Volume 76 No. 2 (2024)
Wahana : Tridarma Perguruan Tinggi
ISSN : 2654-4954 (online) | 0853-4403 (Print)
http://jurnal.unipasby.ac.id/index.php/whn

Analysis of the Effectiveness of Using Active Filters and Passive Filters in Reducing Harmonics Using a Power Simulator (PSIM) at PT. Delta Jaya Mas

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Abstrak

Mesin Extruder di PT. Delta Jaya Mas merupakan mesin untuk memproduksi selang karet ekstrusi, selang PVC, selang buatan mandrel, dan barang cetakan karet. Proses manufaktur di PT. Delta Jaya Mas didominasi oleh mesin Extruder Pada mesin Extruder terdapat motor 3 phase (sinkron) dan beban non – linier yaitu VFD (Variable Frequency Drive) yang berfungsi untuk mengontrol kecepatan dan torsi dari Motor sinkron dengan cara memvariasikan input frekuensi dan voltase pada motor tersebut. Beban non–linear menyebabkan bentuk gelombang keluarannya tidak sebanding dengan tegangan dalam setengah siklus sehingga bentuk gelombang arus dan tegangan keluarannya tidak sama dengan gelombang masukkannya sehingga menyebabkan harmonisa. Harmonisa merupakan suatu gangguan yang terjadi pada sistem tenaga listrik yang diakibatkan oleh distorsi gelombang arus dan tegangan sehingga gelombang menjadi tidak sinusoidal. Penelitian ini bertujuan menganalisis efektivitas filter aktif dan pasif dalam mereduksi harmonisa pada sistem kelistrikan PT. Delta Jaya Mas menggunakan simulasi Power Simulator (PSIM). Simulasi ini membandingkan kinerja kedua filter serta dampak beban non-linear terhadap harmonisa, dengan hasil berupa rekomendasi solusi terbaik untuk meningkatkan kualitas daya. Hasil pengukuran panel SDP Extruder menunjukkan bahwa kandungan THDi tiap fasa R, S dan T yaitu sebesar 54,9%, 56,0% dan 56,0% dimana melebihi batas standar SPLN 2012 yaitu 15%, Sementara kandungan THDv yaitu masing – masing sebesar 2,5%, 2,8% dan 2,7% dimana dibawah batas standar SPLN 2012. Setelah melakukan simulasi menggunakan program PSIM, filter aktif berhasil mereduksi THDi menjadi 1,57%, sementara filter pasif hanya menurunkannya menjadi 34,07%. Penelitian ini diharapkan dapat membantu PT. Delta Jaya Mas menemukan solusi efektif untuk mengurangi harmonisa dan meningkatkan pengetahuan tentang analisis harmonisa serta penerapan filter aktif dalam industri.

Article history
Accepted : 29 October 2024
Approved : 20 November 2024

Kata Kunci:
Filter Aktif, Filter Pasif, Harmonisa, Kualitas Daya

Keywords:
Active Filter, Harmonics, Passive Filter, Power Quality

Abstract

The Extruder Machine at PT. Delta Jaya Mas is used for producing extruded rubber hoses, PVC hoses, mandrel-made hoses, and molded rubber products. The manufacturing process at PT. Delta Jaya Mas is dominated by the use of Extruder Machines, which are equipped with 3-phase synchronous motors and nonlinear loads such as Variable Frequency Drives (VFD). The VFD controls the speed and torque of the synchronous motor by varying the input frequency and voltage. Nonlinear loads cause output waveforms to deviate from proportionality with the input voltage during a half-cycle, resulting in output current and voltage waveforms that differ from the input waveforms, thus generating harmonics. Harmonics are disturbances in power systems caused by waveform distortion in current and voltage, leading to non-sinusoidal waveforms. This study aims to analyze the effectiveness of active and passive filters in reducing harmonics in the electrical system of PT. Delta Jaya Mas using Power Simulator (PSIM) software. The simulation compares the performance of both filters and assesses the impact of nonlinear loads on harmonics, providing recommendations for the best solution to improve power quality. Measurements at the SDP Extruder panel show that the Total Harmonic Distortion of Current (THDi) in phases R, S, and T are 54.9%, 56.0%, and 56.0%, respectively, exceeding the SPLN 2012 standard limit of 15%. Meanwhile, the Total Harmonic Distortion of Voltage (THDv) is 2.5%, 2.8%, and 2.7%, which are within the SPLN 2012 standard limit. After conducting simulations using PSIM software, the active filter successfully reduced the THDi to 1.57%, while the passive filter only reduced it to 34.07%. This study is expected to help PT. Delta Jaya Mas find effective solutions to reduce harmonics and enhance knowledge about harmonic analysis and the application of active filters in the industry.

Introduction

In the modern industrial world, the need for electronic and electrical equipment is very widespread. However, the presence of non-linear loads in the electrical system can cause harmonic distortion. This harmonic distortion is expressed in Total Harmonic Distortion (THD) which is a parameter to represent the harmonic level (Widagdo et al., 2023). The SPLN D5.004-1: 2012 standard is a recommendation for distortion limits that are implemented in the electric power system for a maximum voltage limit of 5% and a maximum current of 20%. PT. Delta Jaya Mas is a manufacturing industry that produces extruded rubber hoses, PVC hoses, mandrel-made hoses, and rubber molded goods. The manufacturing process at PT. Delta Jaya Mas is dominated by the Extruder machine as a requirement for its production process. In the Extruder machine there is a 3 phase (synchronous) motor and there is also a power electronic component, namely VFD or

(Variable Frequency Drive), VFD functions to control the speed and torque of the synchronous motor by varying the input frequency and voltage on the motor. VFD (Variable Frequency Drive) is one of the non-linear loads, non-linear loads are one of the causes of harmonics (Widagdo et al., 2023). Harmonics can cause problems such as overheating, equipment damage, and disturbances that can damage sensitive loads and electrical network infrastructure. Therefore, it is important for companies to ensure that the quality of the electrical power they receive is in accordance with predetermined standards. One approach that can be used to overcome harmonic distortion is the use of active filters. Active filters are one solution to reduce harmonics in electrical systems. Active filters work by producing harmonic currents that are opposite to the harmonic currents produced by non-linear loads, resulting in cleaner electric currents and stable voltages (Widagdo et al., 2023). Non-linear loads trigger the appearance of harmonics in the electrical system which can reduce the service life of electrical equipment. Harmonics are frequency distortions in voltage and current that are not sinusoidal from the original frequency. To achieve good electrical power quality, harmonics in the electrical system must meet established standards. Harmonic analysis is carried out based on the variables that have been measured in each panel, including the SDP panel. Apart from that, it is important to know the type of load that causes harmonics to make it easier to reduce them. This study not only advances knowledge in power quality improvement but also establishes a framework for future research and industrial practices in mitigating harmonics using modern filtering techniques.

