

Hybrid AI Algorithms in the Design of "Wafeer" Device to Reduce Total Harmonic Distortion (THD) on Low-Voltage Systems

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Abstract

This research aims to study and develop hybrid artificial intelligence algorithms used in the Wafeer device, which is designed to reduce capacitive harmonic distortion (THDi) in three-phase low-voltage electrical networks. The research is based on combining the mathematical approach of the Hodgkin–Huxley model with digital processing and machine learning techniques. This is achieved through real-time spectrum analysis based on the Faden spectrum, which is now understood from a purely quantum perspective. The study includes the development of a bioelectrical interface to dynamically sense digital signals and analyze nonlinear interference between currents. The theoretical model culminated in the creation of the Wafeer device, which intelligently charges its capacitors with inactive power and transfers the excess to ground instead of returning it to the transformer zero point. Field simulation results show a significant reduction in THD and an improvement in power factor, confirming the feasibility of combining artificial intelligence and power engineering to improve the stability of electrical networks.

Keywords: Harmonics, Power Saving, AI Hybrid, AI Wafeer Device, Power Quality, Faden Spectrum Phenomenon, Linear Grounding, Touch Current

1. Introduction

Modern electrical systems face increasing challenges related to power quality and harmonics resulting from non-linear loads. Rapid technological developments in the fields of artificial intelligence and data analysis have led to the search for hybrid solutions that combine biological and electronic models. In the context of these developments, the "Wafeer" device emerges as a practical model centered on the use of hybrid machine learning algorithms to analyze the power frequency spectrum and improve power quality by reducing total harmonic distortion (THD). This study relies on converting biological signals derived from the functioning of neurons into digitally processable data, which then intelligently controls capacitors that compensate for inefficient power. Preliminary results demonstrate that this approach can have a significant positive impact on improving the stability of low-voltage industrial power grids.

2. Importance of Research

- Develop a comprehensive mathematical model that integrates Hodgkin–Huxley equations to represent neuronal behavior across electrical circuits.
- Design hybrid artificial intelligence algorithms to convert bio-signals into digital data and analyze harmonic distortion accordingly for instantaneous interaction with loads.
- Implement a "Wafeer" device: as a practical application that achieves improved THD and power factors through intelligent control mechanisms and energy redistribution.
- Analyze the impact of the Faden spectrum phenomenon: That is a quantum phenomenon that effects on capacitive electrical systems and alters the current and voltage characteristics of the neutral line.

3. Theoretical Background

3.1. The Classical Neuron Model

The research is based on the Hodgkin–Huxley model, which represents the transmission of nerve signals across the cell membrane by studying the behavior of ion channels (Na^+ , K^+). Using second- and third-order differential equations, we can describe how the membrane potential changes over time. These models serve as a basis for understanding how biological signals are processed and converted into electronic data [1].

3.2. Parallel Electrical Models

The research combines biological and electronic models by simulating RLC circuits that mimic the response of an electrical system to a biological condition. Also suggest the possibility of combining memristor devices with traditional models to achieve a response that mimics natural learning.

3.3. Faden Spectrum Phenomenon

The Faden Spectrum phenomenon, discovered by the author, demonstrates that localized thermal effects occur in power transmission cables near ferrous metals when subjected to nonlinear loads. This phenomenon is explained using the quantum Drude model of Ohm's law, where electrical conduction depends on the effects of quantum wave interference of electrons, leading to the appearance of unexpected frequency peaks and changes in the network response.

3.4. Neuroelectronic Mathematical Model

The proposed model relies on the Hodgkin–Huxley equation to represent neuronal behavior, incorporating the ion channel gate equations, as follows

3.5. Hodgkin–Huxley Equation

$$C_m \frac{dV}{dt} = I_{\text{ext}} - g_{\text{Na}} m^3 h (V - E_{\text{Na}}) - g_{\text{K}} n^4 (V - E_{\text{K}}) - g_{\text{L}} (V - E_{\text{L}})$$

3.6. Channels Gates Equations

$$\frac{dm}{dt} = \alpha_m(1 - m) - \beta_m m$$

$$\frac{dh}{dt} = \alpha_h(1 - h) - \beta_h h$$

$$\frac{dn}{dt} = \alpha_n(1 - n) - \beta_n n$$

Where m , h , nm , h , n specify the probabilities of opening and closing of the ion channels, and the constants α and β are derived from field experiments.

