

MITIGATION OF HARMONIC DISTURBANCE USING ACTIVE POWER FILTER

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ABSTRACT- Power quality now becomes a major concern especially for commercial and industrial customers. Harmonics distortion produced by the non-linear loads will lead to lots of power quality problems. This paper presents a study on harmonics distortion in an electrical distribution system. The first part of the study is to analyse the real data from UiTM (Pahang Campus). Reliable Power Meter (RPM) Software is used to analyse the harmonics distortion. The second part is to simulate the harmonics distortion theoretically using the 13-bus IEEE Distribution System circuit. The Power System CAD (PSCAD) Software is used for this purpose. Active Power Filter (APF) is used as a method of to alleviate the harmonic distortion.

Keywords – Harmonics disturbance, total harmonics distortion, active power filter.

1.0 INTRODUCTION

Power quality is a customer driven issues and now it become a very important factor. Non-linear loads cause the current to vary disproportionately with the voltage during each half cycle. Examples of nonlinear loads are battery chargers, electronic ballasts, variable frequency drives, and switching mode power supplies [1]. Power system is design to function at the fundamental frequency, which is 50 Hz in Malaysia or 60 Hz in United States. Ideally, voltage and current waveforms are perfect sinusoids. However, because of the increased popularity of electronic and these non-linear loads, the waveforms quite often become distorted.

This deviation from a perfect sine wave can be represented by harmonics—sinusoidal components having a frequency that is an integral multiple of the fundamental frequency[2]. To quantify the distortion, the term total harmonic distortion (THD) is used. The term expresses the distortion as a percentage of the fundamental (pure sine) of the voltage and current waveforms.

$$THD = \frac{\sqrt{\sum_{h=2}^{\infty} I_h^2}}{I_1}$$

Where;

I_h = Harmonic Component

h = Harmonic Number; 2, 3, 4, ... Etc

I_1 = Fundamental Component

Current harmonics is a problem because they cause increased losses in the customer and utility power system components. Below are some examples of effect on harmonics [3]:

- i. Overheating and damage to neutral conductors
- ii. Overheating and damage to panel board feeders
- iii. Line voltage distortion
- iv. Higher Common mode voltage
- v. Nuisance tripping of circuit breaker
- vi. Overheating and premature failure of distribution transformer

This project presents the effect of the non-linear load to the harmonics distortion in an electrical distribution system. To obtain a real view of this project, RPM Software is used to investigate the harmonic distortion of UiTM Distribution System (Pahang Campus). This actually represents the method of identifying the THD for an existing system so that an improvement can be implemented to the system. The simulation was done on the IEEE 13 bus system. PSCAD software is used to measure the level of harmonic distortion produced by the system. IEEE Standard 519-1992, is used as a guide [4].

2.0 CASE STUDY(UiTM PAHANG CAMPUS)

2.1 Background

Power Quality become a major concern for commercial customer like UiTM to ensure all activities and learning process can be smoothly operated. Due to this matter a power quality analysis

is done to identify the level of power quality disturbances. The study is focused on harmonics distortion. For the existing system, the way to monitor the power quality characteristic is by the installation of RPM Meter at each substation. The Main Intake Substation for UiTM Pahang Campus is 11kV. It has 6 Distribution Substations. The study is done at the Pentadbiran Substation which covers the electrical supply to Pentadbiran and Academic blocks. The single line diagram and location are shown in Appendix 1(a) and 1(b). Pentadbiran block contained a PABX System (for communication) and lots of non-linear load (office equipment).

2.2 Power Quality Analysis

The data was acquired from all substations in UiTM Distribution System (3 phase 4wire system). The data was taken directly from the substation, instead of reading it from the SCADA system. The harmonics distortions for all substations show the same pattern. The results for Pentadbiran Substation are taken as an example.

Figure 2.1 shows the distorted voltage waveforms for Phase A, Phase B and Phase C. Figure 2.2 shows the level of individual distortion for odd harmonics for Phase A, Phase B, Phase C and Neutral.

