

# An In-Depth Review on Charging Station Locator for Electric Vehicles

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*Abstract* — Recent years have witnessed a surge in technological advancements designed to operate within self-sustaining ecosystems. One notable example of this trend is the increasing focus on electric vehicles, driven by concerns about depleting fossil fuel resources and the pressing issue of anthropogenic climate change. Consequently, the number of electric cars on our roads has been steadily on the rise. The adoption of electric vehicles holds promise for reducing carbon emissions and minimizing our environmental footprint, with profound implications for our future. Nonetheless, electric cars, like any innovation, come with their share of drawbacks when compared to other transportation options, particularly their limited range. The anxiety associated with range limitations can be a concern, but the establishment of a robust charging infrastructure can effectively address this issue. Thus, there is a growing need for an application that can guide users to the nearest electric vehicle charging station and provide real-time information about the availability of charging ports. In pursuit of this objective, this survey article delves into existing research on this topic, aiming to outline an effective methodology that will be expounded upon in the forthcoming edition of this research article.

**Keywords:** Charging Station Locator, Electric Vehicles

## I. INTRODUCTION

Urban areas are on the cusp of a transformative era, driven by innovative initiatives that prioritize resilience and environmental responsibility. Within this transformation, the transportation sector plays a pivotal role, particularly in addressing environmental concerns, as it accounts for nearly one-third of all energy-related emissions. Traditional private automobiles, primarily running on internal combustion engines, have long dominated our transportation networks, resulting in significant environmental repercussions, including oil shortages, deteriorating air quality, and greenhouse gas emissions. The reliance on fossil fuels, such as gasoline and diesel, not only poses environmental challenges but also has a substantial impact on public health and well-being.

As a response, it is imperative to implement measures and regulations that enhance the efficiency and sustainability of our urban environments. Technological advancements open up new avenues and possibilities, and in urban settings, a transition from traditional vehicle fleets to more environmentally responsible ones could be a catalyst for a sustainable future. Central to this shift are renewable energy sources and emissions reduction, with electric mobility, especially the widespread adoption of electric cars, playing a pivotal role in this transformation. Electric vehicles, despite their long-standing history, are rapidly emerging as the next major automotive breakthrough with broad societal acceptance.

Electric cars, defined as passenger vehicles drawing power from the energy grid and storing it onboard, represent a significant opportunity to reduce fossil fuel consumption, air pollution, and greenhouse gas emissions. The electric propulsion system is environmentally friendly, devoid of local pollutants, and reduces noise pollution, making electrification of vehicles a powerful solution for mitigating the adverse environmental impacts of transportation while increasing its efficiency.

In recent times, rechargeable battery technology has made significant strides, allowing electric cars to travel longer distances on a single charge. However, for extended journeys without frequent recharging, challenges remain. It is imperative that electric cars are readily and conveniently rechargeable, and as their numbers grow in the years to come, the demand for an extensive charging infrastructure will surge. These charging stations must be strategically positioned to enable electric vehicle owners to move about with ease.

Nevertheless, the increasing popularity of electric cars is expected to present both technological and economic challenges, necessitating ongoing research to gauge adaptability. Economic constraints, cost considerations, the expansion of charging networks, the reinforcement of the power distribution grid, project feasibility issues, and security and ethical concerns related to synchronized "smart" charging systems are formidable roadblocks. The frequency and distribution of electric cars play a crucial role in addressing these challenges.

Given the importance of charging infrastructure, its absence or delayed deployment has hindered the growth and adoption of electric vehicles in the automotive industry. Electric Vehicle Charging Stations are becoming increasingly vital, especially as the transition to electric transportation gains momentum. In the complex ecosystem of e-mobility, establishing a sustainable electric car charging infrastructure that prioritizes these vehicles and promotes the use of alternative energy sources is a significant step in the right direction.

Global consumer research underscores the significance of accessible refueling facilities in the widespread adoption of electric vehicles. The phenomenon of "range anxiety," stemming from the lack of an efficient electric car charging infrastructure, amplifies drivers' apprehensions about their vehicle's range. Range anxiety is defined as the fear of not having enough power to reach one's destination. Thus, the provision of user-friendly and convenient recharging facilities for electric car users is paramount in addressing this issue.

