Co-Simulation-Based Analysis of the Grid Capacity for Electric Vehicles in Districts: The Case of "Am Ölper Berge" in Lower Saxony

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Abstract

Battery-electric mobility represents the most promising post-fossil mobility approach as the number of electric vehicles (EVs) worldwide has grown exponentially in recent years. However, the increased electricity demand resulting from EVs' charging processes was unknown when planning the electric grid of existing districts and nowadays may cause violations of operational boundaries. This paper presents an open-source co-simulation using MOSAIK 3.0 to analyze the effects and impacts of an increasing EV penetration rate on the low-voltage grid. The co-simulation is applied to the existing residential district "Am Ölper Berge" in Brunswick, Germany. Within multiple scenarios, user-sided measures for cooperative energy generation, storage, and smart charging strategies are applied to enhance the grid's capacity for EVs by improving voltage regulation. The most effective measure enhancing grid capacity is the self-developed grid correction model, which mitigates voltage range violations using the flexibility of the district's battery storage systems. Solely adding user-sided measures does not create synergistic effects for the grid integration of EVs. Instead, the smart charging strategies enable exploiting these synergies leading to a significant increase in grid capacity. The extendable co-simulation, including the energy system models, simulation scenarios, and input data, will be publicly available and can thus be used for further research.

1 Introduction

International politics (Glasgow Climate Agreement) and German politics (Climate Protection Act) recently tightened their targets for reducing greenhouse gas (GHG) emissions. The German target of reducing GHG emissions by 65% until 2030 particularly affects the transport sector, which contributed 19% of total emissions in 2021. Battery-electric mobility represents the most promising post-fossil mobility approach, as the number of registered electric vehicles (EV) worldwide has grown exponentially in recent years, with a doubling of sales from the previous year to 6.6 million in 2021 [1]. Consequently, the number of charging points and the corresponding charging infrastructure must also grow. The increased load from these charging processes was not considered while planning and building the electric grid of existing districts and nowadays may cause violations of operational boundaries [2]. Grid-sided measures to enhance the grid capacity are effective but cost-intensive and require an intervention in the grid, and its environment [3]. User-sided measures which arise from the growing dissemination of distributed energy resources such as photovoltaic (PV) systems [4] or battery storages [5] represent promising alternatives. In districts, this promotes the establishment of energy communities which are a crucial element for the vision of a renewed sustainable EU energy system according to the Clean Energy Package of the European Union [6]. "Energy community" is a collective term for multiple actors with a geographical connection that jointly consume, produce and share renewable energies [7, 8]. This research aims to analyze the effects and impacts of an increasing EV penetration rate on the low-voltage grid in the residential district "Am Ölper Berge" in Brunswick, Lower Saxony in Germany, and to determine the maximum possible grid capacity for EV charging. Identified limiting factors are then considered in multiple scenarios, turning the district into an energy community. In these scenarios, opportunities for different levels of cooperative energy generation, storage, and smart charging strategies are applied to enhance the grid's capacity for EVs. The simulation scenarios, the used models (self-developed and modified existing ones) are accessible under an open-source license (see [9]) enabling a transparent research process and improving research quality and accessibility as called for in [7]. Researchers can extend the co-simulation with their own models or implement and examine various other districts and communities. Additionally, [7] call for meta-studies, applying models from different sources and authors to the same real-world case to show similarities and differences. This work facilitates this, as all input data will also be open-source. The paper is structured as follows: Section 2