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Strategic deployment of EV charging infrastructure: an in-depth exploration of optimal location selection and CC-CV charging strategies

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ABSTRACT

The continued expansion of the electric vehicle (EV) market necessitates strategic planning for the placement of charging stations to ensure efficient access and utilization of electric infrastructure. This paper presents a comprehensive review of the critical factors in optimizing the selection of EV charging station locations, along with the implementation of constant current-constant voltage (CC-CV) charging models. The study addresses the challenges and opportunities in identifying the most effective locations for charging stations to accommodate the growing demand for sustainable transportation. Furthermore, it examines the benefits of adopting CC-CV charging models to improve the charging process, achieving a balance between charging speed and battery longevity. Through this analysis, the review aims to provide valuable insights to stakeholders involved in the development and expansion of EV charging infrastructure, thereby supporting the transition to a more sustainable and extensive electric mobility ecosystem.

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1. INTRODUCTION

The transport sector is notably energy-intensive, highlighting the need for sustainable alternatives like electric vehicles (EVs). EVs can reduce environmental impacts associated with fossil fuels, but their effectiveness depends on the electricity source, with renewable energy enhancing their benefits significantly [1]. The integration of EVs necessitates strategic planning of charging infrastructure, considering the unpredictable charging behavior of users, which impacts the electrical distribution network [2], [3]. Effective planning models should incorporate user behavior to ensure infrastructure can meet the dynamic demands of an increasing EV population [4]. This study proposes an optimal planning approach for EV charging stations, integrating user behavior to maintain stability in the electrical grid and manage urban traffic efficiently [5]. The technical aspects of EV battery charging, particularly the CC-CV method, are crucial for battery longevity and efficiency [6]. Techniques like particle swarm optimization (PSO) can further optimize charging parameters, enhancing battery performance and sustainability [7]. A robust EV infrastructure requires strategic placement of charging stations and advanced charging techniques [8].

Bhubaneswar, India, serves as a case study, showcasing its shift towards sustainable urban mobility through EV adoption. The city's unique blend of historical and modern development informs its approach to EV infrastructure, highlighting the importance of local context in planning [9], [10]. Bhubaneswar's strategies include policies aimed at reducing carbon emissions and strategically placed charging stations considering local traffic patterns and economic factors [11], [12]. In summary, the study emphasizes the need for a multifaceted approach in EV infrastructure planning, incorporating technical, economic, and social factors [13]. By optimizing charging techniques and considering local contexts and user behavior, cities can effectively promote sustainable urban mobility and reduce their carbon footprint.

2. PROPOSED METHOD

Bhubaneswar, located in Odisha, India, is undergoing a notable shift towards sustainable urban mobility, with a focus on EV adoption. Positioned as a city dedicated to reducing carbon emissions and promoting a green urban environment, Bhubaneswar's journey is influenced by its unique blend of historical significance and modern development [14]. A literature review examines the city's EV landscape, analyzing various EV models and their battery ratings to understand the preferences of its evolving urban population and ensure alignment with the city's character.

2.1. Area of study

The study area encompasses the geographical expanse of Bhubaneswar, accounting for the city's distinctive urban dynamics. Initial data collection involves acquiring comprehensive datasets related to traffic patterns, existing infrastructure, and population density. Geospatial information, including maps and satellite imagery, forms the foundational data for the subsequent application of genetic algorithms (GAs). Table 1 presents the geographical coordinates, specifically the latitude and longitude, of the existing charging stations located within Bhubaneswar [15]. These coordinates are of significant relevance in the context of this paper, as they are utilized in the analysis and planning of EV charging infrastructure within the city.

