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# The Use of Active Filter to Mitigate Harmonics in Cryptocurrency Mining Computer

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**ABSTRACT**

Cryptocurrency mining computers act as non-linear loads, introducing significant harmonic distortions that degrade power quality and system efficiency. This study explores the use of a shunt active filter with an inductance of 0.0075 H to reduce harmonics in a high-load cryptocurrency mining rig. Harmonic measurements were collected using a Fluke 43 Power Quality Analyzer and validated through MATLAB/Simulink simulations. Results revealed a substantial reduction in Total Harmonic Distortion in Current (THDi) from 76.62% to 9.18%, achieving compliance with IEEE 519-2014 standards. Additionally, major harmonic orders—specifically the 3rd, 5th, and 7th—were each suppressed by more than 90%. The system's power factor improved markedly from 0.85 to 0.99, indicating enhanced energy efficiency. These outcomes demonstrate the effectiveness of active filters in improving power quality in cryptocurrency mining operations and suggest their practical application in industrial-scale setups to minimize energy losses, extend hardware lifespan, and support grid stability.
**Keyword:** *Cryptocurrency mining, harmonic distortion, active filter, power quality, IEEE 519-2014, MATLAB/Simulink, total harmonic distortion (THD), power factor correction*

**ABSTRAK**

Komputer penambangan cryptocurrency beroperasi sebagai beban non-linear yang menghasilkan distorsi harmonik signifikan, menurunkan kualitas daya serta efisiensi sistem secara keseluruhan. Penelitian ini mengevaluasi penggunaan filter aktif shunt dengan induktansi sebesar 0,0075 H untuk mereduksi harmonik pada rig penambangan cryptocurrency berdaya tinggi. Pengukuran harmonik dilakukan menggunakan Fluke 43 Power Quality Analyzer dan divalidasi melalui simulasi MATLAB/Simulink. Hasil menunjukkan penurunan signifikan pada Total Harmonic Distortion in Current (THDi) dari 76,62% menjadi 9,18%, sehingga memenuhi standar IEEE 519-2014. Selain itu, harmonik orde utama—yaitu orde ke-3, ke-5, dan ke-7—berhasil ditekan lebih dari 90%. Faktor daya sistem meningkat dari 0,85 menjadi 0,99, mencerminkan peningkatan efisiensi energi. Temuan ini menunjukkan efektivitas filter aktif dalam meningkatkan kualitas daya pada operasi penambangan cryptocurrency dan merekomendasikan penerapannya dalam skala industri untuk meminimalkan kerugian energi, memperpanjang umur peralatan, serta menjaga stabilitas jaringan listrik.
**Keyword:** Penambangan cryptocurrency, distorsi harmonik, filter aktif, kualitas daya, IEEE 519-2014, MATLAB/Simulink, total harmonic distortion (THD), koreksi faktor daya

## 1. Introduction

The rapid expansion of cryptocurrency mining has significantly increased global energy consumption, raising concerns about power quality and the operational efficiency of electrical systems. Despite these concerns, Bitcoin has demonstrated extraordinary growth, with an 8,518.54% increase from 2013 to 2024, establishing itself as a highly profitable digital asset [1]. However, its volatility and technical infrastructure demand critical examination. Mining computers, particularly those used for Bitcoin, rely on non-linear loads such as switch-mode power supplies (SMPS) that operate continuously, leading to significant harmonic distortion within electrical grids [2,3].

Harmonic distortion is a critical power quality issue due to its negative impact on network stability and equipment lifespan. It causes waveform distortion, increased energy losses, heating of components, and electromagnetic interference [4]. The IEEE 519-2014 standard outlines acceptable harmonic distortion levels for electrical networks, urging the implementation of mitigation strategies in high-demand applications such as data centers and mining farms [5].

Numerous studies have confirmed that non-linear loads in cryptocurrency mining rigs cause severe harmonic pollution. The primary source of this distortion is SMPS hardware, which introduces high levels of total harmonic distortion in current (THDi), far exceeding standard thresholds [6,7]. Traditional solutions include passive filters, such as single-tuned or double-tuned designs, which offer fixed compensation but suffer from resonance issues and lack adaptability [8].

