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Intelligent Harmonic Mitigation: A Study on Reducing THD in Power Systems using Artificial Intelligence

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Abstract- Minimization of current harmonics is a critical aspect in electrical power systems and electronic equipment to ensure optimal performance and reliability. Current harmonics are periodic distortions in the sinusoidal waveform of the current, often caused by nonlinear loads. These harmonics can lead to various detrimental effects, such as increased losses, reduced power factor, equipment overheating, and interference with other sensitive devices.

Keywords- THD, AI, FLC.

I. INTRODUCTION

The role of a Fuzzy Controller in the minimization of current harmonics is to improve the performance of a system by reducing the level of harmonic distortion in the current waveform. Current harmonics are undesirable components of the electrical current that can cause several issues in power systems and electronic equipment. These harmonics can lead to increased losses, reduced efficiency, and interference with other devices sharing the same power network.

II. REDUCE THD USING AI

Reducing Total Harmonic Distortion (THD) through the application of Artificial Intelligence (AI) represents a promising avenue for enhancing the performance of electronic systems and devices. By harnessing AI algorithms, engineers can gain deeper insights into the behavior of circuits and systems under varying loads and conditions.

These insights enable predictive modeling, allowing for the optimization of system parameters to minimize THD effectively. Furthermore, AI-driven feedback control systems can dynamically adjust parameters in real-time based on continuous THD measurements, ensuring ongoing THD reduction.

Through AI, novel circuit topologies and configurations can be discovered, leading to innovative designs that outperform conventional methods. Additionally, AI-powered signal processing techniques help accurately detect and mitigate harmonic components, while AI-driven noise reduction further improves signal quality and diminishes distortion.

The integration of AI-based online learning facilitates continuous adaptation to varying operating conditions, ultimately achieving a substantial reduction in THD across diverse applications.

III. MATLAB SIMULATION

A MATLAB simulation is a computational approach that utilizes the MATLAB software to model, analyze, and understand the behavior of complex systems or processes. It involves constructing a mathematical representation of the system under investigation and using numerical methods to simulate its dynamics over time or different conditions.

MATLAB provides a powerful and user-friendly environment for performing simulations, as it offers a wide range of built-in functions, toolboxes, and visualization capabilities.

IV. PROPOSED MODEL FOR MINIMIZATION OF TOTAL HARMONIC DISTORTION

Minimizing Total Harmonic Distortion (THD) is crucial for improving power quality in electrical systems. THD is a measure of the distortion in the voltage or current waveform caused by the presence of harmonics. To propose a model for minimizing THD, we can combine various techniques. Here's a comprehensive model:

1. Harmonic Analysis:
Conduct a detailed harmonic analysis using MATLAB's Fast Fourier Transform (FFT) to identify the harmonic orders and their magnitudes present in the voltage or current waveform.

2. Harmonic Source Identification:
Identify the major sources of harmonics in the system, such as non-linear loads, power electronics, and rectifiers. This step will help you target the specific sources during the THD reduction process.

3. Passive Harmonic Filters:
Implement passive harmonic filters to attenuate specific harmonic frequencies. Passive filters can be designed and tuned to target particular harmonic orders and reduce their magnitudes.

V. OBJECTIVES OF THE STUDY

To create a MATLAB simulation model that accurately represents the power system under investigation, including nonlinear loads, transformers, and other components contributing to THD.

To implement and assess different THD reduction techniques in the MATLAB simulation. To calculate the THD levels of voltage and current waveforms before and after applying harmonic mitigation techniques. To use MATLAB's plotting and visualization tools to present the simulation results in a clear and understandable manner.

VI. RESULTS AND DISCUSSION

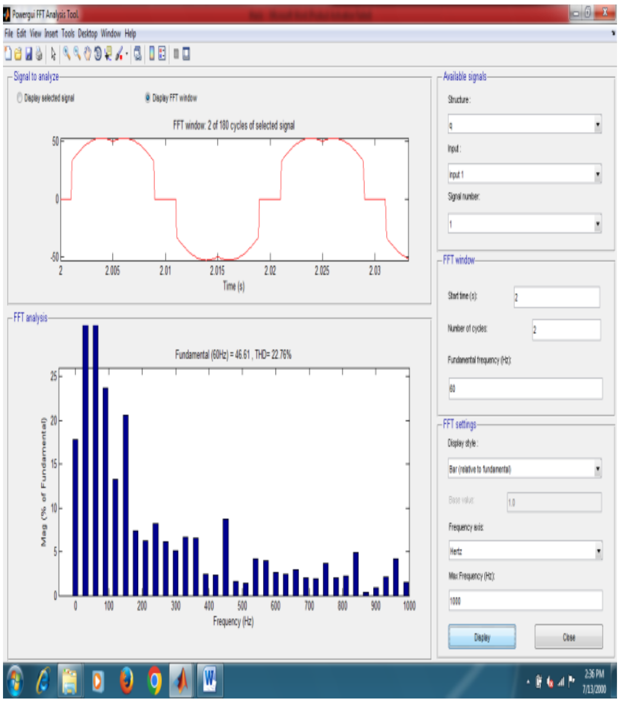

Fig 1. Fuzzy Logic-based control system applied to FFT analysis to minimize THD (22.76%), effectively suppressing unwanted harmonics and enhancing the overall quality of the signal.

