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Experimental Investigation of the Effect of Dust on Moncrystalline Photovoltaic Module Performance in Kirkuk, Iraq

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Abstract

Photovoltaic module surface soiling due to dust deposition is a common problem, especially in the desert environment. In Iraq, Massive dust and sand-storms are environmental phenomena that frequently occurs during the year. Increasing desertification and decreasing vegetation coverage are one of the reasons for the recurrence of this phenomenon. Dust accumulation can reduce the performance of photovoltaic modules output power. This paper investigates the effect of dust accumulation on the performance of PV modules and the possibility of the energy losses experimentally. For this purpose, a microcontroller based dual axes sun tracker is designed and installed at the rooftop of the Engineering faculty Building located at Kirkuk University Kirkuk, Iraq. Two identical PV modules and real-time measurements with data monitoring system are used in this study. This study covers measurements done in August and December (2017). The results showed that the dust deposition on PV module could cause significant losses in PV output power generation on both fixed and sun-tracking modules. However, the losses was less in tracker system.

Keywords: Dust effect, PV module efficiency, tracking system, power generation.

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دراسة عملية لتأثير الأتربة على كفاءة الالواح الشمسية احادية البلورة في مدينة كركوك، العراق

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الملخص

ان اتساخ اسطح الخلايا الكهروضوئية نتيجة تراكم الاتربة هي من المشاكل الشائعة وبالأخص في البيئة الصحراوية. الاتربة الكثيفة والعواصف الرملية هي من الظواهر البيئية والتي غالبا ما تحدث في العراق و خلال السنة. ان ازدياد التصحر وتناقص الغطاء النباتي هي احدى اسباب تكرار هذه الظاهرة. تراكم الاتربة يمكن ان يسبب في انخفاض كفاءة الخلايا الكهروضوئية والتي هي من الاسباب التي قد تؤدي الى خسارة الطاقة المتولدة من الالواح الكهروضوئية والتي يعمل هذا البحث على التحقق منها. ولهذا الغرض ، تم تصميم وتركيب نظام تعقب مزدوج لأشعة الشمس وذلك باستخدام متحكم دقيق حيث تم تركيب المنظومة على سطح مبنى كلية الهندسة والواقعة في جامعة كركوك، كركوك، العراق. حيث استخدم في هذه الدراسة لوحين متماثلين و تمت عملية القياس بواسطة نظام مراقبة وتجميع البيانات. ان هذا البحث يشمل قياسات تم اخدها خلال شهري أب وكانون الاول من سنة 2017. حيث اظهرت النتائج ان تراكم الاتربة على اسطح الالواح الكهروضوئية يمكن ان يسبب خسارة كبيرة في توليد الطاقة لكلا الالواح الثابتة والمتحركة. الا ان الخسائر كانت اقل في نظام التعقب.

الكلمات الدالة: تأثير الغبار، كفاءة الالواح الشمسية (الكهروضوئية)، نظام التعقب ، توليد القدرة.

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1. Introduction

The renewable energy market has witnessed an unprecedented acceleration in recent years. Solar photovoltaics is boosting the growth of renewable in power capacity around the world. In 2016 it becomes the world's fastest-growing source of power. The global installed capacity for the solar photovoltaic electricity has been reached around 290 GWe at the end of 2016 as illustrated in Fig. 1 [1].