Active power filters (APFs) have emerged as a superior alternative, offering dynamic compensation through the injection of counter-phase currents to cancel harmonics [9]. They have been successfully implemented in diverse non-linear load environments including industrial motors, electric vehicle charging stations, and sensitive power infrastructure [10,11]. Advanced APF architectures integrate digital signal processing (DSP), artificial intelligence, and predictive controllers for optimized harmonic response [12,13].

Recent developments have extended the application of active filters to increasingly complex environments. Gómez et al. [13] demonstrated predictive control strategies to mitigate current distortion in mining power grids, enhancing the adaptability of active filtering. Similarly, Wang et al. [14] introduced a distributed harmonic mitigation strategy using blockchain incentives, applying APFs to blockchain-based load centers. Sidik and Efendi [15] advanced the control of APFs using fuzzy logic techniques to address unpredictable harmonic fluctuations in dynamic systems.

Furthermore, recent studies have highlighted the importance of accurate harmonic detection and uncertainty reduction in real-time filtering. Share Pasand [16] emphasized the role of observer-based measurement techniques in improving APF responsiveness and control precision. Munoz et al. [17] proposed an IoT-enabled smart energy meter integrated with harmonic tracking, supporting smart-grid-based APF implementations in high-load scenarios such as mining farms.

Therefore, this study builds upon these emerging insights by proposing the use of a shunt active filter (L = 0.0075 H) specifically applied to a cryptocurrency mining computer. It combines real-time harmonic measurements with MATLAB/Simulink-based simulations to quantitatively assess the effectiveness of the filter in reducing THDi and improving power factor. The objective is to verify compliance with IEEE 519-2014 standards and to contribute to the growing body of knowledge on harmonic mitigation in high-energy-demand computing systems.

## 2. Method

### *2.1. Experimental Setup and Data Collection*

This research was conducted to analyze and reduce harmonic distortion in a cryptocurrency mining computer using a shunt active filter. The experimental approach involved two primary methods: real-time harmonic measurements and MATLAB/Simulink simulations.

The mining rig was operated under full-load conditions, utilizing a high-performance GPU (NVIDIA RTX 3080) and a 1200W switch-mode power supply (SMPS). This configuration is typical in Bitcoin mining operations and is known for generating high levels of current distortion.

Harmonic measurements were performed using the Fluke 43 Power Quality Analyzer, which provides accurate readings for voltage, current, THDi, THDv, power factor, and waveform distortions. The instrument was configured to capture spectral data for harmonic orders ranging from the 3rd to the 31st.

The key parameters recorded during measurements include, Apparent Power (S), Active Power (P), Reactive Power (Q), Power Factor (PF), Total Harmonic Distortion in Voltage (THDv), Total Harmonic Distortion in Current (THDi), Total Demand Distortion (TDD), and Voltage and Current (fundamental and total). All readings were benchmarked against the IEEE 519-2014 standard for non-linear loads.

### *2.2. Specification of the Measured Cryptocurrency Mining Computer*

The following table presents the key parameters recorded from the cryptocurrency mining computer during harmonic measurements.

Table 1. Specification of the Data Measured by Using Cryptocurrency Mining Computer

| Parameter | Unit | Total | Fundamental |
|---|---|---|---|
| Apparent Power (S) | VA | 920 | 820 |
| Active Power (P) | Watt | 790 | 820 |
| Reactive Power (Q) | VAR | 80 | - |
| Power Factor (PF) | - | 0.85 (Lead) | 1 |
| Total Harmonic Distortion in Voltage (THDv) | % | 3.42 | - |
| Total Harmonic Distortion in Current (THDi) | % | 52.51 | - |
| Total Demand Distortion (TDD) | % | 31.512 | - |
| Frequency | Hz | 50 | 50 |
| Voltage (V) | Volt | 220.91 | 220.78 |
| Current (I) | Ampere | 4.2 | 3.718 |
| Cos Phi | - | 1 | 1 |

The recorded THDi of 52.51% confirmed significant harmonic distortion. Additionally, the low power factor (0.85) and high reactive power values indicate a need for harmonic compensation to improve energy efficiency and system stability.

