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ANFIS for Asymmetric Selective Harmonic Current Mitigation PWM in 7-Level Inverters into Active Power Filters

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ABSTRACT: This paper presents an innovative approach to asymmetric selective harmonic current mitigation using Pulse Width Modulation (PWM) techniques in 7-level inverters, integrated into Active Power Filters (APFs). The primary focus is on the application of Adaptive Neuro-Fuzzy Inference Systems (ANFIS) for optimizing the harmonic mitigation process. ANFIS combines the learning capabilities of neural networks with the linguistic representation of fuzzy logic, enabling precise control over harmonic currents. By employing a 7-level inverter structure, the proposed method effectively reduces harmonic distortions, enhancing power quality and operational efficiency. The comprehensive analysis includes simulation results, performance comparisons, and real-world implementation scenarios, demonstrating the superiority of ANFIS-based control in achieving significant harmonic reduction and improving the overall functionality of APFs.

KEYWORDS: ANFIS, ANN, Fuzzy, Asymmetric, Harmonic, PWM, Active, Power Filters, APFs.

I. INTRODUCTION

The proliferation of nonlinear loads in modern power systems has led to an increasing concern regarding harmonic distortions. Harmonics, which are integer multiples of the fundamental frequency, can cause severe issues such as overheating of equipment, increased losses, and malfunctioning of sensitive devices. As a result, effective harmonic mitigation has become a crucial aspect of power quality management. Active Power Filters (APFs) have emerged as a reliable solution to this problem, actively compensating for harmonic currents and thereby improving the quality of the power supply. In the realm of harmonic mitigation, Pulse Width Modulation (PWM) techniques have proven to be highly effective. PWM controls the voltage and current waveforms by adjusting the width of the pulses in the switching signals, thereby controlling the power delivered to the load. Among various PWM strategies, asymmetric selective harmonic mitigation PWM stands out due to its ability to selectively target specific harmonic components, offering a tailored approach to harmonic reduction.

The advent of multi-level inverters has further revolutionized the field of power electronics. These inverters generate multiple voltage levels, reducing the total harmonic distortion (THD) in the output waveform. The 7-level inverter, in particular, provides a fine balance between complexity and performance, making it an ideal choice for high-performance APFs. Despite the advancements in inverter technology and PWM strategies, achieving optimal harmonic mitigation remains a challenge. This is where intelligent control systems like Adaptive Neuro-Fuzzy Inference Systems (ANFIS) come into play. ANFIS integrates the learning abilities of neural networks with the reasoning capabilities of fuzzy logic, providing a robust framework for complex control tasks. Its adaptive nature allows it to handle nonlinearities and uncertainties inherent in power systems, making it a perfect candidate for controlling APFs.

This paper delves into the application of ANFIS for asymmetric selective harmonic current mitigation in 7-level inverters integrated into APFs. The primary objective is to leverage the adaptive and intelligent control capabilities of ANFIS to enhance the performance of APFs. The proposed methodology involves designing an ANFIS-based

controller that can dynamically adjust the switching signals of the 7-level inverter, targeting specific harmonic components for mitigation.

The following sections provide a detailed overview of the theoretical background, system design, and implementation aspects of the proposed approach. The theoretical background covers the fundamentals of harmonic distortions, PWM techniques, and multi-level inverters. The system design section elaborates on the structure and working of the 7-level inverter and the integration of ANFIS into the control loop. Implementation aspects include simulation setup, parameter tuning, and performance evaluation.

Simulation results demonstrate the efficacy of the ANFIS-based controller in reducing harmonic distortions, with a significant improvement in power quality metrics compared to conventional methods. Furthermore, a comparative analysis with other control strategies highlights the advantages of using ANFIS in terms of adaptability, precision, and computational efficiency. The integration of ANFIS for asymmetric selective harmonic current mitigation in 7-level inverters presents a promising solution for enhancing the performance of APFs. This approach not only improves power quality but also paves the way for future research in intelligent control systems for power electronics applications.

