

# **BATTERY CHARGING TOPOLOGY FOR EV APPLICATIONS**

## **Abstract**

Various battery charging topologies for electric vehicle (EV) applications are presented in this study. With the increasing demand for EVs, the limitations of traditional charging methods are becoming more evident, highlighting the need for innovative solutions that can enhance efficiency, speed, and reliability in recharging EV batteries. Despite facing challenges such as charging time, methods, and range anxiety, advancements in charging technologies are crucial for overcoming these obstacles. Different EV charging topologies, including grid-based charging, solar energy utilization, and vehicle-to-grid power transfer, have been explored. Newer methods like Battery Swap Station (BSS), Wireless Power Transfer (WPT), and Conductive Charging (CC) have also been investigated. This research offers valuable insights for both academic and industrial communities.

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## **I. INTRODUCTION**

In a time when energy and transportation systems are changing quickly, the popularity of electric cars (EVs) is evidence of the pursuit of efficient and sustainable mobility. The infrastructure for charging these cars is essential to the progress of this paradigm, and it is urgent to maximize the efficiency of charging techniques for batteries used in electric vehicles. The need for creative solutions that might open up new possibilities for efficiency, speed, and dependability in recharging EV batteries is highlighted by the growing constraints of traditional charging methods as the demand for EVs rises.

This novel approach, which seeks to revolutionize the landscape of EV battery charging topology, represents a pivotal milestone in addressing the challenges and constraints inherent in existing systems. By blending cutting-edge technologies from various disciplines, including power electronics, energy management, and data analytics, this approach aims to transcend the conventional boundaries of charging methodologies. It heralds a departure from the one-size-fits-all approach that has characterized much of the charging infrastructure, and instead advocates for a dynamic and adaptable system that can supply to the diverse needs of various EV models, battery chemistries, and user preferences.

Throughout the following exploration, we will delve into the intricacies of this novel charging topology enhancement approach, unraveling its underlying principles, benefits, and potential implications. The integration of real-time communication, intelligent control algorithms, and predictive analytics forms the cornerstone of this approach, fostering an ecosystem where EVs and charging stations interact harmoniously to optimize charging sessions. As we embark on this journey, we will witness how this approach not only addresses the technical intricacies of charging but also addresses the broader concerns of grid stability, energy management, and user convenience.

By merging innovation with practicality, this novel approach offers a glimpse into a future where the act of charging an electric vehicle is more than just a mundane task; it becomes a symbiotic relationship between cutting-edge technology and the aspirations for a cleaner, sustainable world. Through this narrative, we will navigate the uncharted waters of this charging paradigm, unveiling its potential to reshape the EV landscape and spark a new era of mobility that is not only electric but also intelligent, efficient, and seamlessly integrated into our lives.

The electric vehicle (EV) charging system serves as a crucial energy support mechanism, supplying the essential energy required for the operation of electric vehicles. This system represents a significant milestone in the journey toward the commercialization and industrialization of EVs. EV charging devices can be broadly categorized based on whether they are integrated into the vehicle or not, distinguishing between onboard chargers and non-onboard portable chargers. Additionally, various charging modes exist, including slow charging, fast charging, power changing, wireless charging, and mobile charging, each necessitating specific types of electric vehicle charging cables. The era of electric vehicles spanned from 1890 to 1924, with a notable peak in production occurring around 1912. Historically, electric vehicles required continuous charging. They can be powered by electricity sourced externally or autonomously through batteries, which may be charged via solar panels or by converting fuel into electricity through fuel cells or generators. The

effectiveness of electric charging is influenced by the location and timing of the charging process. Charging can be facilitated by an electric motor or alternative battery charging methods, rather than relying on an internal combustion engine. Despite the concept of electric vehicles being recognized since the mid-19<sup>th</sup> century, interest has surged in the last decade due to concerns over carbon emissions and the environmental consequences of fuel-powered vehicles. A fundamental advantage of commercializing EVs lies in the establishment of accessible, user-friendly, and cost-effective charging infrastructure. However, uncertainties regarding this infrastructure persist. The historical development of electric vehicles is illustrated in Figure 1. Compared to other transportation modes, electric vehicles represent the most efficient option, indicating that future generations of vehicles will increasingly require electric drivetrains.

