Australian Journal of Basic and Applied Sciences, 9(12) Special 2015, Pages: 144-151

ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

Performance Verification of VSI Switches Faults Classification and Identification System

[1]N. Bahari, [2]M. Manap, [3]A.R. Abdullah

[1]*UniversitiTeknikal Malaysia Melaka,Department of Power Electronics and Drives,Faculty of Electrical Engineering,76100 Durian Tunggal, Melaka, Malaysia*
[2]*UniversitiTeknikal Malaysia Melaka,Department of Electrical Engineering Technology ,Faculty of Engineering Technology,76100 Durian Tunggal, Melaka, Malaysia*
[3]*UniversitiTeknikal Malaysia Melaka,Department of Power Electronics and Drives,Faculty of Electrical Engineering,76100 Durian Tunggal, Melaka, Malaysia*

ARTICLE INFO

Article history:
Received 22 February 2015
Accepted 20 March 2015
Available online 25 April 2015

Keywords:
Voltage Source Inverter, S-transform, Switches Faults.

ABSTRACT

The study on switches faults diagnostic in voltage source inverter (VSI)has attracted many researchers recently. Many efforts has been proposed to monitor and enhanced the reliability of the inverter. This paper present a new approach for switches faults classification and identification system in VSI. The phase current signalextracted from VSI is represented in time-frequency representation (TFR) using S-transform technique to estimate signal parameter and characteristics. The performance of the system are then analyzed and compared between, simulation, actual and system.

© 2015 AENSI Publisher All rights reserved.

To Cite This Article: N. Bahari, M. Manap, A.R. Abdullah., Performance Verification of VSI Switches Faults Classification and Identification System. ***Aust. J. Basic & Appl. Sci.,*** *9(12): 144-151, 2015*

INTRODUCTION

Most of electrical drive systems in industrial process are exposed to hash environment which reduces lifespan of the inverter because of natural aging process. Therefore, to maintain the performance of the inverter, reliability and preserving the health is extremely crucial. This issue has attracted many researchers to improve faults detection and diagnosis techniques. Statistical data shows that 63% of the inverter experience faults within the first year of operation and 70% of the faults occurred are related to power switch which categories into short circuit faults and open circuit faults (Ui-Min *et al*., 2015). Generally, fault diagnosis can be categorized into component based and system based. For component based techniques, standard features of industrial power converter such as gate signal monitoring and overcurrent scheme are used to protect solid state switches. To ensure the successful of remedial action, these schemes which are integrated with auxiliary analog circuitry for switch abnormalities detection must operate in less than 10µsec to prevent the silicon chip from damages (Ubale *et al*., 2013). System based techniques on the other hand focusing on waveform analysis while algorithmic techniques to identify type of faults and its location (Gaeta *et al*., 2011).

Early stage of fault detection in inverters is needed for remedial actions prolonged normal operation of inverters and, in some cases, prevents the system from unexpected shutdowns. Normally, when a VSI fault occurs, the associate system has to be stopped for an un-programed maintenance schedule. This sudden interruption can be costly and therefore the development of fault detection system is a must for improving reliability and lowering the maintenance costs.A number of techniques for detection and identification for the switches faults have been proposed by various researcher (Yong *et al*., 2014). For example, Park's Vector used neural network for diagnosis (Mendes *et al*., 2014). But this technique requires a very complex pattern recognition algorithm fault detection by using voltage sensors has also been presented. This method fast but it requires additional sensors to operate (Ghorpade and Jagtap, 2014).

Besides, many techniques have been presented by various researchers for identifying switches faults using signal processing(Yong *et al*., 2014). One of the widely used tools is fast Fourier transform (FFT) analysis for detecting an open transistor. However, the technique only presents spectral of the signal and does not provide temporal information(Smirnov and Tushev, 2014). To solve the problem, short-time Fourier transform (STFT) was proposed that it can

Corresponding Author: N. Bahari, Department of Power Electronics and Drives, Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, 76100, Durian Tunggal, Melaka, Malaysia.
E-mail: hazilina@utem.edu.my

