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Research Article

Modeling and Analysis of 3 MW Solar Photovoltaic Plant Using PVSyst at Islamia University of Bahawalpur, Pakistan

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Conventional means of electrical energy generation are costly, create environmental pollution, and demand a high level of maintenance and also going to end one day. This has made it crucial to exploit the untapped prospective of the environmentally friendly renewable energy resources. To address this problem, present research proposed an efficient, everlasting, and environment-friendly grid-connected PV system at The Islamia University of Bahawalpur, Pakistan (latitude: $29^\circ\ 22'\ 34''$ N, longitude: $71^\circ\ 44'\ 57$ E). Bahawalpur is one of those sites where the potential of solar energy is immense. The global daily horizontal solar irradiance at the site is 1745.85 kWh/m^2, having average solar irradiation of 5.9 kWh/m^2 per day, and the ambient average temperature is about 25.7°C. In this research, the performance ratio and different power losses just like soiling, PV module losses, inverter, and losses due to temperature are taken into account and calculated by using PVSyst. The coal saving per day is 15369.3 kg which is equal to planting 147600 teak trees over a lifetime. The cost of the energy produced is 0.11 US $/kWh whereas in Pakistan the conventional energy tariff is 0.18 $/kWh. From the simulation results, the value of PR comes out 83.8%, and the CUF value is 16% with a total energy generation of 4908 MWh/year. The performance analysis of this grid-connected system would help in the designing, analysis, operation, and maintenance of the new grid-connected systems for different locations.

1. Introduction

The circumstances of the energy zone in Pakistan are very miserable. The primary cause for this situation of the electricity shortage is that we had completely depended on conventional energy means in the previous 2 decades. The only way to sort out energy issues at this moment is to move towards renewable energy sources. In this regard, solar energy is one of the best renewable energy sources abundantly available for countries like Pakistan.

The installation of solar PV (SPV) is an environmentally friendly project. Solar energy is free and present in sufficient amounts in almost every part of the world. Moreover, the maintenance cost of solar PV is very low as compared with other conventional sources [1].

Different types of the PV modules and system schemes were discussed that would help in planning the different renewable energy systems schemes in [2]. Techno-economic feasibility study was conducted which helps in analyzing the performance of the most economical renewable energy system in Pakistan after the detail comparison of the different hybrid energy systems [3]. A detailed economic optimization for off-grid renewable energy systems was assessed for small loads [4].

Pakistan, a developing country, is facing a load shedding problem due to the lack of generation of electricity through the country. The government has initiated the project to convert all the educational institutes of the country to renewable sources. This research provides the benchmark for these types of initiatives in the country.

This paper presents the simulation-based results of the specific area of Pakistan with real-time data of location. The main aim is to replace the conventional energy coming from WAPDA and producing renewable solar PV energy for The Islamia University of Bahawalpur, Pakistan, for meeting its load requirements. The technical sketch of the solar PV system for IUB is simulated by using the PVSyst software and analyzed each element for designing the plant. Furthermore, the evolution of the current economic condition and environmental conditions in the real solar plant is ought to be compared and conducted. The comparison of the results of the proposed PV system with the conventional system of WAPDA is also conducted.

The rest of the paper is arranged as follows: Section 2 gives the site survey for PV plant installation. The modeling of renewable energy system using PVSyst will be presented in Section 3. Section 4 comprises of proposed system results, and comparative study will also be discussed in this section. At the end, the conclusion and future recommendations will be highlighted.

2. Site Survey

Islamia University of Bahawalpur (IUB) is located in the city of Bahawalpur in the south side of the province of Punjab, Pakistan. The longitude and the latitude of The Islamia University of Bahawalpur are $29^\circ\ 22'\ 34''$ and $71^\circ\ 44'\ 57''$, respectively. It is 8 kilometers away from the Bahawalpur city, and the total area allotted for The Islamia University of Bahawalpur (IUB) is around 1280 acres. The Islamia University of Bahawalpur (IUB) consists the one hundred and twenty (123) departments and offering different programs which are 125 in numbers.

The Islamia University of Bahawalpur (IUB) is present in the hot desert of the Bahawalpur which makes it the best spot for the installation and the generation of solar energy to meet its requirement plus it will sell it to the market for earning some revenue. Figure 1 shows the possible sites for the installation of the solar system based on the maximum solar irradiance.

Figure 2 shows the area under the consideration for the solar PV park at The Islamia University of the Bahawalpur which is around 11 acres as represented by the red lines. The longitude of this area is around 77.44 towards the east and making an angle of around 29.22 in the Northside as latitude. The abovementioned parameters are designed and calculated for obtaining the best efficiency in this area as marked in the figure.

The other important factors and parameters of this location are also calculated and presented in Table 1.

The selection of Bahawalpur's location no doubt marks it as an ultimate city to bang into the solar energy resource. The city has average yearly irradiation of about 5.9 kWh/m^2 per day which will not only fulfill the power needs of the country but also enhances an increasing amount to its economy.

Figure 1: Arial view—Islamia University of Bahawalpur, Pakistan.

Figure 3 shows the area which provides the best benefits to the following project in the future due to its environmental conditions and closeness with the grid station.

The comprehensive approximation and power evacuation plan all along with the projected solar PV power park structure are enclosed hereby in detail.

3. System Modeling

The previous literature review shows that solar energy is being widely used throughout the world and has much more potential in Pakistan as well. This chapter primarily contains the research methodology of the thesis. Firstly, the process of the site serving load demand estimation and forecasting data is described. Secondly, the operational parameters and mechanism of solar PV have been elucidated with their mathematical interpretation. Thirdly, the resource assessment of solar PV is explained widely, which includes the method of estimation which is given as input to PVSyst. Fourthly, the AUTOCAD modeling of the system has been done. Fifthly, the designing of the PV system and configuration has been done. Furthermore, component assessment is stated which gives brief information for the system sizing.

It is one of the important factors in designing the solar PV module park. It is defined as the amount of energy emitted by the sun and strikes on the 1 meter square in each second outside the atmosphere of the earth. So, it is the amount of energy that falls on the unit area in unit time. In the successive sections, we are going to find out the different factors for the area of The Islamia University of Bahawalpur, Pakistan, for designing the PV park and selection of the best spot for installing the plant.

The irradiance of the area is found out by the formula given as:

$$\text{Irradiance of the area} = \frac{\text{Avg.Ins}}{\text{Avg.Sun}}, \quad (1)$$

where Avg. Ins is the average insolation of the area and

Figure 2: Proposed site for the installation.

