Faculty of Electrical Engineering

VOLTAGE SOURCE INVERTER SWITCHES FAULTS CLASSIFICATION AND IDENTIFICATION USING TIME-FREQUENCY DISTRIBUTIONS

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DECLARATION

I declare that this thesis entitled "Voltage Source Inverter Switches Faults Classification and Identification Using Time-Frequency Distributions" 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 the candidature of any other degree.

Signature : .....

Name : Nur Sumayyah Binti Ahmad

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for award of Master of Science in Electrical Engineering.

Signature : …….....

Supervisor Name : Prof Madya Dr. Abdul Rahim Bin Abdullah

Date :.....

DEDICATION

This is special dedicated to

My beloved husband,

Khairulzaman Bin Mohd,

my lovely son,
Nur Awfiyah Syahidah& Nur Awliya' Syahidah

my parents,
Ahmad Bin Nordin & NorizanBintiA.Bakar,

and my family for their continuous love and prayers,

also to all my friends for their patient, kindness and cooperation .

I wish to thanks all of you for your support during my studies in UTeM.

May God bless all of them.

ABSTRACT

Three-phase voltage source inverters (VSI) are utilized in a variety of industry applications. Although this technology has already achieved a certain level of maturity, due to their complexity and considering, three-phase VSI are often exposed to high stresses and unexpected faults may occur. Different types of faults occur in three-phase VSI such as open circuit, short circuit and gate misfiring that can influence reliability of entire system and disturb the performance. Hence, detection and classification of the three-phase VSI switches faults important for rectify failures and ensure the quality of power electronics system. This research presents the analysis of time-frequency distributions (TFDs) for three-phase VSI switches faults. The TFDs used are linear TFDs which are short time Fourier transform (STFT) and S-transform and bilinear TFD focusing on smooth-windowed Wigner-Ville distribution (SWWVD). The resulting time-frequency representations (TFRs) represent signals in the jointly time-frequency domains while the parameters of the signals are then estimated from the TFR. The signal parameters are instantaneous of root mean square (RMS) current, RMS fundamental current, average current, total waveform distortion (TWD), total harmonic distortion (THD) and total nonharmonic distortion (TnHD). From the signal parameters, the characteristics of the faults signals are calculated and are then used as input to a rule-based classifier to identify and classify the switches faults. The presented analysis is achieved by analyzing three-phase VSI for open and short circuit switches faults. In addition, based on the signal characteristics measurement, the best TFD is identified in terms accuracy, memory size and computation complexity used. Besides that, an experimental test also conducted to capture the real data for three-phase VSI switches faults. At the end of this research, the comparative analysis of three-phase VSI switches fault using TFDs is reported to highlight the strength and weakness of each technique. Then, the best and effective technique for detection, identification and classification of different types of three-phase VSI switches fault are discussed. The result shows that SWWVD is the best TFD technique for three-phase VSI switches faults detection and classification.

ABSTRAK

Penyongsang tiga-fasa (VSI) akan digunakan dalam pelbagai aplikasi industri. Walaupun teknologi ini sudah telah mencapai satu tahap kematangan, disebabkan oleh kerumitan,penyongsang tiga-fasa VSI seringkali terdedah kepada tekanan yang tinggi dan kerosakan yang tidak di jangka mungkin berlaku. Jenis kesalahan yang berlaku dalam pemyongsang tiga-fasa seperti litar terbuka, litar pintas dan pintu misfiring yang boleh mempengaruhi kebolehpercayaan keseluruhan sistem dan menggangu prestasi. Oleh itu, pengesanan dan pengenalpastian kesilapan suis VSI penting untuk meminimumkan masalah ini. Kajian ini membentangkan analisis pengagihan masa-frekuensi TFDs) untuk kesilapan suis penyongsang tiga- fasa VSI. TFDs digunakan adalah TFDs linear yang masa pendek jelmaan Fourier (STFT) dan transformasi-s dan dwi-linear seperti pengagihan Wigner-Ville halus-berjendela (SWWVD). Representasi perwakilan masa-frekuensi (TFR) mewakili isyarat dalam domain masa kekerapan bersama manakala parameter isyarat maka dianggarkan dari TFR. Parameter isyarat adalah jumlah serta-merta semasa RMS, RMS asas semasa, purata semasa, herotan bentuk gelombang (TWD), jumlah herotan harmonic (THD) dan jumlah gangguan nonharmonic (TnHD).Daripada parameter isyarat tersebut, ciri-ciri isyarat kerosakan dikira dan digunakan sebagai input kepada pengelas berasaskan peraturan untuk mengklasifikasi dan mengenal pasti kerosakan suis. . Analisis yang dibentangkan dicapai dengan menganalisis penyongsang penyongsang tiga-fasa (VSI) untuk kesalahan litar terbuka dan litar pintas suis. Di samping itu, berdasarkan pengukuran ciri-ciri isyarat, TFD yang terbaik akan dikenalpasti dari segi ketepatan, kerumitan pengiraan dan saiz memori yang digunakan. Selain itu, ujian eksperimen juga dijalankan untuk menangkap data sebenar untuk penyongsang tiga fasa (VSI) suis kesalahan. Pada akhir kajian ini, analisis perbandingan kesalahan penyongsang tiga-fasa (VSI) menggunakan TFD di bincangkan mengenai kelebihan dan kelemahan bagi setiap teknik. Kemudian, teknik terbaik bagi pengesanan, pengenalan dan pengelasan untuk pelbagai jenis kesalahan suis penyongsang tiga-fasa (VSI) di bincangkan. Hasil kajian menunjukkan bahawa, SWWVD adalah TFD yang terbaik untuk pengesanan dan pengelasan bagi kesalahan suis penyongsang tiga-fasa (VSI).

