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Design and Performance Analysis of 250 kW Grid-Connected Photovoltaic System in Iraqi Environment Using PVsyst Software

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ABSTRACT

A 250 kW grid-connected photovoltaic (PV) plant systems have been installed at the Ministry of Electricity in Baghdad and penetrated to the Iraqi national grid since November 2017. This is the first high power grid-connected PV system that has been installed in Iraq and it's one of the four parts 1MW large-scale PV systems that should be completed in early of 2019. This paper presents the design and performance analysis of this system using a PVsyst software package. The performance ratio and different losses that occurred in the system are also calculated. The results show that the performance ratio is 75% using 1428 photovoltaic panels type (Sharp 175Wp) spread over an area of 1858 m². The total energy injected into the grid is (346692 kWh/year) .Based on the simulation results that developed in this paper, the practical PV grid-tied system has been implemented in Baghdad site.

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1. INTRODUCTION

PV systems are the one of the major sources of electricity in the power systems. [1-3]. Solar resources are being developed by scientists with better technology to maximize as much as possible energy production. The grid-connected PV system that provides electricity straight to the power grid is one of the leading models of this technology. The system developer is accountable for choosing the various parameters: PV modulus amount and type, the inverter type and the setup area distribution of the parts etc. The values of the design parameters are, however, indirectly proportional and are a major challenge.For instance, the installation of many modules increases the PV plants' energy production; on the other hand, it leads to high cost in installation and lifetime maintenance of the PV plant. That is why designing a grid tied system is challenging for designers. A significant focus on the advancement and improving the energy effectiveness of PV systems has been laid in the research community and in industry [4]. Modeling software packages based on meteorological databases, PV modules and inverter data [5] is an appropriate instrument for productivity forecasting.There is several existing software tools for analyzing and dimensioning the PV grid-connected system. One of these software packages is a PVsyst software. The photovoltaic system package at the University of Geneva was developed over 20 years ago[6] as it integrates the research, sized and simulation assistance of PV systems into pre-feasibility industries [7, 8, 9, 10]. In [11], In order to predict power generation and energy loss, the PVsyst simulation tool was used for an IRB Complex-5 system with a roof integrated photovoltaic (PV) of 200 kW. To assess capacities (CF), efficiency ratios (PR) and efficiencies, an energy-generation analysis and various input parameters were also carried out. A comparative study of grid-tied PV system using PVsyst software package has been detailed in [12]. This scheme simulates a PV of 60 kWp with comparable parameters and analyzes the energy supply to the grid together with the energy produced by the PV array. PVsyst for a 1000-kWp network-connected photovoltaic system was used for simulation. We have examined the performance ratio, generated energy, scope effectiveness and a number of other parameters [13]. The energy produced has been well matched with what is presented in the outcomes of the PVsys simulation in a ten-MW network connected solar power plant[14]. A research with an interactive PV system on a 190 kW grid was carried out. In the research, the practical findings of the PVsys simulations were comparable. The real measured energy was only a little differently at 813kWh / kWp [15] with PVsys simulated yields (823kWh / kWp).

2. GEOGRAPHICAL CONDITIONS

Baghdad is a city in Iraq's core area. The location is 33.1 ° N latitude and 44.3 ° E longitude. The temperature in the summer varies from 35 ° C to 50 ° C and in the winter it is 2 ° C. The Baghdad region is known as a heat-dry zone with large areas of the plain. This offers an optimal atmosphere for any PV project. This is therefore a ideal place to implement the photovoltaic power plant. The Solar Exposure curves in Baghdad show that radiation levels in June (6.55 Sun) [9] have been shown in Fig. 1.

