PV production assessment through real data of a microgrid pilot facility

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Abstract: - Nowadays renewable energy sources are more and more used in microgrid applications; among them the photovoltaic technology has an important role due to its possible exploitation in many conditions and locations. However, the solar source is characterized by unpredictability and an intermittent behavior which must be faced using accurate forecasting tools. In the present paper a comparison between the experimental data coming from two PV plants installed within a microgrid in the north of Italy and the ones obtained through the PVGIS tool is described; the main performance parameters of the aforesaid PV plants as well as statistical indicators resulting from the comparison are shown.

Key-Words: - Solar irradiance, PV production, microgrid, data analysis, pilot facility, university campus

1 Introduction

Since the early years of the last century the world has assisted to a huge exploitation of renewables sources mainly due to a decrease of costs in their manufacturing process and to an increase of public opinion attention on sustainability aspects [1]-[4]. More specifically, the Italian energy mix has fundamentally changed due to a massive introduction of renewables sources from 2010 onwards [5].

Renewable energy sources, such as solar and wind, have two major drawbacks: they are intermittent and unpredictable, leading to a substantial unreliability [6],[7] and this is even more empathized if renewable generation is installed in a microgrid context [8],[9]. To reduce as much as possible these aspects, several tools can be used in order to foreseen their behaviors [10],[11]. Focusing on PV production forecast, the two main approaches are based on historical data coming either from high quality sensors set on the specific location considered or from geostationary meteorological satellite data [12]. This second approach is nowadays one of the most used due to two main reasons: solar radiation data are available for wide spread areas covered by satellite images and for long time series, up to more than thirty years. The disadvantages of this approach are due to the fact that the solar radiation at ground level must be calculated using mathematical algorithms [13]which receive as input also others data such as the atmospheric water vapor, aerosol and ozone [14]. On the other hand, ground based sensors should fulfill a precise set of conditions in order to be effective. Measurements should be performed with a proper frequency while sensors should be calibrated and cleaned regularly [15]. Finally, a third approach, in order to evaluate solar irradiance, derives from the applications of international or national standards.

In this paper results coming from the application of all the previous approaches to two PV plants installed within the Smart Polygeneration Microgrid of the University of Genoa Savona Campus [16]-[18] are reported and compared in order to assess differences and similarities. In particular, data from the PVGIS database are compared with real data gathered through the SCADA system of the microgrid. Moreover, a further comparison is made with the results obtained applying the Italian Standard UNI 10349-3:2016.

The paper is organized as follows. In Section 2 the examined PV plants are described while in Section 3 the applied methodology is reported. In Section 4 the main results of the study are discussed whereas in Section 5 conclusive remarks are highlighted.

2 The PV plant facility

The analysis reported in the present paper is focused on two PV plants connected to the Smart Polygeneration Microgrid at the Savona Campus of the Genoa University shown in the aerial photo reported in Fig. 1 [19],[20]. The microgrid constitutes a pilot facility where research and development activities are carried out in the sustainable energy sector. The microgrid is a LV network which provides energy to the Campus buildings. It is a hybrid polygeneration system, both thermal and electrical, characterized by the presence of cogeneration microturbines, absorption chillers, boilers, PV plants, electrochemical storage batteries and electric vehicle charging infrastructures. All the aforesaid plants are daily operated by an Energy Management Systems whose aim is that of minimizing costs given by the sum of electricity costs (for the amount of energy bought from the public distribution network to which the microgrid is connected) and natural gas costs (for the operation of microturbines and boilers).

Fig. 1 The Savona Campus of Genoa University

As far as the electricity production from the solar source is concerned, at the Savona Campus there are three PV plants: two of them (called PV1a and PV1b) are installed on the roof of Delfino Building, whereas the third one (called PV2) is on the roof of the Smart Energy Building, a new building connected to the Smart Polygeneration Microgrid as energy prosumer [21]. The main rated data of PV1a and PV1b plants, object of the present study, are reported in Table 1, whereas the performance of PV panels at STC conditions is highlighted in Table 2. On the other hand, PV2 plant, which is out of the scope of the present study, has a rated power of 21.25 kW.

