THE STUDY ON HARMONIC DSITORTION
EFFECTS ON TRANSFORMER CONNECTIONS

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STUDY ON HARMONIC DSITORTION EFFECTS ON TRANSFORMER CONNECTIONS

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This Report Is Submitted In Partial Fulfillment Of Requirement For The Degree Of Bachelor In Electrical Engineering (Power Industry)

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"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

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ABSTRAK

Kajian ini bertujuan untuk mengkaji kesan harmonik terhadap pengubah kuasa. Sambungan pengubah kuasa terdiri daripada empat jenis iaitu wye kepada wye, wye kepada delta, delta kepada wye dan delta kepada delta. Setiap jenis sambugan ini menghasilkan jumlah gangguan harmonik yang tersendiri. Kajian dibuat dengan membekalkan voltan dari julat 250V-415V kepada pengubah dan menggunakan ballast elektronik sebagai beban tidak sekata. Berdasarkan ujikaji ini, kesan gangguan harmonik terhadap bekalan kuasa pengubah, sambungan pengubah, kehilangan pengubah dan faktor kuasa pengubah dapat ditentukan. Selain itu, kaedah yang sesuai untuk mengurangkan gangguan harmonik pada pengubah turut dibincangkan. Jenis sambungan yang banyak menghasilkan gangguan harmonic ditentukan berdasarkan analisis

ABSTRACT

The purpose of this study is to analyze the effects of harmonics on transformer. There are four basic transformer connections which are wye to wye, wye to delta, delta to wye and delta to delta. These four types of connections have produced different effects of harmonics. The study was carried by using electronic ballast as non-linear load with varied supply from 250V-415V. The evaluations of experimental are based on harmonic distortion effects at power losses and power factor. Based on experimental, methods reducing harmonic distortion are discussed. Type of transformer producing large amount of harmonic determined based on analysis.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

This project is evaluated the harmonic present on transformer connection. Each types of transformer connection produce different amount of harmonic distortion. The evaluations are based on experimental result and analysis. Basically, the study is determining the harmonic effects on power losses and power factor of transformer.

Transformer is a device to increase or decrease electricity voltage and current. Due to this reason, transformer is important part in power system delivery. There are four types of transformer connection; wye to wye, delta to delta, wye to delta and delta to wye. There are harmonic present in these connections. Each type of connections produce it own harmonic.

Harmonic is an electrical frequency that is an integer multiple of fundamental frequency; for example, 50Hz is fundamental frequency, then 100Hz is second harmonic and 150Hz is third harmonic. Term of harmonic distortion is referring to distortion of the sine wave. General effects of harmonic distortion to a system such as power losses, abnormal heating and permanent damage. Harmonic distortion can be measured as total harmonic distortion; percentage of distortion consisting of spurious frequencies that are multiple of frequencies present in the source material.

The present of harmonic on transformer connections cause the distortion on transformer. This distortion cause various of effects such as abnormal heating of transformer that can lead to explosion and power losses due to hysteresis and eddy current losses. The main reasons behind these effects are third and triplen harmonic component.

There are several recommended methods to reduce the harmonic distortion on transformer connections; such as tertiary connection, delta to delta connection and neutral the primary side of transformer. Those methods have more explanations on chapter 3.

1.2 Project Objective

There are several technical objectives that the project is expected to perform. The objectives lead this project in correct and successful direction. The first objective is to define the root cause or generation of harmonic present in transformer connections. This can be achieved by doing literature review and survey. Second objective is to investigate, analyze and inspect the harmonic distortion for four types of transformer connection. Here, the effects of harmonic on each connection are observed and analyzed. The third objective is to analyze the relationship between power loss and harmonic on transformer connection. The last objective is to analyze the relationship between power factor and harmonic on transformer connection.

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1.3 Project Scope

Scope of this project are study types of transformer connection, determine which connection produce larger amount of harmonic distortion and effects of harmonic distortion. The effects of harmonic distortion are based to power losses and power factor. The supply are varied from 250V-415V with electronic ballast is non-linear load.

CHAPTER 2

METHODOLOGY

This chapter discuss the flow of this project and methodology that being used to accomplish the project. There are variety of method has been use along this project. All methods below are use to detected and to eliminate harmonic that occur at transformer configurations.