To reduce Total Harmonic Distortion (THD) in current and voltage caused by non-linear loads, a passive filter is used. The working principle of a passive filter is to flow a harmonic current of a certain order from a harmonic source, such as a non-linear load, through a filter network. Apart from reducing harmonics, passive filters can also improve the power factor in the system (Hermawan et al., 2021). Active filters are the newest type of filter devices for eliminating harmonics in power systems, which are installed in parallel between the source and the load. The working principle of an active shunt filter is to compensate the load current simply, namely by injecting a harmonic current that has a phase 180º opposite to that produced by the load, so that the harmonics cancel each other out (Prabowo et al., 2015). Harmonics are disturbances in the form of distortion of current and voltage waves in the electrical network caused by non-linear loads such as power electronic equipment that has incorrect components, for example rectifiers or inverters (Antono et al., 2017). Harmonics occur because there are multiple frequencies of the fundamental frequency so that the fundamental wave will be distorted, because this distortion causes the wave to not be sinusoidal (Yusril et al., 2022).

In modern power systems, harmonics have become a major issue due to the use of non-linear devices such as inverters, UPS, and other electronic equipment. These harmonics can cause waveform distortions, power losses, and even equipment damage, making efforts to mitigate them highly important, especially in industries like PT. Delta Jaya Mas. Currently, there are two main approaches to addressing harmonics: the use of passive filters and active filters. Passive filters, consisting of elements such as capacitors, inductors, and resistors, offer a simple and cost-effective solution, although they have limitations such as resonance and dependence on specific frequencies. On the other hand, active filters utilize more advanced technology, with the capability to adapt to various harmonic frequencies, albeit with higher costs and greater complexity. The use of simulation software like Power Simulator (PSIM) has become a cutting-edge method for analyzing and comparing the effectiveness of these filters under real operating conditions. PSIM enables accurate system modeling, reduces risks, and saves on experimental costs. Previous studies have demonstrated the effectiveness of both types of filters, but research focusing on their application in specific industries like PT. Delta Jaya Mas remains limited. Therefore, this study aims to fill this gap by leveraging simulations to evaluate the performance of filters in effectively reducing harmonics.

Method

The research method used in this research is a simulation method with the PSIM software program. Data was collected through surveys and actual measurements of the load on the transformer as well as the harmonic content of odd-order currents and voltages on the SDP panel of the Extruder machine. The analysis results are compared with the PLN standard (SPLN D5.004-1: 2012), if the Total Harmonic Distortion (THD) exceeds the standard, a simulation is carried out without a filter to adjust the harmonic spectrum. Through the PSIM program simulation, researchers can compare the performance of passive filters and active filters in reducing harmonics.

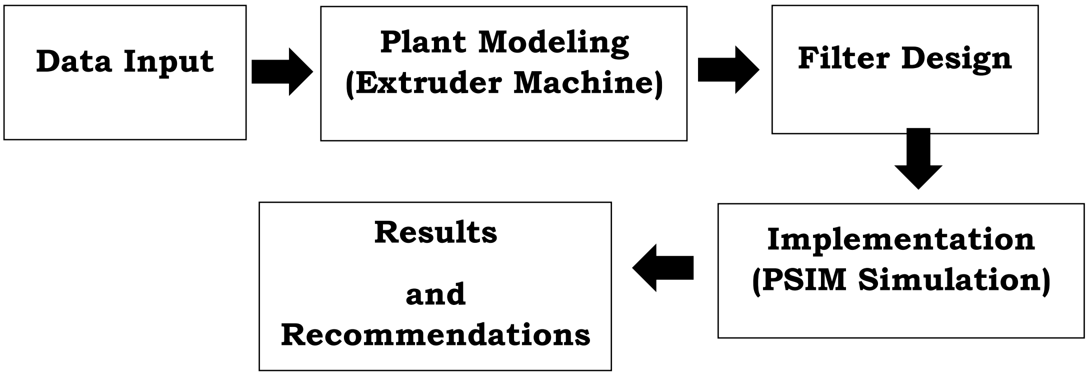


Figure 1. Research Method Block Diagram

Measurement Data on SDP Extruder

The data taken is the current and voltage IHD content. Measurements were carried out using a HIOKI 3286 – 01 power clamp meter.

Table 1. Harmonic Index Content Measurement

Orde	Harmonic's Level					
	Current (A)			Voltage (V)		
	R	S	T	R	S	T
1	46.41	45.36	41.92	227.1	227.6	227.2
3	0.81	1.95	1.70	1.4	0.5	0.7
5	21.44	21.14	19.19	4.8	4.6	4.6
7	13.71	13.95	13.40	1.7	2.6	1.7
9	0.97	0.73	0.54	0.9	0.9	0.6
11	2.39	2.97	3.69	2.2	2.7	2.8
13	1.49	1.83	1.45	1.9	2.5	2.4
15	0.85	0.80	0.73	0.4	0.7	0.6
17	1.34	1.66	1.63	1.1	1.4	0.8
19	0.43	1.06	1.27	0.3	0.2	0.4
21	0.39	0.10	0.21	0.3	0.3	0.3

From the IHD measurement results, the THD value on the SDP Extruder can be analyzed by carrying out calculations to determine the Total Harmonic Distortion of current and voltage with the following equation.

