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Original Article

Climate Change Impacts on Future Solar Photovoltaic System Performance and Power Output in Libya

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ABSTRACT
Climate change has the potential to have a significant impact on renewable energy generation. The current state of the art in forecasting future renewable energy output has centered on regional climate prediction. However, owing to the complexity of climate models, regional climate prediction is fraught with uncertainty. This research provides a new methodology to predict the impact of the climate changes on the Photovoltaic solar system generation by using the extrapolation method for the historical data from NASA organization for the irradiation and the temperature from the year 1880 and extended to 2100. In this paper, the energy outputs of one of the solar power stations expected to be established in Libya, located in the Libyan city of Tajoura, were evaluated and predicted, specifically inside the headquarters of the Centre for Solar Energy Research and Studies. The Simulink Model of the power station was created using the Matlab program. The results showed that during the coming years, the temperature will rise by about three degrees Celsius, and at the same time the solar radiation will decrease and the output power generated by solar energy will decrease with it.

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INTRODUCTION

The growing of pollution that caused by fossil fuel and nuclear-powered generating units is becoming an alarming for the ecology. Many countries have changed their policies for electricity generation by reducing the number of traditional generating units that's work by fossil-fuel and replace them with renewable energy sources such as photovoltaic, wind turbines, and biomass, which are considered sustainable and environmentally friendly, have no fuel costs, and easily to attainable [1]. Solar photovoltaic technology is one approach to use incoming solar energy to generate electricity without emitting carbon dioxide (CO2) [2].

Modeling the thermal characteristics of photovoltaic cell is critical since photovoltaic (PV) systems' power outputs drop as their temperatures rise. Figure (1), for example, depicts the power output (standardized to its value at 25°C) as a function of cell temperature for solar cells consisting of various semiconductors and crystalline silicon cells. The output powers drop as the temperature rises, although at different rates. This means that two cells or modules with the same rated power under Standard Test Circumstances (STC), i.e. (the irradiation is 1000 W.m-2 at 25°C), may yield different powers in real world outside conditions, which are normally significantly different from STC [3].

Moreover, a PV system's energy production is a function of incoming irradiance, which is an undesirable major driver of PV devices. This is due to a combination of two factors: the first one is when solar irradiance is more relevant, the ambient temperature tends to be higher; while the second one is a considerable portion of the incoming irradiation is dissipated as heat within the cell. Obviously, the most important average temperature is one that is based on energy output and is bigger than the average temperature along the time.

