SIMULATION OF THREE-PHASE HARMONICS FILTER

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" I hereby declare that I have read this thesis and in my opinion it is sufficient in terms of scope and quality to be awarded with the Bachelor's Degree in Electrical Engineering (Industrial Power)."

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"I declare that this thesis is the result of my own research except as cited in the reference."

Signature : ....

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Date : 13 NOVEMBER 2005

DEDICATION

For my beloved mother and father, my family,
my teachers and friends.

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ABSTRACT

This project is mainly about doing simulations using MATLAB software to filter harmonics which are found in the electrical utility system. Harmonics are caused by unbalanced loads in power systems. To reduce these harmonics effects, an effective filter system is needed. Among the types used are band-pass filters which block low harmonics such as 3rd, 5th, 7th order and etc harmonics and also harmonics of higher order with a large frequency range. There are two types of filters that are usually used, passive and active filters. This project focuses on analysis of three-phase 12-pulse rectifier using passive filter to eliminate the harmonics. The three- phase 12-pulse rectifier are also known as dual converter and are widely used in high power application such as for dc motor application and dc transmission lines. This converter is normally supplied with the combinations of Y-Y and Y-Δ transfomers. The purpose using the transfomers is to reduce the 5th, 7th, 9th and the other harmonics except harmonics of the 3rd, 11th, 13th and 24th order. Due to this condition, the passive filters will filter the 3rd, 11th, 13th and 24th harmonics only. The harmonics filtering method is done using a double tuned type filter (for harmonics 11th and 13th), high pass (for 24th harmonic) and c-type high pass (for 3rd harmonics). Apart from that, the three phase rectifier in this project has a power factor of about 0.7. Therefore, power factor correction also needs to be done to inprove the power factor of the system. From this project, it is found that the harmonics percentage is improved from 10.62% to 3.50%

ABSTRAK

Projek ini adalah berkenaan melakukan simulasi menggunakan perisian MATLAB bagi menapis harmonik yang terdapat pada sistem utiliti elektrik Harmonik terhasil dari beban tidak seimbang dalam sistem kuasa. permintaan. Bagi mengurangkan kesan-kesan harmonik tersebut, satu sistem penapis yang efektif diperlukan. Jenis-jenis yang digunakan adalah seperti penapis band-pass yang menapis harmonik-harmonik rendah seperti harmonik ke-3, ke-5, ke-7 dan sebagainya dan penapis *high-pass* yang menapis harmonik-harmonik tinggi yang merangkumi julat frekuensi yang besar. Terdapat dua jenis penapis yang biasa digunakan iaitu penapis pasif dan penapis aktif. Projek ini memfokus kepada analisis penerus 12-denyut tiga fasa menggunekan penapis pasif untuk menghapuskan harmonik. Penerus 12-denyut tiga fasa juga dikenali sebagai *dual converter* dan digunakan secara meluas dalam aplikasi berkuasa tinggi seperti motor dc dan talian penghantaran dc. Penukar ini biasanya dibekalkan dengan kombinasi pengubah $Y-Y$ dan $Y-\Delta$. Tujuan penggunaan pengubah ini adalah untuk mengurangkan hormonik ke 5, ke 7, ke 9 dan harmonik- harmonik lain kecuali harmonik ke 3, ke 11, ke 13 dan ke 24. Oleh sebab itu penapis pasif ini hanya akan menapis harmonik yang ke 3, ke 11, ke 13 dan ke 24 sahaja. Kaedah penapisan harmonik dilakukan dengan menggunakan penapis jenis *double-tuned* (untuk harmonik ke 11 dan ke 13, *high-pass* (untuk harmonik ke 24) *dan C-type high-pass* (untuk harmonik ke 3). Selain daripada itu penerus tiga fasa didalam projek ini mempunyai faktor kuasa 0.7. Maka pembetulan faktor kuasa juga perlu dilakukan untuk memperbaiki faktor kuasa bagi sistem ini supaya tidak dikenakan penalti oleh TNB. Daripada projek ini peratus harmonik berjaya diperbaiki daripada 10.62 peratus kepada 3.30 peratus.

