Harmonic Analysis In The New Information Technology Building, State Polytechnic of Samarinda

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Abstract

This study aims to determine the level of harmonics and conduct harmonic analysis on the electrical system in the new Building of the Information Technology Department of Samarinda State Polytechnic. Harmonics are electric waves that have frequencies with multiples of the base frequency of the power source (50 Hz in Indonesia). Harmonics can arise due to the use of electronic equipment that has non-linear load properties. This is becoming a major problem for power quality issues and harmonic analysis is required to scrutinize in component modeling to minimize or eliminate these harmonic disturbances. Based on research the harmonic content in the new building of the Information Technology Department of Samarinda State Polytechnic has not met the standards. In this case, the power quality in such buildings exceeds the specified standards. The method used is the design of passive filter simulation in distribution transformers using ETAP software. The result of this study is a decrease in harmonic currents after installing a passive filter with an initial THDi value in phase S of 59.84% for IHDi values in the 5th order of 57.25% the value does not meet IEEE 519-2014 standards, the use of single-tuned passive filters can reduce the THDi content in phase S to 10.94% and the 5th order phase S down to 10.46 already meets IEEE 519 – 2014 standards, namely THDi 15% and IHDi in the 5th order 12% with SCRatio between 100-1000 A.

Keywords: Harmonic, IEEE 519-2014, single-tuned passive filter, ETAP

I. INTRODUCTION

A reliable electrical power system ensures a continuous supply of electricity with good power quality in terms of voltage regulation and frequency regulation. Continuous electrical energy supply is crucial for educational institutions, research facilities, industrial areas, shopping centers, and households. Industrial areas aim to avoid production losses, which can have significant financial implications. However, power systems often face challenges in providing uninterrupted electrical energy. Power quality issues, particularly voltage instability, can lead to damage to voltage-sensitive equipment, especially electronic devices. Non-linear loads are a significant factor affecting power quality, as they introduce harmonics that degrade power quality [1],[2],[3].

Various disturbances commonly occur in power systems, including voltage sags, power factor reduction, and the presence of harmonics. Voltage sags affect voltage-sensitive equipment, while power factor reduction and harmonics decrease the efficiency of electrical energy use. Therefore, evaluating the electrical system is necessary to mitigate the impact of capacity additions. Power factor plays a crucial role in power calculations, representing the power transferred between the source and the load. Although the power factor ranges from 0 to 1, it is typically expressed as a percentage. Voltage sags primarily occur due to faults in the network system. Other causes include the magnitude of the load (especially in industrial systems) and, at times, inductive load sizes. Non-linear loads are the main source of harmonic distortion in the electrical network, posing a serious problem for large industries. Non-linear loads consist of power electronic devices such as variable speed drives, rectifiers, and inverters. These power electronic devices introduce non-sinusoidal waveforms, leading to high-frequency waveform disturbances (harmonics) that disrupt the power system along with its equipment. The objective of this study is to investigate the power quality of the electrical system at the Department of Information Technology's New Building in the State Polytechnic of Samarinda. This includes examining power factors and harmonics, modeling and simulating the electrical system using ETAP 16 software, and analyzing the simulation results. It is expected that the obtained results will contribute to improving electrical power quality and usage in the industry [1],[4].