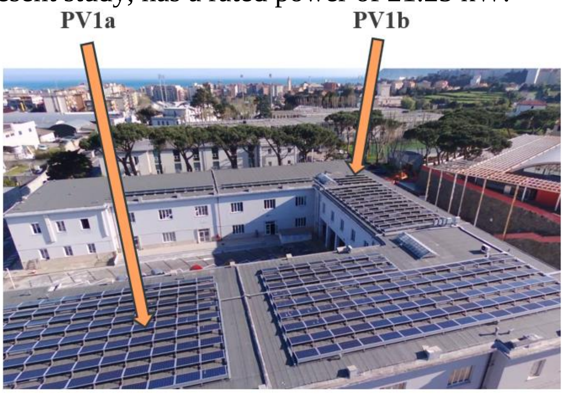

Fig. 2 The PV plants

Table. 1 Rated data of PV plants

	PV1a	PV1b
Peak power [kW]	80.64	15
No. of panels [-]	336	60
Active area [m^2]	490.6	91.3
Azimuth [°]	-30	-30
Tilt [°]	15	15

Table. 2 Performance data of PV panels at STC - Standard Test Conditions

	PV1a	PV1b
Peak power [W]	240	250
Maximum power voltage [V]	29.06	29.81
Maximum power current [A]	8.36	8.46
Open circuit voltage [V]	36.64	37.45
Short circuit current [A]	8.93	9
Fill factor [%]	74.3	74.8
Efficiency [%]	14.46	15.06

3 The methodology

The main aim of the present study is that of evaluating PV plant data acquired at the Savona Campus. The annual operation of PV1a and PV1b plants has been analyzed in detail referring to year 2016. Through the SCADA system of the microgrid it has been possible to collect solar irradiance and PV production data for all the days of the year with a sampling time of one minute. The aforesaid data have been elaborated in order to identify a typical average day for each month of the year.

The main key indicators which have been evaluated are:

- solar irradiance on PV panels, measured in W/m^2 every minute for all the days of the year;
- amount of solar energy captured by PV panels per day, measured in kWh/day;
- PV power output profile, measured in kW, characterized by a value every minute for all the days of the year;
- PV daily energy production, measured in kWh/day;
- PV plant efficiency given by the ratio between the electricity production and the energy amount coming from the sun and captured by PV panels.

The aforementioned parameters are evaluated for each day of the year using real data from the SCADA of the microgrid. On the other hand, PVGIS software has been used to evaluate the same parameters for each typical day representing each month of the year. Finally, the Italian Standard UNI 10349-3:2016 has been used to evaluate solar energy monthly values.

4 Results analysis

In Fig. 3 solar irradiance data are shown referring to four different typical days, one for each season. In particular, the plots reported in Fig. 3 present both real data, derived as average values of measurements collected at the Savona Campus, and values obtained through PVGIS-CMSAF model [22] applied setting the appropriate input referring to the site where PV1a and PV1b plants are installed.

