

Performance Analysis of a Photovoltaic System Koya - Kurdistan of Iraq

Ari Afir Abdulrahman, and Dr. Saman Mirza Abdullah

Abstract— Designing Photovoltaic (PV) systems need a lot of analysis of their performance indicators. They cover some important factors, such yield factor, reference yield, performance ratio, and capacity factor. Only figures from these factors decided whether a PV system can effectively work in an area or not. This study analyzed the radiation rate and the performance indicators for Koya city, as a case of study. The study designed a 200 KW ground mounted PV based on the average radiation rate using Photo-Voltage Geographical Information System (PVGIS) simulation software. The final system yield of this designed system is (1699 hours), and its capacity factor is (19.39%), which is considered satisfactory.

Keywords—Renewable energy, Photovoltaic Systems, performance indicators, yield factors, performance ratio, capacity factor.

I. INTRODUCTION

DUE to many reasons, such as growth of economics and increase in population, demand for electricity in Kurdistan has been increased up to 88% since 2012. More fossil fuels are spent to reach electricity generation up to demand level, which consequently means more load on the budget of the Kurdistan Regional Government (KRG) up to US\$ 5 billion [1]. Although this area is reach with many renewable resources such as wind and solar energy, plans for utilizing such resources not considered yet as there are no good studies about [2]. To address such issues and problems, many studies have been conducted in neighboring areas (Iran, Turkey, Kuwait and Saudi Arabia), and all results indicated that Kurdistan is a fertile area for usability of renewable resources [3-6]. Therefore, it is very essential to analyze the performance of a PV system in this area so that such economical and environmental friendly systems could be included in long term plans. This study focused on designing a 200 KW ground mounted system. The work starts to check the climate of the area to find out the radiation rate. Then, the work going on to design the system, and finally checking the performance indicators.

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II. LITERATURE REVIEW

There are a lot of works have analyzed the performance of PV systems over the world [7, 8].

However, a computed performance for an area could not generalized as it will be changed with the change of area of study (the country). This is because, factors such as the climate, economic, GDP, and electricity demand and prices are affecting the performance rate of an PV system, and they are changeable from a country to another [9, 10]. Therefore, this review section targeted works that achieved in areas that neighbor to Kurdistan region, such as Jordon, Turkey, Kuwait, Iran, and some Mediterranean countries.

The first two countries that their climate and economic somehow analogous to Kurdistan are Turkey and Iran. The work has been achieved in Turkey [11] to analysis the optimal angle and orientation of the panels in a city called Sanliurfa. The work did all require calculations for building a PV system in areas surrounding this city. More works in Turkey achieved to study the impact of PV on pollutions and energy cost effect. The work [4] has study the effect of renewable energy on global warming. The work tested a 5 kwh PV system, and they checked the efficiency of all parameters in electrical circuit. Another work has targeted Turkey's geographical location, and they found that Turkey has several advantages for extensive use of most of renewable energy sources, such as solar PV systems [12]. In southern part of Kurdistan (Saudi Arabian and Kuwait), many works have been achieved on building PV systems [13]. A work achieved a PV system in Saudi Arabian to check the possibility of replacing a gasoline based power generator with PV based power generator system [6]. The work shows that installing a PV system can reduce 21% of the cost energy that consumed using gasoline power plants. Researches also confirmed that PV systems in the southern areas of Kurdistan can provide high performance. In Kuwait, a work has been done to assess the climate of that area against the performance as well as the economic feasibility of a grid connected PV systems [14]. They used the transient simulation program (TRNSYS) to check the performance and economic impacts. Their results showed that this area is very suitable for building grid connected PV systems for getting electrical power.

In the east side of Kurdistan, there is Iran country. For this country, many works have been conducted to check and assess the feasibility of building PV grid connection systems in that area. Two works have covered the economic and the climate of the area [3, 15] and their results have confirmed

the suitability of the area for building PV based power generator plants. Finally, from the west side, there are Syria and Jordan countries. For the Syria country, the annual average long-term solar radiation on a horizontal plane is measured and found to be 5.2 KWh/m² per day [16]. However, for the Jordan country, it was found that depending on the geographical location, the global solar radiation on horizontal surface varied between 1.51 and 2.46 MWh/m²/year with an overall mean value of 2.01 MWh/m²/year [17]. This present work checks the economic feasibility, performance analysis, and environmental assessment of a proposed grid PV system in the Kurdistan area.

III. CLIMATIC AND SOLRA RADIATION STATES

Geographically, Koya city is located in 36°04'37.6"N and 44°38'00.6"E (Error! Reference source not found.) [18]. Over a year, the area has an average of 10 to 12 hours of sunshine. The average solar radiation on the horizontal surface can be represented by the set of 8760 values per hour for a year. Error! Reference source not found., states the average monthly solar irradiation in the area in kWh/m² over a year. The annual average of solar radiation in Koya city is about 4.86KWh/m²/day. Such average rate of the solar energy is enough for installing an efficient grid connected PV system to reduce the electricity shortage problems in Koya city, especially during summer season. The 200 KW PV system for Koya city is designed as a ground mounted based system using records obtained from NASA SEE.



