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Power Quality Improvement in AC-DC Converter Using Harmonic Current Injection Technique

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ABSTRACT: Ensuring power quality in modern power systems is of utmost importance to achieve cost-effective and reliable operations. AC-DC converters are broadly used in many applications including renewable energy systems, electric vehicle supply equipment, and adjustable speed drives. The converter renders the power quality decremented through harmonic currents induced into the power grid, especially due to power contrived by the converter. Hence, a new approach for power quality enhancement in the AC-DC converter, based on a new method, injection of harmonic current, is demonstrated. The proposed approach attempts compensating harmonic currents injected to the converter for reducing the THD of converter output as a power quality measure. The efficiency and viability of the proposed approach are demonstrated theoretically through a mathematical analysis.

KEYWORDS: current modulation circuit, front-end rectifier, power quality, third harmonic current injection, THD, zig-zag transformer.

I. INTRODUCTION

Power quality is an essential requirement in contemporary electrical systems since it ensures the optimal functioning and dependability of diverse equipment and electronic devices. The current trends towards renewables integration and a rapid surge of power electronic equipment complicate the process of power quality maintenance. Harmonic distortion resulting from non-linear loads is one of the most damaging aspects from multiple factors. Due to harmonics, voltage and current get distorted and this leads to a decline in technical performance and serviceability of the equipment, increased energy dissipation, and technical revision. Therefore, power quality maintenance poses as one of the paramount challenges in 21st century electrical engineering and science. In order to solve it, multiple researchers have been developing and suggesting the solutions.

The idea behind the harmonic current injection approach is based on the superposition principle, which states that unwanted harmonics can be lessened or eliminated by adding extra current to the system. Harmonic distortion can be efficiently reduced and power quality can be improved by carefully adjusting the injected harmonic currents' amplitude, phase, and frequency. This method has a number of benefits, such as being easy to apply, economical, and compatible with current power electronics systems.

Reducing harmonic distortion in AC-DC converters is one of the main uses for harmonic current injection, especially in systems with non-linear loads like variable frequency motors, rectifiers, and inverters injection

1.1. OBJECTIVES

- In order to ensure that electrical systems operate effectively and dependably, standards and regulations require a reduction in harmonic distortion in the current waveform.
- To balancing the output voltage reduces the possibility of equipment damage and malfunction while preserving a consistent and reliable power supply. Reducing total harmonic distortion (THD) enhances overall power quality and minimizes interference with other electrical equipment.
- Reducing reactive power usage can enhance the power factor, improve energy efficiency, and decrease utility costs.

- To improving the conversion process' efficiency, resulting in decreased energy losses and better overall performance.

1.2 CONTRIBUTION

To regulate the harmonics of an AC-DC converter, an appropriate PWM control diagram is generated for a three-phased converter using a fuzzy controller.

II. LITERATURE SURVEY

[1] Several distinct kinds of electronic equipment employ switching power supply, mostly because of their great efficiency and small design. This article gathers a collection of design exercises and ideas that address design methodologies and concepts in the context of developing switching power supply. The purpose of the abstract is to highlight the crucial significance that switching power supply play in modern electronics while outlining the topics that the paper covers.

[2] Demand for improved power quality in single-phase AC-DC converters has increased. The widespread use of power electronic devices and integrating renewable energy resources to the grid makes this necessary. This review explores new techniques and developments that have been proven to improve power quality in the single-phase AC-DC converter. The abstract conveys the main results and contributions of the paper, enabling the reader to gain an understanding of the current research and developments. The review will explore the background and introduce power quality in a single-phase AC-DC converter and the disadvantage of harmonic distortion, power factor correction, and voltage regulation. It will also capture the impact of a low power factor and the output of a single-phase AC-DC converter.

The review is started with a brief consideration of the importance of power quality for single-phase AC-DC converters and the problems that exist in this regard: the high level of harmonic distortion and the poor quality of power factor correction and voltage regulation. The detrimental impact of poor power quality and the quality of the electricity at the consumer level on the operation of electrical appliances, stability of the network and energy consumption efficiency are stressed as key issues to be addressed by policymakers and regulators in order to legislate the development of new, efficient, and broad-scope mitigations.

