

Energy Yield Analysis and Design of Solar PV Plants

Raheem H. Rhaif

Department of Physics, College of Science, University of Sumer, Rifai, Iraq

Abstract:

The sun is considered one of the largest environmentally eco-friendly and sustainable energy sources, and Iraq ranks among the countries with substantial natural wealth. Iraqi population have recently suffered from the high number of hours of electrical power outage for the local and government sectors this depends on fossil fuels, as Iraq imports most of the liquid gas used for this purpose, and from this point of view, it is necessary to search for energy sources that support the supply of electrical energy and compensate for the shortage in the hours of processing of electric current. In the present research project. The solar photovoltaic system was connected on the rooftop of structure in Baghdad. A comprehensive performance assessment of this on-grid system is carry out under the local climatic conditions of Baghdad. Over the monitoring period, the system achieved an annual energy output of 166.893kWh. The daily array yield, final yield and reference yield were determined to be 4.72 kWh/kWh, 4.23 kWh/kWh, and 5.58 kWh/kWh, respectively, indicating the systems operational efficiency under real-world conditions. The results further revealed that annual average regular total losses, array fatalities and system losses are 1.35 kWh/kW, 1.12 kWh/kWh, and 0.23 kWh/kWh, additionally, the yearly efficiencies of the inverter, the overall systems, and array were found to be 98.38%, 75.91% and 20.98%. The presentation ratio and average capacity issue were 17.6% and 75.91%.

Keywords: Final yield, Capacity Factor, Solar system, performance Ratio, Reference yield.

Introduction

The demand for energy has increased with increasing population growth and urban and technological development in the countries of the world. Where fossil fuels are one of the important and basic sources of energy supply, but these resources are on their way to being depleted and their price are constantly increasing, and the use of this type of sources is accompanied by the emission of greenhouse gases, which are sources of environmental pollution and a major cause of global warming. Therefore, the world began to invest other sources of energy, represented by environmentally friendly and renewable energy sources. The investment of the types of these sources varies between countries of the world according to their availability.

Sundry studies have been conducted on solar energy investment in Iraq, beginning with evaluating of solar panels performance under Iraqi environmental conditions [1] and measurement of solar radiation levels reaching the earth surface [2], followed by efforts to enhance the efficiency the solar panel [3,4]. Based on the findings these studies, effective solar system were subsequently formulated and applied to optimize energy generation [6].

In an effort to increase the influence of renewable energy to electricity group, countries worldwide have recently begun deploying both on-grid and off-grid astral system of varying capacities, tailored to sort of application. For instance, South Korea reached a solar capacity of 4.8 GW in 2021 [7]. And by the end of the same year, the country had installed a total of 22 GW solar power plants [8]. A key approach to assessing the economic viability of such project is the performance evaluation of photovoltaic PV systems. This evaluation considers all external factors affecting system operation, including solar irradiance, relative humidity, ambient temperature, the tilt angles, and wind speed [9-14].

The inverter, battery bank, utility grid, PV array, and charge controller are consists of PV solar system (see Fig.1).

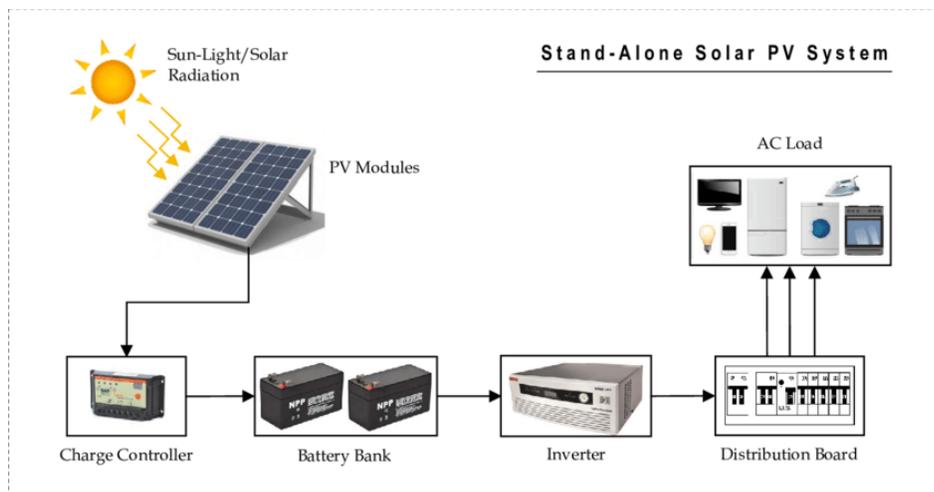


Fig. 1. Stand-Alone solar PV system [20]

