IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.311 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 3, March 2026

DOI: 10.17148/IARJSET.2026.133108

"Designing Sustainable and Resilient Charging Hubs"

Mr. Vijay. D. Vadnere[1], Veerkumar Tayade[2], Aaryan Tupsakhare[3], Pournima Shinde[4], Sakshi Gunjal[5]

Research Scholar, Department of Civil Engineering, Shri JJT University, Jhunjhunu, Rajasthan, India[1]

Third year diploma student, Civil Engineering, Met Bhujbal Knowledge City, IOT, Polytechnic, Nashik, India[2]

Third year diploma student, Civil Engineering, Met Bhujbal Knowledge City, IOT, Polytechnic, Nashik, India[3]

Third year diploma student, Civil Engineering, Met Bhujbal Knowledge City, IOT, Polytechnic, Nashik, India[4]

Third year diploma student, Civil Engineering, Met Bhujbal Knowledge City, IOT, Polytechnic, Nashik, India[5]

Abstract The rapid growth of electric vehicles (EVs) has created a significant demand for reliable and efficient charging infrastructure. However, most existing charging stations in India are highly dependent on grid electricity and lack proper sustainability and resilience features. This study focuses on the design of a sustainable and resilient EV charging hub using civil engineering principles and relevant Indian Standards. The proposed model integrates solar energy systems, battery storage, rainwater harvesting, permeable pavements, and proper structural planning to ensure long-term performance and environmental responsibility. A case study of an existing charging station highlights current limitations such as grid dependency and lack of renewable integration. The study develops a theoretical design suitable for Indian climatic conditions, ensuring energy efficiency, safety, and operational continuity during adverse conditions. The results indicate that integrating renewable energy and sustainable design practices can significantly improve the efficiency, reliability, and environmental performance of EV charging infrastructure.

Keywords: Electric Vehicles (EV), Charging Infrastructure, Sustainable Charging Hub, Renewable Energy, Solar Power, Resilient Design, Civil Engineering, Rainwater Harvesting, Energy Storage System, Green Infrastructure

I. INTRODUCTION

The future of sustainable and resilient EV charging hubs is highly promising with the rapid growth of electric mobility and continuous technological advancements. As governments promote clean transportation and stricter environmental regulations are implemented, the demand for advanced charging infrastructure will increase significantly. Future charging hubs will not only serve as energy stations but also act as integrated smart infrastructure systems supporting urban development. With the rise in EV adoption, there will be a greater need for efficient, fast, and widely accessible charging networks across both urban and rural areas.

In the coming years, charging hubs can be developed as fully energy self-sufficient systems by increasing the capacity of solar power generation and advanced battery storage solutions. The integration of smart technologies such as IoT and real-time monitoring systems will improve energy management, operational efficiency, and user convenience. Charging infrastructure can also be expanded to support electric buses and heavy vehicles, along with the introduction of battery swapping stations to reduce charging time.

Further developments may include the use of prefabricated construction techniques for faster and cost-effective installation, as well as the adoption of recycled and eco-friendly materials to enhance sustainability. Integration with smart city planning will allow better coordination with urban infrastructure, traffic systems, and energy networks. Additionally, expansion of charging stations in rural areas and along highways will improve accessibility and support large-scale EV adoption. Overall, continuous innovation in technology and infrastructure planning will make EV charging hubs more efficient, sustainable, and widely accessible in the future.

1.1 Purpose of the Study

- To develop a sustainable and resilient EV charging hub.
- To reduce dependency on conventional grid electricity by integrating renewable energy.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.311 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 3, March 2026

DOI: 10.17148/IARJSET.2026.133108

- To improve infrastructure planning using civil engineering principles.
- To ensure safe and continuous operation under environmental challenges.

1.2 Objectives

- To study existing EV charging infrastructure and identify its limitations.
- To analyze research papers related to sustainable charging systems.
- To design a theoretical layout of a charging hub suitable for Indian conditions.
- To integrate solar energy and battery storage systems.
- To propose rainwater harvesting and drainage systems.
- To ensure structural safety using relevant Indian Standards.
- To evaluate environmental and economic performance of the proposed model.