The New Building of the Department of Information Technology is a government-owned educational facility equipped with electrical equipment to support the work of its employees. These devices can be damaged if supplied with unstable electricity. Therefore, an analysis of power quality titled "Harmonic Analysis in the
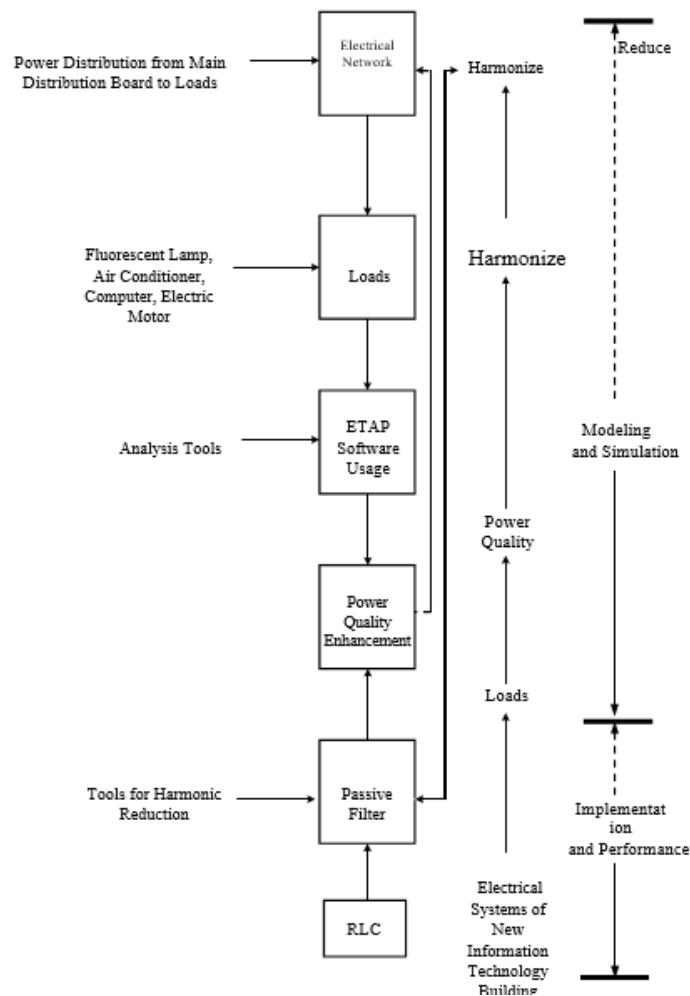

New Building of the Department of Information Technology at the State Polytechnic of Samarinda" will be conducted with the hope of ensuring that the power supply and system in the New Building of the Department of Information Technology at the State Polytechnic of Samarinda are always well-maintained, along with the existing equipment. One solution to reduce the impact of harmonics on the distribution system is to utilize passive filters, which are used to enhance the power quality of the electrical system. Various techniques have been applied to rectify harmonics [2],[3],[5],[6].

II. RESEARCH METHOD

Research Preparation Stage

The research framework is the thought flow for researchers related to the scope, material limitations, and desired outcomes in the research stage, explained in the form of a flowchart.

Based on Figure 1, the flowchart shows that in the New Building of the Department of Information Technology, there are non-linear loads such as fluorescent lamps, computers, air conditioners, and electric motors. These loads can deteriorate power quality and cause harmonics. This can affect the performance of the system and electrical equipment, leading to changes in current and voltage. One way to help reduce harmonics is to use a harmonic filter installed in the electrical system network. The filter contains a series of RLC components that function to reduce harmonics and can improve power factor due to the presence of a capacitor component. Based on this description, the research framework related to the target to be achieved is as follows:

Picture 1: Research Framework

1. Model and simulate the electrical power system in the New Building of the Department of Information Technology using ETAP software, then test to ensure that the model is ready for analysis using a harmonic filter.
2. Implement and evaluate the improvement in power quality that has been made with conditions before and after the installation of the harmonic filter.

Figure 2 illustrates the flowchart of the research operational framework, showing that the research process begins with a literature review consisting of literature studies and case studies, followed by the acquisition of reference data and field data from the New Building of the Department of Information Technology at the State Polytechnic of Samarinda. The programs (software) used for analysis include ETAP 16, Microsoft Word, and Microsoft Excel, and the literature review results in specifications and functions of the harmonic filter.

The research continues with the data processing stage, where reference and field data are analyzed using ETAP software, resulting in processed data in the form of power flow. The processed data is then reprocessed to determine the capacity of the harmonic filter. After designing and applying the filter to the circuit, it is checked if it complies with the IEEE THD standard. If it does, the analysis phase proceeds; if not, it returns to the filter design stage.

Finally, the last stage presents the simulation results showing the effects of filter installation, along with the analysis of the simulation results using tables, graphs, and images.
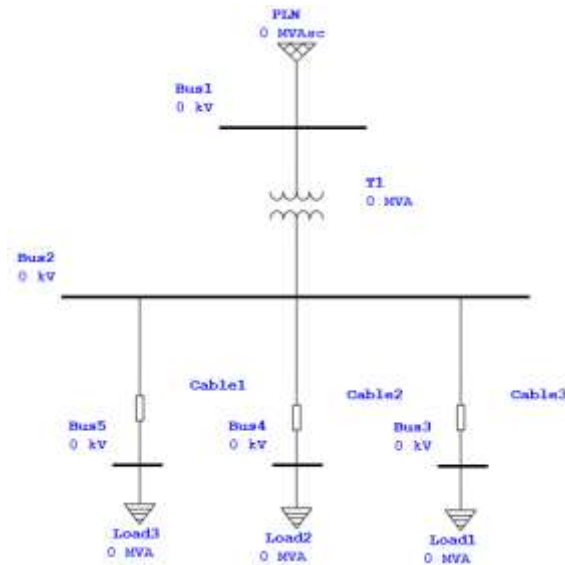
ETAP Software Simulation Design

