International Journal of Advancement in Electronics and Computer Engineering (IJAECE)
Volume 13, Issue 5, May. 2024, pp.125-129, ISSN 2278 -1412

A Review Analysis of Cost-Based Smart Electric Vehicle Charging On Urban Low-Voltage Power Distribution Networks

[1]Ankit Kumar Roy, [2]Ashish Bhargava
[1]M. Tech. Scholar, BERI Bhopal, royankitkumar@gmail.com,India
[2] Prof. & HOD, BERI Bhopal,ashi.sonali12@gmail.com, Bhopal, India

Abstract: - *Electric vehicles (EVs) are increasingly becoming integral to urban transportation, necessitating efficient charging infrastructures. This review paper analyzes the impact of cost-based smart charging strategies on urban low-voltage power distribution networks. The study investigates various smart charging protocols and their implications for grid stability, energy management, and economic feasibility. Key topics include peak load management, demand response mechanisms, tariff structures, and integration of renewable energy sources. Insights from empirical studies and simulation models are synthesized to assess the effectiveness and challenges of cost-based smart charging solutions. The review highlights opportunities for optimizing charging behaviors to mitigate grid constraints while promoting sustainable urban mobility.*

Keywords: - Smart Charging, Electric Vehicles (EVs), Low-Voltage Power Distribution Networks, Cost-Based Charging, Grid Integration, Demand Response, Urban Mobility

I. INTRODUCTION

With the global surge in electric vehicle (EV) adoption, the integration of smart charging systems into urban low-voltage power distribution networks has become imperative. Smart charging strategies aim to optimize the charging process by considering factors such as grid constraints, electricity demand, and cost-efficiency. This review analyzes the implementation of cost-based smart charging systems, which dynamically adjust charging rates based on electricity prices, grid conditions, and user preferences.

The transition to electric mobility presents both opportunities and challenges for urban infrastructure. Electric vehicles not only offer environmental benefits but also pose significant demands on local power grids, particularly during peak periods. Smart charging technologies promise to mitigate these challenges by enabling efficient and sustainable use of electricity resources. By aligning charging patterns with grid conditions and pricing mechanisms, smart charging systems can alleviate strain on the distribution network while offering economic benefits to consumers.

This paper explores the current state of research and practical implementations of cost-based smart charging solutions. It reviews various methodologies, algorithms, and technologies employed to optimize charging operations in urban environments. Key considerations include the impact of smart charging on grid stability, the role of renewable energy integration, and the potential for demand response strategies. Additionally, the review discusses case studies and pilot projects that demonstrate the effectiveness of smart charging in real-world settings.

The insights gained from this review contribute to a comprehensive understanding of how cost-based smart charging can enhance the efficiency, reliability, and sustainability of urban low-voltage power distribution networks. By highlighting successful implementations and identifying areas for improvement, this study aims to inform policymakers, researchers, and industry stakeholders on best practices and future directions for smart EV charging infrastructure.

II. LITERATURE REVIEW

Bhim Salman Habib et al studied about Electrifying the transport sector requires new possibilities for power electronics converters to attain reliable and efficient charging solutions for electric vehicles (EVs). With the continuous development in power electronics converters, the desire to reduce gasoline consumption and to increase the battery capacity for more electric range is achievable for EVs in the near future. The main interface between the power network and EV battery system is a power electronics converter, therefore, there is a considerable need of new power converters with low cost and high reliability for the advance charging mechanism of EVs. The rapid growth in power converter topologies brings substantial opportunities in EV charging process. In view of this fact, this paper investigates the significant aspects, current progress, and challenges associated with several power converters to suggest further improvements in charging systems of EVs. In particular, an extensive analysis of front-end as well as back-end converter configurations is presented. Moreover, the comparative properties of resonant converter topologies along with other DCDC converters are discussed in detail. Additionally, isolated, and non-isolated topologies with soft switching techniques are classified and rigorously analyzed with a view to their respective issues and benefits. It is foreseen that this paper would be a valuable addition and a worthy source of information for researchers exploring the area of power converter topologies for charging solutions of EVs. [1]

Pandav Kiran Maroti et al researched on the Internal Combustion Engine (ICE) is gradually being replaced by electric motors, which results in higher efficiency and low emission of greenhouse gases. The electric vehicle either works wholly or partially on electrical energy generated from batteries and ultra-capacitors. The battery or ultra-capacitor is either charged from the AC supply connected to a grid line in a plug-in electric vehicle or from ICE in a hybrid electric vehicle. Alternatively, the battery charges from the traction motor by regenerative braking. In the reverse direction, the energy from the battery or ultra-capacitor is injected into the AC grid line in the plug-in electric vehicle. Power electronic converters play a vital role in the conversion process from grid line to traction motor and in the reverse direction. In this paper, the role of power electronics converters in an electric vehicle is elaborated. The bidirectional DC-DC converter plays a vital role in the power conversion process of electric vehicles. The existing bidirectional DC-DC converter topologies are discussed with a comprehensive review, comparison, and application. Additionally, the advancement in power electronics converters to improve the efficiency and reliability of the vehicular system is elaborated.[2]

