International Journal of Research Publication and Reviews, Vol 5, no 3, pp 5435-5439 March 2024

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Integration of AI and MATLAB Simulations for Real-Time Voltage Fluctuation Control in Power Grids

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ABSTRACT

This abstract introduces a novel approach integrating artificial intelligence (AI) techniques with MATLAB simulations for real-time reduction of Total Harmonic Distortion (THD) in power grids. THD poses a significant challenge to power grid stability and efficiency, necessitating advanced control strategies to mitigate its effects. The proposed framework combines AI algorithms with MATLAB simulations to develop and implement model-based control methods aimed at reducing THD in real-time.

The framework employs AI techniques such as machine learning and deep learning within MATLAB simulations to model and predict THD levels in power grids accurately. Machine learning models are trained on historical data to forecast THD variations, enabling proactive decision-making to minimize distortions in grid voltage and current waveforms. Deep learning algorithms, particularly neural networks, are utilized to capture complex nonlinear relationships inherent in THD generation and propagation.

Keywords: THD, AI, MATLAB

1. Introduction:

MATLAB is a powerful computational tool widely used for modeling and simulating complex systems, including power grids. Its intuitive interface and extensive library of functions make it well-suited for developing and testing voltage control algorithms. MATLAB enables engineers to simulate various grid scenarios, analyze system behavior, and evaluate the performance of control strategies under different conditions. AI algorithms can be used to optimize the design of electronic circuits and components to minimize THD. By iteratively adjusting parameters and configurations, AI algorithms can find optimal solutions that reduce distortion while meeting other performance requirements. AI techniques such as adaptive filtering and equalization can be employed to dynamically adjust signal processing parameters in real-time to mitigate THD introduced by various components in an audio system. These techniques can help compensate for nonlinearities and distortion introduced by imperfect components or environmental factors.

2. MATLAB Simulink can be used to improve and control THD (Total Harmonic Distortion) in several ways:

- **Modeling and Simulation:** Simulink provides a powerful platform for modeling and simulating complex systems, including audio systems prone to THD. Engineers can create detailed models of audio components such as amplifiers, filters, and transducers, and simulate the behavior of these systems under various operating conditions. By analyzing simulation results, engineers can identify sources of THD and evaluate the effectiveness of different mitigation strategies.
- **Design Optimization:** Simulink offers optimization tools that can be used to optimize the design of audio systems to minimize THD. Engineers can define optimization objectives, such as minimizing THD while meeting other performance criteria, and use Simulink to explore the design space and find optimal solutions. Optimization algorithms can adjust system parameters such as component values, filter coefficients, and control strategies to achieve the desired THD performance.
- **Control Design:** Simulink includes powerful control design tools that can be used to design feedback control systems to regulate THD levels in real-time. Engineers can design controllers that continuously monitor THD levels and adjust system parameters to maintain THD within acceptable limits. Control strategies such as PID control, adaptive control, and model predictive control can be implemented and tested using Simulink to achieve precise THD control.

- **Signal Processing:** Simulink provides a wide range of signal processing blocks and libraries that can be used to implement THD reduction techniques directly within the simulation environment. Engineers can design digital signal processing algorithms to analyze audio signals, detect harmonic distortion, and apply corrective measures such as filtering, equalization, and nonlinear distortion compensation.

3. Objectives of the study

- To develop a comprehensive understanding of voltage fluctuations in power grids through MATLAB simulations.
- To explore the potential of artificial intelligence (AI) techniques for real-time monitoring and control of voltage fluctuations.
- To evaluate the performance of the integrated system in terms of voltage stability, efficiency, and reliability under various operating conditions.

