PROJECT REPORT

On

Optimal Placement of Electric Vehicle Charging Stations using Bayesian Networks

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ABSTRACT

With increasing energy consumption, dependency on fossil fuels, increase in carbon foot- prints, a paradigm shift towards sustainable and viable options is necessary. As an effort towards greener technology, the inclusion of electric vehicles and electrification of transportation systems is being encouraged in various countries. The introduction of alternative vehicle technologies in the existing self-contained transportation system poses questions and challenges. Solely expanding the population of EVs in a city without enough road connections and corresponding charging and parking infrastructure will suppress the feasibility of EVs. Thus, supportive charging infrastructure is of utmost priority for large-scale adoption of EV systems. The charging station placement is a complex optimization problem involving power distribution network and road network and thus its solution must superpose the considerations of both the systems. Therefore, to find an optimal solution to this problem, multi-stage multi-objective solution approach is followed. Stage I aims at determining the candidate locations based on parameters like voltage stability factor, distance between nodes of traffic and distribution networks and congestion. Furthermore, in stage II optimization of the candidate locations based on cost of installations, penalties, range anxiety etc.is carried and off solutions are obtained. Initially, analysis is done on a 25-node transport network superposed on a 33-bus radial distribution network. Thereafter, the proposed model is applied to real urban network.

Keywords - Electric Vehicle, Charging Station Placement, Optimization.

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1. INTRODUCTION

1.1 Problem Definition

The increasing adoption of electric vehicles (EVs) necessitates the strategic placement and design of EV charging stations to meet the growing demand. This process involves integrating urban and power networks, taking into account factors such as charging capacity, user preferences for charging modes, and the overall EV load. The challenge lies in determining the optimal locations for charging stations, considering various geographical, technical, and transportation parameters. Additionally, the problem involves analyzing the distribution network and assessing the capacity of Distribution Transformers (D'Ts) in feeders connecting charging stations, along with power sources and upgrades.

Significance

The siting and designing of EV charging stations are crucial for the successful development of an Electric Mobility (E-mobility) ecosystem. Addressing this challenge ensures the creation of a sustainable and efficient charging infrastructure, catering to the specific needs of urban areas. By considering factors such as heavy and slow traffic, commercial establishments, and population density, the placement of charging stations can be optimized to accommodate the growing number of EV users. This significance extends to the overall enhancement of E-mobility, reducing carbon emissions, and promoting the widespread adoption of electric vehicles.

Objectives

1. Optimal Siting: Identify candidate locations for EV charging stations through a two-stage planning model, involving an initial selection process followed by optimization for the best results.

2. Capacity Determination: Analyze the distribution network to determine the optimal placement of Distributed Generators (DGs), taking into account the penetration of electric vehicles in the context of Indian urban cities.

3. Model Development: Develop a comprehensive model for the placement of EV charging stations that considers both traffic parameters and electric grid characteristics. This model aims to

provide a robust and sustainable solution for accommodating the increasing number of EV users in urban areas.

1.2. Methodology

1.2.1 Data Collection and preprocessing

The process begins with comprehensive data collection, encompassing various factors like power distribution networks, road networks, voltage stability, traffic patterns, and distribution node distances. Historical data on congestion and traffic flow further enriches the dataset. Data preprocessing follows, involving thorough cleaning and normalization to ensure the reliability and consistency of the information. This step is pivotal in eliminating outliers and standardizing data for effective analysis. With the data ready, the next phase involves defining specific objectives. These objectives could range from minimizing congestion and maximizing voltage stability to optimizing the deployment costs associated with charging stations.

1.2.2 Model Development

a. Utilize pre-trained deep neural networks and also machine learning models as feature extractors.

b. Fine-tune the remaining layers on the traffic dataset. Adjust hyperparameters such as learning rate, batch size, and optimizer.

c. Train the modified models on the training dataset.

1.2.3 Testing

Test the various models on testing data, new unseen data and find the metrics for all the models and select the best model among all.

1.2.4 Evaluation

Model Performance Metrics:

a. For each model evaluate performance using metrics such as accuracy, precision, recall, and F1 score on the validation dataset.

b. Monitor training and validation loss to avoid over-fitting.