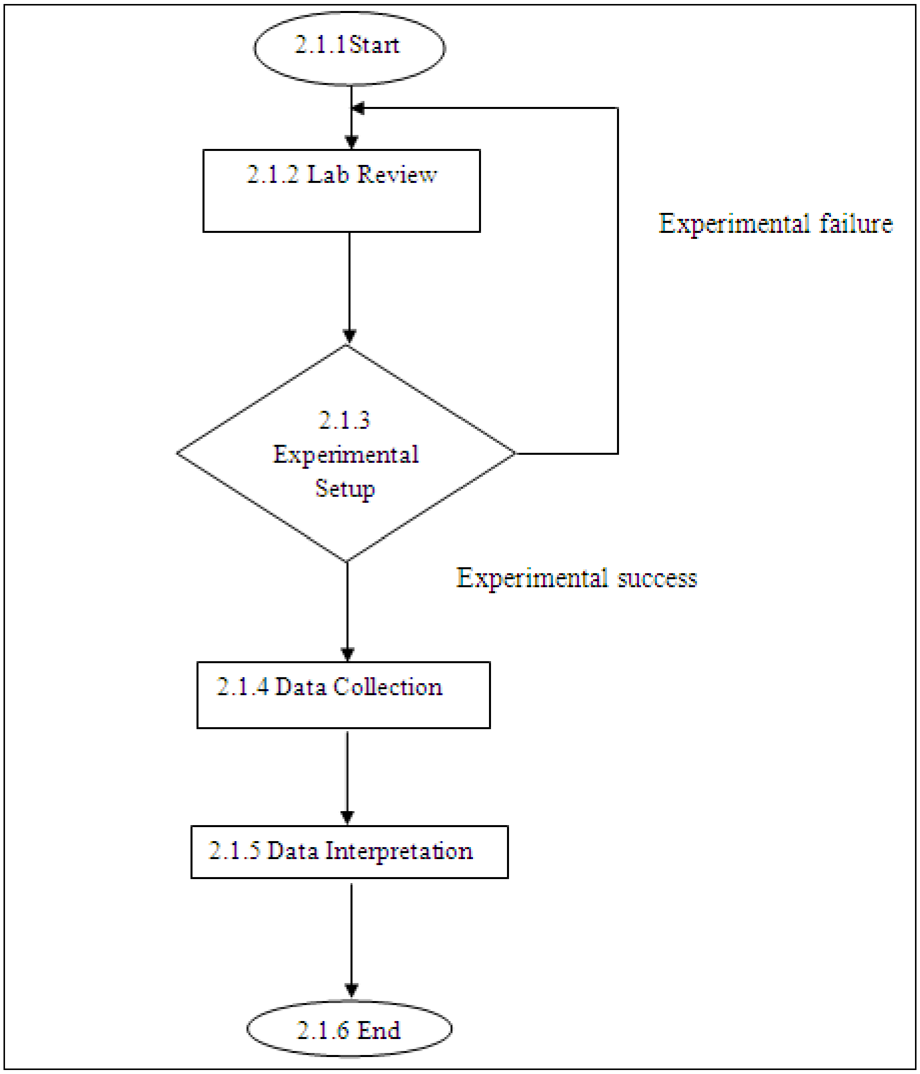
2.1 Flowchart

Figure 2.1 show the methodology flowchart of this project. Flowchart is important for a project because it indicates the step or flow of the project. If any problem occurs, by referring to flowchart the problem might be solved. The description of the flowchart is on the next sub topic.

2.1.1 Start

This section is about collecting information for lab experiment and literature review. All information gathers are based on internet, book, and discussion with supervisor. The main focus in this step is to define suitable lab experiment, finding the component of third harmonic, transformer connections, harmonic distortion effects and method to eliminate or reduce harmonic distortion in transformer connections.

Figure 2.1: Flowchart



2.1.2 Lab Review

This stage is to choose the best experimental set-up for this research project. However it depends on the availability of the equipments at faculty. The suitable experimental will be performing at the next stage. The suitable transformer is choose based on rated voltage, rated frequency, rated apparent power and rated current.

Based on research and finding, this experiment has to use Fluke meter due to technological advantage. However, oscilloscope provided by campus does not have function to capture waveform. Other than that, Fluke meter can give reading more precise and can save data.

