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Single Phase Active Filter Performance Study For Electrical Loads In Residential Home

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ABSTRACT
Along with the development of electronics technology, electrical loads are also developing. Originally, electrical loads are linear. However, as a result of the development of electronics technology, a non-linear electrical loads appear. Non-linear loads installed in a single phase power system such as computers, air conditioners, televisions, and energy saving lamps can produce current or voltage harmonic distortion. The greater the harmonic content of a system, the worse the quality of the power it produces. The use of harmonic filters in electrical power systems has been proven to be able to reduce voltage and current harmonic distortions caused by non-linear loads. The active filters is one solution to harmonic interference problem. This research aims to study the performance of active filters to compensate harmonics currents that can improve the quality of power in residential houses. The result obtained from this research is that electrical loads in residential houses have very high harmonics components, with Total Harmonic Distortion (THDi) reaching up to 183%. By installing an active filter in parallel with the non-linear loads, THDi could be reduced up to 9.5%.

Keywords: *Harmonics, Non-linear load, Active filter, Residential loads*

1. INTRODUCTION

Electricity loads for residential homes are generally in the form of lighting, television, air conditioners, etc. The installation used for those electricity loads is a single phase installation. Along with the development of technology, electrical loads are also developing. For example, most people nowadays are using energy-saving lamps or LED., televisions and laptops, these are kinds of non-linear loads. Non-linear load is an electrical load that absorbs non-linear currents. These loads are loads with non-sinusoidal waveforms. Non-sinusoidal waves will produce harmonic currents which will raises several problems, such as increased losses, low power factor, which overall reduces the power quality. [1]

Household electrical loads such as energy saving lamps, LED lights, televisions, and laptops are loads that use a DC voltage source. Therefore, the single phase power supply from State Electricity Company (PLN) is rectified using a diode rectifier and filtered using a capacitor.

2. SINGLE PHASE RECTIFIER

2.1. Single phase bridge system rectifier

A single phase rectifier is a converter used to convert an AC voltage system to a DC voltage system. Figure 1 is a picture of a full wave single phase rectifier circuit in a bridge system with R-L loads.

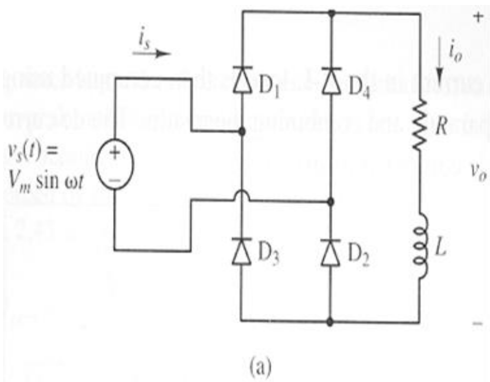

Figure 1 Bridge system rectifier with R-L load

Voltage and current waveforms are shown in Figure 2.

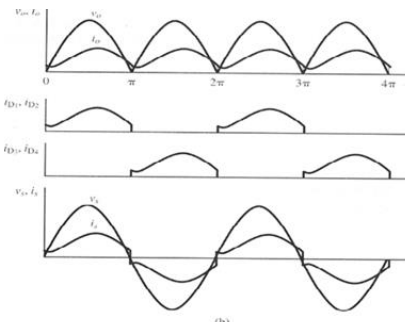

Figure 2 Voltage and current waveforms at the rectifier output and input

It appears that the rectifier output wave is not smooth or not flat And the rectifier input current waveform is not sinusoidal. Current waveforms that are not sinusoidal will give rise to harmonics [2]. To produce a flat DC wave, capacitor filter is used.

2.2. Electricity loads harmonics in residential houses

As mentioned before, the electrical power supply for residential loads is DC voltage that comes from the rectifier with a capacitor filter. This rectifier circuit is shown in Figure 3.

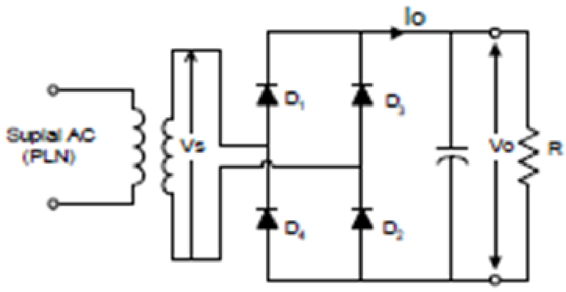

Figure 3 Rectifier with capacitor filter

The capacitor will be charged with electricity when the voltage on the capacitor is lower than the voltage working on the capacitor (supply voltage), which means the charging current occurs in the capacitor. The capacitor will release its charge if the voltage at the capacitor is higher than the voltage working on the capacitor. The waveforms of the rectifier output and input current are shown in Figure 4.