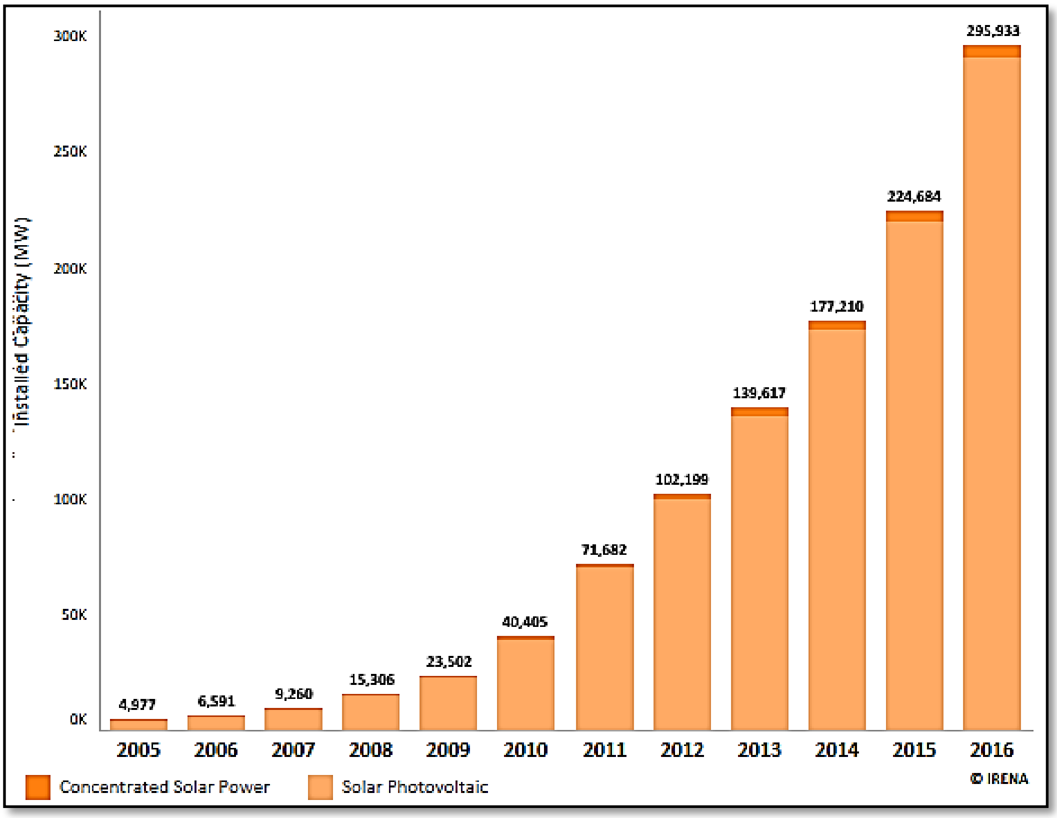

Fig. 1: Trend in solar energy installed capacity [1]

Increasing trends in the installation of PV systems needs for more accurate prediction of their operational performance under different condition. Manufacturers rate the output power, and the efficiency of PV module under standard test conditions (STC), with 25 ℃ Temperature, 1000 W/m^2 solar radiation, 1.5 Air Mass Ratio [2]. STC is rarely realized in outdoor, the performance of photovoltaic module is negatively affected by weather conditions [3]. Dust accumulation and photovoltaic surface temperature are important factors which must be considered, especially in desert areas. Dust deposition on the surface of PV modules causes a reduction in the amount of incident solar radiation on the panel which leads to decreases in the generated power [4]. In literature, some studies have been carried out to investigate the effect of weather conditions on photovoltaic performance. Many of these papers examined the relationship between PV output and dust deposition density [5, 6]. Others decided to make comparisons between types of dust and their particle sizes and analyses their effects for specific periods [7, 8]. Most of these studies are implemented for fixed tilt angle. The authors in [9] studied the output power of PV modules for the different tilted angle by using single & dual axes tracker system on the cleaned panel in Kirkuk City. However, the relationship between the dust accumulation and tilt angle in real time study is not cleared yet. This work presents the effect of actual dust accumulation on the performance of photovoltaic modules for a different tilted angle by using a tracking system. The temperature effect is also carried out in this work. A microcontroller based tracker system is designed and implemented to achieve this study.

2. The Climate of Iraq and Dust Effect

Sand and dust storms are familiar weather phenomena in Iraq, and its occurrence at different times of the year, especially during the summer and spring seasons [10]. In the last 14 years, Iraq has been hit by many waves of dust storms, in some years have exceeded 120 dust storms [11]. Fig. 2 illustrates this phenomenon in Kirkuk City .

