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Review of Impact of Electric Vehicle Charging on the Electrical Grid

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***Abstract* - In response to the ever-increasing demand for energy and climate change, the concept of e-mobility has emerged in the 21st century, with a shift from conventional vehicles to electric vehicles (EVs). However, the growing number of EVs poses a significant threat to the power distribution network. The increase in demand for power required to charge EVs may impact the smooth performance of the power distribution network. It is therefore essential to analyze the impact of EV charging stations on the power grid to ensure its secure and stable performance. Extensive research has been conducted in recent years on the effect of EV charging stations on the power distribution network, and this review study considers the literature on this topic.**

Keywords: Charging station, Electric Vehicle, Peak load, Power grid, Voltage stability.

I. INTRODUCTION

Due to growing environmental concerns associated with vehicles powered by internal combustion engines (ICE), there has been a surge in the market for electric vehicles (EVs). EVs play a crucial role in reducing air pollution and greenhouse gas emissions. Despite some shortcomings, such as limited driving range, high battery costs, short battery life cycle, and scarcity of electricity for charging, EVs are gaining popularity. As a result, there is an urgent need to analyze the impact of charging station loads on the power grid network. The increase in load due to EV charging may have adverse impacts such as voltage instability, reduced reserve margin, deteriorated reliability indices, and power quality issues. On the other hand, the implementation of the vehicle-to-grid (V2G) concept can enhance the performance of the power grid. Extensive research in the field of EVs in the 21st century has led to various areas of study, including the impact of EV charging stations on the power grid network.

II. EV CHARGING INFRASTRUCTURE

Charging stations serve as the primary point for refueling electric vehicles (EVs) and are composed of cords, connectors, and interfaces with the power grid. A robust charging infrastructure is a crucial factor for the widespread adoption of EVs. The Electric Power Research Institute (EPRI) has classified charging levels into three categories: Level 1 AC, Level 2 AC, and Fast Charging DC.

TABLE I. Comparative Analysis Of Different Charging Levels

Type	Input voltage	Input current	Charging time	Typical use
Level 1 AC	120 V	15 A	10-13 Hrs.	Home or Office
Level 2 AC	240 V	40 A	1-3 Hrs.	Private or Commercial
Level 1 DC	208 V	80 A	0.5-1.44 Hrs.	Public

Table I provides a comparative analysis of various charging levels, taking into account input voltage, current, charging time, advantages, and drawbacks. In addition to the charging levels mentioned above, wireless charging methods for EVs have gained popularity among users. This technology uses an electromagnetic field to transfer electricity to the EV battery.

III. IMPACT OF EV CHARGING STATION ON POWER GRID

The electrification of the transportation sector has numerous benefits, including reduced CO2 emissions, decreased pollution, and less global warming. However, the negative impacts of EV chargers on the power distribution network cannot be ignored. Despite this, the V2G concept can also produce favorable impacts on the power distribution

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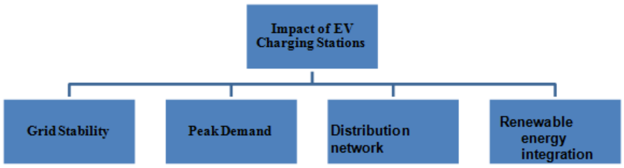
network. Figure 1 shows the operating parameters that are affected by the placement of a charging station.



The uncoordinated charging of a large number of electric buses can have significant impacts on the electrical grid. Here are a few possible impacts:

Peak demand: Uncoordinated charging of electric buses can lead to a sudden increase in electricity demand during peak hours. This can put a strain on the electrical grid, especially if the grid is not equipped to handle sudden spikes in demand. This can lead to power outages or brownouts, which can have significant economic and social impacts.

Grid stability: Uncoordinated charging of electric buses can also affect the stability of the electrical grid. The sudden increase in demand can lead to voltage fluctuations, which can destabilize the grid and potentially damage electrical equipment. This can cause disruptions to the grid and increase the risk of power outages.

Distribution network: Uncoordinated charging of electric buses can also affect the distribution network. The sudden increase in demand can overload transformers and other electrical equipment, leading to damage and potential failures. This can result in longer downtime and higher maintenance costs for the utility companies.

Renewable energy integration: Uncoordinated charging of electric buses can also affect the integration of renewable energy sources into the grid. If a large number of electric buses are charged simultaneously, it can lead to a mismatch between electricity supply and demand. This can make it more difficult to integrate variable renewable energy sources, such as wind and solar, into the grid.

To reduce these impacts, utilities can implement a variety of strategies, such as coordinated charging, smart charging, and time-of-use pricing. Coordinated charging involves scheduling electric bus charging to prevent sudden increases in demand. Smart charging employs software and sensors to optimize charging based on electricity demand and availability. Time-of-use pricing involves charging higher rates during peak hours to incentivize users to charge during off-peak hours. These strategies can mitigate the effects of uncoordinated charging on the electrical grid.

Positive Impacts of V2G scheme

The concept of Vehicle-to-Grid (V2G) involves electric vehicles that are plugged in interacting with the grid by returning their excess power to the grid. This provides charging stations with an opportunity to generate revenue. Table II details the benefits of this V2G scheme.

TABLE II. ADVANTAGES OF V2G SCHEME [13]

Sl No	Benefit
1	Peak load shaving
2	Spinning Reserve
3	Load management
4	Stabilize grid voltage
5	Line loss reductions
6	Frequency control

IV. DISCUSSIONS

The key discoveries of this review work are presented in this section. All the research works examined reach a consensus that introducing EV charging load can negatively affect the operating parameters of the power grid. However, despite these negative impacts, the potential benefits of the V2G scheme cannot be ignored. Future research in this area should focus on the following directions:

1. Analysis of the effect of EV charging station on reliability indices
2. Analysis of the effect of EV charging station on economic losses incurred by the utility
3. Mitigation of the negative impacts of EV charging loads by coordinated charging

V. CONCLUSIONS

The increasing concern for air quality has led to the electrification of transportation. To address the limited driving range of EVs, charging infrastructure has been established globally, but this has also brought about the challenge of increased load and security risks to the power grid. Recent research studies have shown that poor planning of EV charging stations could cause disruptions to the power system's smooth operation. Therefore, when planning the charging infrastructure for the power system, it is crucial to consider the power network's operating parameters. This review paper provides a qualitative and quantitative analysis of recent literature in this field, identifying research gaps and suggesting future research directions.

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