Table 1. EV charging stations (EVCSs) location

Charging station	Latitude	Longitude
EVCS	20.28964	85.815643
Tata_CS	20.436195	85.884811
Ather_Cs_1	20.259975	85.787926
Ather_Cs_2	20.242743	85.841011
Ather_Cs_3	20.282398	85.839249

2.2. Particle swarm optimization in load forecasting

In the context of load prediction for EVCSs in Bhubaneswar, PSO offers an advanced algorithmic method for forecasting and optimizing energy usage patterns. Bhubaneswar's urban dynamics, influenced by varying traffic, population density, and infrastructure use, necessitate a flexible and robust load forecasting mechanism [16], [17]. Inspired by natural phenomena such as bird flocks and fish schools, PSO optimizes future energy usage by refining a swarm of particles that represent potential forecasting solutions. Algorithm 1 provides the pseudocode for using PSO in load forecasting. This approach, adaptable to changing urban dynamics, holds significant promise for predicting and optimizing energy usage at EVCSs in cities like Bhubaneswar.

Algorithm 1. Pseudocode for PSO in load forecasting
```
initialize_particles()
initialize_velocity()
while not converged:
for a particle in particles:
evaluate_fitness(particle)
update_personal_best(particle)
global_best_particle = find_global_best()
for a particle in particles:
update_velocity(particle, global_best_particle)
update_position(particle)
update_convergence_criteria()
generate_load_forecast(global_best_position)
```

Where, particles: an array or list containing all the particles in the swarm, global_best_particle: a variable representing the global best particle found by the swarm, find_global_best(): a function to determine the global best particle among all particles in the swarm, update_position(particle): a function to update the position of each particle based on its current position and velocity, mutate(individual, mutation_rate): a function to apply mutation to an individual particle with a certain mutation rate (this may not be typical in PSO, as it's more common in genetic algorithms).

2.3. Advantages of CC-CV charging mode

In the context of Bhubaneswar's distinctive environmental conditions and diverse usage patterns, the study underscores the advantages of employing the CC-CV charging mode. Recognized for its ability to delicately balance charging speed and battery health, CC-CV emerges as a viable solution to address concerns related to overcharging. This charging mode not only enhances the longevity of EV batteries but also ensures a sustainable and user-friendly charging experience for residents [18].

2.4. GAs application in strategic placement of EV charging infrastructure

GAs are essential for optimizing charging station placement by using evolutionary principles. The process begins with a fitness function that evaluates criteria such as accessibility, proximity to populated areas, and integration with urban infrastructure [19]-[21]. The second step involves identifying optimal locations for charging stations. To ensure every node can be reached by an electric car within its range, the minimum number of nodes for charging stations is selected as illustrated in the flowchart. A value of 0.7 is used for optimization, and a mutation rate of 0.05 is applied to choose charging station locations. The initial optimization stage employs an integer linear programming approach [22], [23], defined by specific equations.

$$\text{Min} \sum_{s,e\in N}^{s\neq e}(t\ \text{se Vse} \ + \ \text{tes Ves}) \tag{1}$$

Where V_{se} is a variable that denotes the branch from node s to node e; it can have two values: 1 (for the branch to be selected as a path component) or 0 (for the branch not to be picked as a path component), V_{es} is variable that denotes the branch from node e to node s it can have two values 1 (for the branch to be chosen as a path segment) or 0 (for the branch not to be chosen as a path segment.), t_{se}=t_{es}=distance corresponding to the branch from point to other, N represents the cases which will be taken from the graph.

2.5. Voltage drops and energy capacity

The objective is to minimize costs while meeting EV charging demand by considering voltage drop and energy capacity. The aim is to ensure charging stations can supply power efficiently while minimizing expenses related to design choices. The algorithm focuses on a realistic goal, balancing economic factors like energy capacity, voltage drop, and meeting power demand effectively. This approach reflects the complexities of charging infrastructure design. The PSO algorithm offers flexibility in optimizing electric systems, providing real-time visualization for intuitive decision-making [24]. This framework advances optimization techniques and supports sophisticated decision-making in EV charging infrastructure. As electric systems evolve, such algorithms are crucial for efficiency, cost-effectiveness, and sustainability in charging stations, making the PSO algorithm a valuable tool for researchers [25]. Algorithm 2 presents the pseudocode utilized to minimize costs by factoring in voltage drops and the energy capacity of battery packs. This pseudocode outlines the algorithmic steps involved in optimizing the design of EVCS, ensuring efficient power supply while minimizing expenses associated with voltage drop and battery energy capacity.

