Solar Panel Efficiency in Oman

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Abstract—**Solar panels are widely used in different locations and for different purposes including electricity production, satellites, mobile devices, and lights. It is also considered to be one of the cleanest and most renewable applications to produce electricity, yet there are various environmental factors that affect solar panel efficiency and production rate depending on the installed location. This paper aims to analyze the impact of dust accumulation on photovoltaic (PV) panel efficiency in Oman. The experiment is done on two different poles of solar cells, one oriented in the east direction and the other one on the west direction. The east side panels are cleaned daily; however, the west side panels are kept dirty to check the temperature and irradiance effect on solar panels efficiency and power output. The results show that the east solar panels were producing more efficiently than the west side due to the dust accumulation on the west side panels. The dust accumulation on the west side panels worked as a shading layer for the irradiance to enter the solar cells. However, the dust accumulation did not have any impact on temperature values, which was almost constant for both side panels.**

Keywords—Solar panel, Ambient temperature, Irradiance, Efficiency, Dust, Performance ratio.

I. INTRODUCTION

Scientists are always looking for sources of energy which have less pollution, are renewable, and thermodynamically free. In 1839, scientist Edmond Becquerel found that sunlight can cause electricity to come from metals and a few other scientists studied the relation between material, light and electricity, such as Albert Einstein. Then, a scientist called Russell Ohl made the first functional solar cell in 1954, which is similar to the ones used these days, and it is made from Silicon. Silicon (Si) material can be found in rocks or sand. Furthermore, this solar cell was enough to generate electricity for regular electrical devices. The solar cell became very useful in human life as it has been used widely in electricity production. As a result, in 1958, scientists used the solar cell in space satellite for the first time and it was used as the first power generation plant that can produce 1000 kW in 1982 in California, USA [1].

In 2014, Professor Shanaz Ghazi found that the North Africa and the Middle East (MENA) region are considered to have the highest dust collection area. In hot dusty areas, solar panels produce low electrical power due to the appearance of dust and the negative effect of dust on solar panel performance which can be daily, monthly, annually, or seasonally, in terms of time. Dust accumulation on PV modules tends to pose a reflection problem for the sunlight to enter the PV cells. As a result, solar panels absorb less irradiance and sunlight. This tends to generate less electrical power, which means low solar panel efficiency. Moreover, dust particle size varies with site and environment [2].

This paper is structured as follows. Section II presents the review of the literature and discusses the factors affecting solar panel performance and the dust factors and its adhesion on solar panels surface. Section III discusses the research objectives. Section IV discusses the case study and the experimental setup. Finally, Section V discusses the results.

II. LITERATURE REVIEW

This section discusses past works in factors that affect solar panel performance, soiling influence on photovoltaic panels (case studies) and dust properties on solar panels. This literature review is divided into 3 subsections to ensure extensive understanding of the subject matter.

A. Factors affecting solar panel performance

A solar panel does not exceed 20% of its efficiency worldwide, and there are several parameters that lead the solar panels to perform less than ideal [3]. In this subsection, the factors will be summarized in environmental terms.

High temperatures have a negative effect on solar panels. When the ambient temperature recorded is high, the power output and the efficiency of solar cells will decrease because of the high rate of the internal carrier recombination inspired by higher carrier concentration. The higher rate of internal carrier recombination occurs when the high temperature enters the solar cell. As a result of this phenomenon, the electrons inside the solar cell will recombine with positive charges instead of flowing in the negative charges path. This recombination generates electric charges collision which, in turn, results in thermal emissions (heat) inside the solar cell. Basically, solar irradiation and temperature are directly proportional to the photovoltaic cell temperature. Whenever the temperature of the solar cell increases, the current rises gradually, but the voltage will fall significantly, which translates into a big drop in power output and vice versa for low temperatures [4].

