Performance Evaluation and Simulation of ON-GRID PV Plant in Baghdad-Iraq

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Abstract: ***In Iraq, electricity blackouts, rolling blackouts and brownouts remain a very frequent event at grid-connected settlements, leaving the humanitarian community dependent on expensive and polluting diesel generators. Renewables still persist to control a new addition to the global power generation since the past few decades. The capacity of the renewables reached about 2527 GW by the end of 2019, about 176 GW from the former year. Far east once again accomplished more than the half of the new installations of PV system plants. Europe and North of USA, meanwhile, achieving bigger steps in their renewable expansion. Solar power and wind form 90% of the world's newly added renewable capacity. Iraq has been known and listed by affluence oil and gas reservoirs but Iraq also has one of the highest solar irradiation levels in the region at above 1899 kWh/m² in some areas of Iraq west and south areas, such as Al-Anbar and Al-Muthanna governorates respectively. This work analyzes and simulates the performance of a 100kWp ON-GRID connection Si_poly photovoltaic roof-mounted system deployed in the Training and Energy Research Office (TERO) in Baghdad. The yearly performance ratio is around 77.24% and the normalized production of inverter output (O/P) or final system production yield, i.e. beneficial energy is 4.29kWh/kWp/day. The emulation is executed by using PVSyst., V6.88 software. Moreover, the overall losses along the year were also computed.***

Keywords: Solar energy, PV Modules, Iraq solar Irradiation, Performance Monitoring, PV System Losses

1. Introduction

The 100 kWp roof top on-grid solar photovoltaic (PV) system founded at the TERO act as a model for the installation of roof-mounted solar PV systems in the academic field in Iraq, which could play a major role in energy self-sufficiency and security while aiding the city green-house gas emission reduction and electricity shortage problems [1]. The main purposes of the100 kWp PV plant were:

1) To provide the electricity from a renewable energy source. The 100kWp, PV plant generates energy of about 156.7MWh/year.
2) Data base provision to support the researchers and developers [2]. The solar PV plant systems are one of the most promising and cost-cutting alternative for the polluting diesel generators in developing communities like Iraq especially after 2003.
3) To minimize the shortage gap between the generated and demand powers which reaching about 17000MW in 2020 for the Iraqi power grid [3, 4].

2. Specifications of Plant

The fixed rooftop (15º inclined structure) solar photovoltaic plant at TERO, in Baghdad is of 100 kWp capacity with, 25kW SMA. Strings comprise of 20 modules, and every five strings are connected to one inverter. Figure (1), shows a sample of system wiring diagram.

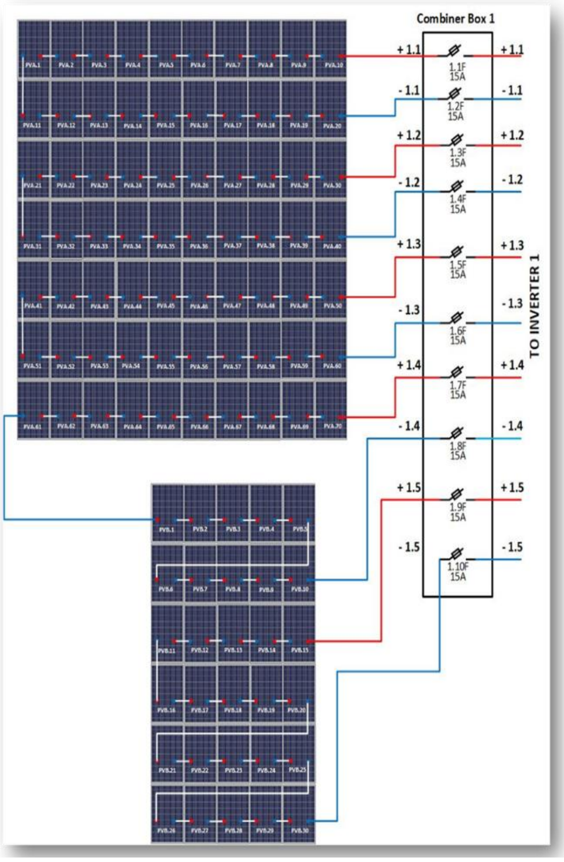

Figure 1: The System Wiring Diagram in TERO

Two types of PV modules are used in TERO and described in Table (1), the operation age of types A and B are 20 and 2 years respectively. The whole plant area coverage is about 700m². The site measurements in Baghdad shown that the daily average fallen solar radiation is ranged from 880 W/m² in summer to 650 W/m² in winter, with average and ranged 11–12 hours in summer days [5].

Table (2), demonstrate the metrological data in Baghdad.