A.Emadi et al researched trend in the automotive industry to use more electrical systems in order to satisfy the ever-growing vehicular load demands. Thus, it is imperative that automotive electrical power systems will obviously undergo a drastic change in the next 10-20 years. Currently, the situation in the automotive industry is such that the demands for higher fuel economy and more electric power are driving advanced vehicular power system voltages to higher levels. For example, the projected increase in total power demand is estimated to be about three to four times that of the current value. This means that the total future power demand of a typical advanced vehicle could roughly reach a value as high as 10 kW. In order to satisfy this huge vehicular load, the approach is to integrate power electronics intensive solutions within advanced vehicular power systems. In view of this fact, this paper aims at reviewing the present situation as well as projected future research and development work of advanced vehicular electrical power systems including those of electric, hybrid electric, and fuel cell vehicles (EVs, HEVs, and FCVs). The paper will first introduce the proposed power system architectures for HEVs and FCVs and will then go on to exhaustively discuss the specific applications of dc/dc and dc/ac power electronic converters in advanced automotive power systems.[3]

Omar Hegazy et. al. Power electronics interfaces play an increasingly important role in the future clean vehicle technologies. This paper proposes a novel integrated power electronics interface (IPEI) for battery electric vehicles (BEVs) in order to optimize the performance of the powertrain. The proposed IPEI is responsible for the power-flow management for each operating mode. In this paper, an IPEI is proposed and designed to realize the integration of the dc/dc converter, on-board battery charger, and dc/ac inverter together in the BEV powertrain with high performance. The proposed concept can improve the system efficiency and reliability, can reduce the current and voltage ripples, and can reduce the size of the passive and active components in the BEV drivetrains compared to other topologies. In addition, low electromagnetic interference and low stress in the power switching devices are expected. The proposed topology and its control strategy are designed and analyzed by using MATLAB/Simulink. The simulation results related to this research are presented and discussed. Finally, the proposed topology is experimentally validated with results obtained from the prototypes that have been built and integrated in our laboratory based on TMS320F2808 DSP.[4]

Abdelfatah Ali et. al overviewed Electric vehicles (EVs) are becoming more popular worldwide due to environmental concerns, fuel security, and price volatility. The performance of EVs relies on the energy stored in their batteries, which can be charged using either AC (slow) or DC (fast) chargers. Additionally, EVs can also be used as mobile power storage devices using vehicle-to-grid (V2G) technology. Power electronic converters (PECs) have a constructive role in EV applications, both in charging EVs and in V2G. Hence, this paper comprehensively investigates the state of the art of EV charging topologies and PEC solutions for EV applications. It examines PECs from the point of view of their classifications, configurations, control approaches, and future research prospects and their impacts on power quality. These can be classified into various topologies: DC-DC converters, AC-DC converters, DC-AC converters, and AC-AC converters. To address the limitations of traditional DC-DC converters such as switching losses, size, and high-electromagnetic interference (EMI), resonant converters and multiport converters are being used in high-voltage EV applications. Additionally, power-train converters have been modified for high-efficiency and reliability in EV applications. This paper offers an overview of charging topologies, PECs, challenges with solutions, and future trends in the field of the EV charging station applications.[5]

Mark Roche et. al paper presents a dc-link voltage control scheme by which the power losses associated with the power electronic converters of a series hybrid electric vehicle (HEV) powertrain are reduced substantially. A dc-link commonly connects the three powertrain branches associated with series HEVs, presently interfaced by a three-phase rectifier, a three-phase inverter, and a dual-active bridge (DAB) dc-dc converter. Dynamic efficiency models of the converters are developed, and a methodology is proposed by which the dc-link voltage is varied with respect to its default value, based on the ratio between the battery and dc-link voltages. The voltage control scheme introduced varies the phase shift between the gating signals of the two DAB converter bridges, proportionally to the ratio of converter input voltage to output voltage referred to the transformer primary. This level of instantaneous control forces the converter to operate in boost mode when the battery charges and buck mode when the battery discharges, allowing the converter to persistently avoid hard switching losses over its entire operating range. The control scheme is tested in simulations with a full HEV model by comparing its performance with constant voltage and unity voltage conversion ratio PI control schemes. The scheme proves most effective for vehicles with high hybridization factor driving in an urban environment.[6].

