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Performance analysis and investigation of a grid-connected photovoltaic installation in Morocco

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ABSTRACT

The paper present an evaluation of a grid-connected photovoltaic (PV) system installed on the roof of a government building located in Tangier, Morocco. The experimental data was recorded from 1st January 2015 to December 2015 based on real time observation. The aim is to encourage the use of solar PV system for government, commercial and residence building in Morocco based on the obtained results. The system is made up of 20 modules of 250 Wp and one inverter of 5 kW. The assessed parameters of the PV installation includes energy output, final yield, modules temperature, efficiency module, performance ratio (PR) and others. The PV park supplied the grid with 6411.3 kWh during the year 2015. The final yield (Yf) ranged from 1.96 to 6.42 kWh/kWp, the performance ratio (PR) ranged from 58% to 98% and the annual capacity factor was found to be 14.84%. The final yield of PV installation is compared with other final yields of solar PV systems located at other places. Finally various power losses are given through a diagram loss.

1. Introduction

The electricity generation in Morocco is largely based on fossil fuels such as oil, gas and coal, about 7.994 GW in 2014, of which 32% is based on renewable energy, Morocco's solar energy potential is vast, as the number of sunshine hours is very important, approximately 300 days/year. The average annual value of global solar radiation in Morocco is 2600 kWh/m^2/year, which is of great importance in order to support the investor's expectations for system performance and the associated economic return. It is clear that PV solar energy will become one of the major future sources of electricity generation in Morocco considering climatic conditions and solar potential. Solar energy, PV in particular, is one of the important projects in Morocco, growing to become a leader in renewable energies. Therefore, Morocco already showed a clear strategy to achieve it by fixing 42% of produced electricity based on renewable energy. PVs represent a large part with a capacity of 2.000 megawatts in five major sites: Ouarzazate, Ain Bni Mathar, Foum Al Oued, Boujdour and Sebkhat Tah. Besides, wind energy 2000 megawatts by 2020, a scheduled electric Production driven from renewable energy of 52% in 2030, which by this strategy Morocco will contribute to the reduction of the reliance on energy, environmental preservation through the limitation of greenhouse gases and the climate change 2015. The performance of a grid connected PV system depends more on technology cells, inverters and installation configuration than on the weather parameters as global irradiance, ambient temperature and soiling losses. Shukla et al. (2016a) analyzed the performance of a solar PV system and compared the performances of different PV technologies based on simulated energy. Saeed et al. (2015) compared the experimental behavior of these two common PV module technologies (m-Si and p-Si). Different studies have been conducted on the performance parameters of installed PV power plants in different geographical locations and different climatic conditions (Padmavathi and Daniel, 2013). Pioneering research in the field of Solar thermal, Solar PV and Solar radiation modeling has been carried out by various researches (Yadav and Sudhakar, 2015; Shukla et al., 2015a-b ; Shukla et al., 2016b). The present paper's purpose is to determine results obtained from the monitoring of a PV installation in Tangier, Morocco during a period of one year, starting from January 2015 to December 2015. The PV system is characterized with different performance parameters including: Reference yield, ambient temperature, final yield, system losses, capacity factor and performance ratio then to offer baseline information for energy and economic evaluation of the polycrystalline PV produced electricity.

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Table 1
PV modules specifications.

PV module	Specifications
STC power rating	250 Wp
Peak efficiency	15.2%
Number of cells	60
Vmp	31.4 V
Isc	8.77 A
Imp	7.97 A
Voc	37.5 V
Maximum system voltage	600 V

2. Description of photovoltaic installation

The PV power plant was installed on the rooftop of a state building in Tangier, Morocco. The grid connected park consists of 20 polycrystalline silicon solar modules 250 Wp each one and comprised 60 solar cells with an overall installed capacity of 5 kWp, covering a total surface area of 30 m^2 and inclined at 32° toward the south. The PV modules are arranged in 2 parallel strings, with 10 modules in each string and connected to a 5000 W Sunny Boy SB5000TL inverter feeding directly into the grid. Its efficiency is 96% in the worst case conditions. At the outlet of the inverter there is a single phase alternating voltage of 230 V, 50 Hz and at the front there is a display to read out the voltage and DC current values, output power, daily and total amounts of electrical energy generated by the solar PV modules. Fig. 1 shows a schematic block circuit diagram of the PV system. Technical data of the PV module are given in Table 1.