## **1. Need of the Study**

The need for the study of this novel approach for enhancing the effects of charging topology for electric vehicle batteries arises from the rapidly evolving landscape of transportation and energy systems. With the surging adoption of EVs as a sustainable alternative to conventional vehicles, the limitations of traditional charging methods have become increasingly evident. As EV numbers grow and charging demands intensify, there is a pressing necessity to design innovative solutions that can optimize the efficiency, speed, and reliability of EV battery charging. Existing charging methodologies often operate with a one-size-fits-all approach, neglecting the diverse array of EV models, battery chemistries, and user preferences that have emerged in the market. Furthermore, the integration of EVs into the broader energy grid requires careful consideration to ensure grid stability and effective energy management. This study seeks to address these challenges by exploring a novel approach that leverages advancements in power electronics, energy management, data analytics, and intelligent control algorithms to create a dynamic and adaptable charging ecosystem. By catering to the unique requirements of various EV and battery types while also considering the broader energy infrastructure, this study aims to begin in a new era of efficient, intelligent, and user-centric EV charging that aligns with the sustainable goals of modern society.

## **2. Charging Topology**

A "charging topology" may mean many different things in the domains of power electronics and electrical engineering; describes the many topologies, circuit layouts, and control mechanisms used in charging systems. Electric cars (EVs), consumer electronics, and renewable energy systems are just a few examples of these uses. All aspects of the charging system's operation, including its usability, efficiency, performance, and safety, are determined in large part by the charging topology. The study's overarching goal is to learn more about charging topology and all the many ways it might be used in different domains, from its fundamental components to design considerations.

The simplest definition of "charging topology" is the arrangement of power sources, converters, transformers, and control circuits that make up a charging system. The goal of this setup is to streamline the process of transferring power from an electrical generator to an electronic device or battery. The application's requirements, the power supplies and load's properties, and the required charging parameters including current, voltage, and rate—are

among the many factors that go into choosing a charging topology. Charge topologies that are often used in electronic devices include buck converters, boost converters, resonant converters, and linear charging.

The linear charging design, for instance, is easy to implement and inexpensive, but it has limited power handling and efficiency characteristics. Therefore, it works well in low-power contexts where high efficiency is not critical. However, buck converters are often used in charging systems because of their ability to regulate voltage and great efficiency. This makes them ideal for uses like portable electronics and phone chargers where precise voltage control and power economy are paramount. The charging system is a typical use for buck converters. Boost converters find widespread usage in energy storage charging systems due to the fact that they are essential for step-up voltage conversion to satisfy the load's voltage requirements. Solar photovoltaic (PV) systems and chargers for electric vehicles are a few examples of such uses.

Charging time, battery chemistry, and safety considerations are all aspects of the load that influence the planned charging profile and, by extension, the charging topology chosen. Electric car chargers and fast-charging stations, for instance, employ fast-charging topologies like high-frequency resonant converters and multi-level converters to shorten the charging time, maximize the usable time of vehicles, and ensure the safety and reliability of the charging process. Similarly, inductive and resonant wireless charging are examples of wireless charging topologies that allow users to charge their electronic gadgets conveniently and on the go without tethering them to a fixed outlet. Their portability and user-friendliness make them ideal for situations when these qualities are paramount.

Furthermore, in smart grid settings, charging topology is crucial for grid interconnection and charging infrastructure management. Coordination and interconnection of electric car chargers, renewable energy systems, and energy storage devices allows for these settings to achieve optimal efficiency, grid stability, and cost-effectiveness. Bidirectional chargers and vehicle-to-grid (V2G) systems are examples of smart charging topologies that enable electric cars to do double duty: receive electricity from the grid and supply it back during peak demand or bountiful renewable energy periods. As a result, EVs may boost the electrical grid's sustainability and resilience by providing grid services.