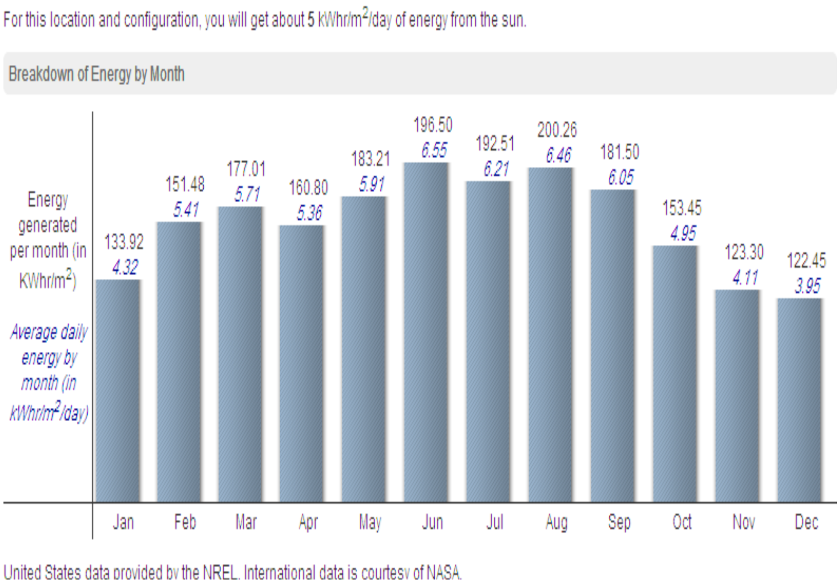

Figure 1. Solar exposure for Baghdad city throughout the year [9]

3. THE DEVELOPED PV GRID-TIED SYSTEM

The PV grid-tied system that has been used in this paper consists of the following known stages: PV modules, a string inverter, and finally a national Iraqi grid. The grid does not require a storage element as the generated energy is sold back to the main grid. The proposed model is illustrated in Fig.2 by the PVsyst software. It is expected that solar panels are not shaded by free horizons during the design and simulation procedure of the photovoltaic systems and simulations will be conducted based on the maximum year-round demand. The PVsyst software database selects inverters and solar panels to satisfy the highest yearly requirements. The tilt angle for the PV array over a car port structures is kept equal to 10° to gain maximum solar irradiation [10, 11]. The modules are oriented south east with two orientation angles (-44°) and (136°) as shown in Fig.3. Table 1 shows the PV modules characteristics which are used in the developed system.

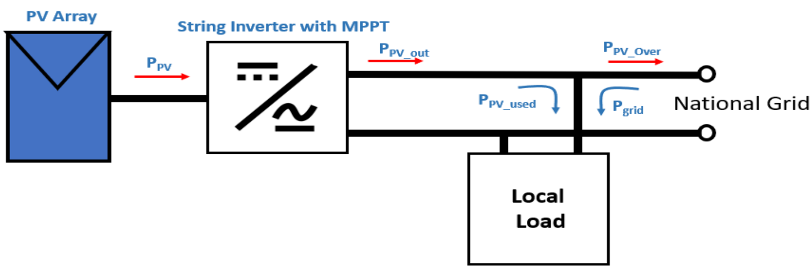

Figure 2. Grid-Connected PV system simulated in PVsyst Software.

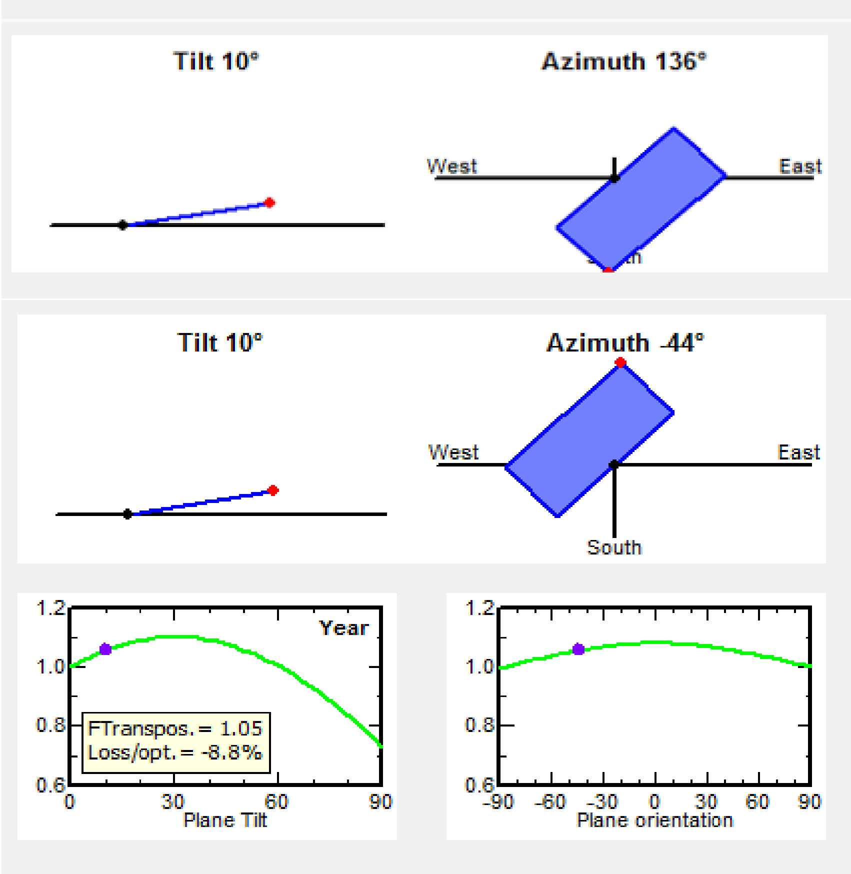

Figure 3. Inclination and Orientation.

