Journal of Integrated and Advanced Engineering (JIAE)
Vol. 3, No. 1, March2023: 23-36
http://asasijournal.id/index.php/jiae
http://doi.org/10.51662/jiae.v3i1.79

Design and Simulation High Pass Filter Second Order and C-Type Filter for Reducing Harmonics as Power Quality Repair Effort in the Automotive Industry

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Abstract
Electrical distribution is one of the most important parameters in industrial processes. Therefore, good power quality is needed as a supply to industrial machines. The use of industrial machines has an impact on the emergence of harmonics. As a result of the large Harmonics, the quality of power is getting worse, affecting productivity in the industry. Therefore, samples were taken using a Power Quality Analyzer on an 800 kVA transformer on the secondary side of the transformer to maximise the supply of electricity to consumers. Then obtained THDi Phase L1 of 23.1%, phase L2 of 24.7% and phase L3 of 21% and IHDi on the 5th order in phase L1 18.3%, phase L2 20.7% and phase L3 16.6% regarding (IEEE Std 3002.8-2018) and (SPLN D5.004-1:2012) the IHDi value should not be more than 7%. Then simulated using MATLAB/Simulink by designing the Second Order High Pass Filter and C-Type Filter. The results obtained by combining the two filters gained THDi results in the L1 phase at 2.53%, the L2 phase at 2.69% and the L3 phase at 2.22% and the IHDi at the 5th order of the L1 phase at 1.48%, the L2 phase 1.62% and L3 phase 1.33%.

Keywords:
C-Type Filter;
Harmonics;
High Pass Filter;
IHDi;
THDi;

Article History:
Received: August 11, 2022
Revised: March 10, 2023
Accepted: March 19, 2023
Published: March 25, 2023

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INTRODUCTION

The growth in demand for electrical energy increases every year on average by 6.9% per year because electrical energy is a life-supporting factor. The quality of electric power (Power Quality) is a wide range of parameters of Voltage, Current, Frequency, Power Factor, and Harmonics. The distribution network is either direct current (DC) or alternating current (AC). Therefore, applying conventional power system operational concepts, such as power flux control, voltage drop control, schematic protection, and fault detection to distribution power systems is possible. Attention to the power quality index of the electrical interactions between the main grid and their customers. It can be separated into two main issues to be addressed: (i) voltage quality concerns the way in which the supply voltage affects the equipment, and (ii) current quality issues are the way the equipment current affects the system [1][2].

The power supply is one of the most important basic services for supporting industrial, commercial and residential applications. From the point of view of the electricity consumer, this basic service must be available at all times (i.e., high level of continuity) and also enable all consumer electrical equipment to work safely and satisfactorily (i.e., high level of power quality). If electricity were called a product, it would be very different from any other product because of its intangible and transient nature. Electricity as a product exists instantaneously at various points of delivery, and at the same time it comes into existence at various points for use. Therefore, the characteristics of these products differ at each point of delivery. In addition, the quality depends on how it is produced and how it feeds the user's equipment. Equipment manufacturers define power quality as a characteristic of the power supply required to make the equipment work properly. These characteristics can vary greatly depending on the type of equipment and the manufacturing process. Thus, power quality is a problem manifested in voltage, current or frequency deviation resulting in failure or mal-operation of utility or end-user equipment. Also, the International Electromechanical Commission (IEC) standard (1000-2-2/4) defines power quality as the physical characteristic of the supplied electrical supply under normal conditions [2][3].

As a result of the magnitude of the Harmonics, the quality of power is getting worse, affecting the company's productivity [35, 36, 37]. Therefore, samples are taken using a Power Quality Analyzer on an 800 kVA transformer on the secondary side of the transformer to maximise the supply of electricity to consumers. After inputting the data using Power Vision software, the THDi value of Phase L1 is 23.1%, phase L2 is 24.7%, phase L3 is 21.0%, and IHDi is on the 5th order in phase L1 is 18.3%, phase L2 20, 7% and the L3 phase is 16.6%. At the same time, IHDi is in the 7th order, the L1 phase is 11.9%, the L2 phase is 11.5%, and the L3 phase is 11% concerning (IEEE Std 3002.8-2018) and (SPLN D5.004- 1:2012) IHDi values in the 5th, and 7th orders should not be more than 7%.

MATERIAL AND METHODS

Power Quality in Industry

Power quality has become a very important issue recently because of its impact on an increasing number of power quality problems for power suppliers [22][23], equipment manufacturers and customers [15, 16, 17]. Power distribution must comply with strict industry standards for harmonic injection [18]. Power quality can be seen in many aspects of industrial operation [14][15]. These aspects include production losses, manufacturing disruptions, lost revenues, decreased competitiveness, lost opportunities, product damage, wasted energy and decreased equipment life [19].

Where production is disrupted due to disturbances in power quality, the business will lose margin on products that are not produced and not sold. In other side, disturbances caused by certain parts of certain manufacturing systems are affected by power quality disturbances. It will affect the entire system that does not meet standard requirements, has low product quality, and reduced production volume. Any disruption that directly affects the manufacturing process can disrupt sales resulting in delayed production schedules. Still, loss of revenue can also occur apart from power quality disturbances. Main Power is idle due to interruptions, operation maintenance, or corrective maintenance and resource diversion, effectively lowering productivity and increasing costs [28, 29, 30].

