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Verification and Assessment of Impact Electronics Trainer Kit for Practicum Education

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Abstract

This study focuses on the verification and evaluation of the impact of an Electronics Trainer Kit (ETK) developed for practical education in electronics. Specifically, the study investigates the effectiveness of the ETK before it is implemented in the third stage of an unaddressed training program. The verification process includes the assessment of the trainer kit's performance as a benchmark for educational use in electronics practicums. The analysis was conducted through a series of laboratory tests that involved evaluating electrical indicators and the performance of the components used in the kit. The testing phase included the assessment of a 3-phase rectifier system. The results demonstrate that the Electronics Trainer Kit developed by Nyana provides a reliable benchmark for educational purposes, effectively supporting the teaching of electronics in laboratory settings. The study concludes that this trainer kit can be a valuable tool in enhancing practical education in electronics, facilitating students' understanding of complex electronic systems through hands-on learning experiences.

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Keywords: Trainer kit, education, electronics

1. Introduction

The current power economy continues to explore advancements in power electronics, with applications expanding across industrial and domestic sectors. Power electronics now play a pivotal role in managing electricity, both in industrial processes and everyday household systems (Larasati, Tarigan, & Adinata, 2024). The rapid development of science and technology has significantly influenced the evolution of power electronics, allowing for greater integration into various applications and industries (Yahya, 2023). The extensive scope of power electronics knowledge is central to the curriculum in electrical engineering education (Nugraha et al., 2023). As such, it is a crucial area of study for electrical engineering students, providing the foundation for skills in electrical systems, electrical installations, industrial automation, and power generation.

Power electronics is integral to courses designed to equip students with both theoretical knowledge and practical applications related to electrical systems, focusing on the role of power electronics in controlling electrical power (Anwar et al., 2021). The development of power electronics has led to innovations that allow students to grasp both theoretical and hands-on concepts, ensuring that they are prepared to apply these principles in real-world settings (Budiastuti, Damarwan, & Triatmaja, n.d.). One of the key components of learning in power electronics is the 3-phase rectifier, which is widely used in the conversion of AC to DC power (Jaya & Mauliana, n.d.). This rectifier plays an essential role in supplying controlled DC electricity, which is a fundamental requirement for various devices and systems (Nugraha et al., 2023) (Çelik, 2017).

The 3-phase rectifier, an essential device in power electronics, converts three-phase alternating current (AC) to direct current (DC), facilitating the efficient transfer of electrical power. This device is crucial in applications where DC power is necessary, especially considering that the majority of power supplied by utilities (PLN) is AC. The need for efficient conversion to DC electricity highlights the importance of power electronics in modern electrical systems. The 3-phase rectifier, especially in uncontrolled configurations such as half-wave and full-wave rectifiers, is more efficient compared to other rectifiers like single-phase rectifiers (Shiddiq, Yuniza, & Nugraha, 2022). This is because the 3-phase rectifier generates DC with relatively less ripple and better efficiency, which is vital in applications requiring stable DC power.

To support the teaching of these concepts, practical training is essential. Power electronics courses should not only include theoretical explanations but also incorporate hands-on laboratory exercises that allow students to directly engage with the equipment and validate the theories they have learned. The use of trainer kits, specifically designed to demonstrate key concepts in power electronics, is critical for this purpose. Trainer kits enable students to perform experiments and tests that replicate real-world applications, enhancing their understanding of the principles and functions of power electronics (As'ad, Yuniza, & Nugraha, 2022).

The development of a specialized Electronics Trainer Kit for power electronics is essential to meet the needs of modern educational practices. The trainer kit should be designed to allow students to perform experiments related to the 3-phase rectifier, both in half-wave and full-wave configurations, as well as other related circuits. The kit must be evaluated rigorously before use to ensure its reliability and effectiveness in

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practical training scenarios. This evaluation process includes verifying that the trainer kit meets the necessary criteria for educational use, such as accuracy, safety, and ease of operation. The verification ensures that the kit is capable of supporting the practical learning objectives of power electronics courses, specifically in terms of 3-phase rectifier operations and other related experiments.

2. Material and methods

2.1. Rectifier

A rectifier is an essential electrical component used to convert alternating current (AC) into direct current (DC). This process involves the transformation of the AC's back-and-forth voltage into a steady DC voltage. The key component in the rectifier circuit is the diode, which is configured in a forward-biased orientation to allow current to flow in only one direction, thus converting AC to DC (Nugraha et al., 2023).

