And., Intl.,J., Appl Sci., Eng., Tech, Vol 05, No 01, March 2025
e-ISSN: 2797-0442

Comprehensive Review of Advanced Multi-Pulse Rectifier Technology and Its Application in Electric Vehicle Fast Charging Systems

Partaonan Harahap[1,2], Muhammad Imran Hamid[2*], Ariadi Hazmi[2]
[1]Department of Environmental Engineering, Faculty of Engineering, Muhammadiyah University of North Sumatra, Indonesia,
[2]Department of Electrical Engineering, Faculty of Engineering, Universitas Andalas, Padang, Indonesia,
[*]Corresponding author, e-mail: imran@eng.unand.ac.id

Abstract- Fast charging technology for electric vehicles (EVs) is one of the key components in supporting the transition to a sustainable transportation system. This article discusses advanced multi-pulse rectifier technology, such as 12-pulse, 24-pulse, and 48-pulse configurations, which are used to improve power efficiency and reduce harmonic distortion. The analysis includes the working principles, benefits compared to conventional rectifier technology, and the challenges of its implementation. The review results show that multi-pulse rectifiers significantly reduce Total Harmonic Distortion (THD), improve power quality, and facilitate integration with renewable energy sources. This article also suggests future research directions to address the limitations of current technology and to encourage further innovations in efficient and environmentally friendly EV charging.

Keywords: Multi-Pulse Rectifier, Electric Vehicle Fast Charging, Harmonic Distortion, Energy Efficiency, Renewable Energy

This article *is licensed under the CC–BY-SA license.*

1. Introduction

The increasing adoption of electric vehicles (EVs) has significantly accelerated the development of fast charging infrastructure. A critical element in these systems is rectifier technology, which converts alternating current (AC) from the power grid into direct current (DC) required for battery charging. Among the various rectifier configurations, multi-pulse rectifiers stand out as an advanced solution that improves efficiency while minimizing harmonic distortion. Utilizing multiple phases and optimized transformer arrangements, this technology ensures high-quality DC output with reduced interference in the electrical network [1][2]. The integration of fast charging stations into existing distribution networks presents challenges, particularly related to harmonic distortion, which can degrade equipment performance and elevate operational costs. Multi-pulse rectifiers not only enhance energy conversion efficiency but also improve overall power quality. By mitigating total harmonic distortion (THD), these systems contribute to grid stability-an essential factor as charging stations continue to expand [3][4]. Additionally, with the growing emphasis on sustainable transportation, integrating renewable energy sources, such as solar power, into EV charging infrastructure has become a research priority.[5]. Multi-pulse rectifier technology facilitates this integration by ensuring seamless energy conversion, thereby supporting a cleaner and more resilient energy ecosystem [6]-[7].

Received: December 16, 2024, Revised: March 10, 2025, Accepted: March 17, 2025
https://doi.org/10.25077/aijaset.v5i1.206

This research explores the recent advancements in multi-pulse rectifier technology, focusing on its topology, harmonic mitigation techniques, and comparative advantages over conventional rectifiers. It also analyzes the impact of various designs on fast EV charging applications, including energy efficiency and grid compatibility. Furthermore, the study examines the key challenges associated with real-world implementation and presents potential solutions to enhance system reliability[8][9]. By providing insights into emerging trends and future research directions, this review aims to contribute to the development of efficient and environmentally sustainable EV charging infrastructure. A comprehensive understanding of multi-pulse rectifiers will equip researchers and industry professionals with the necessary knowledge to optimize power conversion systems and meet the increasing demand for high-performance charging stations [10][11].

2. Method

The methodology for conducting a comprehensive review of advanced multi-pulse rectifier technology and its application in electric vehicle (EV) fast charging systems involves several systematic steps. This approach ensures that the review is thorough, well-structured, and provides valuable insights into the current status of research and development in this field.