Sometimes power quality problems in process plants can result in product damage. So that product damage can be directly observed, and damaged products are disposed of or recycled. Product defects can be expensive if the damage is not visible and the effects take time to resolve. Any disruption to the production process will result in a waste of wasted energy where the reactive power is greater than, and the cost of KVARh will increase. Many systems fail, both detected and undetected, resulting in decreased equipment life. Harmonic Distortion is caused by nonlinear devices in the power system. A nonlinear device is a device whose current is disproportionate to the applied voltage [13, 14, 15].

Individual Harmonic Distortion (IHD)

The ratio of the RMS value of a certain order harmonic component to the RMS value of the fundamental component. From the base. The harmonic standard used is the IEEE Std 3002.8-2018 [18] and SPLN D5.004-1:2012 [19] standards. Two criteria are commonly used to clarify harmonic distortion: the harmonic limit for current and the harmonic limit for voltage. The percentage (%) IHD is the ratio of the total current distorted by the harmonics to its fundamental frequency. To determine the presentation (%) of IHD depends on the magnitude of the ratio of Isc and IL.

$$\text{Ihd} = \frac{Ih}{I1} \text{x} 100\% \tag{1}$$

Total Harmonic Distortion (THD)

The ratio of the sum of the RMS values of all harmonic components up to a certain order to the RMS values of the fundamental components. A measurement of a THD present in a signal is defined as the ratio of the sum of the strengths of all harmonic components to the strength of the fundamental frequency [11][12]. THDv is a ratio of the sum of the RMS values of all voltage harmonic components up to a certain order to the RMS value of the fundamental voltage components. Then it can be determined by the equation:

The equation of THDv value and THDi value are as follows:

$$\text{THDvn}= \frac{\sqrt{\sum_{h=2}^{\sim} V_h^2}}{Vn} \text{x } 100\% \tag{2}$$

$$\text{THDi}= \frac{\sqrt{\sum_{h=2}^{\sim} I_h^2}}{I1} \text{x } 100\% \tag{3}$$

High Pass Filter Second Order

The characteristics of the second-order high-pass filter are shown in Figure 1, with the filters R - X and Z - plots. It has a low impedance above the corner frequency; thus, it will cut off most of the harmonics at or above the corner frequency. This type of Second-order High Pass Filter provides the best filtering performance but has the potential for higher frequency losses compared to third-order filters [3, 27, 28].In addition, the sharpness of adjustment of the high-pass filter is the opposite of that of the ST filter.

High Pass Filter consists of a narrow band branch tuned to the harmonic frequency in the load current spectrum. Separate branches create high-quality parallel resonant circuits with inductance supply systems [29][30].

This can cause the amplification of the non-characteristic harmonics produced by the nonlinear multiphase on the pass filter load to be high, thus simultaneously attenuating several harmonics used to attenuate the resonance mode. However, in most cases, traditional methods can be applied to design second and third-order filters. Such filters have insufficient selectivity and are characterised by significant power losses in the damping resistor at the fundamental frequency. Increasing the order of the high pass filter can reduce the losses in the damping resistor and get the required response frequency, as depicted in Figure 2.

Determining the Data Factor (Cos), the value of the capacitance Qf can be determined by the equation:

$$Q f = P(tan\ 1 - tan\ 2\ ) \tag{4}$$

To determine the reactance of the capacitor with the following equation [3]:

$$XC = \frac{Vs^2}{Qf} \quad (5)$$

$$C = \frac{1}{2\pi f Xc} \quad (6)$$

The value of the inductance (L) must be adjusted to the order of the harmonics, so the following equation can be obtained:

$$X_L = \frac{X_C}{H0^2} \quad (7)$$

$$L = \frac{X_L}{2\pi f} \quad (8)$$

To get the value of R can be used with the following formula:

$$Xn = \sqrt{\frac{L}{C}} \quad (9)$$

$$R = Xn \times Q_{Filter} \quad (10)$$

C-Type Filter

Filter C was first introduced at the France-UK HVDC interconnect project and later at the Intermountain and Quebec – New England HVDC projects. Effectively replacing conventional ST filters and finding their use in installations shows the equivalent circuit of a C-type filter. The filtering performance of a C-type filter lies between the second and third-order types. Its main advantage is the considerable reduction in fundamental frequency loss since C2 and L are tuned in series at that frequency. However, these filters are more susceptible to fundamental frequency drift and component value drift [3][27]. Figure 3 shows a C-Type Filter and Figure 4 presents a Characteristics of C-Type Filter.

