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A Review paper of impact on power grid system's stability during electric vehicle charging

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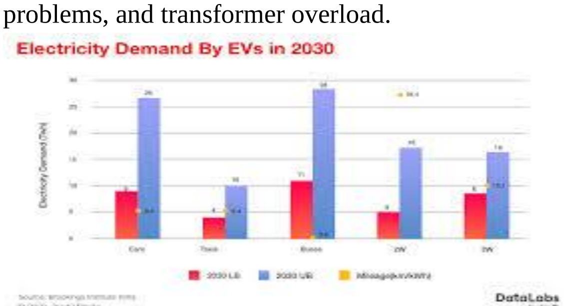
***Abstract*—This study investigates the impact of electric vehicle (EV) adoption on Delhi's power grid, focusing on charging patterns, demand analysis, and infrastructure requirements. The research aims to:**
1. Analyses EV charging behavior: Understanding when and where EVs are charged.
2. Assess grid impact: Evaluating the effects of EV charging on electricity demand and system stability.
3. Identify infrastructure needs: Determining necessary upgrades to support increased EV adoption.
The study also considers the integration of renewable energy sources, aligning with sustainable development goals and environmental objectives.

***Index Terms*—Electric Vehicles, Grid Integration, Charging Infrastructures, Environmental Impact, Megacities**

I. INTRODUCTION

The global market for electric vehicles (EVs) is growing rapidly, driven by environmental concerns and government incentives. As EV adoption increases, it's essential to understand their impact on the power grid. EVs offer several benefits, including reduced air pollution and greenhouse gas emissions. However, their charging can strain the grid, causing issues like voltage instability, power quality problems, and transformer overload.



Research Objectives
This study aims to:
1. Review EV charging infrastructure: Providing an overview of charging systems and their impact on the grid.
2. Analyze grid impacts: Examining the effects of EV charging on voltage stability, power quality, and transformer lifespan.
3. Explore future directions: Discussing potential solutions, such as advanced charging technologies, smart grids, and renewable energy integration.
The goal is to provide a comprehensive understanding of the challenges and opportunities associated with EV adoption, informing strategies to mitigate grid impacts and promote sustainable transportation.

Literature Review
Electric Vehicles and Grid Integration
The growing adoption of electric vehicles (EVs) globally presents opportunities for reducing carbon emissions and advancing power grid integration. Studies predict that EVs will significantly impact city carbon outputs, with some estimates suggesting they will account for 25% of vehicles on the road by 2040.
Global Trends and Best Practices
Research highlights the importance of understanding global trends in EV charging infrastructure and its impact on local electricity networks. Effective strategies for promoting EV adoption include:
1. Rewards and incentives: Governments can offer incentives to encourage EV adoption.
2. Charging infrastructure: Developing comprehensive charging networks is crucial for widespread EV adoption.
3. Pilot schemes: Implementing pilot programs can help test and refine EV-related policies.
Research Gaps and Future Directions
While there is extensive research on EV deployment and grid integration, specific studies on Delhi's

distribution grids are limited. Further research is needed to:

1. Analyze the impact of EV integration: Conducting detailed studies on the effects of EV adoption on Delhi's power supply.
2. Develop targeted policies: Creating policies that address the unique needs of India's EV market.

By exploring global best practices and conducting localized research, policymakers can accelerate EV adoption and foster sustainable transportation ecosystems in Indian cities.

II. METHODOLOGY

This study employs a mixed-methods approach, combining primary and secondary data sources to investigate the impact of electric vehicles on grid system and waste generation.

Data Sources

The research utilizes:

1. Secondary data analysis: Reviewing published articles, reports, and studies to understand EV-grid interactions and waste generation.
2. Monte Carlo Simulation: A statistical technique used to model complex systems and predict future outcomes.

Simulation Modeling

The Monte Carlo Simulation is designed to:

1. Model EV charging scenarios: Analyzing the impact of EV adoption on Delhi's power grid, considering factors like charging station distribution and power generation capacity.
2. Estimate future outcomes: Predicting the effects of increased EV adoption on the grid and waste generation.

Assumptions

The simulation model assumes:

1. Existing charging infrastructure: 1741 charging stations across Delhi.
2. Adequate power generation capacity: The existing electricity system can absorb additional loads from EVs.

Expected Outcomes

The study aims to provide insights into:

1. EV-grid interactions: Understanding the impact of EVs on Delhi's power grid.
2. Waste generation: Analyzing the environmental implications of EV adoption.
3. Policy and infrastructure planning: Informing decision-making for sustainable development and efficient EV integration.

Electric Vehicles and Grid Impact

Electric vehicles (EVs) offer environmental benefits, but their integration with the power grid poses challenges. Key concerns include:

1. Voltage stability: EV charging can disrupt voltage levels, affecting grid stability.
2. Power quality: EV charging can impact power quality, potentially causing issues with electrical equipment.
3. Peak load: Increased EV charging during peak hours can strain the grid, leading to supply-demand imbalances.
4. Transformer lifespan: EV charging can reduce transformer lifespan due to increased load.