2.1 Literature Search

By conducting a systematic literature search using academic databases such as IEEE Xplore, ScienceDirect, SpringerLink, and Google Scholar, using specific keywords related to multi-pulse rectifiers, electric vehicle fast charging systems, power electronics, harmonic mitigation, and renewable energy integration, establish inclusion criteria to select relevant papers published in peer-reviewed journals or conference proceedings in the last decade to ensure up-to-date information[12][13]. From the collection of articles presented, including selected articles that focus on various aspects of multi-pulse rectifier technology, including design configurations (e.g., 12-pulse, 24-pulse, 36-pulse), operational principles, efficiency metrics, and applications in EV charging, as well as performance metrics such as Total Harmonic Distortion (THD), power factor improvement, efficiency levels under different load conditions, and thermal management strategies[14][15].

Table 1. A collection of selected articles focusing on various aspects of EV technology

No	Article Title	Discussion
1	A Novel 48 Pulse Thyristor Rectifer Topology For Fastcharging Stations Of Ev's[16]	Design and configuration of a 48-pulse thyristor rectifier specifically designed for electric vehicle (EV) fast charging stations. The main focus of this article is the operational principles of the new topology, the resulting energy efficiency, as well as practical applications in EV charging infrastructure.
2	Harmonic Mitigation using 36-Pulse AC-DC Converter for Direct Torque Controlled Induction Motor Drives[17]	Explores the use of 36-pulse AC-DC converters to reduce harmonics in induction motor drive systems that control direct torque. This article also explains how multi-pulse configurations can improve power quality and overall system efficiency.

No	Article Title	Discussion
3	12-pulse Rectifier with DC-Side Buck Converter for Electric Vehicle Fast Charging[18]	Presents an in-depth analysis of 12-pulse rectifiers combined with buck converters on the DC side for electric vehicle fast charging applications. The authors discuss the operational principles, the advantages of this design in terms of efficiency and harmonic reduction, and the challenges that may be encountered in its implementation
4	Multi Pulse Rectifier Using Different Phase Shifting Transformers And Its Thd Comparison For Power Quality Issues[19][20]	The use of multi-pulse rectifiers with various transformer transmission phases and total harmonic distortion (THD) comparison for power quality issues. This provides insights into how transformer design can affect the performance of multi-pulse rectifiers in the context of EV charging applications.
5	A Comprehensive Review of Improving the Efficiency of Wireless Charging Systems for Electric Vehicle Applications[21]	in the wireless charging system, it also includes aspects of multi-pulse rectifier technology as part of the EV charging infrastructure. The author analyzes the efficiency metrics and technical challenges associated with integrating this technology into the wireless charging system.
6	Advanced Electric Vehicle Fast-Charging Technologies[22]	Providing an overview of various advanced technologies for fast vehicle charging, including multi-pulse rectifiers. The author discusses the operational principles, advantages of specific designs such as 12-pulse and 24-pulse, as well as their practical applications in modern charging stations.

In the article in Table 1 above, it can be categorized based on themes such as:

- Type of Multi-Pulse Rectifier Configuration
- Harmonic Mitigation Techniques
- Efficiency Improvement Strategies
- Integration with Renewable Energy Sources
- Challenges and Limitations in Implementation

AIJASET – Vol. 05, No. 01, March 2025. 45-54
https://doi.org/10.25077/aijaset.v5i1.206

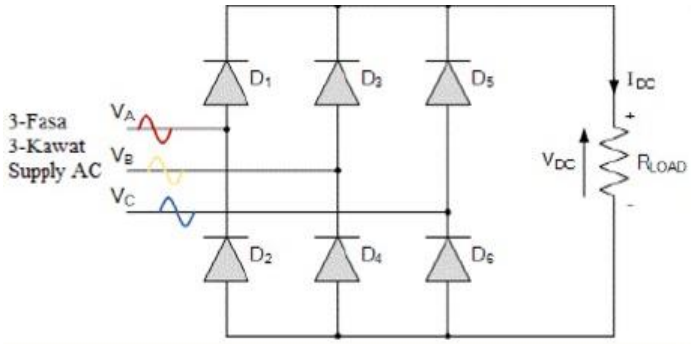


Figure 1. Multi-pulse rectifiers[23]

