Energy 119 (2017) 408–424

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

A worldwide assessment of economic feasibility of HCPV power plants: Profitability and competitiveness

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ARTICLE INFO

Article history:
Received 19 July 2016
Received in revised form
18 November 2016
Accepted 22 December 2016

Keywords:
Internal rate of return
High Concentrator Photovoltaic
Generation parity

ABSTRACT

Numerous exhaustive analyses of the economic assessment of conventional PV systems are available in the literature. However, there is a lack of these studies concerning High Concentrator Photovoltaic (HCPV) technology. Besides, future owners and potential investors on HCPV plant demand information relating to the economic feasibility of their investment. In this work the profitability and competitiveness of HCPV plants in several countries are analysed. To analyse the profitability the internal rate of return (IRR) criterion has been used, while the competitiveness has been analysed based on estimating the so-called HCPV generation parity. As a result of the economic profitability analysis conducted the group of countries where the investment in HCPV could be interesting has been identified. The results obtained could be also useful for researchers to identify the weaknesses of the HCPV technology and take actions at making it more competitive. From the competitiveness analysis carried out in several Eurozone countries and USA for two possible scenarios 2015 and 2020, the results show that HCPV could be competitive in some locations in 2020. Therefore, government organizations of the studied countries, which participate in the design or the selection of support mechanisms for HCPV, can be guided by the results obtained.

1. Introduction

Nowadays, the solar photovoltaic (PV) is one of the most extended renewable energy systems worldwide. Among the different PV technologies, the High Concentrator Photovoltaic (HCPV) technology, based on concentrating the sunlight on a small-size solar cell, is one of the most promising to produce cost-competitive electricity. The HCPV technology uses an optical concentrator to collect the solar radiation and concentrate it, usually in a range from 500 up to 1000 times, onto small and highly efficient solar cells [1]. The optical concentrators used in HCPV are usually made up of a primary optical device to collect and concentrate the direct normal irradiation (DNI), and a secondary optical device to homogenize the light on the solar cell surface, thus improving the performance of the system [2–4]. Regarding the solar cells used in HCPV technology they consist of several p-n junctions of III-V semiconductor alloys with the aim of increasing the efficiency of the device [5–8]. The current efficiency of the solar cells used in HCPV is over 46%, and continues to increase meaning HCPV technology has a great potential for reducing costs.

A HCPV grid-connected system is made up of HCPV modules mounted on a high-accuracy solar tracker, interconnected in series and parallel and connected to a high efficiency DC/AC inverter, and the rest of balance of system components (BOS) [9–12]. As mentioned, the efficiency of MJ solar cells used in the HCPV modules, and therefore, the efficiency of HCPV modules and systems, is increasing over time, and is expected to reach values up to 50%, 45% and 40% for MJ solar cells, HCPV modules and systems, respectively, within the next few years [13,14]. Moreover, HCPV technology has already provided promising results and shows a trend to decrease the cost of electricity generated with these systems at locations with high values of DNI [15,16]. All of this makes HCPV technology an alternative renewable power source with a great potential that could play an important role in the global energy market [17].

Despite the great potential of HCPV in of decreasing the associated costs of the electricity generation, additional costs are involved due to use of optical concentrators, trackers, and operation and management costs, etc. Therefore, further research is needed to remove technical and economic barriers, with the aim of

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http://dx.doi.org/10.1016/j.energy.2016.12.093
0360-5442/

decreasing the electricity production costs and to make this technology truly competitive in the marketplace. Concerning economic aspects the following two main concerns can be cited: on the one hand, a lack of studies that evaluate the economic profitability; on the other hand, the competitiveness of HCPV technology needs to be more thoroughly studied.

In the case of conventional Photovoltaic (PV) technology (either crystalline or thin film ones) there is a significant number of studies and researches papers concerning different economic aspects related to PV systems [18,19]. Others studies analysing the economic profitability of PV systems by means of different methods such as: net present value (*NPV*), discounted payback time (*DPBT*) and internal rate of return (*IRR*) [20–27] and the competitiveness by means of the grid-parity analysis [28,29]. The results of these studies provide invaluable information to assess, on one hand, the feasibility of the investments and, on the other hand, to support policy makers in order to outline renewable energy promotion policies. However, in HCPV technology there is a lack of studies that evaluate the economic profitability or do a detailed analysis of the competitiveness of the power plants based on this technology, only the studies presented in Refs. [30–33] address some economical aspects related to HCPV technology. Thus, in Ref. [30] the authors conducted an analysis of economic profitability using the NPV, the benefit-to-cost ratio (BCR) and IRR criteria for two scenarios 2013 and 2020, while in Ref. [31] a cost analysis using the Levelised Cost of Electricity (LCOE) criterion was carried out at different scenarios. In Ref. [32], an analysis of economic viability using the NPV and the Levelised Cost of Electricity (LCOE) criteria was carried out at two locations (Las Vegas (Nevada) and Ottawa (Ontario)). In Ref. [33] the LCOE of HCPV grid connected systems worldwide is estimated and analysed.

