A Study on Optimal Deployment of Charging stations for Electric vehicles

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ABSTRACT

Integration of Electric vehicles in the modern transportation sector is increasing at a faster rate due to reduction in fossil fuel, lesser maintenance cost and low carbon emission. To meet the required demand the number of charging stations has to be increased basically in smart cities where accommodation of large number of charging station is again an issue taking the route network into consideration. The problem can be solved by taking the route node coverage by considering minimum number of charging stations to cover the most probable routes in the network of transportation.

The objective of this paper is to study the different parameters for maximization of the coverage route with minimum number of charging stations by using different optimization techniques as we can choose strategic location from several possibilities with minimum loses.

Keywords: Electric vehicle, EVCS, charging station, route node coverage, optimization technique, HOMER

I. INTRODUCTION

Economic and environmental issues have triggered the evolution of electric vehicle globally as the fossil fuel is depleting day by day with increase in cost. Charging of electric vehicle through renewable energy sources also has come into prominence due to hazardous emission by high charging loads through fossil fuel power plants.

Development of power electronic converter topologies and implementation of different optimization algorithms and fast charging software has also given the electric vehicle an edge over the conventional fuel-based vehicles.

Vehicle to Grid technology (V2G) is one of the examples of advancement in technology resulting bidirectional power flow from grid to vehicle as well as from vehicle to grid.

It is quite essential to go for the detail analysis of the problems associated with the integration of electric vehicle on power system as its penetration causes the system demand to increase. In a typical distribution system around 10% penetration of EVs has proved to increase peak load by 17.9% while 20% penetration increases peak load by 35.8%. Higher peak load due to integration of EV increases power losses and voltage deviations. It can also cause thermal limit violations of transformers and lines solutions can be derived to lower distribution system losses by coordinated charging scheme. Calculations are based on an assumed EV load model. In coordinated charging is proved to achieve a smooth voltage profile while also reducing power losses When vehicles are charged in a coordinated manner, peak load can be managed to remain within allowable limits. However, the uncertain behaviour of the vehicle owner can make it difficult to implement coordinated charging.

Optimal planning of EV charging stations has been done with different approaches and objectives. This planning for EVCS deployment can help us in achieving better economics and critical parameter improvement such as loss reduction and voltage deviation minimization. Moreover, minimization of power loss and voltage deviation as well as maximization of network reliability is achieved by optimally allocating parking lots with charging stations.

A well-planned charging infrastructure is therefore required to facilitate users in order to increase penetration of EVs. fast-charging station planning is done considering cost and traffic in a distribution network In urban areas where the space is limited, the transportation network must be properly mapped to the number of charging station to get the maximum coverage for which the planning for optimal location and deployment of charging station has become necessary.

II. METHODOLOGIES

Different methodologies are discussed by conspiring different EV load for solar PV plant and wind power integration to the main grid for optimal sizing of the charging station in a distributed urban road network.

In the endeavour to optimize the sizing and placement of electric vehicle (EV) charging stations through the integration of solar photovoltaic (PV) and wind power systems into the main grid within a distributed urban road network, a range of methodologies are explored. These methodologies encompass a comprehensive and forward-thinking approach to address the complex challenges associated with sustainable transportation infrastructure.

Smart Grid Management: Advanced smart grid technologies are vital components of the integration strategy. These systems enable real-time monitoring and control of energy flows, allowing for seamless coordination between EV charging stations, renewable energy sources, and the main grid. This dynamic management ensures efficient energy utilization, minimizes grid congestion, and enhances system reliability.

Energy Market Integration: The methodologies consider the involvement of energy markets, including demand response programs and time-of-use pricing, to encourage EV owners to charge their vehicles during periods of high renewable energy generation. This not only optimizes grid usage but also provides cost incentives for consumers to adopt greener charging habits.

Resilience and Backup Systems: To ensure uninterrupted EV charging services, the integration plans incorporate backup systems such as energy storage units or alternative energy sources like natural gas generators. These systems provide resilience during adverse weather conditions or renewable energy intermittency.

Community Engagement: Public engagement and feedback are integral components. Engaging the community in the decision-making process helps identify ideal charging station locations based on local needs and preferences, enhancing user convenience and adoption rates.

1. Location Assessment: Identify strategic locations for charging stations based on population density, traffic patterns, and proximity to highways, workplaces, and residential areas. GIS and data analysis tools play a crucial role in this phase.