2.1.3 Experimental Setup

The experimental study is focus on four type of transformer connection as mentioned on chapter 1. The transformer receives supply from DeLorenzo power supply. Then transformer connected to load. Loads are 9 electronic ballast with 36watt each and total load is 308watt. Electronic ballast had chosen because it produced more harmonic than other load provide by campus. The highest input voltage is 415volt but on transformer, the rated highest voltage is 480volt. This purpose to avoid transformer winding from melting. The voltage inject must be slowly increasing to avoid short circuit due to melting of winding. To measure the result, the primary side of transformer is observed. Fluke meter being used to observe the harmonic distortion on transformer. The tapping must be on primary side because secondary side is not harmonic distortion by transformer but electronic ballast. Make sure that cable ground and neutral are connected properly.

2.1.4 Data Collection

From the section above, data is collected based on each type of connections. The observations are based on harmonic, power loss and power factor. Basically, there are 12 set of data collections. The advantage of fluke meter is it can capture numbers of data at one time. For some value that can't display from capture, have to be writing down. The outstanding data are based on addition analyzing.

2.1.5 Data Interpretation

Based on data collection from experimental, form table for each examine; such as harmonic, power loss and power factor table. From the table, form the related graph or chart that show relationship between experimental data. Data interpretation important for this project and must focus more. Hence, the results of data interpreting are discussed on chapter 4.

2.1.6 End (Compiling Report)

Start compiling report after perform experimental, data collection and data interpreting. Report must follow the standard given by faculty for final report. Submit draft report to supervisor for any comment. Re-do and correction the mistake based on comment from supervisor. Then, submit the finalize report to supervisor and panel for grading.

CHAPTER 3

LITERATURE REVIEW

The information's are based on books, internet information and discussion with supervisor. The focuses of finding information are third harmonic and transformer connection. How the third harmonic cause major problem than other harmonic. What types of transformer connections produces harmonic and what the effects of harmonic distortion. Below are the findings:

3.1 Harmonic

Based on research and journal, the distortion of harmonic only occurs at primary side of transformer due to circulating current. The circulating current can be occurring at wye or delta winding. This means, harmonic only occur at wye to wye connection and delta to wye connection. For most, harmonic distortion occurs at three phase connections. This harmonic distortion also cause by zero sequence harmonic current, due to 3^{rd} harmonic.

3.1.1 Types of Harmonic

There are varieties types of harmonic define by variety of book or paper work. The harmonic is problem for few industries such as power delivery by transformer and any sector that using motor. This chapter discuss about the types of harmonic that related to this project. Figure 3.1 show the various types of harmonic.

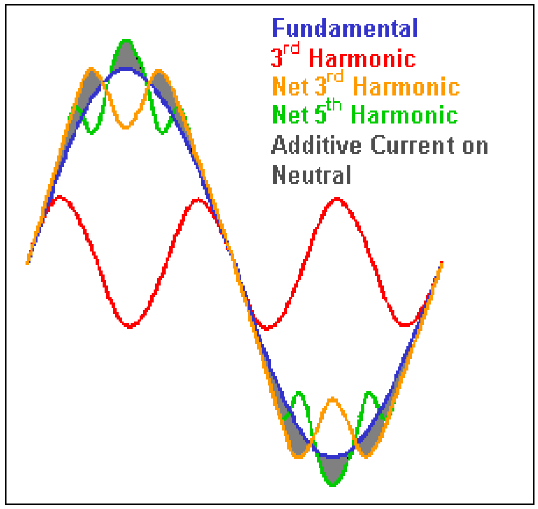


Figure 3.0: Types of Harmonic

3.1.1.1 Odd-ordered Harmonic

Load current that contain the odd-numbered harmonic will increase both eddy losses and others stray losses within transformer. If the harmonic substantial, then the transformer must be de-rated to prevent localized and overheating. Any transformer with load should be not containing more than 5% total harmonic distortion.

3.1.1.2 Even-ordered Harmonic

Analysis of most harmonic currents will show very low amounts of even harmonics (2nd, 4th, 6th, etc.) Components that are even multiples of the fundamental frequency generally cause the waveform to be nonsymmetrical about the zero-current axis. The current therefore has a zeroth harmonic or dc-offset component. The cause of a dc offset is usually found to be half-wave rectification due to a defective rectifier or other component. The effect of a significant dc current offset is to drive the transformer core into saturation on alternate half-cycles. When the core saturates, exciting current can be extremely high, which can then burn out the primary winding in a very short time. Transformers that are experiencing dc-offset problems are usually noticed because of objectionably loud noise coming from the core structure. Industry standards are not clear regarding the limits of dc offset on a transformer. A recommended value is a dc current no larger than the normal exciting current, which is usually 1% or less of a winding's rated current.

