ANALYSIS AND MITIGATION OF HARMONIC AT PERPUSTAKAAN TUN ABDUL RAZAK 3

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Abstract —**This paper propose the analysis and mitigation of harmonic distortion that have been done in PTAR 3 (Perpustakaan Tun Abdul Razak) at Tower two science and technology,UiTM Shah Alam. There are three main focuses for this project, firstly is to calculate the total harmonic distortion (THD) produce by fluorescent lamps, computers and a combination of both when it connected in parallel. Secondly, this project needs to find out which equipment produces the higher THD between computers and fluorescent lamp at the PTAR 3. Lastly, this project also needs to reduce the THD produced by combination of both equipments when it connected together to be lower than 5% to satisfy the IEEE regulation. In order to reduce the THD lower than 5% a passive filter must be installed at the ac source.**

Keyword - **Harmonic, Total harmonic distortion (THD), passive filter**

I. INTRODUCTION

Due to the growing use of non-linear load equipment and new technologies in building, harmonic current generated in distribution system pose a new problem for electrical engineering. This is serious problem when power quality is a prime concern. The problem is due to some non -linear loads showing different current waveform when supplied by a distorted voltage.

This paper show the analysis and mitigation the harmonic distortion produce by florescent lamps and personal computers at PTAR 3 specific at level 3. At PTAR 3 There have around 77 personal computer and 210 unit fluorescent lamps been use at all level, but for the level 3 there are only have 52 unit of fluorescent lamps (2x 36W) and 13 personal computers. All 13 computers and 52 unit fluorescent lamps in PTAR3 were of the same type. Personal computer is non-linear load type power converter which changes ac into dc power meanwhile fluorescent lamp is type arc device. This paper need to calculate the total harmonic distribution from the combination of the 13 personal computer and 52 unit fluorescent lamp (2 x 36W) when it connected in parallel to follow the IEEE regulation. To reduce the harmonic distortion lower than 5% a passive filter must be installed beside the ac source.

The evaluation of the harmonic distortion is carried out in this paper is by a simulation model developed with the Psim software. The simulation model in this paper is been done by following the equipment been used at PTAR3

II. BASIC OF HARMONIC THEORY

The term of harmonic was originated in the field of acoustics, where it was related to the vibration of a string or an air column at a frequency that is multiple of the base frequency. A harmonic component in an AC power system is defined as a sinusoidal component of a periods waveform that has a frequency equal to an integer multiple of the fundamental frequency of the system.

Harmonic in voltage or current waveform can then be conceived as perfectly sinusoidal components of frequencies multiple of the fundamental frequency;

$$F_h = (h) \times (\text{fundamental frequency})$$

Where h is an integer

	2nd harmonic	3rd harmonic	4th harmonic	5th harmonic
50 HZ	100	150	200	250
Sequence	-	0	-	-

Table 1: classification of harmonic (IEEE, 1995) [3]

Figure 1.0 show an ideal 60-hz waveform with a peak value of around 100A, which can be taken as one per unit. Likewise, it also portrays waveform of amplitude (1/7), (1/5) and (1/3) per unit and frequencies seven, five and three times the fundamental freq respectively. This behavior showing harmonic components of decreasing amplitude often

following an inverse law with harmonic order is typical in power system.

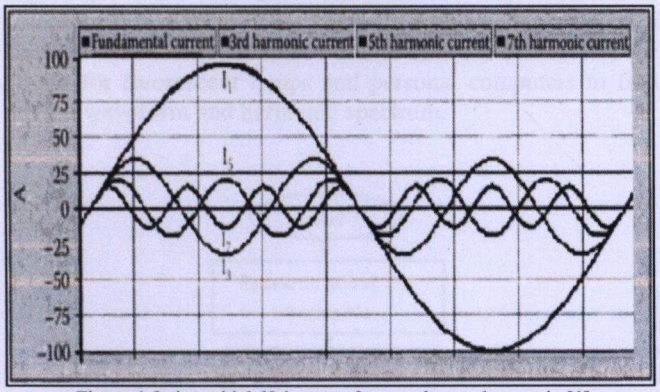


Figure 1.0 sinusoidal 60-hz waveform and some harmonic [1]