Australian Journal of Basic and Applied Sciences, 9(12) Special 2015, Pages: 144-151

provide temporal and spectral information of the signal by representing it jointly in time-frequency representation (TFR) which are very appropriate to analyze non-stationary signal. However, this technique cannot track the non-stationary signal dynamics properly because of the limitation of fixed window width (Alavi *et al.*, 2014).Wavelet transform (WT) provides the time-scale analysis of the non-stationary signal. It decomposes the signal to time scale representation rather than time frequency representation, but it produces time-scale plots that are unsuitable for intuitive visual analysis. Also the absolute referenced phase information cannot be deduced from the wavelet transform(Bandyopadhyay *et al*., 2014). A superior method for time-frequency analysis known as S-transform has been explored, extensively, in various researches as an alternative to the STFT. These techniques allow high time resolution for high frequency component and high frequency resolution for low frequency component(Huda *et al*., 2013).

Several topology of fault tolerant strategy has been introduced as a remedial action to assure a continuous and safety operation of power converter such as switch-redundant, neutral leg, additional phase leg and cascaded inverter. But the technique required major modification of the three-phase VSI (Nguyen *et al.*, 2015). On the other hand, switches faults classification and identification system for open and short circuit has not yet realized until now(Mirafzal, 2014). Therefore, it is important to develop a comprehensive system which offer detection, classifying type of fault and identifying the location of switches fault.

Time Frequency Analysis:

Time-frequency distributions are powerful techniques that represent a signal in, jointly , time and frequency representation (TFR)(Franz and Francois, 2008). From the (TFR), spectral information of a signal can be observed in time domain. For that reason, the TFDs are appropriate method for analyze switches faults signals that consist of non-stationary and multi-frequency components signal. S-transform technique which developed by (Stockwell *et al*., 1996), combines the good features of STFT and wavelet transform (WT). It produces a time-frequency representation of a time series signal by uniquely combining a frequency-dependent resolution that simultaneously localizes the real and imaginary spectra. It can be viewed as a frequency dependent STFT or a phase corrected Wavelet transform. The advantage of S-transform is that it offers multi-resolution analysis while maintaining the absolute phase of each frequency. The general S-transform is defined by the equation(Bollen and Gu, 2006) as

$$S_x(t,f)=\int_{-\infty}^{\infty} x(t)g(\tau-t)e^{-j2\pi f\tau} \quad (1.0)$$

where*x(t)* is the signal and *g(t)* is a window function. Windows function is a modulated Gaussian function expressed by

$$g(\tau)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\left(t^2/2\sigma^2\right)} \quad (2.0)$$

whereσ is function of time and frequency, f defined as:

$$\sigma(f)=\frac{1}{|f|} \quad (3.0)$$

Gaussian window and (g) is a parameter which control the position of the Gaussian window on the x-axis. When the window is wider in time domain, S-transform provides better frequency resolution for lower frequency. While the window in narrower, it provide better time resolution for higher frequency(Bhende *et al*., 2008).

System Development:

The switches fault classification and identification system consists of three major parts which are input, interfacing and computer as shown in Figure 1.1. In this system, current transducers is used as input with measurement capability up to 100 A. The transducers are the connected to NI USB 6009 data acquisition card (DAQ)for interfacing with computer. A user-friendly graphical user interface (GUI) is developed using Visual Basic 2010 to analyze the captured signals from DAQ and then displays and record the signal parameters.

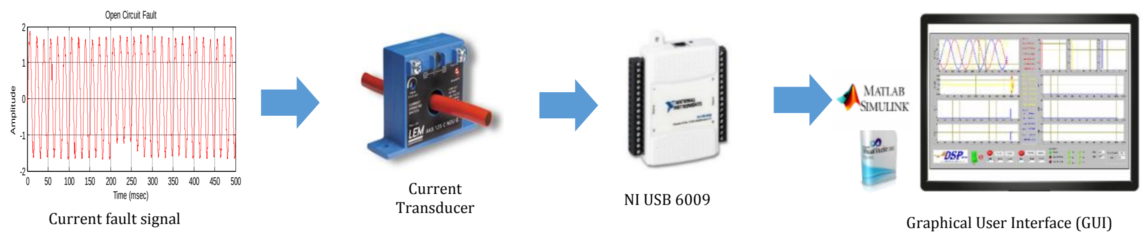


Fig. 1.1: Overall System Development

Australian Journal of Basic and Applied Sciences, 9(12) Special 2015, Pages: 144-151