Multi-pulse rectifiers are used in power electronics to convert alternating current (AC) into direct current (DC) with reduced harmonic distortion. They are commonly employed in high-power applications such as industrial drives and power supplies[13].

a. Basic Components of a Multi-Pulse Rectifier

1. Transformer: The transformer is essential for stepping down or stepping up the voltage levels and providing phase shifts necessary for multi-pulse operation.
2. Rectifying Diodes or Thyristors: These components are responsible for converting AC to DC. In a multi-pulse rectifier, multiple diodes or thyristors are arranged in configurations that allow for multiple phases.
3. Output Filter: This component smooths the output DC voltage by reducing ripple.

b. Common Configurations

1. 6-Pulse Rectifier: This configuration typically uses a three-phase transformer with six diodes arranged in two sets of three, allowing for six pulses per cycle.
2. 12-Pulse Rectifier: This setup involves two transformers with phase shifts (often 30 degrees apart), resulting in twelve pulses per cycle.
3. 18-Pulse Rectifier: Similar to the 12-pulse design but utilizes additional transformers and diodes to achieve even lower harmonic distortion.

2.2 Future Research Directions

- Based on the synthesis of current knowledge and identified gaps, propose future research directions that can further advance multi-pulse rectifier technology.
- Suggest areas where additional experimental studies or theoretical models are needed to enhance understanding or performance.

In the context of fast charging electric vehicles (EVs), the main challenges faced are harmonic distortion and energy efficiency[24][25]. To address this issue, innovative approaches can be applied using several techniques and formulas that have proven effective. Here are the steps and formulas that can be used:

1. Application of Resonant DC-DC Converter
   One way to improve the efficiency of fast charging systems is by using a resonant-based DC-DC converter[26]. This converter can reduce power loss and enhance the overall efficiency of the charging system. The basic formula for calculating the efficiency of a resonant converter is:

$$\eta = \frac{P_{out}}{P_{In}} \text{ x } 100\% \quad (1)$$

2. The Use of Active Filters to Reduce Harmonic Distortion

   Harmonic distortion often becomes a problem in fast charging systems due to the non-linear currents generated by converters. To address this, active filters can be used[27]. The formula to calculate total harmonic distortion (THD) is:

$$THD = \frac{\sqrt{\Sigma_{n=2}^{N} I_n^2}}{I_1} \quad (2)$$

   Where : I_n = the nth harmonic current and
   I_1 = the fundamental current.

3. Optimization of Communication Protocol
   Optimizing communication protocols between electric vehicles and charging stations is also important for improving charging efficiency. Protocols like ISO 15118 enable better two-way communication, facilitating more efficient power management during the charging process.
4. Implementation of Inductive Charging Technology
   Inductive charging is another promising method to increase charging speed while reducing harmonic distortion. In this system, the formula for calculating power transfer through induction is:

$$P = k \cdot \frac{V_1 V_2}{d^2} \quad (3)$$

   Where :
   K = a constant depending on the coil design,
   V_1 and V_2 = the voltage in the primary and secondary coils, and
   d = the distance between the two coils.

5. Integration of Energy Storage Systems
   Integrating energy storage systems such as batteries or supercapacitors in charging stations can help balance the load and reduce power fluctuations, thereby improving overall efficiency. By implementing these approaches, we can create a more efficient fast charging system for electric vehicles while also reducing the negative impact of harmonic distortion[28].

