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Optimal arrangement of photovoltaic panels coupled with electrochemical storages

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Abstract

The ideal orientation of PV panels is a widely debated topic. However, the relevant decrease in photovoltaic (PV) system costs and their consequent rapid spread are moving the attention from the achievement of the maximum areal electricity generation to a PV generation profile in agreement with building energy needs. In fact, national subsidies are going to promote electricity self-consumption in PV systems, in order to avoid imbalances in the grid, already relevant at the present market status, i.e. with a still low share of PV in national yearly electricity generation. For all of these reasons, in the next years PV systems will not be designed just to generate the amount of electricity as high as possible, but even to limit electricity exportation from the building perspective. Thus, orientations and PV configurations with lower electricity generation might be preferred, if they allow the user to achieve a higher degree of electricity self-consumption. Of course, in the achievement of this aim, the PV systems will be supported by electrochemical storages as well. This paper shows the analysis of various configurations of PV systems supported by electrochemical storages, aiming at the increase of electricity self-consumption, considering two Italian climates: Venice, in the northeast (Latitude: 45° 26' N), and Trapani, in southern Italy (Latitude: 38° 01' N). As regards the detailed simulation of the PV system, the analysis took advantage of program Ener_Lux, while the building energy system was simulated via *EnergyPlus*.

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Keywords: photovoltaics; zero energy buildings; electrochemical storage

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1. Introduction

For each site and climate, the ideal combination of photovoltaic (PV) panels' azimuth and tilt angles can be defined, so that the power generation throughout the year is maximized. However, in many contemporary projects of sustainable buildings [1, 2] the surface occupied by the photovoltaic cells is composed of subsurfaces with different orientations and slopes. In the case of re-use of existing buildings, the reason for this choice generally consists in the need for the exploitation of all the available roof surface, whereas new buildings may host PV panels in different azimuth and tilt angles in order to generate electricity with continuity during the day, by taking advantage of surfaces facing the sun in different periods of the day, thus with greater match with the demand time profile. In the latter case, the final purpose would consist in the maximization of the building's autarchy degree, even if at the cost of larger PV panel surface and hence of higher installation costs. The question that arises is the following one: at what extent all of these different solutions are less convenient when compared with a system in which all the PV cells are disposed in accordance with the "ideal" arrangement? This work tries to answer this question by comparing different configurations of the PV system by means of computer simulations. Simulations are a well-established means in the assessment of photovoltaic energy generation [3]. At first, the ideal PV panels arrangement was defined for two Italian sites: Venice, in the northeast (Latitude: 45° 26' N, 2345 Heating Degree Days), and Trapani, in southern Italy (Latitude: 38° 01' N, 810 Heating Degree Days). The consequent PV generation was compared with the ones characterizing other configurations, derived from actual projects. Then a case study was considered, consisting in a residential building typical of the Italian suburbs. Two possible orientations of the building's main axis and the consequent possible PV panels arrangements were considered and compared from different points of view: electricity generation and life cycle assessment (LCA) of primary energy.

In this research activity, the option of battery-supported PV systems is considered as well. Batteries are acknowledged as the most promising means for the widespread integration of renewable energy sources into smart grids [4]. Their application in residential systems is currently limited because of costs, but many authors expect relevant cost reductions, as shown in [5, 6]. Battery sizing is an important factor in the assessment of battery–supported PV systems, as regards both profitability and interaction with the national grid. Weniger et al. [7] used a cost-optimal approach for the achievement of the most convenient PV battery sizing. Moreover, they acknowledged that the orientation of the PV generator will be of smaller relevance in the future PV systems, and the synchronicity of loads and generated electricity will gain much more importance, probably implying optimal PV system size to shrink down to smaller systems with high self-consumption rates. Von Appen et al. [8] showed that, depending on the control strategy, battery systems are able to significantly reduce PV peaks, especially when active power limits for PV feed-in are present. Moshovel et al. [9] developed a management strategy based on persistence forecasts of solar radiation and household load demand, proving that a storage system management based on forecasts has a significantly higher potential to relieve the grid than usual systems maximizing just self-consumption, showing low losses in self-consumption share, equal to about 5 %. Santos et al. [10] focused on the influence of the electricity storage on the grid interaction, by analyzing different roles for the storage utilization, with the objective of optimizing self-consumption and mitigating the peak power flows from and to the grid and evaluating the benefits from a local and grid global perspective. The results showed that the effect of the simulated storage capacity is strongly influenced by the sizing and operating strategy. Similar conclusions are given by Ueda et al. [11], showing how battery proper operation for grid-connected residential PV systems may relieve the over voltage problem at the power distribution line.

Many different kinds of technologies are applied in battery-supported PV systems. However, the most usual ones consist in Lead Acid and Li-Ion batteries. Lead acid are the most common batteries in PV systems because of their apparent low cost, wide availability, and long lifetime. However, they can undergo limited depth of discharge, thus requiring capacity oversizing and consequently increasing actual costs. On the other side, Li-Ion batteries are gaining popularity because of the technical progress and market expansion which are offering high energy density and long life expectations, as well as an increasing profitability. In fact, Li-Ion batteries are applied in another promising market, i.e. zero emission vehicles, thus increasing the large scale effect in production. In fact, the prices contained in [5] for Li-ion battery packs installed and aimed at utility-scale applications are around 550 US$/kWh in 2014, with a forecast of 200 US$/kWh in 2020. As a first reference, in the very next years, battery packs are expected to enter the market with prices between 350 US$/kWh and 430 US$/kWh (inverter and installation excluded) for the residential market [12], down to about 250 US$/kWh for commercial purposes. Similar forecasts are collected by the