Optimal design and simulation of photovoltaic system in Faculty of engineering Guilan university

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Abstract- In this paper, simulation and study the rooftop photovoltaic system on building roofs of the Faculty of engineering Guilan university, Iran. It is now clear that conventional plants heavily contribute to greenhouse gas emissions, so they are not environmentally friendly. Renewable energy sources are an alternative solution. In this study, the design of a grid-connected photovoltaic system was simulated. PV panels and the number of inverters are the main elements of the PV power system. According to the regional weather data and university ceiling structure, shadow analysis, calculation concerning the total number of panels, number of strings, and number of panels per string, and their optimal angles are done. PVSyst software is used for the proposed photovoltaic system design.

Keywords: Design, Photovoltaic, PVSyst software, Rooftop PV system

1.Introduction

Energy consumption is rising in the world. Fossil fuels are the main sources to meet electricity demand. The resulting exploitation of these conventional sources has many disadvantages such as pollution, exhaust and, high cost [1].

In today's world, advanced countries believe that renewable sources can be a good alternative to fossil fuels. Moreover, with the Paris convention, many countries have committed to reducing fossil resources and switching to green sources for electricity generation. Iran is one of the developing countries that has a high share of greenhouse gas emissions and it has put a cap on carbon dioxide emissions [3].

Renewable energy is any form of energy available in the natural environment and can be replenished repeatedly. Among them, solar energy is available and can be easily equipped at home. Photovoltaic system generation differs daily and seasonally. It depends on latitude, solar irradiance, wind speed, air temperature and generally, meteorological conditions of the location to be installed [1,2].

Design and simulation of the PV system can be helpful in monitoring, estimating electricity generation, and analyzing the performance of the system. On the other hand, optimizing the structure of the photovoltaic system is very important among researchers [4,5].

In [6] describes the design and simulation of a stand-alone photovoltaic system for the daily light load of the university of Missouri-Kansas City, USA.

In [7], propose a design of a grid-connected PV system with a capacity of 1 MW in Iraq. The result shows that Iraq has a high potential to install PV systems on large scales. The total life cycle output of this system is about 40,445 MWh.

In [8], investigated various parameters of 11.2 KW grid-connected PV system. This system is installed on the rooftop of a building and generates 14.96 MWh of energy per annum.

There is various software for the optimal design and simulation of a photovoltaic system. Among them, the PV Syst program is more user-friendly.

In [9], a design of a rooftop hybrid system that contains a wind turbine and photovoltaic was studied. The 30 KW and 22.5 KW are simulated on a roof area of 400 m^2. Results indicate that the proposed system can meet 55% of the annual energy demand of the building.

In [10], the design of a photovoltaic system with a capacity of 30 KW on the rooftop of the university building was investigated. The simulation was accomplished with PV syst software. The result shows that the performance Ratio (RP) for this system is 76.1%, and the annual electrical energy generation is 49.80 kWh.

In [11], simulated a 25 KW rooftop solar PV system by using PV syst, PV*SOL, and Solarius software. Research results indicate that the PV*SOL program is the most effective. It was also, concluded that an average of 20 tons of carbon dioxide emissions will be saved annually.

In [12], evaluated a proposed stand-alone PV system that was used to meet the lighting of a footbridge. The arrangement of the main components of this PV system is performed by PV syst software.

In [13], using PV syst software, a 200 KW rooftop photovoltaic system installed at IRB complex-5 Chandgrah in the North of India was designed and simulated. The simulation results show that the annual energy achieved was 292955 KWh.

In this study, a simulation and design of the photovoltaic system was performed with PV SYST software on the rooftop of a Faculty of engineering university building in Guilan province, the North of Iran. The main contributions of this paper are as follows:

1. Designing and selecting solar panels, inverters, the optimal tilt angle of the panels, the suitable distance between the panels of a system according to the regional weather condition, the

ceiling structure of the university building, and technical criteria.

2. Evaluating the performance of the proposed photovoltaic system using PV syst software.
3. Analyzing the shadow

The rest of the paper is organized as follows: Section 2 discusses the methodology of the proposed system and describes the configuration of a photovoltaic system based on meteorological data of site location. Section 3 explains the simulation results. Finally, section 4 concludes this paper.