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CHAPTER 1

INTRODUCTION

1.1 Project background

As we know, most electrical system available nowadays uses a lot of electronic equipment. This electronic equipments cause harmonic disturbance which occurs in the system itself. Normally, filter are installed between the load and control device to eliminate the harmonic at nonlinear system especially power electronic device seriously create distortion current and the system will draw high current from the supplied (TNB). In this project we need analysis and simulation to get the way how to eliminate the harmonic by using the passive filter, and to correct the power factor using capacitor bank..

For this project, we use a system including AC source, three phase rectifier circuit to simulation and design the harmonic passive filter to eliminate the harmonic and also to correct the power factor using capacitor bank.

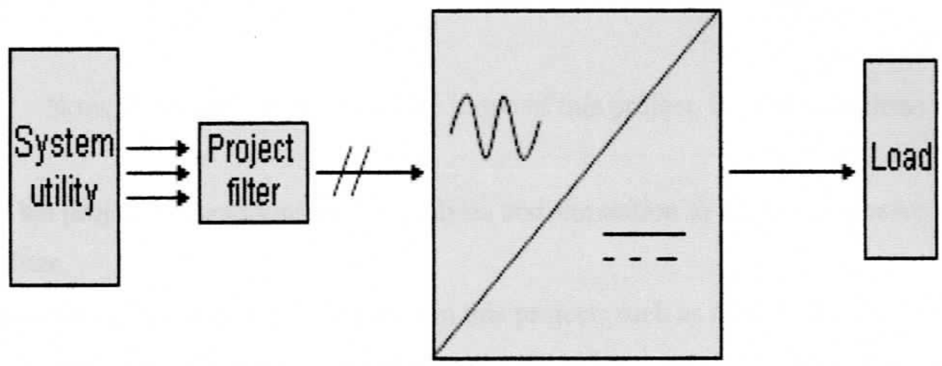

Figure 1.1: Project block diagram

1.2 Objectives of project

a) A simulation module of passive filter is designed, tested and built so that it can eliminate and reduce the harmonic by using a three phase rectifier in the utility system.

b) At the converter with passive filter and capacitor bank will able to eliminate and reduce the harmonic and to correct the power factor.

c) To study how harmonic come out by using the rectifier to the utility system.

d) To ensure compatibility between the passive filter to be designed and rectifier.

e) To determine the suitable passive filter to filter the harmonic.

f) To determine the most suitable theories and calculations to be applied in designing the passive filter and power factor correction.

1.3 Scopes of project

Now, as we are concern with the scope of this project, is listed as below:

a. This project concentrates on the analysis and simulation to design of passive filter.
b. Mastering the software that is used in this project; such as MATLAB.
c. Understanding the principles and theory of rectifier and passive filter. This includes the study on the power factor correction and waveform of harmonic.

1.4 Problem Statement

Three phase rectifier, like most other electronic equipment, do not draw their current as a smooth sinusoid. The supply current waveform is generally referred to in terms of the harmonics of supply frequency which it contains. A filter usually installed between the three phase rectifier and the load. It will filter the harmonic produced by the system itself such as converter and load. In order to prevent the unwanted noise distort the input current waveform. Low power factor is caused of high inductive load.

CHAPTER 2

LITERATURE REVIEW

2.1 Three- phase bridge rectifiers

A three- phase rectifier is commonly used in high- power applications and it is shown in figure 2.1. This is a full- wave rectifier, it can operate with or without a transformer and gives six-pulse ripple on the output voltage. The diodes are numbered in order of conduction sequences and each one conducts for $120°$. The conduction sequence for diode is $D_1 - D_2$, $D_3 - D_4$, $D_5 - D_4$, $D_5 - D_6$, and $D_1 - D_6$. The pair of diode which are connected between that pair of supply lines having highest amount of instantaneous line-to-line voltage will conduct. The waveform and conduction times of diode are shows in figure 2.1[2]

