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Review

Monitoring and checking of performance in photovoltaic plants: A tool for design, installation and maintenance of grid-connected systems

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ABSTRACT

This work represents the Photovoltaic section of the European Project PERSIL, which includes also the study of solar thermal plants. The activity is twofold: the results of 1-year monitoring and checking of thirteen PV systems; the consequent guidelines for the design, installation and maintenance of grid connected PV systems. For accurate estimation of the energy production a two-year analysis of solar radiation has been conducted on the basis of pyranometer measurements in all the Project locations. The checking of energy performance has been carried out by a suitable improvement of a conventional method, that includes the assessment of the energy availability. The corresponding results are excellent for three PV plants, whereas they are strongly negative for five old PV plants which exhibit poor availability (62–78%). The remaining plants behave with acceptable performance ratios (0.65–0.78). Within the guidelines for design, the optimum coupling array/inverter and the related protections have been discussed in detail. About the guidelines for installation, the PV module/inverter cooling, the electric cables and enclosures have been dealt with. Then, concerning the guidelines for maintenance, the main items are the energy production assessment, the glass dirt checking and the maintenance of motors in sun-trackers. Finally, all these guidelines help to maximize the energy availability.

1. Introduction

Nowadays, in Germany, Italy and France various feed-in tariffs are available for PhotoVoltaic (PV) systems and the maximization of productivity is of paramount importance. This goal can be achieved by many solutions, as discussed in the paper [1]. The PERSIL (Solar Performance and Local Industry) [2] was a European project which involved public and industrial organizations in Italy, Environment Park, Province of Turin, Turin Industry Association, and in France, Departments of Savoie and Hautes-Alpes. This project (2009–2011) was thought to achieve the following goals:

- to collect performance data on Solar Thermal and PV plants installed in the local area;
- to enhance the technology transfer between the two Countries;
- to promote the technology innovation through the creation of test sites from the solar technology viewpoint;
- finally, more in general, to boost the collaboration between Research Centres and Industry.

In this framework the "Politecnico di Torino" University was called by the Province of Turin to perform the monitoring activity of thirteen different PV plants installed in its territory [3], during one year period, and, at the conclusion, to define the reference guidelines for the PV designers, installers, Operation and Maintenance (O&M) workers [4]. The PV plants are mainly installed on public schools, but also a test facility, an apartment block, a climbing centre and an industrial site are taken into account. The choice criteria were, obviously, accurate measurements from data-logger, different PV module technology, rated power and kind of installation. The paper is constituted by various sections, in which a study of the two-year radiation in the project locations, the results of monitoring/checking of the thirteen PV systems with the assessment of the energy availability, and the guidelines for design, installation, O&M are discussed.

2. 2009–2010 radiation in project locations

Due to the tutorial goal for PV designers and installers in the area of Province of Turin, updated irradiation data from a wide number of locations have been collected and processed, since the previously available data were 20-year old.

Within the period 2009–2010, ten meteorological stations of the local Agency for Environmental Protection (ARPA-Piedmont),

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equipped with pyranometers for the measurement of the horizontal global irradiation, have been considered from the viewpoint of the energy production in the Province of Turin. Its corresponding surface is about 6800 km^2 with maximum distances among the locations of less than 100 km: the distribution of the 10 sites (Fig. 1), hence, is representative of the climatology in the Province of Turin.

The measurements, performed on the horizontal plane, have been transferred on a tilted plane typical for the building integration (pitched roof towards South with 25° angle). The procedure for the data correction can be carried out by multiple methods, as for example the one proposed in the Italian standard [5] or in other documents [6].

The selected weather stations have been installed in different locations, starting from two in the city of Turin "Via Consolata" (downtown, altitude 290 m a.s.l.) and "Via Reiss Romoli" (outskirts, 270 m a.s.l.). In the peripheral zone three stations have been considered: Avigliana (340 m a.s.l.) towards West; Pino Torinese (600 m a.s.l.) towards East; Bauducchi (230 m a.s.l.) towards South. Far from Turin, in the Western territory of "Susa Valley" two stations have been chosen: Bardonecchia (location Pranudin 2000 m a.s.l.) on a mountain; Borgone at a lower altitude (400 m a.s.l.). Far from Turin, in the Northern "Canavese" zone, two other stations have been included: Caselle (300 m a.s.l.) and Candia (230 m a.s.l.). Finally, the station of Carmagnola (230 m a.s.l.) has been considered as representative of the Southern zone of the Province of Turin.

From the readings of the 2009–2010 data (Table 1a), it is clear that the year 2010 for the radiation has been less profitable than the year 2009, in fact eight out of the ten sites exhibit reductions within 5%–9% with higher frequency in the range of 6%–7%. Only in the stations of Carmagnola and Turin (downtown) the variations are negligible or within the uncertainty of measurements (±3%).

The remarkable reduction of radiation in 2010 is essentially concentrated in February, May, June and October with variations up to 30%. It is worth noting that in 2010 the more impressive decrements in kWh/m^2 are in May and June, while if the percentage decreases are considered, they are found in February and October. Obviously, between the two types of decrements, the most important ones from the productivity viewpoint are those expressed in kWh/m^2. On the other hand, in all the meteorological stations a huge increment has been recorded in April with variations always higher than 30% on the tilted plane.