Algorithm 2. Pseudocode for minimization of cost by considering voltage drops and energy capacity

```
Define realistic objective function:
      def realistic_objective_function(x)
Set PSO parameters:
   Initialize Particles, Velocities, Personal and Global bests
   Initialize 2D scatter plot for visualization
   Main PSO Loop:
        Objective function evaluation for each particle
        Update personal and global bests
        Update velocities and positions using the PSO equation
                  Plot particles on a 2D plot
      dim = 2, swarm_size = 20, max_iter = 50, inertial weight = 0.5, cognitive factor =
       1.5, social factor = 2.0
Display optimal solution:
        Print "Optimal Solution"
        Print "Voltage Drop:", global_best_position [0]
        Print "Energy Storage Capacity:", global_best_position [1]
Print "Objective Value:", objective_function (global_best_position)
```

2.6. Cost-effectiveness

Cost-effectiveness is the main hurdle as the main motive is to minimize it so that it is feasible to common people also [26], [27]. This paper represents a mathematical operation and it is represented by,

$$DE = VE * 195 * 0.3 * 0.05 \tag{2}$$

Where DE is the demand for electricity for public charging stations, VE is the number of EVs, 195 is the average electric car range in India (in km), 0.3 is the electricity consumption needed, i.e., 30 kWh needed for every 100 miles, and 0.05 is the charging happens at public charging stations per 10,000 people. The operational cost of an EV charging station is influenced by both fixed and variable factors. Fixed costs, such as electricity cost and site rent, remain unchanged regardless of the number of chargers [28], [29]. In contrast, variable costs, including back office running costs, maintenance costs, and unplanned maintenance costs, increase with the number of chargers due to additional administrative, upkeep, and repair needs. Therefore, while electricity costs and site rent are constant, the overall operational costs are significantly affected by the scalability of the charging infrastructure.

Figure 1 demonstrates the algorithm for optimizing EV range and finding the shortest route using EVCS data network. The algorithm for optimizing EV range and route using charging station data follows a systematic approach to improve EV efficiency. It initializes particles and velocities, assessing fitness based on objectives and updating positions iteratively [30]. By considering factors like charging station locations and energy demand, it identifies optimal placements and routes, ensuring efficient EV operation. With adaptability to environmental changes, it offers a robust framework for sustainable urban mobility.

Efficient EV charging infrastructure is vital for widespread acceptance, especially in terms of public accessibility. A mathematical model predicts power demand at public charging stations, considering factors like EV quantity, range, and electricity consumption [31], [32]. By factoring in the percentage of charging at public stations, stakeholders estimate the actual demand for effective planning. The model's flexibility to different locations and circumstances enhances accuracy and informs decision-making for policymakers and investors [33]. This approach fosters the transition to cleaner transportation systems globally.

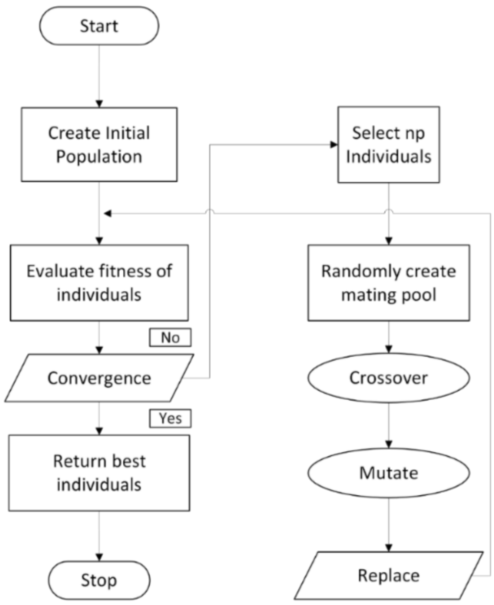

Figure 1. Algorithm for optimizing EV range and finding the shortest route using EVCS data network