2. Methodology

2.1. site information

The photovoltaic system simulated and investigated in this article is Faculty of engineering Guilan university, Iran. The university building is in Rasht, the capital of Guilan province located in the north of Iran with a coordinate of 49°N, 35°E [14]. Figure 1 shows a schematic diagram of the rooftop of the university building.

As shown in Figure 1 building ceil contains five zones. However, in this study the main objective is designing a photovoltaic system on usable and suitable space in zone1,2,3 and 4.

Figure 1. The location and satellite image of the building

The dimension of each rooftop is assumed to be the same. Table 1 illustrates the measured area and suitable area of zone1,2,3 and 4. Therefore, a grid-connected photovoltaic system is the preferred system configuration. When the photovoltaic system generation is not sufficient, it can use power from the utility grid.

Table 1. the area of each zone

location	Total area	Suitable area
zone1,2,3 and 4	2150 m^2	1840 m^2

The most important factors that affect the photovoltaic generation are meteorological data and solar radiation.
These data are collected from [14]. Figure 2 shows the monthly solar radiation of Rasht city. Table 2 shows the meteorological data. This table indicates Average temperature, Average maximum and minimum temperature, Average humidity and sunny hours in each month.

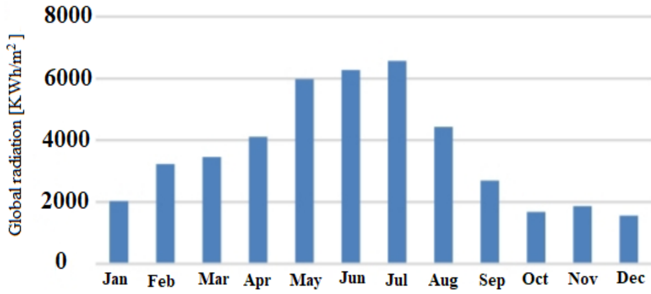

Figure 2. Monthly solar radiation for Faculty of engineering Guilan university [14]

Table 2. Meteorological information of location [14]

	Average maximum Temperature (℃)	Average minimum Temperature (℃)	Average temperature (℃)	Average humidity (%)	Suunny hours
Jan	8.7	0.3	4.5	85	92.4
Feb	14.6	4.1	9.4	80	134.5
Mar	18.8	9.7	14.3	75	102.8
Apr	24.7	14.9	19.8	80	136.5
May	28.8	18.7	23.6	78	230.7
Jun	31	21	25	78	241
Jul	33.1	21.4	27.8	76	246.7
Aug	31.4	20.1	25.3	79	190.7
Sep	23.8	15.6	19.7	84	108.6
Oct	16.3	9.4	12.9	90	71.3
Nov	12.1	2.3	7.2	81	129.8
Dec	11.6	3.6	7.6	85	90.9

2.2. solar panels and inverter selection

The main components of photovoltaic system are solar panels and inverter for power generation. Therefore, it is paramount to realize the characteristics of these two elements before determine proper solar panels and inverters. according to the Rasht weather condition and metrological data, suitable solar panels and inverter was selected.

In this study, poly crystalline, yinglisolar YL250P-29b and SMA are chosen as solar panels and inverter respectively. Table 3 and Table 4 shows characteristics of the selected solar panel and inverter.

Table 3 specifications of solar module

Peak power	P_{max}	250(W)
Short circuit current	I_{sc}	8.837(A)
Open circuit voltage	V_{oc}	37.73(V)
Rated voltage	V_{mp}	30.23(V)
Rated current	I_{mp}	8.271(V)
efficiency		15.30%

Table 4 specifications of inverter

Minimum MPP Voltage	570 (v)
Nominal MPP Voltage	630(v)
Maximum MPP Voltage	800(v)
Absolute Max PV voltage	1000(v)
Nominal AC Power	60(kw)
Nominal AC Current	87 (A)
Maximum efficiency	98.5%
Frequency	50 HZ

2.3 Grid-connected system describe

In this paper, the rooftop photovoltaic system is designed using PVSYST software, based on the important design factor which increase the efficiency of the photovoltaic system. The key design factors are as follow:

1. selecting appropriate solar panels and inverters
2. solar irradiance and metrological data of photovoltaic system site
3. optimum seasonal angle and distance of solar panels
4. calculating photovoltaic system capacity and energy output

In this work, performance ratio (PR) calculated. PR determines the efficiency of the photovoltaic system operation. Studies have evidenced that if PR values are between 75% to 85% the operation of the photovoltaic system is high-performance.