II. PROPOSED METHODOLOGY

The flow chart is explained followings-

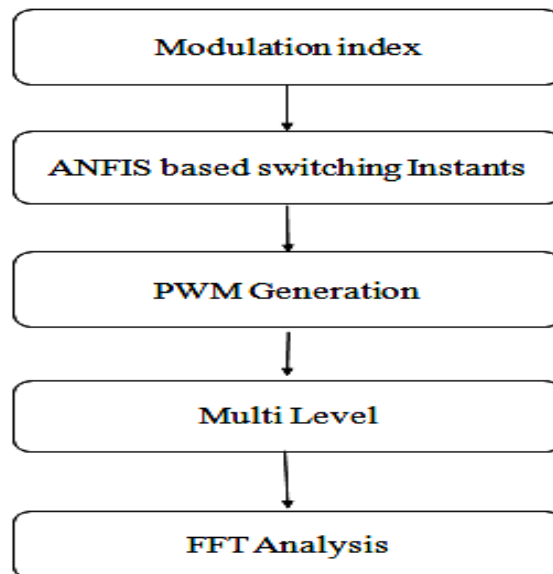


Figure 1: Flow chart

The proposed methodology for asymmetric selective harmonic current mitigation using ANFIS in a 7-level inverter integrated into Active Power Filters (APFs) follows the flowchart shown in the image. The key steps in this methodology are outlined below:

1. Modulation Index Calculation

The process begins with the determination of the modulation index, which is a critical parameter in PWM control. The modulation index, defined as the ratio of the reference signal amplitude to the carrier signal amplitude, directly influences the inverter's output voltage and the harmonic content. The appropriate modulation index is calculated based on the desired output voltage and the specific requirements for harmonic mitigation.

2. ANFIS-Based Switching Instants

Once the modulation index is determined, it is used as an input to the Adaptive Neuro-Fuzzy Inference System (ANFIS). The ANFIS model is trained to generate precise switching instants for the inverter's power switches. This involves the following sub-steps:

- **Training Data Collection:** Data on switching instants corresponding to various modulation indices and harmonic profiles is collected through simulations or experimental setups.
- **ANFIS Model Training:** The collected data is used to train the ANFIS model. The training process involves adjusting the membership functions and rule base to minimize the error between the predicted and actual switching instants.
- **Switching Instant Prediction:** After training, the ANFIS model can accurately predict the switching instants required for the given modulation index to achieve optimal harmonic mitigation.

3. PWM Generation

The predicted switching instants from the ANFIS model are then used to generate the PWM signals. This involves the following steps:

- **Carrier Signal Generation:** A high-frequency triangular or sawtooth carrier signal is generated.
- **Comparison with Reference Signal:** The predicted switching instants determine the points at which the reference signal crosses the carrier signal. This comparison produces the PWM signal, which dictates the on-off states of the power switches in the inverter.

4. Multi-Level Inverter Operation

The generated PWM signals are fed to the 7-level inverter. The 7-level inverter uses these signals to control the power switches, producing a multi-level output voltage waveform. The multi-level structure helps in reducing the harmonic content in the output by approximating a sinusoidal waveform more closely compared to conventional two-level inverters.

5. FFT Analysis

The final step involves the analysis of the inverter's output using Fast Fourier Transform (FFT) to evaluate the harmonic content. This step includes:

- **Harmonic Analysis:** The FFT is performed on the output voltage waveform to decompose it into its harmonic components.
- **Total Harmonic Distortion (THD) Calculation:** The THD, which is a measure of the overall harmonic distortion in the waveform, is calculated from the FFT results.
- **Performance Evaluation:** The effectiveness of the ANFIS-based control in reducing specific harmonic components and the overall THD is assessed. The results are compared with those obtained from conventional PWM strategies to demonstrate the advantages of the proposed methodology.

By following this structured approach, the proposed methodology aims to achieve efficient and precise harmonic mitigation in APFs, leveraging the adaptive and intelligent control capabilities of ANFIS combined with the benefits of multi-level inverter technology.

