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Performance of 1.4 kW Grid connected desert type PV

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Abstract. This paper analyzes the performance of desert type photovoltaic 1.4 kWP grid connected plant. The system was installed in College of Engineering, Sultan Qaboos University, Oman and was monitored since April 2012. The experimental results show that the total measured annual energy produced was 2217.6 kWh with average system efficiency of 15% for the first year. The average capacity factor for the system was 17%..

Key words

Desert type PV, PV performance, Oman

1. Introduction

Several factors affect the PV performance such as solar irradiation, ambient temperature, dust accumulation, installation configuration, wind speed, geographic position, and cell technology. The effects of some of these factors on the performance of PV were reported in [1] [2] [3] [4] [5] [6] [7], to name a few.

The solar energy level in Oman is high, global solar irradiance can reach 6 kWh/m^2/day, as well as the wind speed in some places, mainly in the southern part, is good enough to build wind power stations. Many papers were published about how these resources can be utilized to produce energy [8] [9] [10] [11] [12] [13] [14] [15] [16].
To choose the suitable PV system in the Mediterranean zone two issues were highlighted in [17], which are the site-specifications and data uncertainty. In [18] three photovoltaic systems (concentrating PV, PV with tracking system, and fixed PV) were evaluated for ten months. Based on the actual performance, it was concluded that tracking PV system is the best candidate for Malaysia condition. The performance of two grid connected PV plants were compared for one year in [19]. The first system has modules of mono crystalline silicon wafer surrounded by ultra-thin amorphous silicon layer and the second is equipped with mono crystalline silicon modules only. Based on the performance results both systems are good. The performance assessment of building integrated photovoltaics (BIPV) system in Singapore over 18 months were reported in [20]. A performance ratio of 0.81 was obtained. Two PV technology types (monocrystalline silicon and polycrystalline silicon) are examined for one year in Iran [21]. The output power and capacity factor from polycrystalline PV is found to be more compared with monocrystalline module. The performance analysis of 1.4 kW roof top grid-connected PV system under desert weather conditions in Sohar city, Oman was presented [22]. The performance ratio and capacity factor of the system reported were 0.85 and 0.21, respectively. 1 kW roof top grid-connected PV system in Warsaw was monitored for 1 year [23]. The annual system energy yield was 830 kWh, performance ratio ranges from 0.6 to 0.8, and the system efficiency ranges between 4-5%. The performance of 190 kW polycrystalline silicon PV plant in India was described in [24]. The plant generated maximum energy during three months (March, September, and October) and the minimum energy in January. The analysis of 15 MW PV plant in Mauritania was presented in [25]. The performances of the plant depend on insolation and environmental conditions. The highest values of energy output occurred during Spring, Summer and Autumn seasons. The performance ratio and capacity factor ranges between 0.64–0.74, 0.12–0.21 respectively. The performance loss rates of 11 grid-connected PV systems from different technologies were evaluated [26]. It was stated that Monocrystalline and polycrystalline technologies exhibited maximum performance during winter whereas thin-film technology showed lower seasonal performance [26]. The annual performance of a 5MW grid-connected PV system was monitored in India [27]. The final yield, module efficiency, and system efficiency were found to be 4.810 h/day, 6.08%, and 5.08%, respectively. The performance evaluation of thin film grid-connected PV systems, over one year, installed at the rooftop of a school was discussed in [28] by means of performance ratio and energy yield.

In this paper, the performance of 1.4 kW$_p$ desert type PV is analyzed for the data collected for two years between May 2012 to April 2014. The following parameters are presented and discussed annual average energy generated, annual average efficiencies, the solar irradiations and the ambient and module temperatures.

2. System Configuration

Papers should not exceed six double column A4 (21x29.7cm) pages including figures, tables and diagrams. On the last page try to balance both columns.