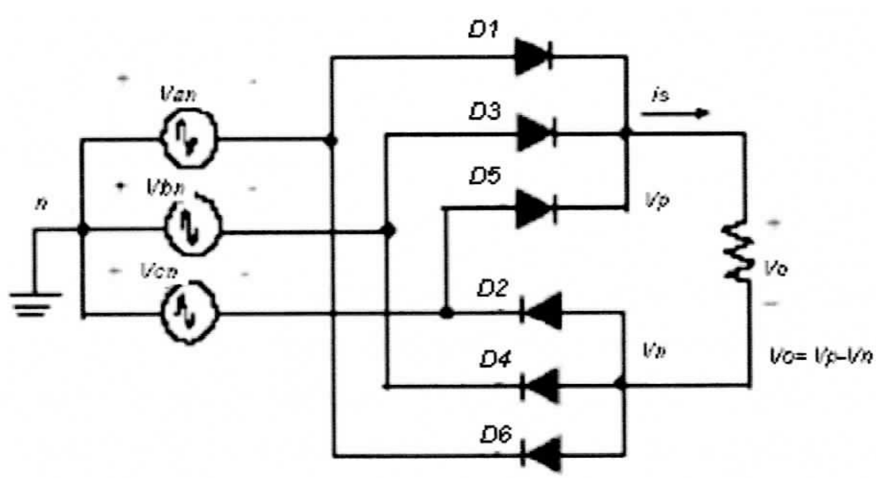

Figure 2.1: Three- phase rectifier circuit

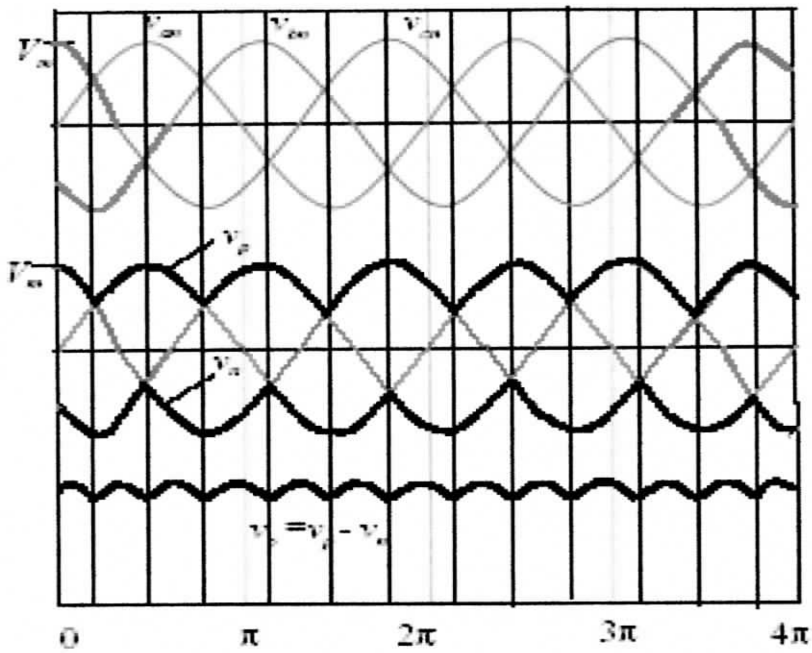

Figure 2.12: Three- phase rectifier waveform

$$V_{o=}\frac{3V_mL-L}{\pi}=0.955V_mL-L \tag{3.1}$$

The resulting output waveform is given as:

$$V_o = V_p - V_n \tag{3.2}$$

2.1.1 Controlled Three-phase

The three-phase bridge rectifier circuit has three-legs, each phase connected to one of the three phase voltages. Alternatively, it can be seen that the bridge circuit has two halves, the positive half consisting of the thyristor D_1, D_3 and D_5 and the negative half consisting of the thyristor D_2, D_4 and D_6. At any time when there is current flow, one SCR from each half conducts. If the phase sequence of the source be RYB, the thyristor are triggered in the sequence D_1, D_2, D_3, D_4, D_5, D_6 and D_1 and so on.