In determining the C-Type, it is necessary to pay attention to the value of the QF. where Qf is the reactive power requirement at the fundamental frequency and Vs is the nominal system voltage. This allows the calculation of C1 directly. As the frequency increases, L starts to resonate with C+C1, which makes the Filter act as an ST filter with a damping resistor.C-Type Filter is used as an alternative approach to avoid errors in designing the calculated filter in a filter is very important. Advantages and disadvantages are identified, and the effectiveness of using the C-type filter in various case studies is demonstrated. The optimal design of the C-Type Filter is made based on minimising the total harmonic distortion of the nonlinear load, where maintaining the load power factor in a certain acceptable range (≥ 90%) is desired [31, 32, 33].

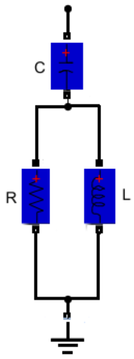

Figure 1. High Pass Filter Second Order

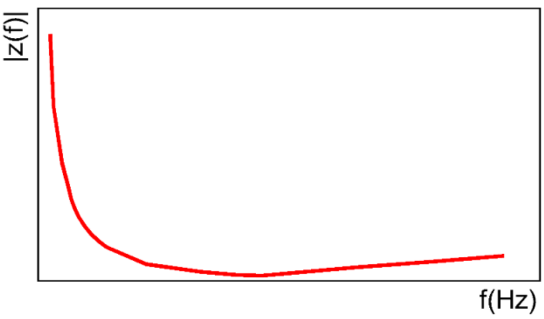

Figure 2. Characteristics of High Pass Filter Second Order

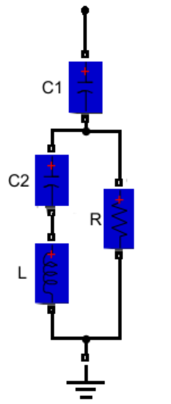

Figure 3. C-Type Filter

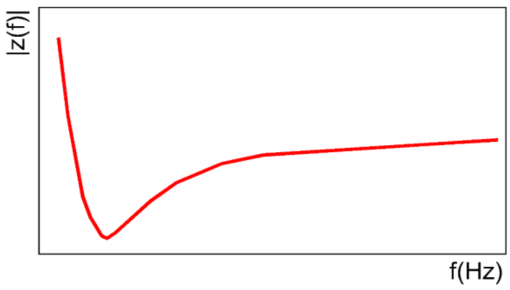

Figure 4. Characteristics of C-Type Filter

The most important concept to illustrate involves evaluating the harmonic voltage limit of the system as a whole. At high frequencies, the filter response is dominated by resistor R, thus exhibiting good damping characteristics. In addition, the filter has a small loss because L and C2 are tuned to the fundamental frequency, which leads to the bypass of the R branch. In designing the C-Type filter, we get the following equation [3][34]:

To determine the Capacitor Reactance is with the following equation:

$$C1 = \frac{\mathrm{Qf}}{2\pi f \mathrm{Vs}^2} \tag{11}$$

$$C2 = (h_{o^2} - 1)\ x\ C1 \tag{12}$$

The value of the inductance (L) must be adjusted to the order of the harmonics, so the following equation can be obtained:

$$L = \frac{\mathrm{Vs}^2}{(h0^2 - 1)\omega f Qf} \tag{13}$$

to get the value of R can be used with the following formula:

$$\mathrm{R} = \frac{\mathrm{Q_{Filter}Vs^2}}{\mathrm{h0}Qf} \tag{14}$$

Methods

At this stage, the researchers took samples with Power Analyzer Circutor Type AR 6 and analyzed with Power Vision software. If the THD value does not match the expected standard, making a model first improves the harmonics value. As well as designing the filter on the system by simulating it with MATLAB/Simulink so that the desired harmonic value is achieved. Figure 5 presents a research flowchart.

RESULTS AND DISCUSSION

In this measurement, the researcher measures in the Automotive company and measures it on the Secondary side of the Transformer, based on measurements using the Power Quality Analyzer, the results of the power quality results will then be identified whether they comply with the standards (IEEE Std 3002.8-2018) and (SPLN D5.004-1:2012). So, from the measurement results obtained, the following data. Table 1 lists the power measurement results

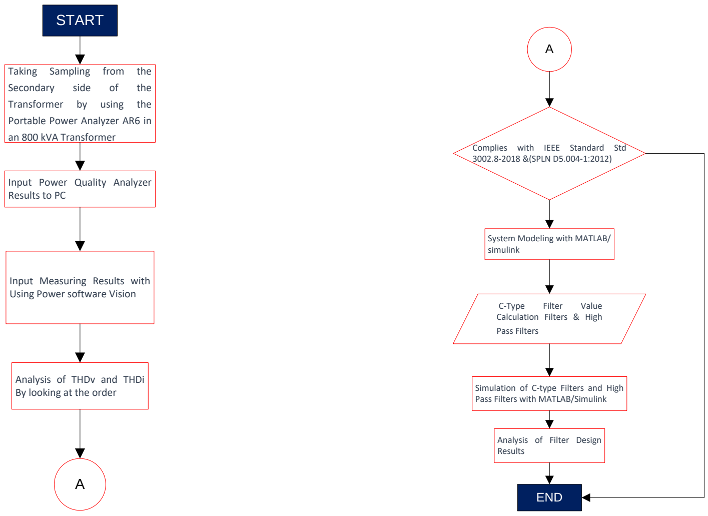

Figure 5. Research Flowchart

Table 1. Power Measurement Results

Description	L1	L2	L3	Unit
Voltage (V)	2 30	2 29	227	V
Current (I)	127.05	119.79	126.8	A
THDv	1.5	1.6	1.2	%
THDi	23.1	24.7	21.0	%
Real Power (P)	27.6	26	27.5	kW
Apparent Power (S)	30	28.1	29.6	kVA
Reactive Power (Q)	11.7	10.6	10.9	kVAR
Frequency (F)	50	50	50	Hz
Power Factor (PF)	0 .701	0.730	0.719	

