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Method to Determine Auto-consumption Profitability

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Abstract

Recognition of the notion of "sustainable development" in 1997 Kyoto climate protocol agreement fostered the evolution of mentalities and the appearance of many eco-citizen behaviors. In this context, it is interesting to focus on a new mode of consumption termed auto-consumption. Auto-consumption is possible with all renewable energies, but here only solar energy has been considered. Present study aims at giving clues for the choice of energetic consumption management mode. This includes economical, technological and energy optimization for a photovoltaic solar installation, using self-consumption. It enables to achieve key results such as finding cities location where auto-consumption is theoretically profitable, and/or electricity price limit necessary to make it profitable.

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Keywords: Auto-consumption; Economic Profitability; Solar Energy.

1. Introduction

To deal with the inevitable greenhouse effect resulting from predicted increase of power production in near future, alternative renewable sources have been studied with the double objective to better fit the distributed demand and to reduce greenhouse effect [1-7]. However, these new sources have the defect of being intermittent and require some organization for being economically attractive, such as solar and wind sources [8-13]. When specializing to photovoltaic systems, aside usual optimization methods [14-17], auto-consumption is a way of consumption using

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directly the electricity produced by a domestic installation. Nowadays, there are only methods to size solar installations for selling produced electricity, but none has been dedicated yet to the dimensioning of such installations which need an associated storage and can sometimes be connected to the grid [18]. Furthermore, the ale of produced energy is not very relevant because the tenet of auto-consumption is to use all available energy to replace the purchased electricity, and the real impact of the storage is not taken into account in case of auto-consumption. Otherwise, the issue of storage also raises the problem of energy optimization which requires performing a precise accumulator dimensioning, because energy storage follows specific chemical rules complicating its uses [19]. Optimization is relevant for auto-consumption, because this concept aims at maximizing energy, and different methods are available for optimizing energy consumption:

- Energy consumption patterns [20]. This concept take mostly into account HVAC systems and commercial buildings. But some of the methods could be applied to domestics systems;
- Consumption profile (in the case of systems in Argentina [21]). In these systems, electric and gas consumption has been studied, but in lower-mid income house;
- Economic and energetic optimization [22]. This method can be adapted to the electricity consumption in the case of autoconsumption : the electricity is not sold to the grid;
- Method to explain the impact of solar system on the environment (for example, energy consumption) [23].

Based on available literature, auto-consumption seems to need to bring together all the pieces of a “puzzle”, because all these pieces are close to this concept.

With all the papers studied previously, the sizing of solar photovoltaic installations, the optimization of energy consumption and solar energy storage are presented. However, all these notions are analyzed independently and do not illustrate auto-consumption. Then, this publication will introduce this mode of consumption, firstly by a method dedicated to design photovoltaic installations and secondly by the obtained results.

2. Dimensioning method for solar systems

To size a solar system using auto-consumption, best way is to dimension an autonomous system, linked to the grid. This technique has some drawbacks, because a house with auto-consumption has just part of its energy coming from renewable sources. To size more precisely the system, three steps are defined:

- The first sizing, with only the physical characteristics of the house;
- The adjustment of first sizing, using the auto-consumption rate;
- The last sizing, with storage specific problem.

First step is to determine the available solar flux according to its geographical location (latitude and longitude). To get the flux on inclined plane, its tilt and orientation are required. Second step is to perform a first dimensioning taking into account the house physical (roof size) and economic (electricity supplier invoices) characteristics, as well as panel (size, available voltage) and inverter (maximum and minimum input voltage) characteristics. Supposing rectangular shaped panel and roof, with respective sizes (L_R,W_R) and (L_P,W_P), the panel number N_P and its fitting are determined by the two ratios :

$$\boldsymbol{\rho_L = [L_R/L_P] \times [W_R/W_P]}, \quad \boldsymbol{\rho_W = [W_R/L_P] \times [L_R/W_P]} \tag{1}$$

If $\rho_L < \rho_W$, the panels are arranged in widthwise direction, otherwise on lengthwise one. ρ_L or ρ_W determine N_P out of which inverter number N_I is evaluated with inverter characteristics by comparing inverter power to panel power. This first approximation can be reduced, the more as to optimize the converter, N_P is reduced so that the new number is the maximum number accepted by inverter. This is determined from the following two ratios M_1 and M_2 :

$$\boldsymbol{M_1 = [V_{LI}/U_{MPP}]}, \quad \boldsymbol{M_2 = [I_{CI}/U_{MPP}]} \tag{2}$$

Where V_{LI} is higher operating limit voltage of the inverter, I_{CI} the allowable direct inverter current at maximum power, and U_{MPP} the optimal potential value at temperature -10°C. Then $\min\{M_1,M_2\} = N_{Pmax}$ the maximum acceptable number of panels per inverter. N_P is reduced by the multiplication between the maximum number of inverters and the maximum number of panels that the inverter can accept. At this point, N_P and N_I are determined,