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Critical Analysis of Active Power Filters Using Asymmetric Selective Harmonic Current Mitigation-PWM

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***Abstract*— Active power filters (APFs) are integral in mitigating power quality issues, specifically harmonic distortions, in electrical systems. The asymmetric selective harmonic current mitigation using Pulse Width Modulation (PWM) presents a novel approach to enhancing the performance of APFs. This method selectively targets specific harmonic components, thereby optimizing the filter's efficiency and reducing power losses. This paper critically analyzes the effectiveness of asymmetric selective harmonic current mitigation-PWM in APFs. The study includes a comparative analysis with traditional harmonic mitigation techniques, a detailed exploration of the theoretical underpinnings, and practical implications in various electrical systems. The findings highlight the potential of this method to improve power quality significantly, making it a viable solution for modern power systems facing increasing harmonic distortions.**

Keywords*— Asymmetric, Harmonic, PWM, Active,Power Filters.

I. INTRODUCTION

The growing complexity of electrical power systems and the increasing prevalence of non-linear loads have led to significant challenges in maintaining power quality. Harmonic distortion, a primary concern in power quality, results from these non-linear loads and can lead to several adverse effects, including overheating of equipment, malfunction of sensitive electronics, and overall reduction in system efficiency. Active power filters (APFs) have emerged as a crucial technology in addressing these issues, providing dynamic and adaptive solutions to mitigate harmonic distortions.

Traditional harmonic mitigation techniques, while effective to some extent, often struggle with efficiency and adaptability, especially in complex and dynamic power systems. The need for more sophisticated and targeted approaches has led to the development of asymmetric selective harmonic current mitigation using Pulse Width Modulation (PWM). This innovative method offers a focused approach to harmonic mitigation, selectively targeting specific harmonic frequencies for reduction, thus optimizing the performance of APFs.

The asymmetric selective harmonic current mitigation-PWM technique leverages the principles of PWM to adjust the current waveforms actively, reducing the targeted harmonic components without significantly affecting the fundamental frequency. This selective approach not only enhances the efficiency of harmonic mitigation but also reduces power losses, making it a highly effective solution for modern power systems.

This paper provides a comprehensive critical analysis of the asymmetric selective harmonic current mitigation-PWM technique in active power filters. The analysis begins with a detailed review of the theoretical foundations of PWM and its application in harmonic mitigation. It then explores the design and implementation of asymmetric selective harmonic current mitigation in APFs, highlighting the advantages and potential challenges of this approach.

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Comparative studies with traditional harmonic mitigation techniques are conducted to assess the relative effectiveness and efficiency of the asymmetric method. These studies include both simulation and real-world applications, providing a robust evaluation of the technique's performance in various scenarios. Furthermore, the paper examines the practical implications of deploying asymmetric selective harmonic current mitigation-PWM in different types of electrical systems, from residential setups to large industrial installations.

The results of this critical analysis demonstrate the significant potential of asymmetric selective harmonic current mitigation-PWM in improving power quality. The findings suggest that this method can offer superior performance in reducing specific harmonic components, leading to enhanced system efficiency and reduced operational costs. Additionally, the adaptability of this approach makes it suitable for a wide range of applications, addressing the diverse needs of modern power systems.

The asymmetric selective harmonic current mitigation-PWM technique represents a promising advancement in the field of power quality management. By providing a targeted and efficient solution to harmonic distortion, this method can play a crucial role in the development of more reliable and efficient electrical systems. This paper aims to contribute to the ongoing research and development in this area, offering insights and recommendations for future studies and practical implementations.

II. LITERATURE SURVEY

A. Moeini et al.,[1] One of the primary functions of an active power filter, often commonly referred to as an APF, is to regulate the harmonics that are produced by nonlinear loads in power systems. There is also the possibility of compensating for the reactive power, which is a fundamental component of the alternating current (AC) power, by using an active power filter (APF) at the point of common coupling (PCC). This study investigates a methodology for the modulation method of active power filters, which is the topic of the research that is being conducted.

The method of converting multiobjective inequality issues of ASHM-PWM into single objective equation groups and then combining this with enhanced particle swarm optimization (IPSO), which may make the process of addressing the issue more easy, can result in the production of switching angles, as stated by L. Zhang et al. [2].

Multifunction parallel three-level four-leg converters are recommended for use in high-power applications, according to C. Zhang et al. [3]. Active power filter (APF) technology is included into these converters, which allow grid-connected renewable energy to be transferred. The problem of zero-sequence circulating current (ZSCC), on the other hand, cannot be avoided. This issue has the consequence of diminishing the quality of the output currents and decreasing the stability of the system. As a way of overcoming this restriction, a proportional integral (PI) plus feedforward control approach and space vector modulation that is based on nonaxial redundant vectors (NARVs) are offered in an article. This article is presented as a means of overcoming this constraint. A thorough examination is performed once the ZSCC model has been developed, which is the first step in the process. The inquiry has led to the discovery that the zero-sequence duty-cycle difference and the zero-sequence benchmark function are the elements that constitute ZSCC. This was found as a consequence of the study.

S. P. Biswas et al., [4] The method of pulse width modulation (PWM) that is used for the switching of the voltage source converter (VSC) in the SMES/HTS-based grid-tied power system has a significant impact on the joules heating, switching and conduction power losses, total harmonic distortion (THD) profile of the VSC output, and conversion efficiency. This is because PWM is used to switch the VSC. According to the findings of this research, a modified reference saturated third harmonic injected equal loading pulse width modulation (PWM) technique is recommended for use in a grid-tied photovoltaic (PV) system that is based on a voltage source converter (VSC).