This waveform can be expressed as:-

$$i1 = Im1 \sin wt \quad [1]$$
$$i3 = Im3 \sin(3wt - \theta 3)$$
$$i5 = Im5 \sin(5wt - \theta 5)$$
$$i7 = Im7 \sin(7wt - \theta 7)$$

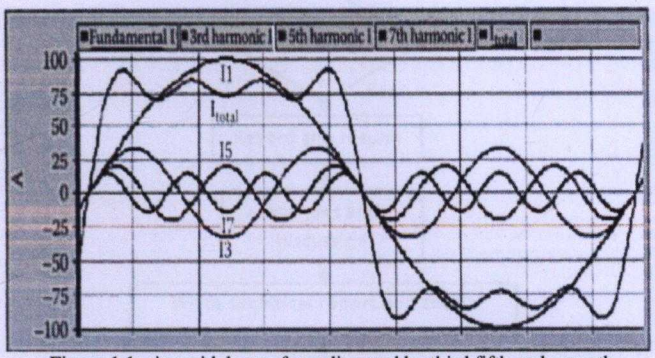


Figure 1.1: sinusoidal waveform distorted by third fifth and seventh harmonics [1]

Figure 1.1 shows the same harmonic waveform as those in figure 1.0 superimposed on the fundamental frequency current yielding I total. If we take only the first three harmonic components, the figure show how a distorted current waveform at the terminal of a six-pulse converted would look. There would be additional harmonics that would impose a further distortion.

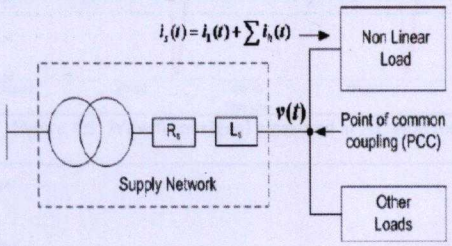
The resultant distorted waveform can thus be expressed as:

$$I\ total = Im1 \sin \theta t + Im1 \sin(3\theta t - \theta 3) + Im5 \sin(5\theta t - \theta 5) + Im7 \sin(7\theta t - \theta 7) + \ldots \quad [1]$$

A summation of perfectly sinusoidal waveform can give rise to a distorted waveform.

III. HARMONIC CURRENT FLOW AND VOLTAGE DISTORTION

Figure 1.2 shows a typical power distribution network. When the nonlinear load is supplied from a sinusoidal voltage source, it injects harmonic current. The Harmonic currents cause harmonic volt drops in the supply network and therefore distort the voltage at the PCC. Any loads, even linear loads connected to the PCC, will have harmonic current injected into them by the distorted PCC voltage



[4]

Figure 1.2 Typical Power distribution network

IV. TOTAL HARMONIC DISTORTION

Total harmonic distortion (THD) index is to measure the effective value of the harmonic components of a distorted waveform. The measurement for the THD can be either voltage or current. Beside that it can indicate how much extra heat will be realized when a distorted voltage is applied across a resistive load or as an indication of the additional losses caused by the current flowing through a conductor.THD can be define as ;

$$THD_V = \sqrt{\frac{\sum_{h=2}^{\infty} Vh^2}{V1}} \quad [1]$$

$$THD_I = \sqrt{\frac{\sum_{h=2}^{\infty} Ih^2}{I1}} \quad [1]$$

V. EFFECT OF HARMONIC

Effect that can get causes of the harmonic distortion is a overheating the transformer, severe lamp and computer are flicker, machine vibration and high neutral current.

VI. METHODOLOGY

Figure 1.3 Show the flow chart for the step followed to complete this project. The Software use for this project is PSIM 6 which the function of this software is to simulate the circuit for fluorescent lamps and personal computers to find out the waveform and harmonic spectrum.