To this end, an effective charging station management approach must be devised to enhance the state of electric vehicle adoption. This approach is informed by an in-depth analysis of prior research in the realm of smart electric vehicle charging infrastructure. The findings of this

analysis, as presented in the following section, have been instrumental in shaping our approach, which will be elaborated upon in forthcoming iterations of this research.

This literature survey paper dedicates section II to evaluating previous work in structuring a literature survey, while section III provides conclusions and outlines future research directions.

## II. RELATED WORKS

S. Zhou et al. [1], presents a pricing technique that considers the charging facility service ratio, traffic flow, and renewable energy generation to optimize the operational efficiency of highway charging facilities and the utilization of nearby renewable energy sources. In order to provide justification for the implementation of the suggested pricing technique, an examination is conducted on the projections of traffic volume and renewable energy output on an hourly basis. Additionally, an analysis is performed to determine the most efficient routes to various charging stations (CSs). A testbed for road networks, utilizing the Dublin traffic network, has been constructed in order to assess the effectiveness of the suggested pricing model. It has been observed that in specific wind-rich geographical areas, the suggested pricing methodology exhibits the potential to significantly enhance the utilization of wind energy, resulting in an increase of up to 82.97%. On average, the implementation of this methodology leads to an improvement of 30.73% in wind energy consumption. Similarly, in solar-rich regions, the proposed pricing methodology has the capability to enhance the utilization of solar energy, resulting in an increase of up to 59.50%. On average, the implementation of this methodology achieves an increase of 29.28% in solar energy consumption. The suggested pricing technique has the potential to mitigate traffic congestion to a certain degree during both peak and off-peak periods.

Stochastic geometry was employed by R. Atat et al. to construct a spatio-temporal expanding grid that serves as an approximation of commonly seen grid configurations. The evolving nature of the models' topological structure and attributes renders them a potent tool for strategic planning in smart grid systems. The formulated model was utilized to establish an allocation strategy for both CSs and DGs over several years, employing a finite horizon dynamic program. The authors conducted computations in order to derive lower-bound expressions for the density of charging stations (CSs) that would provide acceptable charging service levels [2]. This was achieved through the application of stochastic geometry and queuing analytic methodologies. Subsequently, the aforementioned computations were employed to establish the dynamic program, which ascertained the optimal allocation of CSs and DGs in each fiscal year, taking into account the budgetary limitation. The findings have demonstrated that the power grid model based on stochastic geometry provides a reasonable approximation of the topological properties observed in real-world power grids. Therefore, the model proposed in this research holds significant potential for governments seeking a cost-effective approach to facilitate the integration of a growing fleet of electric vehicles (EVs) through a multi-stage growth and deployment plan.

Y. Yang et al. suggest implementing a data-driven methodology to enhance the efficiency of the current charging station network configuration. The proposed approach offers a more realistic solution to the optimization problem of charging station layout. It takes into account the many limits and requirements imposed by government planning departments. There are three key factors to consider in this context: 1) the constraint on the amount of charging stations, 2) the issue of overflow, and 3) the level of consumption [3]. In this research, the authors additionally introduce a theoretical framework for identifying patterns of urban charging behavior. This framework incorporates four primary data sources, namely the ET trajectory dataset, points of interest (POIs), station data, and road network data. Our current research is primarily focused on the trajectory of electric taxis as the basis for the work. However, it is worth noting that the proposed system has the potential to be expanded to include different types of cars in a seamless manner. During the phase of detecting charging events, the reliance is solely on the recorded duration of the detected events. This duration is determined through the process of charging event detection and is not influenced by whether the vehicle in question is an electric vehicle or not. The citywide charging behavior is represented using a 3D tensor. In order to account for missing data in the time and station entries, a context-aware tensor collaborative decomposition approach is employed. This approach allows for the estimation of the time spent at each station and the development of queue systems to calculate the visits between different stations. The two indices not only serve as indicators of the frequency of EV charging but also provide insights into the popularity of charging stations.