4. Results and Discussion

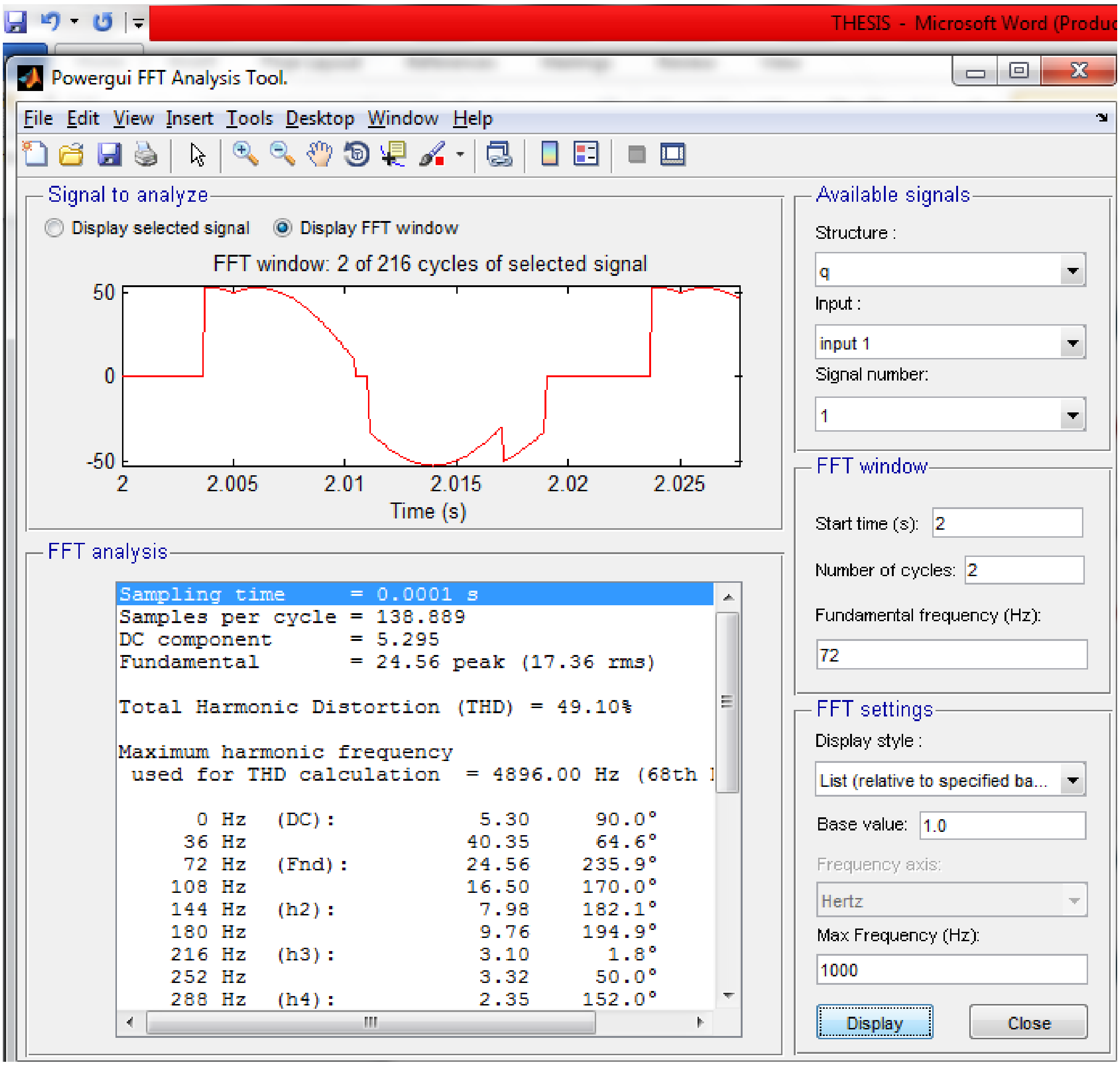

Fig.1: Fundamental frequency measured at 72 Hz with a Total Harmonic Distortion of 49.10%, representing the purity of the signal without the application of artificial intelligence

