International Academic Institute for Science and Technology

International Academic Journal of Science and Engineering
Vol. 8, No. 2, 2021, pp. 31-35.

ISSN 2454-3896

International Academic Journal of Science and Engineering

www.iaiest.com

An Energy-Effective Model for Electric Vehicle Charging Station Placement Selection

Ravi Teja Reddy [a], Neelam Chawla [b]

[a] *High-Performance Computing Division, Telangana Technical University, India.*
[b] *High-Performance Computing Division, Telangana Technical University, India.*

Abstract

To keep up with the progress in electric mobility, installing charging stations for modern transport networks is essential. With the increase in electric vehicle (EV) figures every passing day, public charging stations need to adopt effective charging strategies. A significant challenge will be the energy-efficient allocation of EVs to charging facilities. This work shows a new approach to tackling the assignment problem by considering a range of criteria, including the distance between the current position of the EV and the corresponding charging facility, the difference in elevation between these two sites, and the charging capabilities of the stations. The power the EVs require to get to the stations is determined by the distance and elevation difference from the EVs' locations to the charging facilities. The problem can be formulated as a Mixed Integer Linear Programming (MILP) issue and solved using the Branch and Bound (B&B) method.

Keywords: Energy-Effective Model, Electric Vehicle, Charging Station Placement, Location Selection.

Received: 14 March 2021/Revised: 17 April 2021/Accepted: 10 May 2021/Published: 30 June 2021

Introduction

Vehicles propelled by internal combustion engines (ICE) are considered sources of considerable carbon dioxide (CO2) emissions. They are thought to account for about one-fifth of the total CO_2 emissions of the European Union. Energy-efficient alternatives like electric cars must replace internal combustion engines to deal with environmentally harmful emissions, especially in metropolitan areas (Tagliapietra et al., 2019). Electric Vehicles (EVs) are seen as the most viable alternative to ICE vehicles for many reasons, including energy efficiency, environmental sustainability, and improvements through renewable energy technologies (Sun et al., 2019).

The optimum accessibility and choice of charging stations (CS) in urban areas animate the global adoption of EVs and future transport sustainability. An optimal energy-aware EV location needs to be determined with the help of practical methods, while the focus will be on implementing energy-efficient CS and furthering sustainable urban transportation networks (Danish et al., 2020).

In the last few years, various innovative methodologies and models for determining the optimal locations for EV CS in urban settings have gained attention. A primary concern of recent research is established decision-making techniques, especially Mixed Integer Linear Programs (MILP) and Mixed Integer Nonlinear Programming (MINLP), which represent the most widely spread and robust approaches (Sahinidis, 2019). Different methodologies have introduced various constraints and parameters to identify the answers to the problem.

The word of electric vehicle charging stations (EVCS) has been around; the study has seen a gradual increase in penetration rates for EVs (Liu et al., 2020). The Layered Logit approach was used to study individual electric vehicle users' charging preferences and predict the charging demand for EVCSs (Hadian et al., 2020; Adnan et al., 2017). A MINLP method has been presented to locate and size the EVCSs. This work encompasses the reductions in utility grid supply, energy loss for the EVs, total development and construction costs of EVCSs, and placement of urban highways and electric substations.

A zonal methodology was developed to attain the best placement with the best capacity of the EVCS. The suggested technique includes development costs for EV CS and the utility company's total expected expenses due to the EV charging process. The problem is formulated as a MINLP problem that aims to minimize the total costs of EV charging and is solved using GA.

A fuzzy multi-criteria decision analysis (MCDA) method was employed to locate the optimal CS sites with environmental, urban, and financial parameters in mind (Zanghelini et al., 2018). Another goal is to minimize network losses and sustainability issues, minimize environmental impacts, and improve the power system's resiliency. An elaborate model for the best sizing and placement of EVCSs has been proposed, factoring in grid power reduction and reduction in transport and construction costs. The design for EVCS was optimized using a newly proposed Binary Lighting Search Algorithm (BLSA).

