A STYLIZED ECONOMIC MODEL ON PV PROSUMERS ENCOMPASSING GENERATION AND STORAGE ECONOMIC REQUIREMENTS, LOAD MANAGEMENT, GRID EXCHANGES AND REGULATION RULES.

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Overview

Driven by technical advances and favourable regulatory measures (albeit only in a few countries), the deployment of electricity generation at very small scales, or micro-generation, is shaping a new segment of the electricity system. On-side microgeneration provides electricity services to homes and commercial and industrial businesses from their own premises. Those services include lighting, powering of home appliances (including the car which, in turn, can be a source of energy), cooling and heating. Microgeneration can use very different techniques and fuels (biomass boilers, heat pumps, solar thermal and photovoltaic, etc.) albeit not all of them are necessarily renewable ones. Our contribution focuses on photovoltaic (PV) demand-side generation in residential houses, shops, warehouses or industrial buildings. As it is known, these PV plants currently have up to 25 kW. However, there might also be plants with capacities up to 500kW, e.g., shopping malls or industrial warehouses. All these cases can be considered micro-Photovoltaic Generation (mPVG) if the generated electricity is not to be sold only in the market. The mPVG plants increasingly include batteries and, in a not distant future, devices for demand management. Load management embraces energy savings and energy efficiency goals which could be achieved through measures such as the installation of apropriate appliances, the improvement of the building insulation, the optimization of lighting points, and so on. As a result, the mPVG plants will become a non-negligible techno-economic complex. The three pillars of mPVG (generation and storage, load management, and grid exchanges) will be on the one hand influenced by specific regulations and, on the other hand, by factors such as income, household composition and lifestyle. Our contribution proposes a stylized model to highlight the main economic and regulatory factors shaping mPVG.

Methods

The stylized mathematical model on mPVG encompasses the following elements:

- The plant complies with the avoided cost principle. A notation and different assumptions are established to deal with the allocation of investments and periodic outlays.
- A vector of the hourly generation is defined, which shows positive values (kWh) the hours of PV production.
- The performance of the battery is modeled considering the energy charging and discharging profiles and their associated efficiencies, as well as the maximum charge capacity and the maximum depth of discharge.
- There is an hourly loads vector, expressed in kWh. Its composition includes the energy demanded by the shiftable appliances (be flexible ones such air-conditioner devices or heating system, be deferrable ones such as washing machines and dish washers) and non-shiftable appliances such as lighting, cooking system or TV set.
- The management of shiftable appliances makes sense to load management. The reduction of the electricity expenditure can be explained by a somewhat low consumption rate and/or by the operation of devices during periods of comparatively low retail electricity prices, and when the electricity comes from the on-side installation. Moreover, energy consumption reflects saving and energy efficiency measures implemented in the past, as well as decisions which are taken now. Two dimensions are considered here: their intrinsic energy consumption and the number of times the device is used. Both dimensions can show the rebound effect.
- Different types of market structures have been imagined for mPVG sector. The debate distinguishes four cases: the micro-generation-to-(smart) grid, the peer-to-peer platform, the interconnection of different microgrids, and the prosumers connected to islanded microgrids. This differentiation is the basis to analyze the prosumers grid exchanges (exports and imports of electricity). In the model three situations are distinguished: 1) Self-sufficiency is the priority and, thus, if there are surpluses, these will preferabily feed the battery; 2) Prosumers are allowed to either accumulate the surplus or sell it, regardeless the state of battery charge, and 3) mPVG can freely interact with the grid, so there are commercial prosumers. In these three cases, regulations for market participation are justified.
- Finally, the model defines a reference day throughout which the hourly demand is covered only with electricity imports, with a mix of imports and instantaneous self-consumption, only with instantaneous

self-consumption, with a mix of instantaneous self-consumed energy and energy from the battery, and only with previously stored electricity. Therefore, different periods of costing are modeled.

Results

The proposed model is focused in the analysis of the economic prosumers behaviour whose regulation-oriented goal is self-sufficiency (or residual exports) and those inclined towards partial self-sufficiency. The main resultas are: prosumers should schedule exports as a function of the expectation on the evolution of retail prices; electricity imports to charge the battery depends on the tariffs structure (flat or TOU); and in temperate zones during the cold sunsets a careful programming of the battery and load management is needed in order to avoid relatively expensive imports.

Conclusions

Key aspects which drive/hinder the diffusion of mPVG are the costs of equipment, the regulatory framework and the operational complexity. To be more specific: the LCOE (generation and storage) evolution, the load management rules and the net balance of grid exchanges. All of them are elements under regulatory rules. There is no doubt that new types of electricity markets for prosumers will emerge in the next future. So, policy measures can only delay, but not hamper mPVG diffusion. The discussion on whether mPVG should be focused in reaching the maximum self-sufficiency or its most relevant aim is to contribute to the reduction of electricity demand peaks, is becoming increasingly obsolete. There is an increasing interest in analyzing the ancillary services that the mPVG may provide to the electricity system.

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