INFLUENCE OF ELECTRIC DISTRIBUTION NETWORK TOPOLOGY ON HARMONICS

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This research specially dedicated to both my beloved mother and father
for their support and encouragement,
also to my supervisor Dr. Ahmad Safawi Bin Mokhtar,
my wife, Nurulhuda Mohamed Hatta who always be my strength & my children's,
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ABSTRACT

The invention of electronic equipment has lead to a serious power quality problem in harmonics. The equipments, also known as the nonlinear loads have the ability to distort parameters such as voltage and current. Component of harmonics might increase RMS value of current, thus jeopardizing the power system components. These harmonic currents can in worst cases result in; Overheating or de-rating of transformer, Overheating of wiring, Damaging of capacitor banks, Resonance, Malfunction of electronic equipment, Communication interference and Distorted supply voltage. Due to the impedance of the distribution line the harmonic currents lead to harmonic voltage distortion, which results in increased losses or damaging of parallel loads and in worst case to system instability. The interest in harmonic distortion study has increased in both manufactures of electronic equipment and the power supply authorities. Harmonic studies have become an important aspect of power system analysis and design in recent years. Harmonic simulations are used to quantify the distortion in voltage and current waveforms in a power system and to determine the existence and mitigation of resonant conditions. Driven by challenging environmental constraints, deregulation of the energy market and privatization of the power supply industry, distribution power systems are ever more often operating at their maximal performance limits (and frequently beyond them) to maximize asset utilization. Since the quality of electrical power, example the voltage at the point of common coupling, has become an important feature of consumer goods on the market, the interest on finding, describing and above all in forecasting system behavior grows continuously.

ABSTRAK

Penciptaan peralatan elektronik telah membawa kepada masalah kualiti kuasa yang semakin serius ketika ini. Peralatan elektronik tersebut, juga dikenali sebagai beban tak linear mempunyai keupayaan untuk mencemarkan parameter voltan dan arus di dalam sistem kuasa. Komponen harmonik mungkin meningkatkan nilai RMS, dan menjejaskan sistem kuasa. Arus harmonik juga punca peningkatan suhu atau menurunkan keboleharapan alatubah kuasa, kepanasan pendawaian, merosakkan banka kapasitor, resonan, kerosakan peralatan elektronik, gangguan komunikasi dan menjadi punca voltan bekalan terherot. Oleh kerana galangan talian pengagihan, arus harmonik boleh menjana voltan harmonik, yang menyebabkan kerugian atau merosakkan beban dan ketidakstabilan sistem kuasa. Berdasarkan impak-impak tersebut, kepentingan dalam kajian berkaitan harmonik telah meningkat dalam kedua-dua pengeluar peralatan elektronik dan syarikat utiliti. Kajian harmonik telah menjadi satu aspek penting dalam analisis sistem kuasa dan reka bentuk sejak akhir-akhir ini. Simulasi harmonik digunakan untuk mengukur kadar gangguan dalam bentuk gelombang voltan dan arus dalam sistem kuasa bagi menentukan kewujudan dan langkah pengurangannya. Didorong oleh situasi yang mencabar, diregulasi pasaran tenaga dan penswastaan industri bekalan kuasa, sistem pengagihan kuasa biasanya lebih kerap beroperasi pada had maksimum prestasi mereka untuk mengoptimakan penggunaan aset. Kini kualiti kuasa elektrik, contohnya voltan pada pusat penghantaran kuasa (PCC - *point of common coupling*), telah menjadi satu kriteria penting bagi pengguna. Maka, keperluan untuk menjalankan kajian secara berterusan bagi menerangkan fenomena tersebut dan meramalkan tindakbalas sistem kuasa adalah satu prasyarat dan menunjukkan peningkatan berterusan.

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LIST OF ABBREVIATIONS

TNB	-	Tenaga Nasional Berhad
PCC	-	Point-of-common Coupling
THDv	-	Total Harmonic Distortion Voltage
THDi	-	Total Harmonic Distortion Current
PDCA	-	Plan-Do-Check-Act
PMU	-	Main Intake Sub-station *(Pencawang Masuk Utama)*
PPU	-	Main Distribution Sub-station (*Pencawang Pembahagian Utama*)
SSU	-	Main Switching Station (*Stesen Suis Utama*)
PE	-	Distribution Sub-station (*Pencawang Pembahagian Elektrik)*
LV	-	Low-voltage
SMPS	-	Switch-mode power supply
RMS	-	Root-mean square
EGAT	-	Electricity Generating Authority of Thailand
OLTC	-	On Load Tap Changers
THD	-	Total Harmonic Distortion
ASD	-	Adjustable speed drive
UPS	-	Uninterruptible power supplies
ATS	-	Automatic transfer switch

S/S	-	Static bypass switch
IHD	-	Individual Harmonic Distortion
PWM	-	Pulse width modulation
PSCAD®	-	Power Systems Computer Aided Design
EMTDC	-	Electromagnetic Transients with DC analysis