Fig. 1 Geographical position of Koya city

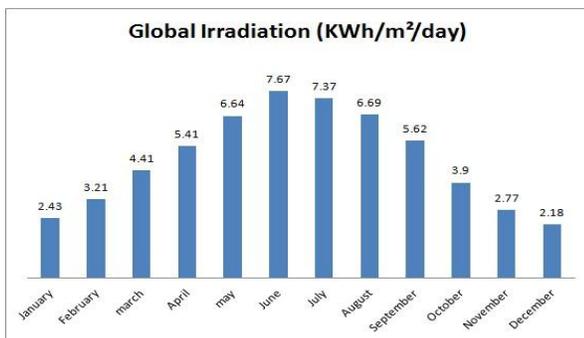


Fig. 2. Global Irridation Rate (KWh/m²/day)

IV. A 200 Kw GOUND MOUNTED PV SYSTEM

It is possible to design and install a PV system for Koya city and connected it to the grid. This work has depended on data and knowledge that obtained from the Department of electricity management of Koya to select the suitable feeder for connection purposes. This work found that Koya has 16 feeders of electricity distributed lines, and the feeder No. 4 is an adequate feeder where the grid connection can support. This is because, the load on this feeder is varying between 325 KW to 650KW over the four seasons, and the 200KW PV system can support this feeder effectively by 30% to 60% of the total load on this feeder.

To analyze and evaluate the irradiation rate, optimal inclination, and average obtained energy, this work simulated with the Photo-Voltage Geographical Information System (PVGIS) software. To set this software on Koya location, the incident global irradiation for the chosen location (36°4'12" North, 44°38'25" East, Elevation: 552 m a.s.l) is determined. Table-1 illustrated obtained factors of Irradiation on horizontal plane (Hh) (Wh/m²/day), Irradiation on optimally inclined plane (Hopt) (Wh/m²/day) and optimal inclination (Iopt) (deg.). Table-1 reveals that optimal inclination angle can be set on 32 degrees. This angle is very important during installing the PV system, because it effects on the electricity production from the given system. More, the average of annual energy in Koya is 5.14 KWh/m²/day. However, by installing PV Panels optimally, it becomes 5.79 KWh/m²/day. The performance of the 200KW designed grid connected PV system in the optimal inclination and orientation to the PVGIV software can be represented in Table-2. The table states that the average daily electricity production is 970 KWh and the average monthly electricity production is 29500 KWh. Moreover, the total electricity production is 354 MWh for the year. The specification of the PV panels, green invertors, and system parameters that used in this work are illustrated in Table-3 [19].

TABLE I
MONTHLY BASED OUTPUT FROM PVGIS SIMULATION SOFTWARE

| Month | Hh | Hopt | Iopt |
|----------------|------|------|------|
| Jan | 2370 | 3670 | 60 |
| Feb | 3110 | 4260 | 51 |
| Mar | 4390 | 5250 | 39 |
| Apr | 5410 | 5680 | 23 |
| May | 6920 | 6620 | 10 |
| Jun | 8300 | 7530 | 3 |
| Jul | 7980 | 7440 | 7 |
| Aug | 7330 | 7500 | 19 |
| Sep | 6090 | 7130 | 35 |
| Oct | 4250 | 5760 | 59 |
| Nov | 3050 | 4780 | 59 |
| Dec | 2320 | 3800 | 62 |
| Average (year) | 5140 | 5799 | 32 |

V.PERFORMANCE ANALYSIS

Parameters describing energy quantities for the PV system and its components have been established by the

International Energy Agency (IEA) Photovoltaic Power Systems Program and are described in the IEC standard 61724 [20]. Three of the IEC standard 61724 performance parameters may be used to define the overall system performance with respect to the energy production, solar resource, and overall effect of system losses. These parameters are the final PV system yield, reference yield, and performance ratio[21]. Although the capacity factor can be take in to consideration.

TABLE II
MONTHLY BASED OUTPUT FROM PVGIS SAMULATION SOFTWARE

| Months | Fixed system: Inclination = 32 deg. Orientation = 1 deg | | | |
|-------------------|--|--------|-------|------|
| | Ed | Em | Hd | Hm |
| Jan | 616.00 | 19100 | 3.67 | 114 |
| Feb | 714.00 | 20000 | 4.26 | 119 |
| Mar | 879.00 | 27200 | 5.25 | 163 |
| Apr | 949.00 | 28500 | 5.68 | 170 |
| May | 1100.00 | 34300 | 6.62 | 205 |
| Jun | 1260.00 | 37700 | 7.52 | 226 |
| Jul | 1240.00 | 38500 | 7.43 | 230 |
| Aug | 1260.00 | 39000 | 7.50 | 232 |
| Sen | 1200.00 | 35900 | 7.13 | 214 |
| Oct | 968.00 | 30000 | 5.76 | 178 |
| Nov | 803.00 | 24100 | 4.77 | 143 |
| Dec | 638.00 | 19800 | 4.80 | 118 |
| Average | 970.00 | 29500 | 5.79 | 176 |
| Total of ONE year | 11627 | 354100 | 70.39 | 2110 |

Ed= Average daily electricity production from the given system (Kwh), Em= Average monthly electricity production from the given system (Kwh), Hd= Average daily sum of global irradiation per square meter received by the modules of the given system (Kwh/m²), Hm= Average sum of global irradiation per square meter received by the modules of the given system (Kwh/m²).