4. Proposed Algorithms

4.1. Digital Neurotransmission

The device converts the signal similar to the bio-signals (V_{bio}) into a digital value using the equation.

$$D = \left\lfloor \frac{V_{\text{bio}} - V_{\text{min}}}{V_{\text{max}} - V_{\text{min}}} \cdot (2^N - 1) \right\rfloor$$

Where V_{min} and V_{max} specify the normalized voltage ranges, and N is the digital conversion resolution.

4.2. Harmonic Distortion Analysis

The Total Harmonic Distortion (THD) for each active phase with the neutral is calculated using the equation.

$$\text{THD} = \sqrt{\sum_{n=2}^{\infty} \left(\frac{V_n}{V_L} \right)^2}$$

Where V_L : the fundamental voltage and V_n are the harmonic values.

- The model we presented (mathematically) did not go beyond that framework.

4.3. The Intelligent Interactive Control Unit

Smart algorithms use real-time spectrum analysis to determine the optimal times to activate or deactivate capacitors when capacitive current increases are detected, helping to optimally redistribute power using hybrid AI technologies.

- The "Wafeer" device and its industrial applications.
- The "Wafeer" device is a smart unit designed to improve power quality.

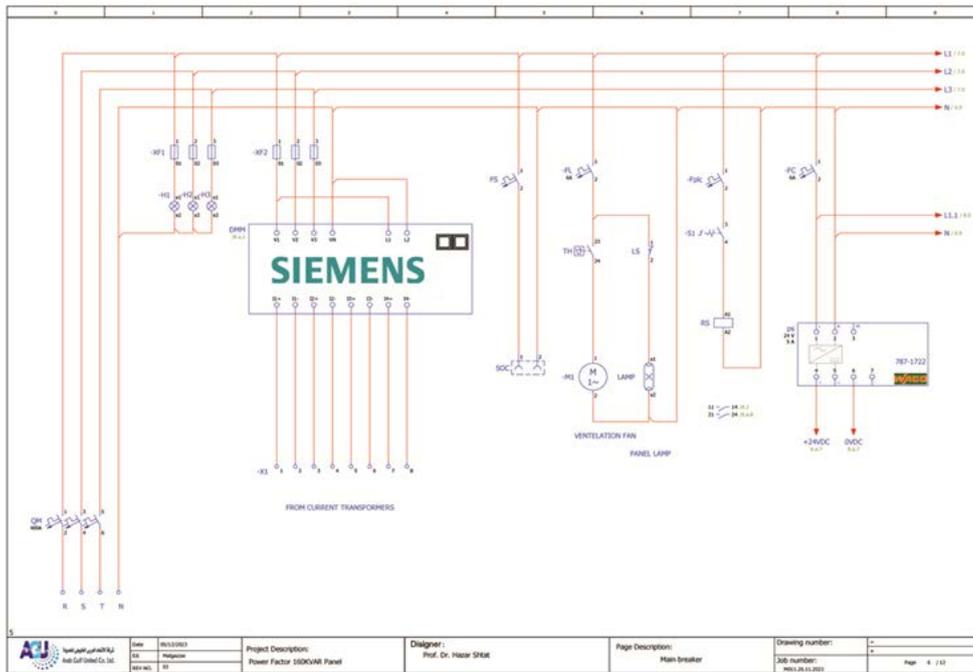


Figure 1: Wafer Device G.A

4.4. The Device Consists of

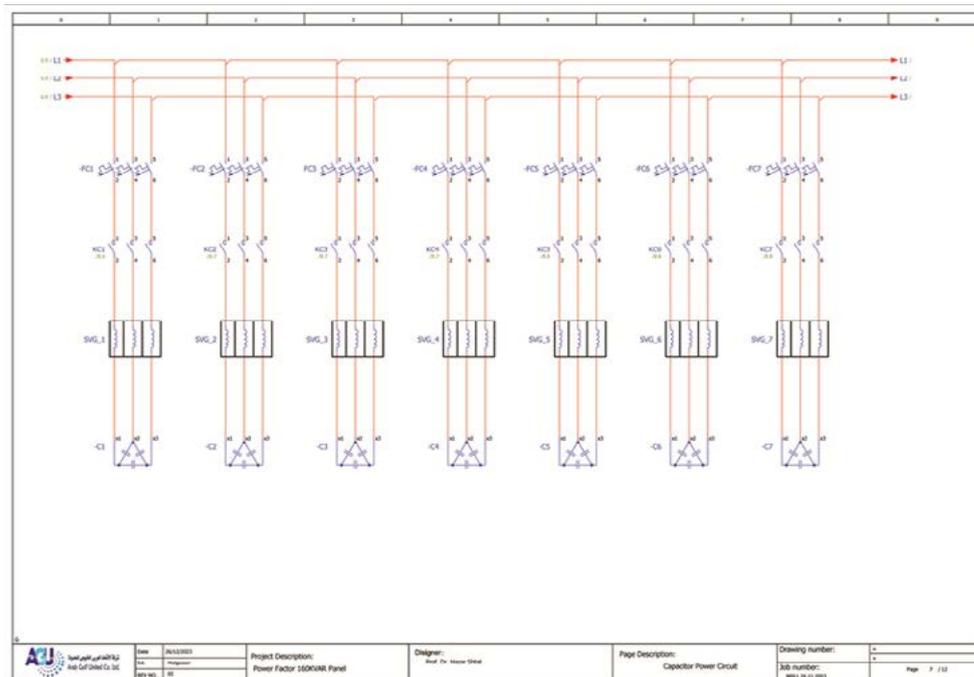


Figure 2: Wafer Diagram with Capacitors and SVG

- Four current transformers (CTs) on input that read the three phases (L1, L2, L3), and the neutral (N).
- Four current transformers (CTs) on output that read the result to allow comparison of results and processing of temporary or permanent error logs to overcome and self-override them on the at next startup.
