Shifting to Off-Peak Electric Vehicle Charging to Save Billions

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Summary

- The Electric Vehicle (EV) market is transitioning from AC charging to DC fast charging.
- The widespread use of EVs may lead to reduced reserve margins in the electrical system.
- Eventually, all electric truck charging stations will be connected to the Medium Voltage (MV) grid.

AC chargers were of primary importance when the EV market was starting but ~~over the years~~ in the last decade (2010-2020) we are observing a transition from overnight slow AC charging to fast DC charging. The shift from AC to DC fast charging is largely driven by:

- The need for fast charging solutions to cater to range anxiety.
- DC charging is more energy efficient than AC charging.
- Increased car battery sizes have rendered AC charging in certain cases infeasible.

Impact of EVs on the grid

As far as the impact on the generation side of the power sector, a greater penetration of EVs will reduce reserve margins in the electrical system.

Definition: Reserve margin ensures that there is more supply than demand. It is essentially the excess capacity in percentage divided by the peak demand of an electrical system ((capacity minus peak demand)/demand). Reserve margins in an electrical system are maintained at a significant cost, falling under capacity charges, and are essential to ensure loss of load is avoided in case of an emergency

A reduction in reserve margins means reduced reliability of the system and additional generation capacity will have to installed in the system. Secondly, reserve margins vary from region to region depending on local conditions and also depend on the nature of generation. For instance, in the U.S., the North American Electric Reliability Corporation (NERC) assigns 15% reserve margin for thermal plants and 10% for hydro plant.

EV charging also imposes an additional load on the transformer which in turn increases the distribution transformer's Loss of Life (LOL) and if the transformer's LOL is allowed to uncontrollably increase it will increase the maintenance requirements and would require early replacement of the transformer.
To mitigate the impact of EV charging on the transformer:

- Bidirectional communication can be installed between the distribution transformer and the charging stations in order to learn the local load profile. Consumer's charging preferences can be adjusted so requirements are met while still keeping a smooth load profile which is beneficial to the transformer.
- DISCOs will have to upgrade their distribution lines and may require additional maintenance and replacement of conductors or further increasing the capacity of overall system.

Cost to Upgrade the Grid

The cost of upgrading the grid will be paid by utilities in most cases. Utilities are expected to recover some of costs from additional sales from EV charging, but they may also have to increase the rates to their customers. Investment costs are likely to increase exponentially as the EV adoption ramps. Hence, pressure on retail rates may be observed in the later stage of market.

Readiness of grid infrastructure for ultra-fast charging

According to PTR the majority of the destination chargers (chargers that are installed by businesses and landowners (e.g. hotels, restaurants) for public use) by 2025, are expected to be of the DC high power category (150-500 kW) where majority of the enroute chargers by 2025 are expected to be in the DC high power category. So, to deal with the detrimental impact of ultra-fast charging on grid long term planning would be required which involves significant investments for reinforcements and modernization of grid.

In the long run, all electric truck charging stations will be connected to the Medium Voltage (MV) grid. The MV grid has a capacity of several MWs and is much less vulnerable than low voltage distribution side.

Time of use optimization and bi-directional communication

Time-of-use (ToU) optimization of EV charging is essential to shave off peak demand. This is achieved by incentivizing consumers to shift their demand from peak hours to off-peak hours. For public charging, the peak load is during the day and in residential charging, the peak load is during the night-time. Unlike, the flat rate tariff, ToU tariff electricity price depends on whether it is peak or off-peak hours. To mitigate the impact of EV charging on the grid, it is imperative that the demand is shifted to off peak hours during ToU tariff regime so that billions of dollars in capacity addition costs are saved. In the U.S., alone it is reported that by shaving off 5% peak demand we can relinquish the need to add 625 power plants in the system.

As mentioned earlier bidirectional communication between the grid and the EV charger is important especially when it comes to shaving off peak demand, managing transformer's load and overall voltage stability. Commercial chargers already have that feature. As seen in Figure 2, the interaction of electric vehicles with the grid can be optimized with technologies like Vehicle to Grid Integration (V2G) which allows bi-direction flow of communication and electricity. Although, smart grid technology is a pre-requisite for V2G, once it is incorporated, it will allow for localized balancing of the grid which will reduce the losses incurred on the distribution side and cater for issues like voltage stability.