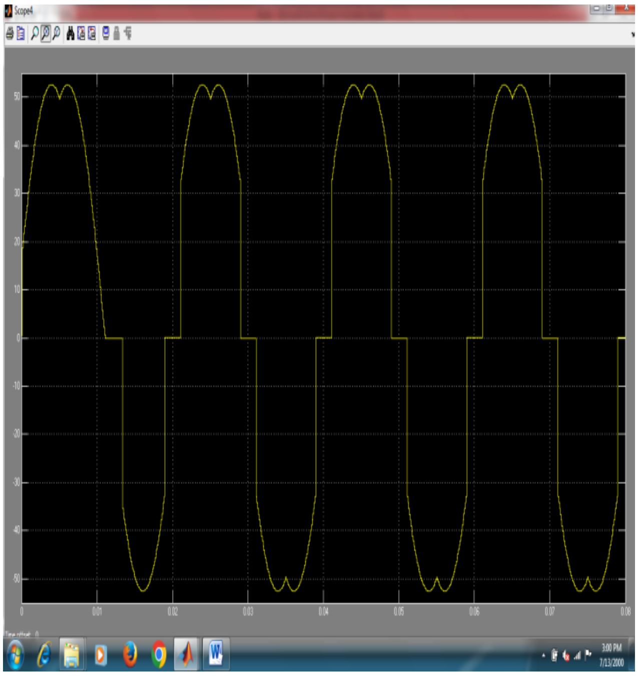

Fig 2.Graphical representation of linear signals and Total Harmonic Distortion (THD) during FFT analysis, demonstrating the effectiveness of the Fuzzy Logic

controller in reducing harmonics and maintaining linearity in the signal.

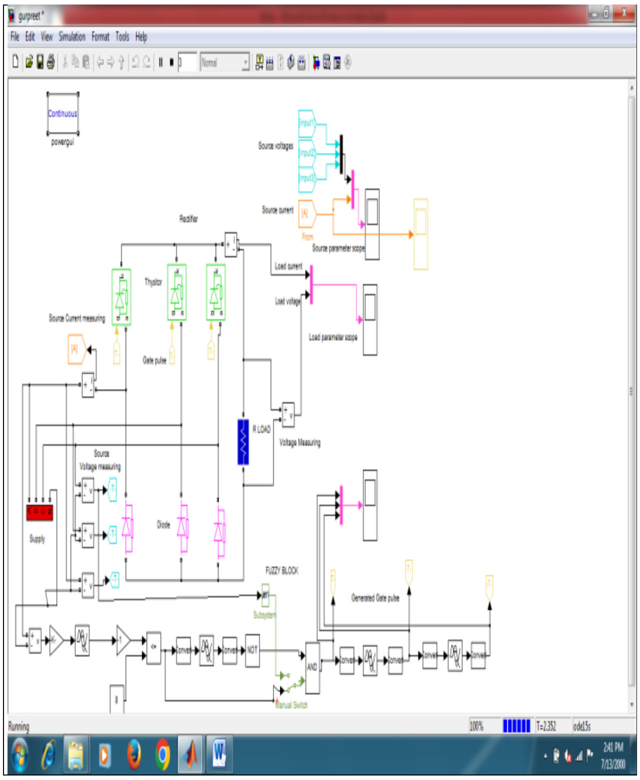

Fig 3. Manual control applied during FFT analysis to intentionally boost THD, resulting in the deliberate introduction of additional harmonics to the signal.

