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Analysis of Impact of EV Bus Charging On Distribution Grid: A Review

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ABSTRACT

Charging Electric Vehicles (EVs), particularly Electric Buses (BEBs), can significantly impact the distribution grid operation. Studies have shown that the integration of high-power charging systems for BEBs, reaching up to 600 kW, requires special consideration due to potential overloading effects on the grid [1] [2] [3]. The presence of EVs in the grid as a load can lead to increased grid losses, affecting parameters like deployment and cost; however, managing EV charging and discharging can help reduce grid losses and positively influence the load curve [4]. Implementing smart charging strategies, such as dynamic tariffs and bi-directional charging, can effectively mitigate grid congestion, voltage problems, and transformer overload risks associated with intensive EV charging, ensuring optimal system performance and stakeholder satisfaction [5].

I. INTRODUCTION

In [1] Study on EV charging effects on distribution system and Analyzes impact on bus voltage profile and power losses. In [2] Study assesses impact of EV charging on power distribution systems also Utilizes software tools to investigate potential overloading and degradation risks. In [3] Evaluates impact of dynamic tariffs on smart EV charging and Aims to minimize grid reinforcement with growing EV share. In paper [4] Impact of fast-charging BEBs on distribution grid analyzed. Study on power quality impact of BEB charging solutions. In [5] EV's in distribution grid impact grid losses and load curve studied with Transition to EV's aims to reduce environmental pollution and emissions. In [9] EVs impact residential distribution network, affecting power quality and reliability and Study analyzes EV penetration effects on distribution substation and transformers. Paper [11] proposes smart charging coordination strategy for electric vehicles in distribution network. Strategy considers price sensitivity of EV drivers and prioritizes charging based on state of charge level. [13] Evaluates impact of dynamic tariffs on smart EV charging also Focuses on reducing grid reinforcement with growing EVs. EVs have environmental benefits but impact distribution network mentioned in [14] Study analyzes performance of distribution substation and transformers

II. LITERATURE REVIEW

Effects of EV charging on bus voltage profile and power losses were studied and also Incorporates DG and capacitor banks in distribution system design [1]. [2] Analyzed impact of EV charging on power distribution systems in Kentucky also Used DRIVE and HotSpotter software tools for investigation. [3] Evaluates effectiveness of dynamic tariffs and network constraints for EV charging and Compares dynamic network tariff with flat tariffs for smart charging. [4] BEBs replacing diesel buses in cities for zero emissions. Super-fast-chargers needed on route lines to meet energy demand. Comparison of EV presence effects on grid losses and Simulation on 74-bus distribution grid with 1000 vehicles were discussed in [5].

III.METHODS USED

Ref No	Methodology used
1	Framework assimilates DG, PV, wind, biogas, capacitor banks. Implemented on IEEE 33-Bus test system using MATLAB.
2	DRIVE and HotSpotter software tools utilized for analysis Multi-physics reliability analysis conducted on distribution transformer
3	Development of a detailed optimisation model for public charging of EVs Evaluation of different levels of network constraints and dynamic tariffs
4	Use of fast-chargers up to 350 kW based on pantograph technology Use of slow-chargers up to 50 kW based on Combined Charging System Type 2 (CCS2)
5	Comparison of EV presence and absence on grid losses. Simulation in DIGSILENT software on a 74-bus distribution grid.
6	Analyzing effects on bus voltage profile and power losses Incorporating Distributed Generation (DG) and capacitor banks in simulations
7	Modeling of EV load on distribution system Impact analysis on power grid stability and charging station locations
8	Model for worst-case analysis of charging station impact Validation on a representative case study
9	Analysis of performance of distribution substation and transformers Examination of performance for various penetration levels of EVs
10	V2G Technology with bidirectional converter for EVs Modeling EV charging behavior to estimate grid load needs
11	Energy management approach considering price sensitivity of EV drivers Priority groups based on EV's state of charge (SoC) level
12	Lookup-table-based charging approach for EVs Comprehensive impact analysis of high-level EV penetration
13	Development of a detailed optimisation model for public charging of EVs Evaluation of different levels of network constraints and dynamic tariffs
14	Analysis of performance of distribution substation and transformers Examination of performance for various penetration levels of EVs

15	Modeling of an EV load and its impact on the distribution system Implementation on the IEEE 33 bus distribution system
16	Strategic planning and control methods to integrate EVs into distribution systems Advanced operations strategies to reduce or eliminate costly grid upgrades
17	SOC-based coordinated charging method with real data-driven profiles Integration of PV generation and BES system for peak load reduction
18	Study existing electric vehicle charging modes Analyze positive and negative effects on urban distribution network

IV. CHALLENGES AND LIMITATIONS

While critically reviewing referenced papers some of the studies have limitations with respect their studied system.