3. PV power plant characteristic parameters

The final yield (Yf), array yield (Ya), reference yield (Yr), energy efficiency (η), and the total energy generated by the PV system E_{AC}, were used in accordance with the IEC 61724 standard to evaluate the performance of a grid connected PV installation.

Array yield

The array yield (Ya) is the ratio of the energy output delivered by the PV modules over a defined period by the PV rated power and is given as (Sharma and Chandel, 2013):

$$Y_a = \frac{E_{DC}}{P_{PV},\, rated}. \tag{1}$$

The daily array yield ($Y_{a,d}$) and the monthly average array yield ($Y_{a,m}$) are given as (Ayompe et al., 2011):

$$Y_{a,d} = \frac{E_{DC,d}}{P_{PV},\, rated} \tag{2}$$

$$Y_{a,m} = \frac{1}{N}\sum_{d=1}^{N} Y_{a,d} \tag{3}$$

where E_{DC} is the DC energy output delivered by the PV modules (kWh).

Final yield

The final yield can be defined as the total AC energy during a specific period divided by the rated power of the installation. It is an important parameter for our system performance comparison with other existing PV systems. The final yield is given as (Al-Otaibi, 2015; Kymakis et al., 2009; Mondol et al., 2005)

$$Y_{f,d} = \frac{E_{AC}}{P_{pv},\, rated} \tag{4}$$

$$Y_{f,m} = \frac{1}{N}\sum_{d=1}^{N} E_{AC,d} \tag{5}$$

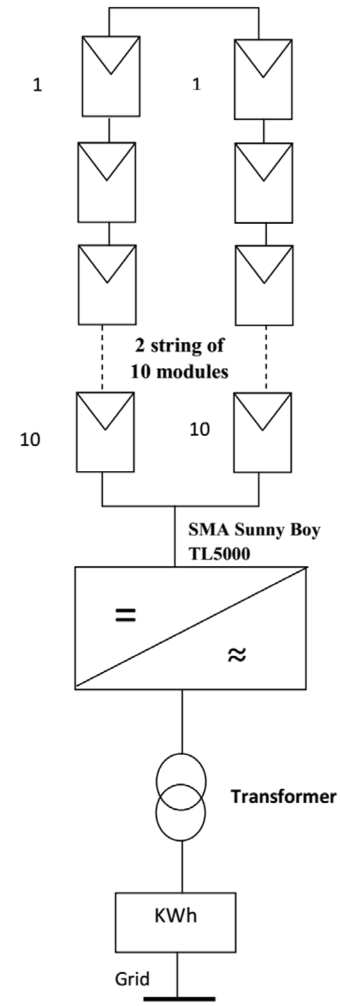

Fig. 1. Schematic block circuit diagram of the PV system.

where E_{AC} is the energy at the output of the PV installation inverter and is given by (Ayompe et al., 2011)

$$E_{AC,m} = \sum_{d=1}^{N} E_{AC,d}. \tag{6}$$

With $E_{AC,m}$ being the monthly AC energy output and N the number of days in a month.

Reference yield

The reference yield is the ratio of the global solar radiation Ht (kWh/m^2) and the PV's reference irradiance. The reference yield is given as (Kymakis et al., 2009):

$$Y_r = \frac{H_t(\mathrm{kWh/m^2})}{H_R} \tag{7}$$

where, $H_R = 1\ \mathrm{kW/m^2}$.

Performance ratio

The performance ratio (PR) is depending on the total losses in the system resulting from conversion operations made by different components as PV modules, inverters and cables. Weather conditions as ambient temperature are also impacting factors.

The performance ratio (PR) can be defined as the final yield divided by the reference yield and is given as (Shiva kumar and Sudhakar, 2015; Chaiyant et al., 2009):

$$PR = \frac{Y_f}{Y_r}.$$