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The Effect of Iraqi Climate Variables on the Performance of Photovoltaic Modules

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Abstract— *This project presents the influence of the temperature, solar radiation, and wind speed on the performance of a Photovoltaic (PV) system. These effect has drawback effect of the electrical output of the PV (current, voltage and power). These climate conditions have massive impact on the PV performance, especially in Iraq due to its variable and severe environment.*

The study results revealed that temperature plays an important role effect on the performance of a Photovoltaic (PV) system. High intensity of Iraq solar radiation has an impressive effect of the PV performance. The effect of wind was limited as well as rain. The effect of dust and pollution accumulation was obvious. The studied parameters effect must be treated for Iraq to make PV technology wide spread in this country.

Keywords— *Iraq, climatic conditions, dust, PV performance.*

I. INTRODUCTION

Iraq is located in the north-east of the Arab world to the south-west of the continent of Asia extending from the latitudes 29-37 north and longitudes 38-48 east and Longitude occupies an extension of its length between the north and south about 925 km. The length of the horizontal extension for meridians amounts between east and west, about 950 km which means it convergence the maximum stretch horizontally or vertically. This site makes Iraq a transitional climate between the desert climate and the climate of the Mediterranean Sea. The continental climate characterized by drought and high temperatures in summer and fall with the lack of rain in winter [1, 2].

Iraq has a fertile soil in most areas and this grant, gift donated by the nature of Iraq, which enables this country to regain the agricultural past and improve cultivation The rivers are the basis of Iraq's economic wealth and importance in the continuation and sustainability of storage and irrigation projects in it. As well as the presence of numerous mineral wealth and huge oil reserves and is the second country in the world in terms of oil reserves and the developed world in dire need of this wealth mismatch equipped capacity and through its industries continue [3, 4].

The National Development Plan for the Years 2010-2014 developed by the Iraqi Ministry of Planning in December 2009 said: "The national electric power generation in Iraq averaged nearly (2958) MW sometime before the second Gulf War in 1990, the stage, where the production covers the entire energy demand until the year 1994. The power generation deficit began increasing due to wars, economic blockade and stopped development plans and increase energy consumption by people. The total realized production capacity on average per year (3409) MW compared to the size of the request (4653) MW during the year 2003 or by the inability of the amount of 27%" [5, 6].

The electric power state continued to deteriorate during the American occupation, where electric power generation rate in 2004 (3828) MW, rising to (4526) MW in 2008 at a rate of evolution of the amount of 63%, while the demand of 5442 MW volume rose in 2004 to 10,000 MW in 2008, the deficit stood at 38% in 2008 ratio. The reason for low volume production capacity of electric power referred to the sabotage and destruction caused to the electrical clades installations affiliate. In addition, the lack of fuel reaching the power stations in many cases. Also, to the difficulty in obtaining spare parts needed to sustain the life of plants and installations producing energy [7]. Finally to the aging of the stations and the scarcity of water, especially for the hydroelectric ones, where the rate of production achieved for those stations fell during the first half of 2008 compared to 2007 rates ranging between (24 and 59%).

Iraqi power stations depend in their generation on fossil fuels as natural gas, diesel and black oil. These fuels are seriously affecting the environment of Iraq and cause a hazardous health situation for the citizens [8-10].

The trend for the use of alternative and renewable energies for electricity production in Iraq has become a necessity to reduce the pollution of the atmosphere and environment protection. Iraq has a very high solar energy as it is located close to the Sunbelt; and the solar radiation intensity for the country ranging from 340 W/m^2 in winter to 980 W/m^{2}in summer. These values are high enough to make the use of solar energy a suitable source of power generation as well as domestic heating water,.., etc [11-14].

Photovoltaic refers to a technology which uses a device (usually a solar panel) to produce free electrons when exposed to light, resulting in the production of an electric current. Photovoltaic is commonly referred to as "PV". PV cells or solar power panels are used to create the energy from the sun. A PV device is a semi-conductor cell which is made of silicon, and when exposed to sunlight, it converts the sun's rays into direct current electricity. The photovoltaic solar power represents one of the most promising renewable energy in the world [15-17].

PV energy is set for bigger and better future, and many countries all over the world start to benefit from this reliable technology depending on their surrounding environment suitability. However, some areas of the world are not able to benefit from photovoltaic technology due to its climate, weather patterns, or high levels of pollution [18-20]. Many areas have understood the efficiency from the use of solar cells. However, the efficiency of the PV cell or its performance depends on several climatic factors such as the solar radiation, the temperature, reflection, wavelength of light and the state of the solar panels. Each of these factors has even good or bad effect on the photovoltaic performance [21-25]

The PV work best at low temperatures, as determined by their material properties. All cell materials lose efficiency as the operating temperature rises. Much of the light energy shining on cells becomes heat, so it is good to either match the cell material to the operation temperature or continually cool the cell to have higher efficiency of the PV system [26-30].

