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Optimizing power quality and placement of EV charging stations in a DC grid with PV-BESS using hybrid DOA-CHGNN approach

C.S. Subash Kumar [a,*], R. Saravanan [b], S. Sankarakumar [c], G. Srinivas [d]

[a] Department of Electrical and Electronics Engineering, PSG Institute of Technology and Applied Research, Coimbatore, Tamil Nadu, India
[b] Department of Electrical and Electronics Engineering, Balaji Institute of Technology and Science, Warangal, Telangana, India
[c] Department of Electrical and Electronics Engineering, National Engineering College, Kovilpatti, Tamilnadu, India
[d] Department of Electrical and Electronics Engineering, GITAM(Deemed to be University), Hyderabad, Telangana, India

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ABSTRACT

Electric vehicle battery chargers have power electronic transformers, which causes significant distortions in electrical energy obtained from distribution system and numerous issues with power quality. This paper presents a hybrid method for optimizing energy quality and placement of Electric VehicleCharging Stations (EVCS) with Photovoltaic with Battery Energy Storage System (PV-BESS) in DC grids. The proposed method combines Dollmaker Optimization Algorithm (DOA) and Contrastive Hyper graph Neural network (CHGNN), referred as DOA-CHGNN technique. The primary goal of proposed strategy is to reduce voltage drop, Total Harmonic Distortion (THD) and increase system's efficiency. The DOA method is used to enhance assignment of EVCS in delivery system. The CHGNN method is utilized to predict the EV load. The MATLAB environment is used to assess and compare the proposed method with other existing techniques. The proposed approach determines betterfindings compared to existing methods like Jellyfish Search Algorithm (JSA), Hybridized Whale Particle Swarm Optimization (HWPSO) and Deep Neural Network (DNN). The proposed methods achieves a THD of 0.9 %, Total cost of 5,520,000$, the execution time of 0.41 s and an efficiency of 98 %.The proposed DOA-CHGNN method outperforms existing techniques, achieving improved THD, higher efficiency, and lower costs in optimizing EVCS placement with PV-BESS in DC grids.

1. Introduction

a) Background

EVs have lately gained significant international attention due to their energy-efficient operation, environmental advantages, and incredible technical advancements [1]. Unlike traditional ICE cars, which power their engines with petrol or diesel, EVs use electricity stored in rechargeable batteries [2]. The automotive industry, the energy sector, and the environment are all significantly impacted by this development in propulsion technology. EVs are a paradigm change in the transportation sector because they work on the basic principle of using electricity to power an electric motor that turns the wheels of the vehicle [3]. The enormous battery pack that stores this power may be recharged in a number of places, including homes and public spaces. The motor efficiently converts electrical energy into mechanical power, allowing the vehicle to move [4]. Technology in the EV industry is developing at a rapid pace due to improvements in battery efficiency, faster charging, and overall performance [5–7]. The substantial expenditures that manufacturers are making in EV autonomous driving technologies are ushering in a new era of mobility [8].

b) Literature Review

In literature, many research works were available based on EV charging stations and ideal assignment in delivery system using various methodsand aspects. Few of them were reviews were followed,

Nandini et al., [9] have developed a hybrid optimization paired with solar photovoltaic technology to assess grid reliance and energy quality for EV charging stations. Using a HWPSO method and fire hawk optimization technique, the index voltage imbalance factor, voltage deviation, and grid dependence for charging electric vehicle capacity were

* Corresponding author.
E-mail addresses: css@psgitech.ac.in (C.S. Subash Kumar), rsharankiruthiga@gmail.com (R. Saravanan), sankarbe2002@yahoo.co.in (S. Sankarakumar), sgangish@gitam.edu (G. Srinivas).

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Table 2
Performance comparison of efficiency with recent techniques.

Solution Techniques	Efficiency (%)
CHHO [11]	79
SHOA [12]	84
MMOSSA [15]	87
Proposed method	98

Table 1 displays the comparison of THD, cost, and execution time with proposed and existing method. The proposed method achieves a THD of 0.9 %, a cost of 5520,000$, and an execution time of 0.41 s, providing a more cost-effective solution with better power quality and faster performance.The performance comparison of efficiency with recent techniques is shown in Table 2. The table compares efficiency across different methods: CHHO [11] achieves 79 %, SHOA [12] of 84 %, and MMOSSA [15] of 87 %. The proposed method outperforms all, achieving 98 % efficiency, and significantly enhancing performance over recent techniques.