In addition to its dusty environment, Iraq's mainly continental climate is characterized by being very hot and extremely dry with mild to cold winters. Usually, the temperature exceeds 50℃ degrees in the summer. Dust and temperature are the main factors affecting the efficiency of the installed photovoltaic modules, and it must be studied with some care.

Fig. 2: Picture showing a dusty day in Kirkuk City

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3. Tracking System Design

A dual-axis sun tracker system is designed and implemented to test the performance of soiling PV modules with a different tilted angle. Over the years, researchers have developed smart solar trackers for maximizing the amount of energy generation. Different designs and algorithms are implemented for this purpose [12]-[14]. The small-scale system is the similarity point between these designs. In this study Photovoltaic mounting system is designed to carry two 100 W PV modules each one with 8.5 Kg weight. The designed tracker system can track the daily sun motion and the annual motion, and that ensures solar radiation is always perpendicular to the surface of the photovoltaic modules. Two linear actuators used for this purpose one for east-west motion (daily tracking) and another one for north-south motion (seasonal tracking). Fig. 3. shows the designed system which is consists of:

1- Light Sensors

2- Control Unit which is composed of a) Microcontroller, b) DC to DC Converter, c) Switch Relays

3- Linear Actuator

4-DC Connection Box

Two pairs of a light dependent resistor (LDR) are used for measuring light intensity by generating a corresponding analog voltage. LDR resistor value is directly proportional to the light intensity falling on it. Equation 1 gives the relationship between R_{LDR} (ohm) and light intensity (LUX) [12].

$$R_{\mathrm{LDR}} = \left(\frac{500}{\mathrm{Lux}}\right) \mathrm{k}\Omega, \quad (1)$$

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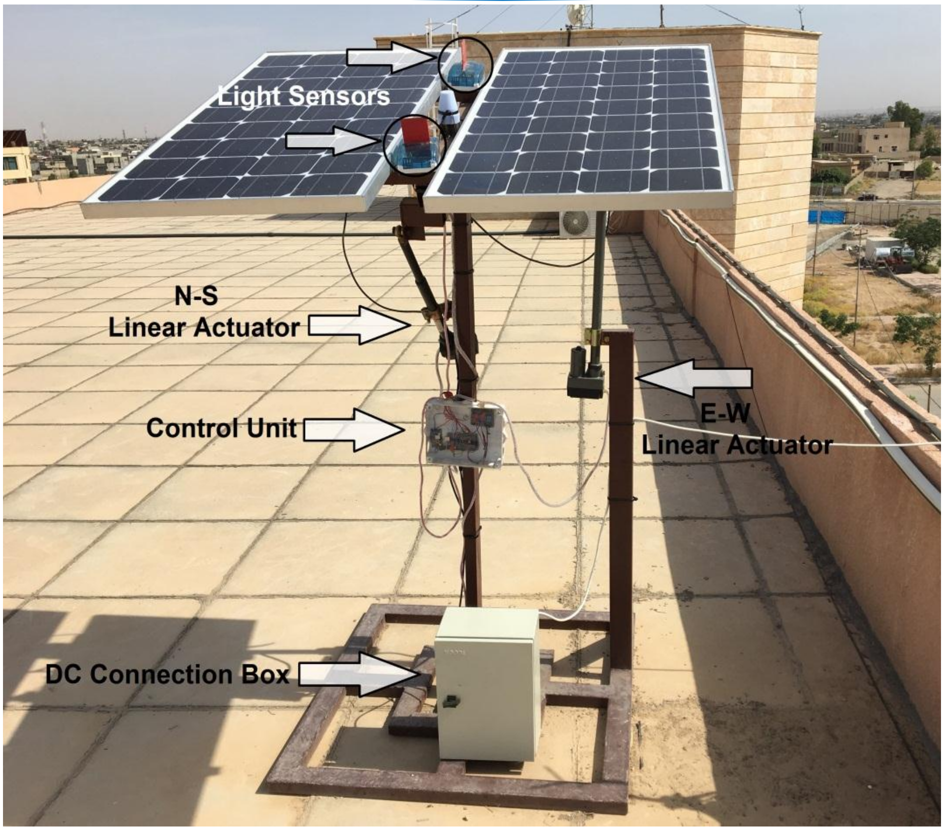