3. RESULTS AND DISCUSSION

Figure 2 shows the trends of the electric vehicle's battery's state of charge which implies that as set before in the system, it will automatically switch from constant current mode to constant voltage mode. For instance, here it is set at 40.1% so the observer can see a small notch at 40.1%. This notch marks the changing of modes. Next, this paper has the current versus time graph which implies that the current remains constant at a set value throughout the charging process but it shows a remarkable drop when the mode of charging changes from constant current to constant voltage. Then again it goes back to the set value and remains constant. This drop marks the change of modes. Here, for illustration it has its set value as 15 A.

Finally, the last garph is the voltage versus time graph which shows the trends of the voltage during charging the EV. Here, the voltage remains constant at the set value but shows a remarkable rise and falls back to the set value again. This instantaneous rise is the point when the charging mode changes from constant current to constant voltage mode. Here, for illustration, it has its set value as 26.15 V.

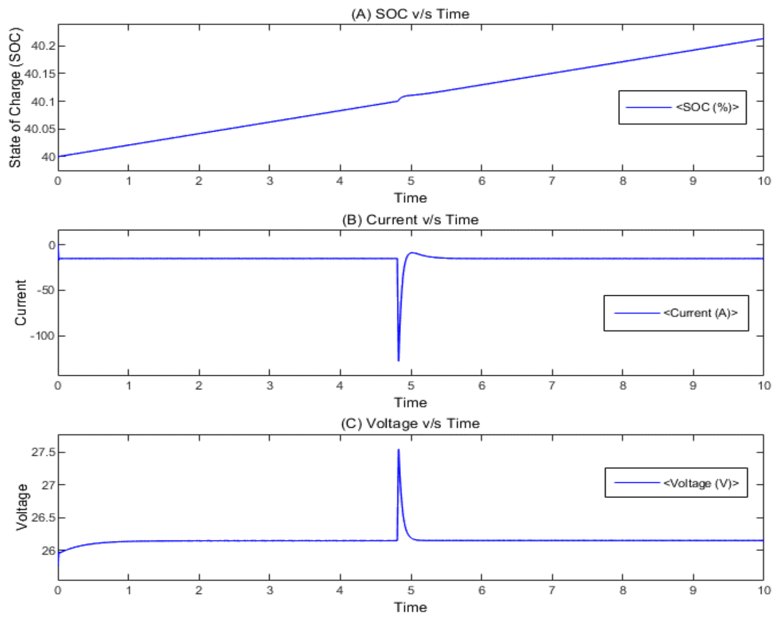

Figure 2. Graphs of SOC vs time, current vs time, and voltage vs time

In response to the imperative for sustainable urban mobility, Bhubaneswar has implemented a meticulously designed network of EV charging stations. This initiative, stemming from a thorough analysis of socio-economic and infrastructural factors, signifies a fusion of foresight and practicality, aimed at mitigating concerns over EV range limitations and promoting eco-friendly transportation alternatives. From Figure 3, the graph may have markers or dots that show the locations of both planned new stations and currently operating charging stations. The number of each of these indicators may represent the degree of accessibility and coverage in various parts of the city. Drawing on demographic data, traffic patterns, accessibility metrics, and EV adoption rates, this strategy embodies a holistic approach to infrastructure development, tailored to align with urban growth trajectories.