Table 1: Parameters of selected site for PV park.

Total area under consideration for PV park	11 acres
Longitude and latitude	71.44 east, 29.22 north
Global horizontal irradiation (GHI)	5.266 $kWh/m^2/D$
Diffuse horizontal irradiation (DUF)	2.532 $kWh/m^2/D$
Global irradiation for optimally tilted surface (GTI)	5.992 $kWh/m^2/D$
Direct normal irradiation (DNI)	4.099 $kWh/m^2/D$
Temperature	27.6 degrees Celsius

Avg. Sun is the average bright sunshine hours daily. Its unit area is kWh/meter square.

Solar irradiance

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

Maximum power

$$P\ \text{max} = V\ \text{max} * I\ \text{max}. \tag{3}$$

PV module efficiency

$$\eta\ \text{max} = \frac{(P\ \text{max})}{S.I * A} * 100. \tag{4}$$

The main design and the equipment of the project are divided into the following categories: DC power, AC power, and the automatic controlling of this equipment employing SCARDA or other systems. The block diagram of the project is present in Figure 4.

All the equipment used in this process has its special worth in the whole procedure [5]. The brief description

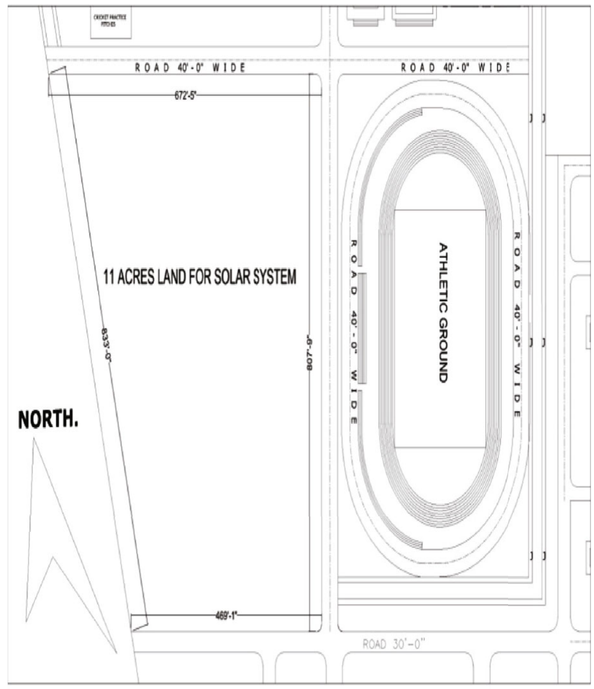

Figure 3: 2-dimensional view of 11 acres area for solar park.

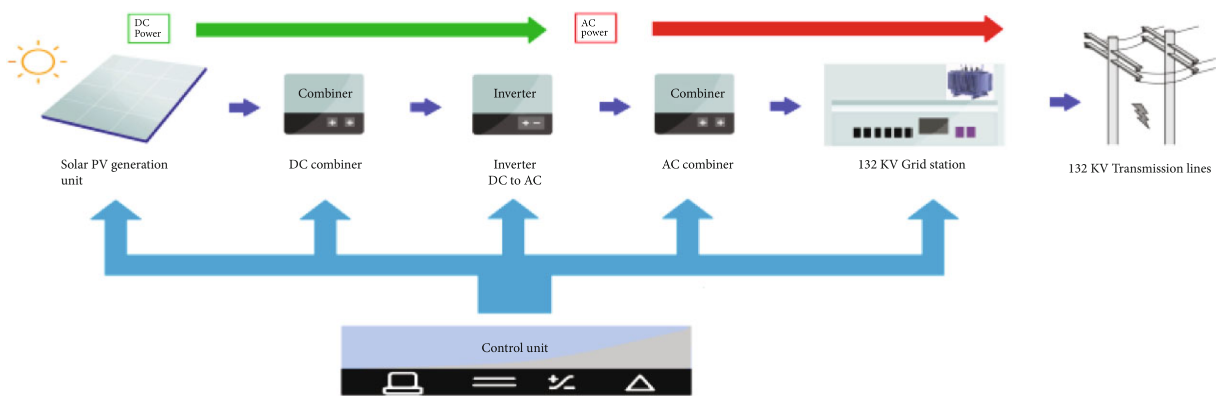

Figure 4: 3 MW complete system scheme.

Table 2: Efficiencies of different solar modules [6].

Solar plate type	Percentage efficiency of solar PV modules
Slim film	7-10%
Monocrystalline	12-16%
Amorphous silicon	6-8%
Polycrystalline	12-18%

Table 3: Specifications of the inverter used.

Rating of the inverter in KVA	630 KVA
Efficiency	Almost 98.7%
DC voltage input	1000 volts DC

Table 4: Specifications of used PV plate for system design.

No.	Parameter name	Reading
1.	Maximum power (P max)	260 watt
2.	Maximum power voltage Vmp	30.6 V
3.	Voc—open circuit voltage	38 V
4.	Short circuit current Isc	9.04 A
5.	Max power point	8.49 A
6.	Total efficiency	16.6%
7.	Life time	25 years