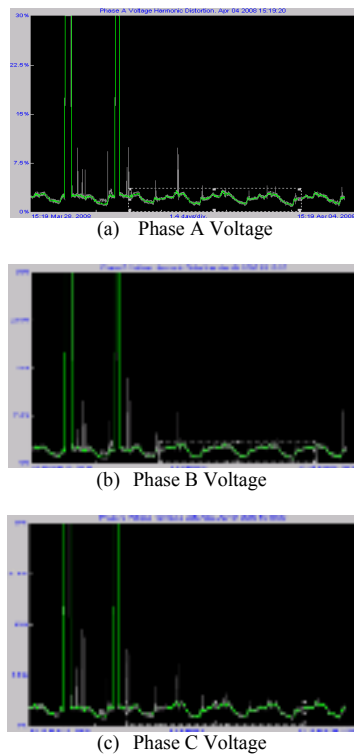


Figure 2.1 Distorted voltage waveform for Phase A, Phase B and Phase C.

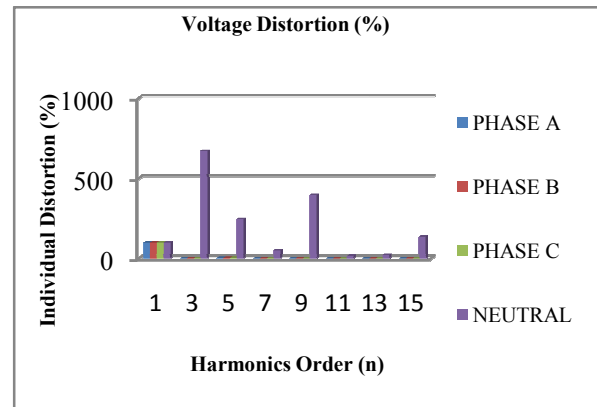


Figure 2.2 Individual voltage distortions

Figure 2.3 shows the distorted current waveforms for Phase A, Phase B and Phase C. Figure 2.4 shows the level of individual distortion for odd harmonics for Phase A, Phase B, Phase C and Neutral.

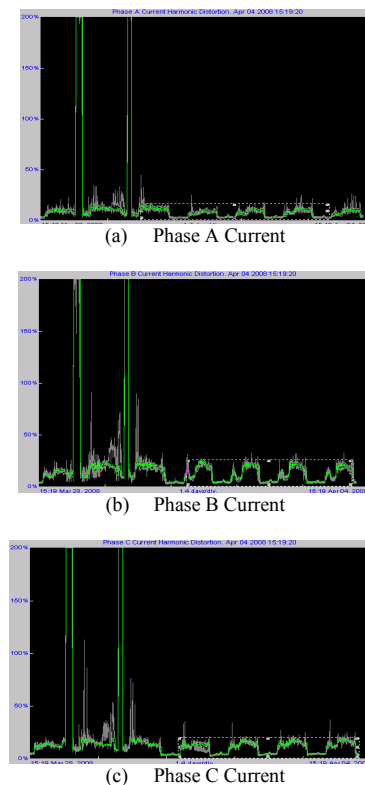


Figure 2.3 Distorted current waveform for Phase A, Phase B and Phase C.

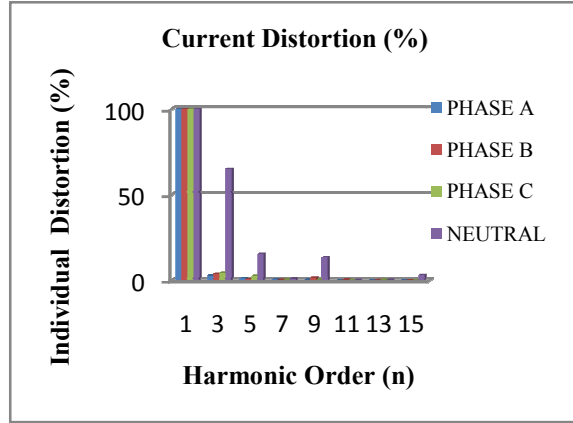


Figure 2.4 Individual current distortions

The results show that the triplen harmonics exist in the neutral current. Triplen harmonics are the odd multiples of the third harmonic ($h = 3, 9, 15, 21, \dots$). They deserve special consideration because the system response is often considerably different for triplens than for the rest of the harmonics. Triplens become an important issue for grounded-wye systems with current flowing on the neutral. Two typical problems are overloading the neutral and telephone interference. One also hears occasionally of devices that misoperate because the line-to-neutral voltage is badly distorted by the triplen harmonic voltage drop in the neutral conductor.

$$I_{N,rms} = (I_{a,rms}^2)^{1/2} + (I_{b,rms}^2)^{1/2} + (I_{c,rms}^2)^{1/2}$$

$$I_{N,rms} = \sqrt{3} \times I_{phase,rms}$$

Some of the effects of Triplen Harmonic to the system are excessive stress due to heating, insulation breakdown, lower operating efficiency, short life span and also acoustic noise. Beside that, triplen harmonic also might cause losses on transformer i.e. core and winding losses. This distribution system should take the corrective action in order to improve the power quality. Some recommendations that are suggested are as follows [5].