Ref No	Limitations
2	• Overloading in distribution systems • Under voltage violations
3	• Capacity limitations due to growing EVs • Congestion and voltage problems in LV distribution network
4	• Voltage variations due to fast-chargers remain below the EN50160 standard limit values. • Total Harmonic Voltage Distortion (THDv) and individual harmonic currents are within acceptable limits.
5	• Grid losses increase with EV presence. • Managing EV charging reduces grid losses.
6	• Limited to steady state system analysis • Focus on IEEE 33-Bus test system for case studies
8	• Grid reinforcement investments needed due to increased loading. • Worst-case charging station impact analysis model presented and validated.
12	• Maintaining power balance during on-peak charging hours • Increase in residential grid voltage sag during high-level charging
13	• Capacity limitations due to growing EVs • Congestion and voltage problems in LV distribution network
14	• Stress on residential electricity distribution infrastructure • Poor power quality, low voltage levels, increased power loss, overloading of feeders, cables, and distribution transformers
16	• Limited load hosting capacity, transformer and line overloads, voltage and power quality degradation • Smaller-scale studies limit ability to capture impacts and opportunities introduced by managed EV charging, regional-scale movement of EVs, and more widespread EV deployment.
18	• Impact on power quality • Economic impact on distribution network

Impact of EV Bus Charging On Distribution Grid

Ref No	Conclusive findings
1	• EV charging affects bus voltage profile and power losses.
2	• Identifies distribution system overload risks and mitigation solutions. • Investigates overload impact on distribution transformers through reliability analysis.
3	• Dynamic network tariff outperforms other flat tariffs by increasing valley-filling. • V2G ensures joint optimum for stakeholders with decreased CPO costs.
4	• Voltage variations due to fast-chargers remain below the EN50160 standard limit values. • Total Harmonic Voltage Distortion (THDv) and individual harmonic currents are within acceptable limits.
5	• EV charging and discharging affect grid losses significantly. • Managing EVs can reduce grid losses in distribution grids.
6	• EV charging affects bus voltage profile and power losses. • Framework integrates DG and capacitor banks for realistic distribution system.
7	• Modeling of EV load and its impact on distribution system • Identification of suitable locations for charging stations
8	• Model for worst-case analysis of charging station impact • Validated on a representative case study
9	• EV penetration in residential distribution networks negatively impacts power quality and reliability. • The performance of distribution substations and transformers is affected by EVs.
10	• The usage of Electric Vehicles (EVs) increases load and losses in the power grid system. • Vehicle-to-Grid (V2G) technology reduces losses in the distribution system.
11	• The proposed smart charging coordination strategy effectively manages EV charging in a LV distribution network. • The algorithm successfully shifts loads while meeting network and EV constraints.
12	• Large-scale EV integration affects bus voltage and line current. • Lookup-table-based charging approach can minimize impacts.
13	• Dynamic network tariff outperforms other flat tariffs by increasing valley-filling. • V2G ensures joint optimum for stakeholders, decreasing CPO costs and grid violations.
14	• EV penetration in residential distribution networks negatively impacts power quality and reliability. • The performance of distribution substations and transformers is affected by EV penetration.
15	• EV load impacts distribution system parameters. • Model helps find suitable locations for charging stations.
16	• EV charging can impact electricity distribution systems • Strategic planning and control methods can minimize grid upgrades
17	• SOC-based coordinated charging method reduces peak load and line loading. • Integration of PV and BES improves energy efficiency in grid.
18	• Electric vehicles have positive and negative effects on the urban distribution network.

- Example simulation with East China Power Grid verifies some functions of electric vehicles connected to the grid.

V. CONCLUSION

In conclusion, the analysis of the impact of Electric Vehicle (EV) bus charging on the distribution grid underscores the critical need for strategic planning and innovative solutions to address the challenges posed by the integration of high-power charging systems. As evidenced by various studies, the rapid adoption of EVs, particularly Electric Buses (BEBs), has the potential to strain the distribution grid, leading to increased grid losses and operational complexities. However, proactive measures such as implementing smart charging strategies can significantly mitigate these challenges and pave the way for a more sustainable and resilient grid infrastructure. By embracing dynamic tariffs and bi-directional charging technologies, stakeholders can not only alleviate grid congestion and voltage issues but also optimize system performance and enhance stakeholder satisfaction. Moving forward, continued research and collaboration between industry stakeholders, policymakers, and academia will be essential in ensuring the seamless integration of EVs into the distribution grid while maximizing their benefits and minimizing their potential drawbacks.

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