In the design and analysis of an electrical power system, a software application is crucial to represent real conditions before a system is implemented. ETAP (Electric Transient and Analysis Program) is one such software application used to simulate electrical power systems. ETAP can work offline for power system simulation and online for real-time data management or system control.

Before conducting research using ETAP software, it is important to first understand the parameters used in the research process regarding harmonics. Below is a simple circuit design that will be used, where phases R, S, and T will be represented as loads in the electrical system of the Department of Information Technology building.
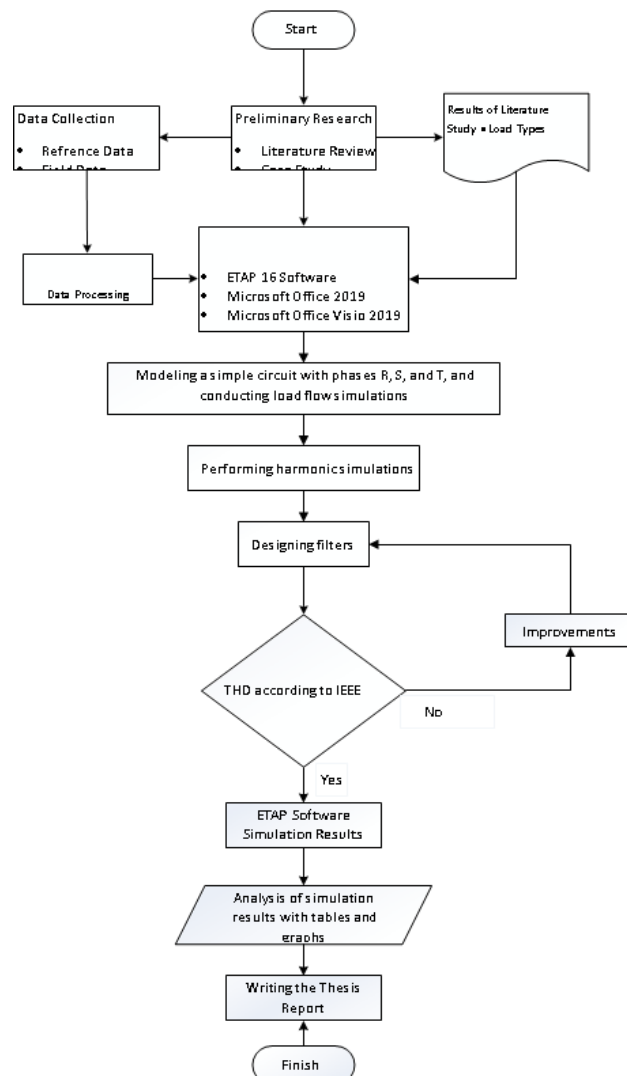
Picture 2: Research Operational Framework

Picture 3: Design of a simple circuit simulation using ETAP software.

Before running the circuit above, we first fill in the parameters used, starting with the power grid.

The Power Grid, or the PLN source, is an ideal voltage source. This means it is capable of supplying power with a constant voltage even when a considerable amount of power is being absorbed. The Power Grid can be a large generator or a Substation, which is part of a larger interconnected electrical power system. Double-click on the Power Grid, then enter the data in the Info and Rating tabs for a 20 kV Power Grid by field measurement data.

Picture4: Data in the Info and Rating Power Grid tab.

Before connecting the Power Grid to the Bus Bar, click and drag the end of the Power Grid to the Bus Bar. If done correctly, the Bus Bar color will change, and no longer gray. Below are the data in the bus editor before the transformer.

Picture5: Filling in the primary bus data.

Next, from the next bus to the transformer. The transformer is a device used to step up or down the system voltage from the PLN source. First, set the rating value used according to the data on the transformer in the Department of Information Technology building, which is 200 kVA with a secondary voltage of 400 V or 0.4 kV. Then click on typical Z&X/R, and the transformer impedance value will appear automatically.


Picture 6: Display of transformer data entry.