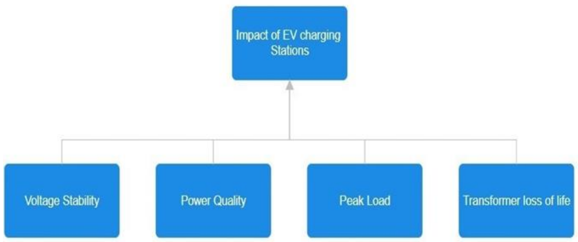


Fig. 2. Impact of EV on the Grid System

Grid Challenges

The growing number of EVs connected to the grid raises concerns about:

1. Grid stability: Fluctuating charging schedules and owner behaviour can impact grid functionality.
2. Power system economics: Increased peak demand can lead to additional costs and strain on the grid.

Key Factors Affected by EV Charging

Several factors are impacted by EV charging, including:

1. Grid stability and control
2. Power quality
3. Peak load management
4. Transformer health

Voltage Stability in Power Systems

Voltage stability refers to a power system's ability to maintain acceptable voltage levels across the network under normal conditions and after disturbances. As electric vehicle (EV) adoption increases, concerns arise about the impact on voltage stability in distribution networks.

Potential Issues

The growing number of EVs connected to residential areas may lead to:

1. Voltage imbalance: Single-phase EV chargers in residential areas can cause voltage discrepancies in three-phase distribution systems.
2. Voltage fluctuations: EV charging loads can impact voltage stability, potentially affecting distribution network performance.

Research Findings

Studies have shown that EV charging can:

1. Degrade distribution network stability: Increased EV charging loads can compromise network performance.
2. Cause voltage fluctuations: EV charging can lead to voltage variations, affecting power quality.

Power Quality Concerns

Power quality is crucial for reliable power distribution, requiring stable voltage and frequency within specified tolerance limits. Electric vehicle (EV) charging can impact power quality, potentially causing:

1. Increased distortion: Irregular charging patterns can distort power waveforms.
2. Power quality degradation: EV charging can compromise power quality, affecting distribution network performance.
3. Equipment stress: Poor power quality can lead to equipment damage, including distribution transformers and lines.

III. RESULTD & DISCUSSION

A Monte Carlo simulation involving 10,000 electric vehicles (EVs), each charging at 0.2 kW over eight hours, was conducted to evaluate the risk of grid overload. With a total grid capacity of 100,000 kWh and 1,000 simulation runs, results revealed that the grid became overloaded in 84% of cases, indicating a critical need for immediate upgrades to prevent failures.

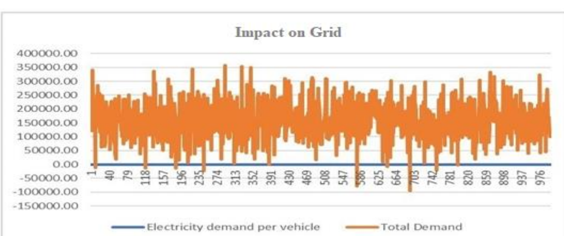


Fig. 3. Monte carlo simulation to represent analysis of grid capacity on different number of EVs

The study also highlighted voltage instability as a major concern, especially in three-phase distribution networks. Increasing EV penetration in residential areas led to voltage fluctuations, higher harmonic distortion, fault currents, and transformer over voltages—deteriorating overall power quality.

Fig- Monte carlo simulation analysis for grid capacity

Harmonic emissions, particularly during the Constant Voltage (CV) charging phase, were shown to shorten transformer lifespan due to excessive thermal and electrical stress. Additionally, uncoordinated charging of plug-in hybrid and battery electric vehicles during peak hours significantly strained the grid, emphasizing the importance of load management strategies like synchronized charging.

Environmental concerns were also raised regarding the disposal of lithium-ion batteries (LIBs), which pose safety and pollution risks at the end of their service life. The study recommended recycling, cascade use, and ultrasonic recovery methods to reduce environmental impact and extend battery usability.

Finally, the role of charger design, power level, and grid conditions in harmonic emissions was investigated. The adoption of advanced charger technologies, smart charging systems, and Vehicle-to-Grid (V2G) integration was proposed to reduce grid stress and improve overall efficiency.

IV. CONCLUSION

This study aimed to deepen understanding of how the growing adoption of electromobility impacts the power grid and to identify critical knowledge gaps. By analyzing power quality and service reliability across medium and low voltage networks—through the lens of transmission and distribution operators, utilities, and end-users—key technical challenges have been identified.

One of the major findings was the presence of waveform distortions, including harmonics, inter harmonics, and supra harmonics, during EV charging. These disturbances vary with each charging session due to uncertainties such as battery state of charge, charging rates, and power electronic configurations. As a result, current models and mitigation strategies are insufficient, highlighting the need for more adaptive and sophisticated approaches. The study also revealed that harmonic aggregation behavior changes depending on the number and timing of EV connections. In particular, conventional summation rules fail when accounting for the randomness of EV charging, especially in the case of inter harmonics. Supra harmonic currents, despite their low magnitudes, were found to trigger protective

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