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Which are the constraints to the photovoltaic grid-parity in the main European markets?

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Abstract

A new concept of Photovoltaic (PV) grid-parity is presented for three typical case studies in Europe by including the distribution-network limits and the fixed costs of the electricity bills. Real cases are described for residential/tertiary sector loads: the PV penetration results, achieved without investments in the distribution upgrading, are presented through the ratio of the admissible PV energy ratio which can be close to 30% of the total consumption for residential users and 45% for tertiary-users. The future approach of distribution limits certainly will increase the electricity bills which have been analysed here in the current situation: in Germany the fixed costs are negligible, whereas in Italy the common loads of apartment-blocks are charged by the cost of the available power. The grid-parity problem is analysed by the net present value which provides the cost effectiveness or not of the PV installation. The results are obtained by the interest rates of 3–6% in Germany and 4–10% in Italy. The grid-parity for dwelling houses and tertiary-sector users is reached in Germany and Central/Southern Italy; it is achieved in Germany for the users in apartment-blocks, while it is unrealistic to be reached in Italy with the current tariff situation.

Keywords: Photovoltaic grid-parity; Distribution limits; Fixed costs; Electricity bill; Economic analysis; Residential/tertiary sector loads

1. Introduction

It is a common practice to provide suitable feed-in tariffs for those technologies which enter the market to achieve economies of scale: e.g., in reference (Spertino et al., 2013) the decline of installation costs is demonstrated for PhotoVoltaic (PV) systems, due to the application of strong incentive policies in the two main markets. It can be highlighted that heavy subsidization of conventional energy is still in force (Ahmad et al., 2011). In this regard, the lack of subsidization for PV technology is the supposed condition within the remainder of this paper.

Roughly speaking, the grid-parity concept (Bhandari and Stadler, 2009; Breyer and Gerlach, 2013) deals with the economic conditions which make the PV electricity as convenient as the electricity produced by the conventional centralised power stations (wholesale cost Reichelstein and Yorston, 2013) or delivered by the distribution system operators (retail cost Branker et al., 2011), thanks to the possibility to install PV plants near the consumers. In particular, as mentioned in Reference (Bhandari and Stadler, 2009), the term grid parity explains the time point when the one-kilowatthour generation cost using solar PV becomes equal to one-kilowatthour electricity price from grid.

The Levelized Cost of Electricity (LCOE) is a life-cycle cost concept which seeks to account for all physical assets and resources required to deliver one unit of electricity output (Hernández-Moro and Martínez-Duart, 2013; Short

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et al., 1995). Installation cost of PV systems, their operation and maintenance costs, prices of electricity injection into the grid are items involved in the LCOE assessment.

Obviously, the economic conditions depend on technical parameters as the reference yield, the performance ratio and the final yield of the PV systems, but now the impressive deployment of PV installations in Europe (as, for example, in the two main PV markets Germany and Italy) induces some technical barriers (Lin et al., 2012; Povlsen, 2002; Baumgartner et al., 2011; Shayani and Gonçalves de Oliveira, 2011) both at transmission level (e.g., the possibility of replacing substantial amount of generation from fossil fuels with intermittent sources as solar PV/wind power systems in the national consumption profile) and at distribution level (e.g., the possibility of inverting the behaviour of passive lines with risk of overvoltage and in general voltage rise for the grid transformers).

Usually, the cost of electricity from utility grid is referred to the consumption in terms of €/kW h, but for deeper insight the cost consists of three contributions, the variable cost function of the consumed energy (generation, transmission, distribution, taxes, incentives for renewable energies, etc.) and two fixed costs, one depending on the delivery/exchange contract, the other depending on the available power.

Therefore, the transmission/distribution limits and the fixed costs must be taken into account in the grid-parity analysis with respect to the photovoltaic systems.

This paper is devoted to the comprehensive study of the conditions, both technical and economic, needed for the true achievement of grid parity in regards to the photovoltaic electricity. The PV systems under study are those on the rooftop, i.e., close to the users, belonging to residential and tertiary sectors, and thus the reference cost is the retail electricity price. The paper starts from the technical barriers (at distribution levels), then it examines the hidden costs within the electricity bill, prior to present the financial analysis of investment, based on the PV installation cost and the solar irradiation, which permit to achieve the full competitiveness with the retail electricity cost.

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2. Technical barriers in the development of PV rooftop systems

2.1. Theoretical background

In the past, most of the distribution networks at high, medium and low voltage level, was designed in order to operate in radial configuration with a single source (Canova et al., 2009). With this kind of network, the power flow is from the substation to the loads in every point of the grid. On the other hand, in the presence of Distributed Generation (DG) as the one from PV systems, i.e., when the network has multiple sources, it is possible to have power flow in reverse direction, from DG units to the substations. The reverse power flow is the main problem that makes the integration of DG units not easy: the distribution limit (bottleneck) is prevailing on the transmission limit that is not considered in this work. Obviously, a grid-connected photovoltaic (PV) system increases the voltage in its point of common coupling (PCC).

The grid behaviour is assumed as that of a Thévenin generator, in which the voltage source E_{Th} and the equivalent impedance Z_{Th} take into account different contributions:

- The e.m.f. of secondary windings of the distribution transformer E_T.
- The primary grid impedance Z_{MVg} (in other terms the short circuit power of the grid in that point) and the short circuit impedance of the distribution transformer Z_{scT}.
- The impedances of the distribution lines Z_{LVl} (by neglecting the capacitive parameters if they are below a given limit).
- The corresponding impedances Z_L of the loads supplied by these lines (however, many times, it is not possible to define a constant impedance when the loads are non-linear as occurs for power electronics, discharge lamps, electro-magnetic machines in no-load condition,...).

Fig. 1 shows an example with two lines and two loads. The value of the equivalent impedance named as Z_{grid}, seen by the DG unit, depends on the PCC. In this case the DG unit is a PV plant represented by a current source (I_{PV}) depending on solar irradiance. If the DG unit is at the beginning of the lines, near the transformer, as in case (a), the voltage drop and power losses of the lines are not influenced; the situation changes if it is at the end, near the loads, as in case (b) with the line which supplies the load Z_{L2}. Usually, as a first approximation, the impedance of the loads are considered infinite in the calculation of Z_{grid} and so in the case (a) it results $Z_{grid} = Z_{MVg} + Z_{scT}$, while in the case (b) it results $Z_{grid} = Z_{MVg} + Z_{scT} + Z_{LVl2}$.

In the latter case, the value of Z_{grid} could be so high that the PV power capacity should be reduced, in order to

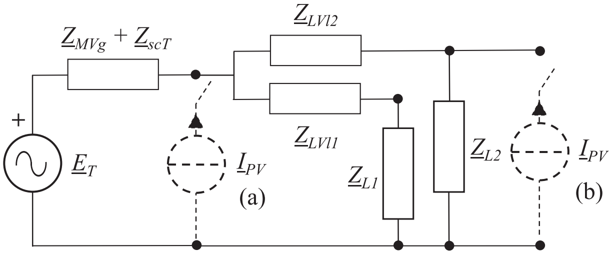

Fig. 1. PCC at the beginning or at the end of the LV lines.