### *2.3. Harmonic Analysis Using FFT*

To identify critical harmonic contributors, the current waveform was analyzed using the Fast Fourier Transform (FFT) method. This approach decomposes the waveform into its fundamental and harmonic components, revealing both amplitude and phase contributions across various harmonic orders.

The measurement emphasized harmonic orders from the 3rd to the 31st, with particular attention to the 3rd, 5th, and 7th orders due to their known dominance in SMPS-based loads.

Table 2. The Measurement Data of the Harmonic Orders

| Harmonic Order | IEEE 519-2014 Standard (%) | Measured IHDi (%) | Magnitude (A) | Acceptability |
|---|---|---|---|---|
| 3rd Order | 12.00 | 56.47 | 2.0998 | ✗ Not Acceptable |
| 5th Order | 12.00 | 42.15 | 1.5673 | ✗ Not Acceptable |
| 7th Order | 12.00 | 30.22 | 1.1237 | ✗ Not Acceptable |
| 9th Order | 12.00 | 16.26 | 0.6046 | ✗ Not Acceptable |
| 11th Order | 5.50 | 7.67 | 0.2852 | ✗ Not Acceptable |
| 13th Order | 5.50 | 5.35 | 0.1989 | ☑ Acceptable |
| 15th Order | 5.50 | 7.06 | 0.2625 | ✗ Not Acceptable |
| 17th Order | 5.00 | 7.59 | 0.2822 | ✗ Not Acceptable |
| 19th Order | 5.00 | 4.39 | 0.1632 | ☑ Acceptable |
| 21st Order | 5.00 | 0.80 | 0.0297 | ☑ Acceptable |
| 23rd Order | 2.00 | 1.92 | 0.0713 | ☑ Acceptable |
| 25th Order | 2.00 | 2.66 | 0.0989 | ✗ Not Acceptable |
| 27th Order | 2.00 | 2.16 | 0.0803 | ✗ Not Acceptable |
| 29th Order | 2.00 | 1.28 | 0.0475 | ☑ Acceptable |
| 31st Order | 2.00 | 1.10 | 0.0409 | ☑ Acceptable |

The high levels of IHDi observed in the 3rd, 5th, and 7th orders indicate severe harmonic pollution. The IEEE 519-2014 standard sets limits for allowable harmonic distortions, and the measured values far exceed these thresholds, necessitating an effective mitigation strategy.