Measurement of IHDi

Measurements were made on the secondary load side of the 800 kVA transformer resulting in a spectrum and current distortion waveform. There is a wave defect with a non-sinusoidal shape for the spectrum at this current. This is influenced by a fairly large IHDi. Figure 6 and Figure 7 show the IHDi wave form and measurement results, respectively. A three-phase nonlinear load (L1, L2, L3) on a distribution transformer of 800 kVA will cause a large current harmonic on the 5th, 7th and so on. Next, it will design a Second Order Passive High Pass Filter and C-Type Filter to standards (IEEE Std 3002.8-2018) and (SPLN D5.004-1:2012). The IHDi measurement results is listed in Table 2.

Table 2.IHDi Measurement Results

Order of Harmonics	IHDi (%)			Harmonic Standard IEEE Std 3002.8-2018 &SPLN D5.004-1:2012 (%)	Remaks
	L1	L2	L3		
3	3.2	1.9	0.0	7.0	Match
5	18.3	20.7	16.6	7.0	No Match
7	11.9	11.5	11.0	7.0	No Match
9	0.0	1.3	0,0	7.0	Match
11	1.3	2.3	1.8	3.5	Match
13	5.8	3.6	3.9	3.5	No Match
15	1.3	2.4	1.8	3.5	Match
17	6.0	7.1	6.0	3.5	No Match
19	0.0	2.4	1.3	2.5	Match
21	0.0	0.0	0.0	2.5	Match
23	0.0	1.3	0.0	1.0	Match

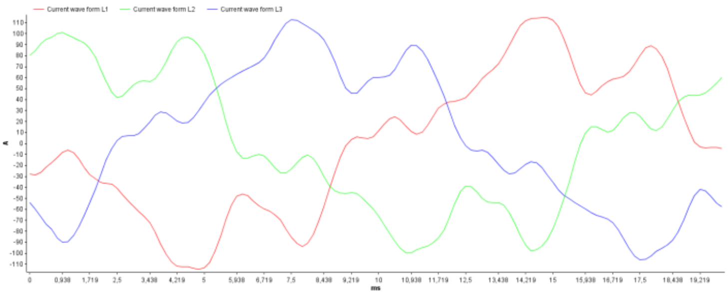

Figure 6. IHDi Waveform

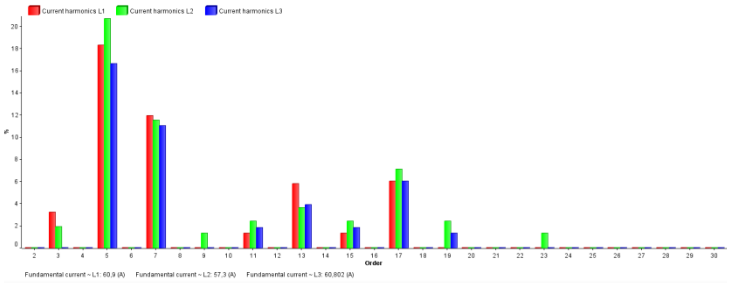

Figure 7. IHDi Measurement Results

IHDv of Measurements

The individual measurement of harmonic distortion at a voltage (IHDv) was carried out on February 1, 2021. The results met all standards, namely <5% of the standards set by (IEEE Std 3002.8-2018) and (SPLN D5.004-1:2012). The highest voltage harmonics' results are only in orders five and seven. On the order of voltage harmonics, in order 5 phase L1 is 0.7%, L2 phase is 0.8%, L3 phase is 0.8%, and in order 7 phase L1 is 0, 8%, 0.7% L2 phase, and 0.7% L3 phase. Figure 8 and Figure 9 show the IHDv waveform and measurement results, respectively. The IHDv measurement results is listed in Table 3.

Analysis and Discussion

The electricity network system at PT MES consists of PLN power entering the incoming 20 kV Cubicle and going to the 20 Kv outgoing Cubicle. So, in this case, the modeling of the electricity network system uses MATLAB/Simulink which is adapted to field conditions. This modeling aims to simulate the electrical network before installing the Second Order High Pass Filter and C-Type Filter. Then the results obtained are IHDi in each order and the spectrum generated through FFT Analysis.