Place the bus bar back to 2 after the transformer to distribute power to the three phases R, S, and T. The busbar data will be automatically filled in at the secondary voltage of 0.4 kV.
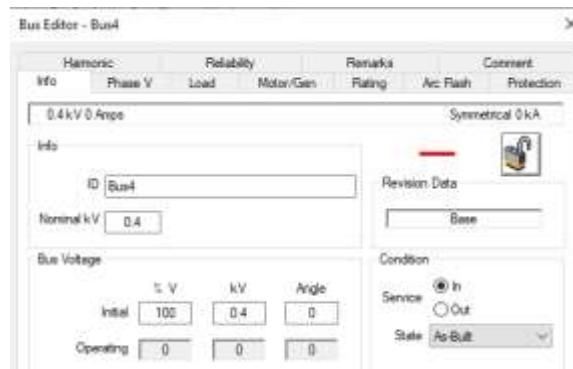

Picture 7: Display of secondary bus data entry.

The load will be divided into three phases: R, S, and T. Before connecting the bus bar to the load, place a cable on each line as shown in the following image.
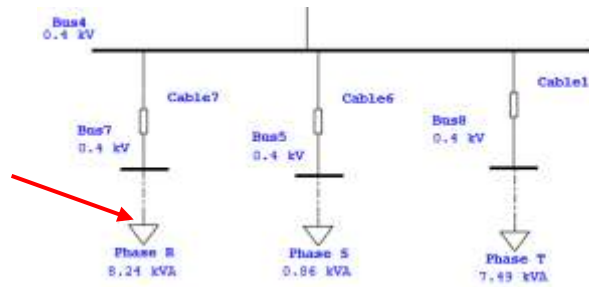
Picture8: Placement of AC cables.

After the cables are installed, double-click on them, then click on Library and set them according to the data. This way, it will look like the image below.
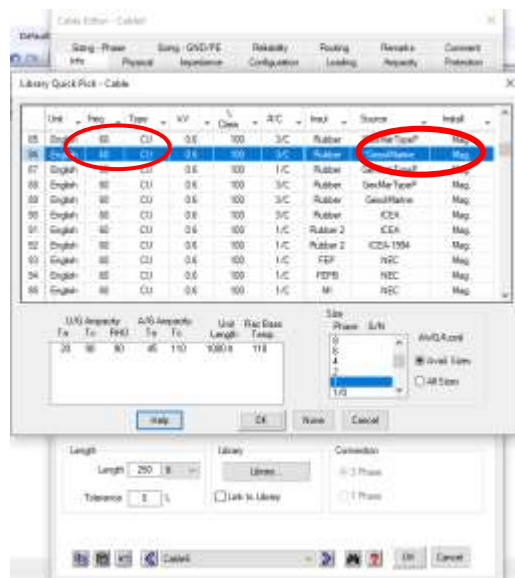

Picture9*: Library cable*.

Lastly, add static load components to the AC component, and set the rating values of each load according to the field measurement data so that it appears as shown in the image.

Picture10: Display of load data entry.

Once the simple circuit is created and the data for each component is entered, the power flow within the electrical system can be determined by running the load flow analysis. This will provide simulation results displayed in red letters as shown in the image.
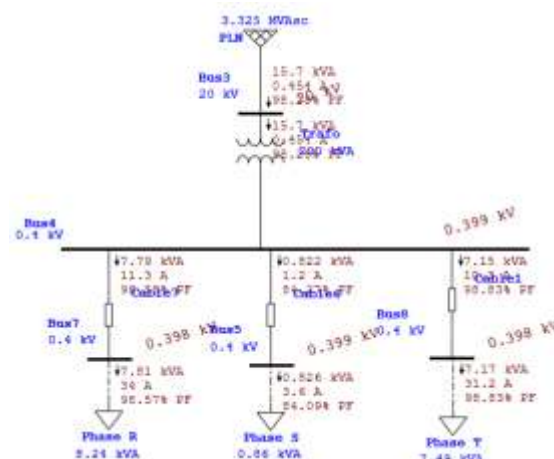
Picture 11: Running load flow circuit.

III.   RESULTS AND DISCUSSION

Overview

The measurements at the Architecture Building of the State Polytechnic of Samarinda were conducted for 8 days from August 22, 2023 to August 28, 2023. To perform calculations, simulations, and analysis of the Single-Tuned passive filter used to mitigate harmonics in the electrical network system of the Department of Information Technology building, the measurement data from August 22, 2023, at 14:57 WITA was used as it had the highest THD value, as shown in Table 3 below.