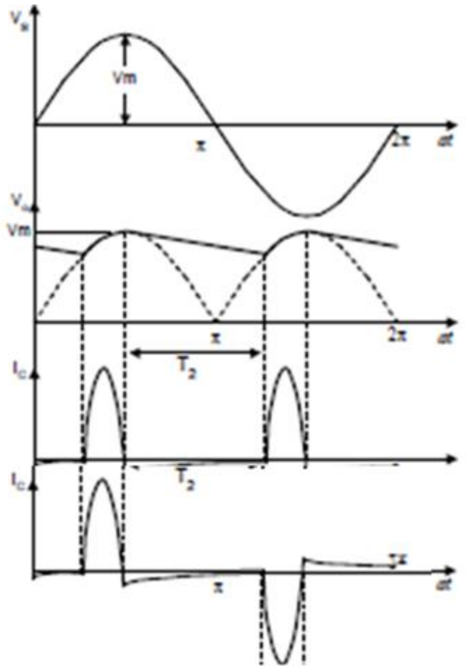

Figure 4 Rectifier input current with filter capacitors.

It appears that the rectifier input current waveform is not sinusoidal. Current waveforms that are not sinusoidal will produce harmonics.

Harmonics are all sinusoidal waveforms whose frequency is a multiple of fundamental frequency. Fourier claimed that every waveform can be stated in a series as follows:

$$y(t) = Y_0 + Y_1(t + Y_2(t) + \ldots\ldots + Y_n(t)$$

$$= Y_0 + \sum_{k=1}^{\infty}(A_k \cos k\,\omega t + B_k \sin k\,\omega t) \quad \ldots.\ (1)$$

Or it can be stated as follow:

$$y(t) = Y_0 + \sum_{k=1}^{\infty} C_k \sin(k\omega t + \theta_k) \ldots\ldots\ldots\ldots \qquad (2)$$

Where,

$$C_k = \sqrt{A_k^2 + B_k^2} \text{ dan } \theta_k = \tan^{-1}\left(\frac{A_k}{B_k}\right)$$

Where the constant Y_0 is the average value of y(t) and is expressed by:

$$y_0 = \frac{1}{2\pi}\int_0^{2\pi} y(\omega t)\, d(\omega t) \qquad (3)$$

Meanwhile, the constant A_k and B_k are expressed by:

$$A_k = \frac{2}{T}\int_0^T y(\omega t).cosk\omega t\, d(\omega t) \qquad k = 1,2,3 \ldots \infty \quad (4)$$

$$B_k = \frac{2}{T}\int_0^T y(t).\,sinkt\, d(t) \qquad k = 1,2,3 \ldots \infty \quad (5)$$

The values of these constants represent the value of the harmonic spectrum. This active filter is designed for simple residential loads which are generally 900 VA or about 4 Ampere. If the load at the residence is assumed to be equal to 80% or about 3.2 ampere, then the supply of non-linear loads is a single-phase rectifier circuit with a filter capacitor whose loading is shown in Figure 5, and its current wave is shown in Figure 6, and its harmonics spectrum is shown in Figure 7.

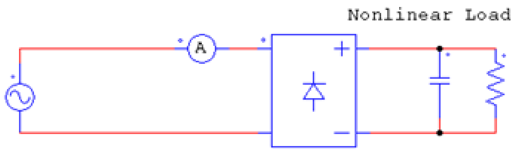

Figure 5 Non- linear single phase load

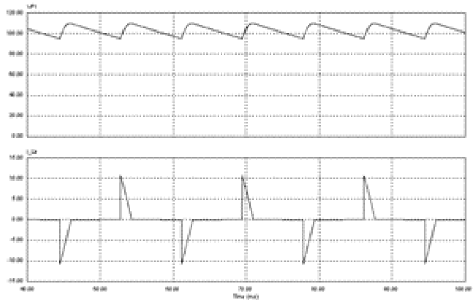

Figure 6 Waveform of output voltage and input current of single phase rectifier

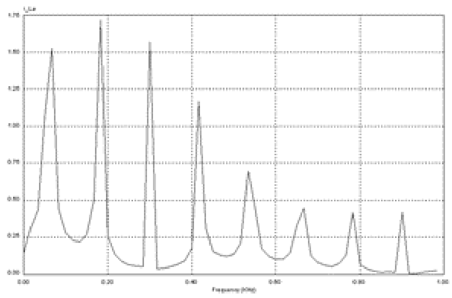

Figure 7 Single phase non linear load harmonics spectrum

From this spectrum it can be seen that the harmonic current component is as in Table 1.