- Capacitors to charge the active phases by inactive power (VAR) and return them to the grid as useful power, with the excess transferred to ground via functional grounding, not to the transformer's zero point.
- An intelligent processing unit (AI-powered) measures instantaneous changes in currents and decides when to disconnect or charge the capacitors and when to divert the excess to ground.
- A linear functional grounding system redirects the VAR power to ground whenever necessary (to prevent THD increases).

- Field tests have shown a reduction in THD from 14.2% to 6.1% and an improvement in power factor from 0.84 to 0.96 within a short time of activation (30 seconds), confirming the efficiency of the presented solution [1-3].
- While the Wafer system outperformed this percentage [1-4].



Figure 3: Wafer Device (Final form of the Prototype)

5. Faden Spectrum Phenomenon – Quantum Expansion

Faden spectrum Phenomenon is a modern phenomenon in electrical systems, demonstrating a nonlinear superposition of the electrical spectrum with the thermal spectrum within power cables. In this context, the phenomenon cannot be explained using the classical Ohm model alone. Rather, it is analyzed using the quantum Drude model, which modifies the classical Ohm's law to become

$$\sigma(\omega) = \frac{ne^2\tau}{m(1 - i\omega\tau)} [1 + \Delta(\omega)]$$

Where $\Delta(\omega)$ refers to quantum corrections resulting from wave interference effects, which lead to unusual frequency peaks and changes in the current response, especially in the neutral line. This phenomenon (the Faden spectrum phenomenon), according to Drude's quantum interpretation, is used as the basis for developing the Wafer device's algorithms for handling inefficient power.