Beyond its immediate objectives, this initiative transcends conventional urban planning paradigms, envisioning a broader societal impact. Strategically locating charging stations along major routes and within urban hubs not only addresses range anxiety but also cultivates a cultural shift toward sustainability. Integration with future urban expansion plans and consideration of parking infrastructure underscore a commitment to comprehensive mobility solutions, reflecting an ethos of environmental stewardship. Through a data-driven synthesis and visionary outlook, this network emerges as a linchpin in sustainable urban development, poised to reshape mobility dynamics and foster environmental consciousness.

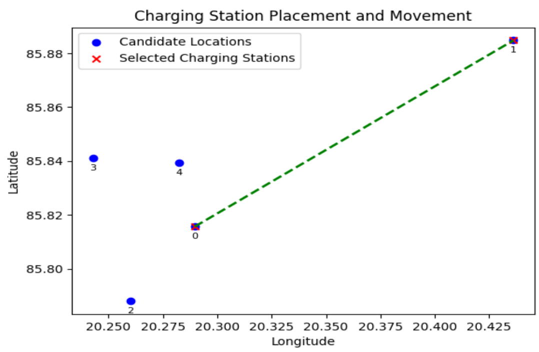

Figure 3. Optimal locations for new EVCSs in Bhubaneswar

Initially, the projected range of electric cars (EVs) in Bhubaneswar was determined to be 100 km by the use of a genetic algorithm in the optimization process. In Figure 4, the method improved battery capacity and motor efficiency significantly over 50 generations by dynamically adjusting both. By the time the optimized EV reached its last generation, its outstanding range of over 180 km demonstrated the effectiveness of the evolutionary algorithm in improving EV performance for the unique local circumstances in Bhubaneswar. While the end plot showed how the optimum fitness evolved over the course of the optimization process, the real-time plot gave a visual depiction of the range's constant growth. This study advances our knowledge of how to optimize EV characteristics for certain regions and increase their accessibility by fine-tuning them with GAs.

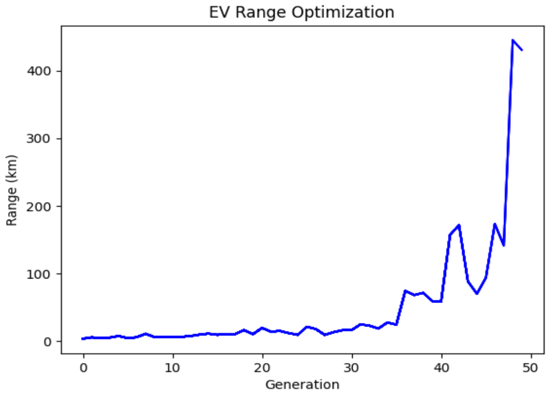

Figure 4. Trends of increasing load on increasing area

The distinctive red cross, serving as a visual indicator within the graph, signifies the financial implications attributed to the specified design parameters, namely voltage drop and energy storage capacity, pivotal within the context of an EVCS. Employing the PSO methodology, this computational framework orchestrates a meticulous optimization process, meticulously navigating the intricate interplay between diverse variables. In Figure 5, these include the imperative to minimize voltage drop, enhance energy storage capacity, and prudently allocate costs to effectively meet the demands of power consumption. Central to the PSO algorithm's mandate is the minimization of this cost metric, thereby steering towards an optimal configuration for the charging station. A reduction in the objective value, ensconced within the confines of the specified objective function, signifies not only a financially viable solution but also underscores the overarching goals of efficiency and efficacy inherent in charging station infrastructure.