[3] A novel three-phase power factor correction rectification technique via a Harmonic Current Injection Method *
Keywords: Power Quality, Power Factor Correction, Inverter, Rectifier, Harmonic Distortion . Abstract: Power quality and efficiency are two highly desirable requirements in modern power systems. As the need for power systems with increasing efficiency and better power quality grows, so does the need for PFC rectification systems with as low harmonic distortion as possible. The abstract should capture what this novel rectifier topology is and how it can help improve power quality and efficiency.

By providing targeted harmonic currents into the system with the HCIM technique, the proposed three-phase PFC rectifier effectively reduces harmonic distortion and enhances power factor correction. Power quality metrics including total harmonic distortion (THD) and power factor (PF) are improved by the rectifier through precise regulation of the injected harmonic currents' amplitude, phase, and frequency.[4] Investigating cutting-edge circuit topologies, materials technologies, and control algorithms is essential to improve the effectiveness and reliability of SUMI-DCCs in HEVs. Improved energy conversion efficiency and system reliability may be possible with the inclusion of modern thermal management techniques and wide-bandgap semiconductors, among other newly emerging technologies.

For faster the development and execution of SUMI-DCCs in next-generation HEVs and further sustainable transportation solutions, cooperation amongst government agencies, industry, and academia is vital.

[4] In present power systems, three-phase current-injection rectifiers (CIRs) compete with topologies for power factor correction (PFC). The need for high-performance, energy-efficient electrical systems is growing, making the development of sophisticated rectification techniques more and more necessary. The abstract provides an overview of the paper's main results and contributions while additionally offering an analysis of the state of the field's research and development at the moment.

A feasible choice for strengthening power quality and efficiency in AC-DC conversion applications is the use of three-phase CIRs. These rectifiers improve power factor correction and lower total harmonic distortion (THD) by introducing particular harmonic currents into the system to offset non-linear load effects and reduce harmonic distortion.

[5] An innovative 20-pulse asymmetric multiphase staggering autoconfigured transformer (AMAST) intended to enhance power quality in electrical distribution networks. The need for dependable and superior power supplies is growing, making it imperative to create novel approaches to reduce harmonic distortion and voltage imbalance. An overview of the suggested AMAST topology and its possible advantages for improving power quality are intended to be provided in the abstract.

An asymmetric multiphase staggered architecture is used by the proposed 20-pulse AMAST to reduce harmonic distortion and enhance voltage balancing. The transformer improves power quality and efficiency by compensating for harmonic currents and voltage imbalances through the use of several secondary windings with staggered phase angles.

[6] The development and application of sensorless voltage control to improve power quality in telecom systems for the front-end rectifier. Enhancing the performance of front-end rectifiers has become essential due to the growing need in telecommunications infrastructure for a dependable and high-quality power supply. An overview of the suggested sensorless voltage management method and its possible advantages for enhancing power quality are given in the abstract.

By applying advanced control algorithms and data processing techniques, the suggested sensorless voltage control scheme does away with the requirement for voltage sensors. Accurately calculating the front-end rectifier's output voltage based on load conditions and system characteristics allows the control system to guarantee perfect regulation and stability without requiring extra hardware.

[7] A novel way to decrease harmonics in a 12-pulse diode bridge rectifier with a zigzag autoconnected transformer is to inject current at the DC side. Reducing harmonic distortion has become crucial in electrical distribution systems due to the growing demand for good power quality and effective operation. The purpose of the abstract is to give a summary of the suggested approach and its possible advantages for enhancing power quality.

To offset the harmonics produced by non-linear loads, the suggested method entails introducing particular harmonic currents at the rectifier's DC side. Through meticulous management of the injected currents, the system attains notable harmonic reduction, resulting in enhanced power quality and efficiency.

[8] A novel approach for improving the efficiency of three-phase rectifiers through suboptimal current injection techniques. A development of novel techniques to enhance rectifier performance is now essential due to the growing need for energy-efficient power conversion systems. The purpose of the abstract is to give a general overview of the suggested strategy and how it might help achieve increased efficiency.