Another factor is the variation of solar irradiation. The differences of intensity of the solar irradiation which falls on the solar module influence some of the photovoltaic panel characteristics including open circuit voltage, power, short-circuit current, efficiency, and fill factor. The relation linking module voltage and module current is that, as the solar irradiance increases, the module currents increase too. Also, the relationship between module voltage and module power is that the power output will increase when the current increase due to their directly proportional relation. As a result, when the solar irradiance increases, the power output will rise as well [4].

The last main factor is soiling. Soiling can be in the form of accumulation of pollutants, bird fallings, dust, and dirt. In essence, soiling works as shading; it is a slim screen which enforces in solar panels and decreases the falling of sunlight on the cell. Dust is a solid particle with diameter less than 500 micro-meters. Soiling can happen when moisture condensates the dust particles which adhere to solar panel layers, especially at the lowest part of the tilted panel due to the gravitational force on the dust particles. The accumulation of soiling will make one thin layer, which can cause partial shading in the lower row cells. Moreover, the power output of photovoltaic system may decrease by 5% to 17% [4] due to the soiling factor. In terms of location, deserted areas and places near highways have more dust in compression to rainy areas. Also, it is better to put the solar panels on a roof top instead of ground solar panels to prevent dust and soil accumulation on the panels. The fine dust creates more performance loss than the large one; this is because the small particles have smaller gaps between each other so the light cannot pass through them [4].

B. Dust and its adhesion on solar panels surface

Soiling is known as a phenomenon that is affected by metrological factors and weather conditions. Furthermore, the parameters that influence the dust on solar panels can be divided into two groups: solar panel installation factors and environmental factors [5].

For the installation factors, horizontal surfaces tend to accumulate more dust than inclined surfaces. Additionally, small particles of dust settle on the tilted surface of solar panels, but the large particles of dust tend to roll down. This is due to the effect of the gravitational force on dust particles. Also, whenever the inclination angle of the solar panel increases, the gravitational force impact in dust accumulation increases. Environmentally speaking, dust has different properties which affect the precipitation on the solar panel surface. In terms of physical properties, the large size dust particles tend to drop off from solar panel screen and for the small size dust particles, they tend to stick to the solar panels surface [5].

C. Critical dust analysis

There are many studies regarding soiling influence on PV cells performance. Some of these experiments are discussed in this subsection.

The first study was in Saudi Arabia, Jizan region, specifically as part of the science collage of Jazan University. The researchers used two PV panels with two different angles (30^o and 55^o) which produce peak power around 30 watt per solar cells and were placed on the roof of a building. The median humidity in the Jazan region is around 70 percent, the temperature range is between 22 ^{o}C to 38 ^{o}C and speed of wind approximately 15 kilometer per hour, all throughout the year [6]. Readings were conducted every Monday at 11:30 AM for 112 days. At the beginning, the cells were washed with water to remove tiny particles to allow for detailed reading. The process of washing was performed whenever the panels got dusty [6]. Both tilted panels produced almost the same path (trend) of efficiency. What is more, the PV panels with higher tilt (55 degree) had a low amount of efficiency reduction compared to the solar panels with lower tilt (30 degree) because of the gravity force that eliminates a certain amount of dust particles spontaneously. Consequently, the total decrease of photovoltaic cells performance because of soiling collection in the Jazan area was approximately 9.7 percent for the 55 degrees panels and 10.4 percent for cells inclined at 30 degrees [6].

Another experiment was conducted in Iran, specifically at Tehran University in 1999. Numerous solar systems with various inclination angles have been mounted on the roof of the Tehran University building. The aim of this experiment was to examine the impact of air contamination from local industry and vehicles on the photovoltaic system performance seasonally [2]. The results showed that the system production differs with the season and that the level of contamination that occurs in the air in various seasons is the justification. The highest air pollution was in the winter season because the air has a high density. As a result, the irradiance is affected by contaminated air, and this leads to a reduction in solar cell performance. Since the climate is windy in the fall season, the dust or pollution frequently flies away, and the efficiency is better in the fall season. The highest performance is in the spring season due to the rainy weather that helps to remove the pollution or dust from the panels. Finally, the summer has an efficiency production amount between spring and fall. The tilt angle increases the production amount for all four seasons. Additionally, the efficiency values of solar panels decrease by more than sixty percent due to the phenomena of air pollution which settles on the surface of photovoltaic panels and works as shading [2].