1.3 Literature Review

The development of sustainable and resilient EV charging infrastructure has been widely discussed in recent research studies.

a) **Hemant Kore and Saroj Koul (2022)** analyzed the major challenges in EV infrastructure development in India, including poor planning, high installation costs, and lack of accessibility. Their study emphasized the importance of strategic location planning and strong policy support for creating a reliable charging network.

b) **Shubham Mishra et al. (2021)** reviewed the current status of EV charging infrastructure and highlighted the transition from conventional fuel vehicles to electric vehicles. The study discussed different types of charging technologies and identified key challenges such as grid load, infrastructure gaps, and high investment requirements. It concluded that efficient and well-planned charging systems are essential for EV growth.

c) **Prahaladh Paniyil et al. (2021)** focused on the integration of renewable energy sources in charging infrastructure. The study proposed solar and wind-based charging systems combined with battery storage to reduce dependency on fossil fuels. It highlighted that renewable energy integration significantly improves sustainability and reduces operational costs.

d) **Soumesh Chatterjee et al. (2024)** presented a solar-powered EV charging system integrated with IoT technology. The research emphasized smart monitoring, efficient power usage, and improved user convenience. It demonstrated how advanced technologies can enhance both performance and sustainability of charging stations.

e) **Arvind R. Singh et al. (2024)** discussed various EV charging technologies and the importance of grid integration. The study highlighted the role of fast charging systems and advanced infrastructure planning in supporting future EV demand. It also focused on scalability and reliability of charging networks.

f) **77 and Regional Sustainability Study (2022),** emphasized the need for proper infrastructure planning, environmental considerations, and policy support. These studies highlighted issues such as demand-supply gaps, maintenance challenges, and lack of sustainable practices in existing charging stations.

Overall, the literature clearly indicates that while EV adoption is increasing, charging infrastructure still requires significant improvement in terms of sustainability, resilience, and efficiency. These research findings form the basis for developing a well-planned, sustainable, and resilient EV charging hub model in this study.

II. METHODOLOGY

The methodology adopted in this study is based on a systematic approach combining literature review, case study, and theoretical design. Initially, various research papers and reports related to EV charging infrastructure were studied to understand current challenges such as grid dependency, poor planning, and lack of sustainability. A site visit to an existing charging station was also conducted to observe real-world conditions including layout, electrical setup, and structural arrangement. These observations helped in identifying the gap between existing infrastructure and the requirements of a sustainable and resilient charging hub. Based on this analysis, a theoretical model suitable for Indian conditions was developed considering factors like accessibility, land use, and climatic conditions.

The proposed methodology further includes planning and design of different components such as site layout, structural system, electrical infrastructure, and sustainable features. Structural design is considered as per relevant Indian Standards to ensure safety and durability. Renewable energy integration is achieved through solar panels and battery storage systems to reduce grid dependency. In addition, rainwater harvesting, proper drainage systems, permeable pavements, and landscaping are included to improve environmental performance. Electrical load estimation, transformer selection, and safety systems are also considered to ensure efficient operation. Overall, the methodology

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.311 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 3, March 2026

DOI: 10.17148/IARJSET.2026.133108

integrates civil engineering principles with sustainability and resilience strategies to develop a practical and future-ready EV charging hub.77

1. Materials Used

The methodology adopted in this study focuses on developing a sustainable and resilient EV charging hub through a systematic approach that combines literature review, practical observation, and theoretical design. Initially, various research papers and case studies were analyzed to understand the current status, challenges, and future scope of EV charging infrastructure. A site visit to an existing charging station was conducted to observe real-world conditions, including layout planning, electrical setup, and structural arrangements. Based on these observations, a theoretical model of a charging hub was developed considering Indian climatic conditions and civil engineering standards. The methodology includes site planning, structural design, integration of renewable energy systems, and environmental considerations to ensure safety, sustainability, and long-term performance.

2. Construction Process

The construction of the proposed sustainable and resilient charging hub involves the use of various materials selected based on strength, durability, and environmental performance. Reinforced Cement Concrete (RCC) is used for the construction of the control room building, foundations, and structural elements due to its high compressive strength and durability, designed as per IS 456:2000 guidelines. Structural steel is used for the canopy structure above the parking area, as it provides high strength with relatively low weight and allows longer spans, making it suitable for supporting solar panels; its design follows IS 800:2007 standards.

Solar photovoltaic panels are installed on the canopy structure to generate renewable energy, reducing dependency on grid electricity. A battery storage system is incorporated to store excess solar energy and provide backup during power failures. For the pavement and parking areas, permeable paving blocks are used in selected locations to improve drainage and allow rainwater infiltration, reducing waterlogging issues.

Sustainable construction materials such as fly ash bricks are considered for wall construction, as they utilize industrial waste and reduce environmental impact. Additionally, electrical materials including transformers, underground cables, distribution panels, and earthing systems are used to ensure proper power distribution and safety. The selection of these materials ensures that the charging hub is not only structurally safe but also environmentally responsible and suitable for long-term use.