Charging topology also makes use of sophisticated control mechanisms including frequency modulation, pulse-width modulation, and phase-shift modulation. Using these control algorithms, charging systems may improve their performance under different load situations by regulating the output voltage and current. Ensuring effective and steady operation, these control mechanisms allow charging systems to adapt to changes in load demand, input voltage fluctuations, and other external circumstances. Furthermore, electric car chargers include state-of-charge estimation and maximum power point tracking algorithms, respectively, to enhance battery management and energy harvesting in renewable energy systems. The battery's life and energy efficiency are both improved by this.

The phrase "charging topology" encompasses a broad range of control mechanisms, circuit configurations, and layouts used in charging systems. Electric vehicles, smart grids, renewable energy systems, and consumer gadgets all fall under this category of uses. By tailoring the charging topology and control approach to each application's specific

requirements, engineers and designers may optimize charging systems' efficiency, performance, and dependability. They can guarantee end-user compatibility, safety, and usability in this way. As we work towards a greener, more electrified world, charging topology will remain a crucial component in developing future electrical charging systems. This is due to the fact that both technology and its uses will progress in the future.

## **II. IMPACT ON CHARGING TOPOLOGY**

The impact of charging topology is changing the face of power electronics, electrical engineering, and renewable energy systems, among many other technological domains. The topology of charging systems, which is determined by the placement of components and control techniques, greatly influences the performance, dependability, and usefulness of several applications. Electric vehicles (EVs), smart grid infrastructure, renewable energy systems, and consumer gadgets are just a few examples of these uses. Energy efficiency, grid integration, technological innovation, and environmental sustainability are some of the many areas that this discussion aims to cover as it delves into the many ramifications of charging topology.

The impact of charging topology on power conversion efficiency and energy efficiency is a major consequence of charging systems. Switching frequency, component losses, and management systems are a few of the factors that impact the efficiency of different charging topologies. One example is the buck converter, which is famous for its ability to adjust voltage and run very efficiently. Therefore, they work well with renewable energy systems and battery charging, two areas where energy efficiency is paramount. In contrast, boost converters worked well for step-up voltage conversion, although their lower efficiency might be due to the higher voltages at which they operate. Thoroughly designing and optimizing boost converters is essential for achieving optimal efficiency.

In addition, the charging topology impacts grid interconnection and smart grid management. To achieve the best possible energy efficiency, grid stability, and cost-effectiveness, these settings link and manage energy storage devices, renewable energy systems, and electric car chargers in a coordinated manner. Bidirectional chargers and vehicle-to-grid (V2G) systems are examples of smart charging topologies that enable electric cars to do double duty: receive electricity from the grid and supply it back during peak demand or bountiful renewable energy periods. The capacity for EVs to provide grid services enhances the electrical grid's overall sustainability and resilience.

In addition, technological innovation and advancement are impacted by charging topology. This is what motivates researchers to come up with new control methods, power semiconductor devices, and circuit topologies to meet the demands of modern applications. Modern power semiconductors made of gallium nitride (GaN) or silicon carbide (SiC) have better operating temperatures, lower losses, and faster switching frequencies than their silicon-based predecessors. Because of this, we can create charging systems that are smaller, more efficient, and more dependable. In addition, state-of-charge prediction and maximum power point tracking are two examples of current control algorithms that allow electric car chargers and renewable energy systems to maximize energy harvesting and battery management. This allows for the optimization of energy efficiency and the extension of battery life.

This shift to a low-carbon economy and environmental sustainability are two additional areas where charging topology has an effect. Reason being, charging infrastructure plays a crucial role in facilitating renewable energy production, electric vehicle integration, and carbon emission reduction. The architecture of charging promotes the use of clean, renewable energy sources like as solar, wind, and hydroelectric power while simultaneously reducing emissions of greenhouse gases and air pollution. Renewable energy storage systems, electric vehicle charging infrastructure, and grid-connected energy storage devices all benefit from this improvement in charging efficiency and reliability.

Another area where pricing topology clearly has an impact is on shaping customer behavior, preferences, and the uptake of new services and technology. The availability of convenient charging methods has likely contributed to the rising demand for electric vehicles and other items powered by electricity. Wireless charging pads, rapid chargers, and intelligent charging stations are all part of the solution set. All things considered, these solutions enhance usability, accessibility, and ease. In addition, charging interfaces, protocols, and communication standards that are interoperable and standardized make charging platforms and devices compatible and easy to use, which boost consumer trust in charging infrastructure and services.

