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EXAMINING THE OPTIMISATION STRATEGIES FOR ELECTRIC VEHICLE CHARGING STATIONS

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ABSTRACT

Despite the restricted range of electric vehicles (EVs) and the limited availability of charging stations, owners of EVs who are contemplating long-distance journeys continue to experience range anxiety from their vehicles. Therefore, it is essential to ascertain whether or not the chosen route is feasible and to figure out the most effective method of charging at the same time. This paper provides a mixed integer linear programming (MILP) solution for the electric vehicle charging strategy problem (EVCSP). The MILP approach incorporates a piecewise linear approximation technique to solve the issues provided by nonlinear charging durations. This approach is an essential component of decision assistance for electric vehicle drivers. For a given route, the suggested optimisation model, which is referred to as CSPM, decides where, when, and how much to charge an electric vehicle in order to save the amount of time and money spent travelling. It is possible to determine the resilience and dependability of the CSPM by analysing the solution time of large-scale test issues and doing a case study on Turkey. In addition, the case study is subjected to the application of two multi-objective optimisation approaches, namely the weighted sum method and the lexicographic method, and the outcomes are analysed. With a range of 46.09 percent across all of the applied charging methods, the findings suggest that the trip cost is more sensitive to the chosen charging strategy. On the other hand, journey time remains more robust, with a maximum variation of 19.77 percent throughout the range of the applied charging strategies. According to the findings of a comparison study with a complete charging approach, the CSPM increases the cost efficiency by 105.72 percent while simultaneously decreasing the amount of time spent travelling by 60.1%.

KEYWORDS: Electric vehicles, scheduling techniques, optimal scheduling, network integration.

INTRODUCTION

The world's intense interest in developing and disseminating alternative energy sources is astounding, given the present situation of things. Consequently, most buyers choose and are familiar with new energy electric vehicles. Reason being, they represent the creation and usage of alternative energy sources (Ahmad et al., 2022). The demand for charging stations tailored to new energy vehicles has surged in recent years, coinciding with the proliferation of electric automobiles powered by these sources. Distributing charging stations in the most effective way feasible will allow us to meet the charging needs of electric automobiles more efficiently. Because of this, this study will address the growing importance of studying the optimal locations for electric car charging stations. Taxis, buses, and private EVs all have access to charging facilities, thanks to the substantial interest in this subject among researchers. Optimal models and algorithms for the distribution of electric car charging stations are proposed in this work, which analyses the issues affecting their placement from several angles, including environmental advantages. Numerous academics also pay close attention to monetary cost and consumer desire. In the long run, the electric car sector will feel the effects of the lack of structure and preparation. Despite the huge and promising electric car industry in many nations, there has been very little investment in charging station infrastructure. Finding the right placement of charging stations for EVs, taking into account market and geographical factors, is therefore a major factor in the expansion of the EV ecosystem. The rapid expansion of electric vehicle (EV) ownership necessitates a parallel expansion of charging infrastructure, especially in major markets such as the United States, Asia, and Europe. It is most appropriate for state and regional governments to supervise electric vehicle uptake and charging infrastructure. The increasing length of time that an EV is connected but not charging is a big problem. This issue impacts transportation infrastructure in terms of size, cost, and accessibility. Improved infrastructure management and more EV adoption might result from more accurate idle time estimations and management made feasible by machine learning (ML), which would be beneficial for policymakers, network owners, and EV drivers alike. A vital component of the modern transportation system, electric automobiles reduce emissions of greenhouse gases and reliance on fossil fuels (Anjos et al., 2020).

BACKGROUND OF THE STUDY

The project aims to reduce peak loads and improve grid stability while minimising the amount of money end users have to pay for charges. Simulations were run under various conditions to show how well the suggested system reduced peak demand and optimised energy use. It is advised that, instead of charging lithium-ion batteries to their full capacity, they be charged to around 80%. Indeed, with most EVs, the researcher has the freedom to set a "target charge" of their choosing (Chen et al., 2020). The best way to figure out how much to charge is to look in the owner's manual. While charging at home is generally safe, researchers should still consult a licensed electrician to ensure a dedicated circuit can handle the amount of power being used if they plan to connect to a level-1 charging cable for long-term charging. Charging a plug-in hybrid electric vehicle (PHEV) using an extension cord is illegal. Being in an abnormally high or low charge state might reduce the battery's lifespan. Modern electric car chargers often include an automated shutoff feature that activates when the battery is fully charged. It is recommended that the researchers always keep the battery between 30 and 80 percent charged. The researcher should only charge the researchers electric car up to 80% of its capacity since charging rates start to drop sharply after that. The second point is that the researchers' vehicle's battery pack will last longer if they keep it below 100% (Huang & Kockelman, 2020).

