Faculty of Electrical Engineering

IDENTIFICATION OF HARMONIC SOURCE FOR ELECTRIC ARC FURNACE LOAD USING FAST-FOURIER TRANSFORM

NurHazwani Binti Saleh

Master of Electrical Engineering
(Industrial Power)

2018

IDENTIFICATION OF HARMONIC SOURCE FOR ELECTRIC ARC FURNACE LOAD USING FAST-FOURIER TRANSFORM

NURHAZWANI BINTI SALEH

A dissertation submitted
in partial fulfillment of the requirements for the degree of
Master of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2018

DECLARATION

I declare that this thesis entitle "Identification of Harmonic Source for Electric Arc Furnace Load Using Fast-Fourier Transform" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :……...

Name :……...

Date :……..

APPROVAL

I hereby declare that I have read this dissertation and in my opinion this dissertation is sufficient in terms of scope and quality as a partial fulfillment of Master of Electrical Engineering (Industrial Power)

Signature :…….

Supervisor Name :…… ……

Date :…….. ……..

DEDICATION

To my beloved family,

Khairul Taib, Khairul Darwisy Fasyin and Khairul Daiyyan Fithri.

To my helpful supervisor and co-supervisor,

Dr. Hyreil Anuar Kasdirin and Assoc. Prof Ir. Dr. Abdul Rahim Abdullah.

And above all,

Allah Subhanu Wa Ta"ala.

ABSTRACT

Harmonic pollution has become a major problem in electrical power networks which can cause problems like the reduction load's lifetime, failure of protection devices to operate efficiently, instabilities of power system interference in operating systems and all these can contribute to economic losses and downtime. Therefore, harmonic source identification is one of the major problems. Proper identification of the harmonics source is an essential for developing penalty based schemes for harmonic generation and for the design of mitigation equipment to reduce harmonic. This dissertation aims to identify and analyze the harmonics source in power system using Fast-Fourier Transform (FFT) with effective cost efficiencies using single-point measurement approach. The sources of harmonic that been focused in this study is Electric Arc Furnace and finally, the applicability of the modelling system is tested with another harmonic source, Rectifier. The signification finding of this research shows the harmonic sources location can be identified by referring to the relationship between fundamental impedance ($\boldsymbol{Zf}$) and harmonic impedance ($\boldsymbol{Zh}$).

ABSTRAK

*Pencemaran harmonik telah menjadi masalah utama dalam rangkaian kuasa elektrik yang boleh menyebabkan masalah seperti pengurangan hayat beban, kegagalan peranti perlindungan untuk beroperasi dengan cekap, ketidakstabilan sistem kuasa, gangguan dalam sistem operasi dan semua ini boleh menyumbang kepada kerugian ekonomi dan downtime. Oleh itu, mengenalpasti sumber harmonik adalah salah satu masalah utama. Pengenalpastian tepat sumber harmonik adalah penting untuk membangunkan skim penalti berasaskan generasi harmonik dan untuk mereka bentuk peralatan bagi mengurangkan harmonik. Disertasi ini bertujuan untuk mengenal pasti dan menganalisis sumber harmonik dalam sistem kuasa menggunakan Jelmaan Fourier Pantas (FFT) dengan kecekapan kos yang efektif dan menggunakan pendekatan mengukur pada satu titik. Sumber harmonik akan telah difokuskan dalam kajian ini ialah Relau Arka Elektrik dan diakhirnya, kebolehgunaan model sistem diuji dengan sumber harmonik yang lain iaitu Penerus. Penemuan signifikasi kajian ini menunjukkan lokasi sumber harmonik boleh dikenal pasti dengan merujuk kepada hubungan antara impedans asas (**Zf**) dan impedans harmonik (**Zh**).*

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude and appreciation to my supervisors, Dr Hyreil Anuar Bin Kasdirin for his interest and encouragement during the work. His guidance, training, constant encouragement and the countless enlightening conversations have helped me to achieve this goal, I am indebted to his support and guidance.

