From76.6 to 80.1 %; PV-System Performance-Ratio in Mexico City

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Abstract

During 2017 and 2018, performance-ratio (PR) of the 60 kWp photovoltaic-system (PVS) was evaluated at the north location of Mexico City. The solar irradiation was detected using the thermopile-pyranometer installed in a plane of array (POA) of PV panels. The average daily generated energy for 2017 was 261.65 kWh/day, with a PR of 80.1%, while in 2018, the generated energy was 254.79 kWh/day with a PR of 76.6%. The day-time average PV module temperature during 2017 was 34.8 ºC and 35.6 ºC for 2018. In addition, and during February 2017, the PVS resulted with a poor PR due to the soiled PV-array, but starting March, due to an abundant rain-fall, the array was cleaned. Then, the cleaned array showed an about 26% increment in energy generation.

Keywords: — PV system performance, solar irradiation measurement, pyranometer, ambient temperature and wind dependency.

1. Introduction

Solar photovoltaic systems (PVS) have achieved as one of the cheapest and environmental-friendly alternative-energy sources in several countries. The PVS is silent, safe and reliable with a low-maintenance cost without any on-site pollutant emissions. The use of utility grid-tied PVS are increasing rapidly in the world and the estimated global PV market grew to over 80 GW annually. The global renewable energy introduction in 2040 as a "new policy scenario", the total volume forecast is 6,504 GW including 2,540 GW of solar PV power (RTS Japan, 2018). Up to 2010, the 85% of the installed PV capacities in Mexico were off-grid and since them, the number of grid-tied systems have grown fastest after the grid-connection was allowed in 2007.

The Mexican energy reform-implementation is expected to have a strong impact for the development of the PV market (CREARA, 2015). The International Energy Agency (IEA) cited the country's energy-reform as a major factor in the significant projected increase in renewables capacity. In doing so, it would open Mexico's energy sector to new players investment and new technology. Mexico is set to hit between 30-40 GW of solar PV installations by 2040 under various scenarios projected by the IEA (Kenning, Tom, 2016). At the third long-term power auction in Mexico, which was held in November 2017, PV-solar achieved a world record average price of US$20.57 per MWh, and around 6 GW of solar power was contracted. The general director of the National Center for Energy Control

doi:10.18086/swc.2019.16.05 Available at http://proceedings.ises.org

Fig. 1. The upper figure shows a section of PV module array and the annemometer installed in CINVESTAV, Mexico City. The lower pictures shows; the thermopile-pyranometer MS-602 arrenged at POA (lefft) and right, the horizontal pyronometer.

(CENACE) said it is estimated an additional 13 GW of generation and 38 TWh of clean energy will be connected to the Mexican grid by 2021 (Bellini Emiliano, 2018).

The present study evaluates the generated electricity from a 60kw PV system in terms of performance-ratio, taking in account Mexico City´s weather conditions. The PR was evaluated based upon thermopile-pyranometer to monitor solar irradiance, which was installed in a plane of array (POA) as Fig. 1. We analyze and discuss the average daily generated energy, the PV module temperature during the period of two years for the PR-measurements. In the present job, also the PV system performance ratio (PR) was compared from previous and after rain fall on a soiled PV-module array.

2. System Description

The 60 kWp PVS which consists of 240 single-crystalline silicon PV modules of 250 Wp each. The detailed description of PVS can be found elsewhere (Urbano, J. A., et al. 2014). The PV module-arrays were installed in the Institution´s building on the fifth-floor roof and fixed on aluminum framed structures oriented 30° East-faced from the geographical South. The system is located at 19° 30' 38" N, 99° 07' 50" W, and the module arrays were installed at the latitude angle of 20°, the plane of array (POA). The PV module arrays are subdivided (the electric-connections) into five sections and is connected to the corresponding 5-inverters; Fronius model IG-Plus-V 11.4-3

DELTA. The solar irradiance was measured using second-class thermopile-pyranometer EKO MS-602, and Kipp & Zonen CMP-3 installed in the same PV-module POA. Also, in a site, a thermopile-pyranometer Yankee Environmental Systems; Model TSP-1, was installed to monitor the global horizontal solar irradiance as Fig. 1 (right lower-side). The horizontal irradiance were measured only to compare respecto to the pyranometers in POA.