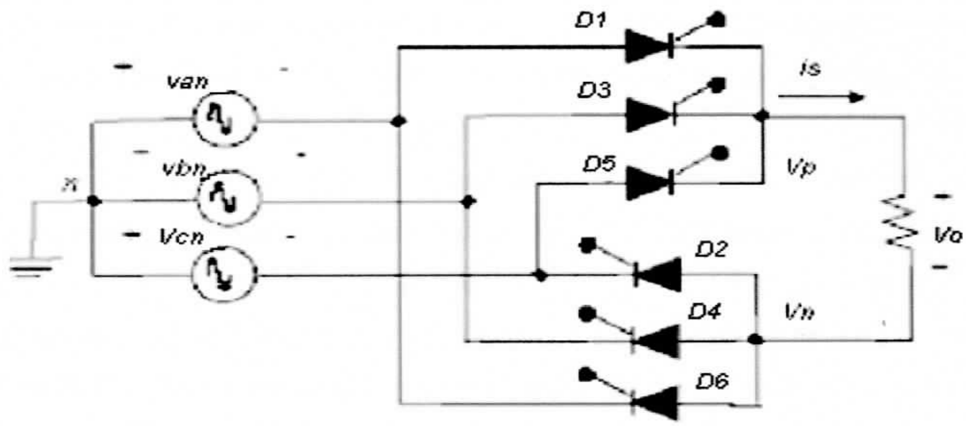

Figure 2.13: Controlled Three-phase circuit

The operation of the circuit is first explained with the assumption that diodes are used in place of the thyristor. The three-phase voltages vary as shown below.

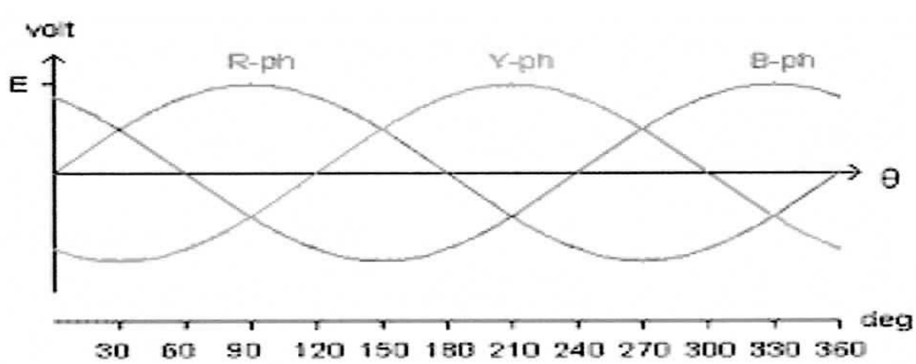

Figure 2.14: Controlled Three-phase three -phase voltages waveform

Let the three-phase voltages be defined as shown below.

$v_R(\theta) = E * \sin(\theta),\ v_s(\theta) = E * \sin(\theta - 120°),$ and $v_s(\theta) = E * \sin(\theta + 120°).$

(3.3)

It can be seen that the R-phase voltage is the highest of the three-phase voltages when is in the range from 30° to 150°. It can also be seen that Y-phase voltage is the highest of the three-phase voltages when is in the range from 150° to 270° and that B-phase voltage is the highest of the three-phase voltages when is in the range from 270° to 390° or 30° in the next cycle. We also find that R-phase voltage is the lowest of the three-phase voltages when is in the range from 210° to 330°. It can also be seen that Y-phase voltage is the lowest of the three-phase voltages when is in the range from 330° to 450° or 90° in the next cycle, and that B-phase voltage is the lowest when is in the range from 90° to 210°. If diodes are used, D_1 would conduct from 30° to 150°, D_3 would conduct from 150° to 270° and D_5 from 270° to 390° or 30° in the next cycle. In the same way, D_4 would conduct from 210° to 330°, D_6 from 330° to 450° or 90° in the next cycle, D_2 would conduct from 90° to 210°. The positive rail of output voltage of the bridge is connected to the topmost segments of the envelope of three-phase voltages and the negative rail of the output voltage to the lowest segments of the envelope [6] .

