POTENTIAL GRID-SERVICE-ORIENTED AND MARKET-ORIENTED OPTIMISATION OF A LOCAL CHARGING INFRASTRUCTURE THROUGH A GENETIC ALGORITHM

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Motivation

The electrification of the mobility sector is one of the implemented strategies to meet the challenges of climate change. This energy transition has led to a rise in the total number of electric vehicles (EVs) in Germany from 84 thousand in 2018 to almost 620 thousand by the end of 2022 [1]. Likewise, during the same time window, the Plug-in-Hybrid vehicles (PHEV) stock has increased from 67 thousand to 864 thousand [1]. The growth of the EV and PHEV fleet has led to the development of the public charging infrastructure (CI) and, consequently, charging points (CPs). The total number of CP increased from almost 20 thousand in 2018 to 84 thousand in 2022, of which 17 % corresponded to fast CP in 2022 [2]. This fact results in a potential simultaneous charging power demand of 2.8 GW [2], which could lead to critical operational conditions. Through the management of the charging processes, it is possible to exploit the flexibilities of EVs and PHEVs to mitigate potential bottlenecks in the electrical power grid. On the one hand, these flexibilities could have a grid-service character to support the grid operation in critical situations [3]. On the other hand, in the absence of grid requirements, they can be traded in suitable energy markets to generate economic revenues [4].

Methodology

This contribution presents the market-oriented and grid-service-oriented optimisation's potential for specific days of the CI located at the Freudenberg Campus of the University of Wuppertal. The CI can simultaneously deliver up to 176 kW through its six charging stations, two of which have two CPs, while the rest have one CP. Through a tool for the generation of probabilistic driving and charging profiles (PDCP) for EVs from previous works [5], the CP's occupancy schedules are determined. Likewise, using historical data of the charging processes, it is possible to determine the parameters of the mathematical models of the respective battery and battery management systems of the charging EVs. These models are usually non-linear and are based on the constant current constant voltage charging (CCCV) method [7].

It is not straightforward to determine the maximum charging power for each time block that leads to the optimal operating point. Such optimal operating point depends on the governing objective function. The objective function may seek a reduction in operating costs [4] or meet a grid requirement [8]. The reduction in operating costs is scheduled a day in advance and it is achieved through the load shifting to times of day when Day-Ahead (DA) market prices are profitable. The grid requirement occurs over a shorter time horizon and it is achieved through a temporary reduction or increase of the power demand of the entire CI at a certain time of the day. An additional constraint must be here considered to reduce the potential energy demand variations with respect to the original marked-oriented schedule. Regardless of the objective function, certain user comfort criteria must simultaneously be guaranteed, i.e., the EVs' state of charge (SoC) at departure must satisfy minimum requirements.

Since the optimisation problem considers non-linear models, different objectives and constraints, Genetic Algorithms (GA) appear as an alternative to conventional optimisation methods. They are capable of considering approaches to examine a wider range of potential solutions that are not intuitively easy to determine, although the final solution might turn out to be suboptimal but still acceptable [9]. The

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paper details the GA parameters' calibration process that improves its convergence speed. It also describes the scenario's selection criteria, which are linked to the daily energy production through renewable energies. Finally, the results of the market-oriented operation are shown and compared with the conventional non-optimised operation (Business as usual - BAU) for each of the defined scenarios. The potential of CI to support grid operation through its flexibilities is also analysed. A general review of the considered methodology is presented in Figure 1.

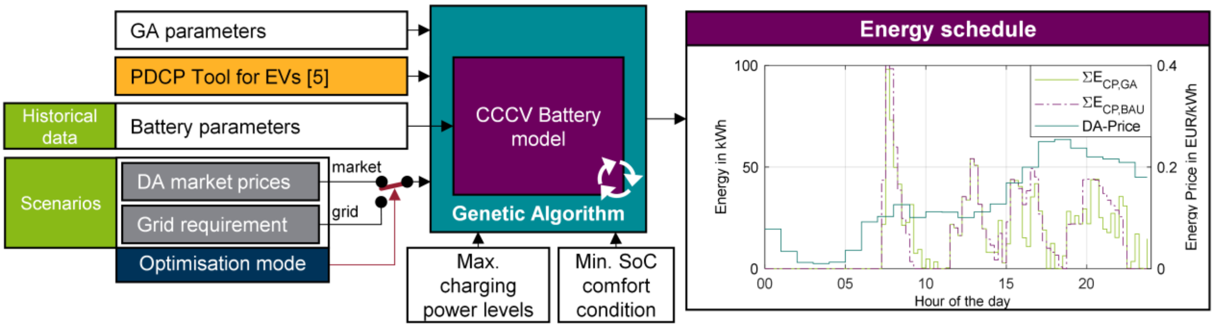

Figure 1: Methodology overview and preliminary market-oriented optimisation results for a given scenario

Preliminary Results

Early results reveal the CP's potential of the case study CI to reduce their operational costs through a market-oriented optimisation considering the DA market. On the right-hand side of Figure 1, the planned energy demand for a representative winter day of 2022 is presented. Here, the market-oriented operation through GA optimisation and BAU operation are considered. Compared to the BAU operation, GA optimisation enables a reduction of the operating costs by 8 %. The results for further scenarios, as well as for the grid-service-oriented operation and the user comfort role will be addressed in the paper's extended version.

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