PR depends on the solar panel temperatures, so it varies from season to season based on the solar radiation received from solar panels [15,16]. Performance ratio can be performed using equation (1)[15]:

$$PR(\%) = \frac{\text{Actual Enegy (KWh)}}{A * r * H} \quad (1)$$

where A is total solar panel area, r is solar panel yield, H is annual average solar radiation on tilted panels (KWh/ m^2)

Table 5 indicates the system configuration. The solar panels have a generation capacity of 380 W and the total number of them are 460. Two number of inverters with 60 KW capacity are selected.

Table.5 Photovoltaic system configuration

System overview	
power of Module	250 w
Solar pv power system	100 kw
Total number of modules	460
Number of string	20
Number of modules per string	20
Number of inverters	2
power of Inverter	60 kw
Capasity of inverters	120 kw

2.4. Optimum tilt angle

Photovoltaic output is affected by several variables, one of them being the tilt angle of solar panels. Proper adjustment of them is a sure way to optimize the output power of the photovoltaic system. When the solar radiations are perpendicular to the panel's surface, the system works with high efficiency. The optimum angle will differ according to the geophysical location and seasons [17].

The angle of solar panels adjusts to the latitude of the location. However, the maximum and minimum annual altitude of the sun changes based on location. Therefore, the angle should be adjusted twice a year [18].

The optimum solar panel angle is determined by subtracting 15° from the location latitude in the summer and by adding 15° to the latitude in the winter [19].

The latitude of location is 32°, so tilt angle for summer and winter shows in table 6.

Table.6 optimal angles during the year

Season	Optimal angle of inclination	Angle of panels
Summer	Latitude-15	17
Winter	Latitude+15	47

Using tracking system is costly, so in this paper, the tilt angle is to be changed manually, just twice a year, summer and winter.

Table 7 indicates a comparison of monthly solar radiation received when the solar panel's angle is 32°, with the monthly solar radiation received at an optimal angle. Seasonal angle adjustment caused to increase in photovoltaic system efficiency. Iran is located in the Northern Hemisphere, so the orientation of the solar panels should point due south.

Table.7 Comparison monthly solar radiation received between at tilt angle 32° and optimal angles

Month	Received radiation in angle 32° (kwh/m^2)	Optimal angle (°)	received radiation (kwh/m^2)
Jan	103.9	47	111.7
Feb	109	47	113
Mar	135.4	47	130.3
Apr	150	17	151.2
May	172.7	17	181.1
Jun	179.6	17	193.2
July	177.1	17	188.7
Aug	181	17	184.7
Sep	167.6	17	163.8
Oct	136.6	47	140.2
Nov	103.7	47	110.3
Dec	89.8	47	97

2.5 Shading analysis

Solar panels are very sensitive to shading. The capability of delivering energy is impacted by total or partial shading analysis is very essential steps in photovoltaic system design. There are not any barriers like tree or buildings around the university building, which lead to shading. The suitable distance between rows of solar panels can be defined as [20]:

$$\frac{Z}{H} = \frac{\sin(180^\circ) - (a + b)}{\sin(b)} \quad (2)$$

Where a is the tilt angle of the panel, b is the minimum of radiation, H is the length of the panel, and Z is a suitable distance.

In addition, the other distances between rows of solar panels were evaluated. Figure 3 shows a trajectory of the sun in the sky when the distance between rows of panels is 1.53 m^2. There is a large shadow, especially on 21st December, when the sun is lowest on the horizon. Figure 4 and Figure 5 the show the shadow diagram when the distances are 2.14 m^2 and 2.66 m^2 respectively.

According to Figure 5 the rate of shadow is lower, but the requirement area for photovoltaic system installation is 2251 m^2 that is bigger than available area. The optimal distance referred to in equation 2 is chosen as 2.14 m^2.