Table 3
Data Of Measurement Results On August 22, 2023

Rabu, 22 Februari 2023 (Jam 14.57)												
Orde	THDv (%)			THDi (%)			IHDv (%)			IHDi (%)		
	R	S	T	R	S	T	R	S	T	R	S	T
3							0,56	0,61	1,08	8,1	42,68	12,16
5							1,43	1,6	1,26	2,47	24,88	2,92
7							0,25	0,55	0,17	3,15	11,59	2,38
9	1,63	1,89	1,82	11,38	59,84	14,6	0,26	0,37	0,55	1,7	17,61	2,04
11							0,27	0,1	0,22	1,87	19,67	2,8
13							0,16	0,36	0,19	1,18	13,65	1,16
15							0,06	0,4	0,17	0,7	4,63	0,66

Determining Short Circuit Current (ISC)

The short circuit current (ISC) can be calculated using Equation (4) as follows.

$$Isc = \frac{100 x Strafo}{\sqrt{3}.V.Z}$$

First, data on the distribution transformer of the electrical system in the New Building of the Department of Information Technology at the State Polytechnic of Samarinda is required. The transformer data to be used is taken from the ETAP simulation data.
1.   Transformer Capacity (kVA): 200 kVA
2.   Secondary Voltage (kV): 400 Volt
3.   Transformer Impedance (%): 6,75
    thus :

$$Isc = \frac{100 x Strafo}{\sqrt{3}.V.Z} = \frac{100 x 200.000}{\sqrt{3}.400.6,75} = \frac{20000}{4.67653} = 4276,66 \, A$$

Determining Maximum Load Current (IL)

To determine the maximum load current value, the total active power, power factor, and secondary voltage of the transformer are needed. The maximum load current (IL) calculated is the load current on April 5, 2023, at

15:41 WITA, as it had the highest THDi value. The maximum load current can be calculated using Equation (5) as follows.

$$IL = \frac{P}{\sqrt{3} \cdot V \cdot Cos\varphi}$$

1. Total Active Power (kW):16.240 W
2. Power Factor: 0.90
3. Secondary Voltage (kV):400 V
   Thus :

$$IL = \frac{16240\ W}{\sqrt{3} \cdot 400 \cdot 0,9} = \frac{16240\ W}{623} = 26,067 A$$

Determining Short Circuit Ratio (SC_{Ratio})

With known values of short circuit current (ISC) and maximum load current (IL), the short circuit ratio (SC_{Ratio}) can be calculated on August 22, 2023, at 14:57 WITA using Equation (6) as follows.

$$SCRatio = \frac{Isc}{Il}$$

1. Short Circuit Current Value (I_{SC}): 4276,66 A
2. Maximum Load Current Value (I_{L}): 26,06 A
   Thus :

$$SCRatio = \frac{Isc}{Il} = \frac{4276,66}{26,06} = 276,85\ A$$

Based on the calculated SCRatio results, the THDi value limit according to IEEE 519-2014 standard is 15% for SCRatio between 100-1000. Among the three Phases, the most dominant harmonic is found in Phase S, which is used as the sample data. The comparison between the field measurement results and the IEEE 519-2014 standard allowed in the electrical system of the Department of Information Technology can be seen in the following table.

Table 4
Comparison Of Thdi Measurement Results With Ieee 519-2014 Standard

Time	Content THDi				Standard IEEE 519 - 1992
	Phase Field Measurements				
	R	S	T		
Wednesday, February 22 2023	11,38 %	59,84 %	14,60 %		
	Fulfill Standard	Does not meet the Standard	Fulfill Standard		15%

Table 4 shows the comparison between the THDi measurement results in the field and the THDi according to the IEEE 519-2014 standard. It can be observed that each phase does not yet meet the standard, particularly in Phase S.