Energy efficiency, grid integration, technological innovation, environmental sustainability, and consumer behavior are just a few areas that charging topology impacts beyond the typical industry boundaries. As we move towards a greener, electric future, the charging topology is crucial. Improving the effectiveness, reliability, and practicality of charging systems allows this to be achieved. A more robust and environmentally friendly energy future for decades to come is possible since charging topology is already having an impact on technology innovation and the uptake of renewable energy sources. This is inevitable given the exponential growth of both technology and the number of useful uses for it.

### **III. TYPES OF CHARGING TOPOLOGY**

For the purpose of efficiently and reliably transferring electrical energy from an electrical source to a load, such a battery or electronic device, charging topology encompasses a vast array of designs and circuit configurations. The design, functioning, and optimal uses of these charging topologies are distinct from one another. Electric vehicles (EVs), smart grid infrastructure, renewable energy systems, and consumer electronics are all examples of such applications. If lawmakers, designers, and engineers are serious about making charging systems more efficient, dependable, and performance-oriented, they need to study up on the various charging architectures. This paper aims to explore the various charging topologies, their main characteristics, benefits, and many sectors where they have been used.

- 1. Linear Charging Topology:** One of the simplest and most straightforward charging topologies is the linear charging topology, which involves connecting a power source directly to a load via a linear regulator or resistor. By adjusting the resistance or controlling the current flow with the linear regulator, the voltage across the load may be regulated in linear charging. Because of this, the voltage may be changed. Despite its low cost and ease of installation, linear charging architecture is inefficient and can only handle

a certain amount of electricity. Hence, it should only be used for low-power applications where efficiency is not a top priority.

2. **Buck Converters:** Because of their high efficiency and voltage regulation capabilities, buck converters—also called step-down converters—find widespread use in charging systems. By modifying the duty cycle of a switching transistor, a buck converter may reduce the input voltage to an output voltage level that is lower. Because of this, the voltage at the output is reduced. Energy efficiency and precise voltage control are two of the most common uses for buck converters. Systems that charge batteries, chargers for mobile phones that use less energy, and other portable electronic devices are all examples of these uses.
3. **Boost Converters:** Boost converters, often called step-up converters, are used to increase the output voltage level from a lower input voltage level. A boost converter's enhanced output voltage is achieved by storing energy in an inductor while the switching transistor is active and releasing it to the load when it is off. Because of this, the voltage output from the converter is increased. A boost converter is a common component in energy storage systems, LED drivers, and photovoltaic (PV) inverters, among other applications that need a step-up voltage conversion. These uses are well-suited to boost converters.
4. **Buck-Boost Converters:** When the input voltage is subject to fluctuations or bidirectional power flow is required, buck-boost converters provide a versatile option for charging systems. Its versatility stems from its ability to convert voltage in two ways: step-down and step-up. The buck-boost converter's output voltage may be higher or lower than the input voltage, depending on the switching transistor's duty cycle. The features of the switching transistor dictate this. Power supplies, voltage regulators, and battery charging systems are just a few of the many common uses for buck-boost converters.
5. **Resonant Converters:** To accomplish effective power conversion, resonant converters make use of resonant circuits. This helps to reduce switching losses and electromagnetic interference (EMI), also known as electromagnetic interference. Because these converters work at high frequencies and have soft-switching features, they are able to achieve higher levels of efficiency while simultaneously maintaining lower levels of component stress. Whenever great efficiency and dependability are of the utmost importance, resonant converters are often used in high-power applications. Some examples of these applications are electric vehicle chargers, inverters for renewable energy, and industrial power supply.
6. **Inductive Charging:** Through the process of wirelessly transmitting electrical energy between a charging pad or transmitter and a receiver coil that is incorporated in the device or load, inductive charging, which is also known as wireless charging, removes the need for physical connections or cords. A few millimeters to a few centimeters is the normal distance that inductive charging topologies cover in order to transmit energy. These topologies make use of electromagnetic induction to do this. Consumer gadgets, electric toothbrushes, and medical equipment are all examples of common applications for inductive charging, which provides a number of benefits, including convenience, safety, and efficiency.
7. **Bidirectional Charging:** Because bidirectional charging topologies allow for the passage of electrical energy in both ways between a power source and a load, they make it possible for power flow and energy exchange to occur in both directions throughout the process. These charging systems are often used in applications that need energy storage, grid integration, and vehicle-to-grid (V2G) capabilities. Some examples of these applications are electric car chargers, renewable energy systems, and energy storage