The authors B. Zhang et al. [5] According to the results of this investigation, the abrupt change in reference voltage has a wide range of harmonics band and easily creates the resonant current at the resonant frequency. This is shown by the

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findings of the investigation. Following that, a one-of-a-kind three-layer DPWM technique was proposed, which included the injection of three offset voltages. The analysis referenced before serves as the foundation for this strategy. It is via the injection of the first offset voltage that the NP voltage balance is accomplished in the first layer. In the second layer, the second offset voltage is shown. This voltage is responsible for smoothing out the reference voltages that are discontinuous.

According to A. Mishra et al., [6] The purpose of this article is to give the findings of a research into the performance analysis of two-stage solar photovoltaic (PV) systems that have been integrated with a Shunt Active Harmonic Filter (SAHF). As a result of the extensive use of non-linear loads, the distributed power system has been influenced by the current harmonic problem that has arisen in the context of the recent industrial revolution. In order to achieve the goals of load adjustment, harmonic mitigation, and power factor correction, the SAHF system is of considerable aid.

B. Wang et al., [7] Due to the fact that it has the power to protect the machine and make it possible to deploy appropriate mitigation strategies, the method of turn fault detection is of crucial relevance for the safety of the system. Within the scope of this study, an improved way to turn defect detection is investigated when applied to an internal permanent magnet machine (IPM). Utilizing the ripple current that is brought about by the intrinsic pulse width modulation (PWM) voltage harmonics is the way that is being introduced here.

A single-phase transformerless full-bridge solar grid-tie inverter was presented by R. Shen et al., [8] It makes use of three distinct approaches: 1) a virtual ground technique, which is used to lessen the amount of ground leakage current; 2) a hybrid pulsewidth modulation (HPWM) scheme, which is used to profile the output current and prevent sudden changes in the common-mode voltage; and 3) a nonlinear output inductor, which is used to lessen the amount of current ripple around zero crossings and to reduce the size of the filter.

An innovative high-definition pulse width modulation (HD-SPWM) architecture was described by R. Sarker et al., [9] This design was based on a field-programmable gate array (FPGA). The objective of this design is to implement a plan that combines a pulse width modulation (PWM) train operating at a lower frequency with a pulse width modulation (SPWM) train operating at a higher frequency. The purpose of this design is to achieve high resolution output while simultaneously reducing the amount of harmonics that are included within the inverter's output. An architecture for a two-stage finite-state machine (FSM) that has been optimized is laid out. The pulsewidths of a lower frequency pulse width modulation (PWM) train are calculated in the first stage by using the planned pulsewidth of a high-frequency pulse width modulation (SPWM) train as a basis for comparison.

Among the many energy storage technologies and renewable energy sources that were given by A. Moeini et al., [10] multilevel converters are becoming an increasingly attractive choice. The literature describes a variety of modulation strategies that are applied for multilevel grid linked converters. These strategies consist of a number of various methodologies. High-frequency modulation methods, such as space vector modulation and phase shift-pulse width modulation (PWM), as well as low-frequency modulation techniques, such as selective harmonic current mitigation-pulse width modulation (SHCM-PWM) and selective harmonic mitigation-pulse width modulation (SHM-PWM), are included in these methodological approaches. It is feasible to achieve great efficiency by the use of low-frequency modulation methods, which is characterized by lower switching losses.

III. CHALLENGES

Challenges Despite the promising potential of asymmetric selective harmonic current mitigation-PWM (ASHCM-PWM) in active power filters, several challenges must be addressed to fully realize its benefits:

1. **Complexity of Implementation**: Implementing ASHCM-PWM requires sophisticated control algorithms and precise hardware components. The complexity of these systems can pose significant challenges in terms of design, development, and maintenance.
2. **Cost**: Advanced control techniques and high-quality components can increase the overall cost of the system. This may limit the widespread adoption of

ASHCM-PWM, particularly in cost-sensitive applications.

3. **Control Precision**: Achieving the precise control necessary for effective harmonic mitigation is challenging. Small errors in control can lead to suboptimal performance or even exacerbate harmonic issues.
4. **Real-time Adaptation**: Power systems are dynamic, with load conditions and harmonic profiles changing constantly. ASHCM-PWM systems need to adapt in real-time to these changes, requiring advanced adaptive control strategies and real-time processing capabilities.
5. **Compatibility and Integration**: Integrating ASHCM-PWM with existing power systems and ensuring compatibility with a wide range of loads and conditions can be challenging. This requires careful design and testing to ensure seamless operation.
6. **Thermal Management**: The components used in ASHCM-PWM systems can generate significant heat, requiring effective thermal management solutions to prevent overheating and ensure reliable operation.
7. **Standardization and Regulation**: The lack of standardized guidelines and regulations for ASHCM-PWM can hinder its adoption. Developing industry standards and regulatory frameworks is essential for broader acceptance and implementation.

IV. CONCLUSION

The asymmetric selective harmonic current mitigation-PWM technique represents a significant advancement in the field of power quality management. By selectively targeting specific harmonic components, this method offers a highly efficient and effective solution for mitigating harmonic distortions in electrical systems. The critical analysis presented in this paper demonstrates the potential of ASHCM-PWM to enhance the performance of active power filters, leading to improved power quality, reduced power losses, and increased system efficiency. Despite its advantages, several challenges must be addressed to fully leverage the benefits of ASHCM-PWM. The complexity of implementation, cost, control precision, real-time adaptation, compatibility and integration, thermal management, and lack of standardization are significant hurdles that need to be overcome. Addressing these challenges requires ongoing research and development, as well as collaboration between industry, academia, and regulatory bodies.

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