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Adaptive Neuro-Fuzzy Inference Systems (ANFIS) for Asymmetric Selective Harmonic Current Mitigation PWM in Active Power Filters

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***Abstract*— The escalating demand for power quality enhancement in electrical systems has spurred innovative solutions, and among them, Adaptive Neuro-Fuzzy Inference Systems (ANFIS) have gained prominence. This paper explores the application of ANFIS in the context of Asymmetric Selective Harmonic Current Mitigation Pulse Width Modulation (PWM) in Active Power Filters (APFs). ANFIS, a hybrid intelligent system combining artificial neural networks (ANNs) and fuzzy logic, exhibits a remarkable ability to adapt and learn complex patterns, making it an effective tool for addressing the non-linear and dynamic characteristics of power systems. The primary focus of this study is to employ ANFIS for the control and optimization of PWM strategies in APFs to mitigate asymmetric selective harmonic currents. Simulation is performed using the MATLAB software. Simulated results shows that the reduction in the harmonic distortion.**

Keywords*— *ANFIS, ANN, Fuzzy, Asymmetric, Harmonic, PWM, Active, Power Filters.

I. INTRODUCTION

In the realm of power systems, the proliferation of non-linear loads and the widespread use of power electronics have led to increased harmonic distortions, posing significant challenges to power quality. Active Power Filters (APFs) have emerged as an effective solution to counteract these harmonic distortions and maintain the integrity of the electrical grid. However, the presence of asymmetric selective harmonic currents demands advanced control strategies to ensure optimal performance.

The Seven-Level Inverter in APFs finds application in various industrial and commercial sectors where stringent power quality standards are imperative. Ongoing research is focused on optimizing control strategies, exploring new modulation techniques, and adapting the technology for integration with emerging smart grid systems, making it an exciting area of development in power electronics.

The 7-Level Inverters into Active Power Filters represent a promising avenue for addressing power quality challenges in modern electrical systems. The enhanced harmonic mitigation capabilities and improved voltage waveform quality make Seven-Level Inverters a key player in the pursuit of a more reliable and efficient power distribution infrastructure.

This work introduces the integration of Adaptive Neuro-Fuzzy Inference Systems (ANFIS) into the control framework of APFs, specifically focusing on Pulse Width Modulation (PWM) strategies for harmonic mitigation. ANFIS, a hybrid intelligent system, combines the learning capabilities of artificial neural networks (ANNs) and the rule-based reasoning of fuzzy logic. This integration endows ANFIS with the ability to adapt to complex and dynamic systems, making it a suitable candidate for addressing the challenges posed by the non-linear and asymmetrical nature of selective harmonic currents.

The proposed approach leverages the adaptive and self-learning nature of ANFIS to dynamically adjust the PWM patterns in real-time, ensuring effective mitigation of asymmetric selective harmonic currents. By doing so, the system can respond promptly to variations in load conditions, ensuring robust and efficient performance in mitigating harmonic distortions.

The subsequent sections of this paper delve into the theoretical foundations of ANFIS, the intricacies of selective harmonic current mitigation, and the design and implementation of the ANFIS-based PWM control strategy

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within the context of APFs. Through comprehensive simulations and analyses, the efficacy of the proposed approach is evaluated, demonstrating its potential to significantly enhance the performance of APFs in mitigating asymmetric selective harmonic currents and thereby improving overall power quality in electrical systems.