Average output voltage can be computed as :

$$V_o = \left(\frac{3V_{m.}L - L}{\pi} \right) \tag{3.4}$$

let α to be delay angle of the SCR

2.1.2 Twelve- pulse Rectifier

The three- phase six- pulse bridge rectifier shows in figure 2.15 a marked improvement in the quality of the DC output over that single- phase rectifier. Harmonic of the output voltage are small and at frequency which are multiples of six times the source frequency shows in figure 2.16. Further reduction in output harmonic can be accomplished by using two six-pulse bridges.

One of the bridges is supplied through a Y-Y connected transformer and other is supplied through a Y-Δ or $\Delta - Y$ transformer. The purpose of the Y-Δ transformer connection is to introduce a 30° phase shift between the source and the bridge. This result in input to the two bridge which are 30° apart. The two bridge output are similar, but shifted by 30°. The overall output voltage is the sum of the two bridge output, the delay angle for the bridge are typical the same. The DC output is the sum of the DC output of each bridge [1].

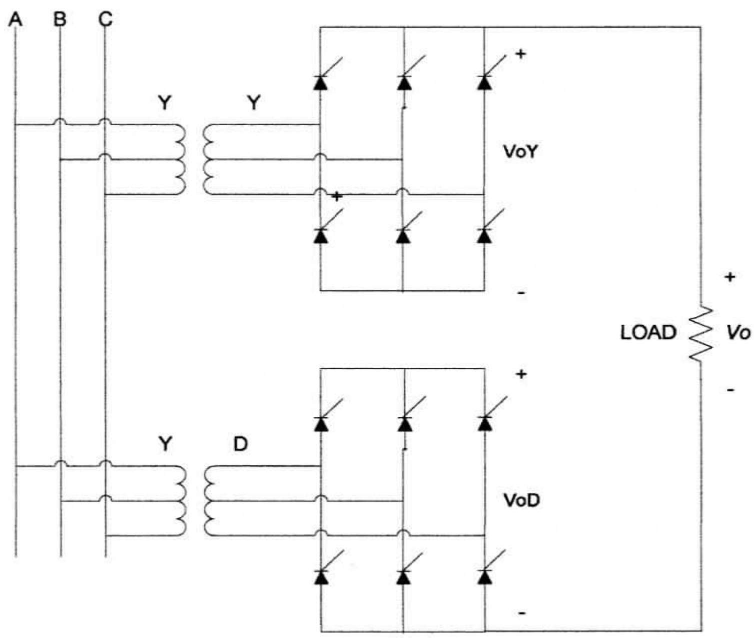

Figure 2.15: Twelve- pulse Rectifier circuit

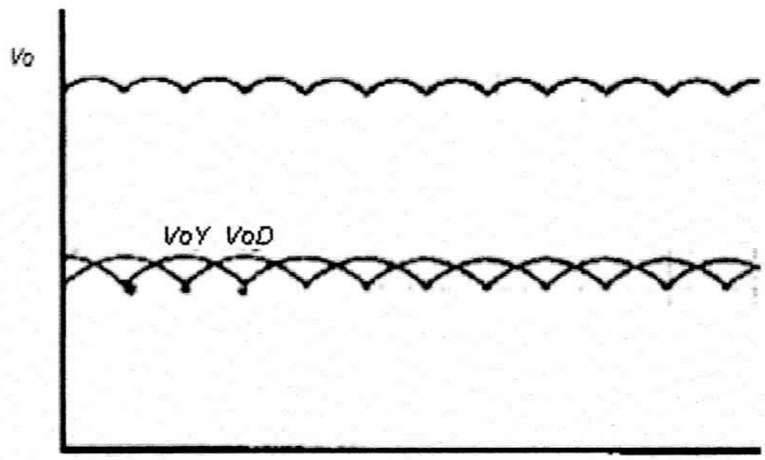

Figure 2.16: Output of twelve- pulse rectifier waveform

- Three-phase transformer connections can be used to shift the phase of the voltages and currents.
- This shifted phase can be used to cancel out the low-order harmonics.
- Three-phase delta-wye transformer connection shifts phase by 30°.