Fig. 3: The Tracking System

Moreover, ARDUINO, MEGA 2560 microcontroller is used for this research. The microcontroller compares the generated voltage signal values digitally and determines the direction of the movement of the actuator in the horizontal and vertical axes. Digital signal generates from the microcontroller and sends it to the switch relay which controls the movement direction of each actuator. Finally, The control signal is interrupted when each LDR receives the same amount of light intensity.

4. Methodology

A comparative study of photovoltaic module output power is carried out in the present work. The experiments have been conducted during August to December (2017) in Kirkuk, Iraq. The Tracker system is mounted on the rooftops of Engineering faculty Building / Kirkuk University. Two identical mono-crystalline photovoltaic solar modules each one with 100 W rated power are used in this study. The electrical specifications of PSS12100 module is shown in Table 1. One module was kept constantly clean other one is left exposed to weather conditions for more than six months.

Kirkuk University Journal /Scientific Studies (KUJSS)
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To make a correct measurement and minimize differences in irradiation, the two modules are kept side by side with the same elevation from the ground. The PV module was connected to a computer-based measurement system located in Electrical Measurements Lab. Output voltage and current are continuously measured for dusty and cleaned module with one hour period from 10:00 am to 02:00 pm. Also, the ambient and the module back surface temperature was measured and stored in the same measurement system. Temperature measurement is done by using Intelligent Digital Multimeter and K-Type Thermocouple with ±(1%+30) accuracy and -40 °C ～ 1000°C temperature range measurement capability.

Table 1: Electrical Specifications of PSS12100 modules

Electrical quantities	Symbol	Value
Nominal Power	Pmax	100 Wp
Open-circuit Voltage	Voc	21 V
Short Circuit Current	Isc	6.8 A
Voltage at Maximum Power	Vmpp	16.8 V
Maximum Power Current	Impp	5.95 A
STC = Standard Test Conditions: Irradiance 1000W/m2, AM 1.5, Cell Temperature 25 ℃ According to Apex Power Concepts manufacture datasheet.		

5. Results and Discussion

The real-time data was collected from the photovoltaic module, and detailed analysis has been made with MATLAB software. Fig. 4 show voltage - current and voltage - power relation for different conditions (STC, With dust, and Without dust). Data are collected in August for two modules one is left under weather conditions for one month another one is cleaned. Both modules are operating at the same temperature and solar insulation. Ambient and module back-surface temperature is measured at the same time, where they exhibit a large difference (about 20 ℃) as shown in Fig. 5.