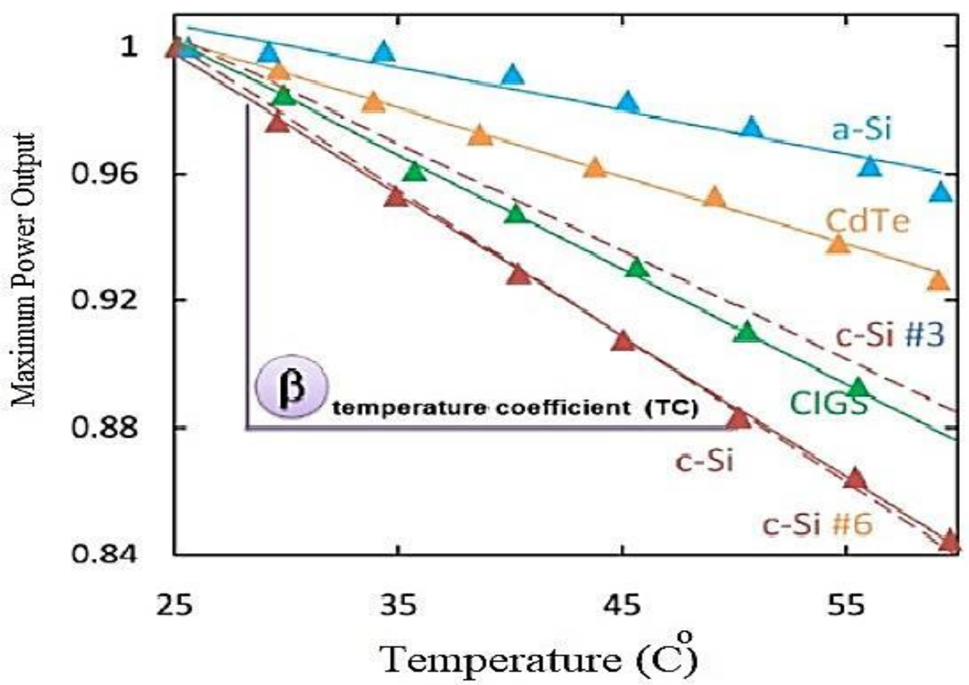

Fig 1. The relationship between the output power and temperature for different types of semiconductors that used in PV manufacturing [3]

Historical research on the behavior of PV systems during global climatic changes began to emerge over the last decade. As a result, researchers have access to a substantial set of literature on this subject. Sawadogo et al., 2019 [4], illustrated the effects of global warming on PV in West Africa; the simulation suggests that the system operates within the RCP8 [5]. The models' ability to recreate climatic factors that impact solar panel cell efficiency (such as solar irradiance, ambient air temperature, surface wind speed, and relative humidity) was tested. More research is needed to figure out how to spot model flaws and decrease their impact on future climate forecasts. Nonetheless, the authors found that future global warming may lower PV across West Africa, but the anticipated maximum reduction is less than 3.8 percent [5].
Jerez et al., 2015 [5], reported that the ambitious global warming mitigation strategies aim for a considerable increase in renewable energy consumption. But this may make the supply system extremely sensitive to climatic unpredictability and change. The authors of this research used the current EURO-CORDEX to assess the effects of climate change on solar photovoltaic (PV) electricity in Europe. According to the findings for this paper, the change in solar PV supply by the end of the century should be in the range of (-14 percent; + 2 percent) when compared to estimates made under present climate circumstances. Future climatic scenarios do not appear to have a significant impact on the temporal stability of electricity generation.
Moreover, Hou and his group in 2021, discuss the impacts of the climate change on the solar power generation and its spatial variability in Europe based on "the sixth phase of the Coupled Model Inter-comparison" CMIP6. Two main scenarios (RCP-2.6 and RCP- 8.5) were taken into the considerations during this work to predicate the PV generation. The scenarios based on the Representative Concentration Pathways (RCP) for each one there are different conditions are used for modeling the future climate evolution. The results shows that the generation of the PV will slightly increase in the north of Europe in the summer only (if the RCP- 8.5 scenario take into consideration), while it will reduced in the south Europe.
Furthermore, Silva et al., 2022 [7], analyzed the goals of identifying climate-related hazards and remedies in solar power plants in Thailand in order to provide points for consideration during long-term energy strategy to assure climate adaption capability. This research studies the impacts of the floods and storms, followed by lightning and temperatures rising, on the behavior of the PV system. The results were achieved by using thematic analysis; self-administered observations, and structured interviews, were identified as important climatic phenomena influencing solar power facilities in Thailand. The authors propose actions that would make it easier to pick climate-resilient locations, such as revising the terms of power

purchase agreements or supporting successful bidders in upgrading their sites' climate change adaptability.

The current study was conducted to predict the state of solar radiation during the coming years, and to establish a model for a solar station and study and forecast its energy output.

METHODS AND RESULTS

Since 1880, the data recorded by NASA organization of the global surface temperature (red line) and the energy from the sun reaching earth (yellow line) in W/m^2 are as shown in Figure (2). Annual values were represented by the lighter/thinner lines, while average changes over 11 years were represented by the heavier/thicker lines. To reduce the inherent noise in the data from year to year, eleven-year averages were employed, enabling the underlying trends to come through. The amount of solar energy received by earth has followed the Sun's typical 11-year cycle of moderate ups and downs, with no net gain, since the 1950s. Over the same time period, global temperatures have risen considerably. As a result, blaming the Sun for the observed global warming trend over the last half-century is highly unlikely [10].