III. SIMULATION RESULTS

The simulation is performed using the MATLAB software-

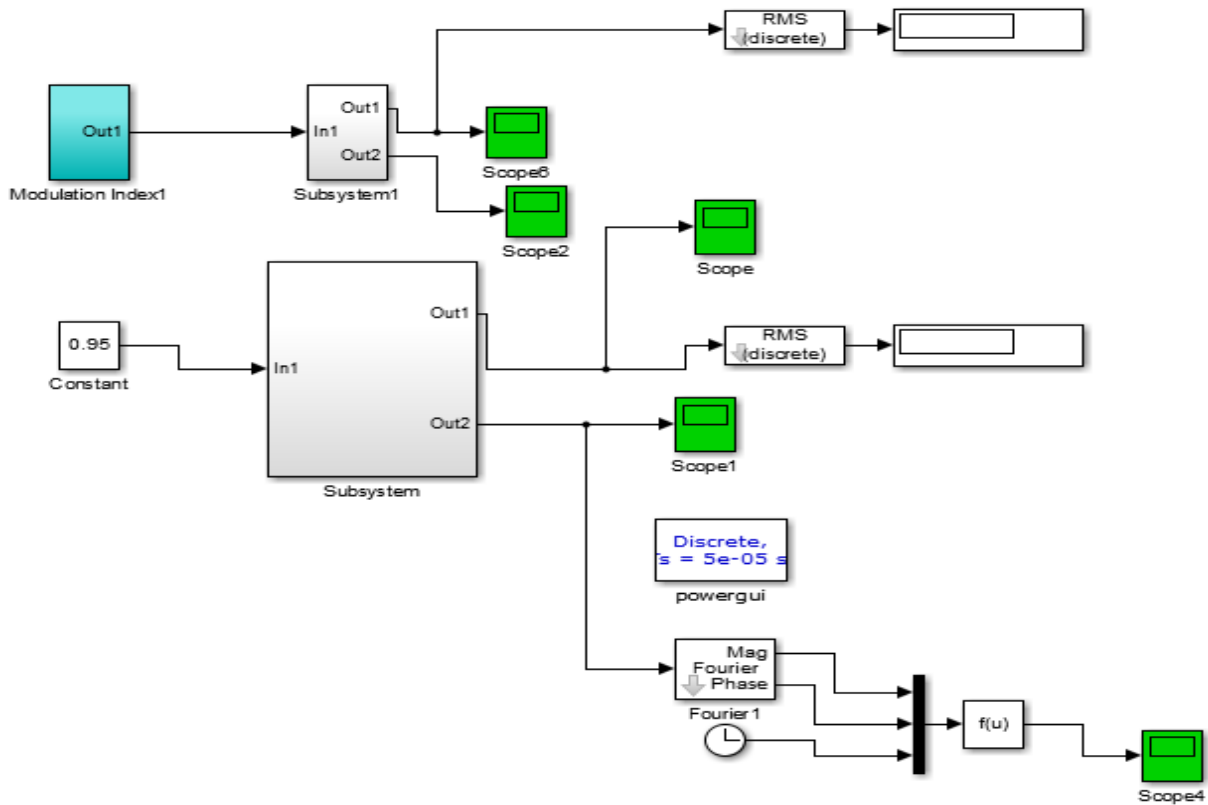


Figure 2: Proposed Model

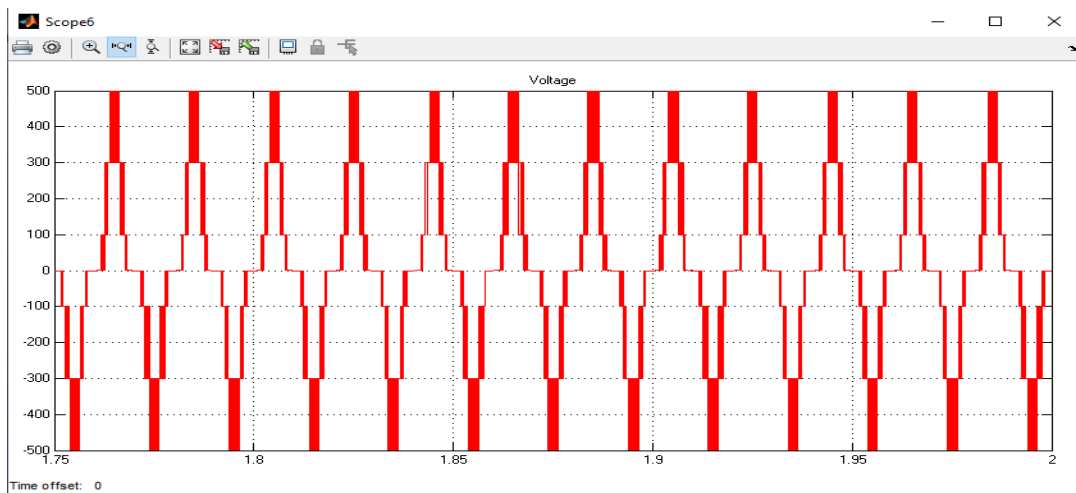


Figure 3: Output Voltage

Figure 3 shows the output waveform. A 7-level multi-level inverter in an Active Power Filter (APF) is designed to generate an output voltage with multiple discrete voltage levels.