- Derate transformers or use K-Factor Transformer.
- Upsize all neutral components for 1.73 times rated full load amps.
- Use neutral over current sensor to trip phase conductors.
- Use true rms, ammeters and instruments with sufficient bandwidth for measurement.

3.0 MITIGATION OF HARMONICS DISTURBANCE USING APF

The second part of this paper is to simulate the harmonic distortion. This method was done to an IEEE 13- Bus Distribution System. PSCAD Software is used for the simulation. The following steps are implemented.

- Run the IEEE 13 Bus system to obtain the THD content of the system current.
- Analyse the harmonics content for Utility Bus, Bus 5, 8 and 10.
- Inject the source of harmonic, ASD which is represented by current source model at Bus 10 [6].
- Analyse the effect of harmonic contents for Bus 1, 5, 8 and 10 after injection of ASD.
- APF is implemented to Bus 10 since its THD is above the limit.
- Record the results after implementation of APF.

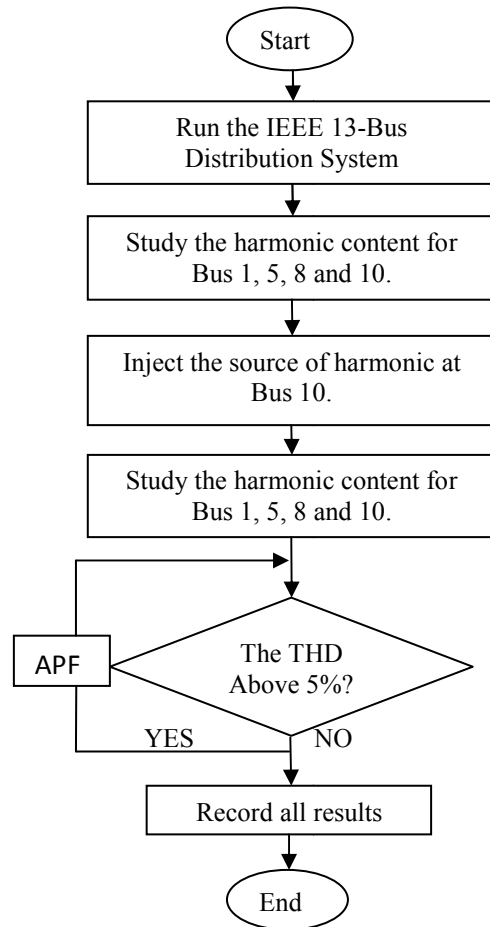


Figure 3.0 Flowchart of the mitigation of harmonics disturbance using APF

4.0 ACTIVE POWER FILTER (APF)

After observing the results of Part II, an action should be taken to reduce the THD level. There are a lot of techniques to mitigate this problem. For this paper, only the Shunt APF is implemented to the system. The schematic diagram is shown in appendix 2. The high pass LC filter is connected to APF to suppress switching ripples generated by APF [7]. The purpose of APF is to compensate the harmonic components of the load current so that only the fundamental frequency components remain in grid current [8]. The APF provide harmonic distortion reduction by cancellation. The APF is using Pulse Width Modulation (PWM) in order to perform the filtering process.

5.0 SIMULATION RESULTS AND DISCUSSION

The simulation results are obtained from IEEE 13 Bus Distribution System. The simulation is done using PSCAD Software. The harmonic distortion is observed for the nominal operation and also after a model of non-linear load is introduced. The schematic diagram is shown in appendix 3 and 4.

5.1 Normal Operation

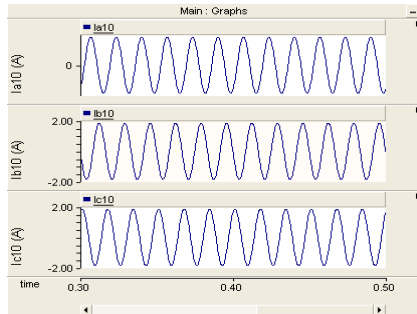


Figure 5.1 Current waveform for Phase A, B and C during normal operation at Bus 10.