It is recommended that, in order to obtain data for the year 2100, the principle of mathematical extrapolation be used to data acquired from 1880 to 2020. The extrapolation method is a method for evaluating the value of data that is presented outside of its range. To put it another way, extrapolation is the act of estimating a value based on the assumption that the current situation will endure for a longer period of time. In mathematics, the extrapolation method is statistics and other disciplines studies [11].

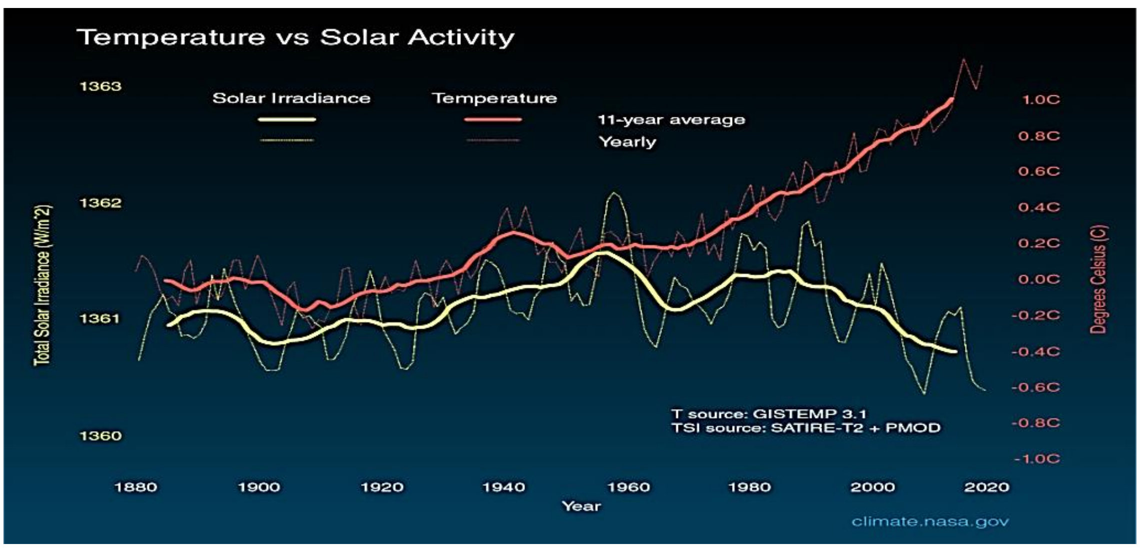

Fig 2. The temperature vs. solar activity [10]

For temperature, the extrapolated temperature from 1880 to 2020 was shown in Figure (3), and represented by the polynomial equation is $y = 0.0013x^2 - 0.0179x + 0.0321$.