THDv *(Total Harmonic Distortion)* Voltage Distortion (Umadevi et al., 2023):

$$THD_v = \frac{\sqrt{\sum_{n=2}^{\infty} V^2 n}}{V_1} \times 100\% \quad (1)$$

Where,

THD_v = *Total Harmonic Distortion (%)*
V_1 = fundamental frequency voltage value (V)
V^2n = nth harmonic voltage value (V)

THDi *(Total Harmonic Distorsion)* Current Distortion:

$$THD_I = \frac{\sqrt{\sum_{n=2}^{\infty} I^2 n}}{I_1} \times 100\% \quad (2)$$

Where,

THD_i = *Total Harmonic Distortion (%)*
I_1 = fundamental frequency current value (A)
I^2n = nth harmonic current value (A)

Passive Filter Modeling

The passive filter simulation aims to compare how the passive filter performs against the active filter in reducing harmonics. Passive filters consist of components R, L and C which are assembled in a star topology and installed in parallel with the load. The passive filter is set at the harmonic frequency with the highest amplitude so that it will reduce the impact of distortion on the wave. The values of resistors, inductors and capacitors in passive filters can be determined using the following equation:

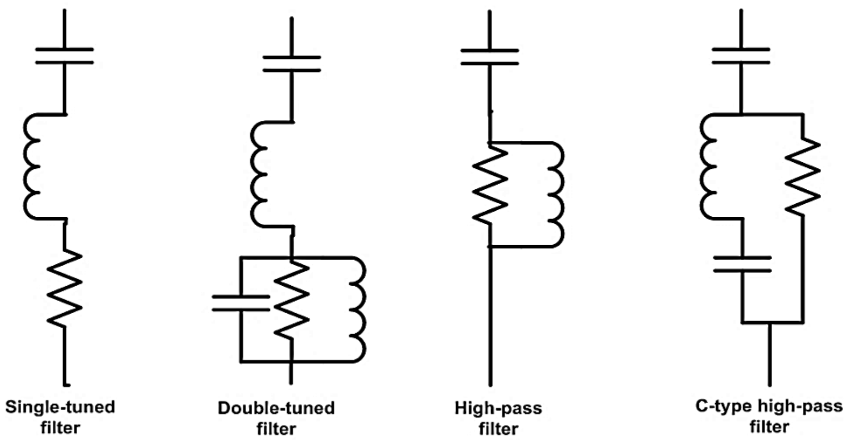


Figure 2. Passive Filter to Reduce Harmonics

Capacitor Calculation

To get the capacitance value (*C*) on a single tuned passive filter, it is necessary to determine the reactive power of the capacitor (*Qc*) so the calculation is as follows (Widagdo et al., 2023).

$$Q_c = \sqrt{\left(\frac{P_1}{PF_1}\right)^2 - P_1^2} - \sqrt{\left(\frac{P_1}{PF_2}\right)^2 - P_1^2} \quad (3)$$

Where,

P_1 = Real Power (kW)

PF_1 = Power Factor Before Filtering

PF_2 = Power Factor After Filtering

After determining the *Qc* value which is needed to meet the reactive power of the harmonic source, then determine the capacitive reactance value (*Xc*) with the following equation.

$$X_c = \frac{kV^2}{Q_c} \quad (4)$$

Where,

X_c = Capasitive Reactance (Ω)

Q_c = Reactive Power of Capasitor (kVAR)

kV = Voltage System (Volt)

After knowing the capacitive reactance value (*Xc*), then determine the capacitance value (*C*) required for the capacitor so the calculation is as follows.

$$C = \frac{1}{2\pi f_0 X_c} \quad (5)$$

Where,

C = Capasitance Value (Farad)

f_0 = Frequency (Hz)

X_c = Capacitive Reactance (Ω)

Inductor Calculation

To determine the inductance value of the inductor on a single tuned passive filter, it is necessary to calculate the inductive reactance value (X_L). After calculating the inductive reactance value (X_L), the inductance value (*L*) for the inductor component can be determined.

$$X_L = \frac{X_c}{h_n^2} \tag{6}$$

Where,

X_L = Inductive Reactance (Ω)

h_n = Orde harmonisa ke-n

X_c = Reaktansi kapasitif (Ω)

After determining the inductive reactance value (X_L), a calculation is carried out to determine the reactance value of the passive filter with the harmonic order chosen being the harmonic with the highest amplitude.

$$X_n = h_n X_L \tag{7}$$

Where,

X_n = Reactance of filter (Ω)

h_n = Harmonic Orde

X_L = Inductive Reactance (Ω)

The results of calculating the inductive reactance value (X_L) are used to determine the inductance value (L) required for the inductor so the calculation is as follows.

$$L = \frac{X_L}{2\pi f_0} \tag{8}$$

Where

L = Inductance Value (H)

f_0 = Frequency System (Hz)

X_L = Inductive Reactance (Ω)

Resistor Calculation

To determine the resistance value (R) of a single tuned passive filter, it can be determined using the following formula.

$$R = \frac{X_n}{Q} \tag{9}$$

Where,

R = Resistance of Filter (Ω)

X_n = Filter Characteristic Reactance (Ω)

Q = Factor Quality (100)

Active Filter Modeling

With a controlled inverter, the harmonics that arise can be regulated in such a way as to produce opposing harmonic output which is injected back into the system busbar with the aim of reducing harmonics in the system. The following is the design of a controlled inverter circuit which is used as an active filter. The second order BPF (Band Pass Filter) circuit in Figure 3 in the active filter functions as a separator for harmonic waves and fundamental waves from the current sensed by the Current Transformer (CT) installed in the system. As for the Band Pass Filter parameters that need to be set, the Center Frequency value is set to 50 Hz and the Passing Band is set to 45 Hz. The results of using the Band Pass Filter are explained in Figure 4.

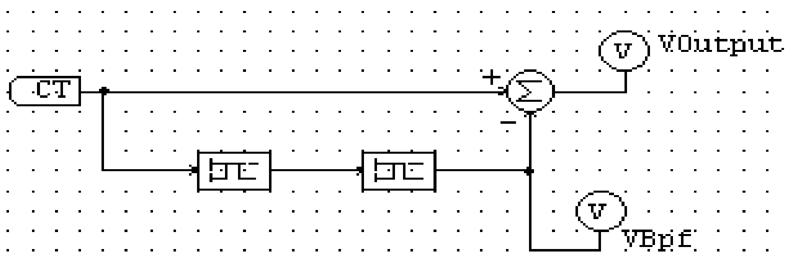
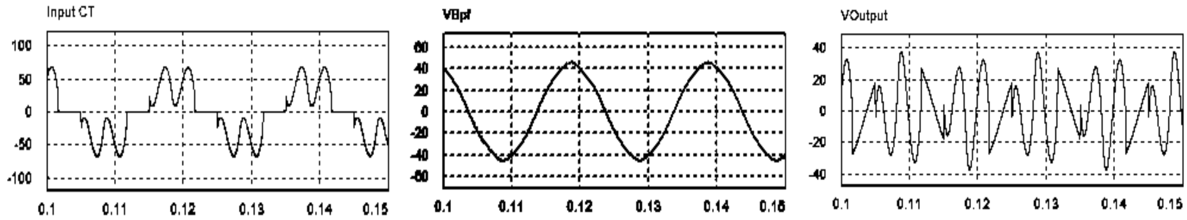