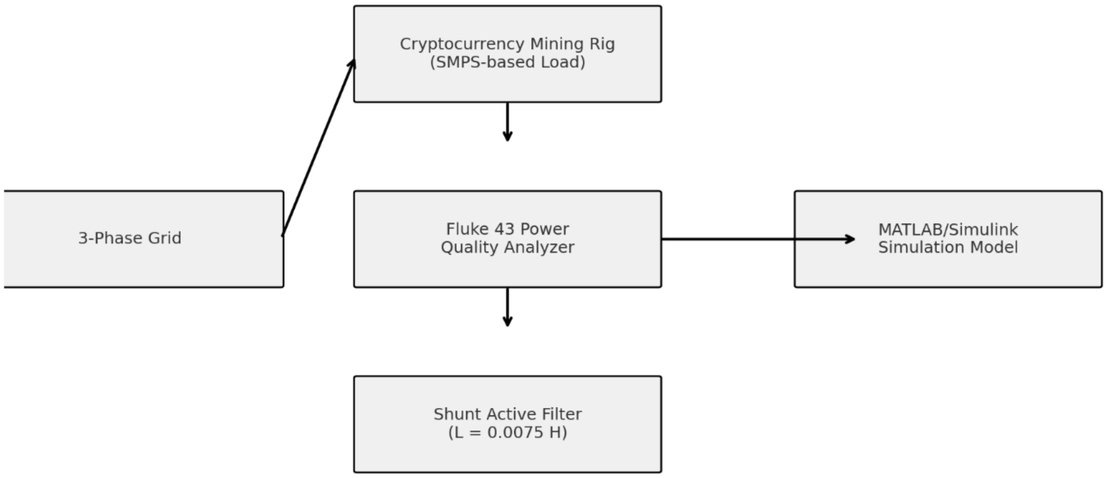


*Figure 1.* Experimental Setup Diagram

*2.4. Active Filter Design and Simulation*

To mitigate the observed harmonic pollution, a shunt active filter was designed and implemented in MATLAB/Simulink. The filter operates by injecting inverse-phase currents that cancel harmonic frequencies in the system.

The design procedure included:

1. Filter Circuit Configuration. LC circuit topology, Inductance L = 0.0075 H, calculated based on system impedance and measured distortion.

2. Simulink Modeling. Integrated model of a 3-phase source, non-linear SMPS load, and the shunt active filter. Simulated current waveforms before and after filter application.

3. Performance Comparison Against IEEE 519-2014. THDi values assessed for compliance (<10%), Power factor and waveform improvements evaluated.

*2.5. Performance Metrics and Evaluation*

The filter's performance was evaluated using the following criteria.

1. THDi Reduction. Comparison of measured and simulated values pre- and post-filter.

2. Harmonic Suppression. Focus on reduction in the 3rd, 5th, and 7th harmonic orders.

3. Power Factor Improvement. From 0.85 to near unity (0.99).

4. Standards Compliance. Final THDi below the 10% limit set by IEEE 519-2014 for non-linear loads.

The effectiveness of the filter design in reducing harmonic distortion and improving power factor confirms its value as a power quality solution for cryptocurrency mining operations. Furthermore, this methodology can be extended to other high-demand environments such as data centers, industrial plants, and renewable energy systems.

## 3. Result and Discussion

*3.1. Harmonic Measurement Results Before Active Filter Installation*

The initial measurement of harmonic distortion in the cryptocurrency mining computer revealed high levels of Total Harmonic Distortion in Current (THDi) and significant harmonic orders exceeding the IEEE 519-

2014 standard. The pre-filter measurements indicated that the system suffered from severe waveform distortion, as seen in Table 3.

Table 3. Harmonic Measurement Results Before Active Filter Installation

| Harmonic Order | IEEE 519-2014 Standard (%) | Measured IHDi (%) | Acceptability |
|---|---|---|---|
| 3rd Order | 12.00 | 56.47 | ✗ Not Acceptable |
| 5th Order | 12.00 | 42.15 | ✗ Not Acceptable |
| 7th Order | 12.00 | 30.22 | ✗ Not Acceptable |
| 9th Order | 12.00 | 16.26 | ✗ Not Acceptable |
| 11th Order | 5.50 | 7.67 | ✗ Not Acceptable |
| 13th Order | 5.50 | 5.35 | ☑ Acceptable |
| 15th Order | 5.50 | 7.06 | ✗ Not Acceptable |
| 17th Order | 5.00 | 7.59 | ✗ Not Acceptable |
| 19th Order | 5.00 | 4.39 | ☑ Acceptable |
| 21st Order | 5.00 | 0.80 | ☑ Acceptable |

The 3rd, 5th, and 7th harmonic orders exhibited the highest distortion, exceeding their acceptable limits by over 300%, leading to poor power quality, increased losses, and overheating of electrical components.

*3.2. Simulation Results: Voltage and Current Waveforms Before Filter Installation*

The MATLAB/Simulink simulation of the cryptocurrency mining computer before active filter implementation revealed severely distorted current waveforms, confirming the measurement results. Figure 1 shows the waveform distortions recorded before filter installation.