Comparison of Models: Compare the performance of the pre-trained models and the proposed model in terms of accuracy, precision, recall, and F1 score. Identify the model with the best validation performance

1.3 Outline of the Results

The proposed work is a multi-stage multi-objective joint planning model is developed for integrated EV charging system and distribution network planning. This research work develops a planning scheme integrated both the future charging facilities and renewable generation in power system planning. The installation of DG is beneficial to avoid both distribution line expansion and fossil fuel plant construction. The sites and sizes of DG could be properly planned to achieve the benefits from DG integration, such as loss reduction, peak load shaving, voltage drop control and investment deferral. This simultaneous optimal planning (placing and sizing) of EV charging system delivers a holistic solution for system planning. Therefore, we have established a sustainable and viable methodology to place the EV charging stations. Also, this work solves the charging station placement problem in the context of Indian cities like Chandigarh. Future works in the same field might address some of the critical issues related to charging infrastructure planning like pricing strategies in the charging stations, planning of Vehicle to Grid (V2G) enabled charging stations, better renewable energy integration, stakeholders, and maximum profits etc.

1.4 Scope of the Project

The developed system on the optimal placement of EV charging stations using Bayesian networks has the potential to address complex, interconnected challenges in sustainable urban transportation, providing valuable insights for stakeholders and contributing to the advancement of EV infrastructure planning. It addresses key challenges in sustainable transportation.

1.5 Organization of the report

The project is structured as follows: It begins with an introduction, outlining the problem, significance, objectives, scope, and methodology, followed by a literature survey that introduces domain terminology, discusses existing solutions, reviews related works, and mentions any tools or technologies. The design of the proposed system is detailed, encompassing block diagrams, module descriptions, and theoretical foundations/algorithms. Implementation is further broken down into data collection, data augmentation and segmentation using segment anything model. Results and evaluation are presented, followed by a section of fine-tuning.

2. LITERATURE SURVEY

2.1 Introduction to Problem Domain Terminology

Siting and designing EV charging stations requires an overlay of the urban networks on the power networks. Factors such as the charging capacity required, preference of users for mode of charging, and the total EV load depend upon various geographical, technical and transportation parameters. Appropriate siting and capacity determination of EV charging step is an important step to building a successful E mobility ecosystem. For appropriate location selection, considerations like heavy and slow traffic, commercial establishments, population density come into play. Thereby, a location specific analysis is essential to identify the needed charging capacity for a particular location. Further, prioritization of EV charging locations would depend on spare capacity in the Distribution Transformers (D'Ts) in the feeders connecting the charging stations, power sources and upgradation. Thus, it is essential to take these parameters when building a charging station.

There have been significant amount of works solving the charging station siting and designing problem. Compared to the existing works, the present work has following contributions: Two stage planning model has been laid for the optimal placement of EV charging station. In first stage, candidate locations are found followed by the optimization to get the best results. Furthermore, distribution network is analyzed to place the DGs effectively considering EV penetration. The charging station placement problem is modelled in the context of Indian urban city. The cities will be having large EV users, hence, there will be a necessity of sustainable charging infrastructure. This work focuses on placing the EV charging station.

2.2 Existing Solutions

[1] This paper uses the method known as particle swarm optimization. The results of the paper are the loading for transformers and distribution lines, voltages at the system nodes, and the losses in the system were considered. The type of EV charger is not considered. The limitations of the paper are charging stations which are not on the route are not considered and investment cost was not a factor.

[2] This paper's objective function is minimizing the total distance travelled for the charging stations. For minimizing the distance, he used the shortest path algorithm. The findings are the charging stations which are not on the route are considered. The result of this paper is investment cost of charging stations in different locations within the city is considered in the objective of the model.

[3] This paper used three different smart charging strategies: They are: Network oriented charging, Renewable energy oriented charging and Cost-oriented charging.
The findings are avoiding infrastructural investments and EV owners could benefit from low energy costs. The limitation of this paper is it requires sufficient / additional RES-E capacities to meet required additional electricity demand from EV. The results are increased system stability and grid functioning.