In practical applications, when the AC voltage is supplied to the rectifier, it is typically stepped down using a transformer. This step-down transformer reduces the voltage to a lower level, suitable for specific devices or systems that require DC power (Agna, Yuniza, & Nugraha, 2022). The rectifier circuit then plays a crucial role in ensuring that the AC voltage is effectively converted to a usable DC output.

There are various types of rectifiers, including half-wave and full-wave rectifiers. A half-wave rectifier allows current to pass only during one half of the AC cycle, while a full-wave rectifier allows current to pass during both halves of the AC cycle. Full-wave rectifiers are more efficient than half-wave rectifiers, as they provide a smoother DC output (Shiddiq, Yuniza, & Nugraha, 2022). A full-wave rectifier can be implemented in two common configurations: the center-tapped transformer configuration and the bridge diode configuration. The center-tapped transformer configuration uses a transformer with a center tap to provide two halves of the AC waveform, while the bridge diode rectifier uses four diodes arranged in a bridge configuration to rectify the AC signal without the need for a center-tapped transformer (Srianthumrong & Akagi, 2002).

In the context of power electronics and engineering education, understanding the operation of rectifiers is essential. Students need to grasp both the theoretical concepts and the practical implementation of these components, especially as they apply to real-world systems. The use of practical tools like the Power Electronics Trainer Kit, which includes rectifier circuits, is critical for hands-on learning in this field. Such kits enable students to experiment with rectifiers, observe their performance, and understand the impact of various configurations on the output DC voltage.

To ensure the effectiveness of these training tools, thorough verification and assessment of the trainer kits are required. This includes evaluating the accuracy, reliability, and efficiency of the rectifier circuits in the kit. The trainer kit should replicate real-world scenarios, providing students with a robust learning experience that reinforces theoretical knowledge with practical application.

2.2. Wave Rectifier

A full-wave rectifier is a type of rectification system that efficiently converts the entire alternating current (AC) sine wave into direct current (DC) (Tangtheerajaroonwong et al., 2007). Unlike half-wave rectifiers, which only utilize one half of the AC cycle, a full-wave rectifier uses two diodes or diode blocks, where each block can consist of one or more diodes connected in parallel (Lee, Son, & Ha, 2014). Each diode operates during a specific phase of the AC cycle: one diode conducts during the positive half-cycle, while the other diode conducts during the negative half-cycle, effectively converting both portions of the AC wave into a usable DC output (Hedayati, Acharya, & John, 2013).

A typical full-wave rectifier is often implemented with a center-tapped (CT) transformer, which provides two outputs of AC signals with opposite phases. This phase reversal is crucial for the rectification process, as it ensures that both halves of the AC waveform contribute to the DC output. As a result, the output of a full-wave rectifier produces a smoother DC voltage compared to a half-wave rectifier. This is because the full-wave rectifier combines both the positive and negative cycles of the AC input, creating a waveform that exhibits fewer voltage ripples. The result is a more consistent and stable DC output, which is a key requirement in various electronic applications, particularly those involving power electronics.

One of the significant advantages of a full-wave rectifier over a half-wave rectifier is the reduction in ripple. The ripple is a variation in the DC output that occurs due to the alternating nature of the input AC signal. A full-wave rectifier minimizes this ripple by effectively merging the positive and negative cycles of the AC signal, resulting in a smoother waveform. This tighter waveform, also referred to as a "pulsating DC" waveform, ensures that the DC voltage is maintained within acceptable limits for powering sensitive electronic components.

In practical applications, full-wave rectifiers are widely used in power supplies, particularly in systems requiring efficient and stable DC voltage conversion. Their design can be found in various configurations, including bridge rectifiers, which use four diodes arranged in a bridge configuration to achieve full-wave rectification without the need for a center-tapped transformer. This versatility makes full-wave rectifiers integral components in power electronics and electrical engineering education, especially when designing and testing power conversion systems.

2.3. Characteristic of diodes

A diode is a two-terminal active electronic component that typically utilizes semiconductor materials, allowing current to flow in one direction while restricting it in the opposite direction (Cheng, Hou, & Li, 2008). In its forward bias condition, the diode permits current to pass, whereas in the reverse bias condition, it blocks current flow. This one-way current behavior of diodes is essential in the operation of many electronic circuits. The functionality of a diode can be compared to that of a valve in fluid dynamics, as it controls the direction of current flow within an electrical circuit.

