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OPTIMIZATION OF MULTIPLE RENEWABLE ENERGY SOURCES INTEGRATED WITH MAIN GRID AND HYBRID ENERGY STORAGE SYSTEM FOR ELECTRIC VEHICLE CHARGING SYSTEM

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Abstract - This research article explores the conversion of renewable energy into electricity through an integrated system composed of multiple components that ensure efficient power delivery to the end user. Key elements, such as a DC–DC converter and a harmonic analyzer, are employed to minimize power loss and enhance voltage stability. To further optimize system performance, the Zebra Optimization Technique is applied for parameter tuning and control. A Zero-Burden Deep Belief Neural Model (ZbDBNM) is introduced to manage critical aspects of the microgrid, including power generation capacity based on source availability, energy storage regulation, and adaptive handling of power and voltage according to load requirements. Additionally, the operational limits of converter–inverter units and varying environmental conditions are considered to maintain reliable and efficient functioning. The proposed approach demonstrates the potential for improved efficiency, stability, and adaptability in renewable energy-based microgrid systems.
Keywords: ZbDBNM (Zero burden Deep Belief Neural Model), ZOA (Zebra Optimization Algorithm), Hybrid Energy Storage System (HESS), Electric Vehicle Charging System (EVCS).

1. INTRODUCTION

Due to the limits of distributed energy supplies such as solar, voltage instability may occur. It can be kept up with this algorithm. Because solar and wind power generation are time-dependent, there is a difficulty with voltage dependability and stability. The ZbDBNM algorithm, in conjunction with a bidirectional controller, addresses these issues.[3]

This work aims to provide the Zebra Optimization Algorithm (ZOA) as an effective solution for optimizing microgrid energy distribution. This study combines ZOA and Artificial Intelligence (AI) methodologies to improve DER management, energy dispatch, and load forecasting capabilities. Distributed energy resources, or DERs, are small-scale energy generation or storage systems that operate close to the loads they serve. DERs are critical to microgrid operation because they enable greater energy sustainability and autonomy.[4]

2. CONTROL ARCHITECTURE

Figure – 2.1 shows the topology / architecture used for multiple renewable energy sources integrated with main grid and hybrid energy storage system for electric vehicle charging system. Figure – 2.1 depicts main components of suggested topology / architecture.

- Solar PV Panel
- Wind Turbine
- Small Hybdro
- Battery Storage System
- Grid
- DC-DC Converter
- ZbDBNM Controller
- Electric Vehicle and Charging System