3.1.1.3 Third Harmonic

The 3rd harmonic component in the supply voltage has the highest effect on the current harmonics and distortion. The effect or higher voltage harmonics gradually diminishes with frequency. The magnitudes of the individual current harmonics follow the same decreasing/increasing pattern of changes as doe's current distortion variation. The corresponding variation in harmonic current phase angles is negligible.

3rd harmonic current and their multiples called triplen harmonic, have zero phase sequence and thus are not three phase quantities. If neutral is not connected, the 3rd harmonic current will be suppressed, the flux will not be sinusoidal and the resultant secondary voltage will not be sinusoidal. Other triplen harmonic, such as the ninth and fifteenth are also circulating in the delta. However, their magnitudes are quite small compared to the magnitude of the 3rd harmonic.

For example, if the incoming frequency is 50Hz. The fundamental is 50Hz and for triplen harmonic. Just multiply with integer.

Third harmonic : 3x50Hz = 150Hz

Ninth harmonic : 9x50Hz = 450Hz

Fifteenth harmonic : 15x50Hz = 750Hz

3.2 Transformer

Transformer is a device that very important in power delivery. Its function to step down and step up the power transmits from power plant. Transformer use as connection between power plant and load (user). With transformer, power plant can deliver smaller amount of power needed by load. To reduce power losses along the transmission line between loads and substation or power plant. The longer distance between loads and source, more losses of the power deliver happen. That's why, transformer important to step up or step down power carry to load due to reduce the power losses.

The main components in transformer connection are wye and delta connection. In wye connection, the neutral is the almost always grounded, since failure to do so well cause significant harmonic distortion. That means, wye have 2 voltage level which are phase-to-phase and phase-to-neutral. Since the transformer winding is exposed only the phase-to-neutral voltage, there is some economy to be realized at high voltage. Therefore, wyes are frequently used in the secondary of step-up application, and the primary of step-down application. The protection is usually simpler because of access to the neutral.

For delta connection, since neutral is not available, there is only one voltage level which could be an advantage. There is no obvious point to ground. For delta connected secondary, sometimes one phase is center-taped and this center point grounded. The secondary voltage replicates the wave shape of the primary voltage. Significant triplen harmonic currents can and will flow internally in all windings.

Figure 3.1: Transformer

3.2.1 Types of Transformer

Transformer comes in two type; shell type and core type. In the construction of a shell-type transformer, the two windings are usually wound over the same leg of the magnetic core as shown in Figure 3.2. In the core-type transformer, each winding maybe evenly split and wound on the both rectangular core as shown in Figure 3.3.

The core material made up of thin laminate iron sheets, each sheet is coated with an insulting varnish and the entire core is then pressed together.

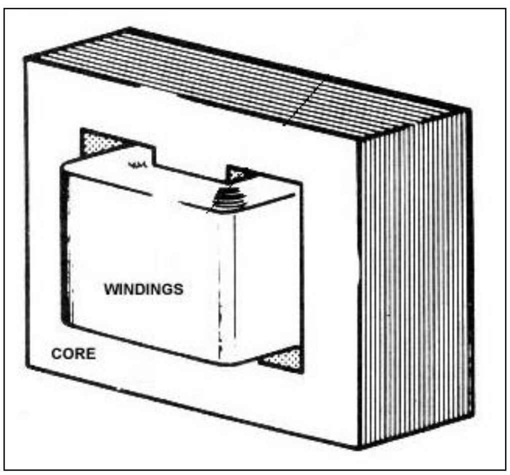


Figure 3.2: Shell type winding

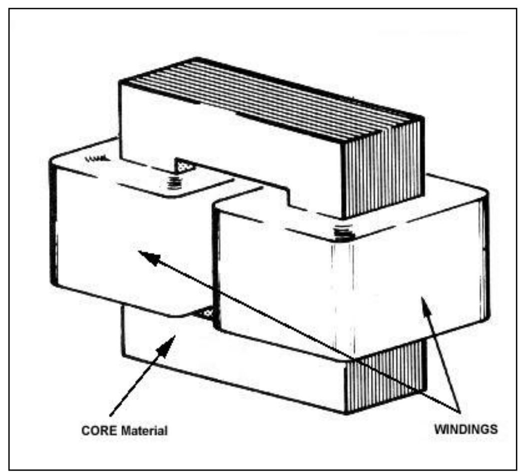


Figure 3.3: Core type winding

3.2.2 Wye to Wye Connection

The line to line voltage on each side of the three phase transformer is √3 times the nominal voltage of the single phase transformer. The main advantage of wye-wye connection is that we have access to the neutral terminal on each side and it can be grounded if desired. Without grounding the neutral terminals, the wye-wye operation is satisfactory only when the three phase load is balanced. The electrical insulation is stressed only about 58% of the line voltage in a Y connected transformer.