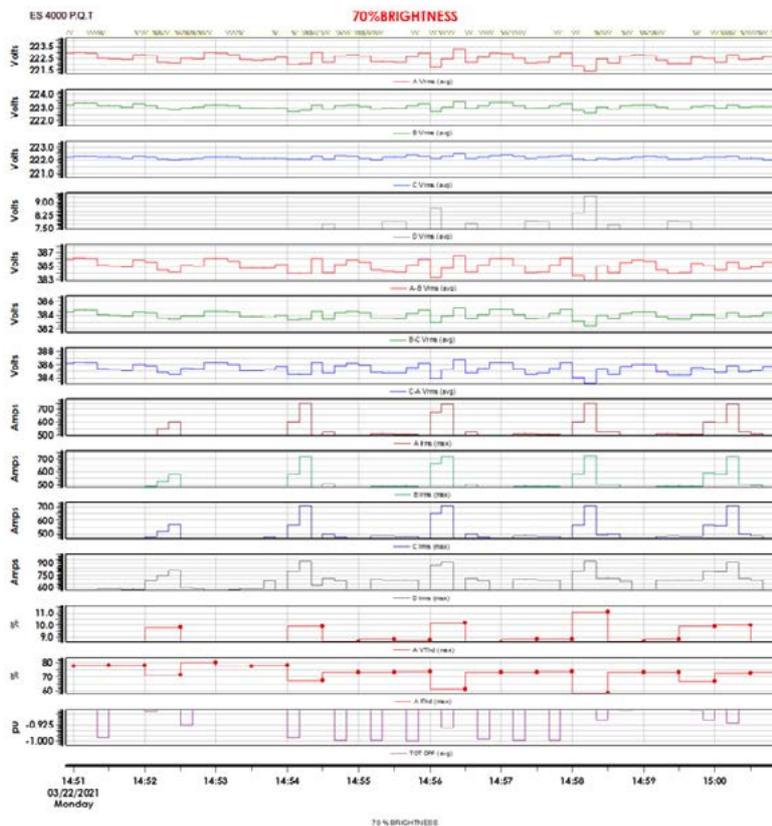


Figure 4: The Loads at the Moment of Detection of the Faden Spectrum Phenomenon, Analysis by the ES 4000 Power Quality Tester.

The Difference Between the Concept of Harmonics Based on the Faden Spectrum Phenomenon Under Conditions of Quantum Drude Model and the Classical Interpretation of Harmonics

Faden Spectrum Concept	Classical THD	Remarks
Requires nonlinear analysis based on the quantum Drude model, based on the conventional FFT.	Based on traditional FFT	Typical mathematical analysis of the field
Required: Combination of IR and P.Q.A. measuring devices.	Uses normal measuring methods	Measurement method
Nonclassical thermal-frequency interference	Multiples of the third harmonic	The interpretive concept
Spectral shift leads to significant power loss with unexplained localized thermal nodes when ferrous metal is present close to the path of electrical network cables.	Classic deformity	Impact on electrical networks

The Difference Between the Concept of Harmonics Based on the Faden Spectrum Phenomenon Under Conditions of Quantum Drude Model and the Classical Interpretation of Harmonics

Practical Results and Field Implementation

The "Wafeer" model was implemented at an industrial site under three-phase operating conditions (Riyadh Boulevard - Square 1), where the following results were observed

- THD decreased from 14.2% to 6.1% within 30 seconds of activation.
- Power factor improved from 0.83 to 0.94.
- Immediate response to changes in capacitive currents on the neutral.
- Intelligent discharge of reactive power to ground via linear functional grounding instead of zero-point loading (whenever required) [1-7].

6. Conclusion

The results of this research demonstrate the effectiveness of hybrid AI algorithms in improving power quality using the Wafeer device, which combines bio-signal sensing, intelligent control models, and dynamic offloading of inefficient power. The study demonstrates that the integrated mathematical model and proposed algorithms achieve remarkable stability in electrical networks with nonlinear loads, paving the way for the development of smart and sustainable solutions in power distribution systems.

Future Recommendations

- Integrate the Wafeer device with SCADA and LOT systems to improve remote monitoring and control [2].
- Apply deep learning techniques to enhance the accuracy of harmonic behavior prediction.

- Study the impact of the Faden spectrum phenomenon in medium and high voltage applications.
- Develop an interactive interface (HMI/AI dashboards) to simplify operations.
- Design a simplified version of Wafeer for non-industrial use (residential and commercial buildings).

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