2. Load Profiling: Estimate electricity demand by analysing traffic data, peak charging times, and anticipated EV adoption rates. This helps determine the required capacity for charging stations and ensures grid compatibility.

3. Grid Integration: Ensure seamless integration with the electrical grid by collaborating with utilities. Implement smart charging solutions that can balance load, minimize grid congestion, and take advantage of off-peak electricity rates.

4. Charging Infrastructure Design: Develop a robust design plan that considers charging speeds, connector types (e.g., Level 2, DC fast chargers), and user accessibility (e.g., ADA compliance). Scalability and future expansion should also be factored in.
5. Renewable Energy Integration: Incorporate renewable energy sources like solar panels and wind turbines to power charging stations, reducing carbon footprint and operational costs.
6. User Experience: Focus on user convenience through user-friendly mobile apps, payment systems, and 24/7 customer support. Accessibility, safety, and ease of use are paramount.
7. Interoperability: Promote interoperability by adopting industry standards (e.g., CHAdeMO, CCS, Type 2) to ensure compatibility between different EV models and charging stations.
8. Regulatory Compliance: Stay up-to-date with regulations and permitting requirements at the local, state, and federal levels. Compliance ensures a smooth deployment process.
9. Environmental Impact Assessment: Conduct environmental assessments to mitigate any negative ecological effects, especially in ecologically sensitive areas.
address concerns, build support, and foster a sense of ownership.
In summary, successful charging station methodologies encompass strategic location selection, grid integration, user-centric design, environmental considerations, and adaptability to evolving technologies. Implementing these strategies is essential to facilitate widespread EV adoption, reduce carbon emissions, and build a sustainable transportation ecosystem.

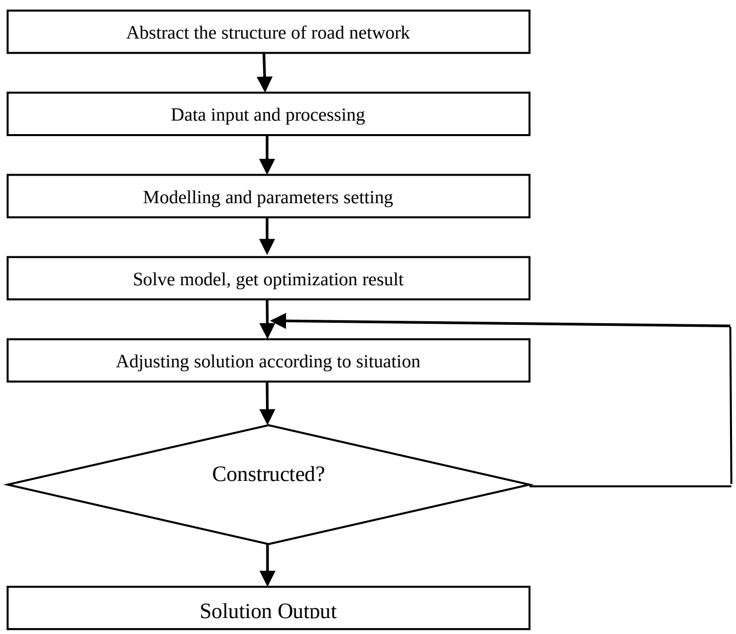

FIG 1
Flow chart for optimal deployment of EV charging station

1.1 **Assumption**

The study is proposed on the following primary assumptions for simplicity:

1. For EV users, charging during daytime is only considered. This is quite convenient for an urban road network.
2. Only fast charging stations are taken to be consideration, where each charger can impart service to maximum number of electric vehicles.
3. Quick access to installed chargers within a considerable travel distance is vital for EV drivers.
4. A single charging station is supposed to charge an EV.

1.2 Planning for Network.

Identification of suitable locations for future charging stations is an essential and important parameter in this research. From the previous research studies the EV charging stations should be proposed near the gas charging station as suitable location. Suitable geographic location could be acquired from Google Maps. In By using graph theory set of possible connection between charging station and possible distances could be derived.

1.3 Programming Models.

Various models can be programmed to optimize the resources taking various location into consideration. Taking the coverage length, it also helps to assure cost reduction and sizing taking all constraint parameters into consideration. Apart from assuring a service coverage distance, these models minimize various costs while subjected to suitable constraints taking sizing and location into consideration.