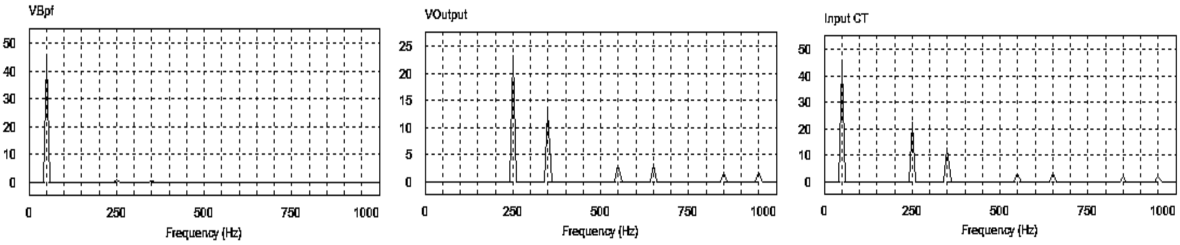
Figure 3. Band Pass Filter



(a) (b) (c)

Figure 4. (a) CT Input Spectrum (b) V_{BPF} Output Spectrum (c) V_{Out} Spectrum

The output of the Band Pass Filter (V_{BPF}) only selects a frequency of 50 Hz. Then the Summing op-amp will add up the input current with the fundamental current only so that the overall output of the Summing op-amp (V_{Out}) is only pure harmonic current, as shown in the FFT spectrum analysis as follows. The results of using the Band Pass Filter in FFT mode are explained in Figure 5.



(a) (b) (c)

Figure 5. (a) CT Input Spectrum (b) V_{BPF} Output Spectrum (c) V_{Out} Spectrum

Proportional Integral (PI) Control and Limitter

With Proportional Integral (PI) Control, the pure harmonic wave signal from the 2nd Order Band Pass Filter output can be processed to produce a current wave with a sinusoidal shape. The output current from the active filter will be used as feedback to produce the desired output current. With the feedback current from the inverter output (I_f), a sinusoidal reference wave signal is obtained.

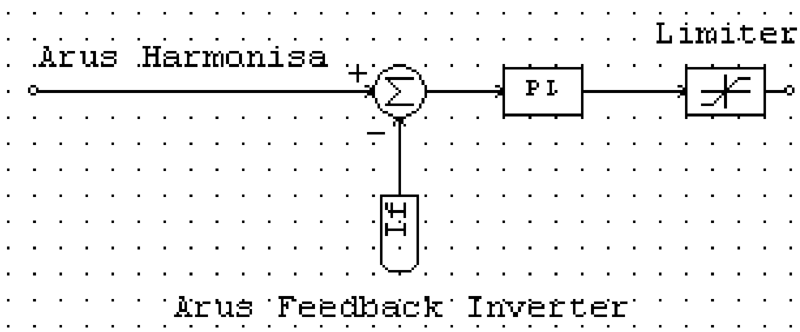
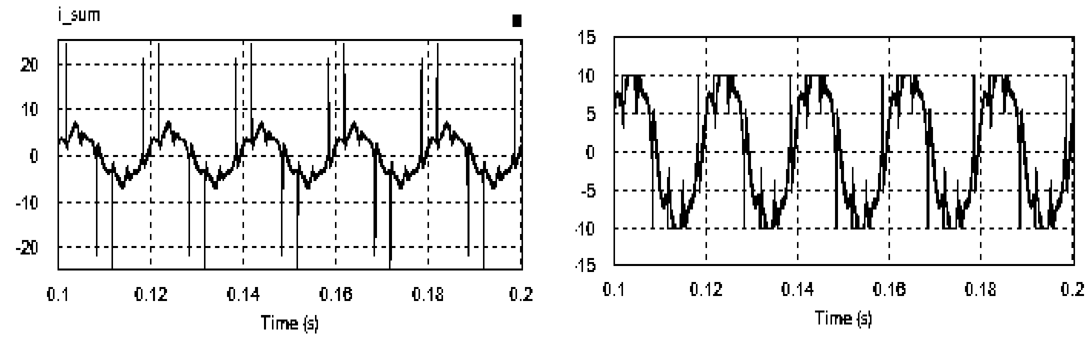


Figure 6. PI Controller and Limitter Modeling

The Proportional Gain parameter will determine how much the error signal will be increased. Meanwhile, the Integral Time Constant parameter will determine how fast the control output signal will be increased by Proportional Gain. In this simulation, the Proportional Integral (PI) control parameter is set, for the value at The Proportional gain is set at 2 and the Integral Time Constant value is set at 0.7, so that the current output is obtained as follows.



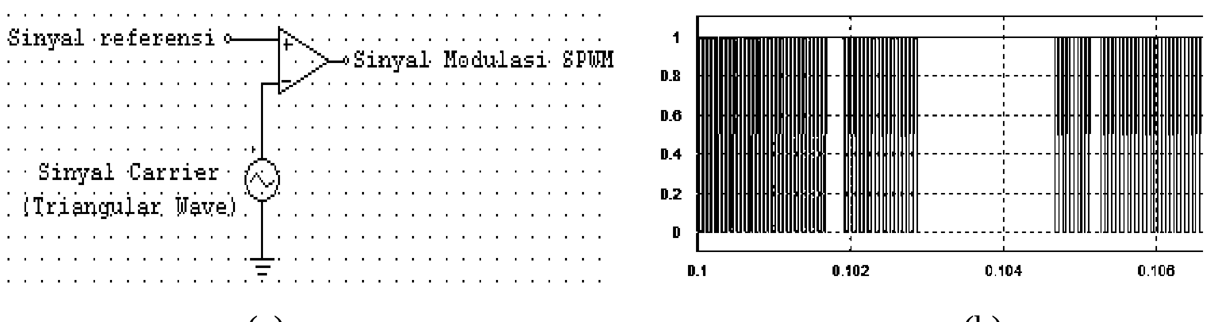
(a) (b)

Figure 7. (a) Op-Amp Summing Signal Output; (b) Output Kontroler Proportional Integral (PI)

The output signal on the Proportional Integral controller will be used as an input signal on the Limitter which functions to limit the signal voltage entering the comparator as a reference signal (Hoon et al., 2019).