5.2 ASD is injected at Bus 10

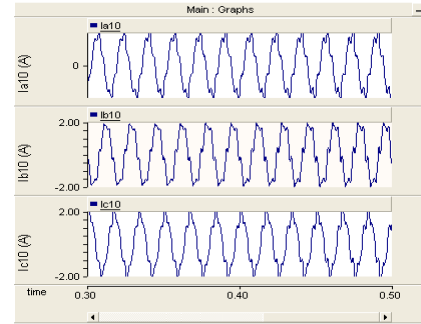


Figure 5.2 Current waveform for Phase A, B and C after injecting non-linear load Bus 10.

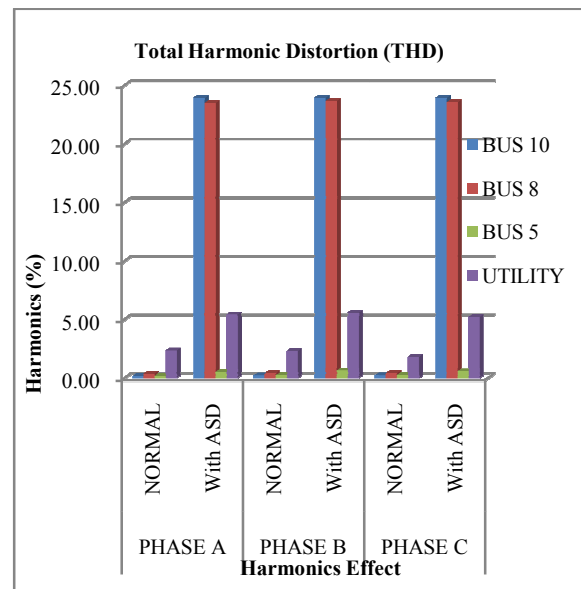


Figure 5.3 THD for normal operation & after injecting ASD

Figure 5.3 shows the THD component during a normal operation and after the implementation of ASD. Figure 5.4 below shows the individual harmonic distortion at Utility Bus, Bus 5, 8 and 10.

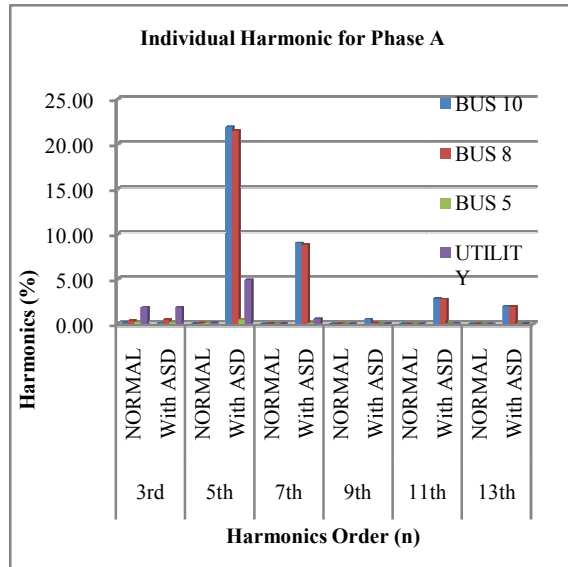


Figure 5.4 Individual current distortions on Phase A

ASD is injected to all three phases. The characteristic of ASD is, it produce odd harmonics except the triplen harmonics. From the results, it has proved this theory. By injecting the ASD the harmonics distortion for these order of harmonic is drastically increased. It was over the limits [4]. This situation affects the supply voltage and the waveform has been distorted as shown in figure 5.2.

The percentage of increased in level of harmonics distortion before and after injecting of ASD are tabulated in Table 5.1. The THD level at Bus 10, where ASD is injected shows the highest. The THD levels of other buses were also affected.

Table 5.1 Effect of non-linear load

BUS	% of increase in THD		
	PHASE A	PHASE B	PHASE C
BUS 10	138.27	105.77	104.01
BUS 8	64.40	57.70	56.89
BUS 5	2.64	2.56	2.32
UTILITY	2.30	2.41	2.91

5.3 Installation of APF to Mitigate Harmonics

In this paper, APF is implemented at bus 10 to mitigate the harmonic level. Appendix 5 shows the installation of APF and ASD.