Table 3.IHDv Measurement Results

Order of Harmonics	IHD v (%)			Harmonic Standard IEEE Std 3002.8-2018 & SPLN and D5.004-1:2012 (%)	Remaks
	L1	L2	L3		
3	0.0	0.0	0.0	5.0	Match
5	0.5	0.7	0.5	5.0	Match
7	1.4	1.4	1.1	5.0	Match
9	0.0	0.0	0.0	5.0	Match
11	0.0	0.0	0.0	5.0	Match
13	0.0	0.0	0.0	5.0	Match
15	0.0	0.0	0.0	5.0	Match
17	0.0	0.5	0.0	5.0	Match
19	0.0	0.0	0.0	5.0	Match
21	0.0	0.0	0.0	5.0	Match
23	0.0	0.0	0.0	5.0	Match

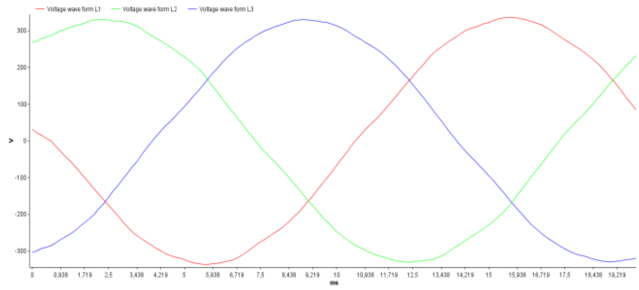

Figure 8. IHDv Waveform

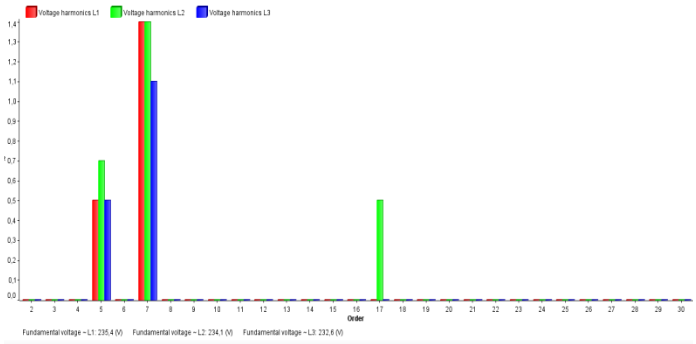

Figure 9. IHDv Measurement Results

Modeling High Pass Filter Second Order

Running on a simulation circuit using FFT Analysis, the results obtained from the High Pass Second Order Filter are sinusoidal spectra with maximum fundamental current at phase L1 88.67A, phase L2 86.58A and Phase L3 83.71A can be seen in Figure 10. The THDi which obtained for the L1 phase 4.12%, the L2 phase 4.58% and the L3 phase 3.55% while the respective values are in the 5th order and 7th order. 3,58% L3 phase 2,70% for 7th order L1 phase the reduced percentage is 1.32% L2 phase is 1.67% and L3 phase is 1.49% with reference to the standard where the THDi should not be more than 8% for the 5th and 7th order IHDi. It should not exceed 7%, so in this simulation process, the harmonics are reduced by the Second Order High Pass Filter. The Second Order High Pass Filter simulation results is listed in Table 4.

C-Type Filter Modeling

The results obtained are the fundamental currents at the L1 phase 89.15A, the L2 phase 91.17A and the L3 phase 84.49A with a sinusoidal spectrum result, as seen in Figure 11.

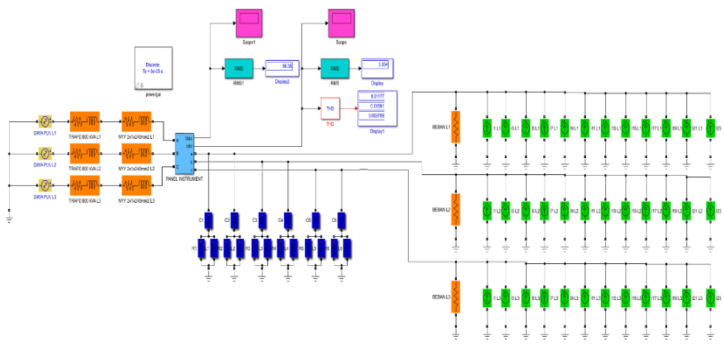

Figure 10. Second Order High Pass Filter Simulation Circuit

Table 4. Second Order High Pass Filter Simulation Results

Order of Harmonics	Measurement Results with AR6 IHDi (%)			Second Order High Pass Filter Simulation Results IHDi (%)			(IEEE Std 3002.8-2018) and (SPLN D5.004-1:2012)(%)	Remarks
	L1	L2	L3	L1	L2	L3		
3	3.2	1.9	0.0	1.16	0.71	0.0	7.0	Match
5	18.3	20.7	16.6	3.15	3.58	2.70	7.0	Match
7	11.9	11.5	11.0	1.32	1.67	1.49	7.0	Match
9	0.0	1.3	0.0	0.0	0.21	0.0	7.0	Match
11	1.3	2.3	1.8	0.24	0.45	0.33	3.5	Match
13	5.8	3.6	3.9	1.25	0.79	0.81	3.5	Match
15	1.3	2.4	1.8	0.31	0.57	0.41	3.5	Match
17	6.0	7.1	6.0	1.49	1.78	1.43	3.5	Match
19	0.0	2.4	1.3	0.0	0.62	0.32	2.5	Match
21	0.0	0.0	0.0	0.0	0.0	0.0	2.5	Match
23	0.0	1.3	0.0	0.0	0.36	0.0	1.0	Match