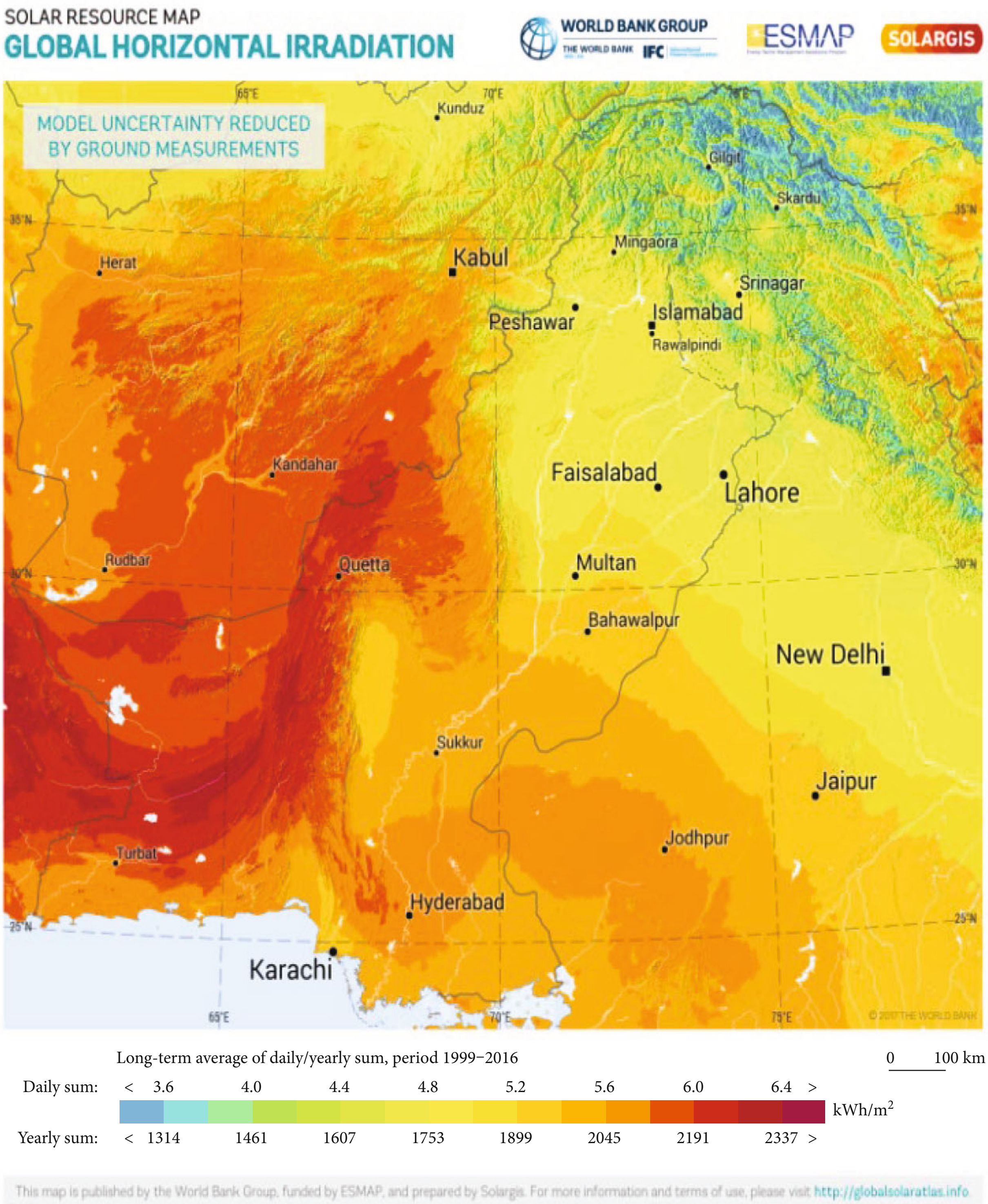

Figure 5: Global horizontal irradiation—SOLARGIS [9].

of the equipment is present in the successive part of the article.

3.1. DC Power System. The system which processes the generation of direct current and deals with it comes under the category of the DC power systems. PV module is one of the significant parts of the generation system in a solar power plant. It is the device used to change solar energy into electrical energy. Many types of solar photovoltaic modules are available in the open market for the solar energy system. Table 2 shows the efficiencies of different solar modules type:

(i) Polycrystalline

(ii) Mono-crystalline

(iii) Thin-film

(iv) Amorphous silicon

Polycrystalline-Si has been preferred for the project because of its efficiency and compatibility with environmental conditions [7].

Another major piece of equipment is the DC combiner box whose job is to combine the direct current from the whole photovoltaic cells. After that, the inverter is used to convert the main solar DC power into AC power.

3.2. AC Power System. It processes all the components which deal with the alternating current. The major parts of the AC power systems are discussed here. Ac combiner box combines the alternating current from the inverter. If the inverter that has been chosen earlier contains the functionality of the inbuilt AC combiner, then this separate combiner is avoided. The performance of the solar power system highly depends on the environment. For example, as the irradiance increases, it will definitely increase the output power, but here, one thing is more important than if the panel temperature will start to increase, it will reduce the efficiency of the system [1]. The clouds or the highly humid days create a hindrance in the energy generation as the wavelengths of the spectrum leave diffused radiations and start to absorb in the atmosphere. In short, it will low energy wavelengths that will reach the earth which is not sufficient to fulfill the energy band gaps of the PV module.

3.3. Controlling System. The things which are used for controlling and monitoring the whole systems consist of the SCARDA and PLC systems additionally with the weather station and the PV power plant constituents. The controlling system will enable us to get the required information anytime with the help of an LCD plus it will display the fault in the panels by hot-spots and enable us to repair it within time [8].

3.4. Inverter. TC 630KH TBEA Xi'an Electric inverters are used in this project for suppressing the harmonics which was formed in the system after the DC to AC conversion. A total of 5 inverters of 630 KW are used for the modules. Inverter specifications are shown in Table 3.

3.5. Solar PV Modules. There are many options for the PV plates which we can use, but we are going to select the PV plate with a 260 W rating. By using the mathematical formula, we can calculate the no. of PV modules required to design the 3 MW solar PV grid-connected system.

$$\text{No.of PV panel needed} = \frac{\text{Total MW Needed}}{\text{Rating of the Single PV Unit}}. \tag{5}$$

Total no. of plates should be installed for 3 MW = 12200 PV plates (rating 260 W). The PV plates which have chosen for this project are manufactured by JA Solar China [5].

Table 5: Energy consumed in kWh for 2018 and 2019.

Sr #	Month	kWh in the year 2018	kWh in the year 2019
1	January	297,040	404,620
2	February	357,840	265,360
3	March	250,240	333,260
4	April	342,000	449,300
5	May	448,660	610,400
6	June	672,660	482,900
7	July	768,880	502,960
8	August	534,500	420,280
9	September	43,360	395,520
10	October	395,580	399,580
11	November	287,160	277,040
12	December	311,860	287,680
13	Total (kWh)	4,709,780	4,828,900
14	Average per year	392,482	402,408

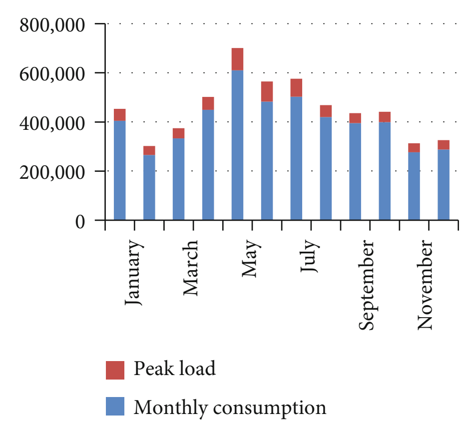

Figure 6: IUB peak load and monthly consumption.