III. RESEARCH OBJECTIVES

This experimental paper helps increase the performance ratio of the solar panel in Oman by checking the effect of dust and irradiance on the top surface of solar cell. Also, we investigated the number of cleanings needed per month for dusty solar panels.

The aim of this research work is to explore the influence of voltage and current parameters on the power output and the efficiency of solar cells and to check the impact of the environmental factor efficiency. The voltage and current are affected by two environmental factors, namely irradiance and temperature change.

IV. CASE STUDY AND EXPERIMENTAL SETUP

A. Case study of solar panels

In this subsection, the case study of the solar panel system is divided into sub-case studies. This includes the location of the solar panel system, the website used for the information of PV panel system and the devices or components utilized in the photovoltaic panel framework. Also, we present the experimental setup and the tools used for this study.

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1) System

The system used in this study is Virtual Control Operator Room developed by meteo-control GmbH Company (mc). This system provides solar panels system data with graph analysis and location of solar panels system. It helps the technicians and clients to check the system to see if there are any problems. Also, it can be used to perform studies and research [7].

2) Location of the site

The research specifically takes place at the German University of Technology in Oman (GUtech), which is located in Halban, Muscat, Sultanate of Oman. The facility is located at a height of 41 meters (m) above sea level. The solar technology facility is structured by Shams Global Solution and British Petroleum Oman (BP Oman) [8].

3) System Components

The solar panels systems at GUtech consist of different components. Each component will be explained fully in this subsection.

The experiment is set up on a flat-roof zone, which is made from multi-crystalline cells 0.15675 × 0.15675 (m) and it is installed on a platform with a height of around 1.5 meters (m). The flat-roof solar module is subjected to two poles (east and west), and it has 12 panels (3 sets × 2 panels at the east × 2 panels at the west) and each panel consists of 72 (12×6) cells, as shown in Figure 1. The dimensions of one panel are: 0.992 m height, 1.960 m width, and 0.04 m depth and it weighs 2.25 kg. Also, the panels are placed at an angle of around 10^o to get more sunlight. The panels are made by Trina-solar and the ID number is TSM-325-PD14 [9].

Figure 1. Flat-roof solar module at GUtech.

A Fronius inverter is used for the flat-roof system and its module number is Fronius Symo 3.0-3-M. The inverter dimensions are 0.645 m height, 0.431 m width and 0.204 m depth, and its weight is around 19.9 kg (with mounting plate). It produces at a maximum efficiency of 98% [10].

On site, there are two sensors used for all four zones, namely the weather sensor and the pyrano-meters. The flat-roof system has one more sensor that measures the panel temperature and irradiance which is called the Silicon irradiance sensor.

- Weather station sensor

To control the solar power plant's production and performance, a weather forecasting device can be incredibly useful, as shown in Figure 2. Additionally, it can be used for scheduling maintenance and washing periods. Fundamentally, it measures parameters like irradiance, other ecological factors like humidity, velocity of wind, direction of wind and module temperature [11].

Figure 2. Weather station sensor at GUtech

- Thermopile pyrano-meters

The thermopile pyrano-meter is an instrument used to detect the sun irradiance (intensity) from the hemispheric view of a flat surface incident. The sensor is made of a pyrano-meter structure, one or two domes, black body absorber and thermopile (it is an instrument which transforms the thermal energy absorbed from the sun in the form of electrical energy), as shown in Figure 3 [12].

Figure 3. Pyrano-meter sensor at GUtech

- Silicon irradiance sensor

This sensor is a solar cell made from Silicon and it can be used to measure the radiation because the relation between short circuit current and radiation is directly proportional. Also, it can measure temperature by connecting the temperature sensor to the Silicon irradiance sensor, as shown in Figure 4 [13]. The sensor is connected near the solar panels directly with the same angle, so it measures the solar irradiance that falls to solar panel directly.