The proposed technique involves injecting suboptimal currents into the three-phase rectifier to optimize its operation under various load conditions. By carefully controlling the injection currents, the rectifier achieves improved efficiency while maintaining satisfactory power quality metrics.

[9] An innovative method for lowering harmonics and increasing power factor in a utility interface of the three-phase diode rectifier type. Maintaining excellent power quality becomes crucial as renewable energy sources are integrated more and more and as power electronic devices proliferate. The purpose of the abstract is to give a general overview of the suggested method and how it can improve power factor and lower harmonic distortion.

In order to reduce harmonic distortion and raise power factor, the suggested method integrates passive and active filtering components into the rectifier circuit. The rectifier constantly modifies its operation to maximize power factor correction and harmonic abatement by utilizing sophisticated control algorithms and real-time monitoring.

The operational concepts and design concerns of the suggested approach, including the choice of control strategies, filtering components, and performance evaluation measures, are covered in the paper. Power quality measures like power factor and total harmonic distortion (THD) can be improved with this technique, as shown by simulation results and experimental validation.

III. STRUCTURED FRONT END AC-DC CONVERTER DESIGN

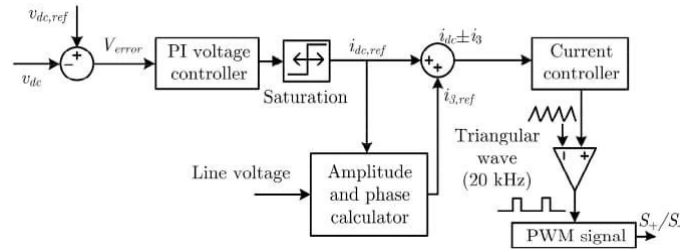


Figure 1, shows the structure of front end AC-DC converter
Source: Authors, (2023).

The proposed three-phase front-end hybrid AC-DC converter is connected to the load for improving the input current quality. The current injection technique and its control schemes are modified and applied to the proposed converter. Here the zig-zag transformer is utilized as the passive current injection circuit. The reference signal is generated by voltage and current controllers. The third harmonic current reference is generated from the input voltages. The magnitude and phase angle are calculated, and it is processed by the controller.

3.1 AC-DC CONVERTER

An electrical device that changes alternating current (AC) to direct current (DC) is called an AC-DC converter, sometimes referred to as a rectifier. Many electrical devices frequently employ this conversion to supply DC electricity for power. It modifies a circuit's current flow by means of semiconductor diodes. The output that is produced is a pulsing DC voltage, which can be further controlled or smoothed down with capacitors to produce a steady DC output.

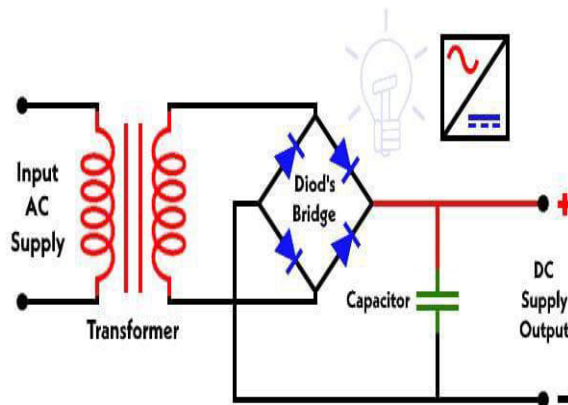


Fig :2 Line Diagram of AC-DC Converter Source: Authors, (2023).

3.2 ZIG ZAG TRANSFORMER

Once the main and secondary windings of a transformer are connected in a zigzag or interconnected star pattern, the result is known as a zigzag transformer. In electrical systems, it's utilized for phase shifting, voltage transformation, and grounding. A neutral point is provided by the zigzag connection, aiding in load balancing and fault protection.

