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Economic assessment of residential PV systems with self-consumption and storage in Portugal

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ABSTRACT

A progressive implementation of renewable microgeneration, mainly small sized Photovoltaics, in low voltage distribution networks is ongoing. In this context, self-consumption with storage allows to highlight the prosumer concept, bearing in mind that this strategy may be interesting both from a technical and economical perspectives. The intelligent network environment or Smart Grid comes close to this new model and may have a critical relevance in the management of intelligent power distribution networks, in the framework of a Smart Environment. This paper intends to give an additional contribution on the subject by investigating the economic profitability of different residential PV systems configurations. These include traditional "injects all into the network/consumes all from the network", self-consumption, storage and net-metering. The joint operation of self-consumption and battery storage is particularly focused as it presents the current trend in residential PV systems. The results of the performed economic analysis point to the conclusion that self-consumption is already attractive, but storage is not a profitable solution, because battery investment is still too high, despite the cost reduction witnessed in recent years.

1. Introduction

Due to the paradigm change that is being currently witnessed in Low Voltage (LV) distribution networks, we are assisting to an increasing penetration of renewable micro-generation (μG) located closer to the customers. These generating facilities are predominantly low capacity Photovoltaic (PV) systems installed in the rooftops of the buildings. PV μG is typically sized in the range of few kW being directly connected to the LV distribution network. This paradigm change can bring benefits, principally in rural areas, as it allows to increase the quality of electrical energy supply (Katiraei and Iravani, 2006; Luque and Hegedus, 2011). The installation of μG next to customers implies power can flow bi-directionally in the LV distribution network, as opposed to traditional LV distribution network, where power always flowed unidirectionally from service substation to end-users loads (Katiraei and Iravani, 2006; Llaria et al., 2011). Consequently, it is essential to promote the shift of the LV distribution network model of exploitation, since it was originally designed to deliver energy to the costumers and not the opposite.

Consumers able to produce their own energy can be called prosumers. The role of prosumers can be highlighted in the framework of the ongoing paradigm change in LV distribution networks, notwithstanding that it may be interesting both from a technical and economical points of view (Rathnayaka et al., 2011; Sun et al., 2013). A prosumer can operate its PV system in several ways: (a) He can export to the grid all the PV production and import from the grid all the electricity consumption. In this case, he does not perform any self-consumption; (b) He can use the PV production to feed its own consumption and exporting to the grid the surplus and importing from the grid the electricity in deficit. In this case, he performs self-consumption without storage; (c) He can use the PV production to satisfy its own demand and storing the excess electricity in batteries for later use. The electricity shortfall is imported from the grid. In this case, he performs self-consumption with storage.

China has introduced a policy of subsidy for micro-producers with self-consumption: self-consumed electricity gets a bonus on top of the saved retail price. In Germany, PV owners were encouraged to self-consume with a premium paid for each kWh of self-consumed PV electricity. This scheme was recently replaced by a simpler self-consumption scheme. In Italy, some kind of hybrid solution between a self-consumption system with some net-

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billing features is in force. Given the low price of retail electricity in France, self-consumption is not used and PV electricity is sold almost entirely through the feed-in tariffs. However, it is currently being discussed a proposal to remunerate PV systems with self-consumption using a tailored self-consumption incentive. In Spain, self-consumption is allowed, but no compensation for the excess PV electricity injected into the grid is given. For installations above 100 kW, the excess PV electricity can be sold on the wholesale market. All systems used for self-consumption above 10 kW are charged with a fee per kWh consumed. It is justified as a “grid backup toll”.

In Portugal, the recently published legislation (Decree-Law 153/2014) promotes the prosumer model by covering all mentioned modes, including the self-consumption mode, therefore encouraging new prosumers to come forward. From the prosumer’s perspective, self-consumption and storage may be very attractive. Batteries are used to store the surplus energy produced during daylight, to be used later when there is no sun power. Furthermore, the prosumer’s strategy of self-consumption and storage allows the possibility of becoming increasingly independent from the public power system.

In the previous Portuguese legislation (Decree-Law 363/2007), prosumers were required to inject all their production into the network and the sold energy was remunerated through a feed-in tariff (FIT) scheme. In recent years, the adverse economic situation of Portugal, in addition with sustainable PV systems cost reduction, contributed to the declining of the FIT scheme. In year 2015, radical changes in the FIT schemes were made, affecting the small-scale PV generation. The FIT scheme was cut and a new grid injection tariff, based on the much lower Iberian electricity wholesale market prices, comes in force (Ordinance 153/2014; Masson et al., 2014). On the other hand, the self-consumption concept was largely promoted and prosumers were encouraged to join this new framework.