I would like to acknowledge the efforts of Assoc. Prof Ir. Dr. Abdul Rahim Bin Abdullah in completion of this work, and thank him for the innumerable technical discussions and warm encouragement. His immense experience and understanding of the subject helped me tackle some of the difficult challenges in this dissertation.

Nothing in life is possible without the love and support from one's family along the journey. I would like to thank my husband Khairul Taib Bin Khairul Anuar and my kids Khairul Darwisy Fayin and Khairul Daiyyan Fithri for their sacrifices, patience, support and unconditional love. Last but not the least; I would like to express my undying love and gratitude to my mother and father for a lifetime of support, encouragement and education. Their love and blessings made everything I have accomplished possible.

May Allah Azza Wa Jalla bless all of you with His love in this life and hereafter.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

LIST OF ABBREVIATION

AC	-	Alternating Current
DC	-	Direct Current
EAF	-	Electric Arc Furnace
FFT	-	Fast-Fourier Transform
HSE	-	Harmonic State Estimation
THD_V	-	Total Voltage Harmonic Distortion
THD_i	-	Total Current Harmonic Distortion
VIC	-	Voltage – Current Characteristic
PCC	-	Point of Common Coupling

LIST OF APPENDICES

LIST OF PUBLICATIONS

A. Journal

1) Jopri, M H., Abdullah, A.R., Manap, M., Ghani, A.b. and **Saleh, N .H.**, 2017 'Harmonic Contribution Analysis of Electric Arc Furnace by Using Spectrogram', *International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS*, 17(3) , pp. 28–36

2) **Saleh, N.H.,** Kasdirin, H.A. and Abdullah, A.R., 2018 'Identification of Harmonic Source for Electric Arc Furnace Load Using Fast-Fourier Transform'. *Journal of Telecommunication, Electronics and Computer Engineering (JTEC).*

B. Conference

1) **Saleh, N.H.,** Kasdirin, H.A. and Abdullah, A.R., 2018 'Identification of Harmonic Source for Electric Arc Furnace Load Using Fast-Fourier Transform'. In *Postgraduate Research Conference (PReCON)*, *January 24, 2018, Faculty of Electronics and Computer Engineeering, Universiti Teknikal Malaysia Melaka (UTeM).*

CHAPTER 1

INTRODUCTION

1.1 Research Background

Power quality can be defined as a set of electrical boundaries allowing an equipment to function in its intended manner with no significant loss of performance or life expectancy. A power system ideal when is define when a perfect sinusoidal voltage signal is seen at load-ends (Durdhavale, S.R. and Ahire, D.D., 2016). As stated by (Huda, Abdullah and Jopri, 2013), power quality is the ability of pure sinusoidal voltage and current waveforms at 50 Hz (frequency power-line in Malaysia) without any disturbances at the approaching side of the supply system. The quality of power delivered to the end user is very important as the performance of the consumer's equipment is heavily dependent on it. But, the power quality is affected by various factors like voltage and frequency variations, presence of harmonics, faults in the power network etc. Among them harmonic is one of the most frequently occurring problem.

Harmonic distortion come generally from equipment with a non-linear voltage or current characteristic. Nowadays a large part of industrial, commercial and domestic loads is non-linear, making the distortion level on the low-voltage supply network a serious concern. As time goes on, more and more equipment is being used that creates harmonics in power systems. These loads disturb the current and voltage waveforms. Consequently, pure sinusoidal currents and voltages cannot be provided to the customers (Yilmaz, A.S., Alkan, A. and Asyali, Musa H. 2008). Due to non-sinusoidal voltage and current waveform, the quality of power delivered to the end user may turn out to be degraded.

Presently, most of industries are very sensitive to harmonic disturbances. Power quality problems associated with harmonics are not new to utility and industrial system. The quality of electrical power in commercial and industrial installation is undeniably decreasing. With the increasing use of solid-state circuit equipment such fluorescent lights, adjustable speed drives, three phase converters (rectifiers and inverters), motor drives, arc furnaces, static VAR compensators and rotating electrical machines becomes more frequent and severe due to non-linear characteristics of such circuits create harmonics by drawing current in abrupt short pulses, rather than in a smooth sinusoidal manner (Soni, M.K. and Soni, N., 2014).