[4] This research paper uses 4 different methods. They are: Iterative MILP, Greedy approach, Effective MILP and Chemical Reaction Optimization. These algorithms converge very fast and can converge within 500 FEs in all the cases. The limitation of this research paper is that it focuses on human factors rather than technological ones for charging station placement.

[5] This research paper uses 2 methods which are MIP model and Stress Test for optimal placement of electric vehicle charging stations. The findings of this study are as the number of charging stations increases, mean and maximum inconvenience experienced by the vehicles drop rapidly. The limitations of this research paper are it couldn't analyze the impact of EV charging on the power grid by geography and time of the day.

2.3 Related Works

SNO	Research Paper	Methods Used	Findings	Limitations	Results
1)	Ahmad Bashaireh; Duaa Obeidat; Abdullah A. Almehizia; Laith Shalalfeh Optimal Placement of Electric Vehicle Charging Stations: A Case Study in Jordan 2023.	Particle Swarm Optimization	Type of EV charger is not considered (Voltage profile of the grid)	Charging stations which are not on the route are not considered. Investment Cost was not a factor.	The loading for transformers and distribution lines, voltages at the system nodes, and the losses in the system were considered.
2)	Kerem Can Arayici; Gokturk Poyrazoglu . The Optimal Placement Model for Electric Vehicle Charging Stations . 2019 .	Objective function is minimizing the total distance traveled for the charging stations. For minimizing the distance, he used the shortest path algorithm.	Charging stations which are not on the route are considered.	Type of EV charger is not considered (Voltage profile of the grid)	Investment cost of charging stations in different locations within the city is considered in the objective of the model.
3)	Electric mobility in Europe – Future impact on the emissions and the energy system, Oeko-Institut and Transport & Mobility Leuven(TML), 2016	Different smart charging strategies: 1) Network-oriented charging 2) Renewable energy-oriented charging 3) Cost-oriented charging	Avoiding infrastructural investments. EV owners could benefit from low energy costs.	Requires sufficient / additional RES-E capacities to meet required additional electricity demand from EV.	Increased system stability and grid functioning.
4)	A. Y. S. Lam, Y. W. Leung and X. Chu, “Electric Vehicle Charging Station Placement:	1) Iterative MILP 2) Greedy Approach 3) Effective MILP	The algorithm converges very fast and can converge within 500 FEs in all	It focuses on human factors rather than technological ones	The algorithm converges very fast and can converge within 500 FEs in all the cases.

5)	M. Andrews, M. K. Dogru, J. D. Hobby, G. H. Tucci, and Y. Jin," Modelling and Optimization for Electric Vehicle Charging Infrastructure," Alcatel-Lucent Bell Labs, 2012.	MIP Model Stress test	As the number of charging stations increases, mean and maximum inconvenience experienced by the vehicles drop rapidly.	It couldn't analyse the impact of EV charging on the power grid by geography and time of the day.	The maximum inconvenience experienced by the vehicles dropped rapidly.