III. ADVANTAGES

- Reduces dependency on grid electricity through solar energy integration
- Lowers carbon emissions and supports environmentally friendly infrastructure
- Provides uninterrupted power supply with battery storage system
- Improves structural safety and durability using proper design standards
- Enhances resilience against extreme weather conditions like rain, heat, and flooding
- Includes rainwater harvesting for efficient water management
- Uses permeable pavements to reduce waterlogging and improve drainage
- Green landscaping improves environmental quality and reduces heat
- Reduces long-term operational cost due to renewable energy usage
- Supports future expansion and scalability of charging infrastructure

IV. DISADVANTAGES

- High initial investment cost due to solar panels and battery storage systems
- Requires skilled professionals for design, installation, and maintenance
- Maintenance of solar panels and batteries increases operational responsibility
- Large land area requirement compared to basic charging stations
- Dependence on weather conditions affects solar energy generation
- Complex system integration (electrical + structural + renewable systems)
- Higher planning and design time compared to conventional infrastructure

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.311 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 13, Issue 3, March 2026

DOI: 10.17148/IARJSET.2026.133108

- Battery disposal and replacement can create environmental concerns if not managed properly

V. FUTURE SCOPE

The future of sustainable and resilient EV charging hubs is highly promising with the rapid growth of electric mobility and technological advancements. In the coming years, charging hubs can be developed as fully energy self-sufficient systems by increasing the capacity of solar power generation and advanced battery storage solutions. The integration of smart technologies such as IoT and real time monitoring systems will improve energy management, operational efficiency, and user convenience. Charging infrastructure can also be expanded to support electric buses and heavy vehicles, along with the introduction of battery swapping stations to reduce charging time.

Further developments may include the use of prefabricated construction techniques for faster and cost-effective installation, as well as the adoption of recycled and eco-friendly materials to enhance sustainability. Integration with smart city planning will allow better coordination with urban infrastructure, traffic systems, and energy networks. Additionally, expansion of charging stations in rural areas and along highways will improve accessibility and support large-scale EV adoption. Overall, continuous innovation in technology and infrastructure planning will make EV charging hubs more efficient, sustainable, and widely accessible in the future.

VI. CONCLUSION

The study highlights the importance of developing sustainable and resilient electric vehicle charging hubs to support the growing demand for electric mobility. It is observed that existing charging infrastructure in India is mostly dependent on grid electricity and lacks proper planning in terms of sustainability and resilience. The proposed model addresses these challenges by integrating civil engineering design principles with renewable energy systems such as solar power and battery storage. In addition, features like rainwater harvesting, permeable pavements, proper drainage, and green landscaping improve environmental performance and resource efficiency.

The study also emphasizes the role of structural safety and proper planning using relevant Indian Standards to ensure long-term durability and reliability. Although the initial investment is higher, the reduction in operational costs and environmental benefits make the project economically feasible in the long run. Overall, the proposed sustainable charging hub provides a practical and future-ready solution that is safe, efficient, and environmentally responsible. It can play a significant role in supporting the transition toward clean and sustainable transportation system.

REFERENCES

[1]. Hemant Kore & Saroj Koul (2022) – Study on challenges in EV charging infrastructure development in India and the need for proper planning and resilient systems.
[2]. Shubham Mishra et al. (2021) – Review of EV charging infrastructure growth and the importance of sustainable systems for supporting electric mobility.
[3]. Prahaladh Paniyil et al. (2021) – Research on renewable energy-based charging systems integrating solar and battery storage.
[4]. Soumesh Chatterjee et al. (2024) – Study on solar-powered smart EV charging stations with IoT-based monitoring systems.
[5]. Arvind R. Singh et al. (2024) – Analysis of EV charging technologies and the role of grid integration in infrastructure development.
[6]. Renewable Energy Review Study (2024) – Overview of EV infrastructure planning, challenges, and sustainable development strategies in India.
[7]. Regional Sustainability Study (2022) – Study on environmental benefits and challenges of EV infrastructure development.
[8]. Rajib K. Mishra & Nitin Sheoran (2025) – Report on India's EV roadmap and future infrastructure requirements.
[9]. Pradeep Vishnuram et al. (2024) – Study on smart grid integration and energy management in EV charging systems.
[10]. Indian EV Infrastructure Review (2023–2024) – Analysis of growth, gaps, and future needs of EV charging infrastructure in India.