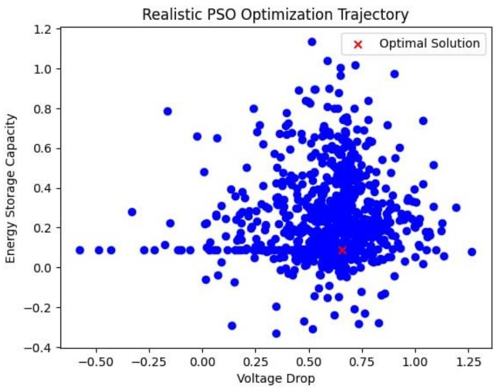

Figure 5. Optimal voltage drop per energy storage capacity using PSO

Beyond its primary objective of cost minimization, the PSO algorithm encapsulates broader imperatives pertinent to sustainable infrastructure development and operational efficiency within the burgeoning domain of electric mobility. By harmonizing efforts to mitigate voltage drop, enhance energy storage capacity, and allocate costs judiciously, the algorithm not only fosters economically prudent charging station designs but also underscores the imperative of environmental sustainability and energy conservation. Moreover, the iterative nature of PSO engenders a dynamic optimization process, endowing charging station designs with adaptability and resilience to fluctuating operational parameters and emerging technological advancements. Thus, the red cross marker, emblematic of financial implications within the graph, transcends its visual representation to symbolize the intricate synergy between engineering innovation, financial acumen, and environmental responsibility in the pursuit of sustainable transportation infrastructure.

4. CONCLUSION

This paper the vital role of GAs in strategically locating EVCSs in Bhubaneswar, accounting for traffic patterns and population density. It underscores the effective load forecasting capabilities of PSO and the advantages of CC-CV charging modes for battery health and sustainability. The methodologies presented, including GA and PSO, provide practical tools for optimizing charging infrastructure. Additionally, a cost-effective mathematical model is incorporated to address power demand at public charging stations. This research offers a comprehensive understanding of the strategies necessary for the successful and sustainable deployment of EV charging infrastructure, providing valuable insights for strategic planning in electric mobility.

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REFERENCES

[1] Z. Miljanic, V. Radulovic, and B. Lutovac, “Efficient placement of electric vehicles charging stations using integer linear programming,” *Advances in Electrical and Computer Engineering*, vol. 18, no. 2, pp. 11–16, 2018, doi: 10.4316/AECE.2018.02002.

[2] K. Schneider, C. Gerkensmeyer, M. Kintner-Meyer, and R. Fletcher, “Impact assessment of plug-in hybrid vehicles on pacific northwest distribution systems,” in *2008 IEEE Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century*, Jul. 2008, pp. 1–6, doi: 10.1109/PES.2008.4596392.

[3] A. Fathollahi, S. Y. Derakhshandeh, A. Ghiasian, and M. A. S. Masoum, “Optimal Siting and sizing of wireless EV charging infrastructures considering traffic network and power distribution system,” *IEEE Access*, vol. 10, pp. 117105–117117, 2022, doi: 10.1109/ACCESS.2022.3219055.

[4] A. Hajimiragha, C. A. Canizares, M. W. Fowler, and A. Elkamel, “Optimal transition to plug-in hybrid electric vehicles in ontario, canada, considering the electricity-grid limitations,” *IEEE Transactions on Industrial Electronics*, vol. 57, no. 2, pp. 690–701, Feb. 2010, doi: 10.1109/TIE.2009.2025711.

[5] A. Y. Saber and G. K. Venayagamoorthy, “Plug-in vehicles and renewable energy sources for cost and emission reductions,” *IEEE Transactions on Industrial Electronics*, vol. 58, no. 4, pp. 1229–1238, Apr. 2011, doi: 10.1109/TIE.2010.2047828.

[6] M. S. Mastoi *et al.*, “An in-depth analysis of electric vehicle charging station infrastructure, policy implications, and future trends,” *Energy Reports*, vol. 8, pp. 11504–11529, Nov. 2022, doi: 10.1016/j.egyr.2022.09.011.

[7] F. Wang, G. Xu, and M. Wang, “An improved genetic algorithm for constrained optimization problems,” *IEEE Access*, vol. 11, pp. 10032–10044, 2023, doi: 10.1109/ACCESS.2023.3240467.