The THDi value obtained is according to the standard (IEEE Std 3002.8-2018) and (SPLN D5.004-1:2012) that the THDi should not exceed 8% in the L1 phase 3.71%, the L2 phase 4.11% and the L3 phase 3, 25%. Meanwhile, IHDI for 5th order and 7th order still exceeds the standard where each phase is less than 7% with reference to the standard that has been described previously. L2 is 1.89% and the L3 phase is 1.50%. For the 7th order, the results obtained at the L1 phase are 0.86%, the L2 phase is 0.88% and the L3 phase is 0.77%. Table 5 lists the simulation Results of C-Type Filter.

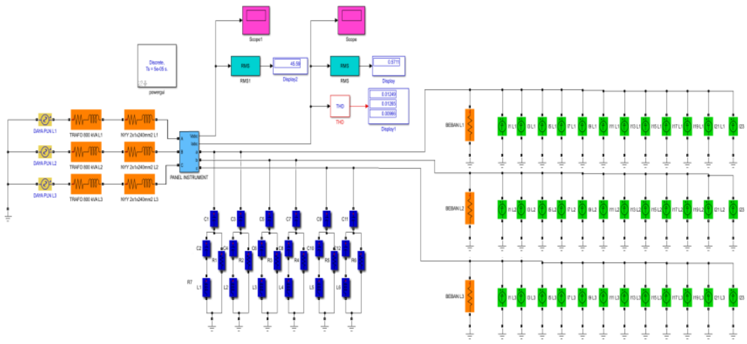

Figure 11. Simulation Circuit C-Type Filter

Table 5.Simulation Results of C-Type Filter

Order of Harmonics	Measurement Results with AR6 IHDi (%)			C-Type Filter Simulation Results IHDi (%)			Standard (IEEE Std 3002.8-2018) & (SPLN D5.004-1:2012)(%)	Remaks
	L1	L2	L3	L1	L2	L3		
3	3.2	1.9	0.0	1.17	0.69	0.0	7.0	Match
5	18.3	20.7	16.6	1.68	1.89	1.50	7.0	Match
7	11.9	11.5	11.0	0.86	0.88	0.77	7.0	Match
9	0.0	1.3	0.0	0.0	0.23	0.0	7.0	Match
11	1.3	2.3	1.8	0.31	0.59	0.43	3.5	Match
13	5.8	3.6	3.9	1.76	1.15	1.18	3.5	Match
15	1.3	2.4	1.8	0.46	0.88	2.63	3.5	Match
17	6.0	7.1	6.0	2.34	2.85	2.34	3.5	Match
19	0.0	2.4	1.3	0.0	1.03	0.55	2.5	Match
21	0.0	0.0	0.0	0.0	0.0	0.0	2.5	Match
23	0.0	1.3	0.0	0.0	0.61	0.0	1.0	Match

Filter Combination Modeling

After the program runs, using the FTT Analysis method on the Block Power Gui, the results obtained are the amount of Fundamental current in phase L1 of 69.91A, phase L2 72.24 A and phase L3 of 64.5A with sinusoidal spectrum results. Each phase can be seen in Figure 12. Table 6 show a simulation Results of Filter Combinations. The total harmonic distortion is even better than the High Pass Passive Filter and the C-Type Filter that has not been combined where the THDi in the L1 phase is 2.53% and the L2 phase is 2.69% and the L3 phase is 2.22% which refers to the standard (IEEE Std 3002.8-2018) and (SPLN D5.004-1:2012) with the THDi percentage, not more than 8% [36]. The IHDi value in the 5th order, which is reduced in the L1 phase is 1.48% the L2 phase is 1.62% and the L3 phase is 1.33%. For the 7th order IHDi, the L1 phase is 0.70%, the L2 phase is 0.77% and the L3 phase is 0.70%.

Analysis of Simulation Test Results

After doing a series of simulation tests using MATLAB/Simulink, the results obtained where at the beginning of the simulation, the THDi value without a filter for the L1 phase is 22.68%, the L2 phase is 22.93%, and the L3 phase is 20.47% with an average THDi of 22.02%. When simulated using a Second Order High Pass Filter, the results obtained at the L1 phase are 4.12%, the L2 phase is 4.58% and the L3 phase is 3.55% with the average reduced to 4.08%. Then on the C-Type Filter the results obtained in the L1 phase are 3.71%, the L2 phase is 4.11% and the L3 phase is 3.25% with the average using a C-Type filter reduced to 3.69%. C-Type filter contributes more to reducing harmonics than using a Second Order High Pass Filter. However, when the two filters are combined, they will sharpen the filter to reduce pollution from harmonics.