3. Monitoring Performance and losses

Data monitoring is one of the important requirements for diverse PVS. Without an accurate data monitoring, the PVS performances cannot reliably be compared to the generated energy. An effective data monitoring not only helps to identify system performance, but it also helps to resolve possible troubles (Southern Energy, 2018). The Fronius inverter system integrates all the monitored data every 5 minutes and logged it, and the solar irradiance by the pyranometers were monitored using Campbell CR300 data logger every minute.

Three of the IEC standard 61724 performance parameters have used to define the overall system performance with respect to the energy production, the solar resource and overall effect of system losses (Marion, B. et.al. 2005).

The performance ratio (PR) or so-called “quality factor”, is the ratio between actual yield (i.e. annual production of electricity delivered at AC) and the ideal yield:

$$PR = \frac{\mathrm{Re}\,al \cdot Yield\,(AC)}{Ideal \cdot Yield\,(DC)}$$

In the present job, the measurements were done form January 1, 2017 to December 31, 2018, during 24 consecutive months. Under normal PV system operating conditions, the measured data contains deviations caused by malfunctions such as string connection defects, shadings, soiling and module or inverter malfunctions that influence the measured performance of a PV system. Sometimes it is intuitive to think in terms of energy losses that occur at every step of the way, rather than component efficiencies. Both concepts are related as: $Losses = 1 - Efficiency$

4. System General Performance

Figure 2 shows the monitored PV system for both, 2017 and 2018, and the detected daily/month averaged solar irradiance in the POA through thermopile-pyranometer MS-602 in 2017 and CMP-3 in 2018.

The average daily solar irradiance was 328.29kWh or 5.47 peak-hour for 2017, and 333.45kW or 5.56 peak-hour for 2018. Despite greater averaged peak-hour detected in the year 2018, the generated electric energy was less than a 2017. This is basically due to the Performance Ratio PR, where in 2017 was 80.1%, but in 2018 it was only 76.6%.

Figure 3 shows the day-time monitored monthly-averaged PV module temperature, ambient temperature and the wind velocity for 2017 and 2018. These average values were extracted from day-time, i.e. from Sun rise to Sun set time.

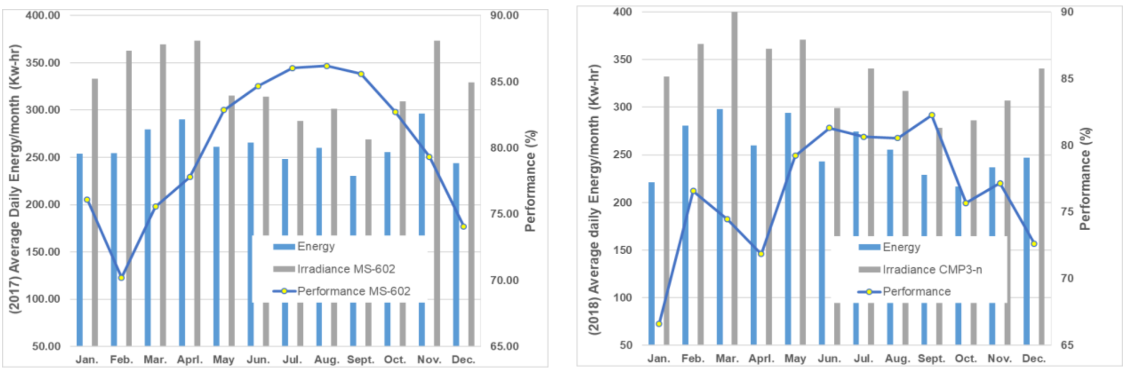

Fig. 2. Measured solar irradiance at the POA by thermopile-pyranometer, the daily averaged PV generated energy and the performance ratio for 2017 (upper) and 2018 (lower).