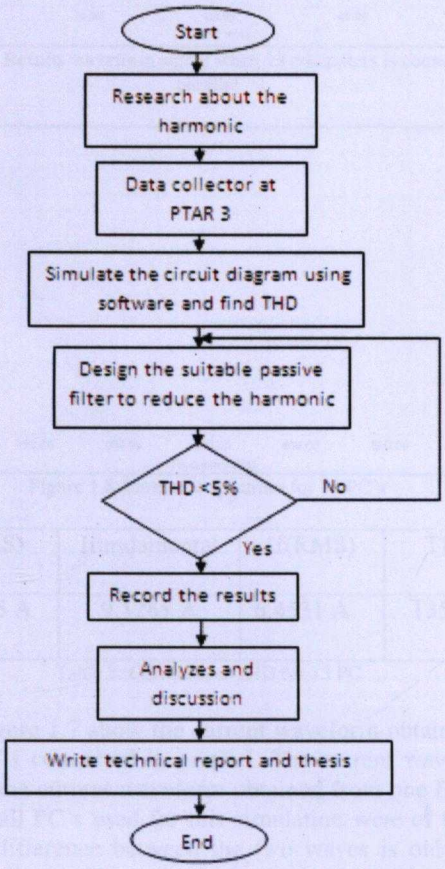


Figure 1.3: Flow chart of project

VII. RESULT AND DISCUSSION

Computer

The personal computer (PC) circuit was simulated as full wave diode bridges with a capacitor at the dc side and resistors as load. At the ac side a RF filter was assumed to be between the ac terminals and the diode bridge. The PC model is show in figure 1.4 taken from [2]

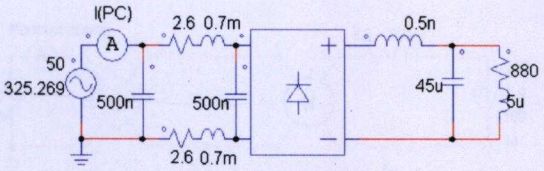


Figure 1.4: Circuit diagram for personal computer (PC)

Figure 1.5: Waveform signal measured at AC side for one PC

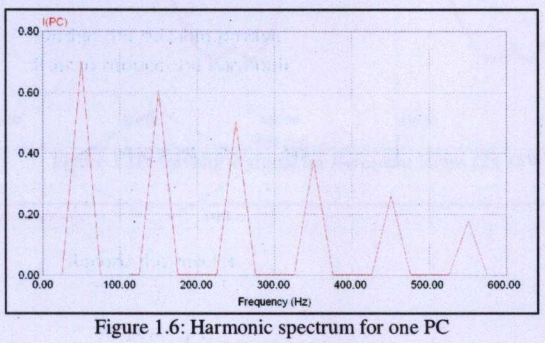


Figure 1.6: Harmonic spectrum for one PC

IS(RMS)	Ifundamental	If(RMS)	THD
0.837036 A	0.702012 A	0.496397A	135.8%

Table 2: Current and THD for PC

From figure 1.5 shows the waveform of current harmonic inject back to the ac source from the non-linear device .The result of harmonic current waveform is totally not equally to sinusoidal waveform. This is because PC is one of non-linear device which the current is not proportional to the applied voltage .When a sinusoidal voltage applied to non-linear load which causes current is distorted [4]. Beside, from figure 1.6 show that PC draw a large amount of zero sequence (3rd, 9th, etc) harmonic. The total harmonic (THD) produce by one circuit of PC is 135.8%.