devices that are linked to the grid using grid connectivity. During times of high demand or when renewable energy sources are plentiful, electric vehicles are able to provide grid services and enhance grid stability by using bidirectional charging, which allows them to not only consume energy from the grid but also supply energy back into the system.

There are many distinct kinds of charging topologies, each of which has its own set of benefits and drawbacks in terms of efficiency, complexity, and the degree to which it is suitable for a particular application. Engineers and designers are able to pick the most suitable configuration for their individual needs by gaining a knowledge of the features and capabilities of each charging topology. This allows them to optimize charging systems for performance, reliability, and cost-effectiveness across a variety of domains. The development of creative charging topologies will play a critical role in facilitating the shift towards a future that is more sustainable, electric, and networked. This is because technology will continue to progress and new applications will arise.

#### **IV. POWER ELECTRONICS CONVERTOR FOR ELECTRIC VEHICLE**

Power Electronic Converters (PECs) play a crucial role in electric vehicle (EV) applications by facilitating the connection between various types of EVs and energy storage systems, as well as charging stations, particularly those utilizing renewable energy sources (RES) as inputs. Consequently, numerous review articles delve into the classifications, configurations, control strategies, applications, specification comparisons, and the influence of PECs on the power quality of utility grids. In addition to exploring significant aspects related to different PEC topologies in EV applications, many researchers also examine emerging trends, evaluations, and future research directions. Accordingly, Table IV presents a summary of recent review articles concerning PEC technologies for EV applications, where A denotes configuration, B indicates control strategies, C refers to power quality, D signifies challenges, E represents optimization methods, F stands for applications, and G pertains to comparative analysis.

To offer a comprehensive overview of the authors' interests in this domain, it is noted that the most commonly employed PEC topology for EV applications consists of various configurations based on DC-DC converters, which are utilized for charging batteries, energy storage systems, and EV charging stations. PEC topologies can be categorized into several technical types, including DC-DC converters, AC-DC converters, DC-AC converters, and AC-AC converters, which are applicable for both high-voltage and low-voltage scenarios. To highlight the essential specifications of different PEC configurations, several comparative analyses are presented among the topologies and their contributions to enhancing power quality. Additionally, a comparison of various switching devices utilized in PECs, incorporating different material composites such as silicon (Si), silicon carbide (SiC), or gallium nitride (GaN), is discussed. This comparison evaluates material properties, weight, volume, and peak efficiency, emphasizing their significant applications in EVs. The studies illustrate the advantages of SiC and GaN-based switching devices in achieving reduced switching losses, enhanced thermal performance, and improved configuration stability, rendering them particularly suitable for these applications.



## **V. POWER ELECTRONICS CONVERTOR TOPOLOGIES FOR V2G APPLICATIONS**

In the context of electric vehicle (EV) applications, vehicle-to-grid (V2G) technology plays a crucial role in facilitating energy exchange between EV batteries and the utility grid or renewable energy sources (RESs). Numerous power electronic converter (PEC) topologies have been explored in various review studies, which can be effectively utilized for V2G technology. In systems that incorporate V2G technology for EV charging, bidirectional converters are typically employed to manage power flow and enhance power factor correction. These converters are designed to minimize total harmonic distortion (THD) and address issues related to power quality. They can be configured with different conversion stages and voltage levels. Prior discussions have identified various types of bidirectional PECs, which are classified into bidirectional AC-DC converters and bidirectional DC-DC converters.