PURPOSE OF THE RESEARCH

Two of the most important objectives of the project are to reduce peak loads, enhance grid stability, and minimise the amount of money that end customers are charged for their purchases. The effectiveness of the proposed method in lowering peak demand and making the most efficient use of energy was shown via simulations that were carried out under a variety of conditions. Electric vehicle charging stations, also known as EVSEs, are responsible for providing power to EVs including both PEVs and other EVs. With any kind of electric vehicle, it is feasible to achieve better fuel economy, lower fuel prices, and a reduction in the amount of pollutants produced. Electricity is an excellent source of power for transportation since it contributes to the development of a more robust system, and it is beneficial to both the environment and public health. Additionally, it makes roadways safer. Charging systems are responsible for preserving the charge of the battery and supplying the researchers' vehicle with the electrical energy it needs to function while it is in motion.

LITERATURE REVIEW

Research on electric car charging station sites primarily focusses on three areas: examining variables impacting the position of the station, constructing a model for optimum location, and studying the algorithm connected with the model (Mastoi et al., 2022). In light of mounting environmental concerns and energy limitations, renewable energy sources and electric vehicles seem to be the most promising alternatives. It is anticipated that this trend will continue. People often park their cars for more than 90% of the time, meaning they stay inactive for far longer periods of time than what is necessary to recharge the batteries. With this in mind, EVs may double as a portable power source and generator. The majority of electric car batteries are made up of cells that include lithium-ion. Lighter electric vehicles have more range and a smaller environmental impact, but this is difficult to do with traditional materials. As the number of people driving electric cars continues to rise, city planners in big cities are starting to consider how to best set up charging stations across the city. The charging distance and power need of electric cars are higher than those of gas-powered automobiles. A four-wheel electric vehicle has fewer moving parts than a gas-powered vehicle. Streamlined construction. Consequently, maintaining such a vehicle is also not expensive. Pollutants in the air are reduced and improved by electric automobiles. Also, modern automobiles don't make as much noise. In the case of an accident, electric cars are less likely to cause serious damage. Their frames don't have a lot of mass, which contributes to their lightweight design. A lot of study has focused on how charging electric vehicles affects the electrical grid. However, the issue of power network instability caused by EV charging has received very little attention (Meng et al., 2023).

RESEARCH QUESTION

- What is the impact of battery storage on electric vehicle charging stations?

RESEARCH METHODOLOGY

RESEARCH DESIGN:

Quantitative data analyses were performed using SPSS version 25. The researchers used the odds ratio and the 95% confidence interval to assess the strength and direction of the statistical link. The researchers determined a level considered statistically significant at $p < 0.05$. A descriptive analysis revealed the key characteristics of the data. Data obtained via surveys, polls, and questionnaires, together with data analysed using computational tools for statistical evaluation, are often examined using quantitative approaches.

SAMPLING:

Research participants filled out questionnaires to provide information for the research. Using the Rao-soft programme, researchers determined that there were 657people in the research population, so researchers sent out 896 questionnaires. The researchers got 823 back, and they excluded 45 due to incompleteness, so the researchers ended up with a sample size of 778.

DATA AND MEASUREMENT:

The study mostly used data acquired from a questionnaire survey. The participant's essential demographic information was first requested. Participants were then given a 5-point Likert scale to evaluate the online and offline channels. The researchers rigorously analysed several resources, especially internet databases, for this secondary data gathering.

