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Monitoring and performance analysis of grid connected photovoltaic under different climatic conditions in south Algeria

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ABSTRACT

The main goal of this study is to present the effect of weather conditions on grid-connected photovoltaic (PV) system performance installed in the Saharan area of south Algeria (Adrar) for the year 2010 has been analyzed on daily base. This region is characterized by high ambient temperature in the summer, strong solar insolation potential and low humidity rate. The data measurement was carried out in the Unit of Research in Renewable energy URERMS in various daily climatic condition (clear, cloudy and Sandstorm day). The performance evaluation based on the monitoring of PV array and inverter performance during the system operation derived parameters included final yield, reference yield, performance ratio and system efficiency. The analysis shows that the lowest value was in the performance ratio and efficiency of the PV module, system and the inverter, and the maximum value was in the capture and system losses, since the values in clear day were 76.5%, 10.88%, 94.65%, 10.29%, 1.18 h/day and 0.26 h/day respectively due to high average ambient temperature 32.3 °C. The lowest value was in reference yield, array yield, final yield in sandstorm day were 2.65 kW h/kW$_p$/day, 2.17 kW h/kW$_p$/day and 2.12 kW h/kW$_p$/day respectively due to low level of solar irradiation was 2.65 kW h/m^2, which caused by high wind speed 6.9 m/s with sand dust particles. The experimental results show that the lowest values of the system efficiency and performance ratio (10.29% and 76.5% respectively) caused by the high module temperature equal to 41.1 °C in the clear day, and the fast-changing of the solar irradiance is caused by variation of clouds cover or dust storm affects the energy generated and stability of the PV system.

1. Introduction

Nowadays, the utilization of renewable energy such as wind power, Hydropower, Solar energy, Biomass [1–3] become more important reason to increasing demand on the electrical energy, which are reducing the environmental pollution and climate changing due to fossil energy resources [4]. One of these solar systems is used to produce the electricity based on photovoltaic system (PV). This latter system can be used in an isolated cites (stand-alone) [5] or in connected to the power grid (grid-connected) such as the public network compensation [6].

The operating performance of photovoltaic systems is affected by various parameters which are meteorological conditions such as ambient temperature, relative humidity, solar radiation [7–19] and also a comparison of the PV system performance which are depend on the different PV technology [20–23], the different locations [24–26] and different tilt angle of PV module [27]. The others parameters such as PV panels degradation after a long-term expose to climatic conditions [28], and accumulation of dust on the photovoltaic panels [29,30].

This paper presents the performance evaluation from monitoring of 1.75 kW$_p$ grid-connected photovoltaic (PV) system installed in the Saharan area of south Algeria (Adrar), in three days under varying climatic condition (clear, cloudy and sandstorm). The experimental measurements analysis shows that the performance indices:

- Efficiency (PV array η_{PV}, Inverter η_{inv} and system η_{sys}).
- Yield (PV array Y_A, reference Y_R and final Y_F).
- Energy Losses (Array capture L_C, system L_S).
- Performance Rate (PR).

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As its known, these performance indices are affected by the changes in the local weather conditions, such as ambient temperature, wind speeds and solar irradiance intensity.

2. Materials and methods

2.1. Details of location and PV System

The 1.75 kWp grid-connected PV system installed in the Unit of Research in Renewable energy URERMS. Adrar located in southern-west of Algeria. This region is known by a high ambient temperature in the summer, strong solar insolation potential and low humidity rate (see Fig. 1).

Tables 1 and 2 respectively provide the geographic information and Monthly average of daily weather parameters (Solar irradiation H, maximum ambient temperature T_{max}, relative humidity RH, wind speed ws) [28]. In Table 2, we can observe for the 8 months (March to October) which the temperature is over then 27.5 °C, the wind speed goes up to 3 m/s, the solar irradiation above 5.5 kW h/m^2 and the relative humidity is over then 25%, and for remain months (January-February, November-December), which the temperature, wind speed solar irradiation and relative humidity are less then, 27.5 °C, 3 m/s and 5.5 kW h/m^2 and 22% respectively.

The grid-connected PV system is composed of PV array, inverter, monitoring tools (see Fig. 2).

2.1.1. PV array

The installed array composed of 10 SOLAR MODULE SHARP(NT-R5E3E) mono-crystalline silicon modules connected in series, the details PV module and array specifications are presented in Table 3.

2.1.2. Inverter

The FRONIUS IG inverter converts the DC generated by the solar modules to AC. This alternating current is injected to the public mains synchronically with the voltage [31]. It cannot generate electric power independent from the grid [32]. The main specifications of The FRONIUS IG inverter are shown in Table 4.

2.1.3. Monitoring tools

The monitoring of the different measurements such as solar irradiance, ambient temperature, outputs DC\AC voltage and current assured by the data logger (Fluke Hydra 2635A) and the meteorological station New Energy Algeria (NEAL). The measurement data recorded on 1 min intervals. The other relevant characteristics of the meteorological station are summarized in Table 5.

Fig. 1. View of the 1.75 kW PV plant installed in field of URERMS, Adrar.

Table 1
Geographic information of Adrar region.

Area	424,948 km^2
Latitude	27.88°N
Longitude	−0.27°E
Altitude	262 m

The temperature T_c of the PV modules is calculated by Eq. (1) [6] below. Where T_a is the ambient temperature and G is the solar irradiance.

$$T_c = T_a + \frac{NOCT - 20}{0.8} \times G \tag{1}$$

2.2. Modeling of PV generator

The modeling and simulation of photovoltaic generator based on single diode model using the software MATLAB, the output current of PV array is given by the following expression [33].

$$I = I_{ph}N_{pp} - I_0 N_{pp}\left[\exp\left(\frac{V + R_s\left(\frac{N_{ss}}{N_{pp}}\right)I}{V_t a N_{ss}}\right) - 1\right] - \frac{V + R_s\left(\frac{N_{ss}}{N_{pp}}\right)I}{R_p\left(\frac{N_{ss}}{N_{pp}}\right)} \tag{2}$$

where

- I, I_{ph} and I_0 are the array, the photo generated and the reverse current respectively.
- V and V_t are the array and the thermal voltage respectively.
- α is the diode ideality factor.
- R_s, R_p are cell series and shunt resistance
- N_{ss} and N_{pp} are the number of modules in series and parallel.

Fig. 3 shows the simulation of P–V and I–V characteristics of PV array at STC conditions (1000 W/m^2 and 25 °C).

2.3. Performance analysis methodology

The analysis of grid connected PV system performance in this work based on the following parameters, as defined in IEC 61724 and the international energy agency task II database on photovoltaic power system [11,34]:

- Array, Reference and Final yield (Y_A, Y_R, Y_F).
- PV array, Inverter and System efficiency (η_{PV}, η_{inv}, η_{sys}).

Table 2
Monthly average of daily weather parameters (2014).

Months	H (kW h/m^2)	T_{max} (°C)	RH (%)	ws (m/s)
January	4.36	22.67	38	2.8
February	5.49	26.06	26	2.9
March	6.64	27.98	21	3.2
April	7.73	32.72	14	3.6
May	7.8	39.76	12	3.4
Jun	8.1	42.42	11	3.1
July	7.48	47.39	8	3
August	6.96	45.86	13	3.3
September	6.16	43.93	15	3.4
October	5.48	37.15	18	3
November	4.23	27.28	35	2.8
December	4.26	20.68	43	2.8
Mean Monthly	6.22	34.49	21.16	3.1