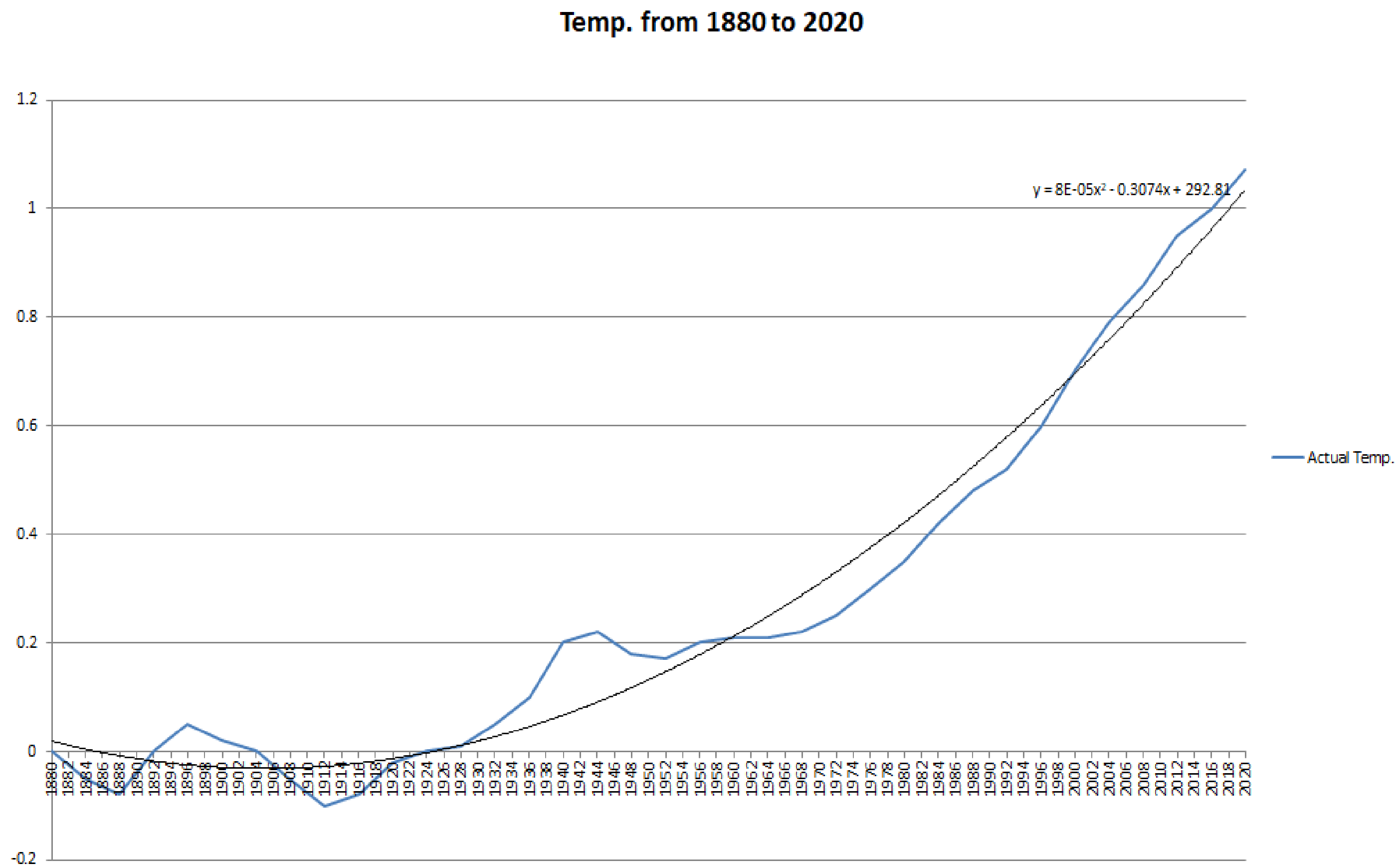

Fig. 3. Extrapolated Temperature from 1880 to 2020.

To extend the data from 2020 to 2100, the same equation was used for this purpose, and then the result was given in Figure (4).