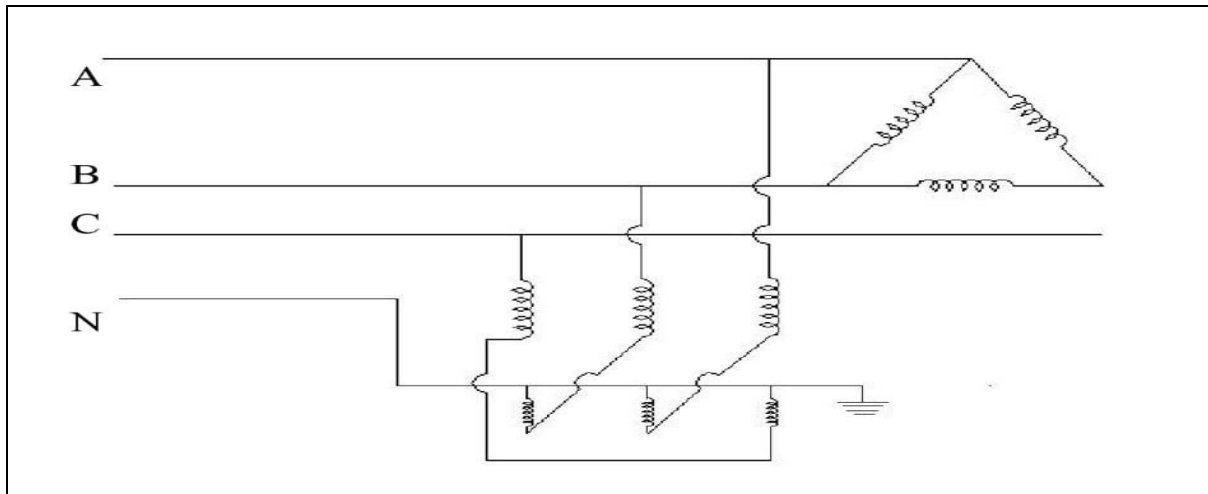


Figure 3: Zig Zag transformer with ground connection, Source: Authors, (2023).

3.3 DC-DC CONVERTERS

In electromechanical terms, the DC-DC converter refers to any device or circuit that converts a DC voltage from one level to another depending on the demands of the circuit. This member of the electric power converter family can be employed for small voltage applications, such as batteries, or used for high voltage applications, such as HV power transmission.

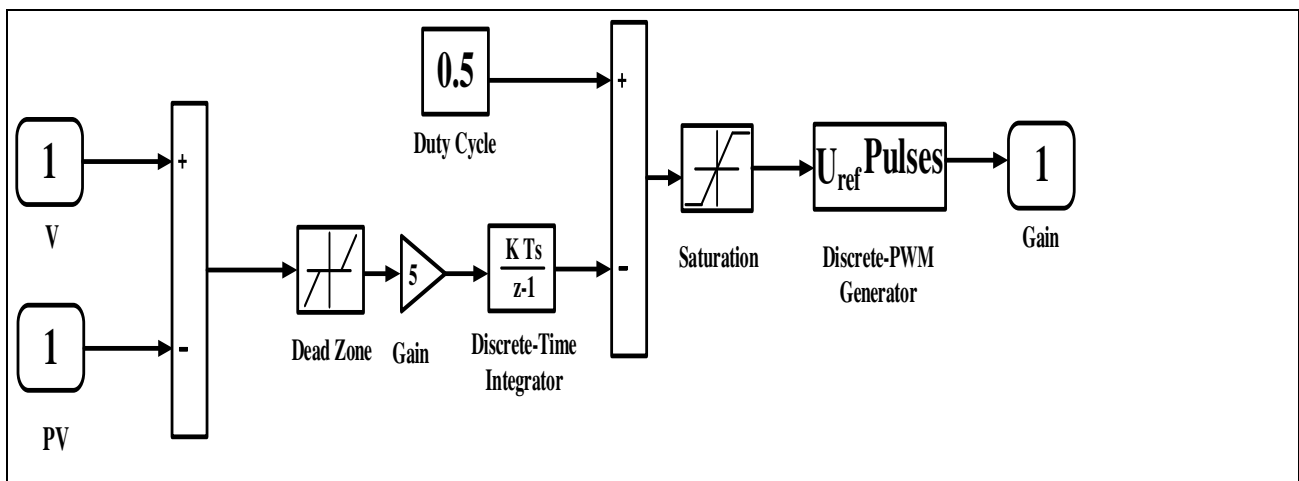


Figure 4: DC-DC converter Source: Authors, (2023)

IV. FUZZY LOGIC CONTROLLER

Fuzzy logic control (FLC) is the most active research area in the application of fuzzy set theory, fuzzy reasoning, and fuzzy logic. The application of FLC extends from industrial process control to biomedical instrumentation and securities. Compared to conventional control techniques, FLC has been best utilized in complex ill-defined problems, which can be controlled by an efficient human operator without knowledge of their underlying dynamics.