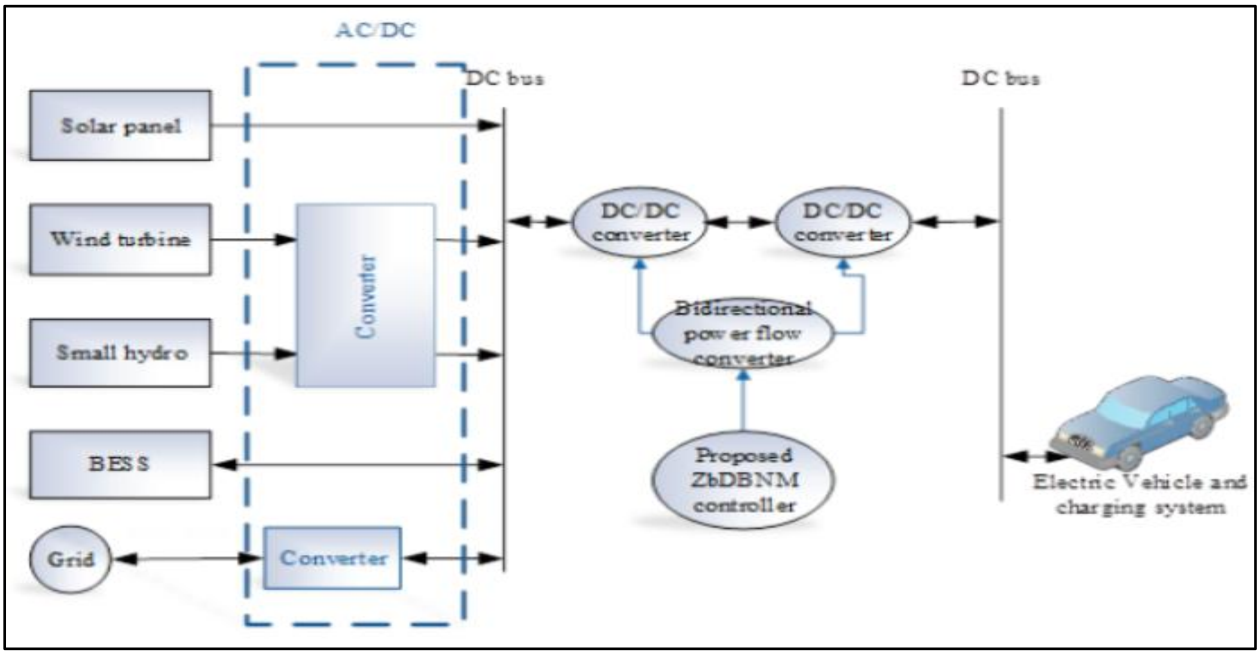

Fig. 2.1 (Control Architecture / Topology used for Integration)

3. OPTIMIZATION

Controlling when to charge and discharge energy storage systems is crucial to attaining microgrid efficiency because of their limited capacity. Energy loss from the charge-discharge cycle could reduce overall system efficiency. Battery degeneration can be accelerated by improper charging cycles. To extend their lifespan and ensure their availability when needed, batteries must be stored correctly. Based on estimates of renewable generation and demand, AI techniques can optimize the cycles of charging and discharging.[5]

4. OPTIMIZATION PROCESS

Implementing optimal microgrid operation in the presence of RES and BESS, or generally DER, is the main goal of the research project. This will reduce power loss, harmonics, and voltage instability in the proposed microgrid system. The formulation of this multi-function optimization issue was based on many restrictions. The formula and constraints listed below are used to formulate the goal function.[6]

$$O_{pt} = f \sum_{i=1}^{n} \underset{\textbf{multi - function optimization}}{\mathbf{Pl} * \frac{\mathbf{Ce}}{\mathbf{\log 10}\sqrt{\mathbf{THD}}} + \frac{\sqrt{\mathbf{Pl}}}{\mathbf{THD}^2} - \frac{\mathbf{Pl*Ce*THD}}{\mathbf{100}}}$$

Here,

P_l = power loss,

C_e = stability constant

THD = total harmonics distortion

The voltage and power from generation sources are considered in the optimization process. The limits mentioned in this article are given below.

$$\mathbf{Vmin} \le \mathbf{V(i)} \le \mathbf{Vmax}$$
$$\mathbf{Pmin} \le \mathbf{P(i)} \le \mathbf{Pmax}$$

Here,

V = voltage of system

P = power of system

This study uses the Zebra optimization algorithm (ZOA) to solve this equation.

5. ZEBRA OPTIMIZATION ALGORITHM

The Zebra Optimization Algorithm (ZOA) is based on simulating the social behaviour of zebra herds in the wild. During the foraging process, a pioneer zebra directs other zebras toward the food source. As a result, as the herd of zebras crosses the plains, the pioneer zebra leads the way. Zebras' zigzag running pattern serves as their major defense against predators. They do, however, gather in an attempt to scare or confound the predator.[7]

The mathematical modelling of these two types of intelligent zebra behaviour is the fundamental source of inspiration for the proposed ZOA architecture. Zebras are part of the ZOA population, which is a population-based optimizer.[8] From a mathematical standpoint, each zebra symbolizes a potential solution to the problem, and the plain containing the zebras is the problem's search space. The positions of each zebra within the search region define the choice variables' values. As a result, each zebra can be described as a member of the ZOA by utilizing a vector whose members represent the problem variables' values. A zebra population can be mathematically represented using a matrix.[9]

$$Z=\begin{bmatrix} Z1 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ Zi \\ \cdot \\ \cdot \\ \cdot \\ Zn \end{bmatrix} = \begin{bmatrix} Z11 \ldots Z1j \ldots Zim \\ \cdot \\ \cdot \\ Zi1 \ldots Zij \ldots Zim \\ \cdot \\ \cdot \\ Zn1 \ldots Znj \ldots Znm \end{bmatrix}$$

n = the number of population members (zebras).
m = the number of choice variables.
Z = the zebra population.
zi = the ith zebra.