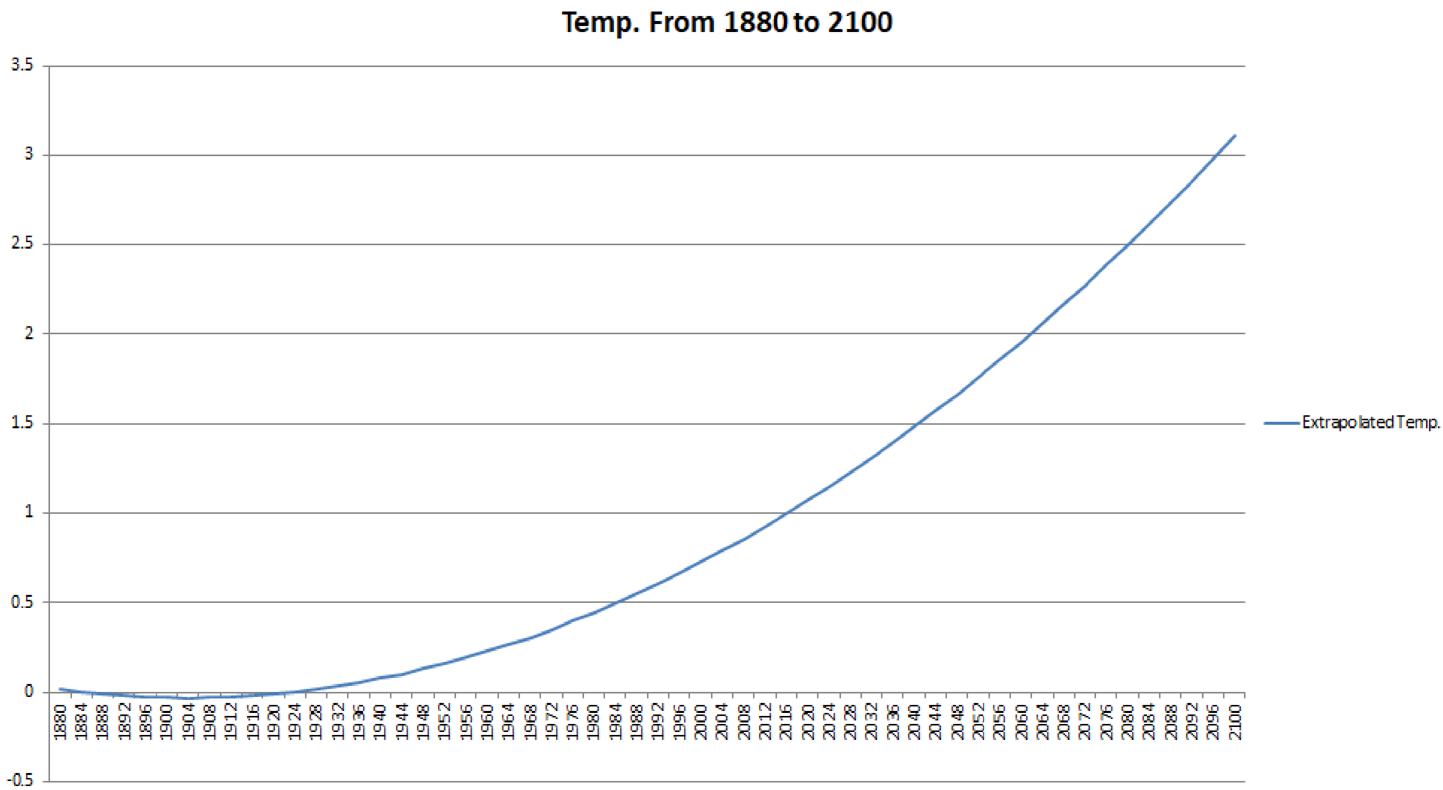

Fig. 4. Extrapolated temperature from 1880 to 2100.

In same way, we had extrapolated the irradiance from 1880 to 2020, then the extrapolated irradiance from 2020 to 2100 was given in Figure (5)