Table 1: Types of PV Modules in TERO

Type (A)-SHARP (210 Wp) ND-F210A1	
Open circuit voltage (V_{oc})	36.6 V
Short circuit current (I_{sc})	7.68 A
Voltage at max. power (V_{mpp})	30.1 V
Current at max. power (I_{mpp})	6.98 A
NOCT	46±2 °C
Minimum system voltage	1000VDC
Type (B)-MANSOUR SOLAR (340 Wp) ZS 340-P 72	
Open circuit voltage (V_{oc})	44.43 V
Short circuit current (I_{sc})	9.57 A
Voltage at max. power (V_{mpp})	37.56 V
Current at max. power (I_{mpp})	9.03 A
NOCT	46±2 °C
Minimum system voltage	1000VDC

Table 2: Annual Solar Irradiation in Baghdad/2019 [6]

Month	Global energy (Kwh/m²)	Direct energy (Kwh/m²)	Diffuse energy (Kwh/m²)
January	79.48	97.63	35.76
February	99.35	114.73	40.06
March	146.26	163.91	47.90
April	162.52	150.26	59.42
May	209.42	175.51	80.93
June	228.85	233.77	57.75
July	230.80	261.06	44.48
August	194.64	201.45	51.26
September	147.69	162.69	40.58
October	103.22	104.11	42.75
November	84.67	111.96	31.09
December	64.29	77.27	31.36

It is practically agreed that TERO plant will produce approximately 450 kWh per day. The total CO2 emission mitigation from the 100 kWp sunshine hours of 7–8 hours in winter days, grid connected rooftop solar PV system considering the life of plant to be 30 year's tops are found to be 7065000 Kg or 3355.3 ton CO2, as shown in Fig. (2).

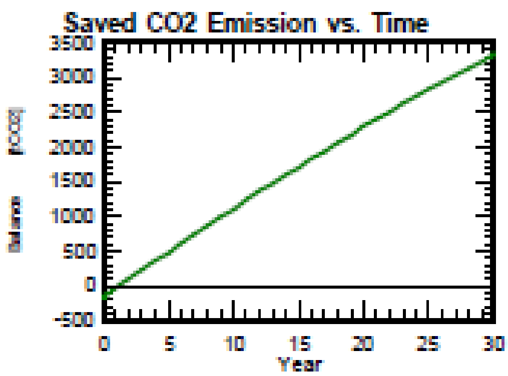

Figure 2: CO2 Emission with Time

3. Site Environment and Inspection

Soiling on the cells of the PV modules has a negative influence on its performance as it causes power losses reducing energy yield due to reduced optical transmittance. Moreover, dust and sand accumulation to energy cause module's abrasion. This energy loss can be quite significant since Iraq is considered as a dusty land facing dust storm 35 day/year, sand storms 30 day/year, and a dusty/sand conditions 195 day/year, the rest is of clear environment, so the accumulation of the dust and/or sand on the surface of the solar panels is a major problem and highly reduce the generation efficiency [7]. In Iraq, high temperatures in cooperation with dust/sand soiling can reduce the overall efficiency of the PV modules in up to 40% specially in summer season [8, 9]. Throughout the visual inspection visits, several failure modes were noticed, some of which are depicted in Fig. (3). Figuratively, the failures mode noticed include the followings:

1) Delamination.
2) Broken glass by impact.
3) Encapsulate discoloration and a little browned in the middle of the cell but bleaching occurred in the part of E. V. A that have access to atmospheric oxygen and/or that are close enough to the edge that the acetic acid diffuses out of the cell [10].
4) Failures caused by and/or during the installation.
5) Broken/cracked cells and snail trails.
6) Mismatched modules.
7) Cells browning much faster than others due to heat difference [11]

Figure 3: Failure Modes in TERO Plant

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4. Performance Parameters

References [12, 13] outlined four performance parameters for the ON-GRID PV systems which can be used for defining the total system performance with respect to; Energy production, resources of the solar and total losses of the PV plant.

The parameters are given hereunder:

i. Array yield (Y. A)

Is the time required by a PV power plant at nominal power state of operation to generate the total energy of PV array (E. A), then:

Y. A= E. A/Po (1)

ii. Final yield (Y. F)

It's defined as the proportion of net energy output of the solar photovoltaic system to its rated power in hours [13]. Final yield ensure the time required by the solar photovoltaic system to operate at rated power to yield the net energy. It is the normalized value the output energy in regards to the capacity of the system. In the expression of solar radiation resource, final yield can estimate the solar PV system performance.

Y. F=System output energy / Rated power (2)

iii. Reference yield (Y. R)

The proportion of aggregate array solar insolation to the reference value of irradiance of solar photovoltaic system in hours called a reference yield. Reference radiation is deemed as 1kW/m² at S. T. C. Reference yield normalizes the available solar radiation with reference radiation. It measures energy input for required output. It generally depends on site metrological data, environmental conditions and direction of the solar photovoltaic array. Reference yield for the solar photovoltaic plant is the running energy that plant would have been produced through S. T. C 1kW/m², 25°C, 1.5 Air-mass [1].