The name of the model is JAP6 (BK)-60-260/3BB. Other specifications of the PV plate are given in Table 4:

3.6. The Number of Combiner Box Calculation. The combiner box possesses the main part which is a protection breaker or the fuse for every sequence and may have the surge protector, so these boxes are also the backbone of the system.

$$\text{Total Number of Combiner Box} = \text{Total No.of Inverters}. \tag{6}$$

In our case, we have chosen a total of 5 inverters, so combiner boxes will be 5.

3.7. Solar GIS Maps. Solar resource maps are obtained from the SOLARGIS shown in Figure 5 which shows immense solar potential at the site of the Bahawalpur.

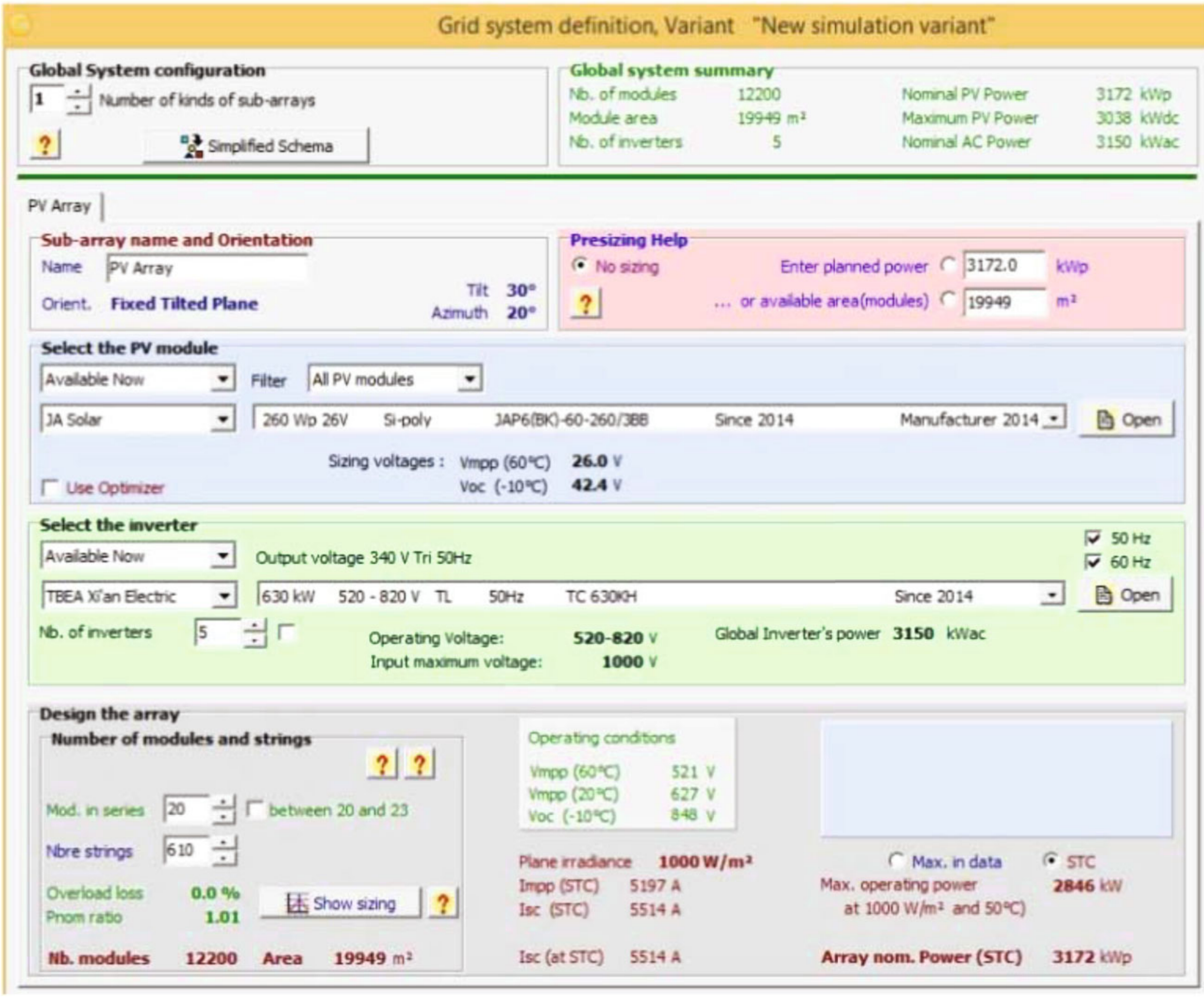

Figure 7: 3 MW complete system modeling on PVSyst.

Table 5 shows the unit consumption of The Islamia University of Bahawalpur which helps in predicating the load demand variation for the years to come as indicated by MEPCO (Multan Electric Power Company) bill.

Figure 6 shows the peak load and monthly consumption of the system.

3.8. Simulation Using PVSyst Software. The PVSyst software is one of the most commonly used software for the designing and estimation of the performance parameters of the solar PV power plant. With the wide options and built-in features, this software provides almost nearer results as compared with the theoretical results. This software enables you to import the data of the different Mateo as well as personnel data which is the best thing about it. This software enables you to assess the main performance of the PV Planet in the following circumstances: stand-alone, grid-connected, and pumping system.

The performance and the effectiveness of the total system of the PV plant are assessed by providing the stipulation of the desired design. The values obtained will be nearer to the comparison if we get from SCADA or SOLARGIS, etc. Hence, the system is designed according to the desired specifications [10]. The parameters of the system are displayed in Figure 7.

Furthermore, this software calculates the system output and different important parameters by using the hourly simulation data. In this work, the PVSyst software is adopted to estimate the annual power yields of the 3 MW PV solar plant designed for The Islamia University of Bahawalpur with grid-connected scheme.

The simulation parameters of the grid-connected system are displayed in Figure 8.

4. Results and Discussion

The results based on the yearly global irradiance and Mateo are presented in Table 6 which are needed for the simulation of the project. Mateo values are important because they will help in deciding the potential of renewable energy at the desired site.

For solar energy, as we know that solar irritation and the ambient temperature play an important role in the generation of PV energy.

