Hosting Capacity Analysis and Managed Charging Solutions for Electric Vehicle Grid Integration

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Abstract It is important for the DISCOMs to ascertain the location and time of charging in order to manage demand response. Electric Vehicles as additional load potentially run the risk of overloading local transformers especially during peak hours of the day. This paper includes a sample HV/LV N/W case study for E-mobility specific Studies in a Software Tool "NEPLAN" covering the typical Outputs of Load Profiling, Hosting Capacity Analysis (HCA) by Connection Point Power / Aggregated Power, Load Flow Time Simulation; and Sensitivity of Bottleneck Equipment wrt to Max ΔV. Charging of fleets would also require special attention from utilities for Depot and cluster charging since they would have strong geographically concentrated load with a distinctive charging profile depending upon the nature and use of an EV Fleet. All this increased load if unmanaged would have an impact on the distribution network leading to irregular load patterns. Additionally, since majority of EV charging is expected to be done at home, during nights the EV loads may also alter the daily load pattern for the DISCOMs. It also highlights the latest trend of Charging Management Systems focused on providing cheaper charging tariffs and the use of smart or managed charging solutions. Managed Charging could be divided into two major categories: Passive Managed Charging solutions that rely on customer behavior to affect charging patterns; Active Managed Charging that relies upon a bi-directional flow of information through multiple communications technologies. However, there is lack of industry protocols for the managed charging.

Keywords E-mobility · Neplan · Hosting capacity analysis · Load flow time simulation · Charging management systems

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R. K. Pillai et al. (eds.), *ISUW 2021*, Lecture Notes in Electrical Engineering 843,
https://doi.org/10.1007/978-981-16-8727-3_16

1 Introduction

With the exponential growth of electrical vehicles soon, utilities need to be prepared to maintain reliability of the grid. The primary impacts on electrical systems are generation adequacy, generation flexibility, transmission grid capacity, and distribution grid capacity.

The main challenge of electrification of transportation expansion lies in the distribution networks and the overloading of network assets:

- Medium voltage substations may be needed (exceed feeder hosting capacity)
- Replacement of the head feeders and the distribution transformers
- Cable sections downstream may still lead to voltage limit violations
- Peak winter or summer demand, heating and cooling

Central challenges for Distribution System Operators consist of communicational and computational barriers, low visibility on distribution grid, optimal allocation of charging infrastructure, lack of regulation and market rules, and network codes devolvement.

2 Challenges of EV Growth

The typical challenges of EV growth that all the stakeholders face are:

- Lack of Regulation and Policy
- Low visibility on distribution grid
- Optimal allocation of charging infrastructure
- Medium voltage substations may be needed (if feeder hosting capacity exceeds)
- Replacement of the head feeders and the distribution transformers
- Cable sections downstream may still lead to voltage limit violations
- Peak winter or summer demand, heating and cooling
- Unmanaged Charging
- Analyzing regional scenarios with different e-mobility diffusion levels
- Potential challenges caused by the uncontrollable charging in different parts of power systems
- Technical solutions which can mitigate potential grid issues

Figure 1 indicates the EV charger types and typical integration in the Grid.

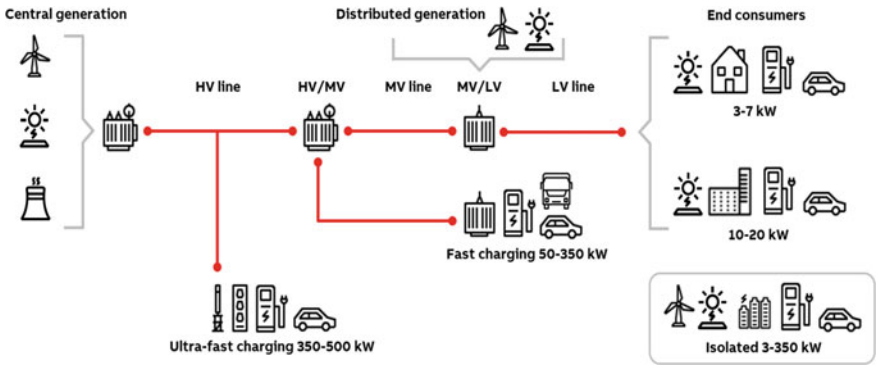

Fig. 1 Electric vehicle connecting to the grid

3 Grid Integration Analysis

The optimized solution for e-mobility charging, power grid management, and planning, Grid integration impact analysis of EV would typically require the following:

- Electric Vehicle (EV) load demand pattern
- Evaluation of distribution grid hosting capacity
- EV impact on distribution grids power quality
- Generation flexibility and response impact
- Cost–benefit analysis
- Analysis of international regulatory frameworks

The detailed E mobility specific power system analysis may be performed by very few software's, one such Simulation Software "NEPLAN", with the feature Hosting Capacity Module is detailed herewith. The Calculation criteria must be selected based on the application. "System Aggregated Power" would give a glimpse of total maximum power a network can support, whereas "Connection Point Power" would give the maximum power that can be connected on a specific location/node (Figs. 2 and 3).

Typical Analysis outcomes are as below:

These Integration have also to be aligned with the International, National and Local DER integration guidelines, few of them as specified in [2–7] and [8] (Figs. 4 and 5).