Table 1. PV Modules characteristics used in the system.

Module type	Mono-crystalline
Rated power	175Wp
Efficiency	13.45%
I_{mpp}	4.95A
V_{mpp}	35.4V
Temperature coefficient	-0.34% /C°

4. THE IMPLEMENTED PV GRID-TIED SYSTEM

As mentioned earlier, the selected grid-tied PV system that has been analyzed in this paper is shown in Fig.2. The most important parts of this system are the types of the PV panel and inverter. According to their technology, there are two kinds of PV modules available: Crystalline Silicon and Thin Film. In this study, the Monocrystalline module has been used because it has higher efficiency than the polycrystalline module. The real PV array that has been installed in the Ministry of Electricity site is shown in Fig. 4a, which is based on Sharp 175Wp. It’s worth to mention here that this real system was designed and implemented based on the designing and the analysis proposed in this paper. In this research, a complete production of 250 kW is obtained using 10 units of SMA Solar Inverters (Fig. 4b). For Iraqi grid compatibility, the inverter output is set to 400V (50Hz). The operating between PV panel's production and the inverters are summarized in Table 2.

Table 2. Operational Conditions.

Parameters	Description
V_{mpp}(50°C)	543V
V_{mpp}(20°C)	595V
V_{oc}(-10°C)	792V
I_{mpp} (STC)	415.8A
I_{sc} (STC)	462A
Max. operating power at 1000W/m2 and 50°C	226kWp
Array nominal power	250Wp


Figure 4. This figure shows the real PV system grid tied that has been installed at Baghdad Site, (a) Solar Array (Sharp 175Wp).; (b) Solar Inverter (SMA 25kW).

The summary of the proposed system configuration is tabulated in Table 3.

Table 3. System configuration.

Parameters	Description
No. of modules	1428
Modules Area	1858m²
No. of Inverters	10
Nominal PV power	250kWp

5. PERFORMANCE ANALYSIS

The results of the simulation reflect the expected monthly average energy injected into the grid in (kWh) is listed in Table 4. It can be observed that the maximum energy injected into the grid in July is (42263kWh). Likewise, the minimum energy injected into the grid in December is (13844 kWh). The total energy injected into the grid is (346692 kWh/year). It's known that the performance ratio (PR) is the ratio of the final PV system yield (Yf) and the reference yield (Yr) [12, 13]. Thus, PR = Yf/Yr. The monthly performance ratio of the grid-connected system for the Baghdad site are depicted in Table 5. It's found that the yearly average performance ratio is equal to 0.75. Moreover, the meteorological and incident energy of the PV system is shown in Table 6, where the global horizontal irradiation (GlobHor) is (1872.0kWh/m2/year) while the horizontal diffuse irradiation (DiffHor) is (686.87 kWh/m2). The overall global incident energy on the collector plane is (1851.0 kWh/m2). However, the loss due to increasing temperature, internal network, and power electronic converters are also considered in the performance analysis. The detailed monthly system average losses in (kWh) are shown in Table 7. The loss in module quality is 12816 kWh / year (Mod Qual). Mispar loss module is (8285.7kWh / year). The loss of Ohmic cable (Ohm loss) is (7168 kWh per annum). Maximum Power Point (MPP) Virtual Energy Array is EArrMPP (372801 kWh / year). The overall loss of the inverters is 26109 kWh per year.

Table 4. Energy injected into the grid.