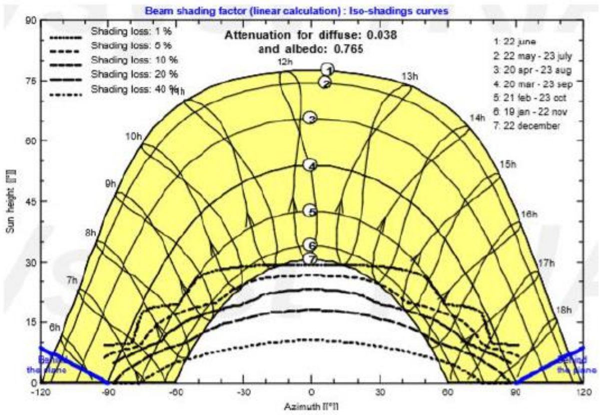

Figure 3. Shadow diagram when the distance between the panel is 1.53 m^2

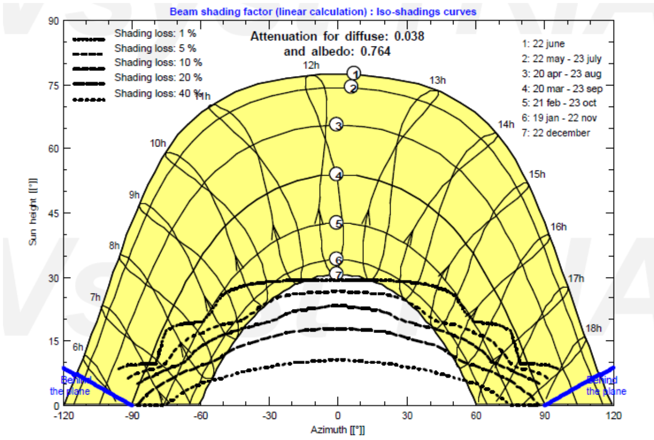

Figure 4. Shadow diagram when the distance between the panel is 2.14 m^2

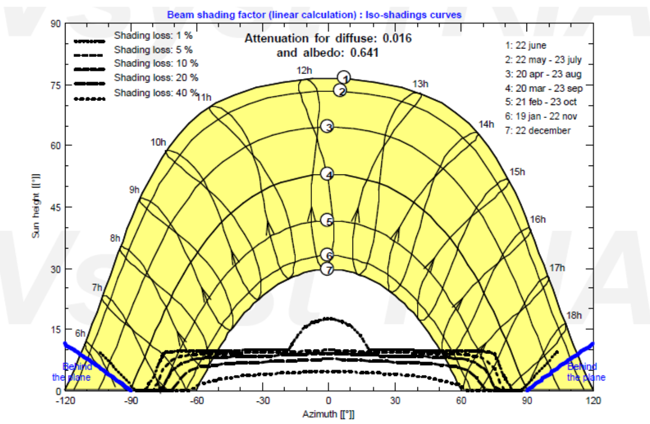

Figure 5. Shadow diagram when the distance between the panel is 2.66 m^2

Table 8 indicates energy output when the distance between rows of panels is 1.53 m^2 , 2.14 m^2 and 2.66 m^2.

Table.8 comparison System energy output with different distances

Month	Energy output (MWh) in different distances		
	1.53 m^2	2.14 m^2	2.66 m^2
Jan	9.6	9.73	13.19
Feb	10.19	10.38	12.73
Mar	13.40	13.40	14.26
Apr	14.90	14.90	13.56
May	17.56	17.56	14.22
Jun	18.37	18.38	14
Jul	17.59	17.59	14.58
Aug	17.71	17.71	14.98
Sep	14.71	15.19	15.62
Oct	12.80	13.04	14.18
Nov	9.57	9.71	12.28
Dec	7.92	8.05	11.63

3. PV SYST simulation result

The PVSYST software simulation results show that the nominal power of each photovoltaic system which will be installed on the suitable area of zone1,2,3 and 4 is 115 KW. Figure 6 shows the quality of proposed systems and their equipment. There are some dispersion points due to the losses of cables and inverters.

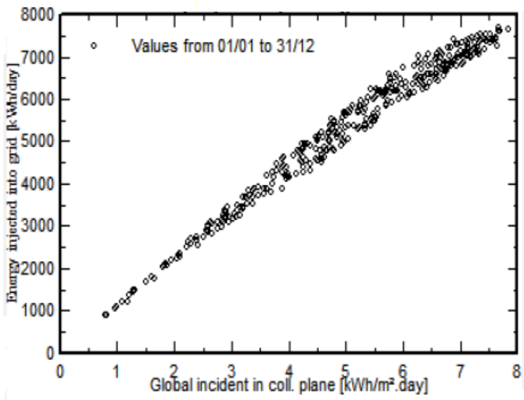

Figure 6. Quality diagram of proposed systems

Figure 7, reports the Performance Ratio (PR). From this PR is 78.1%.