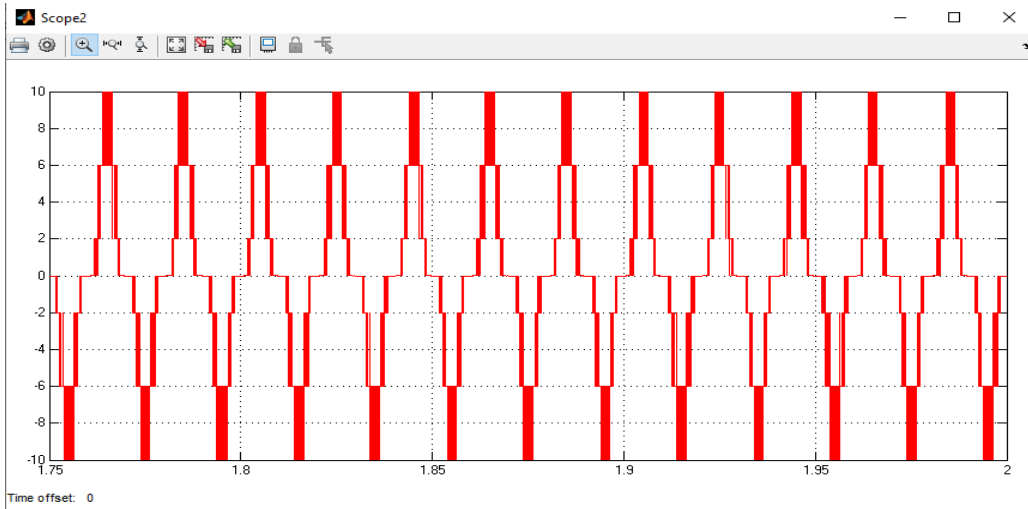


Figure 4: Output Current

Figure 4 is showing the output current. The output current of a 7-level multi-level inverter in an Active Power Filter (APF) is a crucial parameter, especially when considering its role in mitigating harmonics and improving the power quality of an electrical system.

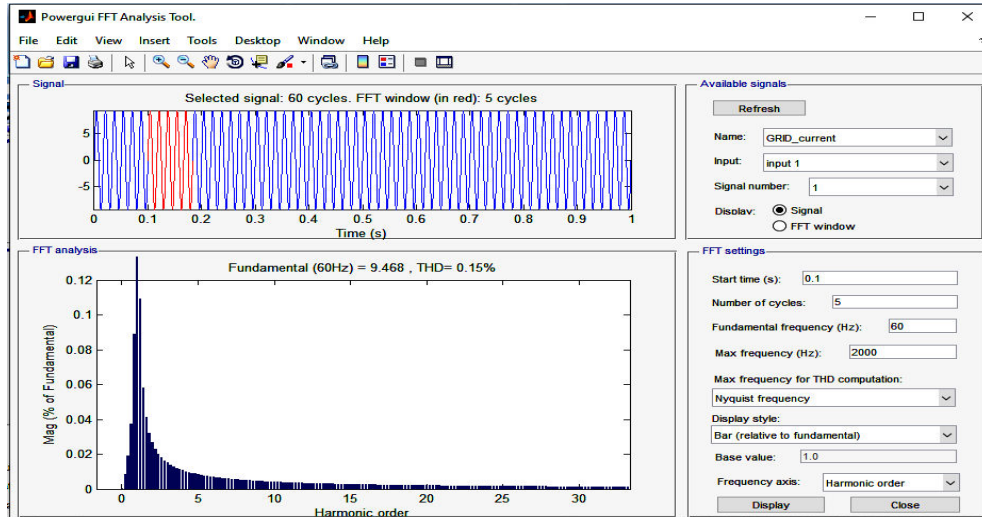


Figure 5: Total Harmonic Distortion (THD)

Figure 5 present Total Harmonic Distortion (THD) which is a measure of the harmonic content present in a signal compared to its fundamental frequency.

Table 1: Result Comparison

Sr No.	Parameters	Previous Work	Present Work
1	Technique	ANN	ANFIS
2	Voltage	200V	500V
3	Current	Not Mentioned	10A
4	THD	3.59%	0.15%

IV. CONCLUSION

For the purpose of asymmetric selective harmonic current mitigation PWM in active power filters, the Adaptive Neuro-Fuzzy Inference Systems (ANFIS) are presented in this study. The simulation is carried out with the assistance of the MATLAB programs. While the previous work was based on artificial neural networks (ANN), the findings of the simulation reveal that the suggested work is based on adaptive neuro-fuzzy inference systems (ANFIS). In the work that is being presented, the overall harmonic distortion has been optimized to be 0.15%, while in the work that came before it was 3.59%. By the work that was suggested, the voltage that was attained was 500V, and the current value that was optimized was 10A, while the previous value was 200V. As a result, the work that has been suggested is much superior to the work that has been done in the past in terms of the approach that was used and the performance of the parameters that were computed.

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