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Energy and economic analysis for large-scale integration of small photovoltaic systems in buildings: The case of a public location in Southern Spain

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ABSTRACT

The integration of grid-connected PV systems into buildings or public areas is one of the most usual applications of the photovoltaic solar energy in developed countries and it is being highly promoted by several European governments. In this paper it has been evaluated the photovoltaic potential of the Campus of the University of Jaén and it has been defined possible areas where the PV systems could be installed according to power requirements, space possibilities, the electrical configuration of the Campus and some social integration requirements too. The definition of the PV potential, together with a technical analysis for the calculation of the energy generated, is the previous step for carrying out an economic and cost analysis in order to certify the profitability of these systems in general, particularizing the study for the case of this University located in Southern Spain. The PV electricity cost generated has been calculated through the concept levelised cost of electricity (LCOE), where in our case is estimated to be around 0.13–0.14 € kWh^{-1}. The results obtained in this economic analysis recommend the implementation of PV grid-connected systems (PVGCS) as the internal rate of return reaches a maximum value of 6.21%, the net present value is positive and the discounted payback time is around 16 years. An additional sensitive analysis shows the influence that some parameters have on the LCOE, specially the initial investment, the energy yield and the nominal discount rate.

Contents

1. Introduction

The integration of grid-connected PV systems into buildings or public areas is one of the most usual applications of the photovoltaic solar energy in developed countries [1,2].

Moreover, in the Spanish legislative framework, with the application of the Royal Decree 1578/2008, it is recognized the benefits of Building Integrated Photovoltaic (BIPV) systems, not only because they do not increase the land occupation but the advantages of the distributed electricity generation as well as their contribution to a social spreading of renewable energies [3]. Apart from the promotion of BIPV systems in Spain, the main reason of this Decree was to rationalize the deployment of PV in Spain and to control the impact of the feed-in tariff in the national economic situation.

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According to the previous law, the Royal Decree 661/2007 from 2007 [4], the RD 1578/2008 implied a 30% reduction of the feed-in tariff and further progressive cuts, which could reach 10% annually. Likewise, it established three installation types: type I.1: systems on top of buildings with a power limit of 20 kW; type I.2: systems on top of buildings with more than 20 kW of power and a limitation of 2 MW and type II: systems on undeveloped areas with a limitation of 10 MW. Also, it was established a power cap of 500 MW in 2009 and a similar one for the following two years. The feed-in tariffs approved for the first quarter of the year 2011, to be paid over 25 years, were: type I.1: 0.3135 € kWh^{-1}; type I.2: 0.2788 € kWh^{-1} and type II: 0.2517 € kWh^{-1}.

Lately, in September 2010 and due to the economic situation of the country, the Spanish feed-in tariff regime was modified for those systems not gathered in the 2011 first quarter registry. The Royal Decree 1565/2010, apart from further promoting PV systems integrated in buildings, either on façades or on top of roofs, implies an additional reduction in feed-in tariffs of 5% for installations of type I.1, 25% for type I.2 and 45% for type II [5].

The feed-in tariff for the projects that have been inscribed in the second quarter of the year 2011 is approximately of 0.2888 € kWh^{-1} for the small systems on roof, 0.2037 € kWh^{-1} for the type I.2 (above 20 kW) and 0.1345 € kWh^{-1} for systems installed on the ground [6].

Additionally, a new Royal Decree-law (RD 14/2010), from December 2010, limits the energy entitled to the feed-in tariff, as it fixes the number of hours of operation, according to the type of installation – fixed, one-axis and two-axis tracking – and the climatic zone established by the Spanish Building Technical Code law [7,8].

Therefore, prospective owners/investors are concerned for any further modification of the present regulatory framework, such as the financial incentives, the number of hours of operation and the years entitled to the feed-in tariff as it may affect the profitability and cost of the Photovoltaic Grid-Connected Systems investment, hence an economical and cost analysis of the PVGCS on buildings to ascertain the influence of the new regulatory framework on the PVGCS's profitability and cost is demanded.

In this paper it has been evaluated the photovoltaic potential of the Campus of the University of Jaén and it has been defined possible areas where the PV systems could be installed according to power and space requirements, the electrical configuration of the Campus and its social integration too. The analysis of the PV potential is the previous step to carry out a cost and economic analysis for implementing this photovoltaic grid-connected integration according to the new regulatory framework in Spain.

Because of the characteristics of the facilities of the Campus of the University, the PV systems will be installed on the building rooftops, parking lots or façades; therefore, the technical analysis will include a complex shading study. The methods for the economic analysis used in this paper are the net present value (*NPV*), the discounted payback time (*DPBT*) and the net internal rate of return (IRR_n). Regarding the cost analysis, it has been focused on the estimation of the electricity cost production through the concept: levelised cost of electricity (*LCOE*), so this result can be compared with other sources of electricity generation.

2. Technical analysis

The University of Jaén campus is the location chosen to carry out the technical analysis that will be used as base case to show the economical and costs results for PV grid-connected systems.

The campus (Fig. 1) is located in Southern Spain (37.73N and 3.67W) and the average annual radiation in this area is favourable for the installation of PV grid-connected systems, both in ground or building integrated.

The technical analysis starts from the identification of potential areas where the PVGCS ensure that the Spanish law is upheld among other aspects, and subsequently it is analyzed each area in order to study its profitability in energy terms.

2.1. Definition of potential PV locations

A first criterion to identify suitable areas for the PV systems is the grid-connection characteristics of the Campus, so an analysis of the electrical grid of the University will allow us to identify possible points of connection to the existing electrical grid.

The maximum power demand goes up to 3200 kW, while the annual consumption of electricity reaches around 6500 MWh. This energy is transferred by a local electrical grid made up of a high-voltage ring network that interconnects five transformer stations, which belong to the University, that supply low-voltage electricity to all the University facilities.

Fig. 1. Aerial picture of the University of Jaén Campus.