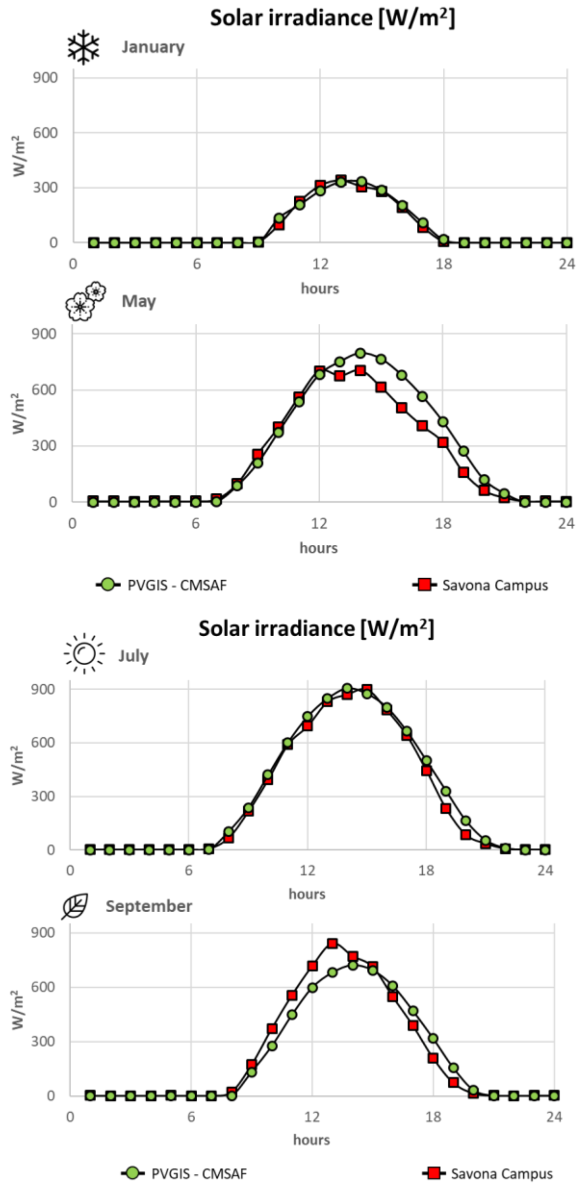

Fig. 3 Solar irradiance profiles: PVGIS vs real measurements

It is possible to appreciate a very good agreement between real data and PVGIS values, above all for the winter and summer months. On the other hand, higher differences, but always very low, occur for the spring and fall months. This is due to the fact that in the aforesaid months it is more difficult to accurately evaluate the solar irradiance since in these periods weather conditions in North of Italy change very rapidly during the day and from one day to the following one.

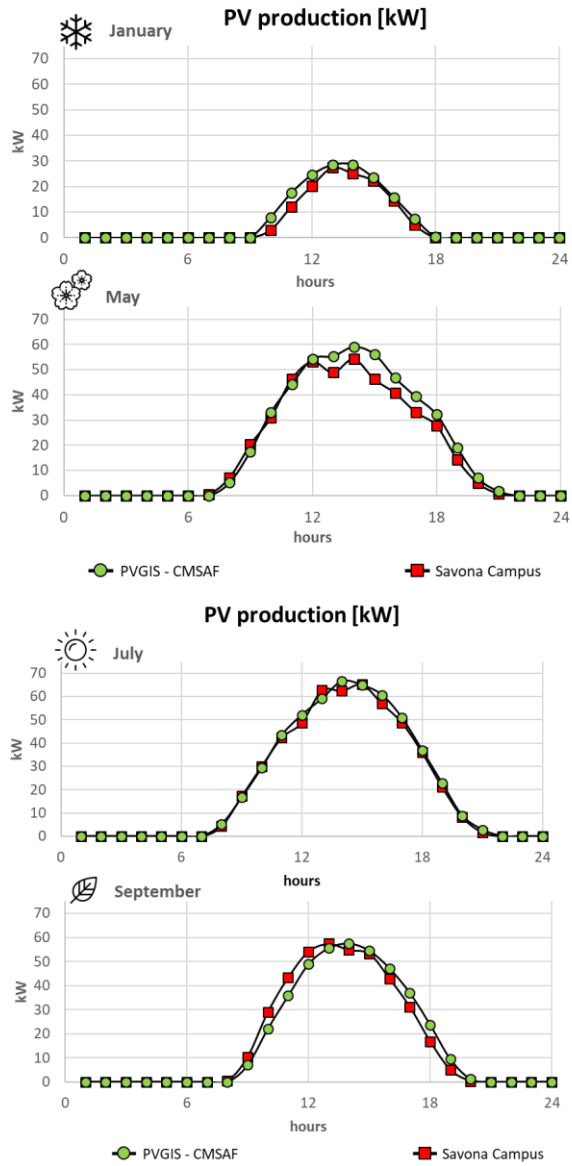

Fig. 4 PV production profiles: PVGIS vs real measurements

In Fig. 4 the PV production profiles for the same months are reported. As can be seen from the plots, similar conclusions as those derived for the irradiance profiles can be made: winter and summer months tend to be the ones showing the best accordance between experimental and PVGIS profiles.