The growing applications of power electronic apparatus and non-linear can result in serious harmonic pollution in electrical power systems (Zang *et al.*, 2016). The voltage or current distortions may cause unsafe and unreliable electrical power supplies, malfunction of equipment, overheating of conductors and can reduce the efficiency, and life of most connected loads. Therefore, harmonic distortion is an undesirable effect for electrical systems. Therefore, harmonic pollution has grown to be a major problem in electrical power networks (Yilmaz, A.S., Alkan, A. and Asyali, Musa H., 2008). Harmonic distortion can be considered as a sort of pollution of the electric system which can cause problems if exceeds certain limits.

1.2 Problem Statement

Harmonic distortions are major problems which have become a great concern nowadays to maintain power quality (Ingale, R., 2014). Electric arc furnace (EAF) is one of the typical industrial non-linear loads responsible for deteriorating the power quality in the distribution network by introducing harmonics causing unbalance in voltages and currents (Bhonsle, D.C. and Kelkar, R.B., 2013). Harmonic can cause problems like reduction load's

lifetime, failure of protection devices to operate efficiently, instabilities of power system, interruption in production and above all it can contribute to economic losses and downtime (Abidullah *et al.*, 2014).

(Yilmaz, A.S., Alkan, A. and Asyali, Musa H. 2008) states that, harmonics have to be determined at an early stage and distinguished for developing solutions for harmonic elimination. Fast detection on power quality problem enable the utility personnel to mitigate efficiently, and at the same time it will improve the reliability and quality of the power system network (Abdullah *et al.*, 2015). According to (Supriya, P. and Padmanabhan, N., 2012), proper identification of the harmonics generated or absorbed by consumer is essential for developing penalty based schemes for harmonic generation and for the design of mitigation equipment. A simple, cost-effective and accurate method for harmonic source detection is yet to make a deep mark in the power sector. Therefore, harmonic source identification have drawn wide concern globally for power system researchers (Zang *et al.*, 2016).

In the recent past, there are many techniques was presented by various researcher for analyze harmonic signal for identifying the location of harmonic sources in power systems based on different theoretical principles, features, advantages and limitations. The real power flow method is one of the earliest method proposed in locating harmonic sources (Abdullah *et al.*, 2014; Abdullah, A. R. *et al.*, 2017). The drawbacks of power flow was covered by Harmonic state estimation (HSE) techniques.

The first the idea of using least square based state-estimation technique to identify the locations of the harmonic sources was proposed by Heydt (1989) (Kumar, A., Das, B. and Sharma, J., 2004). However, this technique required details and an accurate knowledge of network parameters. Poor knowledge of network parameters may lead to large errors in the results (Gursoy, E. and Niebur, D., 2009).

An improvement of HSE method involves the developments in the field of artificial intelligent (AI) techniques (Janani, K. and Himavathi, S., 2013). The problem of identification and tracking of harmonic source using Neural Network has been solved by using the Kaman filter (Kumar, A., Das, B. and Sharma, J., 2004). However, it was successful only for periodic signals and it required lot of computation time (Supriya, P. and Padmanabhan, N., 2012). To overcome the problem related to the solutions of Kalman Filter, Bayesian approach is proposed (D'Antona, G., Muscas and Sulis, S., 2008). However, this technique requires a high multiplicity in the algorithm and very expensive cost to setup the distributed measurement system station (Abdullah, A. R. *et al.*, 2017).

By concerning the mentioned limitations and to solve the related problem, this research proposed frequency domain analysis Fast Fourier Transform (FFT) for identification harmonic source disturbance. FFT is a reasonable approach for stationary signal, which is high accuracy, fast estimation and costs efficient for harmonic source identification.

1.3 Research Objectives

This research has three (3) objectives that are stated as follows:

i. To analyze and detect harmonic signals of EAF using Fast-Fourier Transform (FFT) technique.

ii. To estimate parameter for identifying harmonic source location of EAF by Fast-Fourier Transform (FFT).

iii. To identify the location of EAF as harmonic source based on impedance characteristic.