3. Results and Discussion

A comprehensive review of advanced multi-pulse rectifier technology and its application in electric vehicle (EV) fast charging systems reveals several important insights regarding the performance, efficiency[29][30], and challenges associated with this technology. The following section outlines the main findings from the literature, focusing on operational principles, advantages, limitations, and future directions for research in this field. Multi-pulse rectifiers are designed to improve power quality by reducing harmonic distortion in the AC-DC conversion process. This

system typically uses multiple phases and transformers configured in specific arrangements (e.g., 12-pulse, 24-pulse) to achieve significant reductions in Total Harmonic Distortion. (THD)[22][31].

This review highlights that multi-pulse configurations can effectively reduce the harmonics generated during the charging process, which is crucial for maintaining grid stability and compliance with international standards such as IEEE 519[32][33].

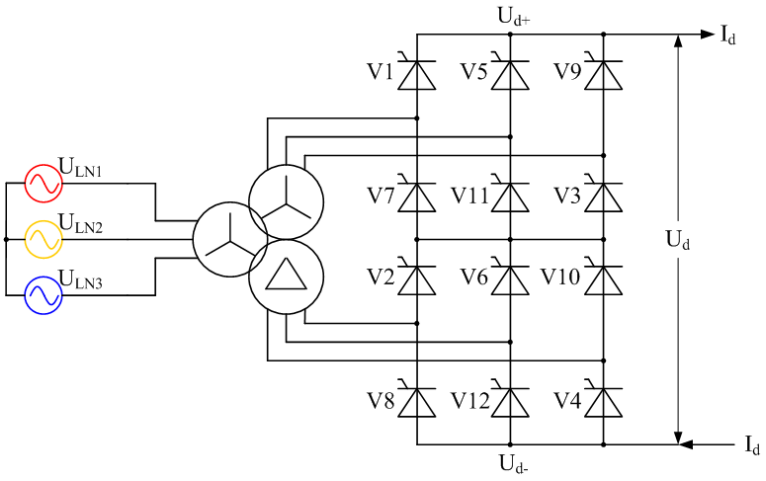


Figure 2. shows a 12-pulse rectifier circuit[34].

The 12-pulse rectifier circuit involves several important steps. This circuit is used to convert alternating current (AC) into direct current (DC) while reducing the harmonics generated during the conversion process[35]. Here are the steps to design a 12-pulse rectifier circuit:

1. Component Selection
   To build a 12-pulse rectifier circuit, you will need the following components:
   - Diodes: A total of 12 diodes are required to form two bridges from three phases.
   - Transformers: Two transformers are needed, one with a delta-wye configuration and the other with a delta-delta or zig-zag configuration.
2. Capacitors: For DC filtering, capacitors can be used after the rectification process. Transformer Configuration
   Transformers play an important role in phase shifting and harmonic reduction. In this circuit:
   - Delta-Wye Transformer: Connected to the first bridge and provides a phase shift of 30 degrees.
   - Delta-Delta or Zig-Zag Transformer: Connected to the second bridge without a phase shift.
3. Connecting the Diodes
   After the transformer is installed, connect the diodes as follows:
   - Each bridge consists of 6 diodes arranged in two sets.
   - Ensure the diode polarity is correct so that the current can flow well from AC to DC.
4. Filtering the DC Current
   After the AC current is converted to DC through the two bridges, use capacitors to filter the generated DC wave. This will help in obtaining a more stable and cleaner DC output[36][37].

The 12-pulse rectifier circuit is very effective in reducing harmonics and improving power quality in industrial electrical systems. By using two bridges and the appropriate transformer, efficient AC to DC conversion can be achieved.