Table (1): PV Array Characteristics

PV Array Characteristics			
PV module		Inverter	
Manufacturer	AE Solar	Manufacturer	Huawei Technologies
Model	AE 500ME-T150	Model	SUN2000-100KTL-M1-480Vac
(Original PVsyst database)		(Original PVsyst database)	
Unit Nom. Power	500 Wp	Unit Nom. Power	100 kVA
Number of PV modules	216 units	Number of inverters	1 unit
Nominal (STC)	108 kWp	Total power	100 kVA
Modules	12 Strings x 18 In series	Operating voltage	200-1000 V
At operating cond. (50°C)		Max. power (=>40°C)	110 kVA
Pmpp	98.9 kWp	Phom ratio (DC:AC)	1.08
U mpp	708 V	Power sharing within this inverter	
I mpp	140 A		
Total PV power		Total inverter power	
Nominal (STC)	108 kWp	Total power	100 kVA
Total	216 modules	Number of inverters	1 unit
Module area	515 m ²	Phom ratio	1.08
Cell area	476 m ²		

Table (2): Array Losses.

Array Soiling Losses		Thermal Loss factor		DC wiring losses	
Loss Fraction	3.0 %	Module temperature according to irradiance		Global array res.	84 mΩ
		Uc (const)	20.0 W/m ² K	Loss Fraction	1.5 % at STC
		Uv (wind)	0.0 W/m ² K/m/s		
Serie Diode Loss		LID - Light Induced Degradation		Module Quality Loss	
Voltage drop	0.7 V	Loss Fraction	2.0 %	Loss Fraction	-0.8 %
Loss Fraction	0.1 % at STC				
Module mismatch losses		Strings Mismatch loss		Module average degradation	
Loss Fraction	2.0 % at MPP	Loss Fraction	0.1 %	Year no	10
				Loss factor	0.4 %/year
				Mismatch due to degradation	
				Imp RMS dispersion	0.4 %/year
				Vmp RMS dispersion	0.4 %/year

Presentation parameters of photovoltaic solar schemes

As reported by of the Intercontinental Energy Agency (IEA), a key component of the performance parameters of a photovoltaic system is the entire energy generated by the system. The control generated contains of performance ratio (PR), capacity feature (CF), finishing yield (YF), reference yield (YR), and system efficiency. [15].

1. Output Energy

A total alternating current vigor produced by the system ended a given retro can be determined by summing the energy produced on an daily, once-a-month, and hourly basis, as calculated using the following:

$$E_{AC;h} = \sum_{t=1}^{60} E_{AC,t} \quad (1)$$

$$E_{AC;d} = \sum_{h=1}^{24} E_{AC,h} \quad (2)$$

$$E_{AC;m} = \sum_{d=1}^N E_{AC,d} \quad (3)$$

2. Finishing PV System Yield

The final photovoltaic PV System Yield, too referred to as the yield issue, is calculated by dividing the alternating current (AC) vigor output of the PV system- measured on a daily, monthly, or annual basis (EAC). [16]. It is expressed as follows by:

$$YF = E_{AC} / P_{PV, \text{rated}} \quad (4)$$

3. Reference yield

The ratio of full solar radioactivity (Ht) in (kWh/m²) to the reference radioactivity G (1 kW/m²) is recognized as reference yield [16]. It is assumed by:

$$YR = (Ht) \text{ (kWh/m}^2\text{)} / G \text{ (1 kW/ m}^2\text{)} \quad (5)$$

4. Performance ratio

The Presentation Ratio is the key indicator used to check the PV Plant's efficiency and effectiveness. [17].

Results and discussion

Iraq experiences high levels of solar irradiance year-round, resulting in substantial electricity generation from photovoltaic panels. During the simulated year, the lowest energy rates in the winter, with approximately 10980 kWh in December, and 12393 in January. Energy output gradually increased toward the summer, reaching a peak of 16957 in June. Despite the highest solar

radiation levels occurring in June and July, power production began to decline owing to elevated ambient temperatures, which negatively affects the competence of the solar panels.