II. PROPOSED MODEL AND METHODOLOGY

The proposed model is as following-

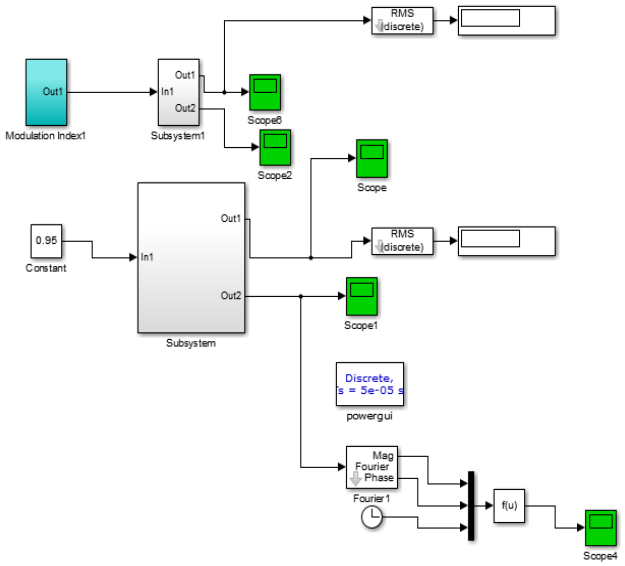

Figure 1: Proposed model

The methodology and working is as following-

1. **Input Data Acquisition:** The ANFIS-based control system for Asymmetric Selective Harmonic Current Mitigation PWM in Active Power Filters (APFs) starts with the acquisition of input data. This involves monitoring the electrical parameters of the power system, such as voltage, current, and harmonic content. The system gathers real-time data to capture the dynamic behavior of the electrical grid.

2. **Fuzzification of Input Data:** Fuzzification is a crucial step where the crisp numerical input data is transformed into fuzzy sets. Fuzzy logic allows for the representation of uncertainty and imprecision in the data. Membership functions are defined to associate each input variable with linguistic terms, converting precise numerical information into linguistic variables like "high," "medium," or "low."

3. **Neural Network Training:** The neural network component of ANFIS plays a crucial role in adjusting the parameters (weights and biases) to optimize the mapping between fuzzy input variables and the desired output. Training involves using a dataset with known input-output pairs to update the neural network parameters through a learning algorithm. Hybrid learning algorithms, often based on a combination of gradient descent and least-squares estimation, are commonly employed in ANFIS.

4. **Fuzzy Inference System (FIS) Operation:** The fuzzy inference system uses the fuzzified input data and the rule base to generate intermediate fuzzy outputs. Each rule's contribution to the overall output is determined based on the degree of matching between the input data and the rule's conditions. These intermediate outputs are aggregated to produce a fuzzy output.

5. **PWM Signal Generation:** The crisp output obtained after de-fuzzification represents the desired Pulse Width Modulation (PWM) signal. In the context of APFs for asymmetric selective harmonic current mitigation, this PWM signal determines the switching pattern of the inverter, generating compensating currents to counteract the undesired harmonic components. The adaptability of ANFIS ensures that the PWM signals are dynamically adjusted in real-time to accommodate changes in the power system conditions.

6. **Implementation in Active Power Filters:** The final PWM signals generated by the ANFIS-based control system are implemented in the active power filter's inverter. The inverter, under the influence of the ANFIS-based control, injects compensating currents into the power system, effectively mitigating asymmetric selective harmonic currents and improving power quality.

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III. SIMULATION RESULTS

The simulation is performed using the MATLAB software-

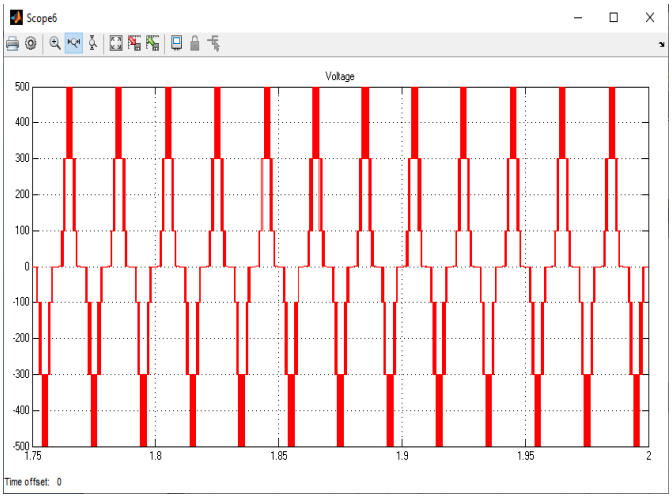

Figure 2: Output Voltage

Figure 2 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.