Sinusoidal Pulse Width Modulation (SPWM) Control

The concept of SPWM control is to compare the reference signal wave from the Proportional Integral Controller output to the carrier wave so that the reference signal will be modulated by a triangular carrier wave, so a comparator is needed to compare the two signal waves. The carrier frequency will be set at 20 kHz with the aim that the harmonic frequency that will be generated by the inverter has a wide harmonic order, so that over-modulation does not occur, the amplitude of the carrier wave must be greater than the reference wave. The comparator signal output in SPWM modulation is shown in the Figure 8.



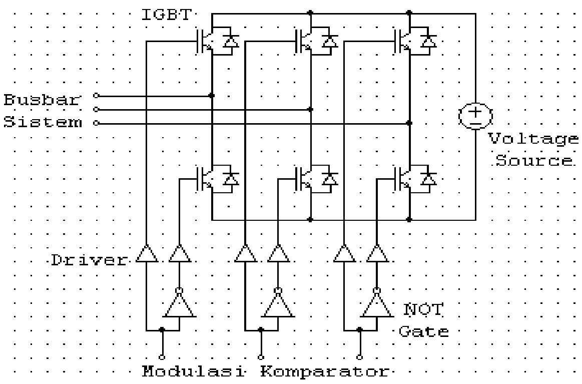
(a) (b)

Figure 8. (a) Signal Modulation with Comparators; (b) Output Modulation Signal on the Comparator

The output of the comparator modulation signal will be used as a switching pulse on the IGBT gate, so that the output on the IGBT is sinusoidal, the modulation frequency must be the same in the system, namely 50 Hz so that there is no potential difference.

Voltage Source Inverter (VSI) Modeling

This IGBT device will be used as a switching device in an inverter circuit that includes six IGBTs and a DC voltage source. The role of these IGBTs is crucial for converting DC voltage to AC voltage by alternately switching on and off (Hadi et al., 2022). To ensure proper operation and avoid simultaneous switching, a NOT logic function is incorporated at each IGBT Gate. This arrangement helps to regulate the switching of each IGBT effectively (Rameshkumar et al., 2023). The NOT logic function plays a significant role in the alternating operation of the IGBTs. The coordination of these switching signals is managed by the modulation comparator, which adjusts the signals sent to the gates of the IGBTs. As a result of this carefully designed switching mechanism, the VSI (Voltage Source Inverter) produces a waveform that can be seen in Figure 9.



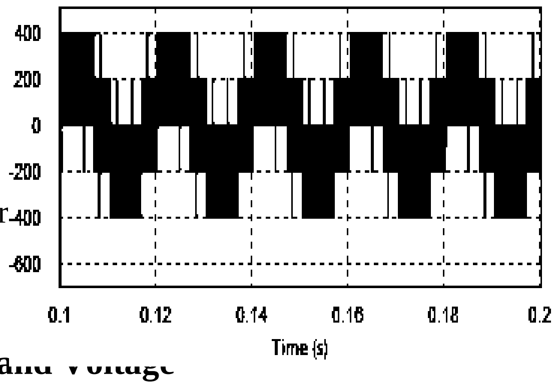


Figure 9. Voltage Sour

Results and Discussion

THD Analysis of Extruder SDP Current and Voltage

To determine the amount of Total Harmonic Distortion (THD) Current and Voltage of the SDP Extruder panel, a calculation is carried out using the following equation:

THDv *(Total Harmonic Distortion)* Voltage Distortion:

$$THD_v = \frac{\sqrt{\sum_{n=2}^{\infty} V^2 n}}{V_1} \times 100\%$$

$$THD_v = \frac{\sqrt{(4.6^2+2.6^2+2.7^2+2.5^2)}}{227.6}\ x\ 100\% = 2.8\%$$

THDi *(Total Harmonic Distorsion)* Current Distortion:

$$THD_I = \frac{\sqrt{\sum_{n=2}^{\infty} I^2 n}}{I_1} \times 100\%$$

$$THD_I = \frac{\sqrt{(1.95^2+21.14^2+13.95^2+0.73^2)}}{45.36}\ x\ 100 = 56.0\%$$

From the results of calculations and analysis of the sources of current and voltage harmonics on the SDP Extruder panel, the graph below is obtained.

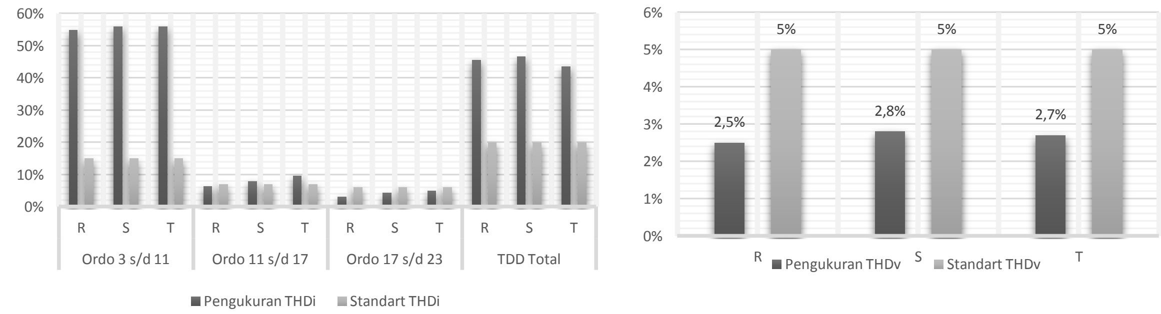
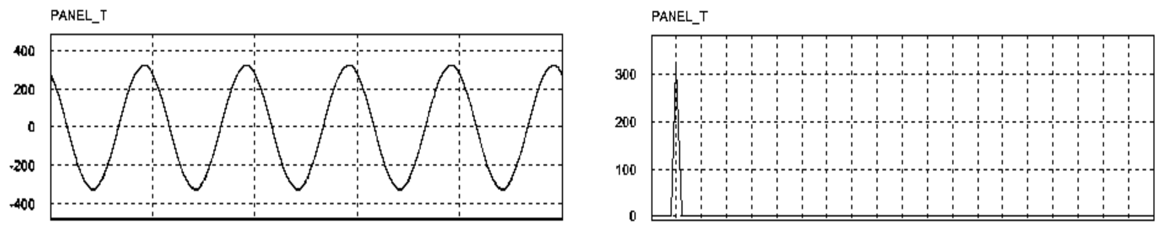


Figure 10. THD values for voltage and current on the SDP extruder

In the graph above it can be seen that the current harmonic content is above the normal limit of the 2012 SPLN standard, where the R, S, T phase measurements are 54.9%, 56.0% and 56.0% respectively. Caused by a VFD connected to a 55KW induction motor. The voltage harmonics on the SDP Extruder are still within normal limits according to SPLN standards. Once it is known that the current harmonic value exceeds the SPLN standard, to reduce these harmonics, a passive filter and an active filter are modeled by simulating them in a PSIM.