To the best of the understanding, current research is lagging since the placement of EVCSs has not considered the elevation difference between the sites of EV and CS or the number of EVs each CS should optimally accommodate. The uniqueness of this proposed methodology rests upon its consideration of elevation differences between the sites of EVs and CSs as an attribute for assessing the optimality of CS locations concerning the overall energy consumption of EVs. The arguments involve the most substantial conceivable number of EVs to be allocated to each CS and contend that both attributes weight the decision-making process of EV users in selecting the most appropriate CS.
The uniqueness of this proposed methodology consists in that it takes into account not merely the distance of the CS to the EV but also the vertical difference between their sites and the charging ability of each station, which means, in turn, the industry believes that elevation differences and CS capacity (that is, the number of connections at each station) are relevant variables that influence the decision-making of EV users when selecting the optimal CS with regards to energy use.

The Primary Contributions of this Study are Outlined as Follows

- Evaluating the impact of altitude disparities between EV locales and CS on the overall energy use of EVs en route to CS.
- This study proposes an energy-efficient technique for allocating EVs to charging facilities. The problem of assigning resources has been defined as an optimization challenge, and the Branch and Bound (BoB) algorithm, adhering to system-wide limitations, has been suggested to address this issue.

Proposed Energy-Effective Model for EVCS Placement

The research assumes that the research region is partitioned into N zones $S_q = \{s_1, s_2, \cdots, s_R\}$. The study presumes that the EV populace inside the same zone possesses identical locational data for elevation as the geographic epicentre of that zone. A zone k is denoted as $S_k = \{s_k^{cp}, s_k^{pop}, s_k^{elv}\}$, where s_k^{cp} is the central position of S_q, s_k^{pop} indicates the EV populace within S_q, and s_k^{elv} denotes the height S_q. The issue of optimization associated with the suggested method can be expressed as:

$$\min\{\sum_{x=0}^{N-1}\sum_{y=0}^{M-1} E_{x,y}p_{x,y}\} \tag{1}$$

$$s.t. \sum_{y=0}^{M-1} P_{x,y} = 1 \; \forall x \tag{2}$$

$$s.t. \sum_{y=0}^{M-1} P_{x,y} < D_y \; \forall y \tag{3}$$

$$P_{x,y} \in \{0,1\} \; \forall x, y \tag{4}$$

The parameter $P_{x,y}$ serves as a binary decision factor, taking values {0,1} to denote the selection of a charging point y by electric vehicle x. $P_{x,y}$ equals one if y is picked; otherwise, it equals 0. Each EV is allocated to a single charge location. D_y represents the ability of the CS y to precisely allocate the maximum amount of EVs to CS y.

The objective functions and the limitations constitute a MILP issue, wherein all choice variables $P_{x,y}$ are restricted to the binary range {0,1}, and the constraints are nonlinear. Fig. 1 illustrates the structure of the methodology. Linear programming methods often address MILP issues. This work employs the Branch and Bound (B&B) strategy to address the assignment issue of EVs, which is characterized by integer factors and linear limits, demonstrating the approach's efficacy.