Results:

Graphical User Interface (GUI) is build using Visual Basic 2010 to displays current input waveform, its power spectrum as well as signal parameters of the switches faults. The signal parameters includes instantaneous of RMS current, average current, fundamental current, total waveform distortion, total harmonic distortion and total nonharmonic distortion. The system is aid with waveform which is represented in color where red color for phase a, yellow color for phase b and blue color for phase c. In addition, other features is "Switches Fault Box" describes the status of the system. Other than that, the system is designed for recording the signal data and when fault occurred. Real input signal are fed through DAQ card into a VB programming environment. DAQ card acts as interface between real input and system. All the analyzed data are then plotted and displayed as shown in Figure 1.2. Finally, a user-friendly classification and identification process of switches faults system is design in this system.

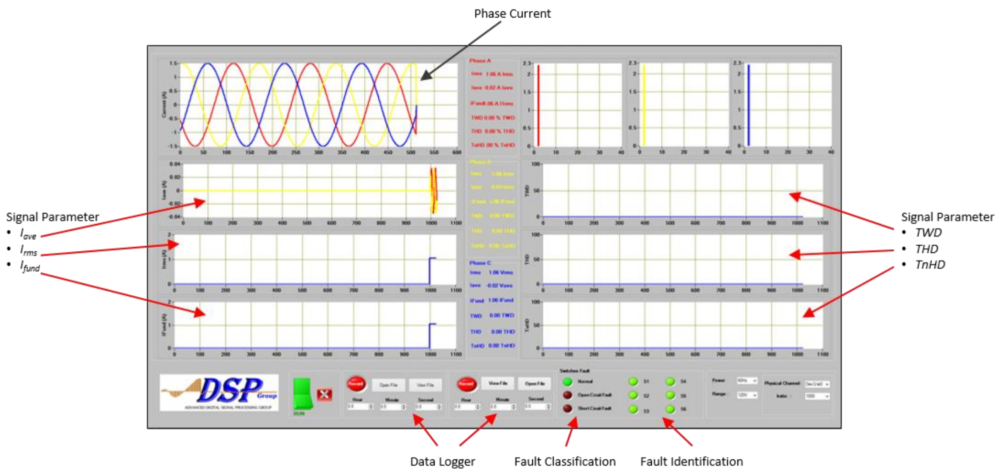
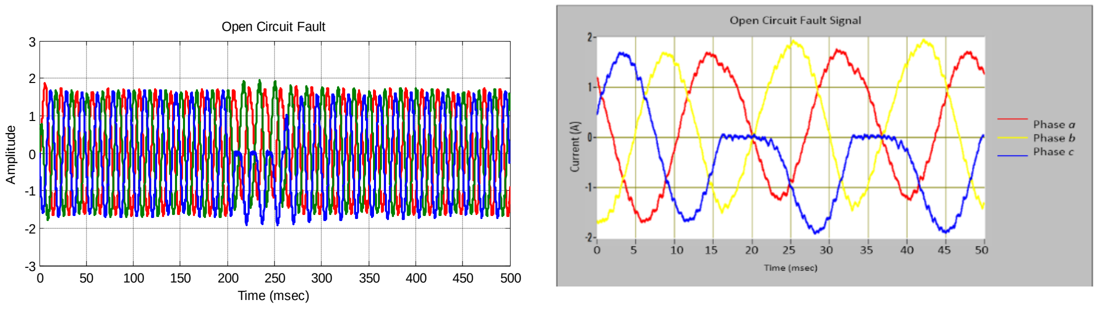


Fig. 1.2: GUI for Switches Faults Identification and Classification System

In order to ensure reliability of the system, the result of the system are verified by comparing between simulation, system and actual result for signal parameters.The three-phase switches faults signals are compared and analyzed between simulation and real system as shown in Figure 1.3 to Figure 1.5. Fault current for both simulation and system exhibit similar results where the current signal are reduced to 0 A when open circuit fault occurred at phase *c*. For phase a and b for both shows similar result indicated in red and green color for simulation while phase a (red color) and phase *b* (yellow color) for system. The three-phase open circuit switches faults signal are shows in Figure 1.3 (a) and (b).