[8] K. Qian, C. Zhou, M. Allan, and Y. Yuan, “Modeling of load demand due to EV battery charging in distribution systems,” *IEEE Transactions on Power Systems*, vol. 26, no. 2, pp. 802–810, May 2011, doi: 10.1109/TPWRS.2010.2057456.

[9] M. E. Kabir, C. Assi, H. Alameddine, J. Antoun, and J. Yan, “Demand-aware provisioning of electric vehicles fast charging infrastructure,” *IEEE Transactions on Vehicular Technology*, vol. 69, no. 7, pp. 6952–6963, Jul. 2020, doi: 10.1109/TVT.2020.2993509.

[10] S. Wang, Z. Y. Dong, F. Luo, K. Meng, and Y. Zhang, “Stochastic collaborative planning of electric vehicle charging stations and power distribution system,” *IEEE Transactions on Industrial Informatics*, vol. 14, no. 1, pp. 321–331, Jan. 2018, doi: 10.1109/TII.2017.2662711.

[11] X. Bai, Q. Sun, L. Liu, F. Liu, X. Ji, and J. Hardy, “Multi-objective planning for electric vehicle charging stations considering TOU price,” in *2017 3rd IEEE International Conference on Cybernetics, CYBCONF*, 2017, pp. 1–6, doi: 10.1109/CYBConf.2017.7985792.

[12] W. Sierzchula, S. Bakker, K. Maat, and B. van Wee, “The influence of financial incentives and other socio-economic factors on electric vehicle adoption,” *Energy Policy*, vol. 68, pp. 183–194, May 2014, doi: 10.1016/j.enpol.2014.01.043.

[13] K. Sheng, M. Dibaj, and M. Akrami, “Analysing the Cost-Effectiveness of Charging Stations for Electric Vehicles in the U.K.’s Rural Areas,” *World Electric Vehicle Journal*, vol. 12, no. 4, p. 232, Nov. 2021, doi: 10.3390/wevj12040232.

[14] F. J. Marquez-Fernandez, J. Bischoff, G. Domingues-Olavarria, and M. Alakula, “Assessment of future EV charging infrastructure scenarios for long-distance transport in Sweden,” *IEEE Transactions on Transportation Electrification*, vol. 8, no. 1, pp. 615–626, Mar. 2022, doi: 10.1109/TTE.2021.3065144.

[15] B. Al-Hanahi, I. Ahmad, D. Habibi, and M. A. S. Masoum, “Charging infrastructure for commercial electric vehicles: challenges and future works,” *IEEE Access*, vol. 9, pp. 121476–121492, 2021, doi: 10.1109/ACCESS.2021.3108817.

[16] S. R. Salkuti, "Editorial Board Members’ Collection series: smart energy system design,” *Designs*, vol. 8, no. 6, 2024, doi: 10.3390/designs8060120.

[17] S. Pagidipala, V. Sandeep, “Optimal planning of electric vehicle charging stations and distributed generators with network reconfiguration in smart distribution networks considering uncertainties,” Measurement: Sensors, vol. 36, 2024, doi: 10.1016/j.measen.2024.101400.

[18] D. Pavković, J. Kasać, M. Krznar, and M. Cipek, “Adaptive constant-current/constant-voltage charging of a battery cell based on cell open-circuit voltage estimation,” *World Electric Vehicle Journal*, vol. 14, no. 6, p. 155, Jun. 2023, doi: 10.3390/wevj14060155.