Kirkuk University Journal /Scientific Studies (KUJSS)
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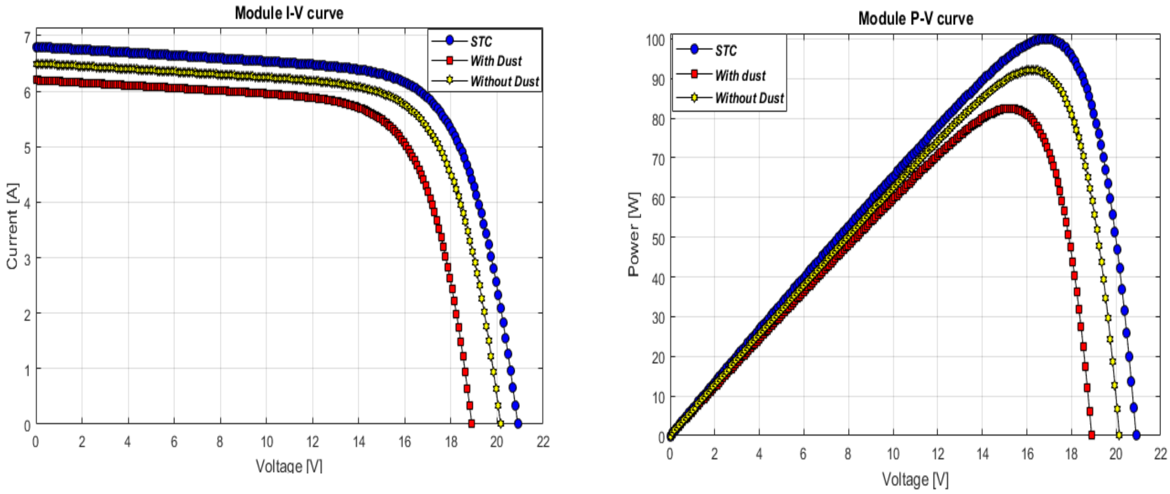

Fig. 4: Photovoltaic module output (a) voltage - current and (b) voltage - power

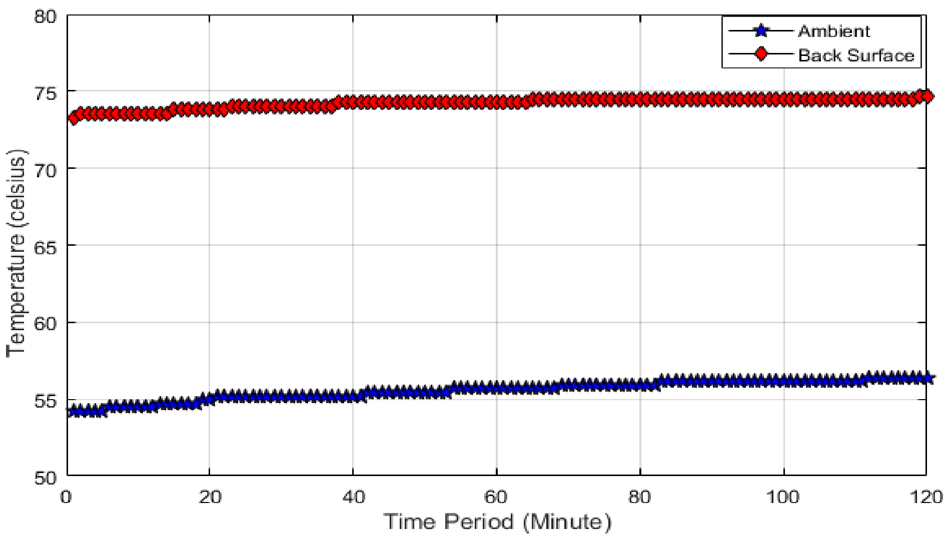

Fig. 5: Ambient and back surface temperature

Another comparison was made for the fixed orientation and tracker system. The data are collected in December on the same modules but with massive dust accumulation on module surface (without cleaning for more than six months). A comparison between result from dusty and cleaned module with and without tracking is shown in Table 2, 3 respectively. The results from Table II and Fig. 6 showed that there are a remarkable difference in maximum power (Pmax) between dusty fixed (DF) module and dusty tracker (DT) for the same solar insulation. The decrease in maximum output current is more evident than voltage; this is due to dust particles that prevent the generation of the photocurrent. The differences in output power between cleaned fixed (CF) and cleaned tracker (CT) are also analyzed as shown in Table 3 and Fig. 7. A comparison between dusty fixed (DF) and cleaned fixed (CF) module at

Kirkuk University Journal /Scientific Studies (KUJSS)
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12 PM is shown in Fig. 8. The results showed that is a remarkable decrease in power (about 27 W) due to dust accumulation.