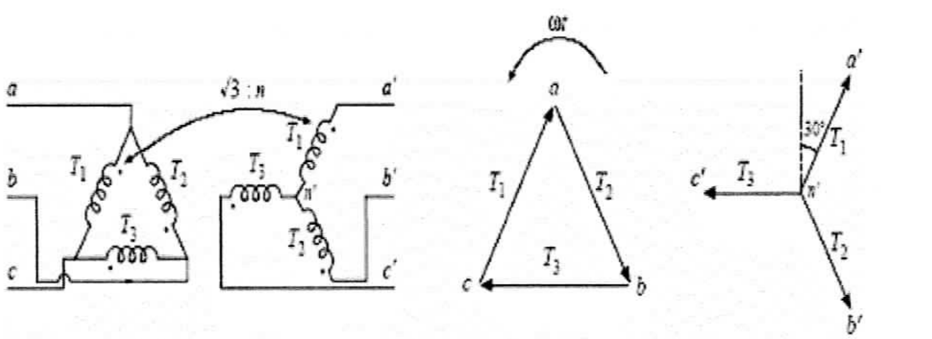

Figure 2.17: Transformer connection circuit diagram

$$V_o = V_{oY} + V_{o\Delta} = \frac{3V_m L-L}{\pi}\cos\alpha + \frac{3V_m L-L}{\pi} = \frac{6V_M L-L}{\pi}\cos\alpha \quad (3.5)$$

The peak output of the twelve- pulse converter occurs midway between alternate peaks of the six- pulse converters. Adding the voltages at that point for α =0 given:

$$V_{o,peak} = 2V_m.L - L\cos(15°) = 1.932V_m.L - L \tag{3.6}$$

Since a transition between conducting SCR occurs every 30°, there are total of 12 such transitions for each period of the ac source. The output has harmonic frequencies which are multiples of 12 times the source frequency (12 k, k= 1,2.3,4….). Filtering to produce a relatively pure dc output is less costly than required for the six- pulse rectifier.

Another advantage of using a twelve- pulse converter rather than six- pulse converter is the reduced harmonics that occur in the ac system. The current in the ac supplying the *Y-Y* transformer is represented by the Fourier series.

$$i_Y(t) = \frac{2\sqrt{3}}{\pi} I_o[(\cos\omega_o)I_o(\cos\omega ot - \frac{1}{5}\cos 5\omega ot + \frac{1}{7}\cos 7\omega ot - \frac{1}{11}\cos 11\omega ot + 13\omega ot - ..)] \tag{3.7}$$

The current in the ac lines supplying the $\Delta - Y$ transformer is represented by the Fourier series

$$i_\Delta(t) = \frac{2\sqrt{3}}{\pi} I_o[(\cos\omega_o)I_o(\cos\omega ot + \frac{1}{5}\cos 5\omega ot - \frac{1}{7}\cos 7\omega ot - \frac{1}{11}\cos 11\omega ot + 13\omega ot - ..)] \tag{3.8}$$

The Fourier series for the two current are similar, but some terms have different algebraic signs. The ac system current, which is the sum of those transformer current, has the Fourier series.

$$i_{ac}(t) = i_y(t) + i_\Delta(t) = \frac{4\sqrt{3}}{\pi} i_o(\cos\omega ot - \frac{1}{11}\cos 11\omega ot + \frac{1}{13}\cos 13\omega ot ..) \tag{3.9}$$

Thus, some of harmonic on the ac side are canceled by using the twelve- pulse scheme rather than six- pulse scheme. The harmonic that remain in the ac system are