Considering Control Approaches for Electric Vehicles in Grid Planning

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Abstract

In this publication, we introduce a methodology for power system planning that considers grid-friendly electric vehicle charging. This methodology is developed within the research project "Ladeinfrastruktur 2.0" in which the cost-optimized integration of electric vehicles into the energy system is studied [1]. It is presented how control strategies for electric vehicles, which were also considered in the field test project "E-Mobility Allee" by the German distribution grid operator (DSO) Netze BW [2], can be integrated into probabilistic, time series-based approaches to determine necessary grid reinforcement and extension measures. The planning is based on worst case situations, which are identified with time series simulations. Since these simulations are computationally expensive, it is crucial to efficiently integrate control strategies into this process. Planning the grid with and without grid-friendly charging methods allows assessing the potential for reducing necessary grid reinforcement with these strategies. To illustrate this process, grid planning results with consideration of a grid-friendly control strategy in real low-voltage grids are presented. Finally, conclusions regarding real-life applications can be drawn based on those results.

Motivation

The growing number of electric vehicles in the electric energy system can pose a big challenge, if the additional load causes congestions that have to be mitigated with grid reinforcements. Determining and optimizing the overall cost of the integration of electric vehicles into distribution grids is one of the main goals of the research project "Ladeinfrastruktur 2.0" that is funded by the German Federal Ministry of Economic Affairs and Energy [1]. As the overall costs are significantly influenced by the amount of grid extension measures that are needed to mitigate grid congestions, the effect of additional electric vehicles in the energy system needs to be analyzed. When doing so for future scenarios of electric vehicle penetration, it is also important to consider the influence of control strategies for electric vehicles, since they can have a significant impact on critical grid situations and therefore influence the need for grid extension measures considerably. The practical effect of such control strategies was shown in the "E-Mobility-Allee", which is a field test project by the German distribution grid operator Netze BW, where the effect of a large share of electric vehicles in a street was investigated [2]. The analyses of this field test illustrated that critical grid situations can be weakened notably when control approaches are applied to the charging processes of the electric vehicles [3], which can lead to a reduction in necessary grid reinforment measures. An additional advantage of controlled charging for grid operators is a much better planning realiability of the power demand of electric cars and their impact onto the grid. To achieve universally valid statements regarding the findings of the field test, analyses involving a high number of probabilistic time series-based simulations are needed. These simulations are performed with grid-friendly control strategies for electric vehicles that are defined and analyzed within the mentioned research project [4]. In order to consider these in approaches for determining grid extension measures, a new methodology for their integration needs to be developed, which is presented within this publication.

Structure

First, the state of the art of considering electric vehicles in conventional grid planning is introduced. Using simultaneity factors, the worst case grid situation that occurs with electric vehicles in the grid can be assessed, which is the basis for the determination of necessary grid extension measures [5]. However, the time of occurrence of this worst case grid situation cannot be determined with certainty. Moreover, this approach is only applicable for vehicles with uncontrolled charging processes as simultaneity factors can only model behavior of electric vehicles that do not take the grid situation into account. While it might be applicable for simple, grid-independent control strategies like static power curtailment, another approach is necessary to integrate grid-dependent dynamic control strategies, which is the case for many control approaches in the project "Ladeinfrastruktur 2.0". In order to estimate their influence on grid extension measures, their effect on the worst case grid situations needs to be analyzed. Their time of occurrence and corresponding load profiles that caused this problem are needed as an input for these analyses. The approach using simultaneity factors is not applicable here, as it cannot provide this information. Therefore, time series-based simulations are required to determine the worst case situations without any active control strategy, their time of occurrence and the corresponding load profiles that caused them. This is achieved by means of a probabilistic approach that assigns randomly chosen charging profiles to all charging points in the grid and calculates the resulting grid situations. Repeating this process for a large number of iterations provides a distribution of possible grid situations. Based on this distribution, the worst case that occurred over all probabilistic iterations can be identified, along with the

according load profiles. With this information, the resulting grid situations with an active control strategy at the time of occurrence of the original problem can be found by performing control strategy simulations for the determined time frame. Based on this, the required grid extension measures with an active strategy can be determined by means of a heuristic optimization. However, if these simulations were carried out only for selected time frames, this could lead to false conclusions: The worst case situations with and without active control strategies might occur at different times during the year, e.g. due to a shift of load peaks. Many control strategies are time-dependent and are therefore often influenced by past grid situations or prognoses, which would be partly disregarded with this particular approach.
Subsequently, a new methodology for the consideration of control strategies in the calculation of grid extension measures is introduced in this publication. It uses a similar approach as the aforementioned time-series based one but considers the control strategies differently. In this approach, it is not assumed that the worst case grid situations occur within the same time frame and are therefore determined independently with and without an active control strategy. Based on this information, the resulting grid extension measures can be determined and compared to those without any active control strategy. The schematic representation of the methodology is shown in Figure 1. The dashed outline of the consideration of control strategies means that the sequence of the methodology can be performed with and without this component to enable comparisons. This sequence would need to be repeated for a large number of different grids to obtain a result that can be generalized, which results in a very high number of calculations to find the necessary grid reinforcements for one particular scenario. This procedure helps find the most fitting control strategies for reducing grid extension measures. Finally, results of the application of this methodology are presented to highlight its functionality.

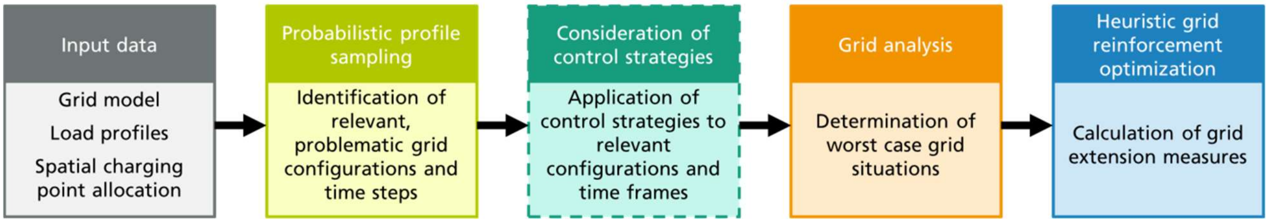

Figure 1: Schematic representation of the methodology sequence

Results

This publication presents a methodology that facilitates the consideration of the effect of grid-friendly control strategies in calculations to determine grid extension measures. To demonstrate the functionality of the methodology, an investigation is carried out, where necessary grid extension measures with and without a control approach for electric vehicles determined in real low-voltage grids are presented. These results are compared to findings from the field test project "E-Mobility Allee" in order derive conclusions for practical applications.
Moreover, the advantages of the methodology in contrast to other approaches are illustrated. While control strategies for electric vehicles are investigated in many publications, only few of those tackle the issue of their influence on grid reinforcements. Some authors, e.g. [6], also use probabilistic approaches. However, the modular, scalable and computationally efficient method introduced in our paper allows for more detailed analyses and larger time frames, aiming at practical applicability in real grid planning processes. Besides, our hybrid approach of time series-based worst case assessment enables the consideration of control strategies as well as heuristic grid reinforcement optimization.

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