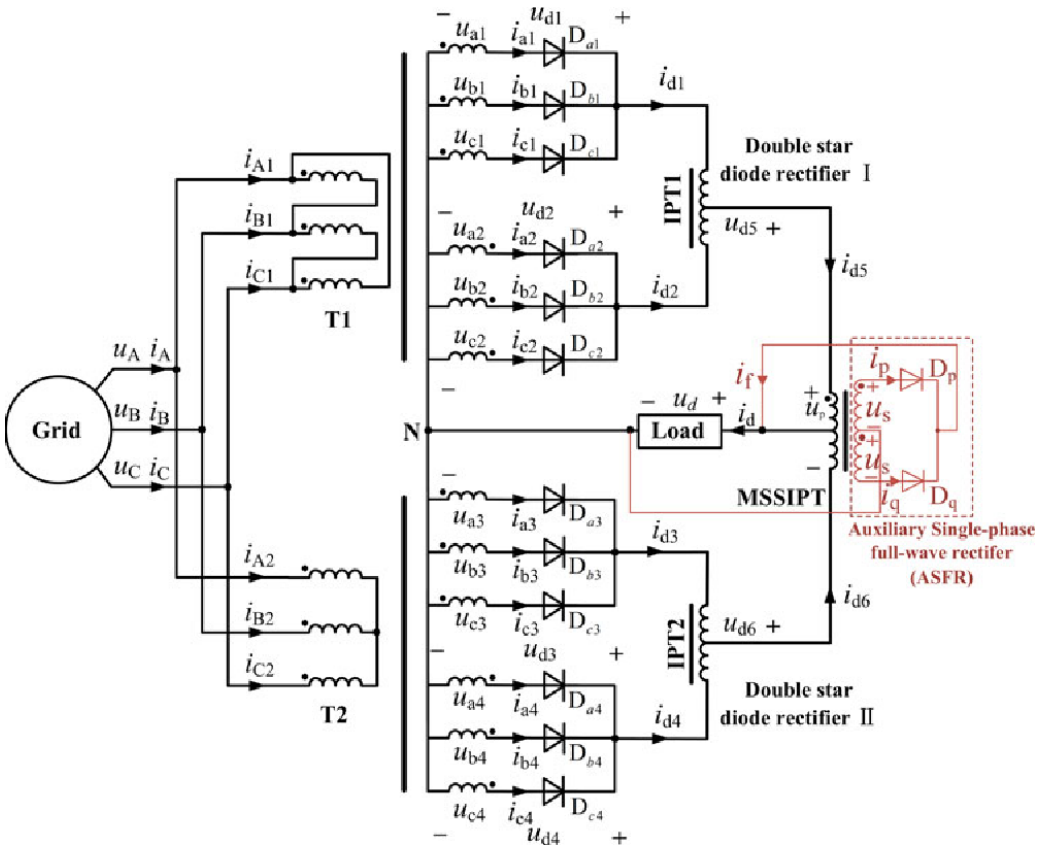


Figure 3. Shows a 24-pulse rectifier circuit[38].

The three-phase circuit converts alternating current (AC) into direct current (DC) by reducing line current harmonics. Here are the steps to design a 24-pulse rectifier circuit[39]:

1. Main Components
   The 24-pulse rectifier circuit consists of:
   - Phase-Shifting Transformer: This is a transformer that provides a 15-degree phase shift between each set of voltages.
   - Diode Rectifiers: Four six-pulse diode bridges are used to convert AC to DC.
   - Interphase Transformers: Two interphase transformers are used to connect the output of the diode bridges.
2. Transformer Configuration
   The phase-shifting transformer will have two delta windings and one star winding. Each delta winding will be connected to the diode bridge, while the star winding will serve as the neutral point.
3. Connecting Diode Rectifiers
   After the transformer is set up, connect four diode bridges to the output of the phase-shifting transformer. Each diode bridge will receive voltage with different phase shifts, resulting in a total of 24 pulses at the DC output.
4. Interphase Transformers
   The output from each diode bridge is then connected to interphase transformers. These interphase transformers help balance the load and ensure that the generated DC current is more stable and free from harmonics.
5. Measurement and Simulation

After all components are installed, it is important to perform measurements and simulations using software such as MATLAB Simscape to verify the circuit's performance. You can monitor the grid voltage, current, and DC-link voltage to ensure that the system operates according to the desired specifications[40].