Figure 4. Silicon irradiance sensor at GUtech

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B. *Experimental setup*

This study took 91 days starting from the 6th of May, 2020. For the first 28 days, both side panels were kept dirty, and this was taken as the baseline. However, for the rest of 61 days, the east side of solar module was cleaned, and the west side of solar module was kept dirty.

At the beginning, the Virtual Control Operator Room website was explained by an employee who works at HTC to teach the user how to use the website and perform studies. Then, self-study of the website helped the user to learn more about the website and get familiar with it; in case the user did not understand something, he/she could go back to process number one (ask the HTC employer for more explanation). Then, an excel sheet was created to make studies and graphs analysis. The east side of the solar panels will be cleaned with a brush, microfiber cloth and water by a GUtech employee, taking time consumption and amount of water used into consideration. Then, the user will check for any sensor or technical problems; in case of any problem, he/she should ask for help from HTC employees and repeat the process starting with repeating the cleaning of the east solar cells. However, in case everything is fine, data can be withdrawn safely and if there is any big change in data due to weather or other side effects, notes should be written down. The process of cleaning, checking for any side effects or technical issues and withdrawal of data will be repeated daily for two months. After two months of repeating the same procedure, the final process will take place by analyzing graphs, comparing data and discussing.

V. RESULTS AND DISCUSSION

A. *Result analysis*

The experimental part focuses on analyzing the outcome of the results obtained, based on utilizing a comparison between different graphs for both solar panel sides (east (cleaned) and west (dirty)). These graphs include Irradiance-DC current, Temperature-DC voltage, and the DC power of photovoltaic panels. The results were collected from the 6th of May to the 5th of August, 2020. The data was taken daily from sunrise (6:00) to sunset (19:00) because the sun is most present during this time frame which leads the solar panels to produce power output. For the first 28 days, both panels were not cleaned, and this was taken as baseline. However, for the first 18 days, the amount of irradiance and temperature falls to solar cells were not stable due to the change in weather.

1) *Irradiance and DC current (East)*

Figure 5 shows the irradiance and DC current on the y-axis and the days number on the x-axis for the cleaned panels. As it can be seen on the graph, the relation linking irradiance and DC current is directly proportional and, from day one to day eighteen, both parameters generate a gradual decreasing line due to soiling accumulation. However, for the remaining 73 days, the production of both parameters remained constant because the east panels were cleaned. Most of the days, the irradiance which fell on the east solar module fluctuated between 552 W/m^2 and 432 W/m^2, and the DC current that was generated by east solar module averaged between 6.31 A and 4.80 A.

On the 24th of May (day 18), the absorbed irradiance on the west solar cells was low from times 14:00 to 17:00 because of weather change which resulted in a low generated DC current, around 4.43 A. On day 39 (14th of June), the irradiance falling to the east solar module was around 510 W/m^2, but the generated DC current was 4.50 A which is out of the daily average range. This drop was due to a technical error that happened to the solar module which shows there was a problem in converting the absorbed irradiance to DC current and a gradual decrease in falling irradiance to solar module, specifically at 11:00.

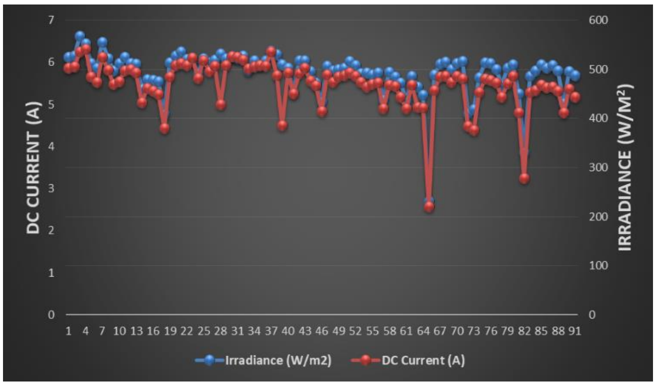

Figure 5. Experimental data of east panels between irradiance and DC current

Also, on day 72 and day 73 (17th and 18th of July), respectively, the absorbed irradiance by the east solar module was approximately 410 W/m^2 and 419 W/m^2 respectively, due to a reduction in temperature specifically from 12:00 to 14:00. As a result of DC current, the east solar panels generated 4.48 A and 4.40 A, respectively. The east solar module generated around 3.24 A on day 82 (27th of July) due to a technical error that happened to solar panels specifically at 12:00, appearing that the DC current was 0 A and low daily average solar irradiance exactly from 12:00 to 19:00 around 331 W/m^2 which fall to the east solar module.