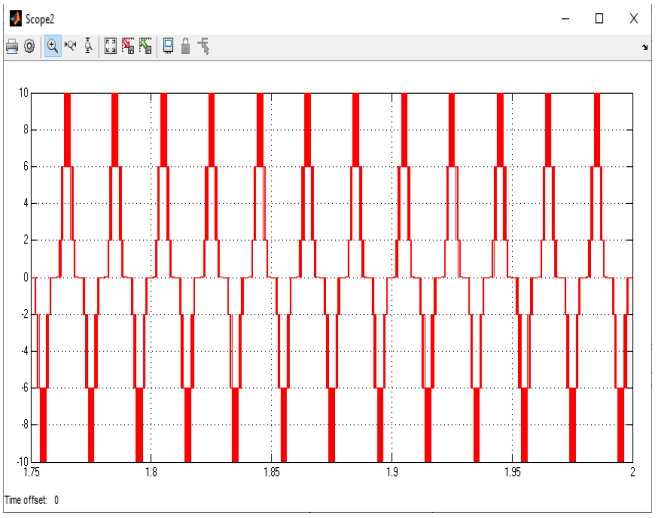

Figure 3: Output Current

Figure 3 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.

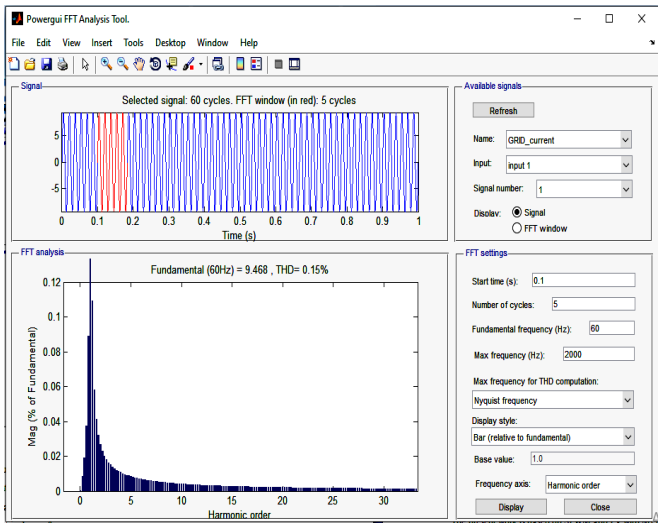

Figure 4: Total Harmonic Distortion (THD)

Figure 4 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%

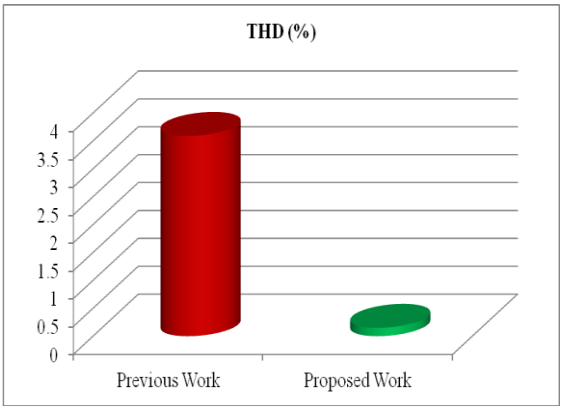

Figure 5: THD Comparison

The figure 5 shows the graphical representation of the total harmonic distortion value of the previous and the proposed work.

IV. CONCLUSION

This paper presents the Adaptive Neuro-Fuzzy Inference Systems (ANFIS) for asymmetric selective harmonic current mitigation PWM in active power filters. The simulation is performed using the MATLAB software. Simulation results show the proposed work is based on Adaptive Neuro-Fuzzy Inference Systems (ANFIS) while previous work is based on ANN. The total harmonic distortion is optimized in the proposed work is 0.15% while in previous it is 3.59%. The achieved voltage is 500V and optimized current value is 10A by the proposed work while previous it is 200V. Therefore the proposed work is significant better than the previous work in terms of the applied technique and calculated performance of the parameters.