Simulation Results Without Filter Harmonics

The results show that the voltage spectrum without an Active Filter contains almost no harmonics according to the results of THD data calculations, so it has no impact on the fundamental frequency so the voltage wave is not distorted.



(a) (b)

Figure 11. (a) FFT spectrum (b) Unfiltered Voltage Wave

Meanwhile, the Current spectrum without an Active Filter shows that the harmonic content arises in the 5th (250 Hz), 7th (350 Hz), 11th (550 Hz), 13th (650 Hz), 17th (850 Hz) and

19th (950 Hz) orders. The appearance of these frequencies will have an impact on the fundamental frequency of the current (50 Hz) so that it can change the distortion of the current in Figure 11. Large current harmonics arise in the orders shown in the Table 2:

Table 2. Unfiltered Current Harmonic Index

Level Harmonics	Value
5th Orde	21,78 A
7th Orde	12,43 A
11th Orde	3,03 A
13th Orde	3,46 A

Therefore, efforts to reduce harmonics are only focused on harmonic currents, because the waves and spectrum of voltage show that there is no harmonic content so they can be ignored. The following is the THD calculation for current without a filter.

$$THD_I = \frac{\sqrt{\sum_{n=2}^{\infty} I^2 n}}{I_1} \times 100\%$$

$$THD_I = \frac{\sqrt{(21.78^2+12.43^2+3.03^2+3.46^2)}}{44.67}\ x\ 100\% = 57.07\%$$

Simulation Results with Single Tuned Passive Filter

The passive filter is set at the 5th order harmonic frequency, namely 250 Hz, with a fundamental frequency of 50 Hz. The following is a calculation of the component parameters required for passive filter simulation.

Calculation of Capacitor Value

Determine the value of the capacitor's reactive power (Q_c)

$$Q_c = \sqrt{\left(\frac{P_1}{PF_1}\right)^2 - P_1^2} - \sqrt{\left(\frac{P_1}{PF_2}\right)^2 - P_1^2}$$

$$= \sqrt{\left(\frac{29{,}35}{0{,}857}\right)^2 - 29.35^2} - \sqrt{\left(\frac{29{,}35}{0{,}95}\right)^2 - 29.35^2}$$

$$= 8{,}00 \text{ kVAR}$$

then determine the capacitive reactance value (X_c) with the following equation.

$$X_c = \frac{kV^2}{Q_c} = \frac{0{,}4^2}{8} = 0{,}02 \text{ k}\Omega = 20\ \Omega$$

Then determine the capacitance value (C) required for the capacitor so the calculation is as follows.

$$C = \frac{1}{2\pi f_0 X_c} = \frac{1}{2 \times 3{,}14 \times 50 \times 20} = 159{,}15\ \mu F$$

Calculation of Inductor Value

Determine the value of inductive reactance (X_L)

$$X_L = \frac{X_c}{h_n^2} = \frac{20}{5^2} = 0{,}8\ \Omega$$

The harmonics that are filtered are 5^{th} order harmonics. So you can know the reactance value of the passive filter characteristics.

$$X_n = h_n X_L = 5 \times 0{,}8 = 4\ \Omega$$

Next, determine the inductance value (L) required for the inductor so the calculation is as follows.

$$L = \frac{X_L}{2\pi f_0} = \frac{0.8}{2 \times 3{,}14 \times 50} = 2{,}54\ mH$$

Calculation of Resistor Value

The selected filter Quality Factor (Q) value is 100. To determine the resistance value (R) on the single tuned passive filter resistor, it can be determined using the following equation.

$$R = \frac{X_n}{Q} = \frac{4}{100} = 0{,}04\ \Omega$$

After determining the passive filter components, the capacitor, inductor and resistor will be connected in series in a star configuration and installed on the system busbar. The passive filter simulation will be designed with the following component parameters.

Table 3. Passive Filter Component Value Parameters

Parameter	Value
Q_C	8 kVAR
X_C	20 Ω
X_L	0,8 Ω
C	159,15μF
L	2,54mH
R	0,04 Ω

The implementation of a passive filter in the system is arranged as shown in Figure 12.

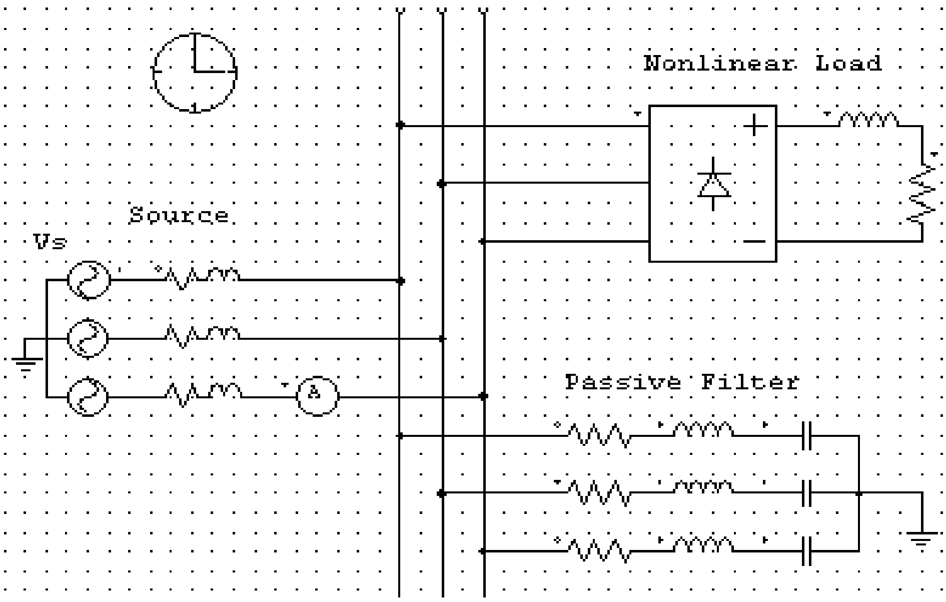


Figure 12. Passive Filter Implementation Simulation

The IHD value of system harmonics after installing a passive filter in the FFT Analysis Spectrum is shown in Table 4 below.

