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Assessing the reflectivity of residential grid tariffs for a user reaction through photovoltaics and battery storage

Johannes Jargstorf*, Cedric De Jonghe, Ronnie Belmans

KU Leuven, Electrical Engineering Department ESAT-ELECTA, Kasteelpark Arenberg 10, B-3001 Heverlee, Belgium
EnergyVille, B-3600 Genk, Belgium

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ABSTRACT

Rising levels of local distributed generation and storage by residential grid users are difficult to integrate into the (energy-based) grid tariffs which are used in several European countries. There are proposals to address this issue, for instance, through capacity-based tariffs. Yet, this can lead to many possible designs which have to be compared. An important aspect of the comparison is the user reaction to the tariff. Tariffs are ex-ante options to use the grid. Grid-users react to this. The actual suitability of a tariff design is only measurable after the reaction. In this paper, a framework to assess tariffs in the context of a reaction through self-generation is designed and implemented. At first, a list of efficiency measures for the comparison is formalized. Then, a simulation model framework to quantify the measures is developed. This framework focuses on the interaction of tariff and self-generation using photovoltaic generation and battery storage. As a case study, different tariff schemes are implemented. The case study outlines the importance of considering the user reaction by showing the extent of the interaction. Also, it provides indications for tariff design by showing the effects on grid upgrade costs related to certain tariff components.

1. Introduction

In several European countries, rising levels of local photovoltaic (PV) generation can be observed [1]. Contributing to the fulfillment of targets for renewable energy generation, this trend is in line with energy policy objectives [2,3]. In some countries, such as Germany, the investment in additional storage is also supported to increase the degree of local self-generation [4].

This development can lead to a conflict with the grid tariff design. Grid tariffs have to recover the costs of grid operation in a reflective way [5,6]. Grid tariffs shall also fit to the overall objectives of energy policy [7]. An example of a conflict can be found in countries where use-of-grid tariffs for residential grid-users are based to a large extent on energy off-take [8]. Belgium[1] and Germany are such examples. Both countries also have a considerable degree of PV penetration [1]. As said, Germany also supports the deployment of battery storage. This combination of tariff and self-generation leads to two main issues:

- Local self-generation reduces off-take by the respective user. However, this does not necessarily reduce the costs caused to the grid. Yet, with the existing energy-based tariffs, the off-take reduction redistributes grid fees towards grid-users without self-generation [9–11]. Their share of fees rises, even though their share of caused costs might stay the same or might even decrease.
- Injection peaks can cause problems and costs for grid operators. Energy-based tariffs provide no incentives to reduce the injection peak. Uncontrolled use of storage can increase the problem by reducing base load while not affecting peak injection [12,13].

These issues have to be addressed in tariff design. In the literature, several proposals for reflective tariff design can be found [14–19]. Specific distribution proposals can be found in [20–25]. These tariff proposals include so-called marginal-cost based tariffs and embedded-cost based tariffs [15]. For the LV-grid, embedded-cost based tariffs are the most relevant [23], thus these tariffs are considered here. For addressing the issues related to self-generation, it is often proposed to focus on tariffs which are, at least partially, capacity-based [8,11,12,26]. An alternative is a move to time-differentiated tariffs [8]. There are thus many possible tariff

* Corresponding author at: KU Leuven, Electrical Engineering Department ESAT-ELECTA, Kasteelpark Arenberg 10, B-3001 Heverlee, Belgium. Tel.: +32 16 32 1714; fax: +32 16 32 1985.
E-mail address: johannes.jargstorf@esat.kuleuven.be (J. Jargstorf).

[1] In the following, the Flanders region instead of Belgium is considered as different regulations apply to the three regions in Belgium.

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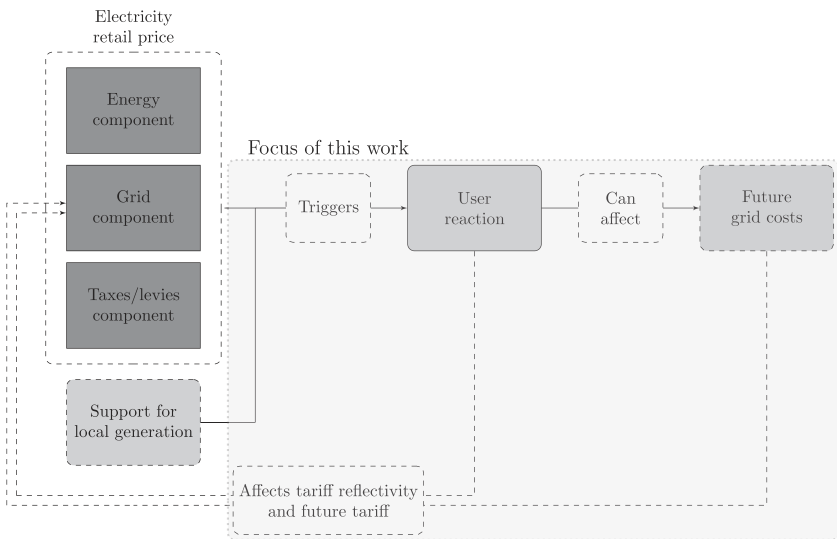