The clearly demonstrates the negative impact of elevated temperatures on the PV systems yield during the hotter months. In December 2026 the reference, array, and final yields showed their lowest values due to reduced solar radiation and lower temperatures. In June the yields increased significantly as a result of higher solar radiation levels, despite the negative impact of high ambient temperatures .In Table 3

	GlobHor kWh/m ²	DiffHor kWh/m ²	T_Amb °C	GlobInc kWh/m ²	GlobEff kWh/m ²	EArray kWh	E_User kWh	E_Solar kWh	E_Grid kWh	EFrGrid kWh
January	94.2	36.7	7.03	136.6	130.3	12393	8493	3131	9090	5362
February	104.4	51.9	9.95	133.0	126.8	11918	7671	3069	8681	4602
March	145.6	73.2	14.83	167.8	159.7	14631	8493	3428	10039	5066
April	176.2	88.2	19.42	186.1	177.0	15883	8219	3857	11772	4362
May	197.1	101.9	25.51	194.0	184.2	16110	8493	4173	11661	4320
June	219.7	97.0	30.58	209.6	199.1	16957	8219	4287	12365	3932
July	215.1	97.7	33.78	208.5	198.1	16669	8493	4297	12067	4196
August	196.8	91.7	33.35	202.5	192.6	16224	8493	4082	11848	4412
September	167.0	68.5	28.34	188.8	179.7	15427	8219	3704	11451	4515
October	126.6	63.1	22.88	155.3	148.0	13137	8493	3478	9436	5015
November	95.9	43.3	13.75	132.3	126.1	11692	8219	2915	7892	5304
December	83.2	37.4	8.74	121.3	115.7	10980	8493	2755	7417	5738
Year	1821.8	850.4	20.74	2035.8	1937.4	172019	100000	43175	123719	56825

Normalized productions (per installed kWp)

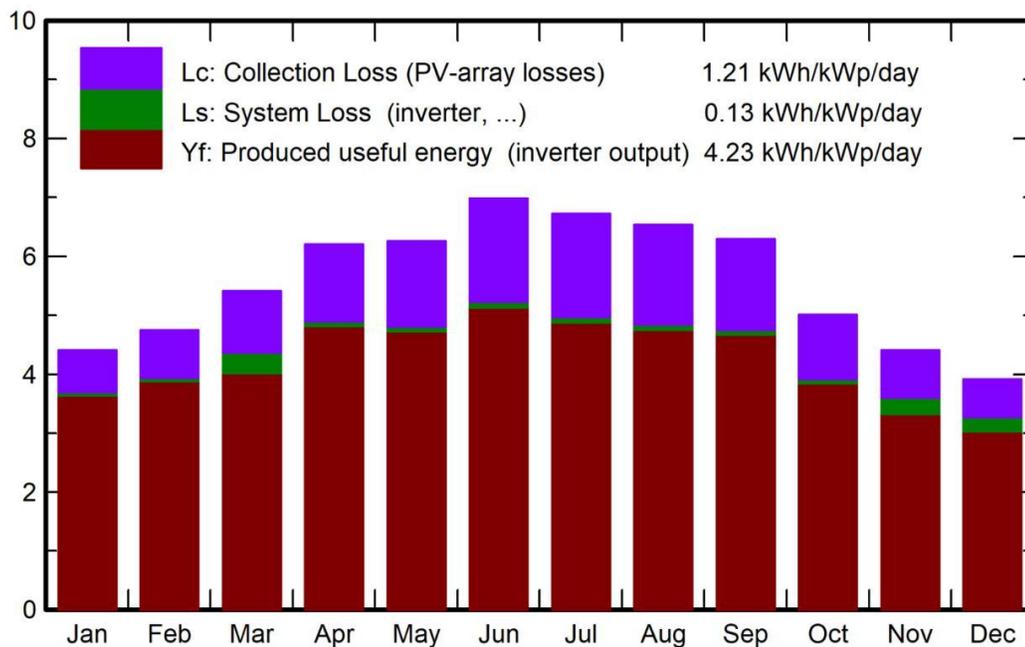


Fig. 2. Electrical energy manufacture during the year.

One of the most significant factors affecting the reduction in electrical output from solar plans is the ambient temperature, as we can see through Figure 2.