Each zebra symbolizes a possible solution to the optimization problem. As a result, the objective function can be assessed using the recommended values for each zebra's issue variables.

$$\mathbf{F} = \begin{bmatrix} \mathbf{F1} \\ \cdot \\ \cdot \\ \cdot \\ \mathbf{Fi} \\ \cdot \\ \cdot \\ \cdot \\ \mathbf{Fn} \end{bmatrix} = \begin{bmatrix} \mathbf{F(Z1)} \\ \cdot \\ \cdot \\ \cdot \\ \mathbf{F\ (Zi)} \\ \cdot \\ \cdot \\ \cdot \\ \mathbf{F(Zn)} \end{bmatrix}$$

Figure-2 shows a flowchart for implementing the zebra optimization technique. The step-by-step technique is explained below.[10]

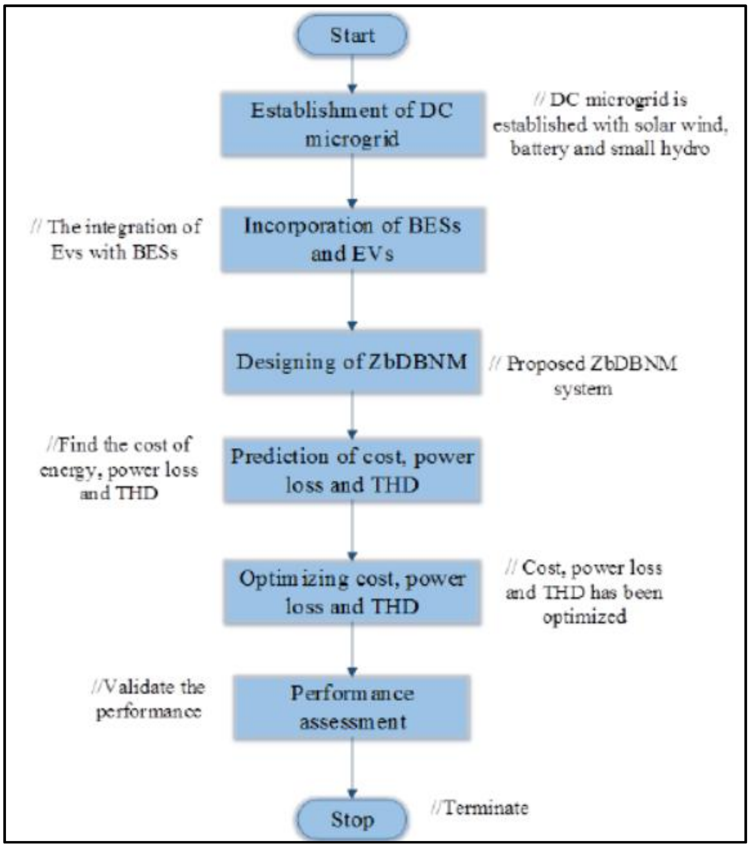

Fig. 5.1 (Algorithm of Zebra Optimization Method)