As could be expected due to the remarkable altitude without important obstructions, the station of Bardonecchia has been characterized by the best radiation (above 1550 kWh/m^2 on the horizontal plane and about 1850 kWh/m^2 on the selected tilted plane in 2009). However, the site of the lower Susa valley (Borgone) has been limited by the shades generated by the surrounding mountains and has a poor ranking. Also the stations of Caselle, Pino Torinese e Bauducchi in the year 2009 show particularly favourable results for the horizontal radiation per annum (above 1400 kWh/m^2): if this value is transferred to the tilted plane of 25° towards South, the radiation exceeds 1600 kWh/m^2. In the station Bauducchi the figures of radiation both on the horizontal and tilted planes are very similar to the station Pino Torinese (explained by the geographical closeness).

The Carmagnola station exhibits a very particular climate, since with the same value in the two-year period the radiation of 2009 yields the number nine and the radiation of 2010 achieves the second place in the ranking. If we examine the two stations of city of Turin (Via Consolata and Via Reiss Romoli), the most important thing is that in 2009 the station located in outskirts (Reiss Romoli) show a higher radiation than the downtown station (Consolata), whereas in 2010 the values of radiation are practically equivalent and quite reduced. In particular, in 2009 the measurements on the horizontal plane provide above 1350 kWh/m^2 in outskirts and below 1300 kWh/m^2 in downtown, but in 2010 both the stations

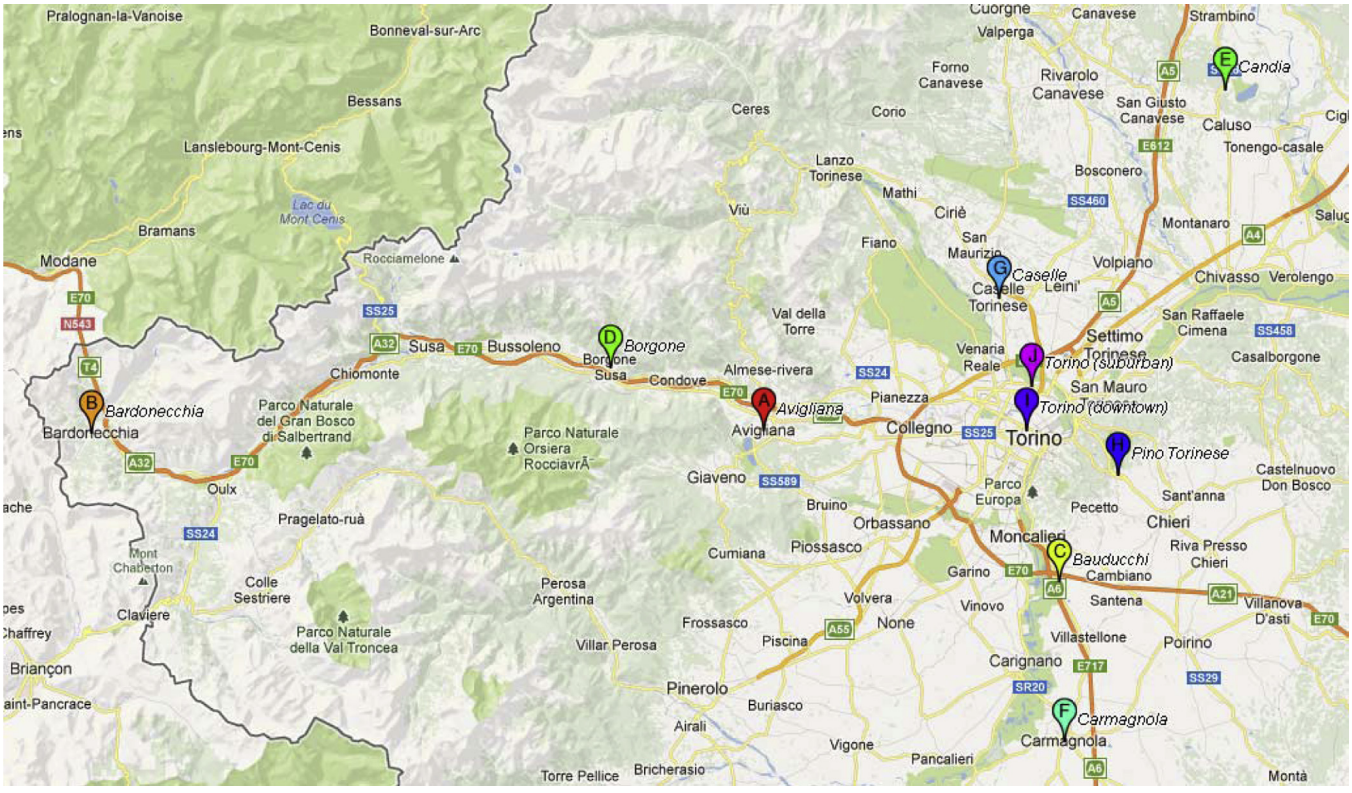

Fig. 1. Locations of the 10 ARPA-Piedmont meteorological stations.