As for the general losses, they touched 5.16kWh/kWp/day as the highest rate in June and their lowermost rates in January and December (2.39kWh/kWp/day). The yearly daily averages of array, system and overall losses are 1.21kWh/kWp/day, 0.13kWh/kWp/day and 1.34kWh/kWp/day, respectively.

Depending on the make and type, the solar inverter consumed an competence of around 98%. Because certain electricity was lost by way of heat and some was accustomed power the inverter, its competence will not be 100%. Plans like MOSFET are used as switches in power electronics, chiefly in the building of electronic converters. This is due to the detail that a change should, in theory, have no fatalities because it should either have zero voltage or zero current, meaning that power losses are continuously zero.

A presentation ratio (PR) is dependents a amount in variables, but the heights of incident solar radiation, the fever rates of the solar boards determined by the ambient temperature, and the taxes of wind speeds are the most vital ones. and there are no clouds or mist, and therefore the recital rates rise to become at their highest standards in the months of April (78%) and September (76%), and then the effect of temperature clearly seems in seasonal months, which damagingly affects the performance ratio. It touched its minimum value in the Jun (74 %). The yearly average of the performance ratio was around 75.91%. According to the alteration in the performance ratio of the solar board system, the capacity factor (CF) changes as exposed. The annually regular of CF was 17.6%.

Performance Ratio PR

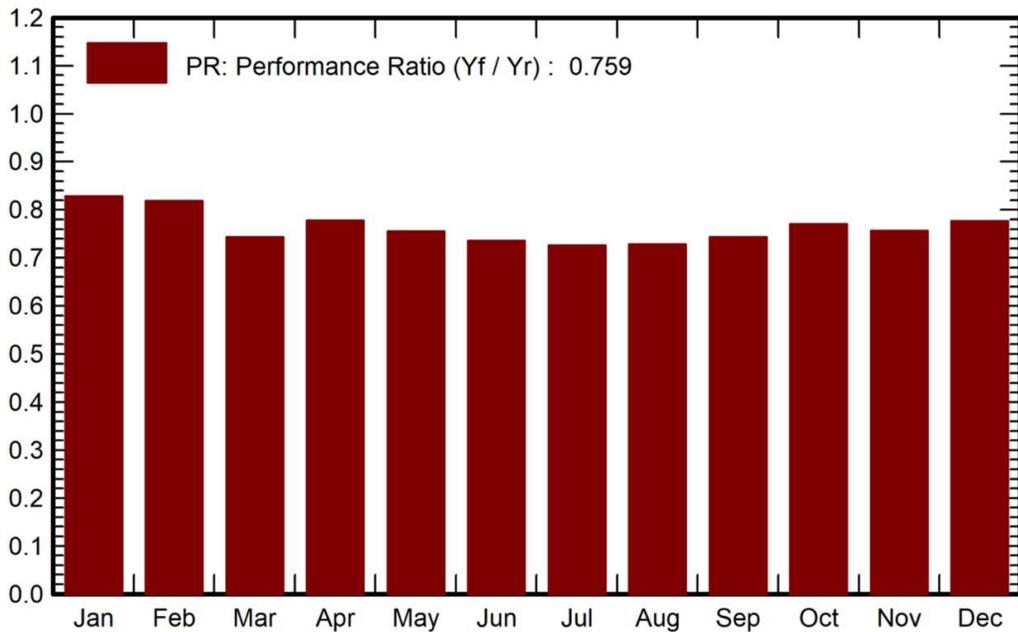


Fig. 3. Variation of performance ratio

The performance ratio assesses how effectively a PV system operates while considering environmental factor like temperature, wind speed, irradiation, and the heterogeneous of the system can be illustrated by the capacity factor, which neglects environmental influences and module degradation. Conversely, the performance ratio incorporates factor such as grid accessibility and the threshold solar irradiance required for operation.

Conclusions

This is particularly relevant under Iraq existing conditions in experiencing a critical shortage of electrical power supply and reduces environmental pollution. Based on finding of the current research.