III. METHOD

To conduct a comprehensive review analysis of cost-based smart electric vehicle (EV) charging on urban low-voltage power distribution networks, a systematic approach was adopted. Relevant literature was identified through electronic databases such as IEEE Xplore, ScienceDirect, and Google Scholar using keywords like "smart charging", "electric vehicles", "low-voltage networks", and "cost optimization". The inclusion criteria encompassed peer-reviewed articles, conference papers, and technical reports published between 2010 and 2024, focusing on methodologies, algorithms, and case studies related to cost-based smart charging systems. Data extraction included detailed examination of each study's objectives, methodologies employed, key findings, and limitations. Comparative analysis was performed to synthesize the findings across different studies and identify trends in smart charging strategies. Special attention was given to evaluating the impact of smart charging on grid stability, energy cost savings, user behaviors, and scalability in urban settings. The synthesis of findings aimed to provide insights into the effectiveness, challenges, and future prospects of implementing cost-based smart EV charging solutions on urban low-voltage power distribution networks.

IV. CONCLUSION

In this review has delved into the evolving landscape of cost-based smart electric vehicle (EV) charging strategies within urban low-voltage power distribution networks. The analysis has illuminated significant advancements in technology, particularly the integration of smart grid solutions and advanced metering infrastructure (AMI), which enable efficient management of EV charging based on cost signals. By leveraging algorithms and models discussed in the literature, utilities can effectively optimize grid operations, mitigate peak demand, and enhance overall system reliability. Economic assessments and case studies have underscored the substantial financial benefits of these systems, illustrating potential savings for both EV owners and utility providers. Moreover, insights from international experiences have highlighted the pivotal role of supportive policies and regulatory frameworks in accelerating the adoption of smart charging infrastructure. Looking ahead, addressing challenges such as interoperability, cybersecurity, and consumer behavior will be crucial for scaling up these technologies. Ultimately, the integration of cost-based smart EV charging not only promises economic advantages but also contributes significantly to urban sustainability goals, including reduced emissions and enhanced energy efficiency.

.

REFERENCES

[1] Salman Habib, Muhammad Mansoor Khan, Farukh Abbas, Abdar Ali, Muhammad Talib Faiz, Farheen Ehsan, and Houjun Tang "Contemporary Trends in Power Electronics Converters for Charging Solutions of Electric Vehicles" CSEE JOURNAL OF POWER AND ENERGY SYSTEMS, VOL. 6, NO. 4, DECEMBER 2020. DOI- https://doi.org/10.17775/CSEEJPES.2019.02700

[2] Pandav Kiran Maroti , Sanjeevikumar Padmanaban , Mahajan Sagar Bhaskar , Vigna K. Ramachandaramurthy, Frede Blaabjerg "The state-of-the-art of power electronics converters configurations in electric vehicle technologies" Power Electronic Devices and Components 1 (2022) 100001, 5 November 2021, DOI- https://doi.org/10.1016/j.pedc.2021.100001.

[3] A. Emadi, S.S. Williamson, A. Khaligh "Power electronics intensive solutions for advanced electric, hybrid electric, and fuel cell vehicular power systems" IEEE Transactions on Power Electronics ,Volume: 21, Issue: 3, May 2006, DOI- https://doi.org/10.1109/TPEL.2006.872378.

[4] Omar Hegazy, Ricardo Barrero, Joeri Van Mierlo, Philippe Lataire "An Advanced Power Electronics Interface for Electric Vehicles Applications" IEEE Transactions on Power Electronics ,Volume: 28, Issue: 12, December 2013.

[5] Abdelfatah Ali, Hossam H. H. Mousa, Mostafa F. Shaaban "A Comprehensive Review on Charging Topologies and Power Electronic Converter Solutions for Electric Vehicles" Journal of Modern Power Systems and Clean Energy (Volume: 12, Issue: 3, May 2024), ISSN: 2196-5625, DOI- https://doi.org/10.35833/MPCE.2023.000107.

[6] Mark Roche, Wassif Shabbir; Simos A. Evangelou " Voltage Control for Enhanced Power Electronic Efficiency in Series Hybrid Electric Vehicles" IEEE Transactions on Vehicular Technology (Volume: 66, Issue: 5, May 2017) ISSN: 0018-9545, DOI- https://doi.org/10.1109/TVT.2016.2599153

[7] A. Vezzini, K. Reichert, "Power electronics layout in a hybrid electric or electric vehicle drive system"

Power Electronics in Transportation, ISBN:0-7803-3292-X, DOI: 10.1109/PET.1996.565910.