6. MATLAB SIMULATION

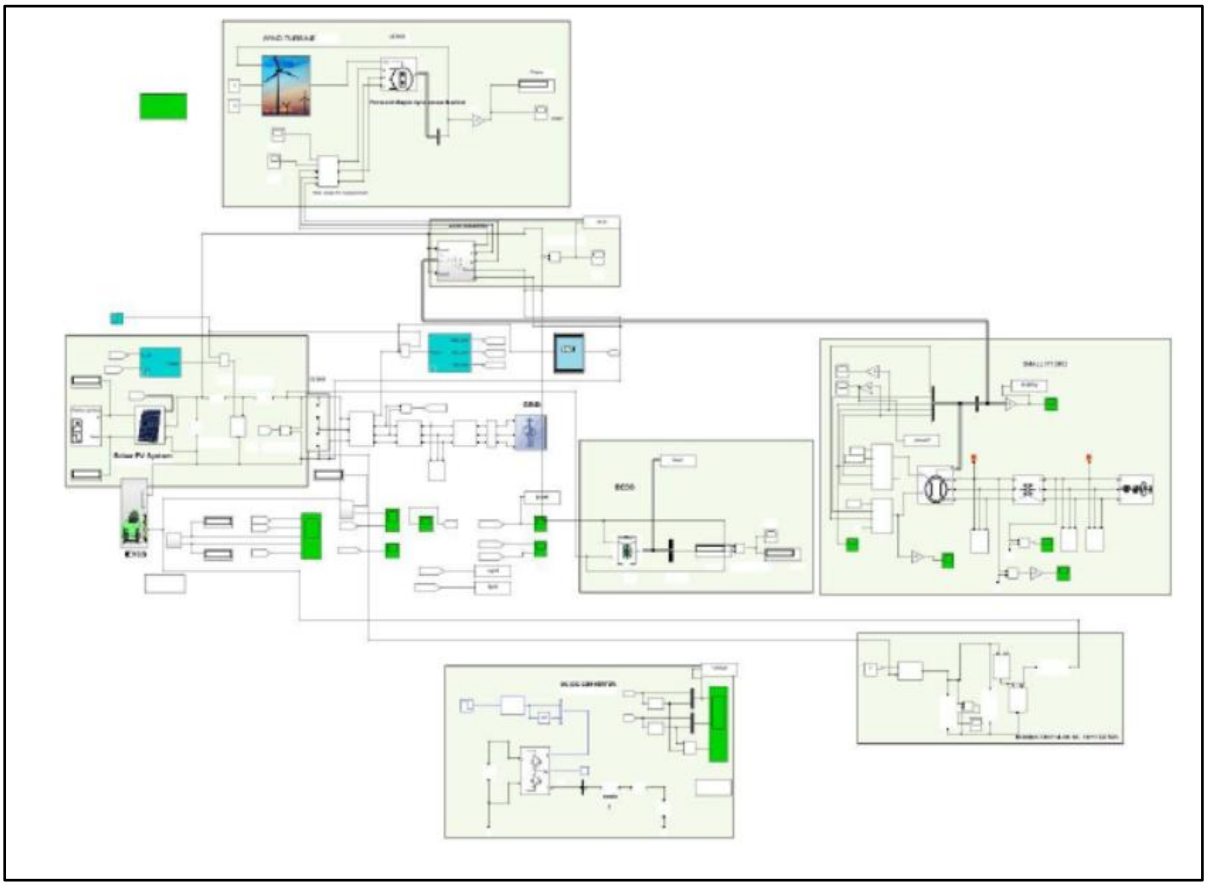

Fig. 6.1 (MATLAB Simulation of Multi Renewable Energy Source Optimization of HESS for EVCS)

Figure-6.1 depicts the system simulated in MATLAB using solar PV, wind turbine, and battery storage systems. This control method uses the zebra optimization algorithm to optimize microgrid operation while taking into account total harmonic distortion (THD), power loss, and voltage instability.[11] The suggested optimization technique performs well in this system and has a faster convergence rate than standard optimization algorithms. This section describes the performance of MATLAB. The parameters of the suggested system are presented in the table below. This is based on genuine weather data from wind and solar power. This simulation includes accounts for the battery's capacity, state of charge (SOC), and charging/discharging efficiency.[12]
Table 6.1 Shown below listed out the parameters to be used for an optimization of Multiple Renewable energy sources integrated with main grid and hybrid energy storage system for Electric vehicle charging system.

Table-6.1 (Parameters for an optimization of Multiple Energy sources for HESS used for EVCS)

Parameters	Description
Platform	MATLAB Version R2021a
Optimization	Zebra
Population	30
Iteration	100
Base MVA	1 MVA
Base kV	11kV
Solar Irradiance	1000
Maximum power	1.2 kW
Panel Temperature	250C
Output voltage	300V
Wind speed	2.5m/s
Maximum power	2.5kW
Cut off speed	22m/s

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Cut in speed	7m/s
Output voltage	500V
Power and X/R	20kW and 0.7
Load	9 kW and 11.25 kVAr
Grid voltage and current	300V and 2A
Real power	1.1 p.u

7. RESULTS

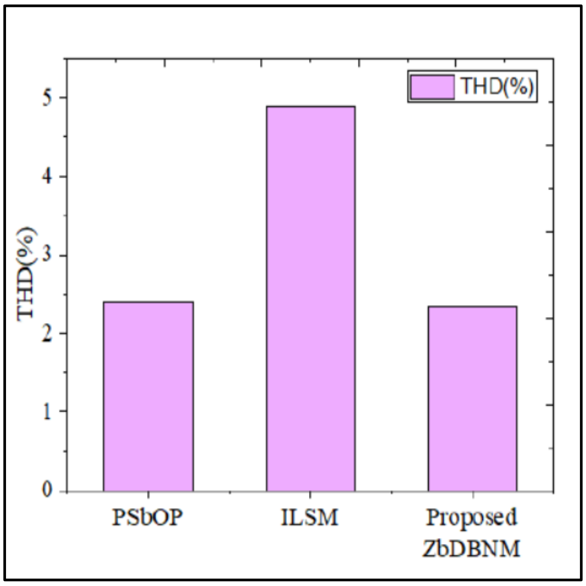

Fig. 7.1 (THD Analysis in MATLAB)