Month	Euser kWh
January	14442
February	18242
March	27938
April	33110
May	41192
June	41971
July	42263
August	39160
September	31399
October	25363
November	17769
December	13844
Year	346692

Table 5. Normalized Performance Coefficients

	Y_r kWh/m².day	L_c	Y_a kWh/kWp/day	L_s	Y_f kWh/kWp/day	L_{cr}	L_{sr}	PR
January	75.35	0.403	0.01	0.164	1.86	0.166	0.067	0.767
February	93.84	0.537	0.01	0.208	2.61	0.160	0.062	0.778
March	142.42	0.719	0.02	0.269	3.61	0.156	0.059	0.785
April	172.00	0.993	0.02	0.324	4.42	0.173	0.056	0.770
May	218.58	1.346	0.03	0.388	5.32	0.191	0.055	0.754
June	228.27	1.602	0.03	0.408	5.60	0.211	0.054	0.736
July	233.20	1.672	0.03	0.395	5.46	0.222	0.053	0.725
August	214.49	1.499	0.03	0.365	5.05	0.217	0.053	0.731
September	170.95	1.203	0.02	0.307	4.19	0.211	0.054	0.735
October	134.58	0.821	0.02	0.246	3.27	0.189	0.057	0.754
November	93.97	0.571	0.01	0.192	2.37	0.182	0.061	0.757
December	73.34	0.420	0.01	0.158	1.79	0.178	0.067	0.755
Year	1850.99	0.985	0.02	0.286	3.80	0.194	0.056	0.750

Table 6. Meteorological and Incident Energy

	GlobHor kWh/m²	DiffHor kWh/m²	T Amb °C	WindVel m/s	GlobInc kWh/m²	DifSInc kWh/m²	Alb Inc kWh/m²	DifS/Gl
January	76.0	42.73	8.60	0.0	75.3	42.38	0.115	0.562
February	95.0	47.61	11.00	0.0	93.8	47.15	0.144	0.502
March	144.0	69.86	14.70	0.0	142.4	69.19	0.219	0.486
April	174.0	72.15	20.20	0.0	172.0	71.44	0.264	0.415
May	221.0	72.02	24.60	0.0	218.6	71.32	0.336	0.326
June	231.0	61.93	29.60	0.0	228.3	61.28	0.351	0.268
July	236.0	64.71	32.50	0.0	233.2	64.04	0.359	0.275
August	217.0	64.70	31.60	0.0	214.5	64.04	0.330	0.299
September	173.0	54.24	28.80	0.0	171.0	53.68	0.263	0.314
October	136.0	54.32	23.00	0.0	134.6	53.80	0.207	0.400
November	95.0	41.79	16.30	0.0	94.0	41.40	0.144	0.441
December	74.0	40.82	11.20	0.0	73.3	40.48	0.112	0.552
Year	1872.0	686.87	21.06	0.0	1851.0	680.21	2.844	0.367

Table 7. Detailed System Losses.

	GlobEff (kWh/m²)	ModQual (kWh)	MisLoss (kWh)	OhmLoss (kWh)	EArrMPP (kWh)	InvLoss (kWh)	EOutInv (kWh)
January	71.2	556	359.4	160	15713	1271	14442
February	89.5	687	443.7	258	19699	1457	18242
March	136.8	1035	669.0	468	30022	2084	27938
April	166.2	1217	786.6	673	35541	2431	33110
May	211.9	1506	974.2	971	44206	3014	41192
June	221.7	1533	991.5	1074	45033	3062	41971
July	226.5	1545	999.3	1085	45331	3068	42263
August	207.9	1433	926.5	960	41992	2832	39160
September	164.7	1156	747.1	691	33707	2308	31399
October	128.7	943	609.4	433	27276	1913	25363
November	88.9	671	433.7	244	19207	1437	17769
December	69.1	535	345.4	149	15075	1231	13844
Year	1783.0	12816	8285.7	7168	372801	26109	346692

Figure 5 is a graph of the incident energy performance ratio for every month of the year. Fig.6 demonstrates a diagram showing the total loss of systems at the Baghdad site. The worldwide horizontal radiation is 1872kWh/m^2. On the collector's level the efficient irradiation is 1783kWh/m^2. The photovoltaic cell then transforms the solar power into energy. The nominal energy Array is 450.8 MWh after conversion. At the Standard Test Condition STC, PV array's efficiency is 13.6 percent. The virtual energy Array is 372.8MWh. The energy available for the inverter is 346,7MWh after the failure of the inverter.As a final result, the energy injected into the grid is (346.7MWh).

The performance comparison in terms of area capacity, energy, CF, and PR with other PV plants in Iraq-Baghdad based on their performance data that obtained from these two sites is given in Table 8. Its worth to mention here that the comparison that based on the two PV plants only because the 250 kW PV system in this research is the first one implemented in Iraq.

