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A comparative analysis of long-term field test of monocrystalline and polycrystalline PV power generation in semi-arid climate conditions

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ABSTRACT

Two different, commercially available photovoltaic modules, monocrystalline and polycrystalline, have been monitored outdoors in the semi-arid area of Iran, over a complete year.

The values of power output, specific energy yield, normalized power output, efficiency and performance ratio of each module have been analyzed and linked to the climatic characteristics of the site.

The result indicates that despite the similar behavior of both PV modules with instantaneous irradiance, the monthly behavior of the modules is different, which is due to different light absorbing and thermal characteristics of each panel. The monthly average module efficiency of monocrystalline module has a gradual decreasing trend in the months with a higher ambient temperature, while polycrystalline module shows an inverse behavior. The results of monthly performance ratio have also shown that the performance of monocrystalline module decreases with increasing monthly ambient temperature.

Monitoring the gross performance of both PV modules shows that the monocrystalline module performed better both regarding maximum efficiency and overall specific energy yield, and was found to be more efficient at this site. This work offers are also useful as a comparison for investigating the productivity of solar plants in different areas with climatic characteristics similar to the semi-arid region of Iran.

Introduction

In recent years, solar energy has become an increasingly important source of renewable energy and it is expected to expand in the near future. It is more important in the middle-east countries where the level of solar radiation is considerably high and it could be as an alternative energy source under conditions that low cost and user-friendly technologies are employed.

One of the finest ways to harness the solar power is photovoltaic technology which is currently being investigated to convert most efficiently the sunlight to electricity.

The performance and efficiency of photovoltaic modules are affected by several factors such as the kind of technology used, the light spectrum, solar irradiance and ambient temperature, humidity and wind (Rahman et al., 2015; Makrides et al., 2012; Daniela et al., 2015). The aging and degradation of photovoltaic modules is also dependent on climatic and environmental conditions (Dubey et al., 2014; Tamizh Mani Mani and Kuitche, 2013).

Independently of the production technology, the most popular type of PV panels are monocrystalline (c-Si), polycrystalline (pc-Si) and amorphous, which are made by connecting photo-electric modules in series and/or in parallel. The energy conversion coefficients for these elements are 12–15, 11–14 and 6–7 accordingly (Zagorska et al., 2012), so mono-crystalline and poly-crystalline panels have begun to be employed commercially and are more widely used in PV panels.

Different researches and scientists have worked on the performance evaluation of photovoltaic system under different climates.

Congedo et al. (2013) focused on the performance of the monocrystalline PV according to the climate characteristics in Southeastern Italy. Their experiments offered a tool to estimate the performances of installed plants with climatic characteristics similar to Southeastern Italy.

Eduardo et al. (2015) experimentally study the performance of monocrystalline and polycrystalline photovoltaic panels for their particular application of water pumping system in Cascavel, Brazil; as for their system with complete pumping, the monocrystalline system presented an average global efficiency of 4.27%, whereas the polycrystalline system showed global efficiency of 5.00%.

Midtgard et al. (2010) Evaluated and compared the performance of three PV modules (monocrystalline, polycrystalline, and triple junction

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Nomenclature

η	efficiency (%)
G	global solar irradiance (kW/m^2)
H	incident solar radiation (kW/m^2)
P_0	PV rated power (kW)
P	instantaneous AC power (W)
$P_{max(STC)}$	maximum power output (W) of panel at standard test conditions
η_P	normalize power output efficiency (%)
PR	performance ratio
PV_A	surface area (m^2)
E_m	the total monthly energy produced by a PV system
γ_m	the monthly average specific energy
N	the number of measuring points for the day
Δt	the time interval of the measurement (min)
M	the number of measured days with complete data sets
η_m	the monthly average efficiency
T	temperature
D_{time}	the duration of the measurements in a day (min)

Subscripts

a	ambient
c	solar module
sys	system
STC	standard test conditions

amorphous silicon) in the climate the site of Norway Eduardo et al. (2015). They concluded that monocrystalline module was better in terms of module efficiency and overall power production.

Another research has been done by Abdelkader et al. (2010) on the behavior of two types of solar panels which are the monocrystalline and polycrystalline and their behavior is measured in Jordan. He has concluded that the efficiencies of the monocrystalline and polycrystalline were very close to each other, but the monocrystalline had a higher efficiency than the polycrystalline.