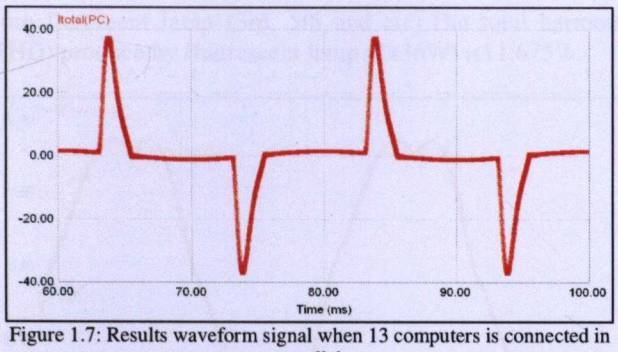


Figure 1.7: Results waveform signal when 13 computers is connected in parallel

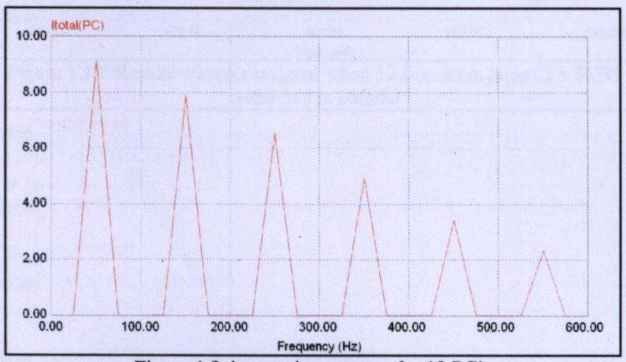


Figure 1.8: harmonic spectrum for 13 PC's

IS(RMS)	Ifundamental	If(RMS)	THD
10.8815 A	9.1261 A	6.4531 A	135.8%

Table 3: Current and THD for 13 PC

By refer figure 1.7 show the current waveform obtained from thirteen PC's connected in parallel. The current waveform is same with the current waveform obtained from one PC , this is because all PC's used for this simulation were of the same type. The difference between the two waves is only on the current amplitude. The Current amplitude obtained by thirteen computers is higher than the current obtained by one computer. Beside, by refer figure 1.8 show that the value of zero sequence (3rd, 9th, etc) harmonic is higher than a single circuit of computer. Moreover, THD value produce by thirteen computers is same as the THD produce by one computer.

Fluorescent lamp

For lighting fixture at PTAR3 was assumed to consist of two fluorescent light bulbs type magnetic ballast rated 36W, 230V which connected in duo configuration. The fluorescent bulbs were simulated as square-wave voltage sources behind an inductor (ballast). The model of the lighting fixture is shown in figure 1.9 taken from [2]

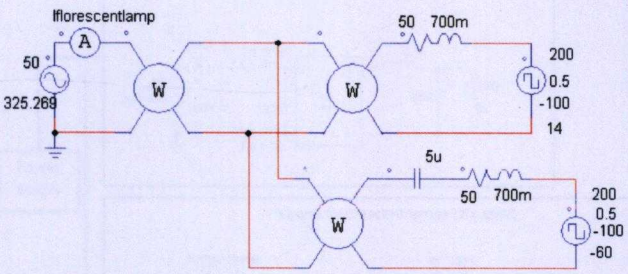


Figure 1.9: Circuit diagram (2x 36W) fluorescent lamp

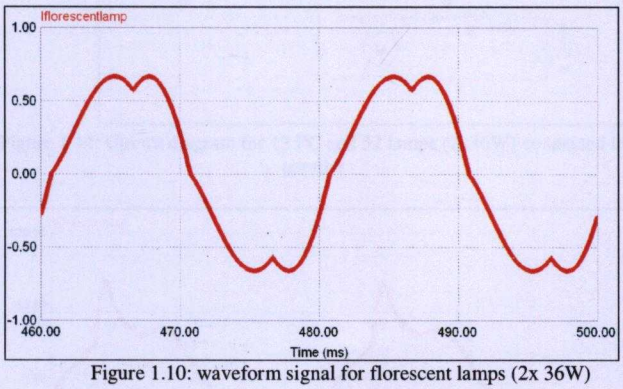


Figure 1.10: waveform signal for florescent lamps (2x 36W)

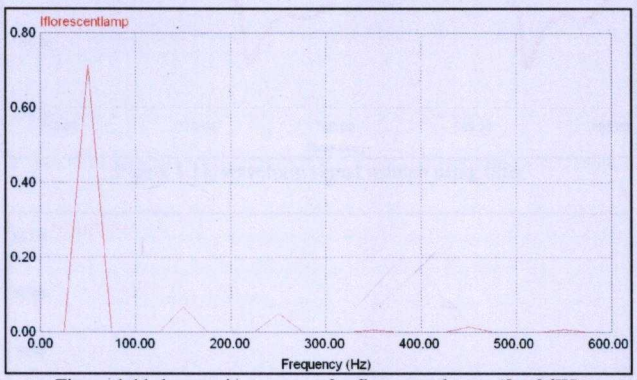


Figure 1.11: harmonic spectrum for florescent lamps (2 x 36W)