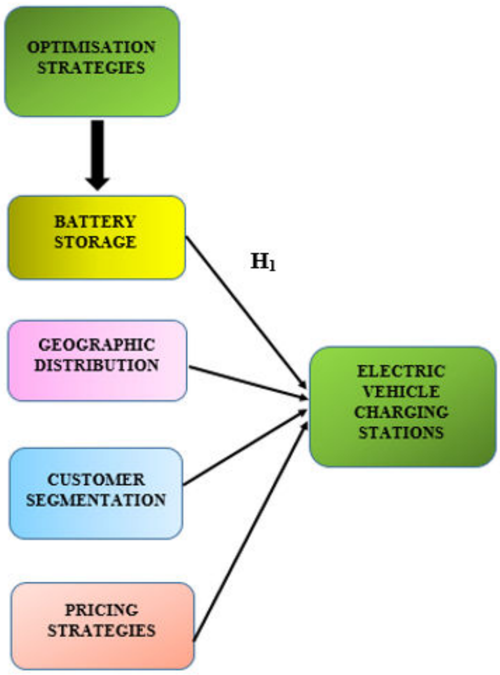
STATISTICAL SOFTWARE:

The statistical analysis was conducted using SPSS 25 and MS-Excel.

STATISTICAL TOOLS:

To grasp the fundamental character of the data, descriptive analysis was used. The researcher is required to analyse the data using ANOVA.

CONCEPTUAL FRAMEWORK



RESULTS

- **FACTOR ANALYSIS**

One typical use of Factor Analysis (FA) is to verify the existence of latent components in observable data. When there are not easily observable visual or diagnostic markers, it is common practice to utilise regression coefficients to produce ratings. In FA, models are essential for success. Finding mistakes, intrusions, and obvious connections are the aims of modelling. One way to assess datasets produced by multiple regression studies is with the use of the Kaiser-Meyer-Olkin (KMO) Test. They verify that the model and sample variables are representative. According to the numbers, there is data duplication. When the proportions are less, the data is easier to understand. For KMO, the output is a number between zero and one. If the KMO value is between 0.8 and 1, then the sample size should be enough. These are the permissible boundaries, according to Kaiser: The following are the acceptance criteria set by Kaiser:

A pitiful 0.050 to 0.059, below average 0.60 to 0.69

Middle grades often fall within the range of 0.70-0.79.

With a quality point score ranging from 0.80 to 0.89.

They marvel at the range of 0.90 to 1.00.

Table1: KMO and Bartlett's Test

Testing for KMO and Bartlett's

Sampling Adequacy Measured by Kaiser-Meyer-Olkin .957

The results of Bartlett's test of sphericity are as follows: approx. chi-square

df=190

sig.=.000

This establishes the validity of assertions made only for the purpose of sampling. To ensure the relevance of the correlation matrices, researchers used Bartlett's Test of Sphericity. Kaiser-Meyer-Olkin states that a result of 0.957indicates that the sample is adequate. The p-value is 0.00, as per Bartlett's sphericity test. A favourable result from Bartlett's sphericity test indicates that the correlation matrix is not an identity matrix.

Table: KMO and Bartlett's

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.957
Bartlett's Test of Sphericity	**Approx. Chi-Square**	3252.968
	df	190
	Sig.	.000

Bartlett's Test of Sphericity further substantiated the overall significance of the correlation matrices. The Kaiser-Meyer-Olkin metric of sample adequacy is 0.957. The researchers calculated a p-value of 0.00 using Bartlett's sphericity test. The correlation matrix was considered invalid because of a significant result from Bartlett's sphericity test.

- ❖ **INDEPENDENT VARIABLE**
- **OPTIMISATION STRATEGIES:**

A number of different tactics are used in the process of performance optimisation. Some of these strategies include load balancing, system tuning, and code optimisation. In addition to these methods, load balancing is also used (Anjos et al., 2020). Its major goal is to improve the computational efficiency of a system in order to reduce the number of resources that are needed and to minimise the length of time that latencies are experienced. Optimisation strategies are a set of systematic activities that are conducted in order to define optimum solutions towards one or multiple parameters while adhering to specific limits in order to either maximise or decrease the goals of particular solutions. The phrase "optimisation strategies" refers to this series of actions. The Multiphase Optimisation Strategy, more often referred to as MOST, is a method that is used in the process of developing therapies that are not only effective but also cost-effective and can be administered in a diversity of different environments. When it comes to the majority of situations, the fundamental goal of MOST is to enhance the efficacy of therapies in terms of improving health or habits. Specifically, in the context of optimisation, a specific sort of equilibrium is one in which there is a goal that has to be completed. In this context, the term "goal equilibrium" is one way to refer to this concept. When it comes to utility maximisation, for example, it is required to establish the quantity of things that should be consumed, given a budget constraint, in order to reach the maximum possible degree of enjoyment for the client. This is done in order to find the optimal solution (Mortimer et al., 2022).