2.4 Tools/Technologies Used

2.4.1 Visual Studio Code

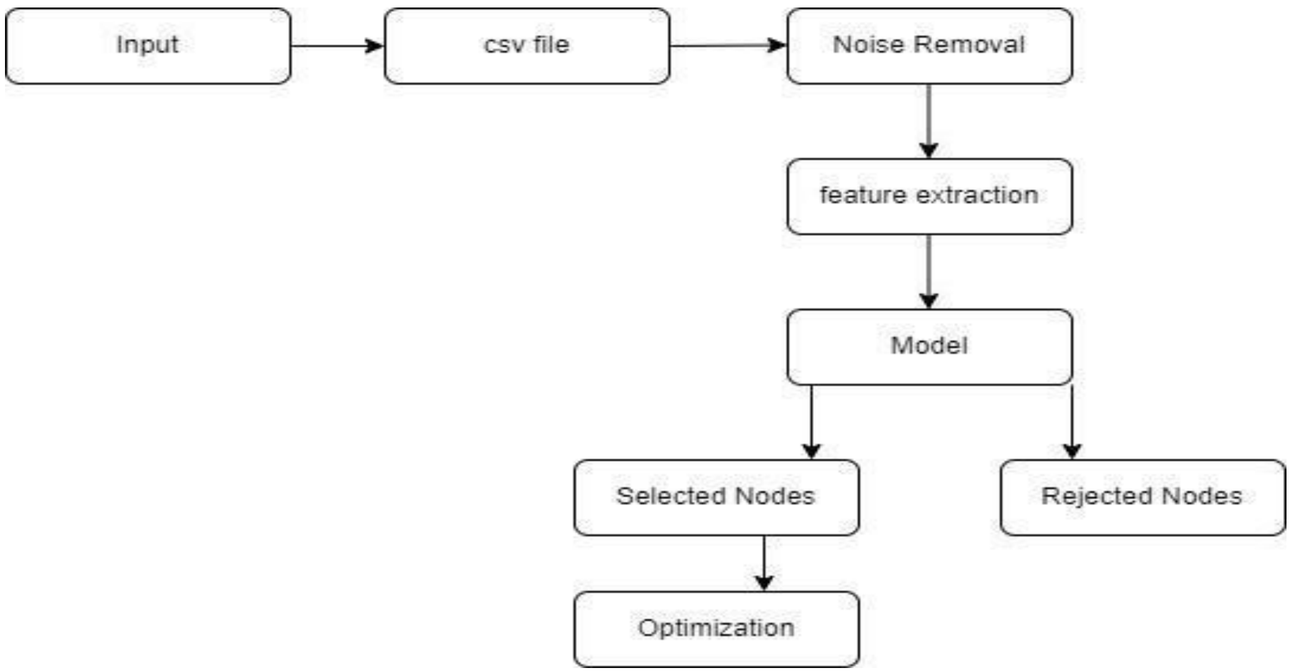
Visual Studio Code is a streamlined code editor with support for development operations like debugging, task running, and version control. It aims to provide just the tools a developer needs for a quick code-build-debug cycle and leaves more complex workflows to fuller featured IDEs, such as Visual Studio IDE.

2.4.2 Machine Learning

Machine learning is a subset of artificial intelligence (AI) that involves developing algorithms and models that enable computers to learn from and make predictions or decisions based on data. It encompasses a wide range of techniques, including supervised learning, unsupervised learning, and reinforcement learning, and is used for tasks like pattern recognition, classification, and regression.

3. DESIGN OF THE PROPOSED SYSTEM

3.1 Block Diagram



3.2 Module Description

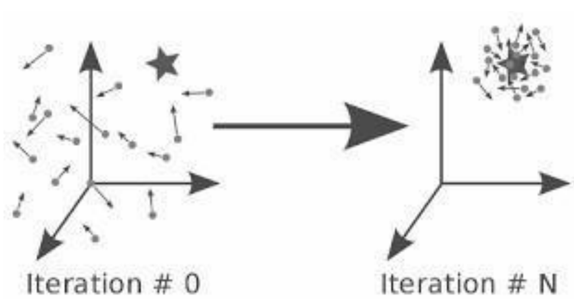
3.2.1 Input: The proposed model takes various attributes of the nodal points from the dataset, which are used to decide which nodes are candidate nodes.

3.2.2 Prediction: On applying the algorithm and comparing with the threshold value the candidate nodes are shortlisted and optimized using the cost function.