Although diodes are fundamental to electronic circuits, they do not exhibit perfect alignment characteristics. Instead, they are governed by a complex relationship between current and voltage that is not linear. This nonlinear characteristic can vary depending on the material and technology used to construct the diode, as well as the operating conditions, such as the temperature and the voltage applied (Nami et al., 2018). Most diodes are made from semiconductor materials such as silicon or germanium, which provide the necessary properties for controlling electrical current.

The earliest diodes, which were based on a crystalline device known as the "cat's whisker" and vacuum tube technology (also called thermionic valves), laid the foundation for modern diode technology. Today, the most commonly used diodes in various applications are constructed from semiconductor materials. These diodes play a vital role in transforming alternating current (AC) into direct current (DC) in electronic devices, which require a stable and continuous flow of electricity to function properly(Son & Ha, 2014).

The primary function of a diode is in rectification, where it converts AC to DC. A rectifier circuit utilizes diodes to achieve this conversion. However, for the output DC to be stable and reliable, the current must be smooth, without fluctuations or ripples that could disrupt the operation of sensitive electronic equipment. If the rectified output is not smooth, it may cause performance issues, such as noise or interference in the electronic devices being powered. Hence, ensuring a "flat" DC output is a critical aspect of rectifier design in power electronics.

2.4. Methods

This feasibility assessment is performed in three distinct stages: testing the electrical parameters of the trainer kit components, evaluating the performance of the circuit, and conducting a final analysis of the test results. Each of these stages is executed in a systematic manner, with all tests being conducted in a laboratory setting to ensure precision and reliability of the data.

A. Testing Electrical Parameters of Trainer Kit Components
The first stage of the feasibility test involves evaluating the electrical parameters of the trainer kit components. This test is crucial to ensure that the components are functioning correctly and meet the required standards for practical use in educational settings. Given that the trainer kit operates with a 3-phase power source, the electrical parameters to be measured include both the phase-to-phase voltage (commonly referred to as line voltage) and the phase-to-neutral voltage (referred to as phase voltage). These measurements are essential for confirming the proper functioning of the power supply system within the trainer kit. Additionally, the maximum current limit that the trainer kit can safely handle is also assessed. This parameter is critical for ensuring that the trainer kit operates within safe limits and prevents potential damage due to overcurrent conditions.

B. Performance Test of the Circuit
The second stage of the feasibility test focuses on evaluating the performance of the circuit within the trainer kit. For this test, one of the circuits in the trainer kit—a 3-phase uncontrolled rectifier circuit—is selected for testing. This choice is made due to the circuit's complexity, which provides a comprehensive representation of a typical 3-phase uncontrolled rectification process. The test involves operating the circuit without the use of full-wave rectification, which presents a more challenging scenario that can effectively simulate real-world applications. The results from this performance test will then be compared to theoretical calculations, providing a basis for evaluating the accuracy and reliability of the trainer kit. This comparison is essential for understanding the alignment between theoretical predictions and practical outcomes, which helps assess the trainer's ability to function as a teaching tool.

C. Analysis of Test Results
The final stage of the feasibility test involves analyzing the results obtained from the electrical parameter and performance tests. In this stage, the measured values from the tests are compared with the theoretical calculations that were made prior to the experiments. The primary analysis technique

used in this process is comparative analysis, where the measured values are compared with the expected theoretical results. The key criterion for determining the trainer kit's eligibility is that the measured values must fall within a ±5% tolerance range of the theoretical values. If the results are within this tolerance, it indicates that the power electronics trainer kit is functioning as expected and meets the necessary criteria for use in practicum education.

The decision on the trainer kit's suitability for educational use is made based on this final analysis. If the measurements align with the theoretical calculations, the trainer kit is deemed to be an effective and reliable tool for teaching power electronics in a practical, hands-on environment. This ensures that students can confidently use the trainer kit in their learning process, which is a vital component of effective engineering education. The theoretical parameters used in the analysis are derived from standard equations and models in power electronics, providing a benchmark for performance evaluation.

3. Results and discussion

The primary objective of this study is to present the results of a comprehensive feasibility analysis of a power electronics trainer, with a specific focus on an uncontrollable 3-phase rectifier trainer. This trainer has been meticulously designed to cater to the educational requirements and technical characteristics necessary for the power electronics practicum, particularly for students enrolled in the Industrial Electrical Engineering Study Program. The design of the trainer aligns with the curricular goals of providing hands-on learning experiences that reinforce both theoretical knowledge and practical application of power electronics concepts. A detailed image of the developed trainer is shown in Figure 1 below.