TABLE III
PARAMETERS OF THE DESIGNED PV SYST

| PV Panel | | Green Invertors | | Designed System | |
|--------------------------|-------------------------|---------------------------|-------------|----------------------------|-------|
| Parameters | Value | Parameters | Value | Parameters | Value |
| Maximum Power | 300 W | Maximum Power Output (AC) | 120 KW | Number of PV Panels | 670 |
| Open Circuit Voltage | 45.1 V | Nominal Frequency | 50 / 60 Hz | No. of PV panels in | 10 |
| Voltage at maximum Power | 35.2 V | Output Voltage | 400/230 VAC | No. of PV panels in Series | 67 |
| Short Circuit Current | 8.94 A | Power Factor | 0.99 | No. of Inverters | 2 |
| Current at maximum Power | 8.52 A | Maximum Efficiency | 85% - 96% | Total covered area (m2) | 1400 |
| Efficiency | 15.3% | | | Output Voltage (KV) | 2.36 |
| Dimensions | W: 994 mm L: 1971 mm | | | Output Current (A) | 85 |
| | | | | Inclination of PV panels | 32° |
| | | | | Orientation of PV panels | 1° |

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A. Final system yield

Yield factor (Y_F) is defined as the annual, monthly or daily net AC energy output of the system divided by the peak power of the installed PV array (Equation-1) at standard test conditions (STC) [22-24].It represents the number of hours that the PV array would need to operate at its rated power to provide the same energy [21].

$$Final\ System\ (Y_F) = E / P_o \tag{1}$$

Where

E is the net Ac energy output of the system KWh AC.

P_o is the peak power of the installed PV array KWDC.

The monthly final system yield for the Koya city can be Seen in **Error! Reference source not found.3**

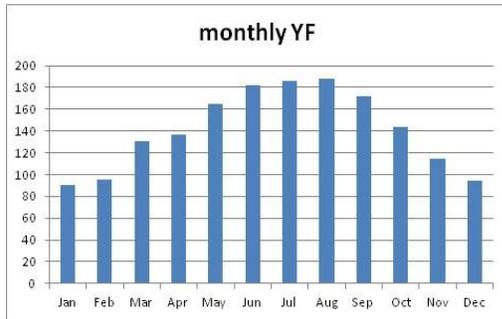


Fig. 3 Monthly Final System Yield for 200 KW PV System in Koya City

B. Reference yield

The reference Yield (Y_r) is the total in-plane solar isolation H_t (kWh/m²) divided by the array reference irradiance (1 kW/m²). It represents an equivalent number of hours at the reference irradiance [23]. It can be found using equation-2 and monthly records of (Y_r) for Koya area are shown in Error! Reference source not found.4.

$$Reference\ Yield\ (Y_r) = H_t / G \quad (2)$$

Where

H_t is the total in-plan irradiance kWh/m².

G is the array reference irradiance (1KW/m²).



Fig. 4 Monthly Reference Yield for 200 KW PV Systems in Koya City

C. Performance Ratio

Performance ratio (P_r) represents the total losses like inverter inefficiency, wiring, is matching, and other losses in the system when converting from name plate DC rating to AC output. It can be obtained by dividing the final yield to the reference yield [20, 23].PR values are typically reported on a daily or monthly or yearly basis [20]. The monthly performance ratio for the proposed PV system is illustrated in Error! Reference source not found.5, and can be computed through equation-3.

$$Performance\ Ratio\ (Pr) = Y_f / Y_r \quad (3)$$



Fig. 5. Monthly Reference Ratio for 200 KW PV Systems in Koya City

D. Capacity Factor

The Capacity Factor (C_F) is defined as the ratio of the actual annual energy output to operates the amount of energy which the PV array would generate when at full rated power (Pr) for 24 h per day for a year. This factor, which could be obtained using either equation-4 or equation-5, evaluates the usage of the PV array [5, 25]. The C_F of the proposed 200 KW PV system in Koya is 19.39%, which is considered good [26].

$$Capacity\ Factor\ (CF) = E / P_0 \times 8760 \quad (4)$$

OR

$$Capacity\ Factor\ (C_F) = Y_F / 8760 \quad (5)$$

VII. CONCLUSION

The design of the first ground mounted grid connected PV system with 200 KW in the Northern part of Iraq (Kurdistan) has been investigated. The analysis has been done in three directions; systems analysis, cost effective impact and environmental impact. The following conclusions have been drawn:

- There are good irradiation rates in the area which is enough to build an efficient PV system.
- The final system yield of this system is (1699 hours), and its capacity factor is (19.39%), which is considered satisfactory.

As a conclusion, the integration of this renewable energy generation with the grid network is considered satisfactory.

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