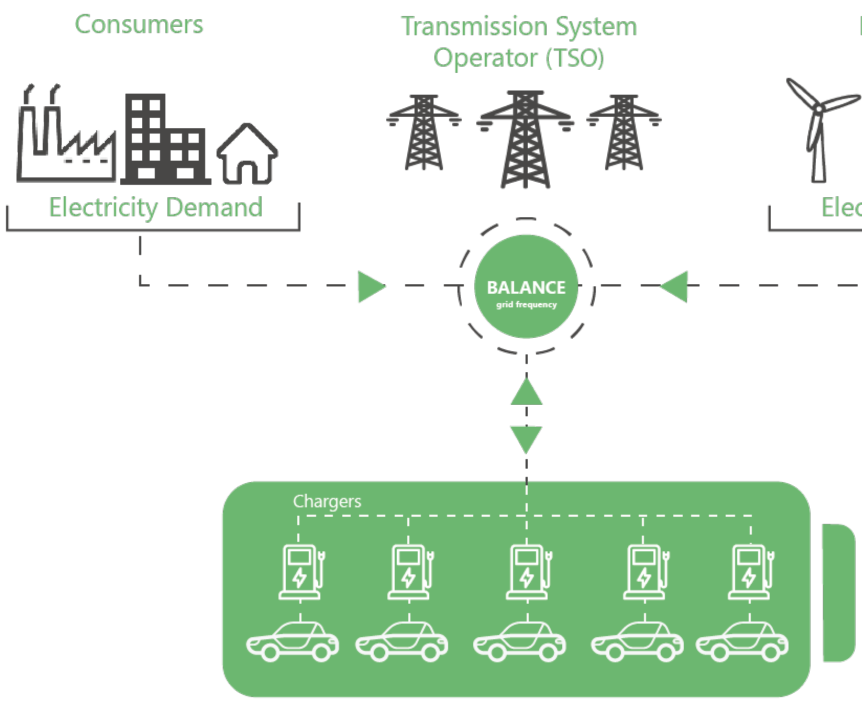

Figure 1: Vehicle to grid integration.

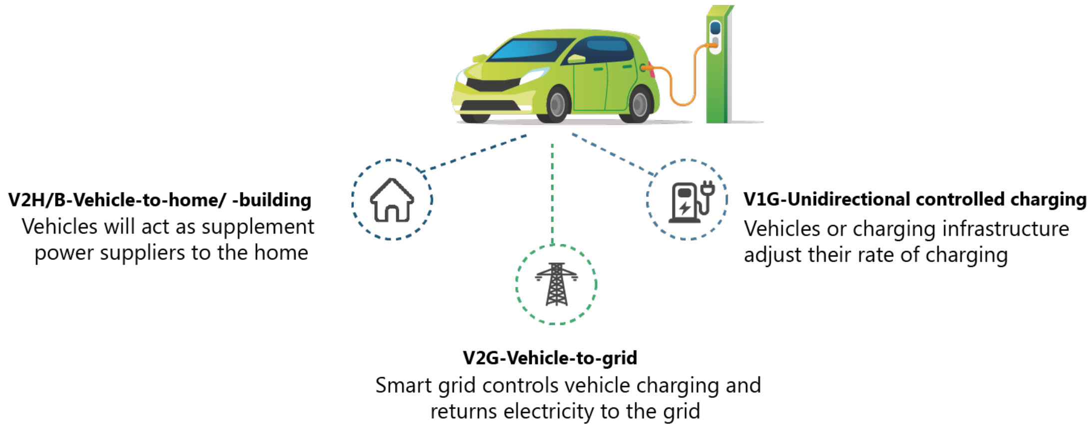

Figure 2: Different types of charging.

Looking Ahead

To reduce the impact of EVs on the grid and ensure the grid’s reliability, a multi-prong approach may need to be considered. Besides the obvious grid capacity additions there will be:

- Time-of-use (ToU) optimization- to shave off peak demand
- Efficient batteries in EVs - extending the time between charging.
- Vehicle to Grid Integration (V2G) - allows the bi-direction flow of communication and electricity which allows for localized balancing of the grid

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