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Grid-Connected System: Simulation parameters

Project :	**Grid-Connected Project at Bahawalpur**			
Geographical Site	**Bahawalpur**		Country	**Pakistan**
Situation	Latitude	29.2°N	Longitude	77.4°E
Time defined as	Legal Time	Time zone UT+5	Altitude	214 m
	Albedo	0.20		
Meteo data:	**Bahawalpur**	Synthetic - MeteoNorm		

Simulation variant :	**New simulation variant**			
	Simulation date	18/06/19 16h23		

Simulation parameters				
Collector Plane Orientation	Tilt	30°	Azimuth	20°
Models used	Transposition	Perez	Diffuse	Erbs, Meteonorm
Horizon	Free Horizon			
Near Shadings	No Shadings			
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	20 modules	In parallel	610 strings
Total number of PV modules	Nb. modules	12200	Unit Nom. Power	260 Wp
Array global power	Nominal (STC)	**3172 kWp**	At operating cond.	2846 kWp (50°C)
Array operating characteristics (50°C)	U mpp	548 V	I mpp	5197 A
Total area	Module area	**19949 m²**	Cell area	17814 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	5 units	Total Power	3150 kWac
PV Array loss factors				
Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	1.5 mOhm	Loss Fraction	1.3 % at STC
Module Quality Loss			Loss Fraction	-0.8 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Incidence effect, ASHRAE parametrization	IAM =	1 - bo (1/cos i - 1)	bo Param.	0.05
User's needs :	Unlimited load (grid)			

PVsyst Evaluation mode

Figure 8: Simulation parameters—grid-connected system.

Table 6: Monthly Mateo values of IUB Bahawalpur, Pakistan.

Months	Glob hor kWh/m^2	T Amb C	Glob Inc kWh/m^2	Diff hor kWh/m^2	DifSInc kWh/m^2	Alb Inc kWh/m^2
January	89.2	11.37	120.0	44.6	51.09	1.195
February	110.9	15.72	141.6	44.7	51.13	1.486
March	153.3	21.49	172.3	64.8	69.06	2.047
April	167.0	26.71	169.0	87.2	86.18	2.230
May	189.5	32.34	176.4	97.9	92.49	2.537
June	190.2	32.14	172.9	99.4	92.48	2.540
July	170.7	30.90	157.1	102.9	95.83	2.270
August	171.7	30.32	166.9	98.2	94.85	2.286
September	163.4	28.13	175.0	75.4	77.49	2.189
October	130.1	24.67	155.7	64.6	70.71	1.743
November	97.1	17.89	127.2	47.8	53.69	1.301
December	86.1	13.28	120.3	40.9	48.13	1.154
Year	1719.2	23.79	1854.3	868.4	883.14	22.978

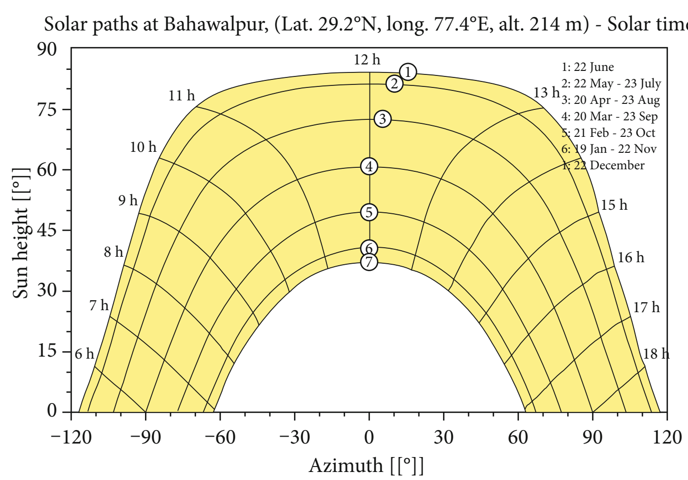


Figure 9: Solar paths at IUB, Bahawalpur, Pakistan, Lat 29.2 N, Long 77.4 E, alt. 214 m.

Figure 9 shows the solar paths for a whole year at the selected spot for the installation of the solar plant.

The main results of the design system are shown in Figure 10, and the daily output of the 3 MW system is shown in Figure 11.

The performance ratio PR is 83.5%.

The total produced energy is 4908 MWh/year.

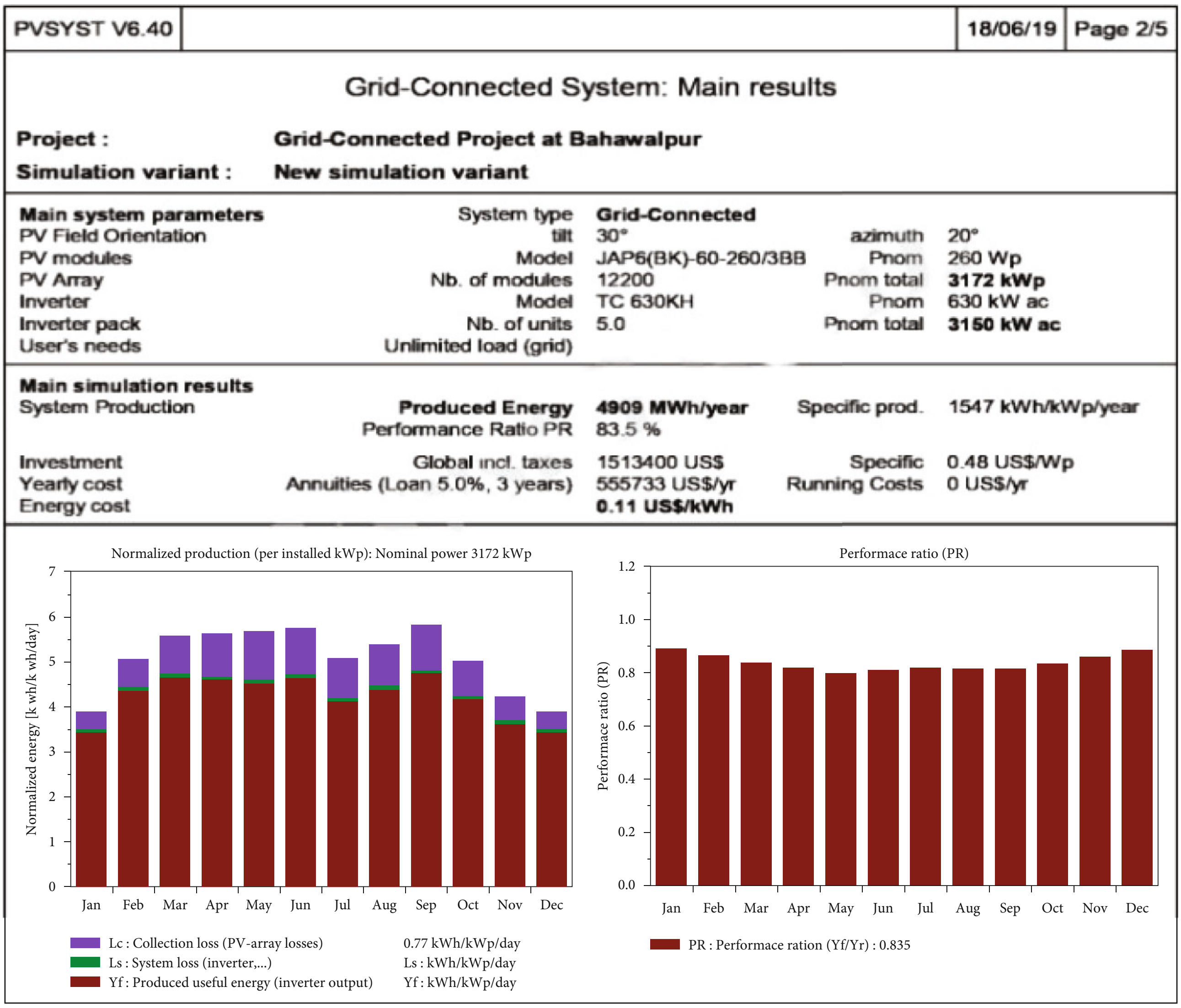
$$\text{Total Specific Production} = \left(\frac{\text{Total Energy obtained}}{\text{Array Nominal Power}}\right), \quad (7)$$