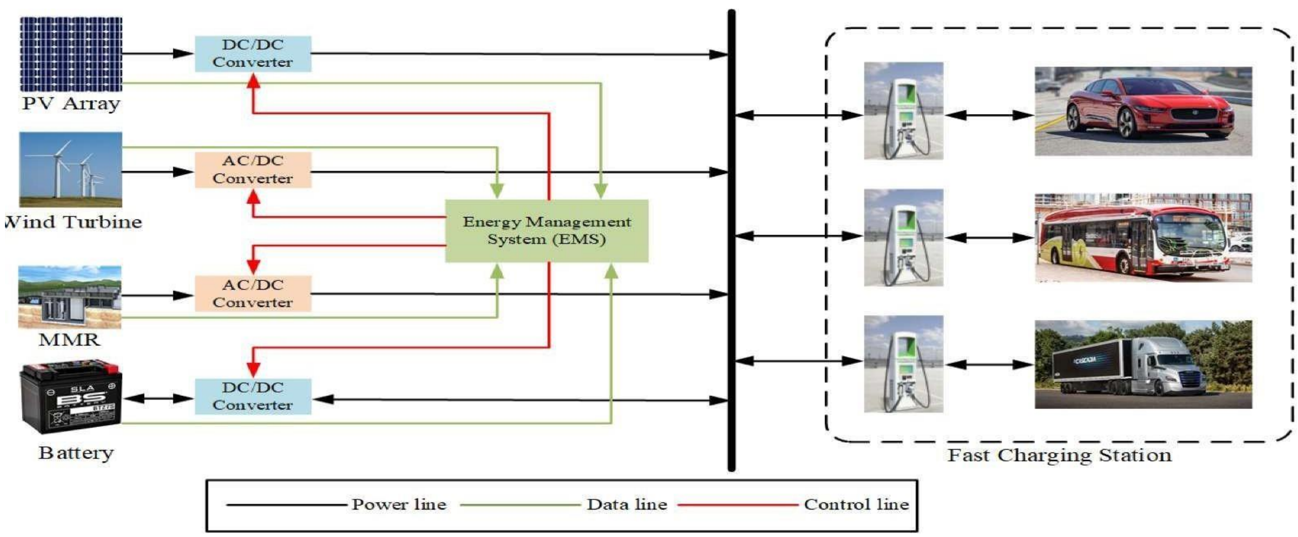
3.2.3 Output: The user gets to predict where the ev charging stations are to be planted that is optimal and number of ports to be placed at each station.

3.3 Theoretical Foundation/Algorithms

3.3.1 Swarm optimization: Swarm optimization is a nature-inspired optimization technique based on the collective behavior of social organisms like ants, bees, and birds. It involves a population of agents (particles) that move through a search space to find the optimal solution by iteratively adjusting their positions. The agents communicate and share information about their best-known positions, allowing the swarm to converge towards the best solution. Popular algorithms like Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO) are examples of swarm optimization methods. Swarm optimization is particularly effective in solving complex, high-dimensional, and non-convex optimization problems where traditional methods may struggle.