References

1. Mohammed T. Hussain and Emad. J. Mahdi, "Assessment of Solar Photovoltaic Potential in Iraq", IOP Conf. Series: Journal of Physics: Conf. Series 1032 (2018) 012007.
2. Nibras Mahmood Obaid, Naseer Kareem Kasim, and Emad Talib Hashim "Performance Assessment of First Grid –tied PV Solar System under Baghdad City Climate Condition", Iraqi Journal of Science and Technology, 10(1) 2019.
3. Naseer K. Kasim, Ahmed F. Atwan, Fadhil Mahmood Oleiwi, and Jaber Sh. Hameed, "Study the performance of V-Trough PV solar system with two axis tracking", AIP Conference Proceedings 2144, 030008 (2019).
4. Naseer K Kasim, Ahmed F Atwan, and Fadhil Muhmood Eliewi, "Improve the performance of solar modules by reflectors", IOP Conf. Series: Journal of Physics: Conf. Series 1032 (2018) 012031.
5. Abdulrahman Th. Mohammad; Zuhair S. Al-Sagar; Ali Nasser Hussain; Majid Khudair Abbas Al-Tamimi, "Performance Analysis of 4.68 kWh Proposed Grid-Connected PV System in Iraq", International Congress of Advanced Technology and Engineering (ICOTEN), INSPEC Accession Number: 21174188, 2021
6. Anas Lateef Mahmood, Amina Mahmood Shakir, Bahaa Abdulkhaliq Numan, "Design and performance analysis of stand-alone PV system at Al-Nahrain University, Baghdad, Iraq", International Journal of Power Electronics and Drive System (IJPEDS) Vol. 11, No. 2, pp. 921~930, June 2020.
7. Anon, "PV magazine International", 2022a. <https://www.pv-magazine.com/2022/01/10/south-korea-installed-4-4-gw-of-pv-capacity-in-2021/> (accessed May 23, 2022).
8. Ali, H., Khan, H.A., "Techno-economic evaluation of two 42 kWp polycrystalline-si and CIS thin-film based PV rooftop systems in Pakistan", Renew. Energy, 152, 347–357, 2020.
9. Farhoodnea, M., Mohamed, A., Khatib, T., Elmenreich, W., "Performance evaluation and characterization of a 3-kWp grid-connected photovoltaic system based on tropical field experimental results: New results and comparative study", Renew. Sustain. Energy, Rev., 42, 1047–1054, 2015.
10. Kumar, K.A., Sundareswaran, K., Venkateswaran, P.R., "Performance study on a grid-connected 20 kWp solar photovoltaic installation in an industry in Tiruchirappalli (India)", Energy Sustain. Dev., 23, 294–304, 2014.
11. Marion, B., Deceglie, M.G., Silverman, T.J., "Analysis of measured photovoltaic module performance for Florida, Oregon, and Colorado locations", Sol. Energy, 110, 736–744, 2014.
12. Seme, S., Sredenshek, K., Štumberger, B., Hadžiselimović, M., "Analysis of the performance of photovoltaic systems in Slovenia", Sol. Energy, 180, 550–558, 2019.
13. Okello, D., Van Dyk, E.E., Vorster, F.J., "Analysis of measured and simulated performance data of a 3.2 kWp grid-connected PV system in Port Elizabeth, South Africa", Energy Convers. Manag. 100, 10–15, 2015.
14. Rebolledo, F., Mendoza-Araya, P., Carvajal, G., Ramírez, G., "Performance evaluation of different solar modules and mounting structures on an on-grid photovoltaic system in south-central Chile", Energy Sustain. Dev. 68, 65–75, 2022.

15. B. Marion, J. Adelstein, and K. Boyle, H. Hayden, B. Hammond, T. Fletcher, B. Canada, and D. Narang Shugar, H. Wenger, A. Kimber, and L. Mitchell, G. Rich and T. Townsend, (2005). Performance Parameters for Grid-Connected PV Systems. In Photovoltaic Specialists Conference, 2005. Conference Record of the Thirty-first IEEE IEEE. (pp. 1601–1606). Lake Buena Vista, Florida.
16. Ayompe, L. M., Duffy, A., McCormack, S. J., & Conlon, M. (2011). Measured performance of a 1.72 kW rooftop grid connected photovoltaic system in Ireland. *Energy Conversion and Management*, 52(2), 816–825.
17. Sidi, C.E.B.E., Ndiaye, M.L., El Bah, M., Mbodji, A., Ndiaye, A. and Ndiaye, P.A., 2016. Performance analysis of the first large-scale (15 MWp) grid-connected photovoltaic plant in Mauritania. *Energy conversion and management*, 119, pp.411-421.