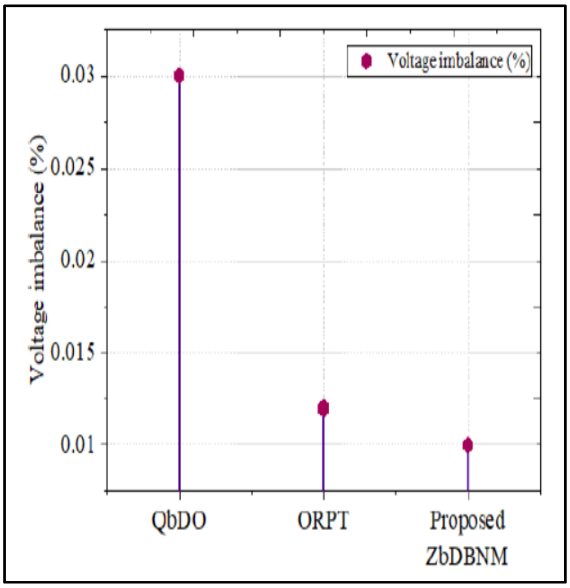

Fig. 7.2 (Voltage Stability Analysis)

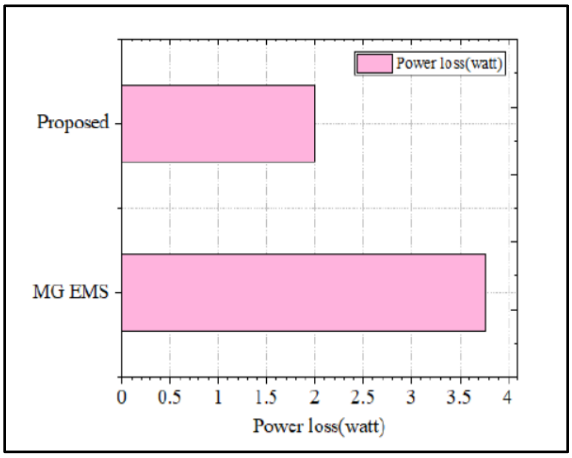

Fig. 7.3 (Power Loss Analysis)

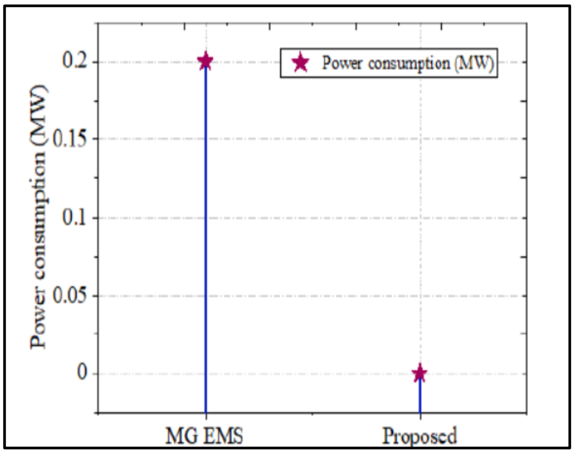

Fig. 7.4 (Power Consumption Analysis)

8. DATA COLLECTION AND RESULT SUMMARY

Table – 8.2 shown below discussed about the data collected from figure – 4, figure – 5, figure – 6 and figure – 7 shown above and results obtained and the interpretation of results.

Table-8.2 (Data collection / Result Summary and Interpretation of Results)

Sr. No.	Data Collected	Interpretation of Result
1	**Figure – 7.1:** THD % by using PSbOP method is 2.5 % THD % by using ILSM method is 4.8% THD % by using proposed ZbDBNM method is 2.4%	By comparing these three methods we can say that THD% is less in out proposed ZbDBNM method.

2	**Figure – 7.2:** Voltage imbalance % by using QbDO method is 0.03% Voltage imbalance % by using QRPT method is 0.012% Voltage imbalance % by using proposed ZbDBNM method is 0.01%	We can say that by comparing these three methods we can get voltage imbalance % is less in out propsed ZbDBNM method.
3	**Figure – 7.3:** Power loss by using MG ESM method is 3.8 Watts Power loss by using Proposed ZbDBNM method is 2.0 Watts	By comparing the results of these two methods we can say that Power loss is less in our prosed ZbDBNM method.
4	**Figure – 7.4:** Power consumption by using MG ESM is 0.2 MW Power Consumption by using proposed ZbDBNM method is 0.01 MW	By comparing these two methods we can see that power consumption is less in out proposed ZbDBNM method.