Table 4. Current Harmonic Index with Passive Filters

Orde Level	Value
5^{th} Level	9,25 A
7^{th} Level	12,40 A
11^{th} Level	3,00 A
13^{th} Level	3,44 A

In the FFT analysis spectrum results, it can be seen that there is a decrease in the value of the harmonic current in the 5th order. Which was previously 21,78 A and decreased to 9,25 A. So the distortion in the wave will be reduced as shown in the Figure 13.

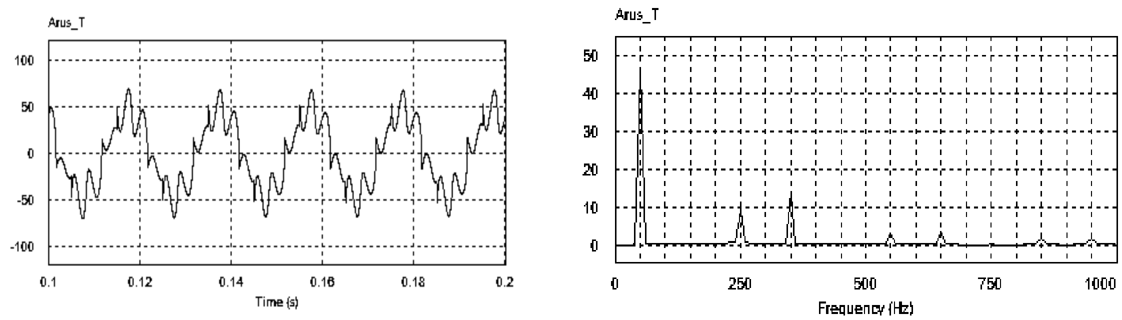


Figure 13. Wave Distortion and Current Spectrum with FFT on Systems with Passive Filters

Figure 13 shows that the waveform is still distorted because the passive filter is only set at the 5th order frequency where the 5th order harmonic value is the highest. The following is the calculation of the current THD after the passive filter is installed in the system.

$$THD_I = \frac{\sqrt{\sum_{n=2}^{\infty} I^2 n}}{I_1} \times 100\%$$

$$THD_I = \frac{\sqrt{(9.25^2 + 12.40^2 + 3.00^2 + 3.44^2)}}{47.01}\ x\ 100\% = 34.31\%$$

The simulation results of the implementation of a passive filter or single tuned passive filter in the system can be concluded that there is a significant decrease in the 5th order harmonic value so that there is an improvement in the wave shape even though it is not perfect. When compared with the simulation of a system without a filter, there is a decrease in the current THD, which previously was 57.07% and after installing the passive filter it decreased to 34.31%. However, the current THD value still does not meet the SPLN standard, namely less than 15%. Therefore, in an effort to reduce harmonics in accordance with SPLN standards, a system simulation with an active filter was carried out.

Simulation Results with Active Filters

Modeling Active filters will be installed on the system busbar to inject opposite harmonic currents. To reduce distortion at the inverter output caused by switching noise, R, L and C filters will be installed at the inverter output.

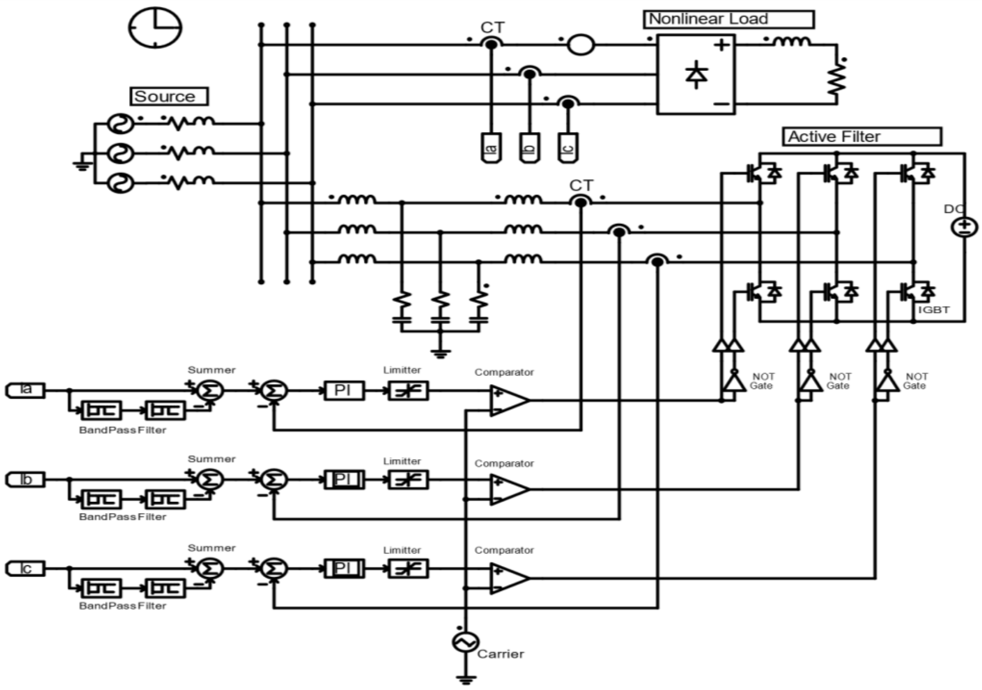


Figure 14. Active Filter Circuit Implementation

The magnitude of the system harmonic IHD value after installing an active filter in the FFT Analysis Spectrum is shown in the Table 5.

Table 5. Current Harmonic Index of Systems with Active Filters

Orde Level	Value
5^{th} Level	0.59 A
7^{th} Level	0,40 A
11^{th} Level	0,23 A
13^{th} Level	0,053 A

In the FFT analysis spectrum results, it can be seen that there has been a significant decrease in the harmonic current value caused by the injection of countercurrent from the active filter, so that the system current waveform has improved as shown in Figure 15.