A. PV Plant Description

The PV plant consists of six PV modules with total area of 6.12 m2 and rated power of 1.4 kWp, single phase SMA 1.2 kW inverter and grid. The rated power of the desert type module is 245 W with rated voltage and current of 30 V and 8.18A, respectively. The plant was installed in 2012 and kept far away from any obstacles which can cause shading on the PV cells as shown in Picture 1. The measurements were started in May 2012 and continue until today.

Fig. 1: Picture of photovoltaic panels

B. Monitoring System

The monitoring system consisted of a PC, data logger, pyranometer (SP-110&AL-110) to measure radiation, and temperature sensors (DK-1281PT100 and RTD- Surface-2m) to measure the ambient and the module temperatures. Additional sensor for measuring the wind speed was also used. The pyranometer sensor installed at the same orientation and inclination of the PV modules. The measurements were taken every five minutes since May 2012 until today. Monitored parameters are voltage and current of the PV, AC power of the inverter, solar irradiance, sunshine duration, ambient temperature, module temperature and wind speed etc. The results discussed in this paper are for two whole years (May 2012 to April 2014). The schematic layout for the complete system is illustrated in Figure 2. The evaluation of uncertainty of the measured results is done by calculating the minimum, maximum and average values of each parameters. For solar irradiance any value exceeds 1600 W/m^2 or less than 0 were disregarded and with respect to the current any value exceeds the rated current by large percentage also were omitted.

C. Meteorological Data

The total solar irradiation for the PV modules measured from May 2012 to April 2013 is presented in Figure 3. These values varied from 483 W/m^2 in July 2012 to 632 W/m^2 in March 2013 and with average value of 554 W/m^2.

The measured average ambient temperature and module temperature during the daytime, and the maximum module temperature over one year are shown in Figure 4. The average ambient temperature reached 22.9oC in January and 36.5 ^{o}C in July. In addition, the average PV module temperature during the daytime increased from 35.4 ^{o}C in December to 48.4 ^{o}C in May. The difference between the measured averaged module temperature and the ambient temperature ranges between 7.5 ^{o}C in April to 10.6 ^{o}C in October, this is owing to the generation of thermal losses which occurs during energy generation. The maximum module temperature measured was 69 ^{o}C in July.

