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Investigating the changes in the effective factors in power generation in different seasons in photovoltaic power plants

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Abstract

An essential component in the construction and operation of solar power plants is identifying the factors affecting power generation in the desired areas based on the season and the amount of radiation in each season for the construction of solar power plants. Therefore, in this study, by examining the output capacity of a small 1kW power plant and analyzing effective data in different seasons, as well as by comparing practical and simulation results, we could identify useful and consistent data about factors affecting the production capacity of the plant. Then, the effect of temperature changes on each cell unit was investigated. Using a 100W YH100W-18-M panel, a practical study of the data was performed based on the STC rate. Meanwhile, the data were simulated and matched, and the final results were extracted. Finally, the diagram of the impact on the power and current of the power plant in all seasons of the year was extracted. The obtained results, namely the effective parameters in compiling this article, indicated the effectiveness of parameters such as the ambient temperature and the amount of radiation, yielding significant results in the output power of the power plant in different seasons.

Keywords: Solar power plant, Photovoltaic arrays, Hotspot, Solar panel, Simulation.

1. Introduction

Global warming and limited fossil fuel resources have increased the need for renewable energy resources [1]. Solar radiation is the largest renewable energy source [2, 3].

The energy consumption in our country will considerably increase in the next few years, transforming Iran from an energy exporter into an energy importer. To counter this threat, certain strategies must be implemented to optimize production, distribution, and energy consumption, as well as to modify its consumption pattern and use renewable energy. Accordingly, universities and knowledge-based companies should act as harbingers in this field. Fortunately, to study and research in universities, the Islamic Azad University, Science and Research Branch, as one of the pioneers in using renewable energy in university units, has built a 12kW solar power plant [4].

Another rarely addressed issue in solar electric systems is the study of errors and the effect of power on these systems and their monitoring methods as another entity. Unlike other new energy generators, such as wind and nuclear turbines, it is much more difficult to troubleshoot and find faults in the panel section than can be detected by humans and mechanically in solar power systems. Therefore, based on the environmental geography and the use of statistical and regional studies, effective events in arrays and panels should be carefully studied, and even the cause and probability of defects should be identified. For example, solar inverters act as the heart of a solar system, converting the generated DC power into AC. Any malfunction of this section could potentially affect output power generation.

Common physical factors contributing to power generation in solar panels investigated in this study include cell connection defects, panel fractures, heat loss, and shadow conditions, which can be separated from the effects of radiation and seasonal temperature changes. Moreover, one of the numerous cases in solar panels is MC4 connectors, which, after the panel, may result in errors as connectors may have been disconnected. Besides, the performance of the generator can be affected by the configuration of a photovoltaic (PV) power generation system, especially if it is susceptible to partial shading. In simulations, the current of a non-parallel diode with shadow cells is a current that flows up to the short-circuit current of the shadow cells [5].

The simulated model utilized in this paper is adapted to the characteristic values of the NAPS NP190GKg PV module [6].

2. Material and Method

This study considered the amount of radiation to be equal to the lowest lighting conditions in Iran's climate. In Mazandaran Province, Sari, the necessary studies have been considered from April 2019 to

February 2000 for a period of 22 months. The capacity of the power plant under study is 1 kW, which has been exploited using ten 100W YH100W-18-M solar panels from Isola Co. Some important parameters include the maximum voltage (18.5 V) and the current (5.41 Amps).

2.1. The nominal output power of solar arrays

To determine the STC rate in the laboratory, the solar panel was tested under ideal conditions to be equal to 1000 W/m² solar irradiation. This is equivalent to the sun shining at noon on a sunny day at the equator.
Figure 1 shows the current-voltage characteristic curve (I-V) and the power-voltage curve (P-V) of a solar panel. Here, V_{OC} and I_{SC} refer to the open-circuit voltage and short-circuit current of the solar panel, respectively.

The maximum power point (MPP) is the point at which the vertex of the P-V curve is obtained or the point on the I-V curve that defines the largest rectangular area possible (Imp × Vmp) under this curve. Although the MPP voltage does not change much as the radiation changes, it increases significantly as the temperature decreases. Therefore, an MPP tracking function is usually included in a solar power system to ensure maximum power is achieved under different operating conditions.

In this study, for best performance and greater stability, non-invasive CT current sensors were used, owing to their better adaptation and coordination with MC4 cables.

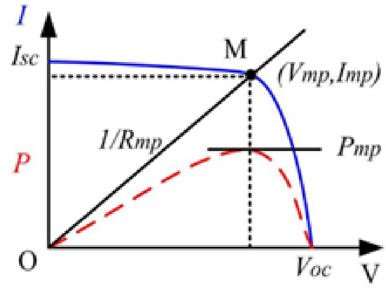

Figure 1. The I-V curve (the continuous line) and the P-V curve (the dotted line) of a solar panel without shading

2.2. The connection map of the 1kW power plant

As shown in Figure 2, using ten 100W panels and connecting them to MC4 connectors to a sinusoidal inverter without a backup battery to evaluate the performance and various tests, we will have 1000 W equal to 1 kW of energy.