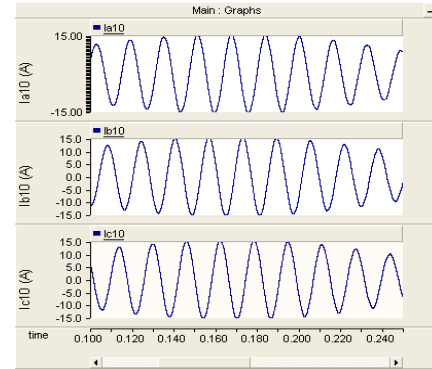


Figure 5.5 Current waveform for Phase A, B and C after implementation of APF at Bus 10.

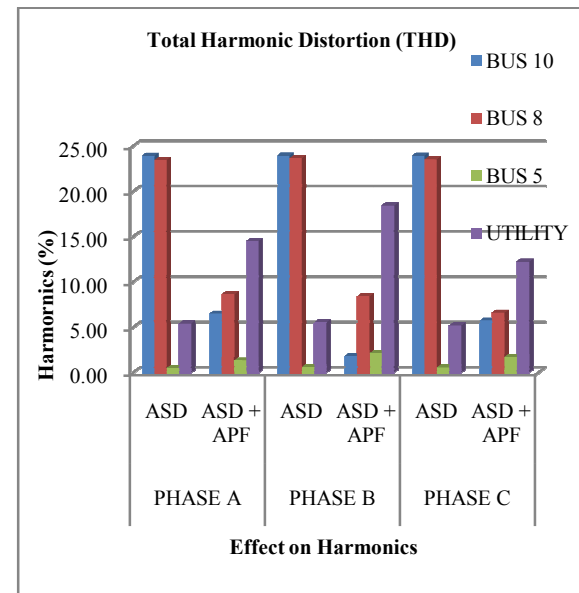


Figure 5.6 THD before and after the implementation of APF

Figure 5.5 shows the current waveform after the implementation of APF. Figure 5.6 shows the THD component before and after the implementation of APF. Figure 5.7 below shows the individual harmonic distortion at Utility Bus, Bus 5, 8 and 10.

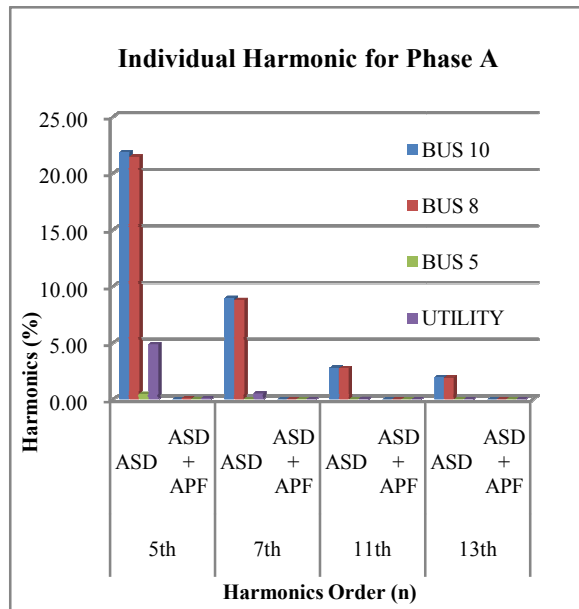


Figure 5.7 Individual current distortions on Phase A

The results show the level of harmonics distortion has been reduced with the implementation of APF. The THD and the individual harmonics distortion now is within the limits.

6.0 CONCLUSION

This paper demonstrates the technique of the identification of power quality disturbance (harmonics distortion) for an existing system using RPM meter. The level of THD and individual harmonic distortion is observed. The simulation was done on an IEEE 13 Bus distribution system to mitigate harmonics using APF. APF is one of mitigation technique for harmonic distortion. The level of THD at Bus 10 is reduced by 72.75% for Phase A, 92.44% for Phase B and 75.98% for Phase C.

7.0 RECOMMENDATION

To overcome this problem for the existing distribution system, it is recommended that a power quality team should be performed to investigate the harmonics problem. By doing this, corrective action can be take to mitigate the harmonics distortion. For a new building or a new electrical installation, the design engineer should take harmonics into consideration and proposed the mitigation technique such as hybrid filtering, a combination of active and passive filtering.

8.0 ACKNOWLEDGEMENT

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8.0 REFERENCES

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