Fig. 1. Interaction between tariff and user reaction.

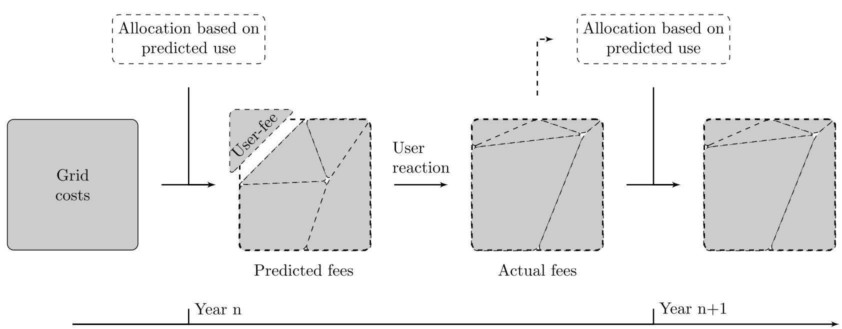

Fig. 2. Interaction between user reaction and allocation.

designs [23]. To define the shares of capacity and energy parts, [24] proposes an optimization model that calculates the cost-reflective shares.

The suitability of a tariff depends on the actual use of the grid which can be a result of the user reaction to the tariff. As part of the retail price, the grid tariff is sent as a signal to the grid-users. Grid-users react to this signal in the short run (e.g. load shift) and in the long run (e.g. investment). The reaction of the users on this ex-ante signal actually defines how reflective costs are allocated. It can also affect the extent of future costs (see Fig. 1). Additionally, the reaction can affect the allocation of costs in the following years, even if the actual costs remain the same. This new allocation again provides signals for a reaction (see Fig. 2). Existing problems with this reaction are outlined in the beginning of this paper.

To assess the reasoning for a change in tariff design, it is therefore important to estimate the extent of the reaction, and the impact on the reflectivity of the allocation and on future costs.

Using self-generation with PV and storage is such a user reaction, which is relevant, as noted in the beginning. Especially (battery) storage is an important aspect, as it can be controlled to react on the tariff. This applies to all tariffs, not only the described energy-based ones. In the literature, however, this problem is only addressed to a limited extent.

A capacity-based tariff, in combination with PV and storage, is simulated in [12]. Results indicate a reduction of the residual load of grid-users and load peaks. Yet the studies are limited to a single household and do not consider allocation aspects and grid upgrade costs.

Results in [10] indicate that redistribution can be avoided through capacity-based tariffs. Yet, fees can be evaded by storage. This work does not include a user reaction specifically on the grid tariff. Also, aspects such as grid upgrade costs are not covered.

A model to compare different tariffs in the MV-grid is proposed in [27]. In that work, user reaction focuses on locational aspects of large generators and not on self-generation. The work also focuses only on future costs, while the allocation between the users is not considered.

To the authors' knowledge, no work addresses this interaction between tariff and user reaction in the described context. To address this issue, in this paper, a framework model is developed which allows comparing the user reaction to different grid tariffs through PV and storage. From the results, the reflectivity of cost allocation and the grid upgrade costs after a user reaction to a given tariff can be derived. This includes the following contributions:

- Efficiency measures for the tariffs, given a user reaction, are proposed.
- A simulation framework to quantify the measures in the context of self-generation with PV and storage in the LV-grid is developed.
- As a case study, an initial capacity tariff is implemented in the framework to derive recommendations based on the proposed measures.

This is done for the present situation in Flanders and in Germany, considering increasing levels of (self-) generation.

The organization of the paper is as follows: The efficiency measures are defined in Section 2. In Section 3, the framework and its five sub-models is described. Section 4 describes the implementation of the model in a case study. There, also the results of the case study are discussed. Section 5 provides a conclusion.