5. Discussion

The proposed DOA-CHGNN method significantly outperforms existing techniques in optimizing the placement of EVCS in DC grids integrated with PV-BESS. It achieves a remarkable THD of 0.9 %, lowers the total cost to 5520,000$, and completes the optimization in just 0.41 s, demonstrating superior performance compared to methods like HWPSO a THD of 4.32 %, cost of 7440,000$, execution time of 2.7 s, JSA as THD of 2.08 %, cost of 6240,000$, execution time of 1.5 s, and DNN as THD of 1.43 %, cost of 5760,000$, the execution time of 0 .9s. The results further highlight that placing charging stations closer to the main feeder minimizes voltage loss and THD, with strategic placement proving essential for maintaining powerquality. The DOA-CHGNN method offers a robust, cost-effective, and efficient solution for optimizing EVCS placement in smart grid systems.

6. Conclusion

This research proposes a unique DOA-CHGNN strategy for electric car charging station location and energy quality optimization in DC grids with PV-BESS. The combination of DOA for optimizing EVCS placement and CHGNN for predicting the dynamic EV load results in a significant enhancement of the system's performance. By using the proposed approach, lower THD and cost are achieved, along with higher efficiency. The proposed method is accessed and contrasted with other current approaches using the MATLAB environment. The proposed strategy achieves the lowest THD of 0.9 %, outperforming existing methods such as HWPSO of 4.32 %, JSA of 2.08 %, and DNN of 1.43 %, while also achieving the highest efficiency of 98 %, surpassing recent techniques like CHHO of 79 %, SHOA of 84 %, and MMOSSA of 87 %. The proposed DOA-CHGNN approach proves to be a robust and efficient solution for optimizing the overall performance of EVCS integrated with PV and battery systems in DC grids. The future scope of this research will focus on real-world applications, considering factors such as PV production variation, distribution network uncertainties, and EV charging times for optimal EVCS allocation.

CRediT authorship contribution statement

C.S. Subash Kumar: Writing – original draft. **R. Saravanan:** Supervision. **S. Sankarakumar:** Supervision. **G. Srinivas:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