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CONCLUSION

This work describes an optimized electric vehicle (EV) charging system that incorporates numerous renewable energy sources (RES), the main grid, and a hybrid energy storage system (HESS), all managed by a revolutionary Zebra Optimization Algorithm (ZOA). The proposed system comprises energy inputs from solar panels, wind turbines, small hydro, and the grid, all of which are connected to a shared DC bus via appropriate converters.

The Zero-Bias Deep Belief Neural Model (ZbDBNM) controls a bidirectional power flow converter, which enables intelligent energy distribution between the DC bus and EV charging stations. The ZOA is a useful tool for managing power flow, reducing energy losses, and optimizing charging efficiency by dynamically picking the most cost-effective and environmentally friendly energy sources based on availability, load demand, and battery state-of charge.

REFERENCES

[1] O. J. Alhayali, A. Ataalla, and A. F. Shafeeq, ‘Optimizing Hybrid Renewable Energy Systems for Electric Vehicle Charging Stations: A Feasibility Study in Iraqi Cities’, J. Intell. Syst. Internet Things, vol. 17, no. 1, 2025, doi: 10.54216/jisiot.170121.

[2] H. M. Mohan and S. K. Dash, ‘Renewable Energy-Based DC Microgrid with Hybrid Energy Management System Supporting Electric Vehicle Charging System’, Systems, vol. 11, no. 6, 2023, doi: 10.3390/systems11060273.

[3] A. Petrusic and A. Janjic, ‘Article renewable energy tracking and optimization in a hybrid electric vehicle charging station’, Appl. Sci., vol. 11, no. 1, pp. 1–17, 2020, doi: 10.3390/app11010245.

[4] H. Kiani, B. Vahidi, S. H. Hosseinian, G. C. Lazaroiu, and P. Siano, ‘Prospective Design and Evaluation of a Renewable Energy Hybrid System to Supply Electrical and Thermal Loads Simultaneously with an Electric Vehicle Charging Station for Different Weather Conditions in Iran’, Smart Cities, vol. 8, no. 2, 2025, doi: 10.3390/smartcities8020061.

[5] Y. K. Güven, Aykut Fatih, ‘Optimization of Hybrid Renewable Energy Systems for a Public Hospital : a Case Study of Grid and Off-Grid Solutions in Yalova , 11 . International European Congress on Advanced Studies in Basic Sciences’, Int. Eur. Congr. Adv. Stud. Basic Sci., no. November, 2024.

[6] Z. Ullah et al., ‘Integrating electric vehicles and renewable energy in modern power systems: A review of EV charging station design, control strategies, and emerging trends’, Ain Shams Eng. J., vol. 16, no. 10, p. 103592, 2025, doi: 10.1016/j.asej.2025.103592.

[7] K. Emdadi, M. Gandomkar, and J. Nikoukar, ‘Energy scheduling of renewable integrated system with hydrogen storage in distribution grid including charging and hydrogen stations of eclectic vehicles’, Sci. Rep., vol. 15, no. 1, pp. 1–22, 2025, doi: 10.1038/s41598-025-99697-z.

[8] W. F. Hassen, ‘smart cities Power Management Approach of Hybrid Energy Storage System for Electric Vehicle Charging Stations’, pp. 4025–4051, 2024.

[9] M. Bilal, P. N. Bokoro, G. Sharma, and G. Pau, ‘A Cost-Effective Energy Management Approach for On-Grid Charging of Plug-in Electric Vehicles Integrated with Hybrid Renewable Energy Sources’, Energies, vol. 17, no. 16, 2024, doi: 10.3390/en17164194.

[10] T. Alharbi, A. Abdalrahman, M. H. Mostafa, and L. Alkhalifa, 'Joint Optimization of EV Charging and Renewable Distributed Energy With Storage Systems Under Uncertainty', IEEE Access, vol. 13, pp. 76838–76856, 2025, doi: 10.1109/ACCESS.2025.3562531.

[11] M. J. Nerella, J. Venkatesh, R. Kumar, A. Arul Johnson, R. Ramaswamy, and S. Mohammed Ghouse, 'Energy Storage Optimization in Electric Vehicles for improving vehicles to grid Performance', E3S Web Conf., vol. 619, 2025, doi: 10.1051/e3sconf/202561901009.

[12] A. N. A. Elghaffar, 'BILTEK-IX', no. July, 2024.