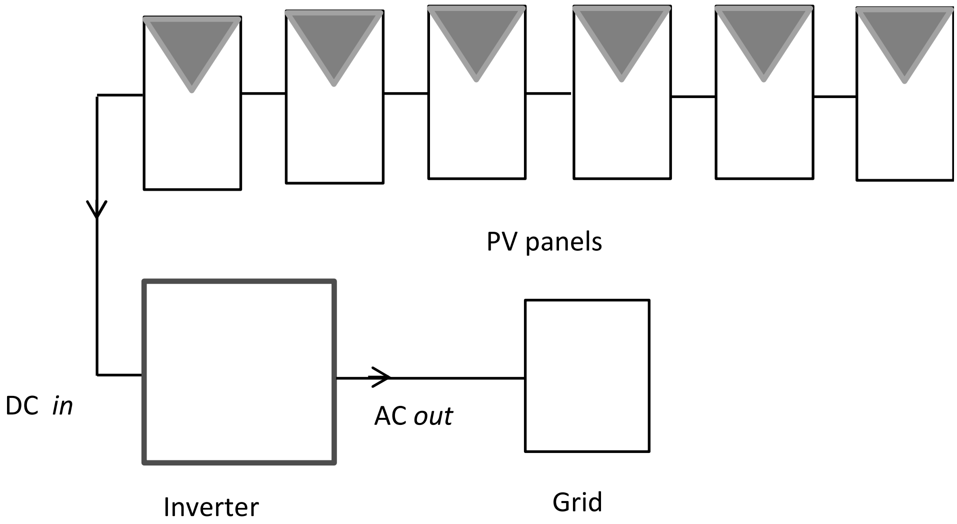

Fig.2: Schematic diagram of the plant

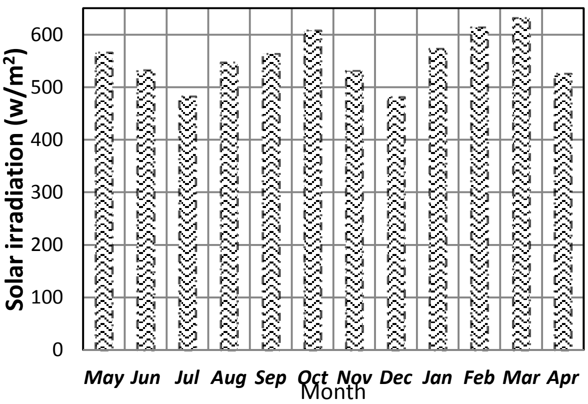

Fig. 3. Measured monthly plan-of-array irradiation at tilt angle of 23° south

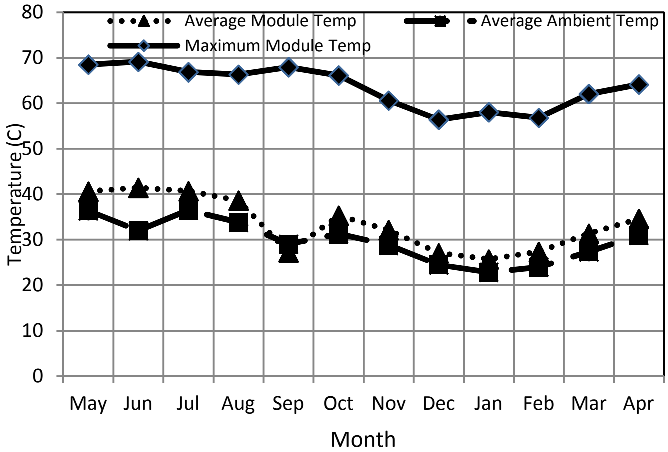

Fig. 4. Measured average monthly ambient temperature, PV module temperature, and the maximum module temperature over the monitored period

3. Performance of PV System

A. Energy Output

The total monthly alternating current (AC) energy generated by the PV system can be calculated as:

$$E_{AC} = \sum_{d=1}^{n} E_{AC-d} \tag{1}$$

where n is the number of days in the month and E_{AC-d} is the total generated daily energy

Figure 5 presents the total energy output per month. The energy varied between 144 kWh in July to 221 kWh in March. The total annual energy produced was 2217.6 kWh.

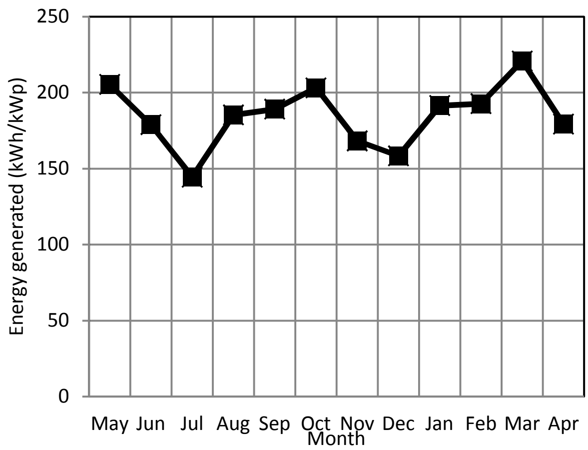

Fig.5. Measured monthly total energy generation over the monitored period

B. Efficiencies

The PV system efficiency can be calculated annually, monthly, daily, and instantaneously. It is defined as a ratio between the inverter AC output power and the multiplication of total in-plan solar radiation (W/m^2) and PV array area (m^2), and is given as:

$$\eta_{system} = \frac{P_{AC}}{G_t A_a} \times 100\% \quad (2)$$

where A_a is the PV array area (m^2)
Figure 6 shows the average system efficiency per month over two years. The average system efficiency for the first year was 15% and for the second year was 14.5%. There is slight drop in the average system efficiency during year 2. The minimum efficiency was during the summer season due to high temperature. The overall efficiency for the is good for the desert type PV given the challenges of a harsh weather in Oman.