2.4 EVs Load Modelling

EV load data is not usually available in most of the power system network. It is quite necessary to model this load while framing for EV integration. EV load is dependent on the number of EV considering the arrival and departure time characteristics of charging and the distance of travelling which are responsible for designing the EV load.

EV load modelling is a critical aspect of grid management and planning, as it helps in assessing the electricity demand caused by the charging of electric vehicles. This modelling technique is essential for utilities, grid operators, and policymakers to ensure a reliable and efficient power supply while accommodating the increasing number of EVs on the road.

2.5. Modelling of test system

The presence of highly unbalanced and nonlinear load makes the system complex while designing for load modelling and tests. The modelling of a test system for the optimal deployment of electric vehicle (EV) charging stations is a critical aspect of urban planning and sustainable transportation infrastructure. This process involves the systematic analysis and evaluation of various factors to determine the most efficient locations for EV charging stations.

To begin, data on EV adoption rates, population density, traffic patterns, and existing charging infrastructure is collected and analysed. Advanced algorithms and simulations are then employed to identify potential charging station locations that can maximize accessibility and convenience for EV owners while minimizing the overall cost of deployment.

Key considerations include proximity to major roads, parking facilities, residential areas, and commercial centres. Additionally, the modelling process factors in future EV growth projections to ensure scalability and long-term viability of the chosen locations.

III. NUMERICAL EXPERIMENTS

Different case studies are compared with results for proposed models for comprehensive analysis. Models are compared by taking different parameters into consideration such as sensitivity, cost of various components and other variables.

3.1. Setting of parameters

The cost of charger to be installed is assumed to be constant and independent of the considered location. The demand of charging is assumed to be evenly distributed between individual charging station.

3.2. Analysis for Sensitivity

The coverage radius for deployment of the optimal deployment of the infrastructure should be analysed properly before selection of the optimal location Increasing the value of coverage radius R is accompanied by lesser charging stations; which signifies that more chargers need to be deployed within the charging stations.

3.3 Impact of Charging Time.

The impact of charging time is a critical factor in the widespread adoption and practicality of electric vehicles (EVs). Charging time directly affects the convenience and usability of EVs, as well as their overall appeal to consumers.

First and foremost, shorter charging times are essential for enhancing the convenience of EVs. Long charging durations can be inconvenient for drivers who rely on their vehicles for daily commutes and errands. As charging times decrease, EVs become more practical for a broader range of users, making them a viable alternative to traditional internal combustion engine vehicles.

Additionally, charging time influences the infrastructure needed to support EVs. Faster charging technologies require more robust electrical grids and charging station networks. Therefore, the speed at which EVs can be charged impacts the pace of infrastructure development and the accessibility of charging stations, particularly in regions with limited resources.

Furthermore, shorter charging times reduce "range anxiety," a common concern among potential EV buyers. As charging becomes quicker, drivers feel more confident in their ability to find a charging station when needed, making long-distance travel more feasible with EVs.

In conclusion, the impact of charging time on electric vehicles is multifaceted. Faster charging times enhance convenience, drive infrastructure development, and alleviate range anxiety, all of which are crucial factors in accelerating the adoption of electric vehicles and reducing our dependence on fossil fuels.

3.4 Effect of the EV Charger Cost.

The cost of electric vehicle (EV) chargers is a significant factor that can influence the adoption and proliferation of electric vehicles. It's important to note that the cost of EV chargers can vary widely depending on several factors, including the type of charger, its power level, and the location where it is installed these are

1. Impact On EV Adoption Rates
2. Charger Infrastructure Development
3. Equity And Accessibility
4. Charger Type and Power Level
5. Government Incentives and Policies
6. Technological Advantages
7. Business Opportunities

The cost of Electric Vehicle (EV) chargers plays a pivotal role in the adoption of electric mobility. Higher charger costs can deter potential EV buyers and slow down the transition to cleaner transportation. It affects consumers by influencing their willingness to invest in electric vehicles, as well as the overall affordability of EV ownership. Furthermore, high charger costs can hinder the development of charging infrastructure, discouraging businesses and governments from investing in widespread charging networks. On the flip side, decreasing EV charger costs can make electric vehicles more accessible, stimulate market growth, and contribute to reducing greenhouse gas emissions, promoting a sustainable future for transportation.

3.5 EV Charging Networks.

For the installation when solely the investor's convenience is regarded, the framework when the convenience of users and investors is equally important, the station opening costs are not taken into account.