IS(RMS)	Ifundamental	If(RMS)	THD
0.50767 A	0.713115 A	0.5042 A	11.67%

Table 4: current and THD for fluorescent lamp

From figure 1.10 shows the current harmonic waveform inject back to the ac source from non-linear device The current waveforms is closely to sinusoidal waveform but have little bit of distortion which can affect the power quality at PTAR3. Beside, by refer figure 1.11 show the harmonic spectrum draw

from florescent lamp (3rd, 5th and etc).The total harmonic (THD) produce by fluorescent lamp (2x36W) is11.675%

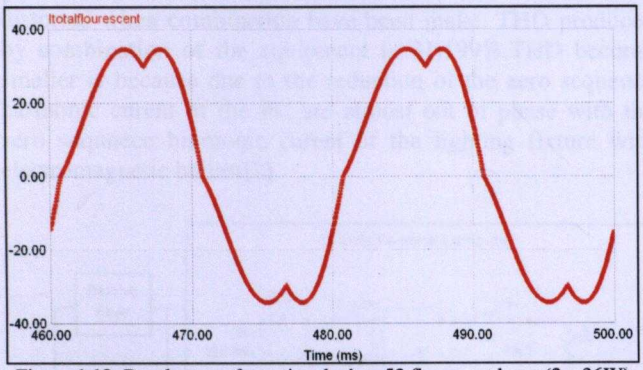


Figure 1.12: Results waveform signal when 52 florescent lamp (2 x 36W) connected in parallel

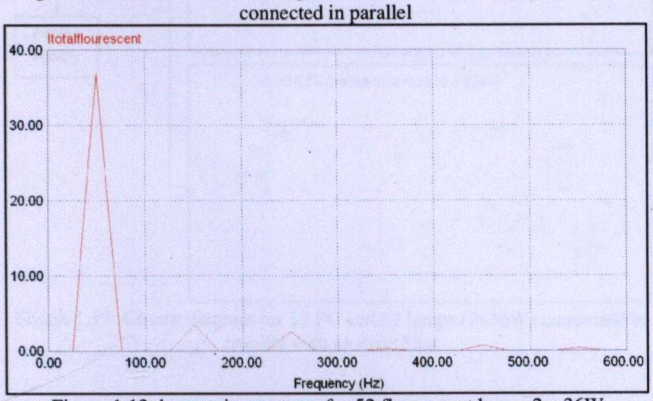


Figure 1.13: harmonic spectrum for 52 fluorescent lamps 2 x 36W

IS(RMS)	Ifundamental	If(RMS)	THD
26.3991 A	37.0820 A	26.221 A	11.677%

Table 5: current and THD for 52 unit of fluorescent lamp

Figure 1.12 show the result of current waveform when 52 unit florescent lamps (2 x 36w) is connected in parallel together. The shape of harmonic current is same with waveform obtained from one unit of fluorescent lamp, this is because all fluorescent lamps which connected together were of the same type. The different between two of waveform is only on current amplitude. The current amplitude for 52 unit fluorescent lamps is higher than current amplitude of one unit florescent lamp. Furthermore by refer figure 1.13, value for (5th, 3rd and etc) harmonic from the 52 unit of fluorescent lamp when it connected together is also increase. Beside, the THD value produce by 52 units is same as the THD produce by 1 unit of florescent lamp. From figure 1.14 show 52 unit florescent lamp (2x 36W) and 13 personal computers are connected in parallel in PSIM simulation.

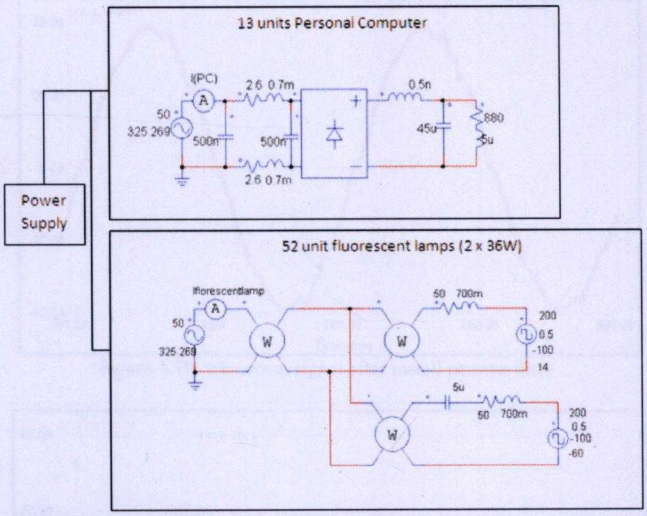


Figure 1.14: Circuit diagram for 13 PC and 52 lamps (2x36W) connected in parallel