Since most of the transformer are designed to operate at or above the knee of the curve, such a design causes the induced electromagnetic field (emf) and currents to be distorted. The reason follows: although the excitation currents are still 120° out of phase with respect to each other, their waveform are no more sinusoidal. These currents, therefore, do not add up to zero. Thus, they affect the waveforms of the induced emfs.

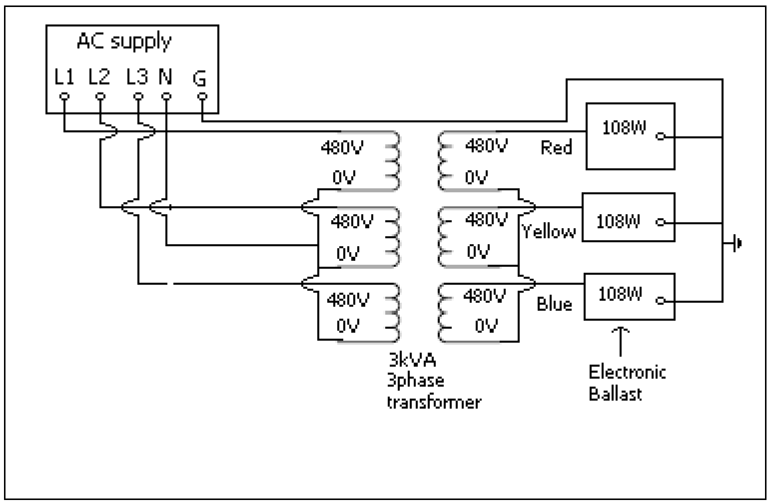


Figure 3.4: Wye to wye connection

3.2.3 Delta to Delta Connection

The line to line voltage on either side is equal to corresponding phase voltage. Therefore, this arrangement is useful when the voltages are not very high. The advantage of this connection is that even under unbalanced loads the three phase load voltages remain substantially equal. This disadvantage of the Δ-Δ connection is the absence of neutral terminal on either side. Another drawback is that the electrical insulation is stressed to the line voltage. Therefore, Δ-connected winding requires more expensive insulation than Y-connected windings for the same power rating.

A Δ-Δ connection can be analyzed theoretically by transforming it into a simulated Y-Y connection using Δ-Y transformations.

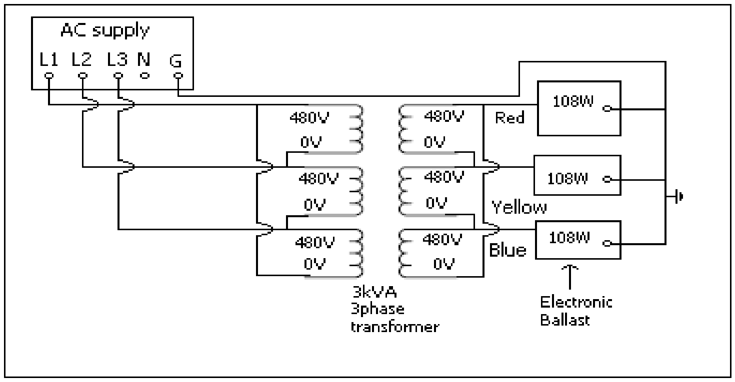


Figure 3.5: Delta to delta connection

3.2.4 Wye to Delta Connection

This connection is very suitable for step down applications. The secondary winding current is about 58% of the load current. On the primary side the voltages are form line to neutral, whereas the voltages are from line to line on the secondary side. Therefore, the voltage and current in the primary are out of phase with the voltage and the current in the secondary. In a Y- Δ connection, the distortion in the waveform of the induced voltages is not as drastic as it is in a Y-Y connected transformer when the neutral is not connected to the ground. The reason is that the distorted currents in the primary give rise to a circulating current in the Δ-connected secondary. The circulating current acts more like a magnetizing current and tends to correct the distortion. The most significant component of this non-sinusoidal induced emf is a third harmonic voltage that causes a 3rd harmonic current to circulate in the delta.