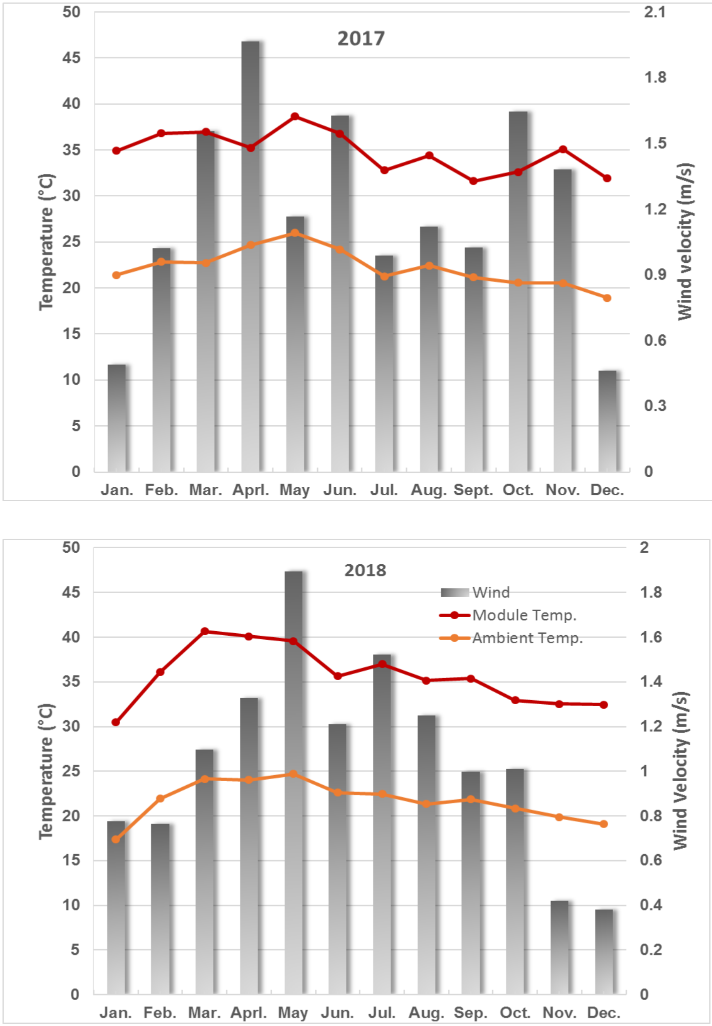

Fig. 3. A day-time monitored, monthly-averaged PV module temperature, ambient temperature and wind velocity for 2017 (upper) and 2018 (lower).

The averaged PV module temperature in 2017 was 34.8 ºC, while in 2018 was 35.6 ºC. This small temperature difference could have influenced, which caused the less PR during 2018.

5. Performance Diagnosis

The monitored PR differences for 2017 and 2018 was suspected to be due to the PV-module temperatures. The detected maximum average temperature for the hottest months was May 2017 and March for 2018, with 38 ºC and 41ºC, respectively. The PV-array worked at the temperatures greater than 35ºC during 5 months in 2017, while in 2018, it operated for 7 months. The highest PV-panel temperature operation was in May 2017, achieving temperatures from 50 to 64°C, and 45 to 63°C during June. But in 2018, the maximum temperature was in March which varied from 58 to 68°C while in April 2018, 56 to 74°C. It means, the highest temperature was both in 2018.

In the other hand, after starting 2017 and during two-months, the PV array got dirty due to the natural soiling. However, at the night time of March 3rd, it was rained intensively, and all the PV array was cleaned up substantially. The sudden PR increment due to the elimination of the soil, was from 65.97% to 82.13%. Fig. 4 shows the soiled PV-array from the different view-angles and specifically close-up to the PV-module, previous and after the rain.

Fig. 4. Aspects of dust accumulation on the PV array; before (lower-left) and after (lower-right) rain fall. Both, the upper image shows the part of soiled PV-module array wich is fixed at the angle of 20° from the horizontal-plane. In a lower-left also shows the soiled module with one of the cleaned solar cells to distinguish the accumulated soil.