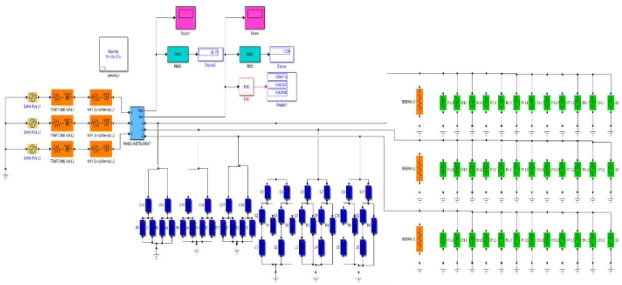

Figure 12. Filter Combination Simulation Circuit

Table 6. Simulation Results of Filter Combinations

Order of Harmonics	Measurement Results with AR6 IHDi (%)			Filter Combination Simulation Results IHDi (%)			(IEEE Std 3002.8-2018) and (SPLN D5.004-1:2012 (%)	Remarks
	L1	L2	L3	L1	L2	L3		
3	3.2	1.9	0.0	0.77	0.45	0.0	7.0	Match
5	18.3	20.7	16.6	1.48	1.62	1.33	7.0	Match
7	11.9	11.5	11.0	0.70	0.77	0.70	7.0	Match
9	0.0	1.3	0.0	0.0	0.16	0.0	7.0	Match
11	1.3	2.3	1.8	0.20	0.37	0.28	3.5	Match
13	5.8	3.6	3.9	1.07	0.67	0.73	3.5	Match
15	1.3	2.4	1.8	0.27	0.50	0.38	3.5	Match
17	6.0	7.1	6.0	1.36	1.59	1.35	3.5	Match
19	0.0	2.4	1.3	0.0	0.57	0.31	2.5	Match
21	0.0	0.0	0.0	0.0	0.0	0.0	2.5	Match
23	0.0	1.3	0.0	0.0	0.33	0.0	1.0	Match

Table 7. Comparison of THDi Before and After Filter Installation

Phase	AR6. Measurement Results	Simulation Results Before Filter Installation	High Pass Filter Second Order	C-Type Filter	Combination Filter	Standard (IEEE Std 3002.8-2018) & (SPLN D5.004-1:2012 (%)	Remarks
	THDi (%)						
L1	23.1	22.68	4.12	3.71	2.53	8.0	Match
L2	24.7	22.93	4.58	4.11	2.69	8.0	Match
L3	21.0	20.47	3.55	3.25	2.22	8.0	Match

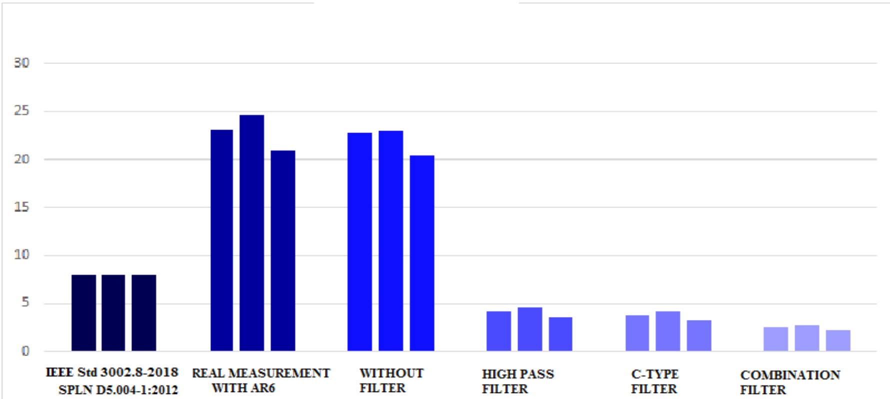

Figure 13. THDi Comparison Graph Before and After Filter Installation

The THDi value in the L1 phase is 2.53%, the L2 phase is 2.69% and the L3 phase is 2.22%, with an average reduction in each phase of 2.48%. With the standard ((IEEE Std 3002.8-2018) and (SPLN D5.004-1:2012)) the THDi should not exceed 8%.

The results of IHDi without simulation experience defects in the 5th order, 7th order, as listed in Table 7 and presented in Figure 13. However, the worst was in the 5th order and 7th order. Where in the 5th order the L1 phase reached 17% in the L2 phase 18.1% and in the L3 phase 15.39% with an average of 16.83% in each phase, for the order the 7th harmonic is the same as the 5th order where the harmonics are quite severe where in the L1 phase 11.7% in the L2 phase 10, 64% and in the L3 phase 10.79% with an average IHDi on the seventh order 11.04 %. To improve the IHDI, two filters are needed, both the High Pass Filter Second Order and the C-Type Filter. because from the analysis results obtained that the 5th order and 7th order are above the threshold. then in each phase (L1, L2, L3) consists of two filters aimed at optimising the performance of a filter. Furthermore, in this study, make a Three Line Diagram simulation using MATLAB/Simulink by entering the calculated R, L, C values according to the measured data. the results obtained in the High Pass Filter Second Order. in the 5th order, the L1 phase was reduced by 3.15%, the L2 phase was 3,58% and the L3 phase was 2,70% with an average reduction of 3,14%. for the 7th order the results obtained in the L1 phase are 1.32%, the L2 phase is 1.67% and the L3 phase is 1.49% with the reduced average reaching 1.49%. the use of the C-Type Filter is the same as the use of the High Pass Filter where the filter is installed or coupled to the measuring panel bus. The results obtained at the 5th order of the L1 phase were 1.68%, the L2 phase was 1.89% and the L3 phase was 1.50%, with the reduced average yield reaching 1.69%. for the 7th order the results obtained in the L1 phase are 0.86%, the L2 phase is 0.88% and the L3 phase is 0.77% with a reduced average of 0.83%.