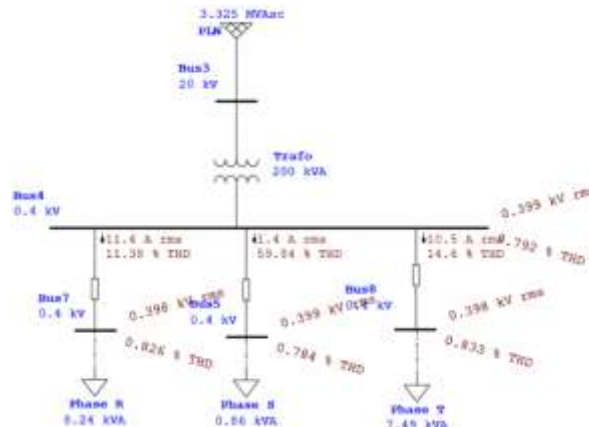***Simulation Before Single-Tuned Filter Installation***

Below is a simple simulation of the electrical system in the New Building of the Department of Information Technology using ETAP software. The load data used in the ETAP simulation is from August 22, 2023, at 14:57 WITA. Figure 4 shows the result of simulating the electrical system in the Department of Information Technology.

TABLE 5
Comparison Of Thdi And Thdv Results At The Department Of Information Technology

Place	Running Results		Standard IEEE 519-2014		Information	
	THDi (%)	THDv (%)	THDi (%)	THDv (%)	THDi	THDv
Phase R	11,38	0,549	15	5,0	Fulfill	Fulfill
Phase S	59,84	0,508	15	5,0	NoFulfill	Fulfill
Phase T	14,56	0,555	15	5,0	Fulfill	Fulfill

As seen in Table 5, the magnitude of the current THD in the electrical system simulation in the Department of Information Technology still does not meet the set standard, as it is still above 15%, especially in

load S which is very dominant. Then, for the voltage THD value, it still meets the IEEE 512-2014 standard, which is still below 5%.

Picture 12: Results of running before single-tuned filter installation.

Based on the results of the simple simulation using ETAP software, it can be observed that the THDi value in Phase S is 59.84%, which is the same as the measurement value on Wednesday, February 22, 2023, at 14:57. The THDv value is 0.678%. According to the IEEE 519-2014 standard, the simulation does not yet meet the standard, especially in Phase S. However, in Phase R and T, it already complies with the standard, which is 15% for ISC/ILoad values <100-1000 A.

Designing a Filter to Dampen Harmonic Distortion
The filter to be used to dampen harmonic distortion is a single-tuned filter. The calculation will be done on Phase S, which has a harmonic current distortion of 59.84%. First, it is necessary to determine the harmonic order to be eliminated, which is located in the 5th order because it has the largest distortion. The calculations can be seen below.

P = 723,012 kW
Cos φ = 0,84
$\theta 1$ = Arc cos 0.84
= 32,83°
$\theta 2$ = Arc cos 0.99
= 8,10°
Qc = P. (tan θ_1 - tan θ_2)
= 723,012 . (tan 32,83° - tan 8,10°)
= 363,67 kVAR

The capacitor value in the simulation will refer to equations 10 and 11 as follows:

$Xc = \frac{kV^2}{kVAR}$

$Xc = \frac{0,4^2}{363,67}$

= 0,000439 kΩ
= 0,43 Ω

$C = \frac{1}{2\pi f Xc}$, with$f$ = fundamental frequency 50 Hz

$C = \frac{1}{2.3,14.50.0,43}$

= 0,006839 F
= 6,839 x 10^{-3} = 6839 µF

The inductor value in this simulation for the filtered order is the 5th order, so the tuning will be slightly below it, at 4.9. This is done as a tolerance for the filter components to prevent any resonance that may occur in the system at disturbing frequencies, and to achieve optimal filter performance. The use of this filter may cause series and parallel resonances with the network impedance, which can result in harmonic amplification at specific frequencies. The inductor value will refer to equations 12 and 13 as follows:
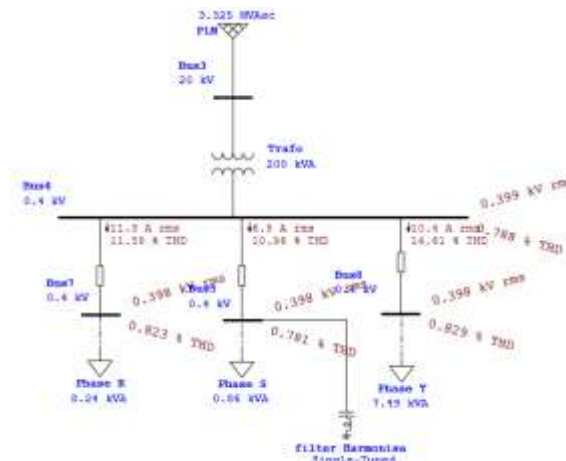
$L = \frac{1}{(C)(2\pi f n)^2}$

$L = \frac{1}{(6,83 \ x \ 10^{-3})(2.3,14.50.4,9)^2}$

= 0,0000614 H
$X_L = 2.\pi.f.L$
= 2. 3,14. 50. 0,0000614
= 19,2796 Ω

Picture13: THD value after filter installation

By comparing the harmonic load flow analysis results without a filter in Figure 5, it can be seen that the percentage of current THD is reduced from the initial 59.84% to 10.96%. This filter has a significant impact on reducing the THD value.