6. Result Analysis
   The analysis of simulation results is crucial for understanding how the circuit operates under real conditions. Observe the graph that shows the relationship between AC input voltage and DC output, as well as the harmonic analysis to ensure that the system meets power quality standards.

4. Conclusion

Multi-pulse rectifier technology provides an effective solution to address harmonic distortion challenges and improve energy efficiency in electric vehicle (EV) fast charging systems. With configurations such as 12-pulse, 24-pulse, and 48-pulse, this technology can significantly reduce Total Harmonic Distortion (THD), which is an important factor in maintaining the stability of the power grid. In addition, the integration of this technology with renewable energy sources, such as solar panels, enables a more environmentally friendly and sustainable charging system. However, major challenges such as optimal transformer design, thermal management, and operational efficiency still require further attention. Therefore, future research needs to focus on the development of more effective harmonic mitigation techniques, new topological innovations, and the utilization of bidirectional communication technology to enhance system efficiency. With this approach, EV charging technology can make a greater contribution to sustainable transportation in the future.

References

[1] S. Vishwakarma and S. K. Sonkar, “Total Harmonic Reduction by Multi Pulse Converters,” vol. 9, no. 2, pp. 930–935, 2022.

[2] A. Ahmad, Z. Qin, T. Wijekoon, and P. Bauer, “An Overview on Medium Voltage Grid Integration of Ultra-Fast Charging Stations: Current Status and Future Trends,” *IEEE Open J. Ind. Electron. Soc.*, vol. 3, pp. 420–447, 2022, doi: 10.1109/OJIES.2022.3179743.

[3] A. Srilatha, A. Pandian, and P. S. Varma, “Harmonicsreduction Technique of 48 Pulse Converter with Pi Controller for Electric Vehicle Fast Charger,” vol. 5, no. 9, pp. 1292–1300, 2020.

[4] M. S. Mastoi *et al.*, “An in-depth analysis of electric vehicle charging station infrastructure, policy implications, and future trends,” *Energy Reports*, vol. 8, pp. 11504–11529, 2022, doi: 10.1016/j.egyr.2022.09.011.

[5] Belt & Aagaard, “Patent Application Publication (10) Pub . No .: US 2002 / 0124520 A1,” *Us Pat.*, vol. 1, no. 19, pp. 12–16, 2002.

[6] A. Hazmi, M. I. Hamid, R. Fernandez, H. Andre, R. W. Pratama, and M. M. Rahman, “Characteristics of lightning-rainfall in Padang tropical thunderstorm,” *AIP Conf. Proc.*, vol. 2891, no. 1, pp. 12–14, 2024, doi: 10.1063/5.0200950.

[7] H. Tu, H. Feng, S. Srdic, and S. Lukic, “Extreme Fast Charging of Electric Vehicles: A Technology Overview,” *IEEE Trans. Transp. Electrif.*, vol. 5, no. 4, pp. 861–878, 2019, doi: 10.1109/TTE.2019.2958709.

[8] E. S. Solutions, “Harmonic Mitigation for 3-Phase Electric Vehicle DC Fast Chargers EV Battery Charger Types”.

[9] J. Rekha, T. M. T. Thentral, and K. Vijayakumar, “Electric Vehicle Motor, Converter,

Controller and Charging Station with Challenges and Configurations: Review," *Int. J. Renew. Energy Res.*, vol. 12, no. 1, pp. 505–528, 2022, doi: 10.20508/ijrer.v12i1.12703.g8430.

[10] Projo Mukti Rifai dan Sriyanto, "Analysis of Work Accidents Using the Failure Mode and Effect Analysis (FMEA) Method Case Study: Automotive Workshop Semarang," *Ind. Eng. Online J.*, vol. 5, no. 4, pp. 1–7, 2017.