This paper aims to evaluate the effect of Iraqi weather conditions on the performance of PV panels, and the suitability of this technology for Iraq. This work is a part of continuous efforts of the Energy and Renewable Energies Technology Center in University of Technology, Iraq to find sustainable and clean alternatives for Iraq power generations and fuels [31-52].

II. Experimental Setup

Solar panel is used to convert solar radiation into DC electricity. Then the electricity will pass through the controller. The basic function of regulator is used to control solar electricity that supplied to battery and avoid a crossing the limited voltage of the battery. Otherwise if we don't have controller the battery will be damage, and then from the battery to the load. The types of our project are called standalone PV system which is electrical power systems energised by photovoltaic panels which are independent (faraway) from a grid-tied. It is vary in size from watches or calculators or remote building or space craft of the utility.

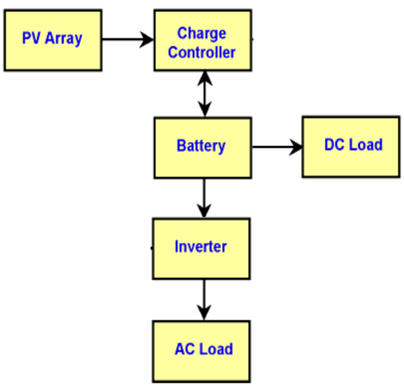

Fig. 1. Diagram of stand-alone PV system with battery storage powering DC and AC loads.

Fig. 1 shows the standalone PV system with battery storage powering DC and AC .The components used in standalone system are very similar to those used in a grid-tied, but for a few additional components. In larger systems AC is usually required an inverter. To convert the DC from the modules or batteries into AC, an inverter is also used.

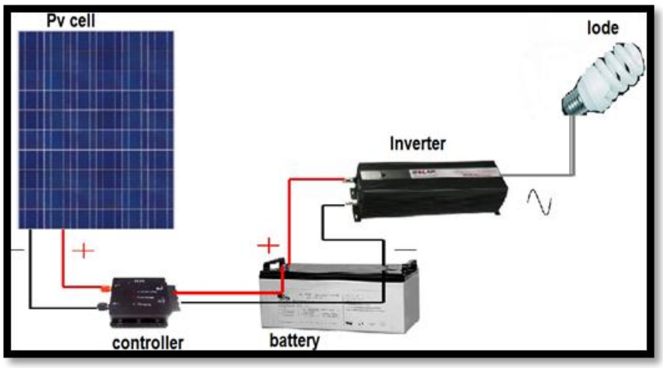

Fig. 2. The connection of PV system.

A. Characteristics Equations of PV Panel

By applying the KCL low the node of the model represented in Fig. 3, from the equivalent circuit it is evident that the current produced by the solar cell is equal to that produced by the current source, minus that which flows through the diode, minus that which flows through the shunt resistor.

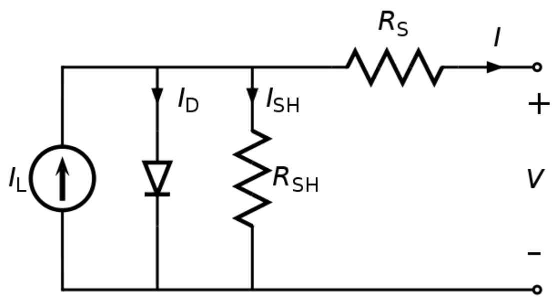

Fig. 3. The PV system electric circuit.

$$I = I_L - I_D - I_{SH} \quad (1)$$

Where

- I = output current
- I_L = photo generated current
- I_D = diode current
- I_{SH} = shunt current

The current through these elements is governed by the voltage across them so:

$$V_D = V_i + IR_S \quad (2)$$

Where

- V_j = voltage across both diode and resistor R_{SH}
- V = voltage across the output terminals
- R_S = series resistance

By the Shockley diode equation is explain the current circulating through the diode is:

$$I_D = I_o\left\{e^{\left(\frac{qV_i}{nKT}\right)} - 1\right\} \quad (3)$$

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By substituting V_i from the equation (2) in eq. (3) then the current diverted through the diode is became:

$$I_D = I_o\left\{e^{\left(\frac{q(V+IR_s)}{nKT}\right)} - 1\right\} \quad (4)$$

Where

- I_0 = reverse saturation current
- n = diode ideality factor (1 for an ideal diode)
- q = elementary charge1.6x10-19 Coulombs
- k = Boltzmann's constant 1.38x10^{-23}J/K
- T = absolute temperature
- At 25°C, the $\frac{KT}{q} \approx 0.0259\ volt.$

By Ohm's law, the current diverted through the shunt resistor is:

$$I_{SH} = \frac{V_D}{R_{SH}} \quad (5)$$

Where

- R_{SH} = shunt resistance.