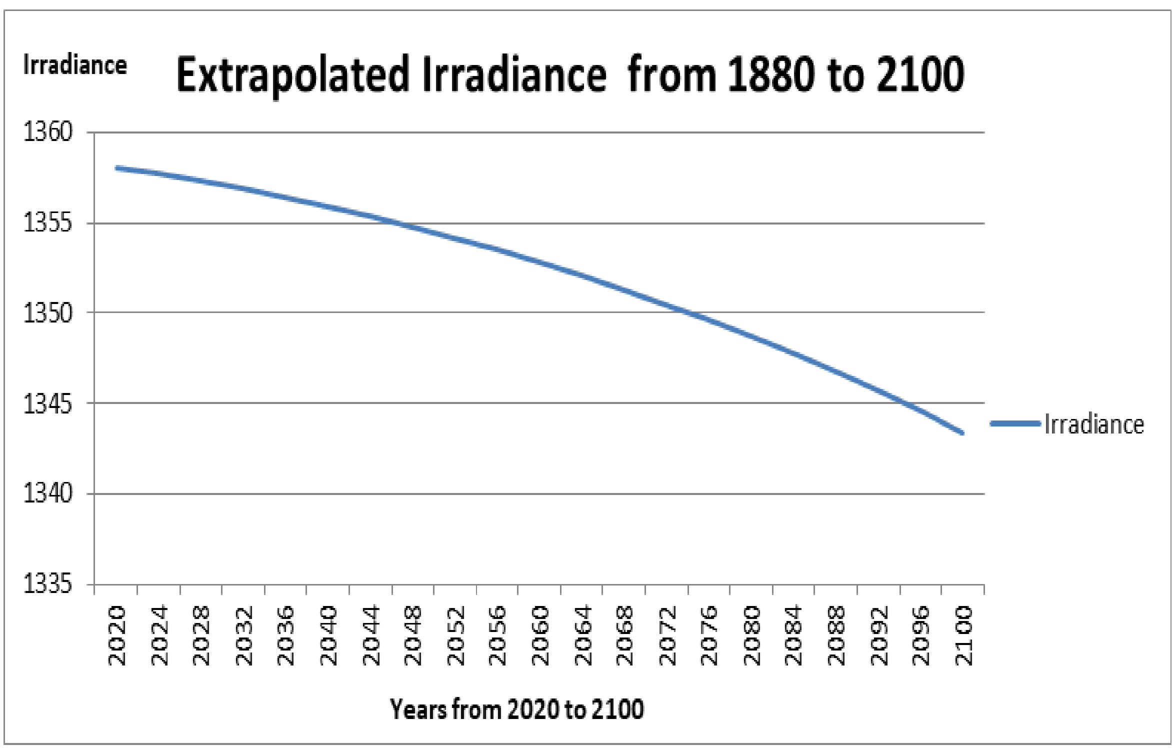

Fig. 5. Extrapolated irradiance from 2020 to 2100.

From figures (3) and (4), results were summarized as: the temperature will be increase about (3.16C°) at the end of the year 2100, while the irradiation will decrease about (1.2881%) at the end of the year 2100 (for the period from 1880 to 2100. The case study will be the new PV solar system generation station at (Centre for Solar Energy Research and Studies (CSERS) in Tajoura- Tripoli/Libya PV solar generation station) with install capacity about 62kW, the average daily temperature is (32C°) [13], then the predicated temperature at 2100 is about (35.16C°). On the other hand, the average current irradiance is about (751 w/m2) [12], while the predicated temperature at 2100 is about (733.8w/m2).
MATALB Simulink program was used to simulate Centre for Solar Energy Research and Studies (CSERS) in Tajoura-Tripoli/Libya PV solar generation station and as shown in Figure (6), while the calculations of the temperature and irradiance are performed by using MS-Excel program.