Figure 1. Trainer kit Un-controlled 3 phase rectifier

3.1. Electrical Parameter Test

The electrical parameter testing is conducted by measuring the outputs of the 3-phase power source integrated into the power electronics trainer kit. The key parameters being measured include the maximum voltage and current values within the trainer. The results of these electrical measurements for the uncontrollable 3-phase rectifier trainer kit are provided in Table 1.

Table 1. Result electrical measurement

Phase	Voltage		Maximum current
	Standart (Volt)	**Measurement**	
R-N	220	221	3
S-N	220	219	3
T-N	220	220	3
R-S	380	380	3
S-T	380	282	3
T-R	380	380	3

As observed in Table 1, the electrical parameters of the power electronics trainer kit for the uncontrollable 3-phase rectifier exhibit values that fall within the expected ranges under standard operating conditions. Although minor discrepancies were noted between the measured values and the reference standards, these differences remain negligible, with all measurements well within the acceptable tolerance of ±5%. For example, while the nominal voltage was expected to be 220 V, the measured voltage was 221 V, which represents a deviation of only 1 V—well within the permissible limit. This slight variation does not impact the functionality or safety of the trainer kit during circuit testing. Furthermore, the precision of the measurement results is deemed adequate for educational purposes, especially within a laboratory setting designed for power electronics education.

3.2. Series Performance

The performance testing of the power electronics trainer kit focuses on the evaluation of a 3-phase uncontrolled full-wave rectifier circuit, which is connected to a pure resistive load. The 3-phase uncontrolled full-wave rectifier is a rectifier system that converts a 3-phase alternating current (AC) power source into direct current (DC), specifically unidirectional electricity. Compared to a single-phase rectifier, the 3-phase rectifier offers enhanced efficiency, particularly in terms of reducing ripple in the DC output. This is a key advantage, as the 3-phase rectifier produces smaller ripple compared to the larger ripples typically observed in the output of a single-phase rectifier. Consequently, the 3-phase rectifier requires a significantly smaller filtering component to achieve a smoother DC output. In contrast, a single-phase rectifier necessitates a larger filter to achieve similar levels of DC purity.

Figures 2 and 3 illustrate the schematic diagram of the rectifier circuit and the test circuit setup used for the performance evaluation of the full-wave uncontrollable 3-phase rectifier circuit within the power electronics trainer kit. These visual representations provide a clear understanding of the system configuration, enabling an accurate analysis of the rectifier's operational performance under typical load conditions.

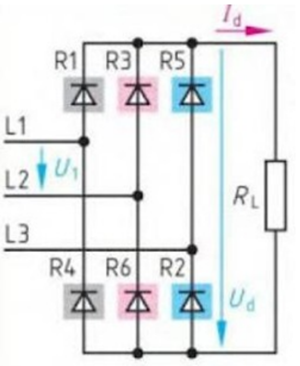

Figure 2. Waveless 3 phase rectifier

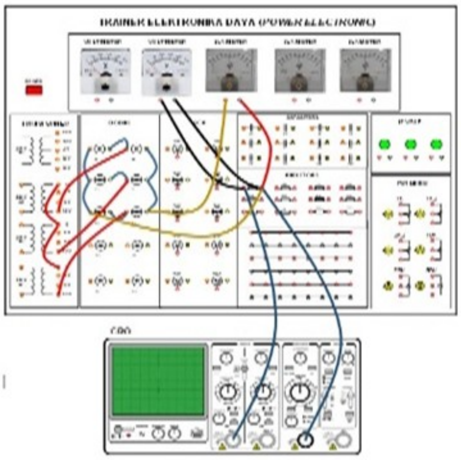

Figure 3. 3 phase Rectifier Circuit Using Power Electronics Trainer Kit

The performance of the power electronics trainer kit is tested by supplying a 3-phase alternating current (AC) to the rectifier circuit, with a nominal line voltage VL= 12 volts. This voltage is provided by a star-connected transformer that delivers the AC power to the rectifier system. The analysis of this circuit's performance focuses not only on the measurement of current and voltage but also on the monitoring of both input and output waveforms using oscilloscopes. This dual analysis allows for a comprehensive evaluation, where both the input conditions and output results are compared against theoretical calculations for a 3-phase uncontrolled full-wave rectifier with a purely resistive load.