- ❖ **FACTOR**
- **BATTERY STORAGE:**

Batteries, often called battery energy storage systems (BESS), are devices that can store energy from renewable sources like wind and solar and then release it when electricity is needed most. Storage battery technology is widely utilised and has a long history of success in many industries, such as power systems and automobiles. The components are sulphuric acid-immersed lead-acid or nickel-cadmium plates. The ability to store and release electrical energy via chemical reactions is made possible by this. The most common choice for battery energy storage systems now is lithium-ion batteries due to its efficiency, long cycle life, and high energy density. Their fast charging and discharging capabilities make them ideal for backup power applications, grid balancing, and renewable energy source integration. As a safety feature, Dell batteries may go into storage mode and automatically shut down when not in use. This keeps the battery from getting too low and helps keep its capacity up. In addition, the purpose of this mode is to improve battery life. One of the materials used to make storage batteries is lead. Furthermore, it is included in pewter, type metal, fusible alloys, bearing alloys, and solder. Ammunition, including shot and bullets, is made from it (Niccolai et al., 2021).

❖ DEPENDENT VARIABLE

- **ELECTRIC VEHICLE CHARGING STATIONS:**

In the context of electric vehicles, "EV charging" means both the act of supplying energy to power the vehicle and the process of charging the car itself. Electric vehicles may have their range extended to around 250 miles in about six to eight hours when charged using a Level 2 charger, which supplies electricity to recharge the batteries of electric automobiles. The researcher can charge the researchers electric automobile the same way the researcher charge any other device: by connecting it into an electrical outlet. This is accomplished by transferring energy to the car using an electrical current that is drawn from a source of 240 volts. More than just a convenient charging option for car owners, it might help reduce emissions and energy costs. Electric car charging stations are a game-changer when it comes to developing greener modes of transportation. Recharging the battery, or charging the electric car, is the process of adding energy to an electric vehicle's storage capacity. This is accomplished by hooking up the electric car to a charging station. A charging station, often called an EVSE or just an EV charging station, allows drivers to add power to their electric vehicles. Level 1 and level 2 chargers, as well as quick chargers powered by diesel, are among the many types of electric car chargers available (Pal et al., 2023).

- **RELATIONSHIP BETWEEN BATTERY STORAGE AND ELECTRIC VEHICLE CHARGING STATIONS**

As EVs become more popular and effective energy management is of the utmost importance, the connection between EV charging stations and battery storage will play a larger and larger role. Improving the efficiency and dependability of electric vehicle charging infrastructure is largely dependent on battery storage systems, especially those that use modern technologies such as lithium-ion or solid-state batteries (Chen et al., 2020). When renewable energy supply is low or demand is high, these storage devices may be utilised to charge electric cars using the extra electricity that is produced from renewable sources like wind or solar. As a result, the grid is better able to balance, peak demand is reduced, and EV owners' energy requirements are always met. Also, in places where the local power grid isn't always dependable, battery storage devices may provide a steady supply of electricity for charging stations. Station operators and users alike may benefit from the integration of battery storage with electric vehicle charging stations since it allows for the reduction of charging costs by using stored energy during off-peak hours, when electricity prices are cheaper. Furthermore, battery storage may bolster fast-charging infrastructure by delivering short bursts of energy to satisfy the immediate high-power needs of some EVs without straining the grid. The capacity to promote energy independence is another essential advantage of battery storage in electric vehicle charging stations. Battery storage keeps charging stations running, so electric vehicle owners may keep their EVs charged even if the power goes out in a region or if they live in a rural place without grid infrastructure. In addition, charging stations that have this kind of connection may take part in energy trading programs, which enable them to earn more money by selling their stored energy back to the grid when demand is high (Shafiei & Ghasemi-Marzbali, 2022).