Filter Installation Results

After conducting simulations before and after the installation of the single-tuned filter of the 5th order, it is known that the THDi and THDv values in Phase S, where the filter is installed, experienced a decrease. Both Phase R and Phase T also experienced a decrease in THDi current, but not as much as in the phase where the filter was installed. Based on the short circuit ratio calculation according to IEEE 519-2014 standards. The following is a comparison of THDi and THDv values before and after the installation of the single-tuned filter with the established standard.

Table 6
Comparison Of Thd Values Before And After Filter Installation

Phase	Results of Running Simulation with ETAP 16 Software.						Standard IEEE 519-1992	
	Before Installation Filter		After Installation Filter		After Installation in Order 5			
	THDi	THDv	THDi	THDv	IHDi	IHDv	THDi	THDv
R	11,38	0,549	11,4	0,548	10,084	0,33	15%	5%
S	59,84	0,508	10,9	0,507	10,461	0,32	15%	5%
T	14,6	0,555	14,6	0,554	13,237	0,32	15%	5%

From Table 6 above, it can be seen that the THDi and THDv values before and after filter installation. The installation of a passive filter can reduce harmonic distortion in the electrical system with a THDi value in Phase R of 11.4%, Phase S of 10.94% from the initial 59.84%, and in Phase T there is no decrease except for the 5th order which decreased to 13.23% from 14.6%. These values already comply with the IEEE 519-2014 standard, which is 15% for SCRatio between 100-1000.

Similarly, THDv experienced a decrease due to the installation of a passive filter. The THDV value of the electrical system in the Department of Information Technology building still meets the IEEE 519-2014 standard, which is below 5%, with the simulation result values for THDv before passive filter installation being 0.50%, and after passive filter installation being 0.33%.

Table 7
Percentage Comparison Of Thdi Before And After Filter Installation In Phase S

	THDi (%) No Filters	THDi (%) with filters	Δ THDi (%)
THDi	59,84	10,94	48,9
Orde 5	57,254	10,461	46,793
Orde 7	14,381	2,626	11,755
Orde 11	7,774	1,444	6,33
Orde 13	2,975	0,543	2,432
Orde 17	3,695	0,668	3,027
Orde 19	2,31	0,418	1,892
Orde 25	1,418	0,267	1,151

Table 7 shows that the use of a passive filter for current THD can reduce harmonics by 48.9%, and at the 5th order, it decreases by 46.79%. Moreover, in subsequent orders, it already complies with the IEEE 519-2014 standard, which is 15% for SCRatio between 100-1000. With the reduction in THD current, the THD voltage will also decrease, indicating an improved voltage quality after the installation of the passive filter.

IV. CONCLUSION

Based on the analysis and simulation results of the study, it can be concluded that:

1. The harmonic content of voltage (%THDv) in the New Building of the Department of Information Technology at the State Polytechnic of Samarinda generally exceeds the allowed standard (5%). However, the harmonic content of current (%THDi) in the same location surpasses the permitted standard (15%), and during periods of heavy load, it can reach up to 56.64%.

2. This research utilized ETAP 16 software to determine the percentage of voltage and current total harmonic distortion (THD) in phase S that exceeds the IEEE 519-2014 standard. The simulation results indicated that on February 22, 2023, at 14:57, the THD current percentage in phase S exceeded the IEEE 519-2014 standard at 59.84%, with the IEEE 519-2014 standard set at 15% for a range of 100-1000 A. For more detailed information, refer to Table 2.4.

3. After the design, simulation, and installation of a single-tuned filter on phase S, which experienced the highest harmonic distortion with a THDi value, there was a reduction from approximately 59.84% to 10.96%. Similarly, for the 5th order of phase S, the distortion decreased from 57.254% to 10.461%. This adjustment aligns with the permitted harmonic distortion standard of 15%.

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