DESIGNING NEW PRICING SCHEMES FOR PROSUMERS

Golnoush Soroush, Politecnico di Torino, Phone +39 3920481684, Email: golnoush.soroush@polito.it
Carlo Cambini, Politecnico di Torino & FSR - EUI, Phone +39 0110907292, Email: carlo.cambini@polito.it

Overview

In recent years, as a result of ongoing discussions regarding overcoming climate change, special attention has been directed towards development of green energy resources as well as energy efficient actions. On one hand, several jurisdictions attempt to promote the settlement of distributed generation. In the European Union for instance, article 14/7 2003/54/EC of the EU electricity directive requires DSOs to consider distributed generation (DGs) as an alternative when planning the distribution network expansion. However, it is important to notice that implementing such directives and eventually entry of DGs to the distribution networks will generate negative externalities for DSOs. In addition, as it is discussed in Jenkins and Pérez-Arriaga (2016), the growing number of distributed generation specially in form of prosumers, make the regulators face various challenges. On the other hand, policies imposing restrictions on carbon emissions, reinforce the exploitation of renewable energy resources such as wind and solar. Technological developments have reduced the installation cost of such resources and made it possible to extend their exploitation as DGs. As a result, traditional electricity consumers can now also become electricity producers, representing the so-called "prosumers".

Prosumers and their effects on electricity production and distribution networks is an emerging subject and it is only in recent years that studies are focusing on this matter. Prosumers' penetration (distributed generation in a broader point of view) can have both negative and positive impacts on the distribution network costs. Low penetration level of DGs can decrease the distribution network costs and the need for excess capacity construction since the overall electricity demand will decrease as a fraction of consumers produce their own electricity. However, as the penetration level of DGs increases, energy losses increase and consequently they impose higher operating costs on DSOs. In order to cover these excess costs, DSOs need to set higher retail prices which will affect not only the electricity prosumers (who are the sources of these extra costs), but also the traditional consumers. In other words, the end-users cross-subsidise the prosumers. To solve this problem the regulator should introduce regulations which would encourage the utilities to invest in their networks and to reduce the distribution energy losses in presence of distributed generation. For instance, the regulator can set specific energy loss targets for the utilities. Furthermore, the corresponding investments by DSOs should be recovered through introducing relevant tariff mechanisms aimed at both prosumers and traditional consumers.

Currently, several methods are used to compensate the utilities as well as the prosumers. Net metering is the most compatible method with the current technological infrastructures including the smart meters. However, there is a debate going on in the literature stating that net metering is not an optimal strategy (see Brown and Sappington 2015 and 2016; Gautier et. al 2016). In particular, applying this model can lead to two major issues: consumers' cross subsidies and utilities' death spiral. Furthermore, to the best of our knowledge, the cost of negative externalities imposed by prosumers on DSOs and related investments required to reduce these effects, are not considered comprehensively in the existing literature on net metering tariff calculations up to now. Therefore, it is relevant to introduce novel tariff structures which not only are compatible with the existing net metering system, but also take into consideration the extra costs which are burdened by DSOs in presence of higher number of DGs.

Methods

We applied a game theoretic model to understand the optimal strategies of the players (DSO, prosumers, consumers). In the model, each type of consumers (prosumers or traditional consumers) try to maximize their utility by decreasing their costs. The utility (DSO) tries to maximize its profit as well, by reducing its operational and capital costs. Finally, the regulator aims to achieve maximum social welfare by setting relevant grid tariffs. Then we used the results of this model and compared the welfare maximization functions to find the optimal tariff scheme set by the regulator. In the whole process, it is important to allocate the costs to all the network users in a way that each consumer type is charged according to its own activities. This mechanism helps to ensure a just allocation of costs between prosumers and other consumers without distributed generation. The primary hypothesis is that it is costly for DSOs to eliminate the externalities caused by integration of DGs. On one hand, a better network infrastructure which facilitates DG connection, will encourage more consumers to become prosumers. This in turn will lead to lower total consumption and therefore lower revenues for DSOs. On the other hand, if the DSO decides to invest in the network to eliminate the externalities caused by the prosumers, its efforts will not be compensated with the current tariff mechanism. Therefore, the regulator should try to compensate the DSO for these costs through setting proper tariffs. In this context, we applied a repeated game to clarify the optimal strategy of each player. The game has a stage game including three players. The regulator who decides whether to consider investments into tariff structure or not. The utility (DSO) which should decide the level of investments. Consumers who would decide whether to become prosumers or not. The game starts with the regulator deciding about including investments in grid tariff calculations. In the next step, consumers, affected by several factors such as the wholesale price of electricity, cost of DG installation and the grid tariff, can choose whether to become prosumers or not. The consumers' decision of becoming prosumers and installing DGs will create some externalities in the network. The effects of these externalities depend on the number of installed DGs and their capacity. Consequently, after observing the decisions taken by the consumers (number of DGs and amount of installed DG capacity), the DSO will decide about the level of network investments. In this stage, the regulator would evaluate the corresponding social welfare outputs and decides about how to compensate the DSO for its investments.

To solve this game, we apply a backward induction method. Starting from the last set of subgames, we analyse the optimal decisions of each of the players according to their corresponding payoffs (SW for the regulator, utility for the consumers and profits for the DSO). For setting up the utility and profit functions of each grid user, we followed a methodology which is closely aligned with a study previously done by Gautier et al. (2016). However, in order to have a better estimation of the payoffs, cost causality method is used to allocate costs to each player responsible for those costs.

Results

When DSOs invest in the network, they will incur extra costs and will need to cover these costs through an increased grid tariff. Evidence from our calculations suggests that if the grid tariff increases, the DSO will fall further into the death spiral effect. Meaning that increasing the grid tariff will encourage more consumers to become prosumers and consequently DSO will lose further revenues and incur further costs. This means that not all investment levels by DSOs are socially optimal. On one hand, these types of investments are necessary for the network to be efficient in long run. On the other hand, it is not socially optimal to include them in DSOs' distribution costs while we have a net metering system. Therefore, regulators should come up with another solution. One solution can be government intervention through subsidising DSOs' investments. In a way that DSOs receive public transfer payments for their investments. If this is the case, the regulator will not include these investments in DSOs' cost function and consequently the grid tariff would not increase. However, the regulator could also decide to subsidies the prosumers. Meaning that the regulator may decide to pay the DSOs, part of the grid tariff which is related to costs caused by prosumers, instead of prosumers themselves paying them.

Conclusions

Currently, as long as more technologically developed meters are not accessible, developing a novel tariff mechanism which considers activities of all players in the grid and their relative effects respectively, in a net metering context, can encourage further network investments by the utilities. By applying such tariffs, the regulator provides the utilities the possibility of recovering the corresponding costs. This would ultimately encourage further investments in renewable sources and contribute to the path of achieving desired climate change targets.

References

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