LIST OF SYMBOLS

V	-	Voltage
AC	-	Alternating Current
DC	-	Direct Current
Hz	-	Hertz
A	-	Ampere
kVA	-	Kilo Volt-Ampere
>	-	Greater than
<	-	Less than
mA	-	mili-Ampere
T	-	Temperature
3^{rd}	-	Third
kV	-	kilo-Volt
%	-	Percentage

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Harmonics have existed in power systems for many years. In the past, most electrical equipment is using balance linear load. A linear load in a power system distribution is a component in which the current and voltage are perfect sinusoidal. Examples of linear loads are induction motor, heaters and incandescent lamps. But the rapid increase in the electronics device technology such as diode, thyristors, etc. cause industrial loads to become non-linear. These components are called solid state electronic or non-linear load. The non-linear load connected to the power system distribution will generate harmonics current and voltage. The effect of current distortion on power distribution systems can be serious, primarily because of the increased current flowing in the system.

In other words, because the harmonic current does not deliver any power, its presence simply uses up system capacity and reduces the number of loads that can be powered. Harmonic current occur in a facilityÑs electrical system can cause equipment malfunction, data distortion, transformer and motor insulation failure, overheating of neutral buses, tripping of circuit breakers, and solid-state component

breakdown. The cost of these problems can be enormous. Harmonic currents also increase heat losses in transformers and wiring.

Nowadays, Power Quality has become the main factor in our life. If this quality of power is being polluted over the electrical power network, serious problems will arise within the modern society and its conveniences. The generation of harmonic currents and voltages cause one of the most harmful power quality problems. Harmonic may affect the whole electrical environment and there are many possible ways it can further degrade the power quality at much larger distances from where it originates. The efficiency of power in our homes, offices, schools, factories and power plants could also be affected by the generation of harmful harmonics. However, to determine the limits of harmonic levels and to eliminate this problem is not a straightforward exercise.

The rapid development in this industrial era and the increasing demand on electricity supply had contributed to a vast expansion of the power system. A distribution network may expand from a small and simple system to a more complicated connection to fulfill the needs arises. This mix of distribution network topology may influence the harmonics level itself. Therefore there is a need to investigate the influence of distribution network topology to harmonics.

1.2 Problem statement

The issue in electricity power sector delivery is not confined to only energy efficiency and environment but more importantly on quality and continuity of supply or power quality and supply quality. Harmonics have always been present in power systems. Thus, harmonic distortion can be considered as a sort of pollution of the electric system which can cause problems if the sum of the harmonic currents

exceeds certain limits. It is important to understand the effects of different type of electric distribution network topology on different level of harmonics. Since nowadays non-linear loads represent a large percentage of the total loads. Under these conditions, total harmonic distortion (THD) may become very high and therefore dangerous for the system.

It is vital to investigate the power system response to harmonics and understand how the network topology influence the harmonics effect itself. In addition, further site harmonic measurements and analysis was carried out at Tenaga Nasional Berhad (TNB) Main Intake SubstationÑs point of common coupling (PCC) to compare the results obtained from the simulation study.

1.3 Objectives

This research has the following objectives:

a) The study the effects of different type of electric distribution network topology on different level of harmonics.
b) To design and model distribution network topology using commercial Engineering Tools/Software.
c) To perform simulation study of different distribution network topology to obtain the effects on harmonics level itself.
d) To investigate the harmonics level in terms of THDv & THDi.

1.4 Scope of project

To achieve the said objectives, this project will study and review previous papers and research to get the relevant methods of harmonics studies technique. This project is using a Plan-Do-Check-Act (PDCA) approach and few scopes and guidelines are listed to ensure the research is conducted within its intended boundary. Firstly, there were many papers on harmonic analysis available mainly focusing on harmonic sources, harmonic analysis and harmonic measurement. This project scope however focused on the impact of distribution network topology on harmonics level only. Secondly, the most important aspect of this project is related to modeling and simulation using PSCAD®/EMTDCØ V4.2.0 and Matlab Simulink R2009a software.

Hence, in order to complete the project, one must have strong knowledge in PSCAD®/EMTDCØ V4.2.0 and Matlab Simulink R2009a. On top of that, as to develop the distribution network topology model, a lot of research and literature review need to be done. Some papers already describe the topologies used to develop this distribution network topology. And some papers shares the problems arise in obtaining the output result. Finally, for this paper, the scope of project is up until the simulation results only. Hopefully, it will be useful as for reference to other students and researchers.

1.5 Thesis Organization

This thesis will be discussing in detail the design stages, the data gathered and the probable output based on the calculations done. This thesis will be divided into five chapters. Chapter One; Introduction, Chapter Two; Literature Review, Chapter Three; Methodology, Chapter Four; Results and Chapter Five; Conclusion.

Chapter one; Introduction will be discussing the background of the study, objectives and scopes of study. Chapter two will discuss in detail the reviewed papers, journals, proceedings and relevant information regarding the methods of harmonics studies applicable. The methodology chapter will be discussing the methods used in this project. Chapter four will then discuss the results obtained in the computer simulation study for this project. The results will be compared with site measurement carried out at Tenaga Nasional Berhad (TNB) Main Intake SubstationÑs point of common coupling (PCC). The last chapter will conclude the findings and recommendation for further improvement in future study.

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