Than by substituting V_D of the equation (2) in eq. (5) then we get:

$$I_{SH} = \frac{V+IR_s}{R_{SH}} \quad (6)$$

After that we substitute the equation of the temperature to use it whenever we want to see the effect of temperature on the PV performance.

$$I_L(t) = I_L\left(1 + TIPH\,(T - T_{mean})\right) \quad (6)$$

Where

- TIPH is the First order temperature coefficient for IL.
- T_{means} is the Parameter extraction temperature.

Substituting these all currents into the first equation which is presenting the characteristic equation of a solar cell, which relates solar cell parameters to the output current and voltage:

$$I = I_L\left(1+TIPH(T-T_{mean})\right) - I_o\left\{e^{\left(\frac{q(V+IR_S)}{nKT}\right)} - 1\right\} - \frac{V+IR_s}{R_{SH}} \quad (7)$$

An alternative derivation produces an equation similar in appearance, but with V on the left-hand side. The two alternatives are identities; that is, they yield precisely the same results.

B. Specifications of PV System

Table I lists the used PV panel specifications.

TABLE I. The used PV panel specifications.

Specification of PV panel	Value
Voltage open circuit V_{oc}	19.7 V
Current short circuit I_{sc}	1.08 A
Peak voltage	19.13 V
Peak current	2.00 A
Maximum	50 V

III. RESULTS AND DISCUSSIONS

Table II represents some of the measured temperatures values for the ambient air and the PV panel. The table indicates that the air temperature and solar radiation vary with time which means that the generated current and voltage from the panel will vary with time, for this reason the batteries are an important part of the PV system to guarantee the generated electricity is regular and steady.

TABLE II. Measurement obtained with instruments.

Time	Wind speed m/s	solar intensity kW/m^2	Air Temp Deg C	RH %
00:19:43	0.88	0	60.08	9.882
01:19:43	1.65	0	60.08	9.677
02:19:43	1.83	0	60.08	9.523
03:19:43	1.13	0	60.08	-95.23
04:19:43	1.5	0	60.08	-95.74
05:19:43	1.81	0	60.08	-95.13
06:19:43	2.31	0.0005	60.08	-95.95
07:19:43	2.75	0.0155	60.08	-96.77
08:19:43	2.94	0.152	60.08	96.77
09:19:43	3.21	0.5818	60.08	96.77
10:19:43	2.9	0.582	60.08	9.216
11:19:43	2.88	0.68	60.08	9.626
12:19:43	2.56	0.752	60.08	9.165
13:19:43	2.1	0.775	60.08	-97.38
14:19:43	1.48	0.798	60.08	9.523
15:19:43	1.29	0.8071	60.08	9.574
16:19:43	0.94	0.605	60.08	9.574
17:19:43	0.81	0.0568	60.08	9.574
18:19:43	1.38	0.0179	60.08	9.728
19:19:43	1.88	0.0056	60.08	9.677
20:19:43	2.58	0.0016	60.08	9.574
21:19:43	2.48	0.0098	60.08	9.37
22:19:43	1.96	0.0098	60.08	9.626
23:19:43	0.69	0.0068	60.08	9.421

Fig. 4 represents the variation in wind speed with time. From the figure there are two main remarks: first the wind speed was low during the measuring period and less that the required limit to operate wind turbines as Ref. [61] declared. The wind here has two main advantages; first it cleans the panel from dust and stops its settlement on the panel face. The second benefit it cool down the panel and reduces its temperature which makes it give better performance.

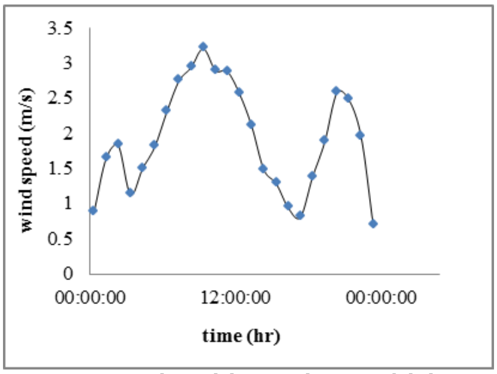

Fig. 4. Wind speed during a day in Baghdad.