Table 2: Results for dusty module

Time	Dusty Fixed (DF)					Dusty Tracker (DT)				
	Isc	Voc	Impp	Vmpp	Pmax	Isc	Voc	Impp	Vmpp	Pmax
10.00	3.04	20.56	2.66	16.45	43.76	3.71	20.43	3.24	16.34	52.94
11.00	3.94	19.88	3.45	15.90	54.86	4.04	19.67	3.54	15.74	55.72
12.00	4.26	20.18	3.72	16.14	60.04	4.39	20.02	3.84	16.02	61.52
13.00	4.20	20.23	3.67	16.18	59.38	4.24	20.20	3.71	16.16	59.95
14.00	3.08	20.22	2.69	16.17	43.50	3.78	20.15	3.31	16.12	53.36

Table 3: Results for cleaned Module

Time	Cleaned Fixed (CF)					Cleaned Tracker (CT)				
	Isc	Voc	Impp	Vmpp	Pmax	Isc	Voc	Impp	Vmpp	Pmax
10.00	4.56	21.18	3.99	16.95	67.63	5.29	21.01	4.63	16.81	77.83
11.00	5.74	20.27	5.02	16.21	81.37	5.86	20.06	5.13	16.05	82.34
12.00	6.05	20.51	5.29	16.41	86.81	6.29	20.30	5.50	16.24	89.32
13.00	6.20	20.54	5.42	16.43	89.05	6.31	20.65	5.52	16.52	91.19
14.00	4.61	20.61	4.03	16.49	66.45	5.37	20.61	4.70	16.49	77.50

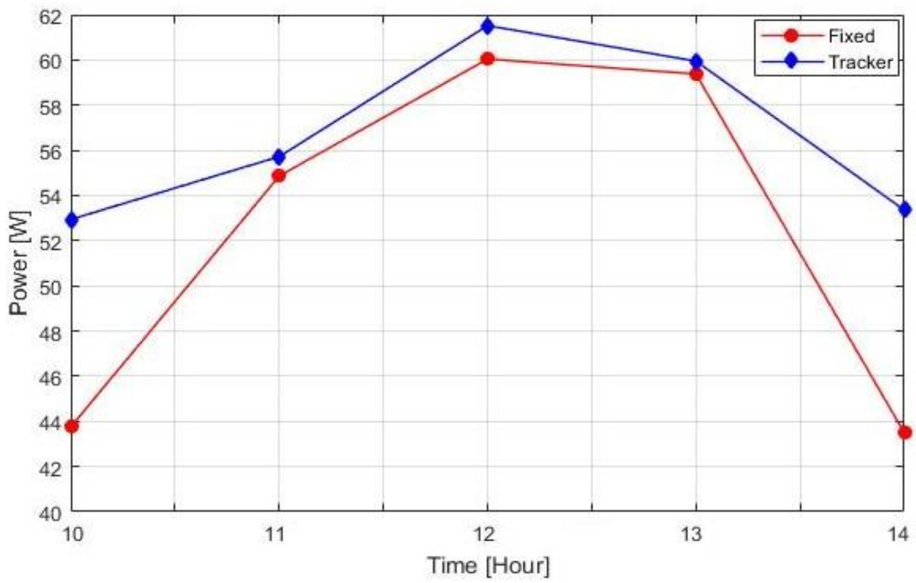

Fig. 6: Output power for heavy dust accumulation.