[19] W. Khan, F. Ahmad, and M. S. Alam, "Fast EV charging station integration with grid ensuring optimal and quality power exchange," *Engineering Science and Technology, an International Journal*, vol. 22, no. 1, pp. 143–152, Feb. 2019, doi: 10.1016/j.jestch.2018.08.005.
[20] M. M. Hoque, M. A. Hannan, and A. Mohamed, "Optimal CC-CV charging of lithium-ion battery for charge equalization controller," in *2016 International Conference on Advances in Electrical, Electronic and Systems Engineering, ICAEES 2016*, 2016, pp. 610–615, doi: 10.1109/ICAEES.2016.7888119.
[21] X. Xi, R. Sioshansi, and V. Marano, "Simulation-optimization model for location of a public electric vehicle charging infrastructure," *Transportation Research Part D: Transport and Environment*, vol. 22, pp. 60–69, 2013, doi: 10.1016/j.trd.2013.02.014.
[22] A. K. Kalakanti and S. Rao, "Charging station planning for electric vehicles," *Systems*, vol. 10, no. 1, p. 6, Jan. 2022, doi: 10.3390/systems10010006.
[23] A. K. M. Yousuf, Z. Wang, R. Paranjape, and Y. Tang, "Electric vehicle charging station infrastructure: a comprehensive review of technologies, challenges, and mitigation strategies," *Canadian Conference on Electrical and Computer Engineering*, vol. 2023-September, pp. 588–592, 2023, doi: 10.1109/CCECE58730.2023.10289005.
[24] N. Shahraki, H. Cai, M. Turkay, and M. Xu, "Optimal locations of electric public charging stations using real world vehicle travel patterns," *Transportation Research Part D: Transport and Environment*, vol. 41, pp. 165–176, 2015, doi: 10.1016/j.trd.2015.09.011.
[25] X. Dong, Y. Mu, H. Jia, J. Wu, and X. Yu, "Planning of Fast EV charging stations on a round freeway," *IEEE Transactions on Sustainable Energy*, vol. 7, no. 4, pp. 1452–1461, Oct. 2016, doi: 10.1109/TSTE.2016.2547891.
[26] S. R. Salkuti, "Emerging and advanced green energy technologies for sustainable and resilient future grid," *Energies*, vol. 15, no. 18, p. 6667, Sep. 2022, doi: 10.3390/en15186667.
[27] S. R. Salkuti, "Advanced technologies for energy storage and electric vehicles," *Energies*, vol. 16, no. 5, p. 2312, Feb. 2023, doi: 10.3390/en16052312.
[28] P. Sadeghi-Barzani, A. Rajabi-Ghahnavieh, and H. Kazemi-Karegar, "Optimal fast charging station placing and sizing," *Applied Energy*, vol. 125, pp. 289–299, Jul. 2014, doi: 10.1016/j.apenergy.2014.03.077.
[29] F. Xie, C. Liu, S. Li, Z. Lin, and Y. Huang, "Long-term strategic planning of inter-city fast charging infrastructure for battery electric vehicles," *Transportation Research Part E: Logistics and Transportation Review*, vol. 109, pp. 261–276, Jan. 2018, doi: 10.1016/j.tre.2017.11.014.
[30] E. Sortomme, M. M. Hindi, S. D. J. MacPherson, and S. S. Venkata, "Coordinated charging of plug-in hybrid electric vehicles to minimize distribution system losses," *IEEE Transactions on Smart Grid*, vol. 2, no. 1, pp. 198–205, Mar. 2011, doi: 10.1109/TSG.2010.2090913.
[31] S. Park and S. R. Salkuti, "Optimal energy management of railroad electrical systems with renewable energy and energy storage systems," *Sustainability*, vol. 11, no. 22, p. 6293, Nov. 2019, doi: 10.3390/su11226293.
[32] C. M. Jung, S. Pagidipala, and S. R. Salkuti, "Emerging technologies for the integration of renewable energy, energy storage and electric vehicles," in *Energy and Environmental Aspects of Emerging Technologies for Smart Grid*, vol. Part F2899, Springer, 2024, pp. 107–124.
[33] J. Wu, X. Cui, H. Zhang, and M. Lin, "Health prognosis with optimized feature selection for lithium-ion battery in electric vehicle applications," *IEEE Transactions on Power Electronics*, vol. 36, no. 11, pp. 12646–12655, Nov. 2021, doi: 10.1109/TPEL.2021.3075558.

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