In the realm of bidirectional AC-DC converters for V2G applications, the full bridge topology is frequently adopted due to its straightforward control and structural advantages. Another notable configuration is the eight-switch topology, which employs a non-isolated half-bridge converter supported by optimization algorithms. To enable power exchange among multiple sources with differing voltage levels and pulse widths, the three-level topology is implemented. Furthermore, the single-stage topology is utilized across various system configurations. The matrix converter-based topology is recognized for its compactness, cost-effectiveness, and reliable performance.

With respect to bidirectional DC-DC converters, isolated topologies are commonly favored for their capacity to manage a broad voltage range, exemplified by the dual active bridge (DAB) topology. Non-isolated topologies are also in use, providing advantages such as soft-switching capabilities, ease of control, and a limited voltage range. Examples of these include buck-boost converters with varying switch configurations and multi-phase interleaved converters. Recently, resonant and multi-port DC-DC converters have gained attention as promising solutions for applications requiring wide voltage ranges, offering advantages such as low electromagnetic interference (EMI), high efficiency, frequent operation, and compact design.

## **VI. PERSPECTIVES FOR PROMINENT CHALLENGES AND CURRENT STATUS**

Numerous review studies have explored the key challenges and prospective research directions for Photovoltaic Energy Converters (PECs) employed in Electric Vehicle (EV) applications. To illustrate the research trends associated with published works on PECs in the context of EV applications, Figure 8 presents the number of publications in this domain from 2010 to 2023. The data indicates a general increase in publications over this period, with the exception of 2020, which experienced a slight decline attributed to the COVID-19 pandemic. A total of 2,785 published research articles were sourced from the Scopus database using the keyword "PECs of EVs." Additionally, Figure 9 outlines the significant challenges and future research prospects related to PEC-based EV applications. This section summarizes the main challenges, focusing on the existing issues concerning PEC configurations and their impact

on the performance of vehicular and power systems. The challenges associated with PECs in EV applications can be articulated as follows.

## **VII. CHALLENGES**

### **PEC Configuration**

- Number of switching components
- Complex control scheme
- High Switching Frequencies
- Compact Size
- Maximum power density
- Overall efficiency
- Switching losses

### **Future Research Opportunities**

- Cost effective topologies with compact size
- Artificial Intelligence applications for energy management
- Wide band gap material compositions
- EV trading & auxiliary services
- Efficient EV Charging System
- Power quality improvement
- PEC,s Configuration design
- Robust control scheme
- WLC technologies

## **VIII. CONCLUSION**

There exist multiple approaches for charging electric vehicle batteries, encompassing both traditional and innovative methods. Traditional techniques often face challenges related to time, efficiency, and cost. However, advanced methods have emerged that effectively address these shortcomings. Recent advancements in electric vehicle charging technology present substantial advantages for the environment, the economy, and the future of transportation. Innovations such as wireless charging, ultra-fast charging, bidirectional charging, solar-powered charging stations, and smart charging systems are enhancing the accessibility, convenience, and sustainability of electric vehicles. These technologies have the potential to significantly lower carbon emissions, generate new employment opportunities, and diminish dependence on foreign oil imports. Moreover, they could transform our understanding of energy storage and the power grid, allowing electric vehicles to function as energy storage units that can supply power back to the grid during peak demand periods. Although challenges remain, including the cost and availability of charging infrastructure, the outlook for this technology is promising as it continues to advance. With ongoing investment in research and development, the future of electric vehicles appears to be very promising across all dimensions. The topology of battery charging is crucial in electric vehicle applications, with various methods available to enhance their effectiveness.