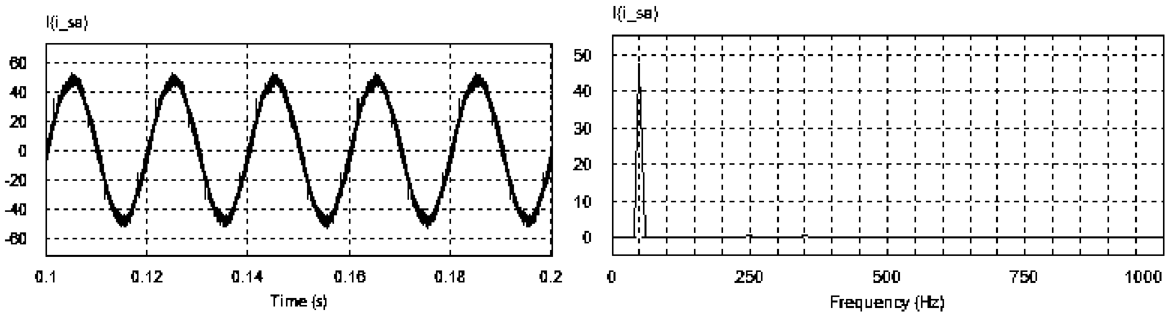


Figure 14. Wave Distortion and Current Spectrum with FFT on Systems with Active Filters

The output current from the active filter is the reverse harmonic current of the system harmonic current as shown in the Figure 15.

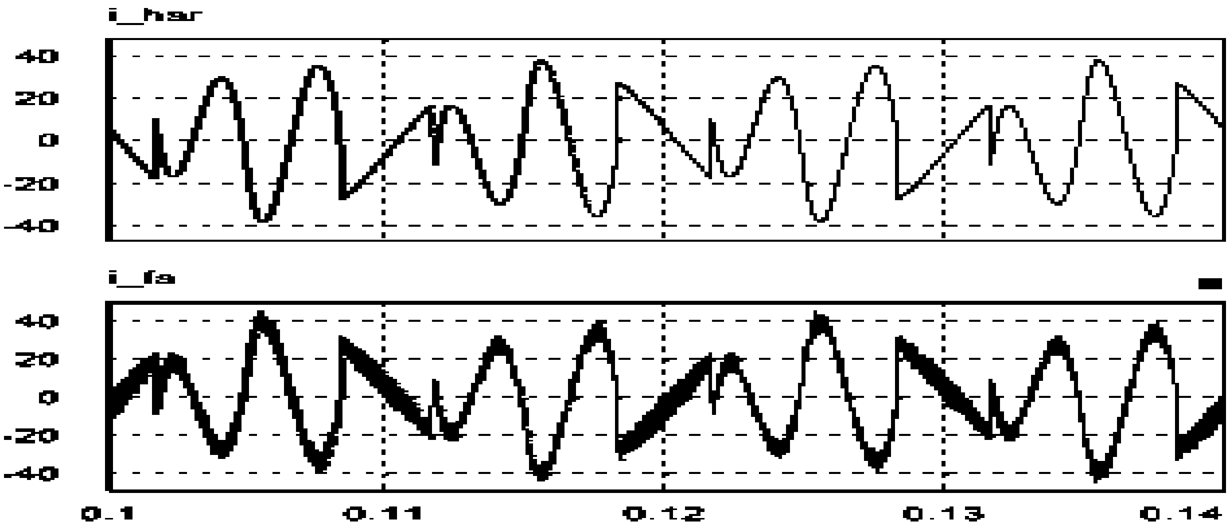


Figure 15. System Harmonic Current Waves and Reverse Current Injection from Active Filters

$$THD_I = \frac{\sqrt{\sum_{n=2}^{\infty} I^2 n}}{I_1} \times 100\%$$

$$THD_I = \frac{\sqrt{(0.59^2+0.40^2+0.23^2+0.053^2)}}{47.65}\ x\ 100\% = 1.57\%$$

When comparing the system simulation results without a filter to those with an active filter, a significant reduction in Total Harmonic Distortion (THD) is observed. Initially, without any filter, the THD of the flow was measured at 57.07%. However, after the installation of an active filter, this value drastically decreased to 1.57%. This indicates a substantial improvement in the quality of the electrical signal. The reduction from 57.07% to 1.57% illustrates the effectiveness of the active filter in mitigating harmonic distortions. Harmonic distortions can cause various issues in electrical systems, such as overheating, reduced efficiency, and potential damage to equipment. In summary, the comparison between the unfiltered system and the system with an active filter demonstrates the significant benefits of using an active filter. The THD reduction from 57.07% to 1.57% showcases the filter's effectiveness in enhancing signal quality, thereby improving overall system performance and reliability.

Comparative Analysis of Passive Filters and Active Filters

The following is a comparison table of the THD and IHD of the current in the system before and after the filter is installed.

Table 6. Comparison of Current Harmonic Content in the System

IHDi	Orde Level					THDi
	1	5	7	11	13	
SDP *Extruder*	45	21	13	2.9	1.8	56.0%
Without Filter	44	21	12	3.0	3.4	57.07%
Passive Filter	47	9.2	12	3.0	3.4	34.31%
Active Filter	47	0.6	0.4	0.2	0.0	1.57%

Table 6 shows that active filters are more effective in reducing harmonics due to opposing current injection, while passive filters are less effective because only one order decreases.

Conclusion

The results of measurements and analysis show that the Total Harmonic Distortion Current (THDi) content on the SDP Extruder panel at PT. Delta Jaya Mas is above the normal limit according to the 2012 SPLN standards. Measurements show that the THDi values in the R, S and T phases are 54.9%, 56.0% and 56.0% respectively. Meanwhile, the Total Harmonic Distortion Voltage (THDv) content in the R, S, and T phases is 2.5%, 2.8%, and 2.7% respectively, which does not exceed the 2012 SPLN standard. Based on simulation results using PSIM program, implementation of active filters can reduce THDi significantly. THDi, which was initially 57.07%, decreased to 1.57%, meeting the SPLN standards (2012) which require THDi to be less than 15%. Meanwhile, the implementation of a passive filter was only able to reduce the THDi value to 34.31%. This happens because passive filters only reduce harmonics of a certain order, while active filters eliminate all harmonics. Therefore, active filters are more effective compared to passive filters. By addressing the challenges of harmonic distortion through practical, evidence-based solutions, this research provides a solid foundation for improving industrial electrical systems and advancing the field of power quality management.

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