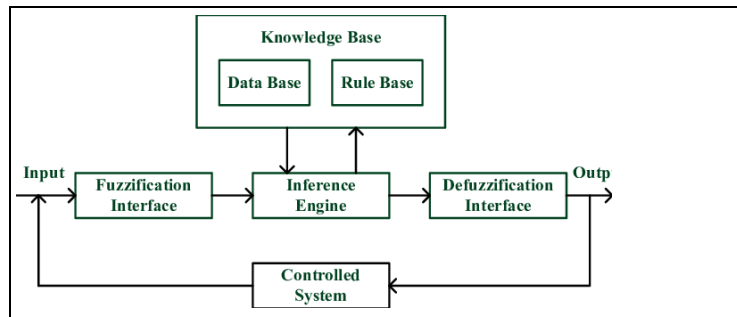


Figure 5: Architecture of Fuzzy logic control system Source: Authors, (2023).

V. RESULTS AND DISCUSSIONS

The suggested system is tested and validated in the Matlab/Simulink environment utilising the controller methods for optimisation procedures. The frequency spectrum for various input currents for various load conditions is displayed

CASE-1: USING PI CONTROLLER TECHNIQUE

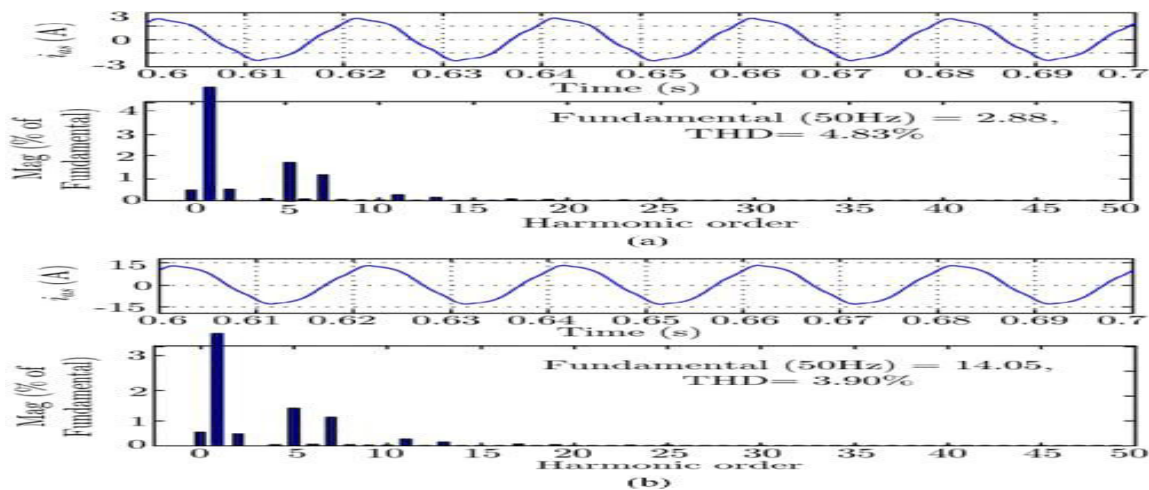


Figure 6: Simulation Results for frequency of input current at (a) light load condition, (b) full load condition Source: Authors, (2023).