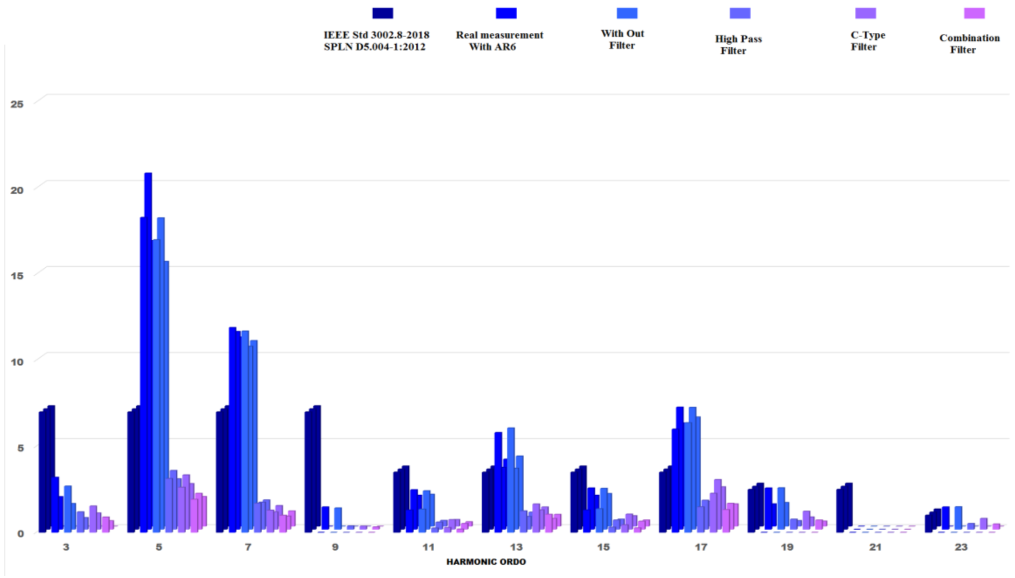

Figure 14. IHDi Comparison Graph Before and After Filter Installation

The characteristics of the two filters are very different for the C-type filter, only sharpening at the 5th and 7th orders, while the use of the High Pass Filter is sharper at the 13th and 17th orders. So that the reduction results are more reliable, the two filters are combined where the results obtained in the 5th order of the L1 phase 1.48%, 1.62% L2 phase and 1.33% L3 phase with a reduced average of 1.47%. for the 7th order, the results of the L1 phase were 0.99%, the L2 phase was 0.70% and the L3 phase was 0.77% with an average of 0.70% with an average of 0.72%. then according to the standard ((IEEE Std 3002.8-2018) and (SPLN D5.004-1:2012)) orders 3 to 9 should not exceed 7%. In a low voltage distribution system on a 20 kV industrial network, power quality improvement is not only in the sector of improvement in the power factor, but improvements in harmonics are needed. The choice of a combination of High Pass Filter Second Order and C-type Filter is needed as a solution as harmonic filtering so that the current wave becomes sinusoidal. So that the age of industrial equipment such as 3-phase motors, conveyors, induction machine, becomes long and can reduce maintenance costs in the production process in the industry. From the results of a series of tests using MATLAB/Simulink Order 5, order 7, order 13 and order 17 have been reduced properly by meeting the predetermined standards [38]. So, these results can be seen in Figure 14.

CONCLUSIONS

Based on the simulation test results using MATLAB/Simulink, the following conclusions can be drawn. Second Order High Pass Filters and C-Type Filters reduce harmonics depending on the number of harmonic orders that do not match the standard. In this study, the 5th order and 7th order, which do not meet the standard, exceed the threshold, so two filters per phase are needed to reduce these harmonics. The simulation results using MATLAB/Simulink show that using C-Type Filter is more effective than Second Order High Pass Filter to minimise THDi. The use of C-Type Filter can sharpen for IHDi reduction on the 5th and 7th order, but in the 11th to 23rd order, the use of the Second Order High Pass Filter is sharper than the C-Type Filter. The combination of the Second Order High Pass Filter and the C-Type Filter is able to sharpen the harmonic reduction two times compared to the use of the Second Order High Pass Filter and the C-Type Filter when not combined.

The suggestions that can be taken from the simulation test results are. Future research recommends using other types of filters to be simulated with MATLAB/Simulink or in combination with several other types of filters. Use of Combination Filters between Second Order High Pass Filters and C-Type Filters very suitable for large industries that use a lot of nonlinear loads, such as factory machines, 3-phase motors, conveyors, industrial lights and so on. In designing the filter, paying attention to the R, L, and C values is necessary because there could be an error in the calculation resulting in the filter not working properly.

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