H. Parastvand et al., presents and applies a graph-based approach to address the placement and sizing of charging stations (CSs) in order to minimize car waiting times at all stations, ensuring that they remain below a predetermined threshold level, such as 15 minutes. The study uncovers the similarities between (i) the positioning of control switches (CS) and the controllability of the network they operate on, and (ii) the sizing of control switches and the design of an ideal controller [4]. Furthermore, this research proposes a deployment strategy for Personal Communication Systems (PCSs) with the aim of enhancing solution quality by mitigating the issue of excessive waiting times during periods of high traffic congestion. Additional research is necessary to provide a comprehensive analysis of the effects of electric vehicle (EV) networks on the solutions of charging station (CS) placement and sizing. However, the findings confirm that the symmetry of the EV graph, as it relates to graph automorphism, has a notable influence on the quantity and positions of CSs. This, in turn, suggests alternative locations for CSs. The newly proposed framework for reformulating computer science placement and sizing, utilizing control and graph theories, enables the incorporation of many notions from both control theory and graph theory.

B. Zeng et al. [5], introduces a novel methodological framework for enhancing the design of a Radio Control System (RCS) in forthcoming smart cities. The authors analysis distinguishes itself from previous works by explicitly considering the strategic behaviors of electric vehicle (EV) users when making charging selections. They

also incorporate these effects into the planning decisions of the charging infrastructure provider, known as the Residential Charging Station (RCS). The challenge is framed as a BP model that considers the optimum decisions of RCSO and EV consumers concurrently inside an interactive framework. Given the computational complexity, the BP problem is restructured into a single-level linear program of equal significance by the use of various strategies. Subsequently, the problem is resolved using a commercially available solution.

The findings derived from the analysis of case studies indicate that the suggested approach, which takes into account the strategic behavior of electric vehicle (EV) users, offers more efficient planning solutions in real market conditions when compared to standard planning paradigms that overlook this strategic aspect.

D. Ji et al., presents an optimization model aimed at strategically planning the optimal locations and sizes of solar-assisted electric vehicle (EV) charging stations within a designated urban region. The primary contribution of this research is in the incorporation of the interplay between location selection and size design of charging stations inside the optimization model [6]. In this research, the authors have put forth a revised metaheuristic approach that incorporates three speed enhancement strategies. The objective of this modification is to enhance the computational efficiency when navigating over an extensive state space for the purpose of optimization. The study utilizes actual historical data from 297 users of an electric vehicle (EV) leasing company for the purpose of conducting experiments.

The findings indicate that the proposed method has the capability to generate decisions of high quality while maintaining an acceptable computational time. This research aims to furnish decision makers with vital information on the integration of solar energy into the electric vehicle (EV) charging infrastructure.

Z. Li et al. [7], proposed a system for coordinating electric vehicles (EVs) in a spatial context is presented, taking into account user behavior and the placement of charging stations (CSs). The system incorporates a coordination information center to ensure the protection of private information. The uncertainty of traffic conditions is taken into account while modeling the impact of connected vehicles (CS) and electric vehicles (EV) by considering several elements related to mobility. A proposed model is introduced in this research, which is based on user behavior in the field of computer science. The objective of this model is to optimize the selection process for computer science programs in order to increase the satisfaction level of prospective users who are interested in pursuing a career in this field. Electric vehicle (EV) customers will select a charging station (CS) based on their preferences for travel distance, journey time, and waiting time at the CS. The effectiveness of the proposed coordination system is demonstrated through the simulation of electric vehicle (EV) cooperation in both single and multiple charging stations (CSs). The findings indicate that the suggested coordination approach enhances the degree of satisfaction among electric vehicle users during the charging coordination process and effectively redistributes the burden of charging stations in a spatial manner.

A. Hussain et al., presented a proposed optimization technique for determining the appropriate size of Battery Energy Storage Systems (BESS) in a Future Combat System (FCS). This strategy takes into account the objectives of cost reduction, peak shaving, and resilience augmentation. The estimation of the charging station's load has been conducted by utilizing the stochastic load profile derived from the individual electric vehicles (EVs) that are registered with the FCS [8]. The mathematical model reveals that the demand for FCS is contingent upon several factors, including the charging level of the FCS, the quantity of EVs within the FCS, the residual energy level of the EVs, and the battery capacity of the EVs registered with the FCS. The resilience load of the FCS is determined by both the proximity of the present FCS to the nearest operational FCS and the remaining state of charge (SOC) of the electric vehicles (EVs).