$$\text{Specific Production} = \frac{4908528\,\text{kWh}}{3173000\,\text{kWp/year}} = \frac{1546.96\,\text{kWh}}{3173000\,\text{kWp/year}}. \quad (8)$$

The maximum energy which is generated is 458294 kWh which is obtained in March, and the minimum energy generated is 339333 kWh in December. The other important results are yearly global horizontal irradiation, energies, power output, and system efficiency.

The highest power production achieved was more than 19000 kilowatt hour per day in March at the module temperature of 21.49°C and plant efficiency of around 83.8%. The total energy output attained from the solar photovoltaic array is 4990 MWh. The total efficiency of the system is 13.27% which is quite good. The total global incident energy GHI which falls on the collector area plane yearly is 1854.3 kWh/m^2. Figure 12 shows the normalized production per installed kWp. Table 7 shows the main results of the system obtained from the PVSyst.

4.1. Performance Ratio. The average yearly PR is 83.5% for the PV plants at The Islamia University of Bahawalpur with a maximum PR of 89.2% in January, and the minimum PR is 79% in May. Table 8 shows the normalized performance efficiency of the plant. Figure 13 shows the performance ratio PR—month-wise. The PR obtained



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Grid-Connected System: Main results

Project : **Grid-Connected Project at Bahawalpur**

Simulation variant : **New simulation variant**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	20°
PV modules	Model	JAP6(BK)-60-260/3BB	Pnom	260 Wp
PV Array	Nb. of modules	12200	Pnom total	**3172 kWp**
Inverter	Model	TC 630KH	Pnom	630 kW ac
Inverter pack	Nb. of units	5.0	Pnom total	**3150 kW ac**
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	**Produced Energy**	**4909 MWh/year**	Specific prod.	1547 kWh/kWp/year
	Performance Ratio PR	83.5 %		
Investment	Global incl. taxes	1513400 US$	Specific	0.48 US$/Wp
Yearly cost	Annuities (Loan 5.0%, 3 years)	555733 US$/yr	Running Costs	0 US$/yr
Energy cost		**0.11 US$/kWh**		

Figure 10: Grid-connected simulation results.

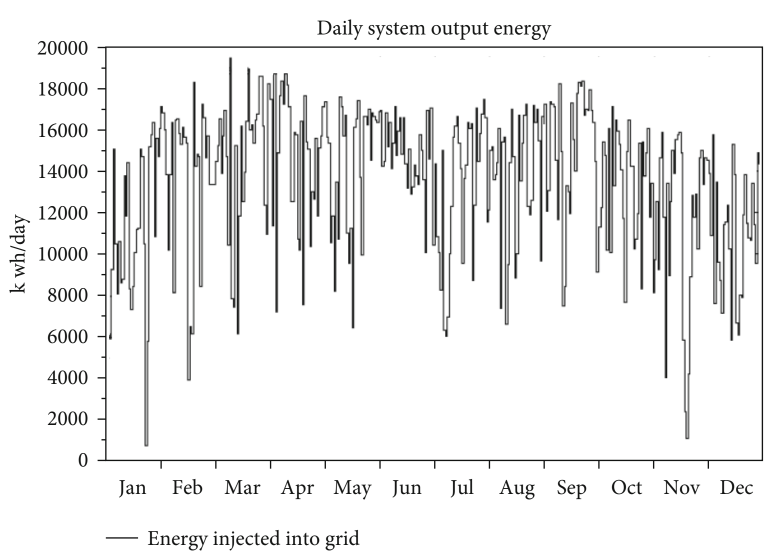

Figure 11: Daily system output energy.

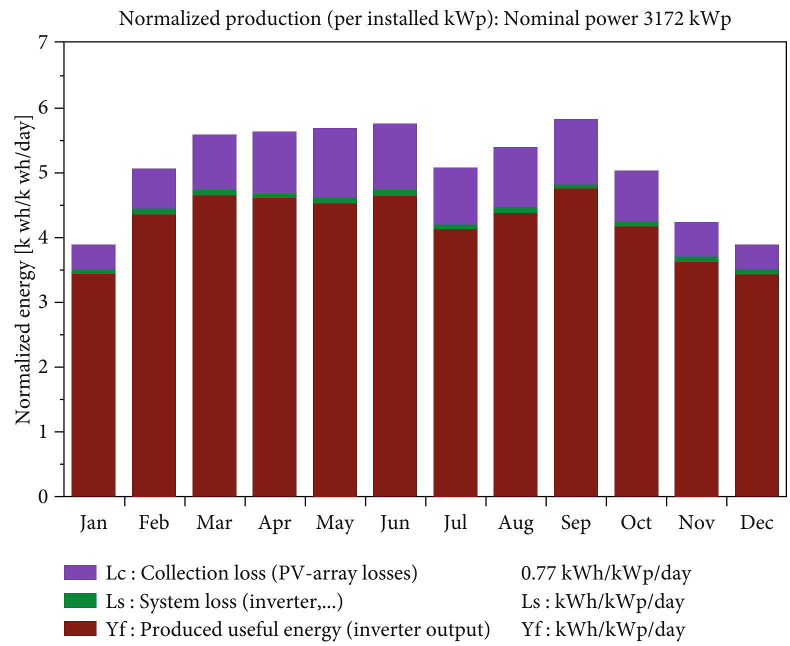

FIGURE 12: Normalized production per installed kWp.