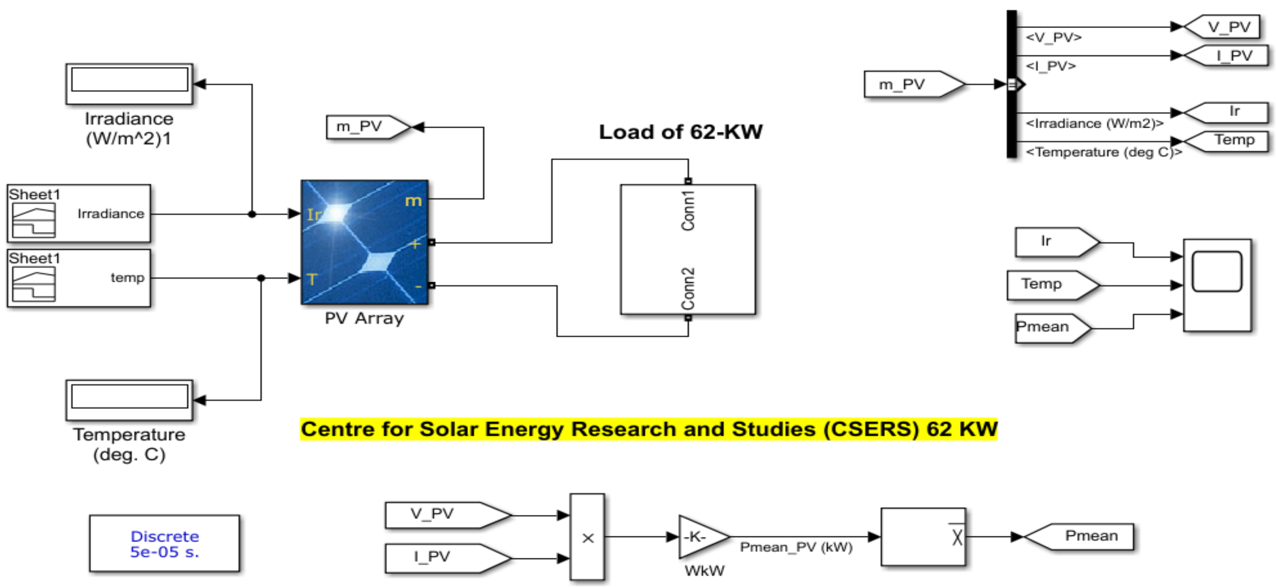

Fig 6. Centre for Solar Energy Research and Studies (CSERS) PV solar generation station (case study) represented by MATLAB Simulink program

The install capacity of the (CSERS) PV solar system station is 62 kW; the maximum power can be achieved at irradiation of 1000 W/m^2 at 25C°. According to the actual case study, the irradiation is 751 W/m^2 and the temperature is 32C°, thus will reduce the output power to 36.65 kW. At the end of the 2100, the generation of the PV system will reduce according to the lightly reduction in the irradiation and the increasing in the temperature. The results of the simulations show that, the output of the power it will be about 35.25 kW. The percentage of the reduction in the output power is about 2.72% from the generation capacity. The obtained results of increasing in temperature is within the scenarios of the climate changes, Figure (7) shows the Representative Concentration Pathways (RCP's) scenarios, the achieved results were fall between the RCP6 and RCP8.5. The percentage of the power reduction of the PV system can be varying according to the forecasted scenarios.

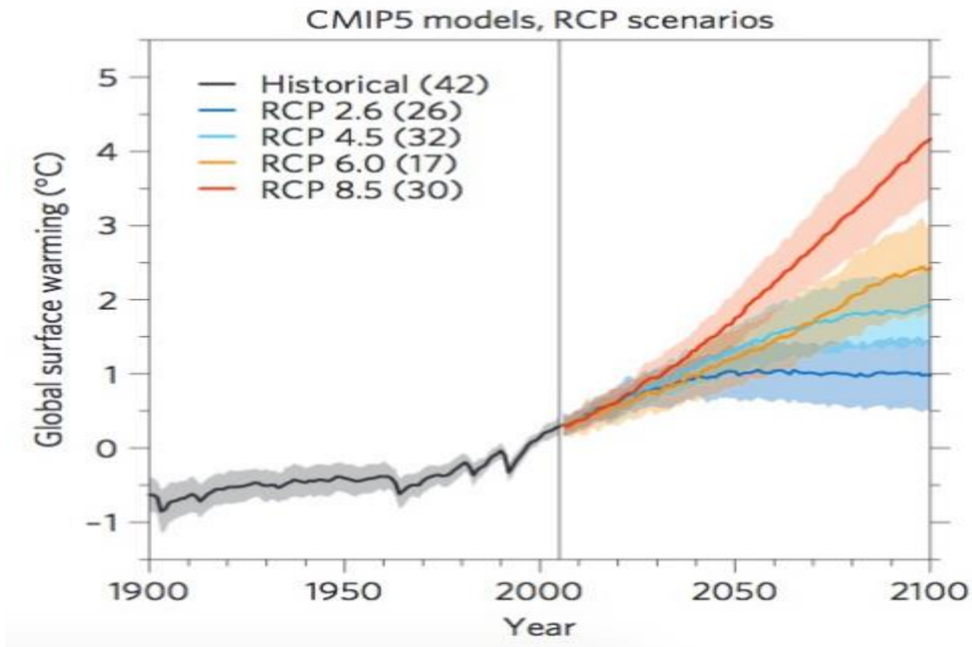

Fig. 7. The RCP scenarios [14]

The output of the proposed PV system with temperature and irradiance was presented in Figure (8).