Fig 5 shows the relationship between time and solar radiations. The solar radiation intensity starts to increase from the first morning until afternoon at 14:24 pm. During the measuring period, the solar radiation was high reached to 0.8 kW/m^2 then decrease until reached to zero, so would be, at night. The solar radiation divided into two sections when it is absorbed by the PV panel. One part, the small one (about 20%) goes to generate power. The second part, the large one (about 80% of the radiation) goes to heat up the panel.

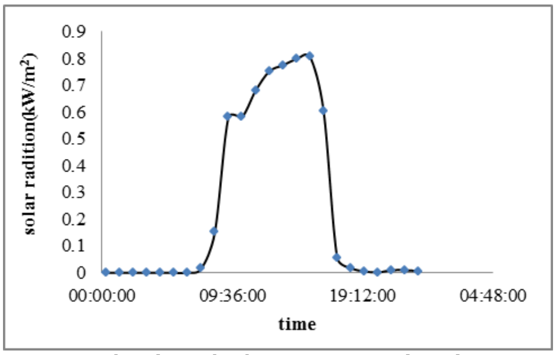

Fig. 5. The relationship between time & solar radiation.

Fig 6 represents the variation in ambient, PV panel, and frame temperatures with time. The temperatures increase till they reach their maximum values at about 1 PM, after that the temperature decline till sunset. The figure clarifies that the PV panel absorbed most of the heat came with the solar radiation and for this it has the largest measured temperatures. The PV frame as it is in contact with the PV and it is fixed under the panel it gain heat from the panel and cooled down by the ambient air, and for this reason its temperatures are less than the PV panel and larger than the ambient air all the time interval. The ambient temperature which was measured in shadow is the lowest temperature and this condition gives it and advantage to cool the PV panel.

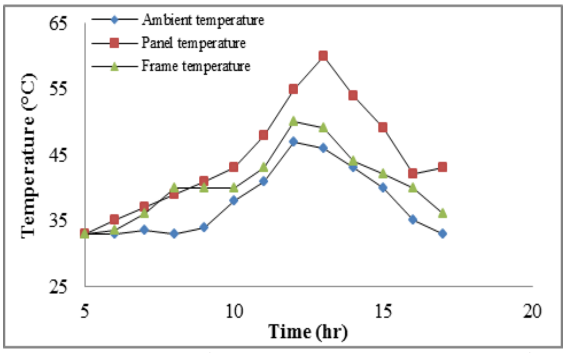

Fig. 6. Temperature variation for the ambient air, PV panel and the frame with time.

TABLE III. The impact of variable temperatures on the PV voltage.

Time	PV Voltage	Temperature			load
		Cell	Frame	Ambient	
5:30	32.0	32.1	33.2	10.612	0.6A
5:51	32.0	32.4	32.9	11.616	0.6A
6:33	33.3	33.4	32.7	11.917	0.6A
6:58	36.1	35.5	33.4	11.864	0.6A
7:15	36.9	36.2	33.6	11.915	0.6A
7:45	38.5	39.5	34.2	11.967	0.6A
8:56	42.6	37.8	34.3	12.060	0.6A
9:17	40.2	39.9	34.7	12.069	0.6A
9:45	40.8	39.1	33.0	12.22	0.6A
10:15	41.2	38.1	32.3	12.53	0.6A
12:44	62.4	50.5	47	13.501V	0.6A
1:15	55.3	49.1	42	12.823V	0.6A
2:25	48.3	45.8	38.9	11.851V	0.6A
3:00	49.4	47.3	40	11.674V	0.6A
3:30	45.7	42.2	45.7	12.172V	0.6A
4:12	36.4	37.7	34.9	11.736	0.6A
4.:50	44.6	34.5	32.3	11.841	0.6A
5:20	45.1	33.6	32.2	11.693	0.6A

Table III represents the relation between the PV's voltage and the temperatures of ambient ait, PV panel, and frame. From the tables it is clear that the PV voltage relatively increased with the temperature increase.

IV. Conclussions

Iraq environment is seriously in need for changing the energy profile. The massive use of fossil fuels caused a very dangerous air pollution that impacts the health of people and plants. The use of PV which is a clean source of energy will reduce the air pollution and helps in adding new power for the tired power generation system in Iraq.

The study focused on the effect of several parameters on the performance of the PV panel. The results revealed that wind speed is lower than that needed to operate wind turbines but it is suitable for cooling down the PV panels. The solar radiation intensity in Iraq is high enough to generate electricity in all weathers conditions. However, it is too high that it may cause high temperatures in the PV panel body which results in lowering the generated power. PV's voltage was relatively increased with temperature increase while the current wasn't affected.

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