TABLE 7: Balance and main results of the system.

Months	Glob incident kWh/m^2	Array energy kWh	Grid energy kWh	Eff ArrR %	Eff SysR %
January	120.0	345926	339575	14.45	14.19
February	141.6	395408	388716	14.00	13.77
March	172.3	465913	458294	13.55	13.33
April	169.0	445751	438839	13.22	13.02
May	176.4	454150	447116	12.90	12.70
June	172.9	450636	443615	13.07	12.86
July	157.1	414872	407915	13.24	13.02
August	166.9	440013	433113	13.21	13.01
September	175.0	460285	453142	13.19	12.98
October	155.7	418933	412185	13.49	13.27
November	127.2	352877	346686	13.91	13.67
December	120.3	345600	339333	14.40	14.14
Year	1854.3	4990366	4908528	13.49	13.27

from the PVSyst is almost the same calculated with the mathematical formulas.

$$\text{Performance Ratio} = \frac{\text{Total Energy recorded (kWh)}}{\text{Energy obtained}}, \quad (9)$$

$$\begin{aligned}\text{Energy obtained} = {} & \text{Total Active area of panel } \left(\mathrm{m}^2\right) \\ & * \text{ Solar Irradiance at Place } \left(\mathrm{kWh/m}^2\right) \\ & * \text{ Total Module efficiency.}\end{aligned} \quad (10)$$

4.2. Loss Diagram. The most important factor which should be taken into account while designing is power system losses. It plays an important role in the calculation of the power generation output. The GHI is 1719 kW h/m2, and the efficient irradiation which falls in the day time on the collector plane is almost 1800 kWh/m^2. So, basically, total system loss in the energy is 0.70-1% [11]. Figure 14 shows the loss diagram over the whole year.

When the solar energy falls on the solar panel, it will convert into electrical energy, and after the transfer, the array ostensible or the main nominal energy is around 5510 MWh, and the efficiency of the solar photovoltaic system array at that moment is 15.90%, so we can say that the

Table 8: Normalized performance coefficient.

Month	Yr kWh/m^2.day	Lc	Ya kWh/kWp/day	Ls	Yf kWh/kWp/day	PR
January	3.87	0.352	3.52	0.065	3.45	0.892
February	5.06	0.604	4.45	0.075	4.38	0.866
March	5.56	0.820	4.74	0.077	4.66	0.838
April	5.63	0.948	4.68	0.073	4.61	0.819
May	5.69	1.072	4.62	0.072	4.55	0.799
June	5.76	1.027	4.74	0.074	4.66	0.809
July	5.07	0.848	4.22	0.071	4.15	0.819
August	5.39	0.910	4.47	0.070	4.40	0.818
September	5.83	0.996	4.84	0.075	4.76	0.816
October	5.02	0.762	4.26	0.069	4.19	0.835
November	4.24	0.531	3.71	0.065	3.64	0.859
December	3.88	0.367	3.51	0.064	3.45	0.889
Year	5.08	0.770	4.31	0.071	4.24	0.835

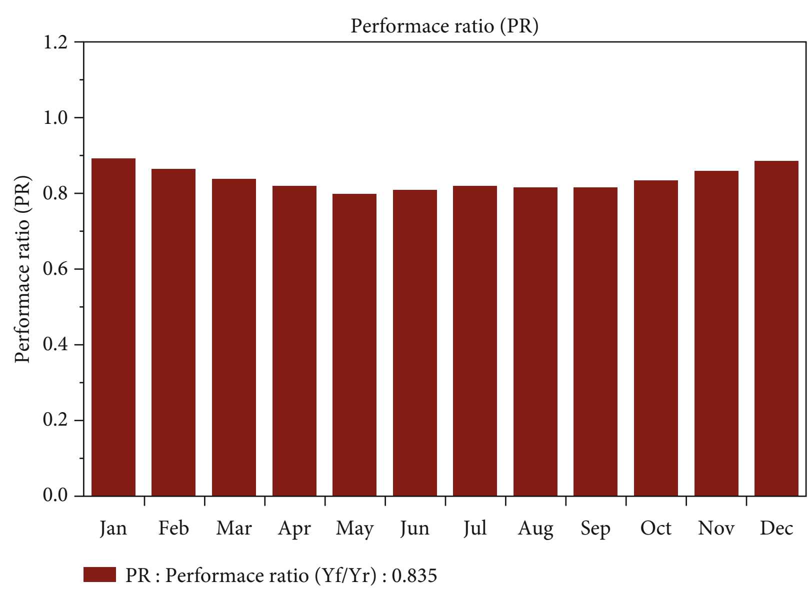

Figure 13: Performance ratio PR—month-wise.

array virtual power then obtained is roundabout 4990 MWh, and after the losses in the inverter section, the amount of energy obtained from the output of the inverter is around 4709 MWh which will be injected into the grid station.

4.3. Cost Analysis of Proposed System. 3 MW grid-connected system for The Islamia University of Bahawalpur was designed and analyzed. Gross total investment without taxes is 1441333 US $ or 22.7 Croc Pakistani Rupees. Taxes on the investment (VAT) and the rate of VAT are 5% which is around 72067 US $. The gross investment (including taxes) is 1513400 US $ OR 24 Croc Approx.

The cost of the energy produced is 0.11 US $/kWh whereas in Pakistan the conventional energy tariff is 0.18 $/kWh. The estimated COE is very less than the current energy tariff of Pakistan. PVSyst also considers the scaled annual average of load for calculations of future demand. All the results are calculated with the PYSYST software which is considered best for sensitivity analysis, simulation, and optimization. In the next chapter, the conclusion of the overall research and results has been elucidated concisely.