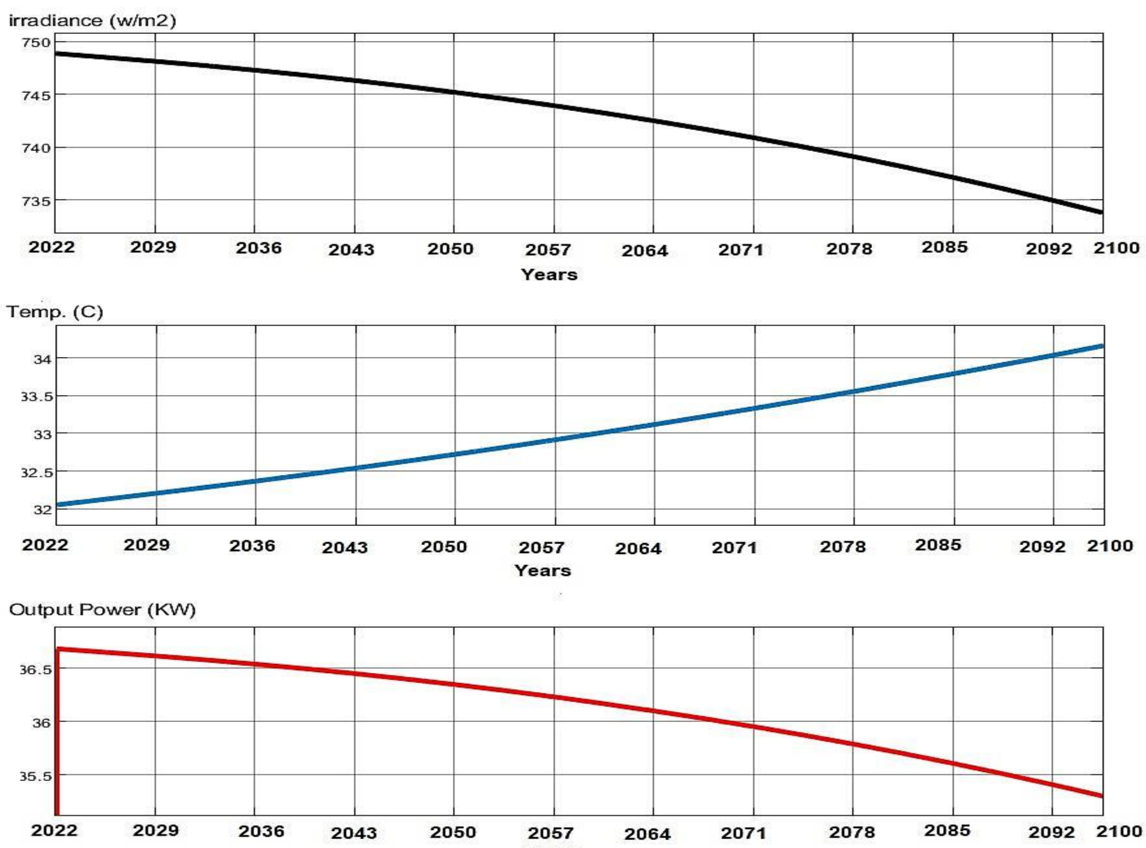

Fig. 8. Temperature, irradiation and output power of the proposed system for the period (2022 to 2100)

CONCLUSION

The result shows that the increasing in temperature is within the RCP6 and RCP8.5 scenarios of the climate changes. Engineers should be find new cooling and tracking strategies to increase the efficiency of solar panels that operate in non-optimal temperature settings since solar panels perform best in specific weather and temperature circumstances. While knowing the temperature of a solar PV panel is vital for predicting its power production, knowing the PV panel material is also important because the efficiencies of different materials are dependent on temperature in different ways. As a result, a PV system must be constructed not only with an awareness of the materials used in the PV panel, but also with the maximum, lowest, and average environmental temperatures at each location. A temperature coefficient is used to describe a material's temperature dependence.

Disclaimer

The article has not been previously presented or published, and is not part of a thesis project.

Conflict of Interest

There are no financial, personal, or professional conflicts of interest to declare.

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