[11] J. Suvvala, S. K. K, C. Dhananjayulu, H. Kotb, and A. Elrashidi, "Integration of renewable energy sources using multiport converters for ultra-fast charging stations for electric vehicles: An overview," *Heliyon*, vol. 10, no. 15, p. e35782, 2024, doi: 10.1016/j.heliyon.2024.e35782.

[12] V. L. Nguyen, T. Tran-Quoc, and S. Bacha, "Harmonic distortion mitigation for electric vehicle fast charging systems," *2013 IEEE Grenoble Conf. PowerTech, POWERTECH 2013*, 2013, doi: 10.1109/PTC.2013.6652435.

[13] A. Das, "Multipulse Transformer".

[14] D. Lan, Y. Wu, T. B. Soeiro, P. Granello, Z. Qin, and P. Bauer, "12-pulse Rectifier with DC-Side Buck Converter for Electric Vehicle Fast Charging," *IECON Proc. (Industrial Electron. Conf.*, vol. 2022-Octob, pp. 1–6, 2022, doi: 10.1109/IECON49645.2022.9968872.

[15] H. Ataullah, T. Iqbal, I. U. Khalil, A. S. Mohammad, N. Ullah, and M. Emad Farrag, "Analysis and Verification of Leakage Inductance Calculation in DAB Converters Based on High-Frequency Toroidal Transformers under Different Design Scenarios," *Energies*, vol. 15, no. 17, 2022, doi: 10.3390/en15176176.

[16] Ezenwobodo and S. Samuel, "International Journal of Research Publication and Reviews," *Int. J. Res. Publ. Rev.*, vol. 04, no. 01, pp. 1806–1812, 2022, doi: 10.55248/gengpi.2023.4149.

[17] R. Abdollahi, "Harmonic mitigation using 36-Pulse AC-DC converter for direct torque controlled induction motor drives," *J. Appl. Res. Technol.*, vol. 13, no. 1, pp. 135–144, 2015, doi: 10.1016/S1665-6423(15)30012-2.

[18] J. Wang, Y. Lv, X. Yao, L. Li, and Q. Chen, "Input Current Step-Tripling for 12-Pulse Rectifier Using a Passive Four-Tap Changer," *IEEE Trans. Ind. Electron.*, vol. 70, pp. 65–75, 2022, doi: 10.1109/TIE.2022.3146545.

[19] K. Gamit and K. Chaudhari, "Multi Pulse Rectifier Using Different Phase Shifting Transformers and Its THD Comparison for Power Quality Issues," *Int. Res. J. Eng. Technol.*, vol. 3, no. 1, pp. 1025–1033, 2019.

[20] P. Nencioni, S. Gianfranceschi, M. C. Terzi, and G. Landgraf, "E Arthnet O Nline Xml F Ront - E Nd," *Online*, pp. 1–28, 2003.

[21] V. Ramakrishnan *et al.*, "A Comprehensive Review on Efficiency Enhancement of Wireless Charging System for the Electric Vehicles Applications," *IEEE Access*, vol. 12, no. April, pp. 46967–46994, 2024, doi: 10.1109/ACCESS.2024.3378303.

[22] R. Collin, Y. Miao, A. Yokochi, P. Enjeti, and A. Von Jouanne, "Advanced electric vehicle fast-charging technologies," *Energies*, vol. 12, no. 10, 2019, doi: 10.3390/en12101839.

[23] I. H. Mitigation, "White Paper Multi-Pulse Rectifier Solutions for Input Harmonics Mitigation," pp. 1–6, 2005.

[24] B. N. Harish and U. Surendra, "A review on power quality issues in electric vehicle interfaced distribution system and mitigation techniques," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 25, no. 2, pp. 656–665, 2022, doi: 10.11591/ijeecs.v25.i2.pp656-665.

[25] M. S. Mastoi *et al.*, "A study of charging-dispatch strategies and vehicle-to-grid technologies for electric vehicles in distribution networks," *Energy Reports*, vol. 9, pp. 1777–1806, 2023, doi: 10.1016/j.egyr.2022.12.139.