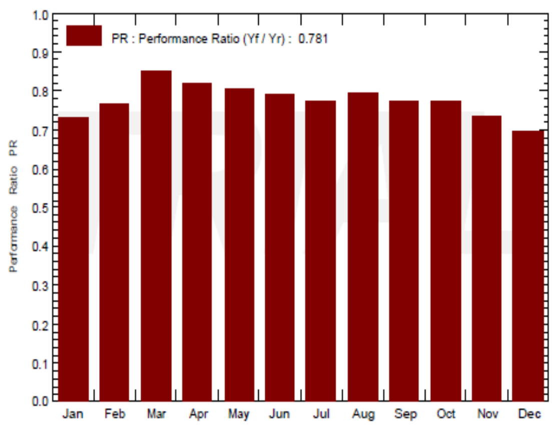

Figure 7. Performance Ratio

Figure 8, The normalized production over the whole year, is demonstrated. The monthly averages throughout the year of collection loss, system loss, and the produced useful energy are 0.78, 0.07, and 3.92 respectively. The highest generated energy production belongs to September. On the contrary, the lowest production would occur in December.

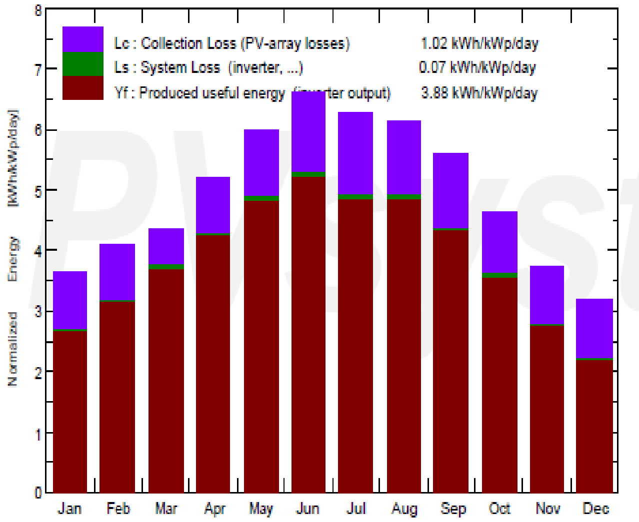

Figure 8. Monthly energy output with losses

Table 9 shows the annual balances and main results of the proposed photovoltaic system. According to this table the effective energy at the output of the array is 167.51 MWh.

Table 9. Results of Simulation

Month	Effective global irradiance (KWh/ m^2)	Effective energy (MWh)	Energy injected into Grid (MWh)	PR
Jan	87.9	9.73	9.54	0.730
Feb	97.0	10.38	10.18	0.768
Mar	127.6	13.40	13.16	0.850
Apr	148.5	14.90	14.65	0.818
May	177.9	17.56	17.27	0.805
Jun	190.4	18.38	18.08	0.791
Jul	185.8	17.59	17.31	0.775
Aug	181.9	17.71	17.42	0.798
Sep	149.8	15.19	14.93	0.773
Oct	124.7	13.04	12.80	0.777
Nov	89.6	9.71	9.52	0.736
Dec	73.2	8.05	7.89	0.693
Year	1634.4	165.62	162.74	0.781

4. conclusion

Designing and simulation of the photovoltaic system before implementation lead to enhancing the entire efficiency of the system.

In this study, a proposed grid-connected photovoltaic system which can be installed on the rooftop of the faculty of the engineering university building. The grid-connected system was chosen as a power supply for this building; when the power production is insufficient, it can use power from the grid.

Selecting the system components and configuration considerably depends on the geographical site location, solar irradiance and absorption of the most solar radiation of the panels.

Hence, determine the optimal tilt angle of solar panels was analyzed and then the best distance between rows of the panels based on available area to prevent shading was selected. The simulation results show that seasonal angle adjustment caused to increase in photovoltaic system efficiency**.**

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