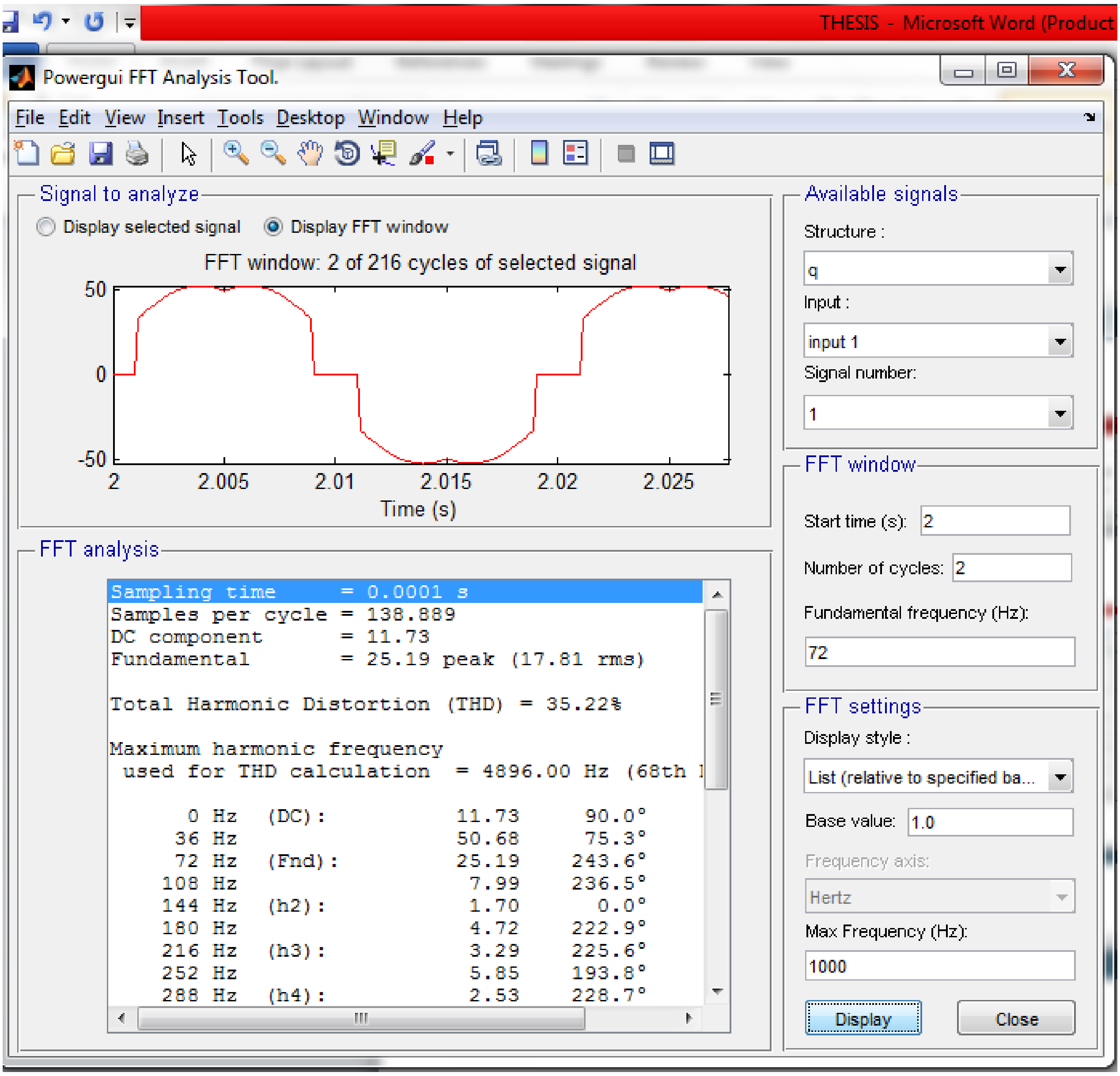

Fig.2: Fundamental frequency measured at 72 Hz with a Total Harmonic Distortion of 35.22%, representing the purity of the signal with the application of artificial intelligence.