The potential for integration of energy storage technologies can be further improved by combining the intelligent power distribution networks or Smart Grids (SG) Lampropoulos et al., 2010; Pagani and Aiello, 2014. Currently, it is well-known that SG may be beneficial to the network in terms of efficiency, safety and economy (Putrus et al., 2013). Furthermore, the development of information and communication technologies allows the growth of SG, emerging as an assimilated vision for the future power systems (Miceli et al., 2013; Borlase, 2012). Accordingly to this perspective, the so-called Cyber-Physical Systems (CPS) can be the next step for the evolution of SG (Khaitan and McCalley, 2015). CPS is potentially the novel generation of engineering systems that offer close interaction between cyber and physical components (Abad et al., 2012). From the SG perspective, CPS approach can bring increased benefits in terms of safety, economy, efficiency and reliability (Hu, 2013). Smart-meters are a classical example, as its combination with CPS allows monitoring and managing the power of a smart house. This idea can be generalized as CPS are able, not only to manage and monitor the smart house, but also to manage and monitor the entire electrical network as a whole, therefore allowing the net-metering model to be applied.

The net-metering model is based on the concept that the power system can be used as a long-term storage (Eid et al., 2014). The surplus energy production is injected into the network and is recorded as credits, that can be compensated later for consumption over an extended time period. This operation mode is not allowed in Portugal, at present time.

Several studies on the economic assessment of PV systems have been made, with the goal of verifying the profitability of PV systems in various viewpoints. A brief literature review of this subject is presented, as follows.

An historical overview on FIT schemes was done in Ming-Zhi Gao et al. (2015), in order to predict its evolution and the influence in the economy of several countries. An analysis of the impact of PV related to FIT regime and the prediction of their evolution in selected European member states was also evaluated in Campoccia et al. (2014), Forbes et al. (2014). The research in Bhattacharya et al. (2016) presents the effects of renewable energy on the economic growth of various countries in the world. The challenges and side effects posed by an increasing level of Distributed Generation (DG) penetration related to network tariff design are investigated in Gallego-Castillo and Victoria (2015), Picciariello et al. (2015).

The European Union (EU) energy policy concentrates on accomplishing an equilibrium between three main vectors: growth the security of supply, decrease the impact of climate change, and develop economic competitiveness. Consequently, in order to accomplish these objectives, the EU actively promoted the renewable energy as discussed in Chaves-Avila et al. (2015). The assessment of the support policy for solar PV systems in the residential sector of the major European markets is carried out in Dusonchet and Telaretti (2015), De Boeck et al. (2016). A profitability analysis of rooftop PV self-consumption in residential and commercial buildings, considering an absence of subsidies, is addressed in Lang et al. (2016).

Some researches present positive results related to bill savings, in net-metering context, as presented in Darghouth et al. (2014, 2011). However, it is well known that net-metering applications are relatively limited in EU countries (Masson et al., 2014). The research in Christoforidis et al. (2015) and Sajjad et al. (2015) addresses an economic evaluation of a series of net-metering policies from a prosumer bill saving perspective in Greece and Italy, respectively. On the other hand, economic assessment implies to have information on the investment and operating costs, and, if the net-metering context is to be considered, proper definition of on-line buying and selling of electricity prices are required (Baker and Powell, 2009).

The most common definition of grid parity is the intersection of the price of the electricity generated by a PV system and the price of conventional electricity production (Munoz et al., 2014; Elliston et al., 2010). In other words, the dynamic grid parity model is based on the historical relationship between two trends: the decrease in PV production costs and the constant rise in electricity prices (Biondi and Moretto, 2015).

The cost of PV energy production is expressed as Levelized Cost Of Electricity (LCOE), which defines the constant theoretical cost required for the production of a kWh with a PV system, integrated all-over the project lifetime (Perez et al., 2013). The modelling improvement of the PV LCOE and grid parity, considering the effective lifetime of PV technologies, is discussed in Said et al. (2015), Kästel and Gilroy-Scott (2015). A grid parity and PV self-consumption analysis under the regulatory framework, in Spain and Germany, respectively, is addressed in Talavera et al. (2014), Karakaya et al. (2015).

As seen, existing literature reports several studies on the subjects of PV systems, self-consumption and storage. They approach different topics, like the effects of net-metering and feed-in tariffs schemes, new tariffs for distributed generation, computation of the levelized cost of energy and electricity prices and bills, support policies, profitability in the absence of subsidies, grid parity and so on.

This paper follows an approach that, in our opinion, has not been touched yet. It presents an integrated economic assessment of the different PV systems solutions that are currently being offered in the market. The system components (PV module, inverter, bidirectional counter and battery) investment and Operation and Maintenance (O&M) costs are taken from the information pro-