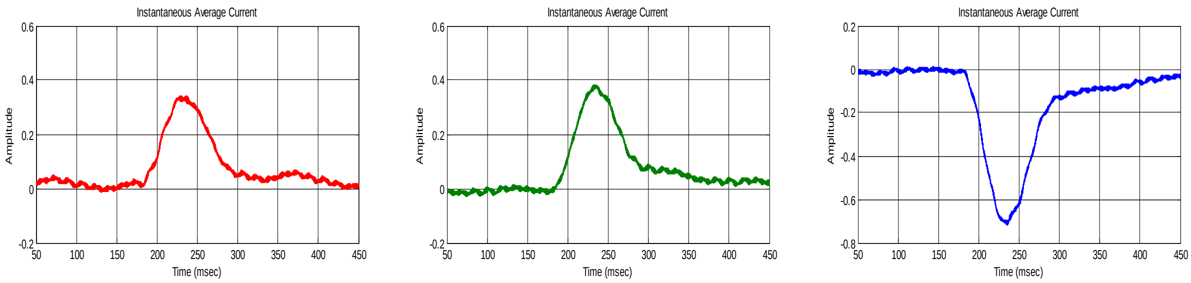


(a) (b)

Fig. 1.3: Three-phase Switches Faults Signal. (a) Simulation and (b) System

The signal parameters extracted from TFRs are shown in Figure 1.4 to Figure 1.9. Both simulation and system experience the same result for average, RMS and fundamental RMS current. The average current for phase *a* and*b* are increasing to 0.35 A from its nominal value, 0 A, while phase *c* is drop to -0.7 A, respectively. In addition, the average current for phase b is suddenly increased to 0.39A for simulation and system. Furthermore, from analysis shows that the result for both simulation and system are comparable.

Australian Journal of Basic and Applied Sciences, 9(12) Special 2015, Pages: 144-151



(a) (b) (c)

Fig. 1.4: Instantaneous Average Current by Simulation. (a) Phase *a*, (b) Phase *b* and (c) Phase *c*

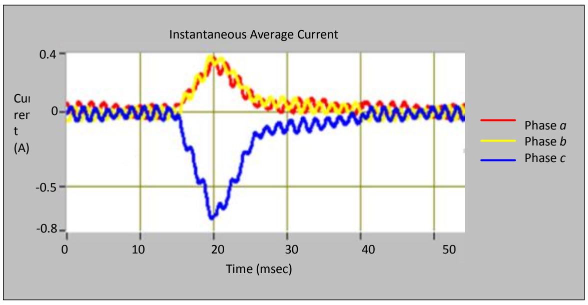
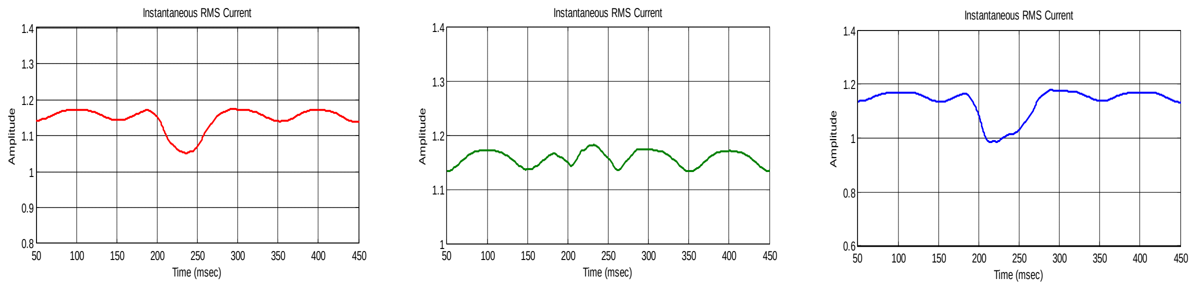


Fig. 1.5: Instantaneous Average Current Displayed on System

The RMS current for phase *a*, *b* and *c* for both simulation and system are slightly similar for open circuit switches faults. The current is reduced from 1.18 to 1.04 A for phase *a*, while phase *b* is drop to 1.13A. The RMS current for phase *c*, is suddenly, drop to 0.96A from 200 to 260 ms for duration 60ms. The result for simulation (Figure 1.6) is similar with the system (Figure 1.7).