REFERENCES

1. A. Moeini, M. Dabbaghjamanesh, J. W. Kimball and J. Zhang, "Artificial Neural Networks for Asymmetric Selective Harmonic Current Mitigation-PWM in Active Power Filters to Meet Power Quality Standards," in IEEE Transactions on Industry Applications, doi: 10.1109/TIA.2020.3007596.
2. L. Zhang, W. Hong, C. Gao, R. Liu, Q. Yu and C. Wei, "Selected Harmonic Mitigation PWM Power Matching Control Strategy for Asymmetric Cascaded H-Bridge Multilevel Inverter," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 10, no. 4, pp. 4059-4072, Aug. 2022, doi: 10.1109/JESTPE.2021.3137337.
3. C. Zhang, R. Zhang, X. Xing and X. Li, "Circulating Current Mitigation and Harmonic Current Compensation for Multifunction Parallel Three-Level Four-Leg Converters," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 10, no. 3, pp. 2805-2818, June 2022, doi: 10.1109/JESTPE.2021.3072437.
4. S. P. Biswas et al., "A Modified Reference Saturated Third Harmonic Injected Equal Loading PWM for VSC-Based Renewable Energy Systems," in IEEE Transactions on Applied Superconductivity, vol. 31, no. 8, pp. 1-5, Nov. 2021, Art no. 5000405, doi: 10.1109/TASC.2021.3096484.
5. B. Zhang, C. Zhang, X. Xing, X. Li and Z. Chen, "Novel Three-Layer Discontinuous PWM Method for Mitigating Resonant Current and Zero-Crossing Distortion in Vienna Rectifier With an LCL Filter," in IEEE Transactions on Power Electronics, vol. 36, no. 12, pp. 14478-14490, Dec. 2021, doi: 10.1109/TPEL.2021.3088610.
6. A. Mishra, S. Chauhan, P. Karuppanan and M. Suryavanshi, "PV based Shunt Active Harmonic Filter for Power Quality improvement," 2021 International Conference on Computing, Communication, and Intelligent Systems (ICCCIS), Greater Noida, India, 2021, pp. 905-910, doi: 10.1109/ICCCIS51004.2021.9397214.
7. B. Wang, L. Luo, W. Fu, W. Hua, G. Wang and Z. Wang, "Study on the PWM Ripple Current Based Turn Fault Detection for Interior PM Machine," in IEEE Transactions on Transportation Electrification, vol. 7, no. 3, pp. 1537-1547, Sept. 2021, doi: 10.1109/TTE.2021.3050560.
8. R. Shen and H. S. -H. Chung, "Mitigation of Ground Leakage Current of Single-Phase PV Inverter Using Hybrid PWM With Soft Voltage Transition and Nonlinear Output Inductor," in IEEE Transactions on Power Electronics, vol. 36, no. 3, pp. 2932-2946, March 2021, doi: 10.1109/TPEL.2020.3016867.
9. R. Sarker, A. Datta and S. Debnath, "FPGA-Based High-Definition SPWM Generation With Harmonic Mitigation Property for Voltage Source Inverter Applications," in IEEE Transactions on Industrial Informatics, vol. 17, no. 2, pp. 1352-1362, Feb. 2021, doi: 10.1109/TII.2020.2983844.
10. A. Moeini, M. Dabbaghjamanesh and J. W. Kimball, "Q-Learning-Based Smart Selective Harmonic Current Mitigation-PWM (S2HCM-PWM) for Grid-Connected Converters," 2020 IEEE Energy Conversion Congress and Exposition (ECCE), Detroit, MI, USA, 2020, pp. 5068-5075, doi: 10.1109/ECCE44975.2020.9236369.