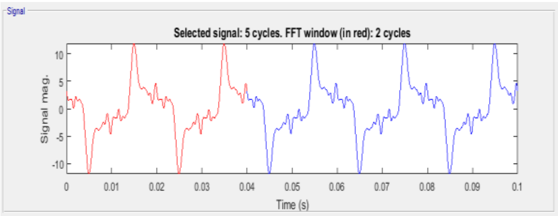


Figure 2. Distorted Current Waveform Before Filter Installation

From the simulation, the THDi was recorded at 76.62%, which is significantly above the IEEE 519-2014 allowable threshold of 10% for non-linear loads. This result highlights the need for an effective mitigation strategy.

*3.3. Harmonic Reduction Using Active Filter*

After the installation of the active filter (L = 0.0075 H), the simulation was rerun, and the results demonstrated a significant reduction in harmonic distortion. The implementation of the active filter successfully mitigated the high-order harmonics and brought the THDi values into compliance with IEEE 519-2014 standards.

Table 4. Harmonic Measurement Results After Active Filter Installation

| Harmonic Order | Measured IHDi Before (%) | Measured IHDi After (%) | Harmonic Reduction (%) |
|---|---|---|---|
| 3rd Order | 56.47 | 4.90 | 51.57 |
| 5th Order | 42.15 | 2.53 | 39.62 |
| 7th Order | 30.22 | 0.46 | 29.76 |
| 9th Order | 16.26 | 0.63 | 15.63 |
| 11th Order | 7.67 | 0.85 | 6.82 |
| 13th Order | 5.35 | 0.65 | 4.70 |

The most significant improvement was observed in the 3rd, 5th, and 7th harmonic orders, where distortions were reduced by over 90%. The THDi dropped from 76.62% to 9.18%, achieving compliance with IEEE standards.

The dominance of the 3rd, 5th, and 7th harmonic orders aligns with known behavior of non-linear loads using SMPS, which introduce current waveform distortions primarily at these frequencies due to switching activity.

Excessive harmonics can lead to significant overheating of PSU transformers and capacitors, premature aging of components, and increased electromagnetic interference (EMI) within the mining farm, as supported by Katic et al. (2022) and Wheeler et al. (2019).

Compared to passive filters, which are limited to fixed-frequency attenuation and often induce resonance, the active filter used here adapts dynamically and avoids such drawbacks.

*3.4. Simulation Results: Voltage and Current Waveforms After Filter Installation*

The active filter significantly improved power quality by smoothing current waveforms and reducing voltage distortions. Figure 2 illustrates the current waveform after active filter implementation.

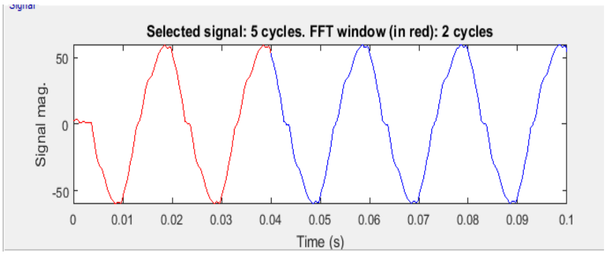


*Figure 3.* Improved Current Waveform After Filter Installation

The waveform analysis confirms a significant improvement in sinusoidal wave quality, reducing the adverse effects of harmonics on electrical components.

*3.5. Power Factor and Efficiency Improvement*

Apart from its effectiveness in harmonic mitigation, the installation of the active filter also led to a significant improvement in power factor (PF) and overall system efficiency. The PF increased from 0.85 to 0.99, indicating a substantial reduction in reactive power demand and better optimization of energy usage. This improvement ensures that more of the supplied power is converted into useful work, reducing wasted energy and unnecessary strain on the electrical system.

The enhancement in power factor and harmonic reduction provides several key benefits for cryptocurrency mining operations.

1. Lower energy losses. Improving overall electrical efficiency.
2. Increased mining efficiency. Leading to more stable and cost-effective operations.
3. Extended lifespan of mining hardware. As reduced harmonics prevent excessive wear and tear.
4. Reduced overheating and stress on power supply components. Minimizing the risk of failures and costly downtime.