Installation costs and EV users' access costs. Several previous studies have been focused on EVCS in existing parking lots, fuel stations with different aspects, such as minimizing the total cost, and minimizing the total system cost. The proposed installation of Electric Vehicle Charging Stations (EVCS) varies depending on whether the focus is solely on investor convenience or if both user and investor convenience are equally important. In the former scenario, decisions may prioritize investor preferences without considering the station opening costs, potentially limiting accessibility for EV owners. However, when both aspects are taken into account, it involves a holistic approach that considers installation costs, operational expenses, and the accessibility and convenience for EV users. Several prior studies have delved into optimizing EVCS placement within existing parking lots and fuel stations, aiming to minimize the overall cost, enhance accessibility, and ensure the satisfaction of both investors and EV owners. These studies contribute valuable insights for the sustainable growth of EV infrastructure.

3.6 EV charging from Renewable energy integrated to Micro grid

A microgrid is typically embedded with distributed generation, load, and energy storage devices confined in closed proximity that utilizes renewable energy for clean and green energy. It includes solar distributed energy, wind power, etc., which can run parallel to the public grid and a specialist energy storage unit and load connection. In the literature on the widespread use of microgrids, microgrids' great benefits for owners and available grids are addressed. Electric Vehicle (EV) charging powered by renewable energy integrated into a microgrid represents a sustainable and forward-thinking solution. By harnessing clean energy sources like solar panels or wind turbines, EV charging becomes environmentally friendly and reduces carbon emissions. The integration with a microgrid adds reliability and resilience to the charging infrastructure, allowing it to function independently during grid outages.

This approach promotes energy self-sufficiency, reduces dependency on fossil fuels, and mitigates the strain on the traditional power grid. Moreover, excess renewable energy generated can be stored or shared within the microgrid, benefiting both EV charging and other localized energy needs. As the world transitions towards cleaner transportation and energy systems, the synergy of EV charging and renewable energy within microgrids plays a crucial role in building a sustainable and eco-friendly future.

3.7 Renewable **Energy Sources.**

The Distributed Energy Resources (DERs) like solar, wind, and fuel cells are considered the primary sources embedded with batteries and supercapacitors as energy storage devices. Solar and fuel produce DC power directly, whereas wind turbines with an induction generator or Synchronous Generator converted to DC with a power electronic interface. Solar cells are the fundamental components of solar panels, able to work efficiently at lower ambient temperatures. By the principle of the photoelectric effect, light electricity is converted directly to electricity. After installation, photovoltaic solar power generation will not cause pollution and harmful greenhouse gas emissions; therefore, it has special advantages as an electricity source and simple power requirement scalability. With increasing temperatures, solar cells' energy efficiency changes little. With this change of temperature and radiance, results are nonlinear curves between voltage-current and power-voltage. There is only one maximum power point that varies with radiance or temperature at any point in time. This paper reviews offline methods, including OC voltage methods, SC current methods, and artificial intelligence methods; P&O methods are involved in online methods. The MPPT algorithm for perturbation and observation (P&O) is widely used because of its easy application. MPPT technology, where the MPPT parameters can alter the converter performance under dynamic conditions. This method enables the efficient use of P&O MPPT to be improved with stable oscillations reduced and the algorithm to lose its tracking direction eliminated. The MPPT algorithm closes the MPPT and minimizes oscillation and raises the amount of interference phases.

FIG-2

Renewable energy integration for EV charging

IV. CONCLUSION

EVs are currently regarded as the most efficient potential alternative in modern transportation network taking energy and environmental impacts into consideration. The deployment and installation of the optimal designing for charging infrastructure is essential for promoting EVs. This study analysis an effective method for locating fast charging stations. It is based on the optimization technique Optimization techniques such as fast charging software can be used for better output and efficiency. HOMER (Hybrid optimization of multiple energy resources) software can also be used for optimal deployment of the charging station taking the cost of different components and future cost into consideration. Furthermore, as the global shift towards electrified transportation accelerates, the study highlights the need for ongoing research and collaboration among governments, utilities, and private sector entities to continually refine deployment strategies, incorporate emerging technologies, and meet the evolving needs of EV users.

Ultimately, the optimal deployment of charging stations is a critical solution for the widespread adoption of electric vehicles, contributing to reduced carbon emissions, improved air quality, and a sustainable future for transportation.

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