(a) (b) (c)

Fig. 1.6: Instantaneous RMS Current by Simulation for (a) Phase a, (b) Phase b and (c) Phase c

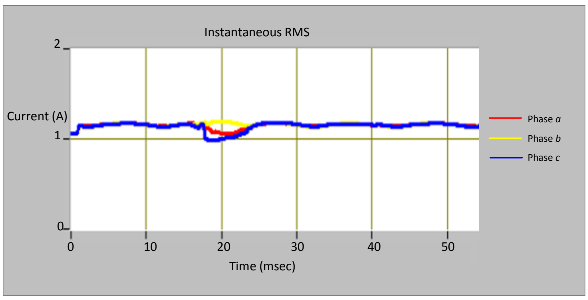
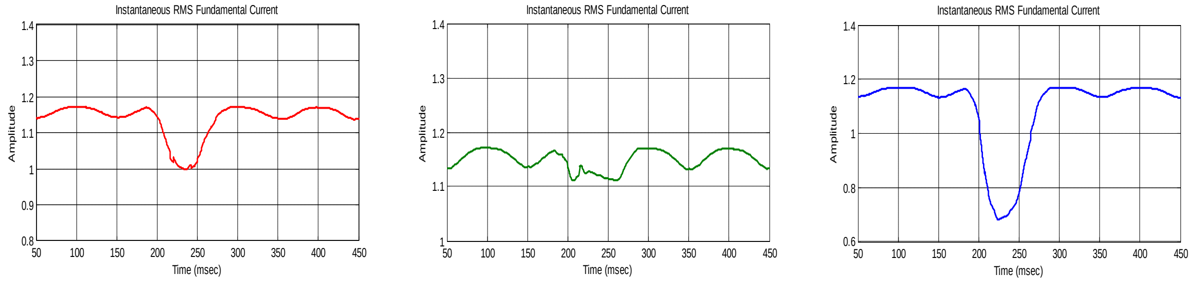


Fig. 1.7: Instantaneous RMS Current Displayed on System

For fundamental RMS current, both phase *a* and phase *c* current are decrease to 1.0 and 0.7 A, considerably, which is similar for both simulation and system as shown in Figure 1.8 and Figure 1.9. Therefore, for phase *b* the current drop to 1.1A. Similar result obtained for system, phase c drop lower compared to other phases.

Australian Journal of Basic and Applied Sciences, 9(12) Special 2015, Pages: 144-151



(a) (b) (c)

Fig. 1.8: Instantaneous RMS Fundamental Current by Simulation. (a) Phase *a*, (b) Phase *b* and (c) Phase *c*

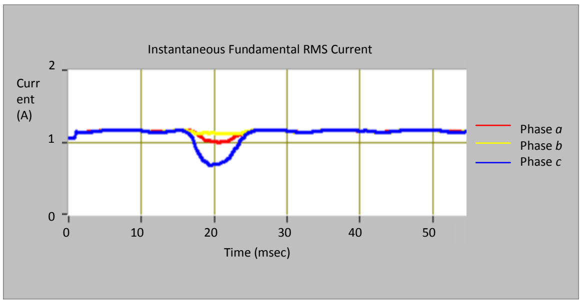
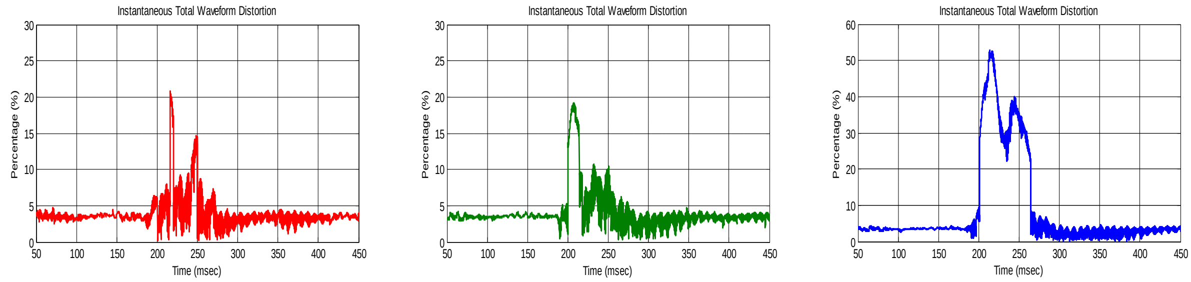