4.4. Comparison with Previous Work. A comprehensive research of the analysis and design of the implementation of the 3 MW solar photovoltaic system based on the grid-connected power plant at The Islamia University of Bahawalpur was conducted, and few of the conclusions which are drawn from the comprehensive study

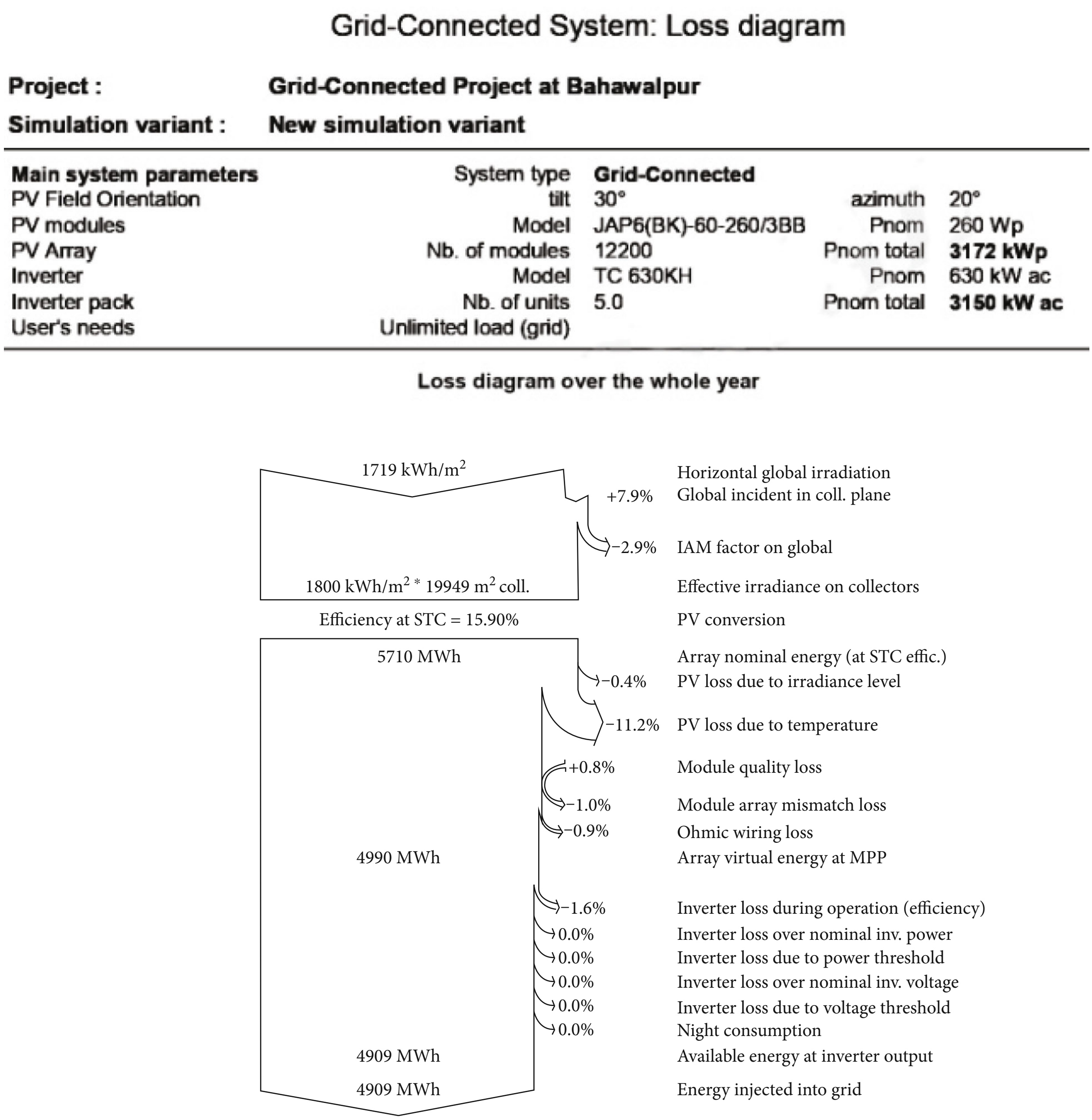

Figure 14: Loss diagram over the whole year.

Table 9: Comparison of proposed system with QASP.

Plant names	Performance ratio	Cost of energy unit	Conversion losses in inverter
Proposed plant at IUB	83.5%	0.11 $/kWh	0.8%
Quaid-E-Azam Solar Park	79%	0.13 $/kWh	2%

of the location and the working of the system are as follows:

(i) *First Finding*. The maximum energy which is produced or generated from this system is 458294 kWh which is taken out in March, and the minimum energy generated is 339333 kWh in the last month of December

(ii) The total energy output taken out from the solar photovoltaic system array is 4990 MWh. The total efficiency of the system is 13.27%

(iii) The average yearly PR is 83.5% for the PV plants at The Islamia University of Bahawalpur with a maximum PR of 89.2% in January, and the minimum PR is 79% in May

From the simulation results, the value of PR comes out 83.8%. It is also concluded that it is equal to 15369.3 kg of the coal saving per day by installing 3 MW solar plant which is equal to planting 147600 teak trees over the lifetime. The implication of this paper will help people to install their efficient solar park.

The proposed solar system and Quaid-E-Azam Solar Park (QASP) are compared. The performance ratio, cost of energy, and conversion losses in comparison with QASP are given in Table 9.

It was found that the proposed system outperforms in comparison with Quaid-E-Azam Solar Park (QASP). The performance ratio of proposed system calculated was 83.5% while QASP has PR of 79%. Moreover, cost of energy was calculated as 0.11 $/kWh which is less than the already installed QASP.

5. Conclusion

This present research summarizes the 3 MW solar power plant at The Islamia University of Bahawalpur with in-depth reports about the annual production, power losses in the plant, and future impact regarding the shortage of energy crises. Few of the conclusions which are drawn from the comprehensive research of the location and the system are as follows:

(i) The maximum energy generated from the system is 458294 kWh which is taken out in March, and the minimum energy generated is 339333 kWh in the last month of December

(ii) The total energy output taken out from the photovoltaic system array is 4990 MWh. The total efficiency of the system is 13.27%

(iii) The average yearly PR is 83.5% for the PV plants with maximum PR of 89.2% in January, and the minimum PR is 79% in May

From the simulation results, the value of PR comes out 83.8%. It is also concluded that it is equal to 15369.3 kg of the coal saving per day by installing 3 MW solar plant which is equal to planting 147600 teak trees over the lifetime. The implication of this research will help people to install their efficient solar park.

6. Future Recommendations

This research endows with the imminent to spot the location, compatibility of the project for installing or designing the solar plant anywhere in the world. It will also help in analyzing the performance of the solar plants. The information presented in this research is quite useful in finding out the operational and environmental benefits of the solar photovoltaic projects based on the net energy yield. The theoretical data and the operating experience of the solar photovoltaic plant can be applied for greater scale projects in the future. This type of project would help the country in meeting the shortage of energy and would play its part in reducing the cost of energy. Effect of environmental condition-sand storms on PV modules in Bahawalpur are needed to be addressed in future to cater the practical issues of the system.

Data Availability

Data is made available in supplementary files.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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