The test also includes measurements related to varying the resistive load during operation. The resistive load is gradually increased throughout the testing process, and for each step, current, voltage, and waveform characteristics are measured at both the input and output. These measurements provide insight into the dynamic behavior of the 3-phase rectifier circuit, including how the output performance evolves as the load resistance is modified. The data collected will show how the performance of the 3-phase uncontrolled full-wave rectifier with a purely resistive load changes across the load's value range, from the smallest to the largest resistance.

The results of the performance evaluation for the 3-phase uncontrolled full-wave rectifier circuit, measured using the power electronics trainer kit, are presented in Table 2. This table summarizes the observed variations in current, voltage, and waveform properties as a function of the load resistance, providing valuable data for further analysis and comparison with theoretical predictions.

Table 2. The results of the performance of the 3 phase rectifier series of strokes controlled full wave

Load R (Ω)	**Input**		**Output**			
	Vm (Cm)	**Vrms (Volt)**	**Idc (mA)**		**Vdc (Volt)**	
			Calculation	**Measurement**	**Calculation**	**Measurement**
100	10	7,07	63,66	62,90	6,366	6
150	10	7,07	42,44	43,00	6,366	6,1
200	10	7,07	31,83	32	6,366	6,1
220	10	7,07	28,93	29	6,366	6
300	10	7,07	21,22	22,01	6,366	6
400	10	7,07	15,91	16,02	6,366	6,1
440	10,05	7,12	14,53	15	6,397	6,2
470	10	7,07	13,54	14,03	6,366	6,3
1k	10	7,07	6,37	7,302	6,366	6,3

Based on the data presented in Table 2, it is evident that the measured performance parameters of the 3-phase uncontrollable full-wave rectifier circuit, as tested using the power electronics trainer kit, closely match the values derived from theoretical calculations. While some discrepancies between the measured and calculated results exist for certain parameters, these differences are minimal and fall well within the accepted tolerance limit of ± 5%, which is typically established for laboratory equipment.

These results confirm that the power electronics trainer kit, designed for the 3-phase uncontrollable rectifier, produces outcomes that align with theoretical predictions and meet the established laboratory standards. Consequently, the trainer kit has been validated as a suitable tool for practical learning. It fulfills the criteria for use in educational settings, specifically in the context of power electronics practicum. The trainer kit supports the learning process for both half-wave and full-wave 3-phase rectifier circuits, providing students with hands-on experience and reinforcing theoretical knowledge in power electronics.

4. Conclusion

Based on the findings and subsequent analysis presented in this study, it can be concluded that the power electronics trainer kit designed for 3-phase uncontrolled rectifiers meets the established criteria for laboratory equipment and serves as an effective medium for practicum-based learning in the power electronics curriculum. Specifically, the trainer kit has been verified and validated as suitable for students enrolled in the Industrial Electrical Engineering Study Program at the Department of Electrical Engineering, Faculty of Engineering, Padang State University.

The trainer kit, tailored for educational purposes, has undergone rigorous testing of its electrical parameters and circuit performance. These tests confirm that the equipment operates safely within acceptable standards, ensuring its suitability as a practical learning tool for students engaged in power electronics practicum sessions. Furthermore, the design and construction of this trainer kit are aligned with the learning objectives of the power electronics practicum, focusing particularly on 3-phase uncontrolled rectifiers, including both half-wave and full-wave configurations.

In summary, the power electronics trainer kit for 3-phase uncontrolled rectifiers fulfills the educational and operational requirements necessary for its use in academic settings. It offers a reliable, effective, and safe platform for students to engage with core concepts in power electronics, thus contributing positively to the development of practical skills in this field.

Credit authorship contribution statement
Author Name: Conceptualization, Writing – review & editing. **Author Name**: Supervision, Writing – review & editing. **Author Name**: Conceptualization, Supervision, Writing – review & editing.

References

Larasati, S., Tarigan, A. D., & Adinata, Y. (2024). Design and Build Basic Electronics Trainer as a Practicum Teaching Aid at the Electronics Engineering Laboratory, Universitas Pembangunan Panca Budi, Medan. Journal of Information Technology, computer science and Electrical Engineering, 1(3), 46-53.

Yahya, M. (2023). The Role of the Use of IoT (Internet of Things) Microcontrollers in the Electronics vocational education sector in Practicum Learning. Journal of Embedded Systems, Security and Intelligent Systems, 91-96.