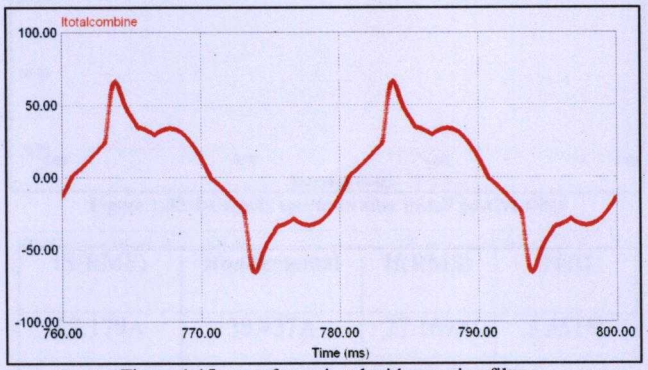


Figure 1.15: waveform signal without using filter

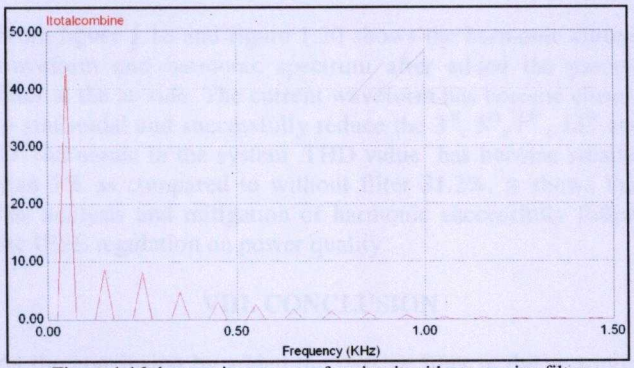


Figure 1.16: harmonic spectrum for circuit without passive filter

IS(RMS)	Ifundamental	If(RMS)	THD
32.5509 A	43.9448 A	31.0737A	31.199%

Table 6: Current and %THD for circuit without passive filter

From figure 1.15 shows the current harmonic waveform when 52 unit fluorescent lamps and 13 PC's are connected in parallel together. The harmonic current wave become more distorted when combination have been make. THD produced by combination of the equipment is 31.199%.THD become smaller is because due to the reduction of the zero sequence harmonic curent of the PC are almost out of phase with the zero sequnece harmonic curent of the lighting fixture with electromagnetic ballast[2]

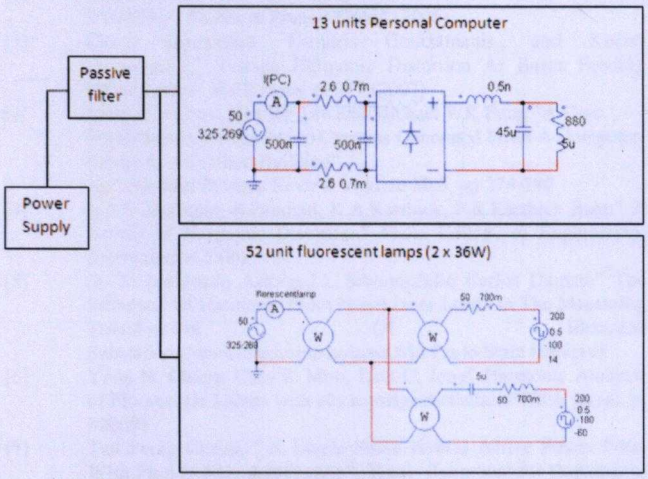


Figure 1.17: Circuit diagram for 13 PC and 52 lamps (2x36W) connected in parallel with passive filter

