IMPACT OF E-MOBILITY ON DISTRIBUTION SYSTEMS:THE ROLE OF SMART TARIFFS FOR VEHICLE GRID INTEGRATION

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Overview

Advanced economies and emerging countries are developing net-zero emissions roadmaps to reach carbon neutrality in the mid of this century. They are supported by several international agencies and organizations, which are building different scenarios to reach globally this goal, with all the underlying challenges. In recent times, with the energy crisis triggered by the conflict in Eastern Europe, it appears evident that decarbonization of our economies is also beneficial for energy security, with renewable sources that can be freely leveraged to produce energy decreasing the dependency on fossil fuels (often concentrated in few areas). In last years the electricity sector has been a forerunner in the decarbonization through RES, especially in EU where the CO_2 emissions in this segment decreased by almost 50% in comparison with 1990. However, other sectors lag behind in the decarbonization path, such as transportation: indeed, in the EU transport was the only sector to register an increase of CO_2 emissions (+25%) in 2019 with respect to 1990. Therefore, significant efforts shall be focused on this segment, where according to IEA emissions shall decrease from 2020 levels by 20% in 2030 to be on track to reach carbon neutrality in 2050. One of the most relevant solutions for the decarbonization of transport sector is represented by e-mobility, which can leverage on higher efficiencies compared to internal combustion engines and on the widespread diffusion of renewable power plants that can supply cleaner electricity to the vehicles. The diffusion of alternative vehicles will also be supported by normative initiatives, such as the EU proposal to ban the sale of new fossil fuel cars from 2035, which has been endorsed by the European Parliament.

The transformation of the transport sector, which will be to a larger extent covered through electrification, will have a non-negligible impact on the power system and their infrastructure: alongside the electrification of end-uses which will increase the power consumption in the next decades, a relevant amount of electricity shall be supplied to vehicles, leading to needs for replacement and upgrade of power infrastructure. With regard to e-mobility the major challenges are related to the power component, due to the possibility of having multiple charging events concentrated close to the current power peaks (e.g. in the evening), leading to the substitution of power components such as transformers, feeders and cables. The possibility to leverage on smart charging mechanisms, and in the first place to smart tariff schemes aiming to flatten the demand profile could deliver significant benefits in a systemic perspective.

Methods

CESI developed a methodology and a specific tool to estimate the additional investments needed in a distribution system due to the presence of electric vehicles, and the related savings that can be obtained in case of an improved tariff scheme. In the specific case, the comparison has been done between a flat tariff (a unique price for the entire day) and a Time of Use tariff (enabling to have a lower price during the night, period characterized by a lower electricity demand).

The analysis has been divided in two main tasks: (i) Assessment of the demand of electric vehicles, (ii) Quantification of investments in the distribution grid.

For the first task, CESI developed a proper tool to estimate the demand of e-mobility in a certain area, which consider a series of factors, including:

- Type of vehicles (e.g. passenger cars, light duty vehicles, heavy duty vehicles, bus, etc.).
- Charging points, with differentiation based on nominal power and technology (e.g. unmanaged charging, V1G or V2G).
- Charging behavior (i.e. timing and duration of charging events).
- Charging location, considering habits of different types of users.
- Use of the vehicle (i.e. travelled distance).
- Share of electrification, with the possibility to assess different scenarios of e-mobility penetration.

The type of tariff implemented is also considered in the tool, with the flat tariff that does not affect the time of the day a user will recharge its vehicle, while the ToU tariff incentivizes the driver to recharge the EV when the price is lower. Considering those factors, it is possible to calculate the demand profile associated to EVs with an hourly discretization.

In the second task, according to the information available on the distribution components, a proper classification of the different assets with respect to their load factor (i.e., the ratio between the maximum power and the nominal power) shall be carried out. This activity could be done by splitting the components in classes according to their load factors (e.g., 10% of the transformers present a load factor of 0.9, 20% have a load factor of 0.8, etc.). Subsequently, the conventional load (i.e., the electricity demand excluding e-mobility) is calculated considering the rate of load growth foreseen for the year in the targeted scenario. Through a proper distribution of the electricity demand on the different underlying distribution assets is possible to calculate the new load factors associated to the increase of the conventional load. After setting a proper threshold for the load factor above which the component shall be substituted, it is possible to calculate the investments needed related to the increase of the conventional load. This calculation shall rely upon a solid base of costs related to the specific components and to the area object of the study. Finally, adding the contribution of e-mobility to the electricity demand is possible to identify the eventual new peak power and repeat the previous steps for calculating the new investments needed. In this way it will be possible to clearly identify and quantify the additional investments needed in the distribution grid exclusively caused by e-mobility and compare the cases between flat and smart tariff.

Results

According to the analysis made, which are dependent on the context in terms of load profile and future growth, uptake of electric vehicles and ageing of distribution components, the introduction of a ToU tariff could lead to savings in investments even greater than 50%. However, the possibility to defer grid investments to this extent depends also on the willingness of the users to adopt the tariff scheme and the availability of technologies that could enable a proper programming of the charging events. On the other side, ToU tariffs could represent the first and easiest step for the integration of EVs in the network, suggesting the presence of a relevant potential for investment savings through more complex smart charging technologies (e.g. V1G, V2G) and the possibility to proactively use EVs as a useful resource for the power system.

Conclusions

After a brief recall of the decarbonisation objectives set by the EU with special focus on transport sector, the paper will provide an overview of the tariffs schemes adopted in some key countries highlighting pros and cons for e-mobility, considering the specific environment of Saudi Arabia. Thereafter, the methodology adopted to minimize the investment effort in distribution grids leveraging on tariff schemes will be described in detail. Finally, the possible benefits to the Kingdom arising from appropriate tariff schemes in terms of peak demand reduction will be discussed.