The largest drop in the east solar module current output was on day 65 (10th of July). The solar module produced around 2.58 A. This was because of a low amount of falling irradiance to the east solar module, approximately 237 W/m^2, which was influenced by the presence of clouds.

2) *Irradiance and DC current (West)*

Figure 6 shows DC current and irradiance on the y-axis and the days number on the x-axis for the non-cleaned panels. As per the figure, the relation between irradiance and DC current is directly proportional and there is a steady decrease in the DC current from the first day to the last day. Additionally, the absorbed irradiance of the west solar module is constant and nearly the same as the one on the east side. The absorbed irradiance by the west solar module fluctuated between 445 W/m^2 and 571 W/m^2, but the DC current which was generated by the west solar module declined from the peak amount of 4.52 A to about 2.96 A.

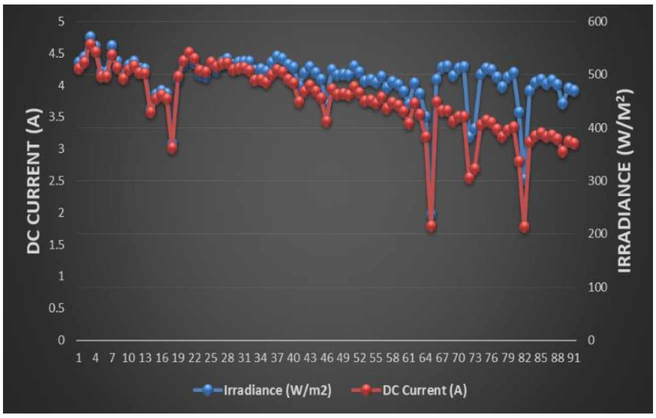

Figure 6. Experimental data of west panels between irradiance and DC current

On the 24th of May (day 18) the falling irradiance on the west solar cells was low in the afternoon from 14:00 to 17:00 due to weather change. As a result, the produced amount of DC current was 3.02 A. On day 72 and day 73 (17th and 18th of July) respectively, the absorbed irradiance by the solar module was around 383 W/m^2 and 399 W/m^2 respectively, due to a reduction in temperature specifically from 12:00 to 14:00. Accordingly, the west solar panels generated around 2.55 A and 2.67 A, respectively. A technical issue happened on day 82 (27th of July) to the west solar module exactly at 12:00, and the DC current produced was 0 A. This affected the daily produced DC current which reached around 1.79 A. Also, the daily solar irradiance to the west solar panels was around 304 W/m^2, which played a role in decreasing the current, especially from 12:00 to 19:00.

The highest decline in producing current by the west solar module was on day 65 (10th of July). The west solar module produced around 1.79 A. The problem on day 65 was a low amount of falling irradiance to the west solar module around 232 W/m^2 which was influenced by dust accumulation and the presence of clouds. Additionally, the effect of dust on the west solar modules started from day 67 (12th of July). Consequently, a high irradiance rate was absorbed by the silicon irradiance sensor, but vice versa for the solar panels, which shows low DC current rates.

3) Temperature and DC voltage (East)

Figure 7 shows cell temperature and DC voltage on the y-axis and the days number on the x-axis for the cleaned panels. It appears from the graph that the relation between cell temperature and DC voltage is inversely proportional and almost constant values for cell temperature and DC voltage for three months. The temperature at the east solar module was oscillating between 57.59 ºC and 46.76 ºC, and DC voltage which was produced by east solar module was between 178 V and 192 V, on average.