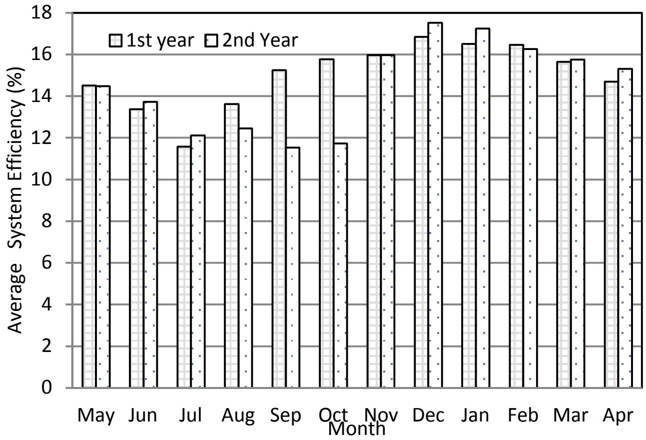

Fig. 6: Average monthly variation of PV module, system and inverter efficiency

C. Capacity factor(CF)

It indicates the electric energy supplied by power station. The capacity factor would have a value of one, if the generation plant supplied the full load power continuously. It can be interpreted as the real annual energy output divided by the amount of energy generated by the PV plant when operated at full load for a year and is given as [29] [30]:

$$CF = \frac{E_{AC}}{P_{PV,rated} \times 8760} \quad (3)$$

Figure 7 shows the PV capacity factor and the daily energy production over one year. The capacity factor varied between 0.13 in July to 0.2 in February and March, and with annual average of 0.17. This indicates that PV system is producing the maximum power during two months of the year. The average annual value of CF (0.17) is more compared with the average CF of a typical plant in Morocco (0.1484) [31], in India (0.1569) [32], and in Serbia (0.1288) [33]. The average daily energy production is low in July and December which can be explained due to the fact that solar irradiation for these 2 months are also low as illustrated in Figure 3.

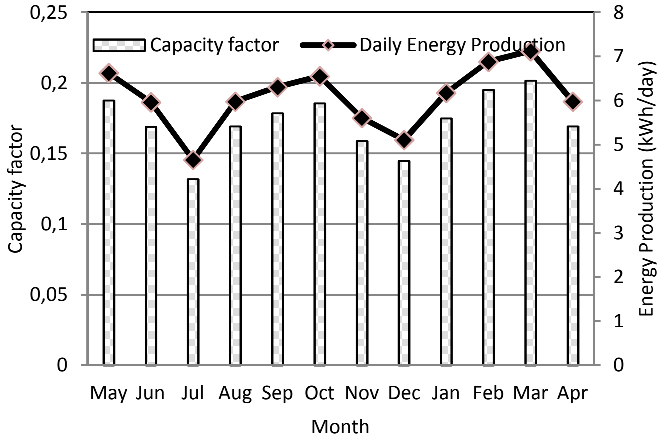

Fig. 7: Average monthly capacity factor and average daily energy production over one year

4. Conclusion

In this paper, a grid-tied 1.4 kW$_P$ PV plant installed in Sultan Qaboos University, Oman was monitored since May 2012. The PV technical performance was evaluated on average daily, monthly, and annual basis. Meteorological data during one year (May 2012-April 2013) showed that annual average daily ambient temperature, daytime PV module temperature, and solar radiation were 30.2 ^{o}C, 42.75 ^{o}C, and 555 W/m^2, respectively. The monthly total energy output ranged between 144 kWh in July to 221 kWh in March and the annual total output was 2217.57 kWh. Relatively lower level of solar radiation in July and December produced low energy output.
The efficiency of the PV plant ranged between 11.6% to 16.8%. The minimum efficiency was in July and the maximum was in December. The monthly average daily capacity factor varied between 0.13 in July to 0.2 in February and March, and with annual average of 0.17.
Comparison of results from this paper with those obtained from other research internationally revealed that the monthly average daily capacity factor reached 17% which is higher compared with other systems installed in different places world-wide.

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