Numerous strategies exist for charging electric vehicle batteries, which include both traditional and cutting-edge methods. Conventional techniques often encounter issues related to time, efficiency, and cost. In contrast, advanced techniques have been developed to effectively mitigate these challenges. The latest innovations in electric vehicle charging technology provide considerable advantages for environmental sustainability, economic growth, and the evolution of transportation. Technologies such as wireless charging, ultra-fast charging, bidirectional charging, solar-powered charging stations, and smart charging systems are making electric vehicles increasingly accessible, convenient, and sustainable. These advancements can lead to a significant reduction in carbon emissions, the creation of new job opportunities, and a decrease in reliance on imported oil. Furthermore, they hold the potential to transform our approach to energy storage and the power grid, enabling electric vehicles to serve as energy storage units that can return power to the grid during peak demand times. While challenges such as the cost and availability of charging infrastructure persist, the future of this technology remains optimistic as it continues to evolve. With sustained investment in research and development, the prospects for electric vehicles are bright in all respects. The configuration of battery charging is vital for electric vehicle applications, with various charging topologies available to improve their efficiency.

## REFERENCES

- [1] Hussain, Shahid&Irshad, Reyazur & Pallonetto, Fabiano& Jan, Qasim& Shukla, Saurabh& Thakur, Subhasis & Breslin, John. (2023). Enhancing the Efficiency of Electric Vehicles Charging Stations Based on Novel Fuzzy Integer Linear Programming. *IEEE Transactions on Intelligent Transportation Systems*. 10.1109/TITS.2023.3274608.
- [2] Dow, L. & Marshall, M. & Xu, Le & Romero Agüero, Julio & Willis, H.L.. (2010). A novel approach for evaluating the impact of electric vehicles on the power distribution system. *IEEE Power and Energy Society General Meeting*. 1 - 6. 10.1109/PES.2010.5589507.
- [3] Srivastava, Manaswi& Verma, Arun&Tomar, Pavan. (2019). Design and implementation of a novel auxiliary network based ZVS DC/DC converter topology with MPWM: an application to electric vehicle battery charging. *IET Power Electronics*. 12. 10.1049/iet-pel.2019.0258.
- [4] Wang, Hengsong& Huang, Qi & Zhang, Changhua& Xia, Aihua. (2010). A novel approach for the layout of electric vehicle charging station. 10.1109/ICACIA.2010.5709852.
- [5] Katta, Pradeep & A, Mohammed &Kandasamy, Prabaakaran& M, Priya& K, Keerthana& J, Preethi. (2020). A Novel Design of Electric Vehicle Battery Charger using Modified Bridgeless Landsman Converter. *Innovations in Information and Communication Technology Series*. 20-23. 10.46532/978-81-950008-1-4\_005.
- [6] Khalid, Mohd& Ahmad, Furkan& Panigrahi, Bijaya& al-Fagih, Luluwah. (2022). A comprehensive review on advanced charging topologies and methodologies for electric vehicle battery. *The Journal of Energy Storage*. 53. 105084. 10.1016/j.est.2022.105084.
- [7] Wang, Liangrong& Liang, Jianing&Xu, Guoqing&Xu, Kun & Song, Zhibin. (2012). A novel battery charger for plug-in hybrid electric vehicles. 168-173. 10.1109/ICInfA.2012.6246802.
- [8] Jhunjhunwala, Ashok & Kaur, Prabhjot&Mutagekar, Sushant. (2018). Electric Vehicles in India: A Novel Approach to Scale Electrification. *IEEE Electrification Magazine*. 6. 40-47. 10.1109/MELE.2018.2871278.
- [9] Bayati, Mahdi &Abedi, Mehrdad &Hosseinian, Seyed Hossein & B. Gharehpetian, Gevork. (2017). A Novel Control Strategy for Reflex-Based Electric Vehicle Charging Station with Grid Support Functionality. *The Journal of Energy Storage*. 12. 108-120. 10.1016/j.est.2017.03.013.
- [10] Liu, Zhiyong& Wang, Zengping. (2014). A Study on the Model of Electric Vehicle Charger and Battery. 10.1007/978-1-4614-4981-2\_100.
- [11] Garg, Akhil&Ruhatiya, Chaitanya& Cui, Xujian&Peng, Xiongbin&Bhalerao, Yogesh&Gao, Liang. (2019). A Novel Approach for Enhancing Thermal Performance of Battery Modules Based on Finite Element Modeling and Predictive Modeling Mechanism. *Journal of Electrochemical Energy Conversion and Storage*. 17. 1-23. 10.1115/1.4045194.