On the 21st of May (day 15), the east panels were having a technical error to convert the absorbed temperature to DC voltage due to dust accumulation on the Silicon irradiance sensor. Consequently, the relation between these two parameters is shown to be a directly proportional one. On day 57 and day 59 respectively, the cell temperatures of the east solar module were around 50.53ºC and 46.53ºC independently however, the generated DC voltages were 190.87 V and 183.23 V independently. Consequently, in these two days, the east solar module was having a technical error issue of measuring the absorbed temperature because the surrounding temperature was investigated to have an inverse proportion relation with cell temperature. Due to this issue, the relation between the cell temperature and the DC voltage was directly proportional. The cell temperature was 50.09ºC on day 89 but the DC voltage was high (185.38 V) which shows the relation is direct proportional between these two parameters. As a result, from 9:00 to 10:00, the surrounding temperature was low around 33ºC and this influenced the average DC voltage to increase.

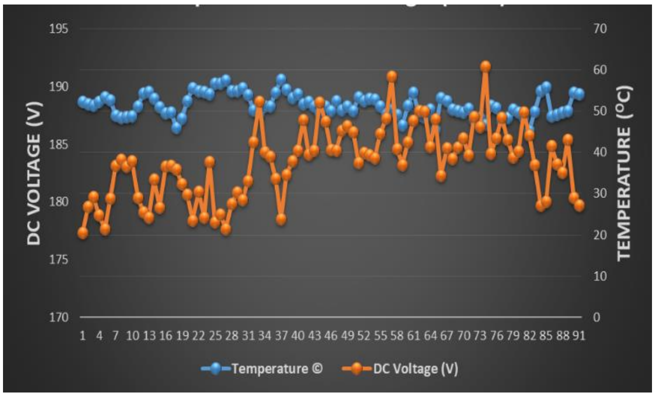

Figure 7. Experimental data of east panels between temperature and DC voltage

4) Temperature and DC voltage (West)

Figure 8 illustrates cell temperature and DC voltage on the y-axis and the days number on the x-axis for the non-cleaned panels. Evidently, from the chart, the relation between cell temperature and DC voltage is inversely proportional and there are almost constant values for cell temperature and DC voltage for three months. On most days, the temperature of the west solar module fluctuated between 57.76 ºC and 47.88 ºC, and DC voltage produced by the west solar module averaged between 182 V and 191 V.

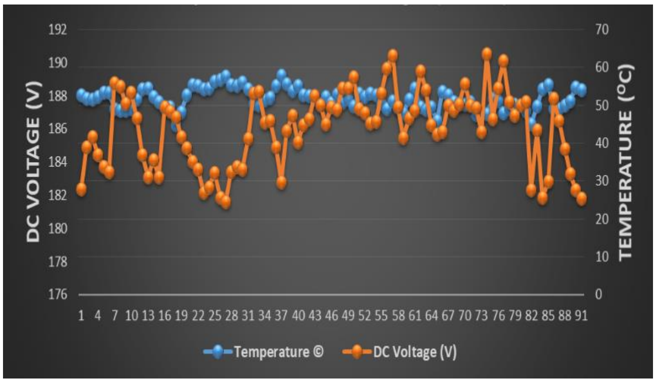

Figure 8. Experimental data of west panels between temperature and DC voltage

On day 15 (21st of May), the west module was having a technical error to transfer the absorbed temperature to DC voltage because of soiling on the Silicon irradiance sensor surface. As a result, the relation linking DC voltage and temperature is a directly proportional one. On day 82, day 85, and day 91 respectively, the cell temperatures of the west solar module were around 45.03 ºC, 55.4 ºC and 54.1 ºC independently but, the generated DC voltages were 182.34 V, 182.82 V and 181.83 V independently. As a result, in these three days, the west solar module was having a technical error issue of measuring the absorbed temperature because the surrounding temperature was investigated to have an inverse proportion relation with the cell temperature. Because of this problem, the relation between the cell temperature and the DC voltage is shown to be directly proportional. In addition, during week five, exactly on day 57, day 59, day 61, day 63 and day 65 respectively, the cell temperatures of the west solar module were generating a direct proportional relation with the DC voltage. This was due to an error that happened to Silicon irradiance sensor which was affected by dust accumulation.