The values of the average daily measured efficiency of PV plants are compared with the ones derived by PVGIS data in Fig. 5. As can be seen the efficiency monitored values are always lower than the average rated efficiency of the two plants, depicted with a dot line. Moreover, during the spring and fall season a better performance is highlighted mainly due to air temperature close to the STC conditions. The best accordance between the two set of data is reached during summer months.

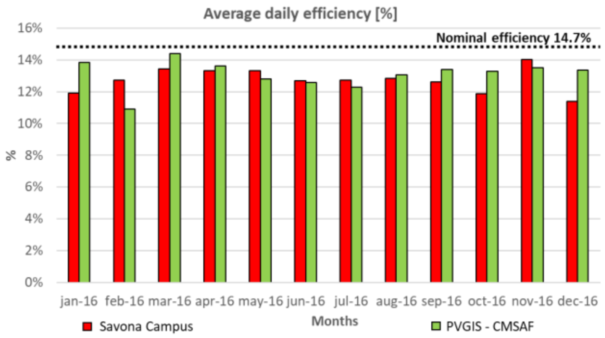

Fig. 5 PV efficiency values: PVGIS vs real measurements

In Fig. 6 the average daily PV production values are plotted together with the error between PVGIS and experimental measurements. From March to September the error is acceptable and below 10%. On the other hand, higher discrepancies arise in the remaining months.

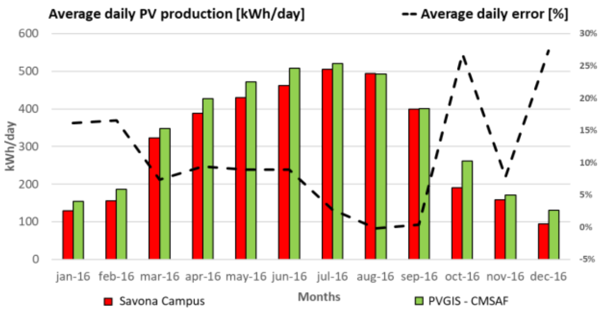

Fig. 6 PV average daily production for each month: PVGIS vs real measurements

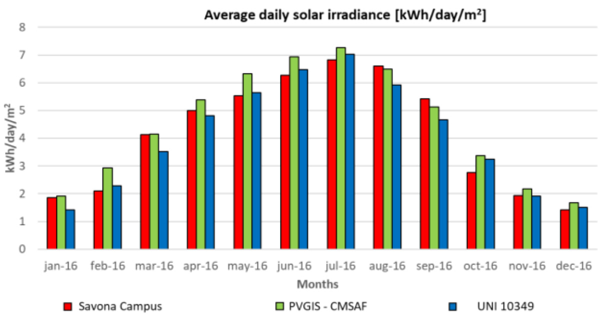

Fig. 7 Average daily solar energy values for each month: PVGIS vs real measurements vs UNI10349-3:2016

Finally, in Fig. 7 the values of average solar energy per squared meter of PV panel, calculated using UNI10349-3:2016 Italian Standard are compared with PVGIS and experimental measured values. PVGIS values tend to be almost always higher than the other two, while results coming from the Italian Standard are in most of the cases more conservative.

4 Conclusion

The importance of microgrid monitoring and data analysis has been highlighted, focusing the attention on PV technology. A comparison between different sets of data, coming from different approaches (experimental campaign, software tools, Standards), have been carried out for PV plant installations located in the north of Italy. Future developments could involve the application of the proposed methodology to other sites, considering different PV panel orientation and reanalysis-based solar irradiation data sets.

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