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LIST OF SYMBOLS

A	-	Ampere
ms	-	milliseconds
t	-	Time
f	-	Frequency
fo	-	Fundamental frequency
fr	-	Frequency resolution
fs	-	Frequency sampling
Kx	-	Bilinear product of a signal
Td_{fault}	-	Duration of fault
Tr	-	Time resolution
$w(t)$	-	Window function
FFT	-	Fast Fourier transform
TFD	-	Time frequency distribution
TFR	-	Time frequency representation
STFT	-	Short time Fourier transform
SWWVD	-	Smooth-Windowed Wigner-Ville Distribution
WT	-	Wavelet transform
$x(t)$	-	Observation window in continuous
$Iave(t)$	-	Instantaneous average current

$Irms\,(t)$	-	Instantaneous root means square current
$I1rms\,(t)$	-	Instantaneous root means square fundamental current
$ITnHD(t)$	-	Instantaneous total nonharmonic distortion current
$ITHD\,(t)$	-	Instantaneous total harmonic distortion current
$ITWD\,(t)$	-	Instantaneous total waveform distortion current
pu	-	Per-unit
THD	-	Total harmonic distortion
$TnHD$	-	Total nonharmonic distortion
TWD	-	Total waveform distortion
AC	-	Alternating Current
DAQ	-	Data acquisition
DC	-	Direct current
PWM	-	Pulse width modulation
MAPE	-	Mean absolute percentage error
VSI	-	Voltage source inverter

LIST OF PUBLICATIONS AND AWARDS

A. Journal & Conferences

1. N.S.Ahmad , A.R.Abdullah, E.F.Shair, A.Jidin (2013)," Open Switch Fault Analysis in Voltage Source Inverter using Spectrogram" International Power Engineering and Optimization Conference (PEOCO), 3-4 June 2013, Pg 438-443

2. N. S. Ahmad, A. R. Abdullah, N. H. Bahari, Mr. M. Manap, A. Jidin, M. H. Jopri, "Short Circuit Faults Analysis in Voltage Source Inverter using Spectrogram", International Conference on Electrical Machines and Systems 2013 (ICEMS 2013), 26-29 October 2013, Busan, Korea

3. N. S. Ahmad, A. R. Abdullah, N. Bahari, M. A. A. Hassan (2014), " Switched Faults Analysis of Voltage Source Inverter (VSI) using Short Time Fourier Transform (STFT), International Review of Modelling and Simulations (I.RE.MO.S), Vol. 7, N. 3 June 2014

4. N. S. Ahmad, A. R. Abdullah, N. Bahari (2014), “Open and Short Circuit Switches Fault Detection of Voltage Source Inverter Using Spectrogram”, Journal of International Conference on Electrical Machines and Systems, Vol. 3, Issue. 2, Pg. 190-199.

5. N. S. Ahmad, A. R. Abdullah, N. Bahari, S.Daud, M.A.A.Hassan (2014), “Voltage Source Inverter Fault Detection System Using Time Frequency Distribution”, Journal of International Conference on Design and Concurrent Engineering

B. Other Publication

1. M. Manap, A. R. Abdullah, N. Z. Saharuddin, N. A. Abidullah, N. S. Ahmad, N. Bahari, “ Voltage Source Inverter Switches Faults Analysis Using S-Transform” Applied Mechanics and Materials Journal, 2014.

2. M. Manap , N. S. Ahmad, A. R. Abdullah, N. Bahari (2015), “Comparison of Open and Short-Circuit Switches Faults Voltage Source Inverter Analysis Using Time-Frequency Distributions” Applied Mechanics and Materials Journal, 2015.

3. M. Manap, A. R. Abdullah, N. Z. Saharuddin, N. A. Abidullah, N. S.Ahmad, M. H. Jopri, “Performance Comparison of VSI Switches Faults Analysis Using STFT and S transform” Applied Mechanics and Materials Journal, 2015.

C. Awarded

1. Awarded i-ENVEX 2014 silver medal for the invention "Voltage Source Inverter- Fault Detection System (VSI-FaDS)" at International Engineering Invention & Innovation Exhibitions (i-ENVEX) on 11-13th of April 2014, Universiti Malaysia Perlis, UNIMAP.

2. Awarded INNOFEST 2014 special award for the invention "Voltage Source Inverter- Fault Detection System (VSI-FaDS)" on 18th May 2014, Universiti Teknikal Malaysia Melaka (UTeM)

CHAPTER 1

INTRODUCTION

1.1 Introduction

The voltage source inverter (VSI) is increasingly used is powered wheelchairs, electric vehicles, aerospace, medical and military applications, and nuclear power plants due its advantages such as high power density, efficiency and simple control. In this application, because the fault can result in huge damages to the human life and environments, the reliability of the drives is one of the most importance factors guarantee the safe, continuous and high performances operation under even some faults. Generally, when fault occurs, the drive system has to be stopped for emergency or non-programmed maintenance schedule. Due to the high cost of unexpected maintenance, the development of a reliable system is the area of interest (UiMin et al., 2015 and B.Tabbache et al. 2014).

A prompt and accurate diagnosis of faults are needed to ensure the reliability of power electronics and reduce the risk of failure (Iannuzzo et al., 2013). To keep the power electronics reliability at a higher level, an accurate technique is required to determine, classify and diagnose the problem. According data provided, the reliability of power electronic devices is very important because semiconductor failure and soldering joint failure in power devices take up 34% of power electronics system failures and 38% of faults in variable-speed as drives are due to failure of power devices. Besides, statistical data also shows that 63% of the inverter experience faults within the first year of operation