5) DC Power (East and West)

The DC power of the photovoltaic panels is influenced by the DC voltage and the DC current. Both factors have a direct relation to power output. Consequently, if there is any sudden drop, rise or change in the DC power data, then there would be a variation for either the DC voltage or the DC current.

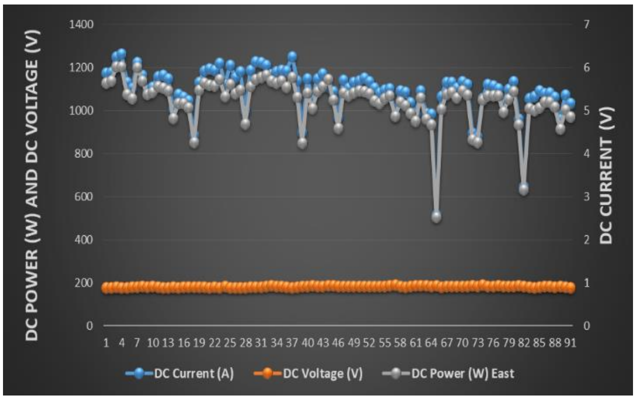

Figure 9. Experimental data of east panels between DC power, DC current and DC voltage

Figure 9 shows the chart between DC power, DC current and DC voltage on the y-axis and days number on the x-axis for the cleaned panels. Clearly, from the chart, the DC power is mainly affected by the DC current since the DC voltage produces a nearly constant line. The DC power which was generated by the east solar module was fluctuating between 1205 W and 917 W and it has a constant generating line.

Different days (18, 39, 72, 73 and 82) in Figure 5 show a sudden drop in the DC power which produces less than 860 W. This happened because of the low production in the DC current. The critical drop happened on day 65. It produced around 506 W. This was also due to a drop of the DC current to around 2.58 A.

Figure 10 depicts the DC power, the DC current and the DC voltage on the y-axis and the days number on the x-axis for the non-cleaned panels. From the chart, we see that the DC power is mainly affected by the DC current since the DC voltage is producing almost a constant line. Nonetheless, the DC power line is decreasing progressively from peak power around 907 W to minimum power approximately 569 W.

Several days (72, 73 and 82) in Figure 10 show dramatic decline in DC power generating less than 526 W, this happened due to low production in DC current. The maximum drop occurred on day 65, producing around 350 W. This was also attributed to a decrease in DC current to around 2.58 A.

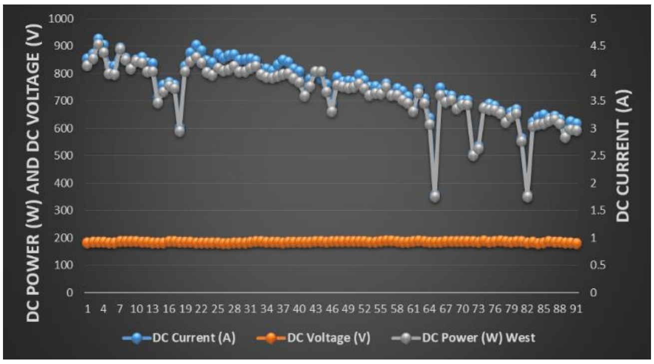

Figure 10. Experimental data of west panels between DC power, DC current and DC voltage

B. Discussion on Results analysis

From the above detailed analysis, it can be concluded that dust accumulation on solar cells affects the irradiance and current only because the cell temperature and voltage were constant for both panels. There were big differences between the amounts of DC power of the east panels compared to the west panels due to dust accumulation on the solar cell glass. The east panels generated more power than the west panels. Additionally, the power of the west panels started to drop in week six. As a result, the falling irradiance amount was almost the same for both panels, but the generated current of the west panels was low.