Table 1. Non-linear load harmonic spectrum

Harmonic	Ampere	Percent
Fundamental	1.5	100
3	1,75	117
5	1,6	107
7	1,2	80
9	0,7	47
11	0,48	32

From the table above, we can calculate the effective current value:

$$I_{rms} = [1.5^2 + 1.75^2 + 1.6^2 + 1.2^2 + 0.7^2 + 0.48^2]^{1/2}$$

$$= 3.16 \text{ Amp.}$$

And THDi = 183 %

3. SINGLE PHASE ACTIVE FILTER

Single phase active filter basically consists of IGBT based full bridge inverter, both Voltage Source Inverter (VSI) and Current Source Inverter (CSI) with different control strategies [2,4], that produces harmonic current output. There are many control strategies including compensating for harmonic currents without compensating for reactive power [3], Single phase active filter with reactive power compensation [4], and others. In this paper we will discuss single-phase active filters with load current sensors designed only to compensate for harmonic currents.

A load current of 3.16 amperes with 183% THD_I which is censored using a current adapter is used to generate harmonic currents with opposite polarity to the harmonics of the load current. Furthermore, this current is injected into the source where the non-linear load is connected. In this way, the current at the harmonic source can be reduced or even eliminated. This filter circuit is shown in Figure 8.

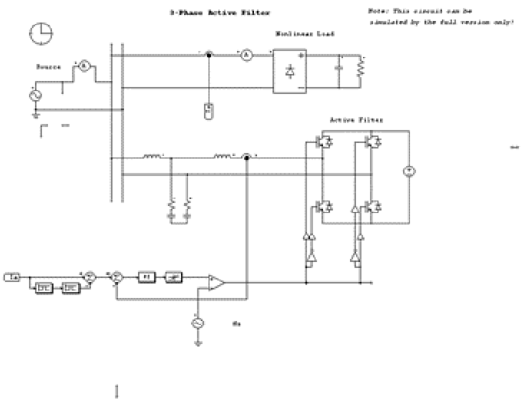

Figure 8 Single phase active filter circuit

This circuit is run by the current from the non-linear load located on the sensor. This current consists of fundamental current and harmonic current, as shown in Figure 7. Then, this current is filtered using a bandpass filter so that fundamental waves are generated. This fundamental wave is then subtracted from the non-linear load current wave so that only harmonic waves are generated. Furthermore, this harmonic wave is used to activate a single phase inverter, so that the inverter produces a harmonic current wave which is repulsed back to the source. Thus, the harmonic current wave at the source will decrease. The results of this circuit simulation are shown in Figure 9.

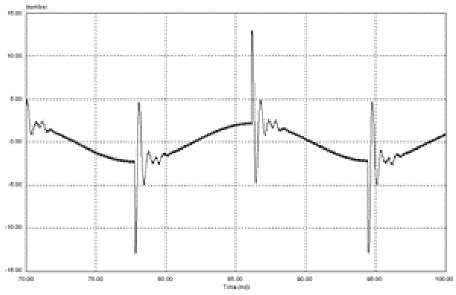

Figure 9 Current source waveform after filtering

The harmonics spectrum of the current waveform is shown in Figure 10.

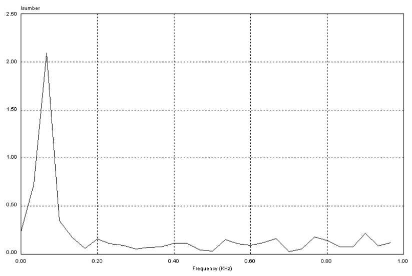

Figure 10 Current source harmonics spectrum

From the picture above, it appears that the dominant current source component is the fundamental component, while the harmonic component is significantly reduced. Components of the current source can be seen in Table 2.

Table 2. Components of the current source

Harmonic	Ampere	Percent
Fundamental	2.1	100
3	0,1	5
5	0,1	5
7	0,1	5
9	0,1	5
11	0,1	5

From those current source components, the effective current source value based on Fourier series is:

$I_{eff} = [2.1^2 + 0.1^2 + 0.1^2 + 0.1^2 + 0.1^2 + 0.1^2]^{1/2}$

= 2.11 Amp.

And THDI = 9.5 %

4. CONCLUSION

From the data obtained, electricity loads in residential houses, which are generally non-liner loads, constructed from the bridge system rectifier with capacitor filters have very high harmonic components with THDi values reaching up to 183%. After the active filter which is paralleled with component loads is installed, harmonic currents can be reduced significantly. Thus, the THDi value can be reduced to 9.5%, and the effective current value at the source can also be reduced from 3.16 Amperes to 2.11 Amperes.

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