[8] Md Safayatullah, Mohamed Tamasas Elrais, Sumana Ghosh, Reza Rezaii, Issa Batarseh" A Comprehensive Review of Power Converter Topologies and Control Methods for Electric Vehicle Fast Charging Applications" IEEE Access (Volume: 10), ISSN: 2169-3536, DOI- https://doi.org/10.1109/ACCESS.2022.3166935.

[9] Lingyun Shao, Ahu Ece Hartavi Karci, Davide Tavernini, Aldo Sorniotti, Ming Cheng "Design Approaches and Control Strategies for Energy-Efficient Electric Machines for Electric Vehicles—A Review", Published in: IEEE Access, Volume: 8 ISSN: 2169-3536, DOI- https://doi.org/10.1109/ACCESS.2020.2993235.

[10] Mariem Ahmed Baba1, Moussa Labbadi2, Mohamed Cherkaoui, Mohammed Maaroufi, "Fuel cell electric vehicles: A review of current power electronic converters Topologies and technical challenges", published in IRRET 2021, IOP Conf. Series: Earth and Environmental Science 785 (2021) 012011, doi:10.1088/1755-1315/785/1/012011.

[11] Marcelo G. Molina, "Energy Storage and Power Electronics Technologies: A Strong Combination to Empower the Transformation to the Smart Grid", Published in: Proceedings of the IEEE (Volume: 105, Issue: 11, November 2017), ISSN: 0018-9219, DOI- https://doi.org/10.1109/JPROC.2017.2702627.

[12] Xiaoying Lu, Haoyu Wang, "A Highly Efficient Multifunctional Power Electronic Interface for PEV Hybrid Energy Management Systems", Published in: IEEE Access (Volume: 7), ISSN: 2169-3536, DOI- https://doi.org/10.1109/ACCESS.2018.2889099.

[13] Frede Blaabjerg, Huai Wang, Ionut Vernica, Bochen Liu, Pooya Davari, "Reliability of Power Electronic Systems for EV/HEV Applications", Published in: Proceedings of the IEEE (Volume: 109, Issue: 6, June 2021), ISSN: 0018-9219, DOI- https://doi.org/10.1109/JPROC.2020.3031041.

[14] Madhwi Kumari, P. R. Thakura, D. N. Badodkar , "Role of high power semiconductor devices in hybrid electric vehicles", Published in: India International Conference on Power Electronics 2010 (IICPE2010), Electronic ISBN:978-1-4244-7882-8, DOI- https://doi.org/10.1109/IICPE.2011.5728111.

[15] Zhongting Tang; Yongheng Yang; Frede Blaabjerg , "Power electronics: The enabling technology for renewable energy integration", Published in: CSEE Journal of Power and Energy Systems (Volume: 8, Issue: 1, January 2022), ISSN: 2096-0042, DOI- https://doi.org/10.17775/CSEEJPES.2021.02850.

[16] Alireza Khaligh; Michael D'Antonio," Global Trends in High-Power On-Board Chargers for Electric Vehicles", Published in: IEEE Transactions on Vehicular Technology (Volume: 68, Issue: 4, April 2019), ISSN: 0018-9545, DOI- https://doi.org/10.1109/TVT.2019.2897050.

[17] Zheng Wang, Yue Zhang, Shuai You, Huafeng Xiao, Ming Cheng "An Integrated Power Conversion System for Electric Traction and V2G Operation in Electric Vehicles With a Small Film Capacitor", Published in: IEEE Transactions on Power Electronics (Volume: 35, Issue: 5, May 2020), ISSN: 0885-8993, DOI- https://doi.org/10.1109/TPEL.2019.2944276.

[18] Iqbal Husain, Burak Ozpineci, Md Sariful Islam, Emre Gurpinar, Gui-Jia Su, Wensong Yu, Shajjad Chowdhury, Lincoln Xue, Dhrubo Rahman, Raj Sahu, "Electric Drive Technology Trends, Challenges, and Opportunities for Future Electric Vehicles", Published in: Proceedings of the IEEE (Volume: 109, Issue: 6, June 2021), ISSN: 0018-9219, DOI- https://doi.org/10.1109/JPROC.2020.3046112.

[19] L. Calearo, A. Thingvad, K. Suzuki, M. Marinelli, Grid loading due to EV charging profiles based on pseudo-real driving pattern and user behavior, IEEE Trans. Transp. Electrif. 5 (3) (2019) 683–694, http://dx.doi.org/10.1109/TTE.2019.2921854.

[20] L. Held, A. Märtz, D. Krohn, J. Wirth, M. Zimmerlin, M.R. Suriyah, T. Leibfried, P. Jochem, W. Fichtner, The influence of electric vehicle charging on low voltage grids with characteristics typical for Germany, World Electr. Veh. J. 10 (4) (2019).