C. Performance ratio (efficiency) analysis

The performance ratio (PR) of the photovoltaic cell is calculated by taking the sum of the DC power produced by the PV cells at time (day) to the sum amount of irradiance multiplied by the sectional area of PV cells and efficiency. The PV cells efficiency varies with the irradiance rate and the DC power.

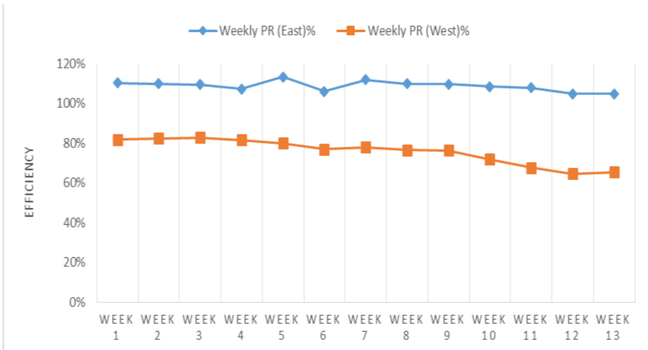

Figure 11. Solar panel efficiency

Figure 11 compares the performance ratio change during thirteen weeks for the east and the west panels. From the graph, the east panels tend to have a higher efficiency when compared to the west panels because they are cleaned daily for two months with no dust accumulation on their surface. The east panels generated constant values of efficiency between 113% maximum and 105% minimum for all thirteen weeks. The west panels started with a constant rate of efficiency between 83% and 81% for the first five weeks. After week five, the impact of dust on the west solar cells started to appear, the west panels generated a gradual decrease efficiency from 77% to 65%. As a result, the west panels' efficiency began to decrease weekly by approximately 2.2%.

D. Discussion on Performance ratio analysis

It can be concluded from the analysis of performance ratio that the east solar cells were more efficient than the west solar cells and produced constant values. This is because the east solar panels absorbed more irradiance compared to the west solar panels from sunrise to sunset in the summertime. Also, the dust accumulation tends to reduce the amount of irradiance on the west PV cells. The generated DC power for the east panels is higher than the west panels. Moreover, from the performance ratio analysis, it can be recognized that the performance ratio values of the east PV cells exceed 100% because of different reasons. One of these above-mentioned reasons is that the Silicon irradiance sensors for both sides were dusty, and this resulted in an error in reading the real integers. Additionally, the inclination accuracy of the Silicon irradiance sensor compared to the panels might affect the amount of absorbed irradiance which, in turn, affects the performance ratio. Another reason can be the relative humidity that could impact the Silicon irradiance sensor accuracy.

VI. CONCLUSION

The leading target of this experiment was to measure the dust effect on solar panel efficiency in Oman. A case study was performed to understand the working system of solar panels at the German University of technology in Oman and to plan for experimental setup. The experiment was done using two different poles of solar cells, one oriented in the east direction and the other one in the west direction**.** The east side panels were cleaned daily; however, the west side panels were kept dirty. This was done to compare the efficiency of the solar panels with and without dust accumulation.

The results show that the east solar panels were producing more current than the west side panels due to the dust accumulation on the west side panels which works as shading layer for the irradiance to enter the solar cells. The generated current from the east solar panels was almost constant between 6.31 A and 4.80 A, however, the west side of PV cells were producing a decreasing line, at maximum 4.52 A to about 2.96 A. In terms of voltage, both sides panels were producing almost the same amount of voltage, between 178 V to 192 V, with almost constant amount of absorbed temperature during the three months.

As a result of the analyses, the main factor that affects the power output and efficiency of the solar cells is the current which is environmentally affected by the irradiance amount. Moreover, the east solar panels were producing constant amount of power and efficiency, however, the west panels were generating a decreasing amount of power and efficiency. In addition, from the analysis of the irradiance-current, power and efficiency of dusty solar cells, we see that in week five, the influence of dust on solar cell performance generated low values for all three parameters.

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