- [12] Chen, Xiaopeng&Shen, Weixiang& Cao, Zhenwei& Kapoor, Ajay. (2014). A novel approach for state of charge estimation based on adaptive switching gain sliding mode observer in electric vehicles. *Journal of Power Sources*. 246. 667-678. 10.1016/j.jpowsour.2013.08.039.
- [13] Channegowda, Janamejaya&Pathipati, Vamsi Krishna & Williamson, Sheldon. (2015). Comprehensive review and comparison of DC fast charging converter topologies: Improving electric vehicle plug-to-wheels efficiency. 2015. 263-268. 10.1109/ISIE.2015.7281479.
- [14] Jia, Xiaoyu& Wang, Huaibao& Wang, Baocheng&Guo, Xiao-Qiang& Wang, Xiaoyu. (2017). A novel boost four-leg converter for electric vehicle applications. *Chinese Journal of Electrical Engineering*. 3. 79-83. 10.23919/cjee.2017.7961325.
- [15] Arif, S.M.; Lie, T.T.; Seet, B.C.; Ayyadi, S.; Jensen, K. Review of Electric Vehicle Technologies, Charging Methods, Standards and Optimization Techniques. *Electronics* 2021, 10,
- [16] Sanguesa, J.A.; Torres-Sanz, V.; Garrido, P.; Martinez, F.J.; Marquez-Barja, J.M. A Review on Electric Vehicles: Technologies and Challenges. *Smart Cities* 2021, 4, 372–404. [Google Scholar] [CrossRef]
- [17] Chowdhury, S.R. A Three-Phase Overlapping Winding Based Wireless Charging System for Transportation Applications; University of Akron: Akron, OH, USA, 2021. [Google Scholar]
- [18] Martínez-Lao, J.; Montoya, F.G.; Montoya, M.G.; Manzano-Agugliaro, F. Electric vehicles in Spain: An overview of charging systems. *Renew. Sustain. Energy Rev.* 2017, 77, 970–983. [Google Scholar] [CrossRef]
- [19] García-Triviño, Pablo, et al. "Control of electric vehicles fast charging station supplied by PV/energy storage system/grid." 2016 IEEE International Energy Conference (ENERGYCON). IEEE, 2016.
- [20] K. Parmesha, Rashmi Prafullakumar Neriya and M. Varun Kumar "Wireless Charging System for Electric Vehicles" Parmesh et al. 2016. *Int. J. Vehicle Structures & Systems*, 8(5), 285-288 *International Journal of Vehicle Structures & Systems* ISSN: 0975-3060 (Print), 0975-3540 (Online).
- [21] Otchere Peter Kweku "Wireless Mobile Charger using Inductive Coupling" *International Journal of Engineering and Advanced Technology (IJEAT)* ISSN: 2249 – 8958, Volume-7 Issue-1, October 2017. [4] <http://standards.sae.org/wip/j2847/2/>
- [22] F. Ahmad *et al.* An enhanced approach to optimally place the solar powered electric vehicle charging station in distribution network *J. Energy Storage* (2021)
- [23] N. Wang *et al.* A two-stage charging facilities planning method for electric vehicle sharing systems *IEEE Trans. Ind. Appl.* (2021)
- [24] Ahmad, A.; Khan, Z.A.; Alam, M.S.; Khateeb, S. A Review of the Electric Vehicle Charging Techniques, Standards, Progression and Evolution of EV Technologies in Germany. *Smart Sci.* 2017, 6, 36–53. [Google Scholar] [CrossRef]
- [25] Martínez-Lao, J.; Montoya, F.G.; Montoya, M.G.; Manzano-Agugliaro, F. Electric vehicles in Spain: An overview of charging systems. *Renew. Sustain. Energy Rev.* 2017, 77, 970–983.
- [26] K. Parmesha, Rashmi Prafullakumar Neriya and M. Varun Kumar "Wireless Charging System for Electric Vehicles" Parmesh et al. 2016. *Int. J. Vehicle Structures & Systems*, 8(5), 285-288 *International Journal of Vehicle Structures & Systems* ISSN: 0975-3060 (Print), 0975-3540 (Online).