CASE-2: USING A PROPOSED SYSTEM AT LIGHT LOAD CONDITION

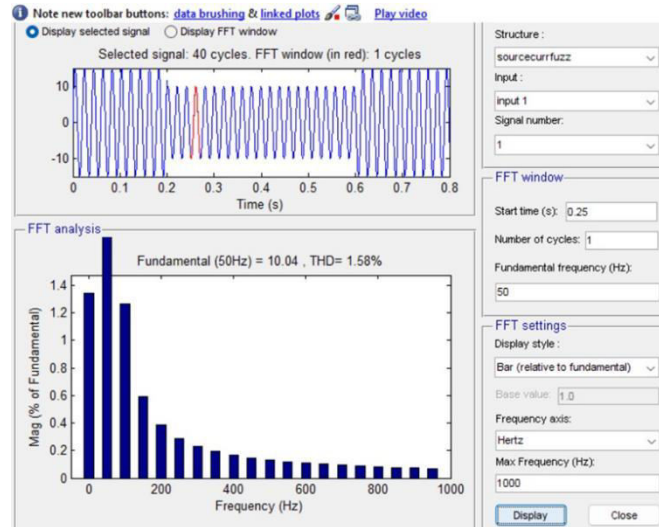


Figure 7. Frequency spectrum for input current at light load condition Source: Authors, (2023).

CASE-3: USING A PROPOSED SYSTEM AT FULL LOAD CONDITION

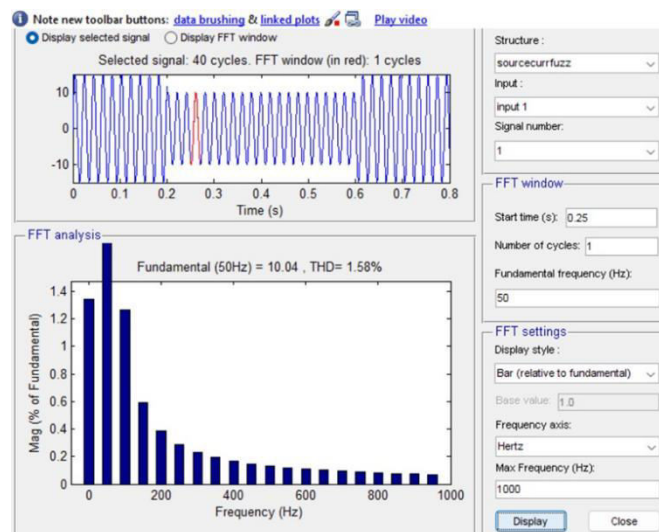


Figure 8: Results of the simulation utilising the FUZZY Controller for Frequency spectrum for input current at light load condition Source: Authors, (2023).

LIMITATIONS

The implementation of existing method results in poor power quality and high harmonic distortion.

VI. CONCLUSIONS

The proposed system of a three-phase rectifier with sub optimal current injection represents a promising advancement in power electronics technology with several notable advantages. By introducing sub optimal current injection techniques, this system aims to address the limitations of traditional diode rectifiers, such as poor power factor and high harmonic distortion, while also improving overall efficiency. One of the key advantages of the proposed system is

its ability to achieve improved power factor and reduced harmonic distortion without the need for complex control algorithms or additional hardware. By injecting sub optimal currents into the rectifier circuit, the system optimizes its operation under varying load conditions, leading to better power quality and efficiency. Furthermore, the proposed system offers simplicity, cost-effectiveness, and compatibility with existing infrastructure, making it suitable for a wide range of applications. Its modular design allows for easy integration into existing power systems, while its scalability enables it to meet the requirements of both low and high-power applications. Moreover, the proposed system leverages the latest advancements in semiconductor technology, control algorithms, and system integration methods to achieve its objectives. By combining these innovations, the system demonstrates potential for significant improvements in power conversion efficiency and power quality.

AUTHOR'S CONTRIBUTION

Conceptualization: M. Ashwitha , M. Shashidhar

Methodology: M. Ashwitha , M. Shashidhar

Investigation: M. Ashwitha

Discussion of results: M. Ashwitha , M. Shashidhar

Writing – Original Draft: M. Ashwitha , M. Shashidhar

Writing – Review and Editing: M. Ashwitha , M. Shashidhar

Resources: M. Ashwitha

Supervision: M. Ashwitha , M. Shashidhar

Approval of the final text: M. Ashwitha , M. Shashidhar

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