These differences were calculated based upon the average data for three days previous and three days after the rain. It means, almost within the same week-based environmental conditions as temperatures, wind velocities. From the experimental values, the soiling effect reduced about 20 % of the energy which should have to be generated.

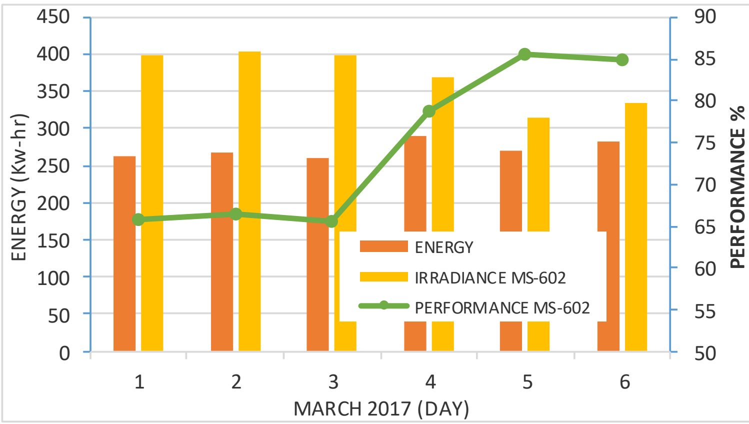

Fig. 5. Daily-measured PV generated energy and solar irradiation at the POA from March 1st to 6th, 2017. At the night-time of March 3rd, the rain fallen, which washed up taking away the accumulated dust on the PV-array.

6. Discussion

From the above calculated 60 kWp PVS performance ratio during 24 consecutive months, the PR differences of 80.1% (2017) and 76.6% (2018), might be influenced due to the average PV module temperature differences of 34.8 ºC and 35.6 ºC for 2017 and 2018, respectively. The temperature coefficient TC of the single-crystalline silicon solar cells influences for the energy conversion. The indicated specification, the PV-module TC is about 0.47 % of power reduction for every one degree-Celsius (1°C) of temperature increment.

For the PV system monitored during 2017, and for the initial months of this year, the PV-array was got dirty (January to February) due to the natural atmospheric soiling. Fig. 5 shows a daily energy production in kW-h for six consecutive days starting in March 1st. Also, it is shown the corresponding solar irradiance and the calculated PR. As can see, the PR increases suddenly since March 4th, which was resulted from the naturally-cleaned PV-array by the rain fall at night-time of March 3rd. The calculated average-PR during the three-days prior to rain fall, was 65.88 %, while the 3-days average-PR after the rain was 83.02%. It is confident that the six initial days on March, no apparent change for the natural ambient conditions were observed. i.e. no connoted differences in PV-module temperatures and or differences in an average wind velocity. Another observation is that the solar irradiance during the three initial days are almost the same. Even though, the irradiance from 4th-day was reduced and up to 6th day, but the generated energy was maintained at almost the same magnitude during these last three-days. So, it was apparent the soiling effect previous and after to rain-fall. The dust or the soiling effect on PV-array, can provoke a great energy-loss as occurred in the present experimental evaluation.

7. Conclusions

It was evaluated the performance ratio of a grid-connected 60 kWp photovoltaic system at the north Mexico City during 2017 and 2018. The daily produced energy was analyzed and interpreted together with the incident solar irradiation which was measured by standard thermopile-pyranometer. The obtained performance ratio was 80.1% and 76.6% for 2017 and 2018, respectively. The corresponding daily average generated energy was 261.65 kWh/day and 254.79 kWh/day for the corresponding years, respectively. One of the most possible PR differences amongst the years was the PV-module operating temperature. It means that the direct incidence of solar irradiance on PV modules, it increases the temperature above 60 °C achieving up to 74°C as in April 2018, causing lower PR. In addition, the soiling on PV module causes great PR reduction of about 20% from the expected energy generation.

8. Acknowledgements

We would acknowledge Mr. Martín Jiménez, Dr. Jaime Vega and Mr. Miguel Galván for their kind support to overcome logistics and to facilitate PV-system measurements.

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