The optimization problem demonstrates that the primary goal of the defined model is to strike a balance between the capacity of the Energy Storage System (ESS) and the procurement of electricity from the grid during periods of high prices. This purpose is pursued while also assuring the ability to withstand disruptions caused by Electric Vehicles (EVs). To effectively meet the resilience requirements, it is necessary to impose a penalty cost for violating resilience limits that is greater than the penalty cost associated with peak interval violations. The findings indicate that the penalty price for peak intervals has a greater influence on the size of the Battery Energy Storage System (BESS) compared to its impact on the annual cost of the Frequency Control Service (FCS). This influence is comparatively lower than that of a rise in the market price.

X. Liu et al. [9], presents a proposed strategy for rapid charging stations that incorporates a dynamic response approach, taking into account the interaction of many electric vehicles. This research focuses on the selection of EV charging navigation schemes and emphasizes the modelling aspect from the perspective of electric vehicles. This approach allows for the examination of the interactive impact of charging station selection among a significant number of electric vehicles and caters to the diverse response characteristics of electric vehicle users. In the investigation of the interaction between electric vehicles (EVs) and charging stations, the charging service charge takes into account the management of users' charging behaviour and the impact of pricing competition across numerous stations in order to balance the load among charging stations. The efficacy of the dynamic response approach is assessed using actual data from the Sioux Falls urban road network system.

D. Yan and colleagues have proposed a two-stage methodology to tackle the challenges associated with power allocation and charging coordination for plugged-in electric vehicles (EVs). Their approach relies on game theory-based control to address the interactions among various components, each with its own preferences. In the first phase, the focus is on determining how power should be allocated among the photovoltaic (PV) system, battery storage, and the electrical grid, while also calculating the overall charging power needed for electric vehicles (EVs) [10]. The second stage involves coordinating the distribution of charging power among individual EVs, considering the total charging power determined in the first phase. Consequently, the

method efficiently resolves the two critical energy management issues related to charging stations in a sequential manner. To validate their approach, the authors conducted simulations and experiments, and the results of these validations highlight the advantages of their method compared to existing benchmarks.

S. Zhou et al., introduce a strategic framework that combines planning and real-time pricing strategies for electric vehicle (EV) charging stations (CSs). The proposed methodology adopts a bi-level paradigm to comprehensively address the concerns of both governmental entities and electric vehicle (EV) charging station operators throughout the design phase. From the standpoint of promoting societal well-being, the government assumes the role of a decision-maker at a higher level, aiming to optimize the charging price matrix. This matrix serves as a transfer variable, indirectly influencing the decisions made by operators at a lower level. Subsequently, each operator situated at the lower level assesses their scale in accordance with the objective of maximizing their own revenue, and subsequently transmits the scale matrix to the upper level [11]. A Logit model is utilized to forecast the drivers' preference while choosing a customer service provider. Additionally, this research presents an enhanced particle swarm optimization (PSO) algorithm that incorporates a punishment function to address the challenges posed by the nonlinear nonconvex bi-level model. This study utilizes the proposed Bi-level planning model to assess the performance of a single center small/medium-sized city. Three scenarios are used to analyse various factors such as equipment utilization rate, payback period, and traffic attraction ability. The findings demonstrate that the model exhibits strong performance in common distribution situations within the field of computer science. Additionally, the model showcases a fair station payback period, averaging 6.5 years. Furthermore, the equipment utilization rate is relatively high, at 44.32%.

The use of electric vehicles (EVs) presents difficulties in ensuring the secure functioning of electric distribution systems. The difficulty of locating EV charging infrastructure should prioritize the provision of convenient charging options while limiting any adverse effects on power networks. S. Muthukannan et al., presents the development of a novel planning model for a multi-objective electric vehicle (EV) charging station. The model considers three objective functions: total coverage, loss minimization, and voltage profile enhancement [12]. The PSO-DS algorithm was selected as the method of choice for solving the mathematical model because to its effectiveness and straightforwardness. The research demonstrate that the suggested methodology has effectively produced appealing construction plans for electric vehicle (EV) charging stations, while also ensuring the economic viability and security of the power system.