[26] H. J. Bergveld, W. S. Kruijt, and P. H. L. Notten, *Battery Management Systems*. 2002. doi: 10.1007/978-94-017-0843-2.

[27] H. D. Saputro, "Harmonic Analysis Of Current And Voltage Electricity In The Unnes Bptik Building And E11 Electrical Engineering," p. 88, 2019.

[28] A. G. Abo-Khalil and M. Alobaid, "A Guide to the Integration and Utilization of Energy Storage Systems with a Focus on Demand Resource Management and Power Quality Enhancement," *Sustain.*, vol. 15, no. 20, 2023, doi: 10.3390/su152014680.

[29] A. P. Report, "Modeling And Simulation Study Of Multi- Output Phase Shifting Transformer Application In High Power Ac- Dc Converters In Indian Institute Of Technology , Madras Chennai - 600036," no. May, 2018.

[30] U. A K, C. S. E, S. J. T G, M. A. S, and A. Joseph, "Shunt hybrid active power filter for harmonic mitigation: A practical design approach," *Sadhana - Acad. Proc. Eng. Sci.*, vol. 40, no. 4, pp. 1257–1272, 2015, doi: 10.1007/s12046-015-0370-x.

[31] Rimbawati, M. A. Siregar, Z. Siagian, J. Riandra, P. Harahap, and B. Oktrialdi, "Lightning Arrester Design as a Security System for Photovoltaic Systems in Pematang Johar Village," *Proceeding - ELTICOM 2022 6th Int. Conf. Electr. Telecommun. Comput. Eng. 2022*, pp. 54–59, 2022, doi: 10.1109/ELTICOM57747.2022.10038261.

[32] IEEE 519-2014 standard, "IEEE 519-2022 Review What has changed from the previous 2014 version ?," pp. 1–5, 2022.

[33] F. De León, S. Purushothaman, and L. Qaseer, "Leakage inductance design of toroidal transformers by sector winding," *IEEE Trans. Power Electron.*, vol. 29, no. 1, pp. 473–480, 2014, doi: 10.1109/TPEL.2013.2251429.

[34] F. Exchange, "12 Pulse Rectifier Test Power Electronics Control in Real Time," pp. 1–3, 2024.

[35] T. Mahmood and M. A. Khurshid, "Araştırma Makalesi An Improved Multi-Pulse Rectifier Circuit for Input Current Harmonic Suppression Using Passive Devices," no. May, pp. 358–365, 2023, doi: 10.59287/ijanser.738.

[36] A. Electrolytic and A. P. Capacitor, "Application Note Aluminum Electrolytic vs . Aluminum Polymer Capacitor and how its benefits are used properly Application Note Aluminum Electrolytic vs . Aluminum Polymer Capacitor and how its benefits are used," pp. 1–8, 2018.

[37] Y. Liu, L. Wang, D. Li, and K. Wang, "State-of-health estimation of lithium-ion batteries based on electrochemical impedance spectroscopy: a review," *Prot. Control Mod. Power Syst.*, vol. 8, no. 1, 2023, doi: 10.1186/s41601-023-00314-w.

[38] D. P. I. D. Controller, "Design Power Conversion Controls Faster with Simulink," pp. 1–3.

[39] G. Perilla, M. Perez, G. Yamhure, A. Fajardo, and C. I. Paez-Rueda, "Improving Circuit and Transformer Complexity for 24-Pulse AC-DC Converter Topology," *IEEE Access*, vol. 12, no. October, pp. 156994–157005, 2024, doi: 10.1109/ACCESS.2024.3480689.

[40] A. Srivastava and S. Saravanan, "Harmonic mitigation using optimal active power filter for the improvement of power quality for a electric vehicle changing station," *e-Prime - Adv. Electr. Eng. Electron. Energy*, vol. 8, no. November 2023, p. 100527, 2024, doi: 10.1016/j.prime.2024.100527.