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 13, Issue 2, June 2018, pp. (127 - 138)
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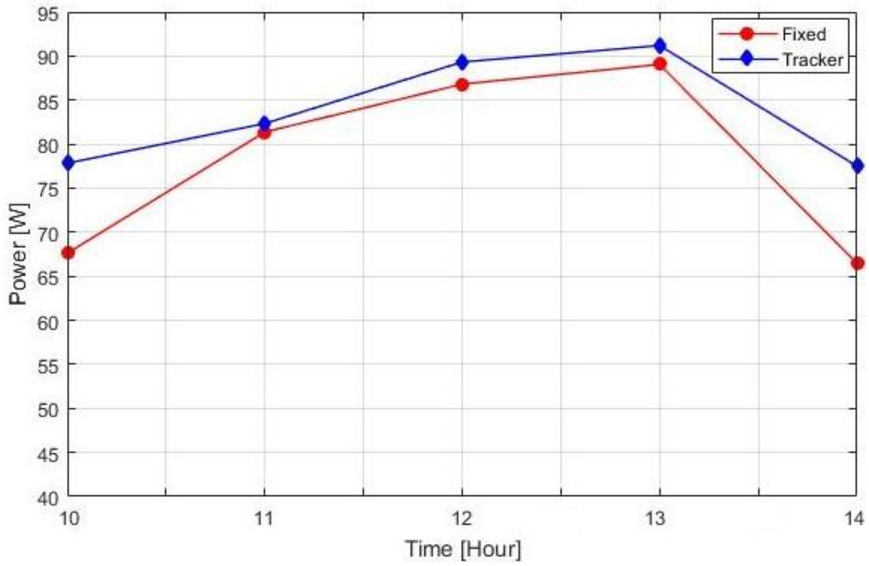

Fig. 7: Output power for cleaned module

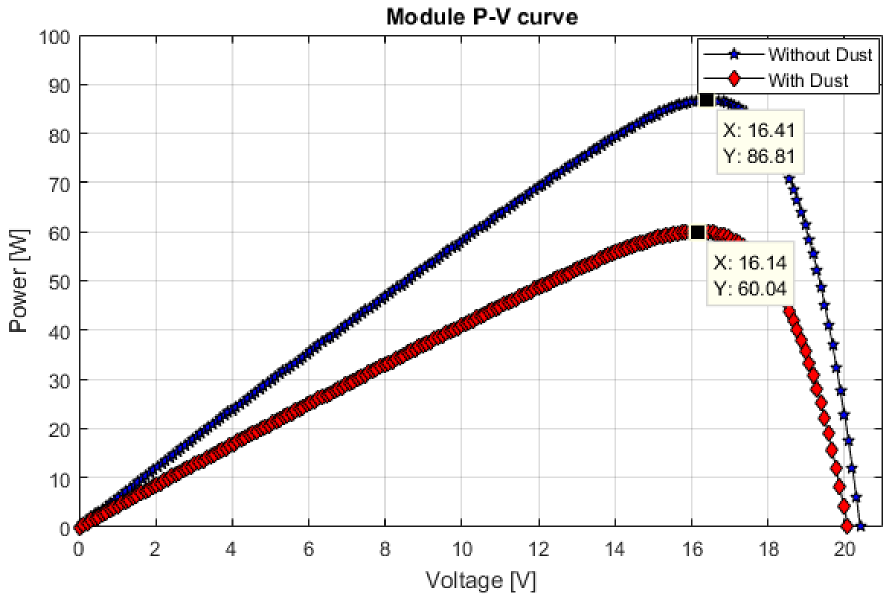

Fig. 8: Output power for fixed orientation

According to the data gathered, it is clear that the dust deposition on Photovoltaic module can cause a significant loss of PV power generation. The results showed that tracker system is more efficient than fixed one for the dusty module, especially in morning and evening time.

6. Conclusions

In this paper, the effects of dust deposition on fixed and tracker Photovoltaic modules output power have been investigated through outdoor experiments under Kirkuk climatic

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 13, Issue 2, June 2018, pp. (127 - 138)
ISSN 1992 – 0849 (Print), 2616 – 6801 (Online)

conditions. The output powers are measured for the fixed modules and compared with a tracker system. Both dust and cleaned modules are examined in this study. The results have shown a decrease in generated power due to dust deposition. Moreover, the results showed that high temperature would increase these losses. It is also concluded that the module efficiency has been improved when we are going to the tracking system.

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