4 Managed Charging Infrastructure

Managed electric vehicle charging is an intelligent system that can control the time and/or rate of charging of one or more electric vehicles. Managed EV charging

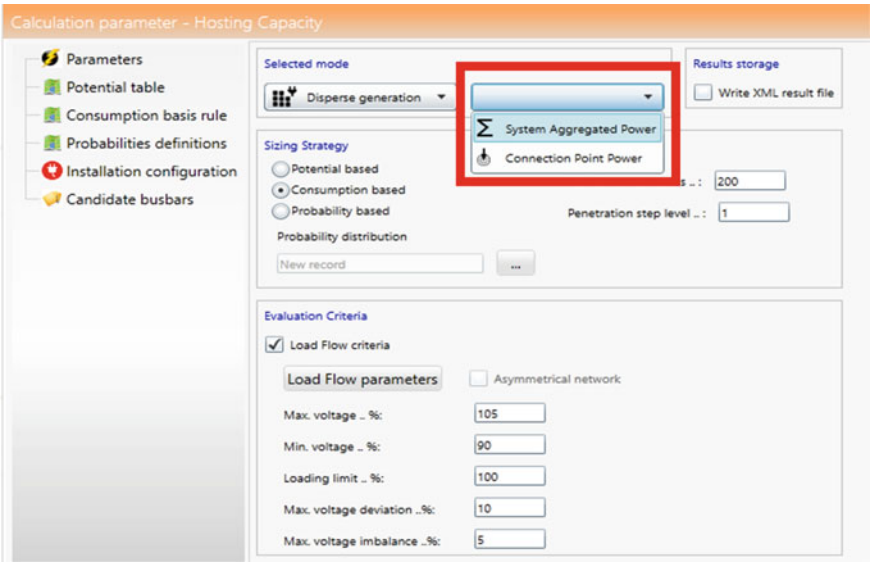

Fig. 2 Calculation strategy for hosting capacity analysis [1]

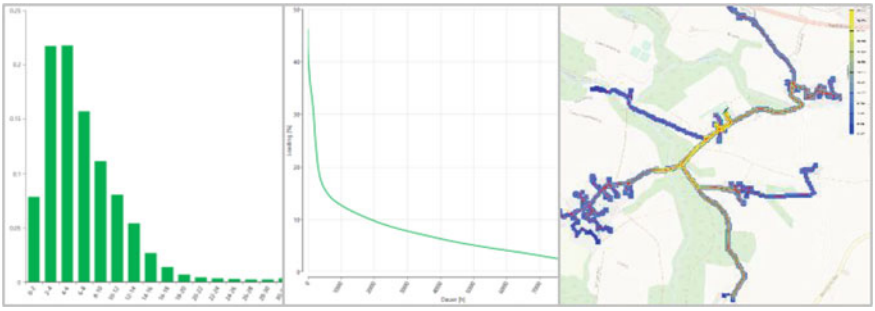

Fig. 3 Result of a time simulation—histogram, duration curve and heat map of the loading [1]

systems generally consist of three key components; a smart charger, a control system and the service user.

EV Assisted DSM: The development of EVs offers benefits not only in environmental protection and economics but also in demand response. Employing EVs in load scheduling enables the consumers to help alleviate the network load burden while reducing their own electric bills. For a household network, EV can be used as an auxiliary power supply for energy consumption of home appliances on special occasions, Energy Sharing Model can be developed for a cluster of houses. However, various factors like EV Behaviors, Scheduling patterns, user preferences must be taken into consideration while designing any such model.

Fig. 4 Result of the module hosting capacity: maximum loading depending on the additional charging power [1]

Fig. 5 Analysis of module hosting capacity—different penetration levels of charging stations in a distribution network [1]

Integration of Solar PV and Battery with charging Infrastructure: The application of renewable sources such as solar photovoltaic (PV) to charge electric vehicle (EV) is an interesting option that offers numerous technical and economic opportunities. An energy management strategy based on optimal power flow is also proposed by integrating a solar PV generation system with charging station to alleviate the impact of fast charging on the grid. The combined system along with the power output of

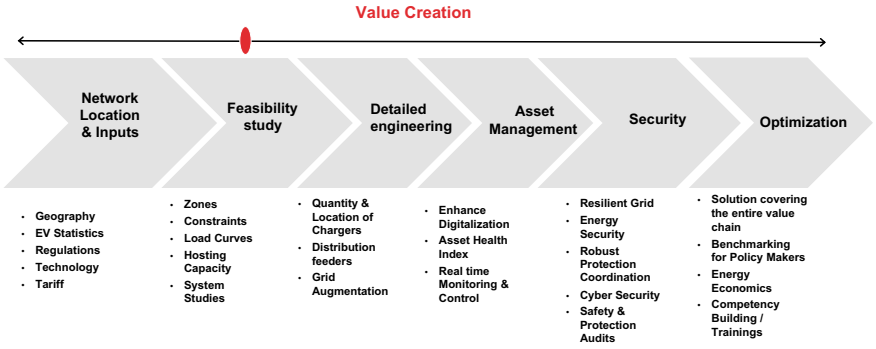

Fig. 6 Optimized solutions for various EV integration stages

EV fleet batteries available at the charging station reduces the net energy provided by the grid, thereby decreasing the overall load on the grid as well as minimizing the conversion losses.

Managed Charging could be divided into two major categories: Passive Managed Charging solutions that rely on customer behavior to affect charging patterns; Active Managed Charging that relies upon a bi-directional flow of information through multiple communications technologies. However, there is lack of industry protocols for the managed charging.

5 Conclusion

It is interesting to note that by a detailed Hosting Capacity Analysis, the challenges of Grid integration can be met with. The Electric Vehicle (EV) load demand pattern, Evaluation of distribution grid hosting capacity, EV impact on distribution grids power quality, Generation flexibility and response impact, Cost–benefit analysis and Analysis of international regulatory frameworks are significant aspects that would accelerate the growth of upcoming EV technology. Glimpse of value creation at various stages is also presented in Fig. 6.

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