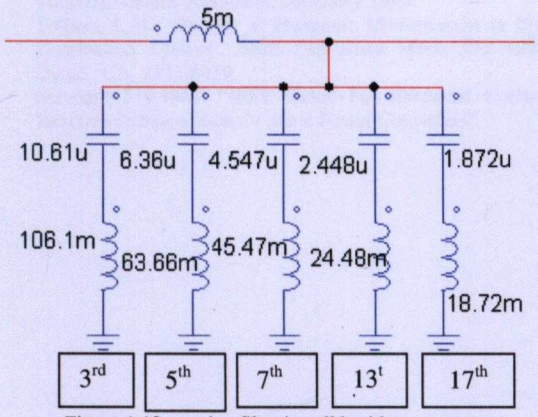


Figure 1.18: passive filter install beside ac source

To reduce the THD, single tuned passive filter has been added at the ac source. From the Figure 1.17 and Figure 1.18 shows the location filter been added at the ac source and the combination of single tuned for 3^{rd}, 5^{th} , 7^{th} ,13^{th} and 17^{th} harmonic been use to reduce the THD below than 5%.

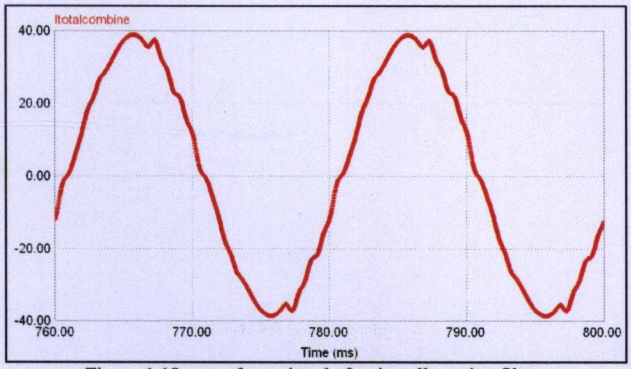


Figure 1.19: waveform signal after install passive filter

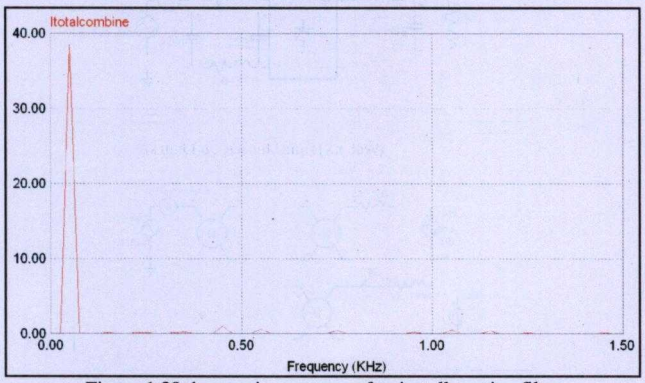


Figure 1.20: harmonic spectrum after install passive filter

IS(RMS)	Ifundamental	If(RMS)	THD
27.179A	38.437A	27.169A	3.551%

Table 7: Current and %THD

From figure 1.18 and figure 1.20 shows the harmonic current waveform and harmonic spectrum after added the passive filter at the ac side. The current waveform has become closely to sinusoidal and successfully reduce the 3^{rd}, 5^{th}, 7^{th} , 13^{th} and 17^{th} harmonic in the system .THD value has become smaller than 5% as compared to without filter 31.2%. It shows that this analysis and mitigation of harmonic successfully follow the IEEE regulation on power quality.

VIII. CONCLUSION

As the conclusion by added the passive filter at the ac source the harmonic distortion (THD) can successfully been reduce lower than 5% to follow the IEEE regulation. Besides, from this paper too shown that, personal computer produce the higher THD in PTAR 3 compare with the florescent lamp. Moreover, mixing PC's with florescent lamp that operate with magnetic ballast reduces the current THD due to the reduction in the neutral current. Furthermore, when simulation the

connection of the same product is made, the form of waves and the number of THD current will remain the same. Lastly, the increasing use of nonlinear load in PTAR 3 is keeping harmonic distortion in distribution network on rise which can affect power quality to the consumer from the same feeder.

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