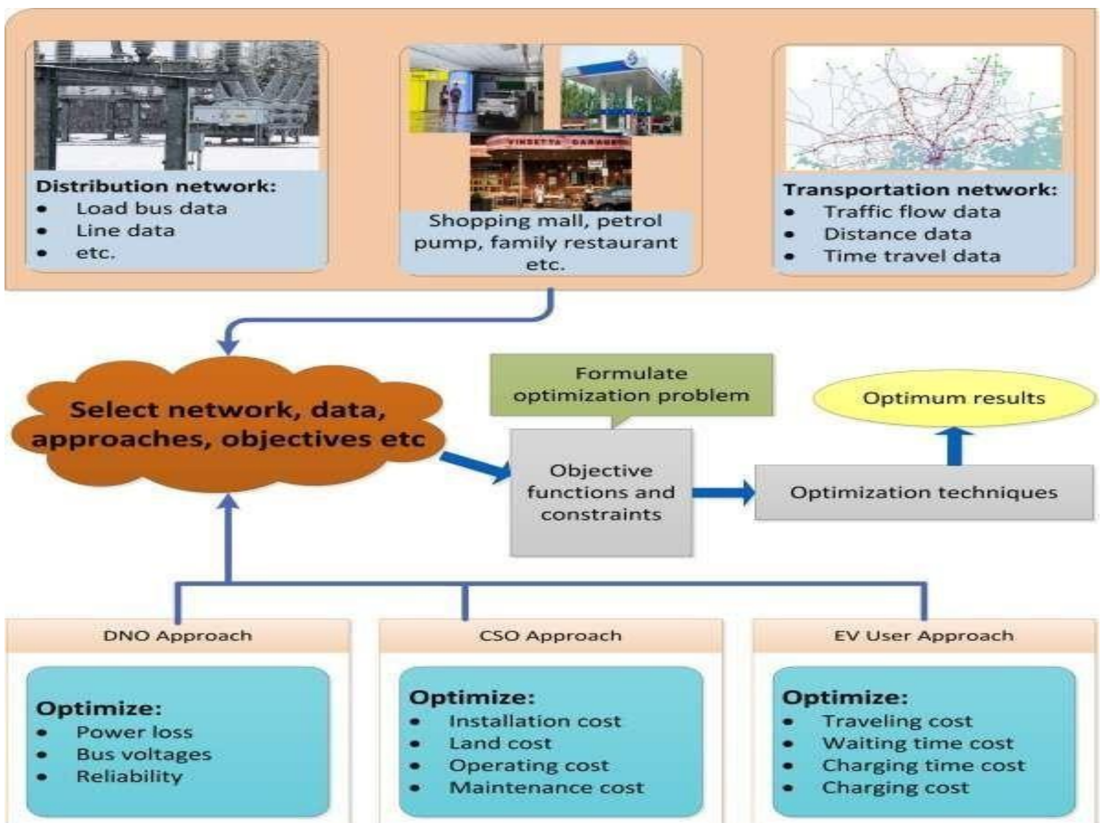


3.3.2 Mixed-Integer Linear Programming : MILP is a mathematical optimization technique used to solve problems with discrete and continuous variables, where some variables are restricted to take integer values. It is widely applied in various fields, including engineering, economics, and logistics, to model decision-making problems with both discrete and continuous aspects. MILP problems are formulated as linear equations and inequalities, but with the additional constraint that certain variables must be integers. Solving MILP problems can be computationally demanding, and specialized solvers like CPLEX and Gurobi are often used for efficient solutions. MILP finds applications in production planning, resource allocation, supply chain management, and many other domains with discrete decision variables.



3.3.3 Bayesian Network : A Bayesian network is a probabilistic graphical model representing a set of variables and their conditional dependencies using a directed acyclic graph (DAG). It provides a compact way to represent joint probability distributions and infer relationships between variables. Bayesian networks are extensively used in fields like machine learning, artificial intelligence, healthcare, finance, and genetics for decision-making under uncertainty. The nodes in a Bayesian network represent random variables, and the edges denote probabilistic dependencies between them. Inference in Bayesian networks allows for predictions, diagnoses, and decision-making by updating beliefs about variables given new evidence.

3.3.4 Greedy Approach : The greedy approach is a heuristic strategy that makes locally optimal choices at each step with the hope of finding a global optimum. It is simple, intuitive, and computationally efficient, making it useful for solving problems where finding an exact solution is impractical. However, the greedy approach does not always guarantee the best solution and may lead to suboptimal results in some cases. Greedy algorithms are commonly employed in problems like the knapsack problem, scheduling tasks, and constructing minimum spanning trees. Despite its limitations, the greedy approach can be a powerful tool when used appropriately and can provide near-optimal solutions for certain types of problems.



4. CONCLUSION

In this research work, a multi-stage multi-objective joint planning model is developed for integrated EV charging system and distribution network planning. This research work develops a planning scheme integrated both the future charging facilities and renewable generation in power system planning. The installation of DG is beneficial to avoid both distribution line expansion and fossil fuel plant construction. The sites and sizes of DG could be properly planned to achieve the benefits from DG integration, such as loss reduction, peak load shaving, voltage drop control and investment deferral. This simultaneous optimal planning (placing and sizing) of EV charging system delivers a holistic solution for system planning. Therefore, we have established a sustainable and viable methodology to place the EV charging stations. Also, this work solves the charging station placement problem in the context of Indian cities like Chandigarh. Future works in the same field might address some of the critical issues related to charging infrastructure planning like pricing strategies in the charging stations, planning of Vehicle to Grid (V2G) enabled charging stations, better renewable energy integration, stakeholders, and maximum profits etc.

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