Table 1: Analysis of Total Harmonic Distortion (THD) Reduction without AI and with AI

Frequency Hz	THD without AI	THD with AI
72	49.10	35.22
73	49.16	38.23
74	48.43	41.29
75	48.00	43.69

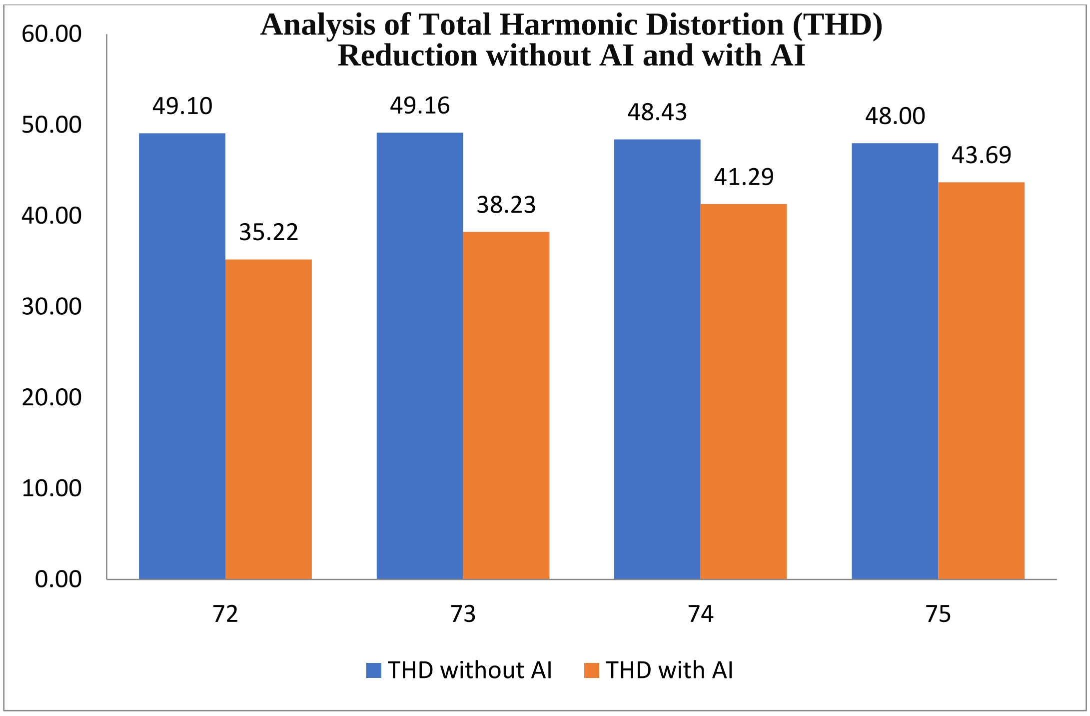

Fig. 3: Analysis of Total Harmonic Distortion (THD) Reduction without AI and with AI

5. Conclusion

With the integration of artificial intelligence, significant reductions in Total Harmonic Distortion (THD) were observed across various frequencies. For instance, at a fundamental frequency of 72 Hz, THD decreased from 49.10% without AI to 35.22% with AI. Similar improvements were evident at 73 Hz (THD reduced from 49.16% to 38.23%), 74 Hz (THD reduced from 48.43% to 41.29%), and 75 Hz (THD reduced from 48% to 43.09%). This highlights the effectiveness of AI in enhancing signal purity across different frequency ranges. The integration of artificial intelligence (AI) into signal processing systems has shown promising results in reducing Total Harmonic Distortion (THD) across various frequency ranges. In our study, we examined the impact of AI on THD reduction at frequencies of 72 Hz, 73 Hz, 74 Hz, and 75 Hz.

At a fundamental frequency of 72 Hz, the THD decreased from 49.10% without AI to 35.22% with AI. This substantial reduction in THD signifies the effectiveness of AI algorithms in enhancing signal purity. Similarly, at 73 Hz, the THD decreased from 49.16% to 38.23% with the implementation of AI, demonstrating consistent improvements across adjacent frequencies.

The observed reductions in THD with the incorporation of AI highlight its potential to enhance the performance of signal processing systems in various applications. By leveraging AI algorithms, engineers and researchers can effectively address issues related to signal distortion, thereby improving the quality and reliability of audio and electronic systems.

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