In this research, the panels were analyzed and tested in different conditions. Various and sometimes separate tests were conducted to study the more accurate results to evaluate the performance of the studied parameters in the power plant. The temperature conditions and the average radiation studied are presented in Table 1, extracted based on the data contained in the World Meteorological Organization (WMO) database.

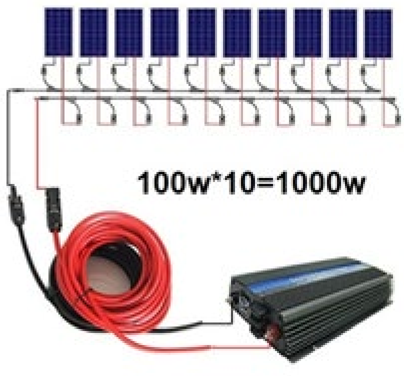

Figure 2. The Connection map of 1000 W set by ten 100W panels

Table 1. Average temperature and radiation in the seasons

	SPRING	SUMMER	AUTUMN	WINTER
AVERAGE TEMPERATURE (^{O}C)	20.29	26.336	14.713	8.876
AVERAGE RADIATION (W/M^2)	1930.85	1765.383	963.6	1159.483

3. Results and Discussion

To better understand the impact of factors affecting the output power of the solar power plant, it is necessary to read the output currents and output power extraction and adapt the STC and meteorological data in MATLAB simulation (Simulink) to obtain the final results in different seasons of the year.

3.1. Spring

The maximum power is 1001 W at 25°C and 1021 W at 20.29°C, indicating an approximately 2% increase in the maximum output power of solar arrays.

The maximum power is 1001 W at 1000 W/m^2 and 1909 W at 1930.85 W/m^2, indicating an approximately 90.7% increase in the maximum output power of solar arrays.

Table 2. A comparison of the effect of different parameters on the output power of a solar power plant under simulated and realistic conditions - Spring

	Under simulated conditions	Under realistic conditions
Ambient and panel temperatures (^{O}C)	+2%	+10%
radiation (W/m^2)	+90.7%	+28%

3.2. Summer

The maximum power is 1001 W at 25oC and 998.2 W at 26.34oC, indicating an approximately 0.28% decrease in the maximum output power of solar arrays.

The maximum power is 1001 W at 1000 W/m2 and 1751 W at 1765.3865 W/m2, indicating an approximately 74.93% increase in the maximum output power of solar arrays.

Table 3. A comparison of the effect of different parameters on the output power of a solar power plant under simulated and realistic conditions - Summer

	Simulation	Reality
temperature of Environment and panels (^{O}C)	-0.28%	-16%
radiation (W/m^2)	+74.93%	+10%

3.3. Autumn

The maximum power is 1001 W at 25oC and 1047 W at 14.71oC, indicating an approximately 6.4% increase in the maximum output power of solar arrays.

The Maximum power is 1001 W at 1000 W/m2 and 962.7 W at 963.6 W/m2, indicating an approximately 3.74% decrease in the maximum output power of solar arrays.

Table 4. A comparison of the effect of different parameters on the output power of a solar power plant under simulated and realistic conditions – Autumn

	Under simulated conditions	Under realistic conditions
Ambient and panel temperatures (^{O}C)	+6.4%	+8%
radiation (W/m^2)	-3.74%	-7%

3.4. Winter

The maximum power is 1001 W at 25ºC and 1073 W at 8.88ºC, indicating an approximately 7.2% increase in the maximum output power of solar arrays.

The maximum power is 1001 W at 1000 W/m^2 and 1159 W at 1159.48 W/m^2, indicating an approximately 15.78% increase in the maximum output power of solar arrays.

Table 5. A comparison of the effect of different parameters on the output power of a solar power plant under simulated and realistic conditions – Winter

	Under simulated conditions	Under realistic conditions
Ambient and panel temperatures (^{O}C)	+7.2%	+7%
radiation (W/m^2)	+15.78%	+6%

4. Conclusions

This research investigated the effective factors in power generation in different seasons in photovoltaic power plants. For this purpose, a model for a 1kW power plant (including ten 100W monocrystalline solar panels) in Simulink, MATLAB, and a real sample, is presented and compared. In this model, various experiments were performed to separately study the effect of radiation and temperature on the output power of photovoltaic power plants. The results suggested that the lower the panel and ambient temperatures, the higher the maximum power output of the power plant. Besides, as the amount of radiation on the panel increases, the maximum output power of the photovoltaic power plant also increases.

Studies have shown that, in spring, temperature and radiation increase the output power of solar power plants. Likewise, radiation has a greater effect on the output power of solar power plants than temperature. In summer, although increased temperature reduces the output power of a solar power plant, increased radiation increases the output power of the power plant. In autumn, as the amount of radiation decreases, the output power of the power plant slightly decreases. However, with decreasing temperature, the output power of the solar power plant increases by a very small amount. In winter, temperature and radiation do not result in a sharp drop in solar panel output. All these conclusions have been drawn under climatic conditions of Mazandaran Province with STC geography studied.

In general, it can be concluded that temperature and radiation in each season are significantly correlated. These extracted relationships play a key role in power generation in photovoltaic power plants. Any change in each of these parameters will give rise to a change in power generation.

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6. References

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