Nugraha, Anggara Trisna, et al. "TRAINER KIT KOORDINASI PROTEKSI PADA SISTEM DISTRIBUSI PT. X MENGGUNAKAN TEORI GRAPH." Seminar MASTER PPNS. Vol. 8. No. 1. 2023.

Anwar, M., Triyono, M. B., Hidayat, H., & Syahputeri, V. N. (2021). Design of trainer kit as a fault-finding based on electricity and electronics learning media. Jurnal Pendidikan Vokasi, 11(2), 192-203.

Jaya, H., & Mauliana, I. Development Of Virtual Laboratory Touchscreen Based For The Student Of Vocational High School In Order To Support The Practice Learning.

Budiastuti, P., Damarwan, E. S., & Triatmaja, A. K. Development of Electrical Machine Training Kits to Improve Electrical Machine Competence.

Çelik, S. A. (2017). The investigation of the effects of robotic-assisted practices in teaching renewable energy sources to seventh-grade students in secondary school. The Eurasia Proceedings of Educational and Social Sciences, 6, 167-172.

Nugraha, Anggara Trisna, et al. "Three Phase Controlled Rectifier Circuit for Characteristic Control in DC Shunt Motor." (2023).

Shiddiq, Muhammad Jafar, Salsabila Ika Yuniza, and Anggara Trisna Nugraha. "The Design of Uncontrolled Rectifier Three Phase Half Wave with Single Phase AC Generator Source." International Journal of Advanced Electrical and Computer Engineering 3.2 (2022).

As’ad, Reza Fardiyan, Salsabila Ika Yuniza, and Anggara Trisna Nugraha. "The Effect of 3 Phase Full Wave Uncontrolled Rectifier on 3 Phase AC Motor." International Journal of Advanced Electrical and Computer Engineering 3.2 (2022).

Nugraha, Anggara Trisna, et al. "Three Phase Controlled Rectifier Circuit for Characteristic Control in DC Shunt Motor." (2023).

Agna, Diego Ilham Yoga, Salsabila Ika Yuniza, and Anggara Trisna Nugraha. "The Single-Phase Controlled Half Wave Rectifier with Single-Phase Generator Circuit Model to Establish Stable DC Voltage Converter Result." International Journal of Advanced Electrical and Computer Engineering 3.3 (2022).

Shiddiq, Muhammad Jafar, Salsabila Ika Yuniza, and Anggara Trisna Nugraha. "The Design of Uncontrolled Rectifier Three Phase Half Wave with Single Phase AC Generator Source." International Journal of Advanced Electrical and Computer Engineering 3.2 (2022).

Srianthumrong, S., & Akagi, H. (2002, October). A medium-voltage transformerless AC/DC power conversion system consisting of a diode rectifier and a shunt hybrid filter. In *Conference Record of the 2002 IEEE Industry Applications Conference. 37th IAS Annual Meeting (Cat. No. 02CH37344)* (Vol. 1, pp. 78-85). IEEE.

Tangtheerajaroonwong, W., Hatada, T., Wada, K., & Akagi, H. (2007). Design and performance of a transformerless shunt hybrid filter integrated into a three-phase diode rectifier. IEEE Transactions on Power Electronics, 22(5), 1882-1889.

Lee, W. J., Son, Y., & Ha, J. I. (2014). Single-phase active power filtering method using diode-rectifier-fed motor drive. IEEE Transactions on Industry Applications, 51(3), 2227-2236.

Hedayati, M. H., Acharya, A. B., & John, V. (2013). Common-mode filter design for PWM rectifier-based motor drives. IEEE Transactions on Power electronics, 28(11), 5364-5371.

Cheng, P. T., Hou, C. C., & Li, J. S. (2008). Design of an auxiliary converter for the diode rectifier and the analysis of the circulating current. IEEE Transactions on Power Electronics, 23(4), 1658-1667.

Son, Y., & Ha, J. I. (2014). Direct power control of a three-phase inverter for grid input current shaping of a single-phase diode rectifier with a small DC-link capacitor. IEEE Transactions on Power Electronics, 30(7), 3794-3803.

Nami, A., Rodriguez Amenedo, J. L., Arnaltes Gomez, S., & Cardiel Alvarez, M. A. (2018). Active power filtering embedded in the frequency control of an offshore wind farm connected to a diode-rectifier-based HVDC link. Energies, 11(10), 2718.