Y. R= Solar insolation / Ref. irradiance (3)

iv. Performance ratio (P. R)

P. R is a dimensionless value and can be defined as a proration between final energy yield of a PV system to the reference production [1, 13]. It gives a specific about the day impact of the total system losses on its rated output. The losses include solar PV array losses, module's tilt angle losses, loss due to soiling, loss due to partial or complete shading, loss due to the variance in module's temperature [14]. Performance ratio has effect on system down time and failure of components. It is used to study the performance of solar PV system annually and decrease in performance ratio is a signal of the degeneration of the system performance. Performance ratio indicates how close the solar PV plant to process the ideal performance in real-time circumstance. The performance of 100 kWp roof-top solar PV plant was carried out and P. R was found to be in the range of 0.74 to 0.88 and the variation is shown in Fig. (5). P. R can be calculated as below,

P. R= Y. F/Y. R (4)

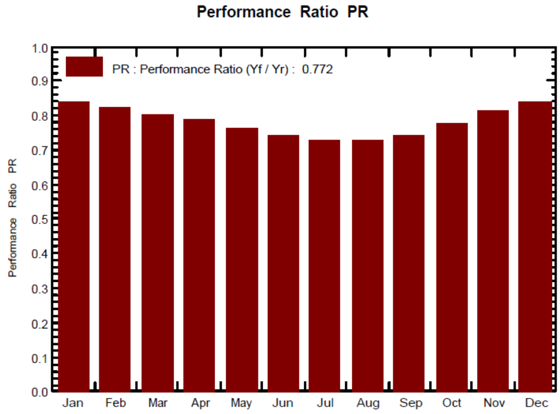

Figure 5: The Performance Ratio per Month

v. System loss (L. s)

The total loss of the system can be expressed as the difference of amount between the total yield of array to the final yield.

L. s = Y. A – Y. F ………. . (5)

0.31kWh/kWp/day, whereas the collection loss is 0.95kWh/kWp. day^{-1}. Figure (6) demonstrate the annual losses occurred in the system in addition it shows the available energy at the inverter output and the total energy injected to the grid, 156.7MWh annually injected by 100kWp PV plant to national grid [15].

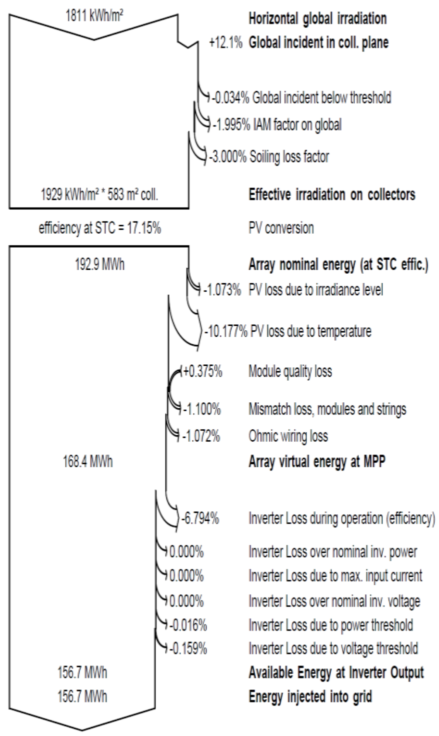

Figure 6: Annual Losses in TERO Plant

5. Conclusion

The performance simulation of a 100 kWp ON-GRID connection Si_poly PV system is executed in this paper by using PVSyst., software program. In this study the following illations were deduced:

i. As a yearly statistic, 156.7 MWh/year is the energy that is supplied into the grid with certain production on yearly base / installed (The virtual module's array energy at M. P. P) kWp is 168.4 MWh.

Ultimate energy feed into the national grid was during September 4.85kWh/kWp. day-[1], and the lowest energy was during the month of December of 3.3 kWh/kWp. day-[1], as shown in Fig. (7).

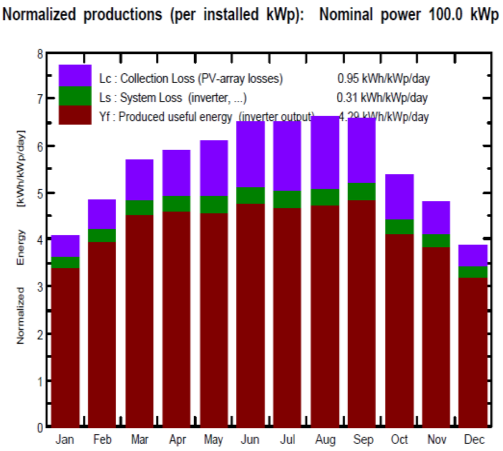

Figure 7: Normalized PV Production per Month

ii. The average performance ratio (P. R) of the said plant was 77.2 %.

iii. Based on the site visits, the simulation results, and the high ambient temperatures in summer ranged (45 ºC to 53 ºC), the following recommendations can be put forward:

iv. Provision for frequent cleaning of the PV modules and visual inspection is always required for ensuring maximum energy yield [16].

v. PV plants installed in isolated areas and/or in harsh environment shall be equipped with robotic system for cleaning.

vi. According to the in hand system simulation PVSyst., the tilt angle plane showed that the angle should be 32º to achieve maximum irradiation throughout the year for the "Fixed Tilted System Structure". The onsite structure is tilted by 15º which definitely leeds to lower yearly power and higher pollution and dust accumulation.

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