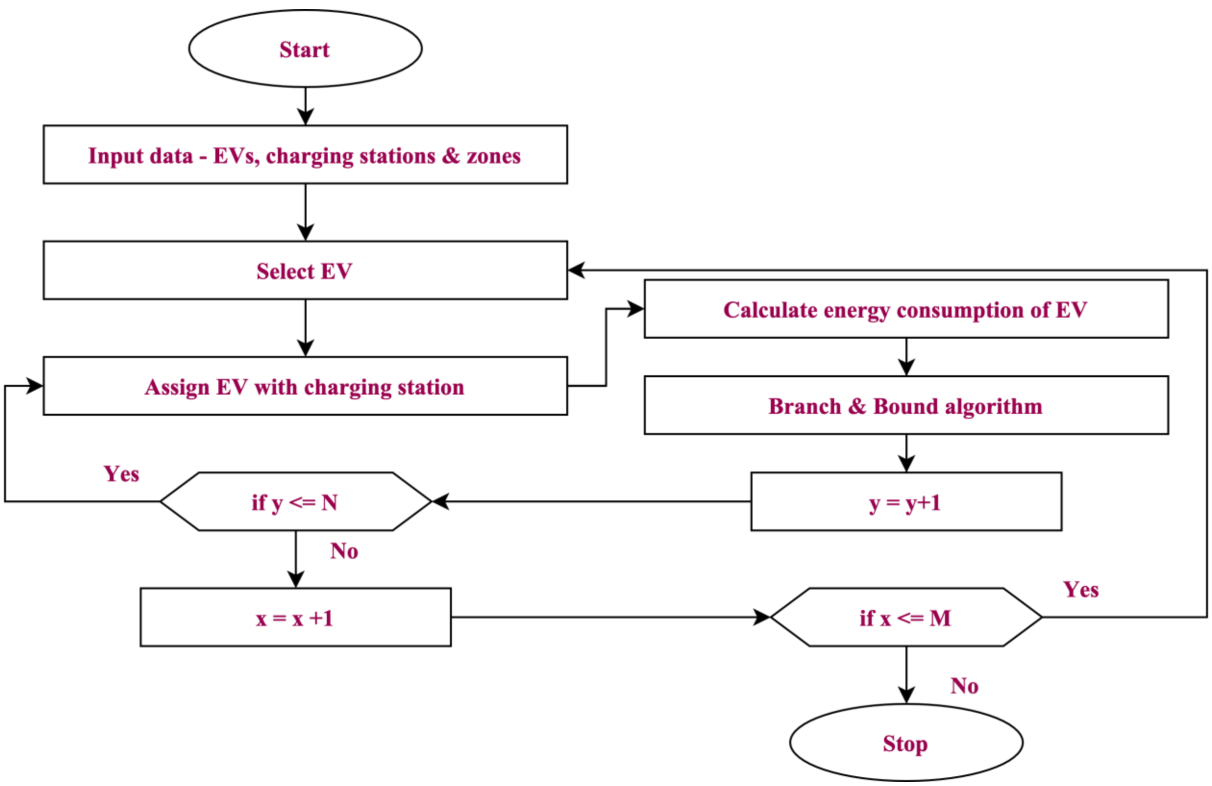

Fig. 1: Flowchart of the System

Results

The suggested methodology has been implemented in the study region. The movement of EVs to CS sites, the height differential between these places, and the capacity variance of the CS have been taken into account for the assignment of EVs to CS. To achieve this outcome, the power use of EVs to arrive at CS must be assessed. Fig illustrates the CS identifiers and their locations indicated by blue rectangles. Black circles denote the geographical centre of the area, while small blue dots represent the EV population. Solid lines mark the boundaries of the regions, and the underlying map was omitted to enhance the figure's clarity. Each charging point possesses a specific quantity of connections, with each connector capable of charging three EVs each hour.

To assess the efficacy of the suggested methodology, the research considers the following situations:

1. The movement between the EV and the CS and the height differential between their sites will be considered in this situation.
2. In this case, the research posits that the vantage point of the initial CS is raised to 100 m, while the elevations of the subsequent CS and areas stay unchanged from scenario 1.
3. In this case, the research posits that all CS (utilized in situation 1) is increased while the height of zones remains the same.
4. In the preceding situations, the research presumes that all CS within the research region possess identical capacities and precisely the same number of connections. In this situation, the study assumes that the quantity of connections at each CS varies.

In scenario 1, the allocation of EVs to CS is determined by minimal elevation discrepancies between the positions of the EVs and the CS. This situation will serve as the foundation for subsequent scenarios. The results from the preceding scenario indicate that the job at CS1 has attained the maximum capacity of EVs due to its proximity to several EV outlets in the research area and its low altitude.