Q. Ma et al. primary objective is to examine the process of EV charging station development with a particular emphasis on achieving a balance between the interests of all stakeholders involved [13]. The initial step involves establishing a charging demand model for a single electric vehicle (EV) by incorporating the concepts of temporal and spatial factors, drawing upon the principles of trip chain theory. The methodology for assessing charging congestion at electric vehicle charging stations, known as the nodal EV

charging wait model, is provided. The Monte Carlo simulation is utilized to determine the overall charging needs of electric vehicles (EVs). Subsequently, taking into account the concerns and preferences of many stakeholders, a multi-objective optimization model for an electric vehicle (EV) charging station is put forth. The suggested optimization model is solved using the Cuckoo search method, which has been enhanced by the inclusion of a dynamic search stage. The findings indicate that the proposed approach successfully achieves a balance between several factors, including the interests of stakeholders, the waiting time for electric vehicle users, the revenue of station investors, and the stable functioning of the power grid.

A. Hafeez et al., proposes a comprehensive architecture for a data-driven-based demand side management scheme in the context of electric vehicle-connected microgrids. The deep learning time-series approach was employed to predict the loads associated with the MG. The data necessary for training the deep learning approach were gathered from a power substation. Furthermore, a data-driven technique was utilized to model the photovoltaic system connected to the microgrid. The modeling of the Electric Vehicle Charging Station (EVCS) was conducted by treating it as a singular energy source. Additionally, the State of Charge (SoC) of the corresponding Electric Vehicle (EV) battery was predicted by the utilization of deep learning techniques [14]. The LSTM model was selected for State of Charge (SoC) estimate due to its superior validation efficiency of 99.51%, surpassing the VARIMA model's performance of 99.13%. The proposed efficient deep learning controller was successfully utilized to accomplish DSM.

R. Venugopal et al., centers on the examination of non-isolated unidirectional converters utilized in the context of off-board charging. Several standards and references have been put forth with the purpose of facilitating rapid off-board charging. The predominant mode of transportation has shifted towards Electric Vehicles (EVs), which rely on the grid supply for charging. However, it is important to note that the grid supply is primarily generated by the combustion of natural fuels, hence raising environmental issues. The utilization of sustainable energy sources for charging purposes has the potential to render future electric vehicles (EVs) as entirely environmentally friendly modes of transportation. The existing research gap pertains to the integration of sustainable energy sources and rapid charging for Direct Current Electric Vehicles (DCEVs) in order to achieve a fully eco-friendly transit system. The initial phase in achieving environmentally sustainable transportation involves the identification of an appropriate converter that can effectively address the existing research deficit within the given location. A straightforward methodology has been employed to ascertain the appropriate DC-DC converter for direct current fast-charging electric vehicles. The present article meticulously identified appropriate topologies derived from Boost, SEPIC, Cuk, Luo, and Zeta converters for the purpose of facilitating clean electric vehicle (EV) charging applications.

### III. CONCLUSION AND FUTURE SCOPE

As a consequence of the escalating utilization of fossil fuels, the entirety of fossil fuel reserves will gradually reduce in the forthcoming years, ultimately resulting in the complete depletion of fossil fuel reservoirs owing to their finite nature. The utilization of fossil fuels by humans has experienced a significant surge, leading to a notable escalation in carbon emissions, consequential climate change, and a host of related environmental concerns. Electric vehicles have been under development worldwide as a means of transportation that has the potential to significantly reduce reliance on fossil fuels in an effective manner. Moreover, given the current worldwide concern regarding the issue of global warming, it is anticipated that there would be a surge in the adoption and advancement of technology pertaining to renewable energy sources, smart grid networks, and electric vehicles. One of the primary limitations connected with the extensive adoption of electric vehicles pertains to the constrained driving range of these vehicles. The successful mitigation of this issue can be achieved by implementing intelligent charging infrastructure, which can furnish data pertaining to the closest charging station and the accessibility of charging slots. This study article aims to critically assess previous studies conducted on the subject matter in order to develop and present our proposed methodology, which will be further detailed in subsequent iterations of this research.

This idea can be enhanced to work as generic application for all the locations of worldwide with the help of Google map API.

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