References

[1] H. Li, D. Son, B. Jeong, Electric vehicle charging scheduling with mobile charging stations, J. Clean. Prod. 434 (2024) 140162.
[2] S. Çelik, O. Şeyda, Electric vehicle charging stations: model, algorithm, simulation, location, and capacity planning, Heliyon. 10 (7) (2024).
[3] Y. Zheng, et al., Effects of electric vehicle charging stations on the economic vitality of local businesses, Nat. Commun. 15 (1) (2024) 7437.
[4] K.C. Akshay, et al., Power consumption prediction for electric vehicle charging stations and forecasting income, Sci. Rep. 14 (1) (2024) 6497.
[5] S. Nagaraj, S.P. Sivakumar, L.S. Annabel, V.R. Joshi, M.B. Patil, Utilising skyscript for open-vocabulary categorization, extraction, and captioning to enhance multi-modal tasks in remote sensing, Remote Sens. Earth Syst. Sci. 7 (3) (2024) 149–158.
[6] S.P. Maniraj, J.D. Rose, R. Arunachalam, K. Rangasamy, V.R. Patil, S. Kathirvelu, Polar region climate dynamics: deep learning and remote sensing integration for monitoring arctic and antarctic changes, Remote Sens. Earth Syst. Sci. 12 (2024) 1–4.
[7] V.U. Pinjarkar, U.S. Pinjarkar, H.N. Bhor, Y.V. Mahajan, V.R. Patil, S.D. Rajput, P. Kothari, D. Ghori, Student engagement monitoring in online learning environment, Int. J. Intell. Syst. Appl. Eng. 12 (1) (2023) 292–298.
[8] C. Calvo-Jurado, J.M. Ceballos-Martínez, J.C. García-Merino, M. Muñoz-Solano, F. J. Sánchez-Herrera, Optimal location of electric vehicle charging stations using proximity diagrams, Sustain. Cities. Soc. 113 (2024) 105719.
[9] K.K. Nandini, N.S. Jayalakshmi, V.K. Jadoun, A combined approach to evaluate power quality and grid dependency by solar photovoltaic based electric vehicle charging station using hybrid optimization, J. Energy Storage. 84 (2024) 110967.
[10] S. Anita, Y. Sukhi, Y. Jeyashree, N. Manoj Kumar, Torque fault compensation in electric vehicle switched reluctance motor drives: a jellyfish search optimization method, Optim. Control Appl. Methods. 45 (5) (2024) 1990–2007.
[11] V.M. Kumar, C. Bharatiraja, A. ELrashidi, K.M. AboRas, Chaotic harris hawks optimization algorithm for electric vehicles charge scheduling, Energy Rep. 11 (2024) 4379–4396.
[12] T. Yuvaraj, S. Arun, T.D. Suresh, M. Thirumalai, Minimizing the impact of electric vehicle charging station with distributed generation and distribution static synchronous compensator using PSR index and spotted hyena optimizer algorithm on the radial distribution system. E-Prime-Advances in Electrical engineering, Electron. Eng. 8 (2024) 100587.
[13] A. Kazemtarghi, A. Mallik, Y. Chen, Dynamic pricing strategy for electric vehicle charging stations to distribute the congestion and maximize the revenue, Int. J. Electr. Power Energy Syst. 158 (2024) 109946.
[14] S.A. Hasib, M.M. Gulzar, A. Shakoor, S. Habib, A.F. Murtaza, Optimizing electric vehicle driving range prediction using deep learning: a deep neural network (DNN) approach, Results. Eng. 24 (2024) 103630.
[15] M.S. Abid, R. Ahshan, R. Al Abri, A. Al-Badi, M. Albadi, Techno-economic and environmental assessment of renewable energy sources, virtual synchronous generators, and electric vehicle charging stations in microgrids, Appl. Energy. 353 (2024) 122028.
[16] M. Aktas, K. Awaili, M. Ehsani, A. Arisoy, Direct torque control versus indirect field-oriented control of induction motors for electric vehicle applications, Eng. Sci. Technol. Int J. 23 (5) (2020) 1134–1143.
[17] S. Wang, L. Lu, X. Han, M. Ouyang, X. Feng, Virtual-battery based droop control and energy storage system size optimization of a DC microgrid for electric vehicle fast charging station, Appl. Energy. 259 (2020) 114146.
[18] E. Kannan, M. Avudaiappan, S. Kaliyaperumal, S. Muthusamy, S. Pandiyan, H. Panchal, K. Manikam, C. Shanmugam, A novel single phase grid connected solar photovoltaic system for state of charge estimation using recurrent neural networks, Energy Sources, Part A: Recovery Util. Environ. Eff. 45 (1) (2023) 841–859.
[19] M. Amir, Zaheeruddin, A. Haque, F.I. Bakhsh, V.B. Kurukuru, M. Sedighizadeh, Intelligent energy management scheme-based coordinated control for reducing peak load in grid-connected photovoltaic-powered electric vehicle charging stations, IET Gener. Transm. Distrib. 18 (6) (2024) 1205–1222.
[20] G. Sugumaran, P.N. Amutha, An improved bi-switch flyback converter with loss analysis for active cell balancing of the lithium-ion battery string, J. Electr. Comput. Eng. (2024), 2024.
[21] A.P. Singh, Y. Kumar, Y. Sawle, M.A. Alotaibi, H. Malik, F.P.G. Márquez, Development of artificial intelligence-based adaptive vehicle to grid and grid to vehicle controller for electric vehicle charging station, Ain Shams Eng. J. 15 (10) (2024) 102937.
[22] M. Shadnam Zarbil, A. Vahedi, Power quality of electric vehicle charging stations and optimal placement in the distribution network, J. Oper. Autom. Power Eng. 11 (3) (2023) 193–202.
[23] K. Kaabneh, I. AbuFalahah, K. Eguchi, S. Gochhait, I. Leonova, Z. Montazeri, M. Dehghani, Dollmaker optimization algorithm: a novel human-inspired optimizer for solving optimization problems, Int. J. Intell. Eng. Syst. 17 (3) (2024).
[24] Y. Song, Y. Gu, T. Li, J. Qi, Z. Liu, C.S. Jensen, G. Yu, CHGNN: a semi-supervised contrastive hypergraph learning network, IEEE Trans. Knowl. Data Eng. (2024).

[25] A. Jamna, P. Velmurugan, V.V. Prabhu, K. Palanisamy, Optimal power quality enhancement of photovoltaic and plug-in electric vehicle for smart grid using HBA-GJO technique, Electr. Eng. (2024) 1–14.
[26] R. Banupriya, R. Nagarajan, S. Muthubalaji, Power electronic converters in the unbalance compensation method for renewable energy-powered active distribution systems: AOA-RERNN approach, Soft. Comput. 28 (17) (2024) 10583–10600.
[27] M. Sithambaram, P. Rajesh, F.H. Shajin, I.R. Rajeswari, Grid connected photovoltaic system powered electric vehicle charging station for energy management using hybrid method, J. Energy Storage. 108 (2025) 114828.