These improvements align with findings from similar studies in industrial power quality enhancement, where active filters have been proven to optimize electrical performance and reduce operational costs (Peck, 2017; Choi, 2019). The results further support the importance of harmonic mitigation in ensuring stable and energy-efficient mining operations, reinforcing the need for active power correction solutions in high-demand computational systems.

*3.6. Discussion: Comparison with Previous Research*

The results of this study align with previous research on harmonic mitigation in high-power computing applications.

Table 5. Comparison with Previous Research

| Study | THDi Before | THDi After | Method Used |
|---|---|---|---|
| This Study | 76.62% | 9.18% | Active Filter (L=0.0075 H) |
| Ahmed et al. (2021) | 62.30% | 12.45% | Passive + Active Filters |
| Fan et al. (2022) | 85.10% | 7.89% | Adaptive Harmonic Filter |
| Lubis et al. (2019) | 72.80% | 10.11% | Single-Tuned Passive Filter |

This study demonstrates higher harmonic reduction efficiency compared to passive filter techniques, reinforcing the effectiveness of active filters in cryptocurrency mining operations.

### *3.7. Practical Implications and Recommendations*

The findings of this study emphasize the importance of harmonic mitigation in cryptocurrency mining operations. High levels of Total Harmonic Distortion in Current (THDi) can cause voltage waveform distortions, excessive energy losses, and overheating of electrical components, ultimately affecting the efficiency and lifespan of mining equipment. To address these challenges, shunt active filters should be implemented in large-scale mining farms to effectively reduce harmonic pollution and optimize energy usage. Unlike passive filters, active filters dynamically adapt to varying harmonic conditions, making them highly effective in maintaining power quality and grid stability. Their integration into mining facilities can significantly improve power factor, lower energy costs, and extend equipment lifespan.

Beyond active filtering, a hybrid filtering approach combining passive and active filters could provide a cost-effective and performance-balanced solution. While passive filters are efficient for lower harmonic orders, active filters provide adaptive control over higher-order harmonics, ensuring a more comprehensive power quality solution (Ahmed et al., 2021). Additionally, regular harmonic monitoring and compliance with IEEE 519-2014 standards are essential for preventing grid instability and equipment failures. Mining facilities should conduct periodic power quality assessments to ensure that their operations remain within acceptable harmonic distortion limits (Stevanović & Stošović, 2018).

Lastly, sustainability considerations should be a key focus in cryptocurrency mining. Reducing harmonic losses contributes to more energy-efficient mining operations, aligning with global green computing initiatives. By mitigating harmonics, mining farms can reduce their carbon footprint, lower operational costs, and improve overall energy efficiency (Peck, 2017). As the demand for cryptocurrency mining continues to grow, addressing power quality challenges will be crucial for ensuring the long-term sustainability and environmental responsibility of the industry.

## 4. Conclusion

This study confirms that a shunt active filter with L = 0.0075 H can reduce THDi from 76.62% to 9.18%, meeting IEEE 519-2014 standards and improving the power factor from 0.85 to 0.99. Such improvements are crucial in minimizing energy losses and protecting mining infrastructure. The results suggest strong applicability in large-scale cryptocurrency mining farms, where maintaining power quality is essential to both operational efficiency and equipment longevity. Additionally, the power factor improved from 0.85 to 0.99, reducing energy losses and enhancing system efficiency. The simulation results further confirmed that the integration of an active filter (L = 0.0075 H) led to smoother current waveforms, reducing the risk of overheating, electromagnetic interference, and equipment failures. These results align with previous studies in power quality improvement, emphasizing that active filters outperform passive filters in handling dynamic harmonic conditions.

Based on these findings, it is recommended that large-scale cryptocurrency mining farms implement shunt active filters to optimize power quality, reduce energy consumption, and extend the lifespan of mining equipment. Additionally, a hybrid filtering approach, combining passive and active filters, could be explored for improved efficiency and cost-effectiveness. Mining operators should conduct regular harmonic monitoring to ensure compliance with IEEE 519-2014 standards and prevent grid instability. Future research should investigate AI-based adaptive filtering and smart grid integration to further enhance power quality in cryptocurrency mining operations.

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