The present work tries to resolve this lack by conducting an economic profitability analysis and a competitiveness analysis for HCPV power plants in worldwide countries and regions. In order to analyse the economic profitability of these plants the internal rate return method has been used. From the internal rate return method the value of the required tariff of a specific HCPV power plant is obtained. The required tariff is the price obtained for kWh generated and injected to the electrical grid by a HCPV plant, and that allows the minimum profitability sought by future owners or investors of HCPV plants to be reached. In order to determine the required tariff, the specific parameters of each country have been taken into account: the irradiance (*DNI),* the financial cost, income tax rate and inflation. Other parameters such as the initial investment cost of HCPV plant have been considered the same for all locations. As result of this analysis, the required tariff for HCPV power plants will be estimated in countries around the world. In particular, the analysis will cover 133 countries and the results obtained will be graphically shown in a set of original worldwide maps.

The competitiveness analysis of HCPV power plants has been analysed basing on the estimation of the so-called HCPV generation parity. The HCPV generation parity happens when the tariff required by owners or investor matches the electricity price in the wholesale market. Therefore, in the competitiveness analysis, the required tariff for a HCPV plant (in c€/kWh) is compared with the wholesale electricity price, in some locations considered. It will show where HCPV power plants could be competitive with respect to conventional electrical generation systems, how long it will take to reach parity or if it has already been reached in the country.

The proposed methodology is going to be a useful tool to identify those countries where the HCPV plants can be a feasible technology as a power source. Moreover, the results obtained are an original contribution regarding HCPV electrical generation profitability on a global basis. Furthermore, the map-based methodology proposed in the paper is easy to handle and can be consulted and managed by future owners, investors and financial entities involved in HCPV plants. But these studies are not only valid for future owners and investors, they will be also useful for researchers in order to identify the main weaknesses of the HCPV technology depending not only on technological but also economical and geographical parameters, and to propose improvements aimed of making this technology more competitive.

Finally, it is important to highlight that in the present paper a HCPV power plant is defined as a HCPV grid-connected system with a nominal power greater than 10 MWp. On the other hand, concerning the data, i.e. direct normal irradiation (DNI), since this work is a global analysis and the values of the parameters can be obtained from different sources, the results obtained may differ slightly depending on the sources of data used (e.g. Meteonorm, PWATTS, PVGIS, etc.).

2. Methodology and data

As mentioned above, in this paper, the economic profitability analysis is done through the internal rate return method while to evaluate the competitiveness of HCPV power plants the so-called HCPV generation parity is studied. In the first case, the values of the required tariff of a specific HCPV power plant is obtained with the IRR method, this tariff being that which satisfies the minimum profitability sought by the owners or investors. To evaluate the competitiveness of HCPV power plants, the required tariff is compared with wholesale market prices of electricity, in order to determine if generation parity has been reached or how long it will take.

In this section, the methodology used to analyse economic profitability and competitiveness of HCPV power plants (>10 MWp) is described in detail. The analysis has been conducted from the point of view of owner or investor as power producers that sell the generated electricity to the wholesale market.

2.1. Economic analysis

The most common criteria aimed at measuring the economic feasibility of the project investment are: Net Present Value (NPV, in €), Benefit-Cost Ratio (BCR), Internal Rate of Return (IRR) and Discounted Payback Time (DPBT, in years). Criteria based on NPV, BCR and IRR are addressed at measuring profitability, while DPBT is aimed at measuring the liquidity of the investment.

As mentioned, the internal rate of return (IRR) criterion has been used for analysis of economic profitability in this paper. The procedure followed to calculate this criterion, similar to those presented in previous work [17,22,34,35], is shown below. First of all, the Net Present Values criterion is going to be formulated since it is necessary for calculating the IRR.

The NPV of a project is defined as the difference between the present values of the cash inflows and cash outflows generated by the investment over the lifetime of the project. This is given by the expression:

$$NPV = -HCPV_I + \mathrm{PV}[NCF(N)] \tag{1}$$

where $\mathrm{HCPV_I}$ (€) is the initial investment cost of a HCPV power plant, PV[*NCF*(*N*)] (€) is the present value of the net cash flows over the lifetime of the power plant and N (years) is the lifetime of the HCPV power plant.

The present value of the net cash flows PV[*NCF*(*N*)] may be written:

$$\mathrm{PV}[NCF(N)] = \mathrm{PV}[CI(N)] - \mathrm{PV}[CO(N)] + PV[DEP(Nd)] \tag{2}$$