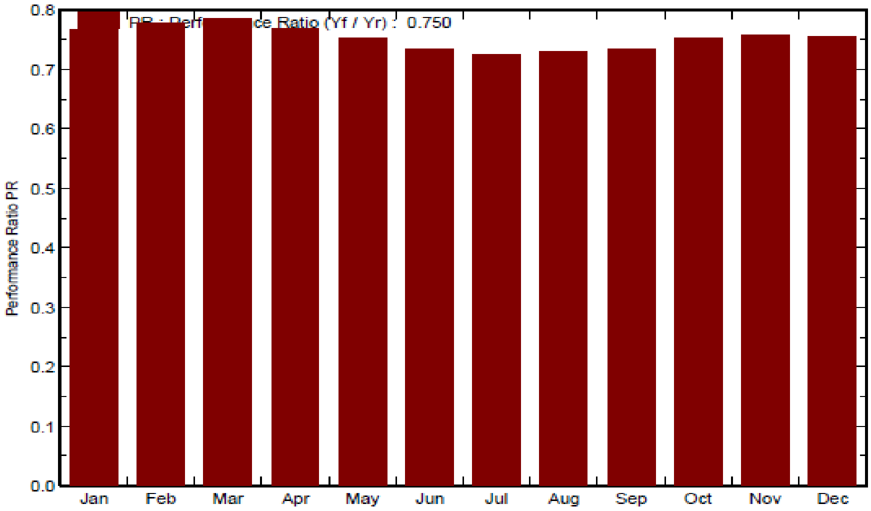

Figure 5. Graphical representation of Performance Ratio.

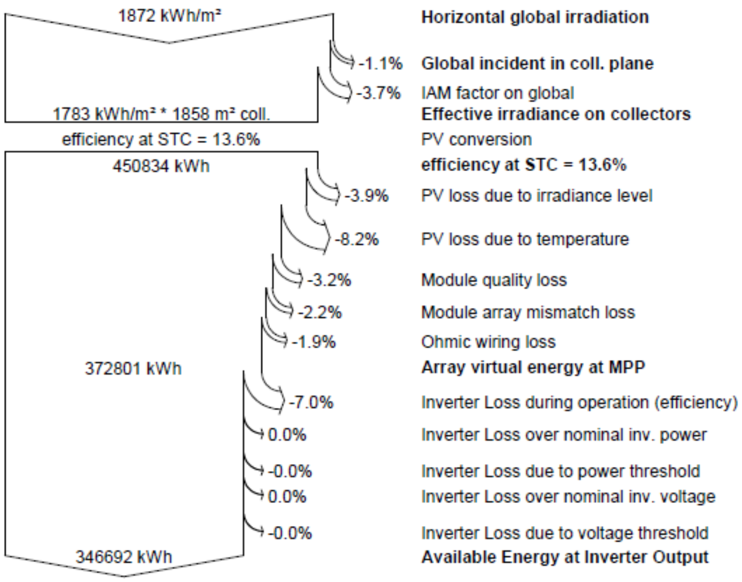

Figure 6. Loss Diagram throughout the entire year.

Table 8. Performance comparison of the two PV plants installed in Baghdad

Locations in Iraq	Array capacity (kW)	Installation type	Energy(MWh)	CF(%)	PR(%)	Energy loss(%)
North-Baghdad	12[1]	Rooftop	19.53	16.4	79.2	-15.6
Southeast-Baghdad	250[2]	Car ports	347	13.5	75	-30.1

[1]Array type :Sanyo HIP-205 NHE1.
[2]Array type : Sharp 175Wp Monocrystalline.

6. CONCLUSION

This document modeled and simulated in PVsyst software for energy evaluation a 250 kW grid connected photovoltaic system situated at Baghdad site. The results indicate that maximum solar irradiation at tilt angle 10° was accomplished at a value of 450.8 MWh. The scheme also consists of (1428) 175W solar panels, and ten SMA 25kW inverters. This shows that Baghdad has great potential for solar energy utilization due to its strategic location. This concludes that most of the PV projects in Iraq should be allocated in many areas like Baghdad city. It is worth to mention that this system represents Zone (A) one part of the 1MW large scale PV system that is currently being implemented in the building of the Iraqi Ministry of Electricity in Baghdad. Once the construction of this part is completed, the system operation parameters will be taken and compared with the data of the simulation to explain the compatibility of the system's real parts.

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