Consequent on the above discussion, the researcher proposed the following hypothesis for analysis the relationship between Battery Storage and Electric Vehicle Charging Stations.

"H_{01}: There is no significant relationship between Battery Storage and Electric Vehicle Charging Stations."
"H_1: There is a significant relationship between Battery Storage and Electric Vehicle Charging Stations."

Table 2: H_1 ANOVA Test

ANOVA					
Sum					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	39588.620	287	5655.517	1055.922	.000
Within Groups	492.770	490	5.356		
Total	40081.390	777			

The outcome is noteworthy in this investigation. Statistical significance is achieved with a p-value of.000 (less than the.05 alpha level), and the value of F is 1055.922. What this implies is that researchers may accept the alternative hypothesis, ***"H_1: There is a significant relationship between Battery Storage and Electric Vehicle Charging Stations"*** is accepted and reject the null hypothesis.

DISCUSSION

A persistent obstacle in the way of fully electric transport is the expansion of the current charge station infrastructure. There is increasing demand on businesses to upgrade their employee parking lots with more charging stations for electric vehicles in anticipation of the rapid adoption of these vehicles by broader demographics. In order to accommodate the anticipated rates of electric vehicle adoption, a recent study by Charge UK forecasted that the number of chargers installed in workplaces will grow fivefold by 2030. Local and regional network operators have mostly been in charge of planning the growth of charging stations, along with the technical and economic issues that come with it. Because of this, and mostly because of a lack of internal energy management skills, individual enterprises have not been able to do predicted effect evaluations of the increased demands from EV charging. In a similar vein, the researchers found that there is a lack of research on the topic of how individual companies should go about planning the expansion of their EV workplace charging infrastructure (in the introduction). The study fills this need by focussing on business owners and managers as vital players in the mobility industry's efforts to shift to a low-carbon energy system. The researchers demonstrate that massive, unregulated rollouts of EV workplace charging infrastructure may result in major inefficiencies, such as inflated charging prices, increased carbon emissions, and much higher peaks. On the other side, efficient SC tactics and cutting-edge control mechanisms may save a tonne of money while also helping the environment and the economy. After doing a temporal sensitivity study, the researchers found that the models consistently outperformed UCC in each of the important measures, proving that they are resilient to time-variant factors. Nevertheless, the researchers demonstrate that when the EV adoption rate above a certain point, the relative performance of other measures, such maximum peak, may be compromised by a CCM or CEM model design that only considers one aim. This emphasises the inevitability of trade-offs between different goal functions and the corresponding result measurements. Based on real-world facts, researchers iteratively test models in changing situations to obtain these findings.

CONCLUSION

In conclusion, electric car charging stations are very important for the broad adoption of electric vehicles and the convenience they provide. Within the context of the successful implementation and promotion of sustainable mobility, it is essential to strike a balance between the advantages and the obstacles. Through this optimisation, the charging infrastructure may be used more effectively, hence reducing the amount of congestion that occurs while charging. Both the availability and the variability of renewable energy sources are taken into consideration by the model. Increasing the efficiency with which these sources are used contributes to the stabilisation of the electricity system. The term "electric vehicle" (EV) refers to a motor vehicle that is propelled entirely or mostly by batteries that are powered by electricity. Electric vehicles (EVs) comprise a broad variety of means of transportation, including as electric cars that travel on roads and rails, electric boats and vessels that operate underwater, electric aeroplanes, and electric spaceships. At night, the majority of individuals plug in their electric automobiles so that they may charge them while they are sleeping. In the event that the researchers charger is equipped with a timer, be sure to set it to turn off at least one or two hours before the researcher want to leave the researchers home in the morning. Cars that are fuelled by fossil fuels release substantially more greenhouse gases than electric cars, which do not emit any emissions from their tailpipes. It is possible to save up to Rs. 1, 50, 000 in yearly fuel expenditures and up to one tonne of emissions of greenhouse gases by purchasing an electric vehicle. Electric vehicles, sometimes known as EVs, are automobiles that are propelled by electric power. A fundamental feature of matter that is carried by some elementary particles and that determines the way in which the particles are influenced by an electric or magnetic field is known as electric charge. There are distinct natural units that are the source of electric charge, which may be either positive or negative. Electric charge is neither generated nor destroyed.

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