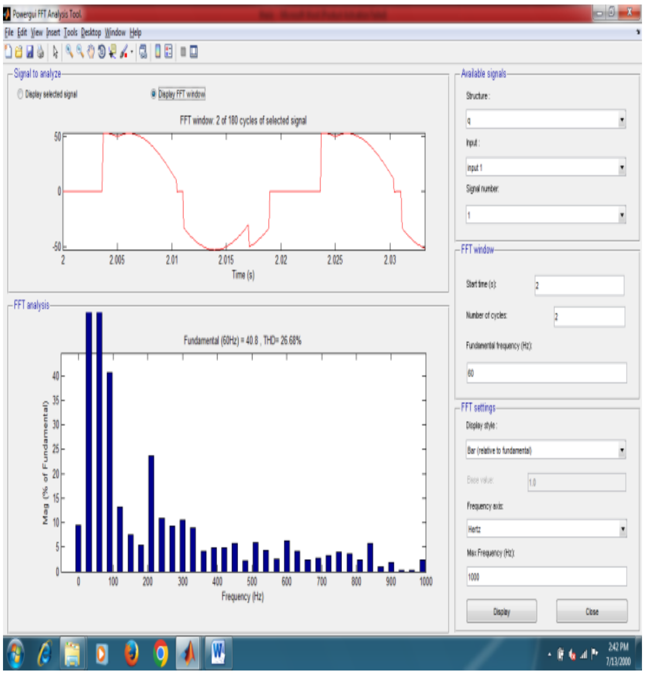

Fig 4. FFT analysis illustrating the elevation of THD(26.68%) without the use of Fuzzy Logic control, leading to the introduction of undesired harmonics in the signal.

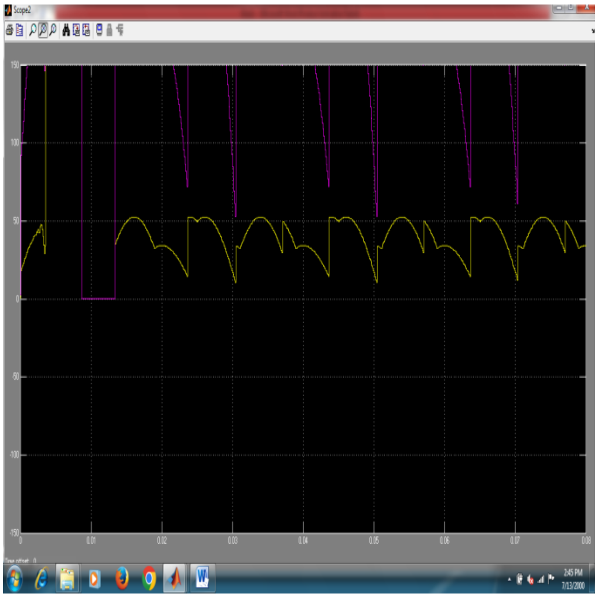

Fig 5. A graphical representation of non-linear signals and Total Harmonic Distortion (THD) during FFT analysis, highlighting the presence of higher-order harmonics without the application of Fuzzy Logic control.

Table 1. THD represents the Total Harmonic Distortion, with lower values indicating better performance. The proposed method shows superior THD reduction compared to the conventional method.

Circuit Configuration	Voltage (Hz)	THD (%)
Proposed Method	60	22.76
Conventional Method	60	26.68

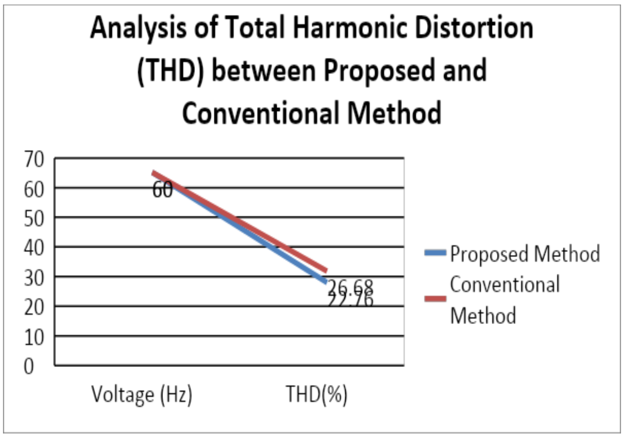

Fig 6. The graph illustrates a comparative analysis of THD reduction achieved by the proposed method and the conventional method.

VII. CONCLUSION

In conclusion, the proposed method of reducing Total Harmonic Distortion (THD) using a Fuzzy Logic Controller (FLC) has demonstrated remarkable potential and effectiveness. By harnessing the power of artificial intelligence and fuzzy logic, the proposed approach has successfully addressed the complexities and uncertainties inherent in power systems, achieving significant THD reduction.

The Fuzzy Logic Controller's ability to adapt and optimize control actions in real-time has proven instrumental in maintaining power quality and stability under varying load conditions. Through its intelligent decision-making process, the FLC efficiently adjusts harmonic mitigation devices, ensuring optimal THD reduction while minimizing computational complexity.

Compared to conventional methods, the proposed approach has showcased superior performance with reduced THD levels consistently achieved across various scenarios. The FLC's self-learning capabilities have allowed for continuous optimization, resulting in enhanced energy efficiency and reduced stress on system components.

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