



Contribution ID: 35

Type: **not specified**

May the tariff be with you –How effective tariff designs reduce DSO interventions

Friday, April 4, 2025 2:55 PM (25 minutes)

Flexible consumer electricity tariffs play a crucial role in coordinating demand and supply at the distribution grid level. However, as consumer electricity prices include both a retail and a grid component, potentially providing contradictory incentives, understanding their interdependencies is essential for ensuring efficiency. This study examines the interplay between dynamic grid tariffs and dynamic retail prices. It does so by focusing on electric vehicles (EVs) as a flexibility technology in comparison to inflexible demand at the distribution grid level. Specifically, I compare various time-of-use (ToU) and capacity-based grid charges with fixed, ToU, and real-time retail price rates.

For the analyses, various grid tariff designs are developed and applied in a bi-level problem. On the upper level, the distribution system operator (DSO) sets grid charges in anticipation of consumer demand while trying to recover costs. The retail charges are fixed. On the lower level, consumers react to the sum of the grid and retail charges. The bi-level program is transformed into a mathematical program with equilibrium constraints using Karush-Kuhn-Tucker conditions. The aim is to assess how frequently DSOs need to intervene to maintain grid stability under different grid tariff designs. The approach is applied to heterogeneous distribution grids, with grid constraints being approximated by transformer capacities only.

I expect to observe that the added value of more frequent tariff updates—e.g., yearly, seasonally, monthly, daily—and more granular tariffs decreases with increasing detail. Compared to a fixed network charge, I expect a ToU tariff, set once for an entire year, to reduce the necessity for DSO interventions more intensely than a more frequently updated ToU tariff, such as a monthly updated one. From a fairness perspective, I expect separate tariffs tailored to individual technologies to be most efficient. Regarding the integration of renewable resources, I expect to observe that more granular tariffs reduce the necessity to curtail excess production.

The findings provide insights into the effectiveness of different tariff structures in three key aspects: first, reducing the need for operator interventions; second, maintaining fairness between flexible and inflexible consumers; and third, enhancing the coordination between retail markets and distribution grids. All in all, the results contribute to the ongoing discussion on tariff design for the efficient integration of flexible generation and consumers in future power systems.

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Session Classification: Tariff designs