In scenario 2, the research posits that the height of C'S1 rose by approximately 100 m, but the elevations of EVs and other CS remained identical. In this case, the rise or fall of CS results in an approximately 30% reduction in the allocation of EVs to CS compared to the prior situation. This significant difference arises because EVs utilize alternative CSs to minimize the energy required to ascend the incline to reach the CS. The network's total energy usage has grown by approximately 31% relative to the outcomes of the preceding scenario. The findings indicate that the beneficial relationship between the positions of EVs and CS influences the allocation of EVs to charging outlets and the overall energy usage of EVs in reaching these CSs.

In situation 3, the research posits that the height of all the CSs is twice that of the height in situation 1. The entire energy use outcomes of the system have significantly escalated compared to prior instances. Compared to the first and latter scenarios, energy consumption has risen by approximately 64% and 31%, respectively. The allocation of EVs to CS has been altered, as EVs aim to access the most efficient CS with minimal energy expenditure.

In situation 4, the allocation issue has been addressed by taking into account the variability in the capacity of CS. The number of connections at each CS significantly influences the allocation of EVs to the optimal CS. The number of connectors available at the location augments the allocation of EVs to CS. The allocation of EV to every CS has been entirely modified according to the number of connections at the stations. The findings validate that the ability of charging facilities influences the allocation of EVs to these locations, as posited in the suggested methodology.
The allocation of EVs to the charging facility CS stayed consistent across every situation, primarily due to the proximity of most EVs within the study area, resulting in the placement of only the closest EVs to this location (CS2). CS2 has a somewhat higher elevation level than other nearby CS.

Conclusion

This research presents an energy-efficient method for assigning EVs to charging facilities in urban settings. The disparity in the upward trend among the positions of EVs and chargers and the variation in the station's ability are among the elements used in the proposed methodology. The results indicate that the suggested method effectively assigns EVs to the optimal CS based on the energy required to reach those stations. This article presents many scenarios to demonstrate the impact of elevation and CS availability on EVs' allocation and energy usage to access CS. The findings of the suggested technique indicated that the total electrical energy used by EVs to arrive at CS escalates with the altitude differential between the sites of the vehicles and the CS.

References

Tagliapietra, S., Zachmann, G., Edenhofer, O., Glachant, J. M., Linares, P., & Loeschel, A. (2019). The European union energy transition: Key priorities for the next five years. *Energy Policy*, *132*, 950-954.

Sun, X., Li, Z., Wang, X., & Li, C. (2019). Technology development of electric vehicles: A review. Energies, 13(1), 90. https://doi.org/10.3390/en13010090

Danish, S. M., Zhang, K., Jacobsen, H. A., Ashraf, N., & Qureshi, H. K. (2020). BlockEV: Efficient and secure charging station selection for electric vehicles. *IEEE Transactions on Intelligent Transportation Systems*, *22*(7), 4194-4211.

Sahinidis, N. V. (2019). Mixed-integer nonlinear programming 2018. *Optimization and Engineering*, *20*, 301-306.

Liu, L., Xie, F., Huang, Z., & Wang, M. (2020). Multi-objective coordinated optimal allocation of DG and EVCSs based on the V2G mode. *Processes*, *9*(1), 18. https://doi.org/10.3390/pr9010018

Zanghelini, G. M., Cherubini, E., & Soares, S. R. (2018). How multi-criteria decision analysis (MCDA) is aiding life cycle assessment (LCA) in results interpretation. *Journal of Cleaner Production*, *172*, 609-622.

Hadian, E., Akbari, H., Farzinfar, M., & Saeed, S. (2020). Optimal allocation of electric vehicle charging stations with adopted smart charging/discharging schedule. *IEEE Access*, *8*, 196908-196919.

Adnan, N., Nordin, S. M., Rahman, I., Vasant, P. M., & Noor, A. (2017). A comprehensive review on theoretical framework-based electric vehicle consumer adoption research. *International Journal of Energy Research*, *41*(3), 317-335.