 years	~8–10 years
ROI (25 years)	345%	100–150%
CO_2 Emissions	Zero	High (Coal: 900g CO_2/kWh, Gas: 450g CO_2/kWh)
Environmental Impact	Minimal	High (GHG emissions, pollution, coal ash, etc.)

4 Conclusion

The present research shows in-depth results and simulation of solar power generating station at Model City, Lodhran. Yearly power production, power metrics and losses in the system along with the future recommendations regarding the energy crisis are also included. The aforementioned tables highlighted that the maximum energy produced in September 2021 is 161011 kWh and the minimum energy produced in January 2022 which is 132179 kWh. The overall energy yield from the PV array is 1790653 kWh per year with an efficiency of 70%. The average yearly performance ratio (PR) is 68.8% which is quite significant with a minimum PR of 65.6% in May and a maximum PR of 73.3% in January at Model City, Lodhran Location. From this work, the calculated per unit cost comes 0.11$/kWh which is quite good as compared to Quaid-e-Azam Solar Park (QASP) which has per price is 0.13$/kWh. By the installation of the Solar Lodhran Plant, the Sun fuel generating station will be able to save around 5000 kg of trees over a whole life span.

The efficient temperature that comes out from the simulation is 31.29 ºC and the practical average temperature is 32 ºC which is quite near to the simulated value. This concludes that PV plant will produce power efficiently at the proposed site Model City, Lodhran.

This research furnishes useful information for site identification and project compatibility evaluation for installations of solar plants across the globe. It also allows the analysis of performance in solar facilities. The information used is presented to identify the operational and environmental benefits of solar photovoltaic projects in terms of net energy yield. Both theoretical perspectives and actual operational experience can guide planning for larger-scale projects in the future. Such projects can assist in resolving energy deficits and minimizing overall energy expenses. Future research needs to investigate the influence of environmental factors such as, sand storms on PV panels in Lodhran district to overcome operational system issues.

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