Jacques et al. (2013) tested monocrystalline solar panels in France, while controlling the ambient temperature and the wind speed. They compared their experimental results with a MATLAB/SIMULINK thermal model for a monocrystalline cell under the same conditions and they obtained consistent relations.

All the above-mentioned studies either focuses on the test results of the efficiency of the different types of solar panels for particular days or in some cases during some months of a year.

The test result of long-term overall performance of monocrystalline and polycrystalline with the evaluation of PV panel performance, according to the irradiance and ambient temperature in semi-arid climate condition is very rare.

The aim of the present study is to evaluate the performance of the most commercially available PV modules (monocrystalline and polycrystalline) in Iran; the country in the middle-east with wide regions in semi-arid climate conditions and huge potentials for harvesting the solar power.

In addition, this study will provide a recommendation for the PV system designer to choose the panels suitable for different areas in the Middle East countries according to the environmental characteristics in this area.

The whole paper is organized as follows: Climate data analysis section focuses on the climate data analysis of the region of the study. Experimental setup and methodology section presents the experimental setup and methodology. Analysis procedure and results are mentioned in Data analysis section and Conclusion section summarizes the relevant conclusions.

Climate data analysis

Fig. 1 illustrates the average annual radiation in Iran and shows its huge potential of harvesting solar energy of Iran. The sun is shining around 2800 h in a year with the average global radiance more than 2000 kWh/m^2. The solar radiation data, displayed in Fig. 1, shows that the solar irradiance in the southern part of Iran, in particular in arid and semi-arid regions, is higher and consequently has more potential for harvesting the solar energy (http://solargis.info/doc/_pics/freemaps/1000px/ghi/SolarGIS-Solar-map-Iran-en.png).

The location of the measuring city is presented in Fig. 1; Rafsanjan City, in the southeast of Iran, is characterized by a semi-arid climatic conditions. The analysis of the testing period, is useful to obtain a general trend of the climatic variation.

In the following, the climate data of Rafsanjan were analyzed in terms of solar radiation, sunshine time, temperature, humidity and wind speed during 12 months of 2014. Fig. 2 shows the solar radiation and sunshine time of Rafsanjan; according to the meteorological data, the average value of the global radiation ranges between 2.8 kWh/m^2 per day in winter months and 7.5 kWh/m^2 per day in summer months for a horizontal surface (http://www.suna.org.ir).

Fig. 3 shows the maximum, minimum and average temperatures collected in 2014. The warmest month is July, characterized by the average value equal to 36.5 °C, whereas the minimum average value is equal to 4.8 °C in January.

The monthly average wind speed of the testing period, is reported in Fig. 4. This parameter is important to estimate the productivity the PV module due to its effect on cooling the PV module by heat convection. The monthly average values of the wind speed of 2014 is in the range 1.7–4.48 m/s.

Moreover, another climatic variable which would effect on the productivity of the PV module is the monthly average humidity (Rahman et al., 2015). The recorded data shows that the humidity is in the low values during the whole year; the humidity values are generally below 25% and can reach 40% in the cold months (Fig. 5). This low range of humidity is typical for the semi-arid regions and does not vary dramatically.

Experimental setup and methodology

Location of study

The experiments have been carried out in solar site of Vali-e-Asr university of Rafsanjan.

The two tested panels were installed on the same stand-alone frames in a similar inclination angle of PV modules (Fig. 6). Based on the location of Rafsanjan city (30.40° N, 55.99° E), the PV modules were placed on a south facing structure at a fixed tilt angle of 34° with the horizontal plane; this angle is near the yearly optimum tilt angle of Rafsanjan, which yields the maximum annual incident solar radiation.

Test systems

Such a PV system consists of PV arrays, data acquisition and monitoring system, and DC to AC inverter. Power generated in the stand alone PV unit can be supplied for a corresponding load. Therefore the solar PV panels are simultaneously converting solar radiation into electricity.

The power monitoring system, includes Sunny Web Box and Sunny Sensor Box, which is interfaced with a data acquisition board. The output of electric current and voltage was measured by the block in a certain period of time and recorded in an SMA sunny web box. The amount of irradiation, the module's temperature, the output current and power generation, daily energy production and total energy production were measured and recorded simultaneously.