Fig. 1.9: Instantaneous Fundamental RMS Current Displayed on System

Figure 1.10 to 1.15 shows the comparison of total waveform distortion, total harmonic distortion and total nonharmonic distortion between simulation and system. From the simulation of TWD, it shows that the magnitude of phase c highlighted in blue color is increased by 55% while the system shows the percentage of TWD is, approximately, at 50%. For THD, the simulation and system record an increasing magnitude of phase *c* from 2% to 29% and 28% respectively. Similarly, the simulation and system present an increasing of magnitude of phase *c* from 2% to 45% and 43% respectively for TnHD.



(a) (b) (c)

Fig. 1.10: Instantaneous TWD Current by Simulation. (a) Phase *a*, (b) Phase *b* and (c) Phase *c*

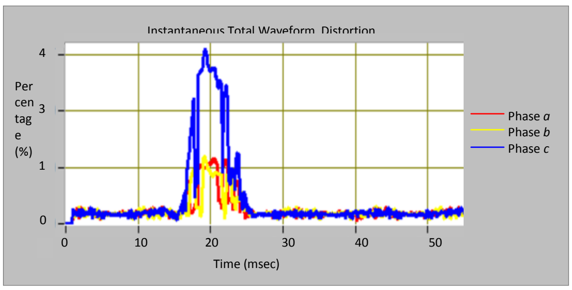
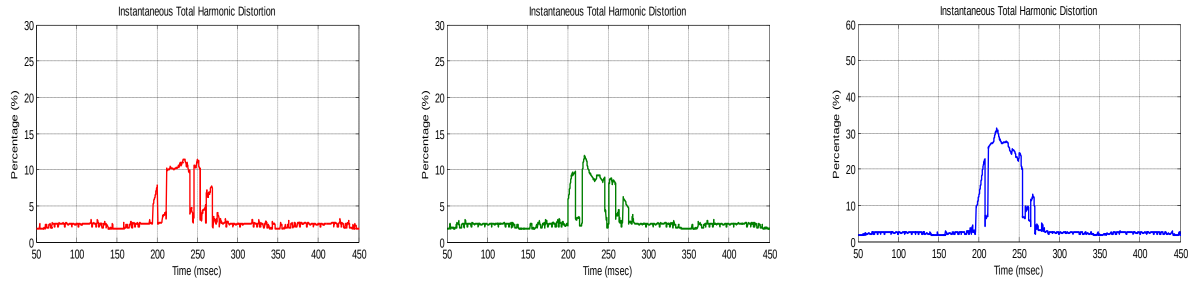


Fig. 1.11: Instantaneous TWD Displayed on System

Australian Journal of Basic and Applied Sciences, 9(12) Special 2015, Pages: 144-151



(a) (b) (c)

Fig. 1.12: Instantaneous THD Current by Simulation. (a) Phase *a*, (b) Phase *b* and (c) Phase *c*

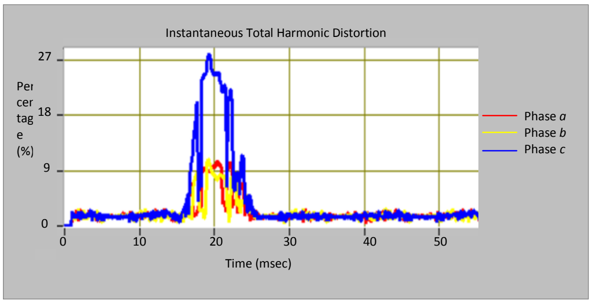
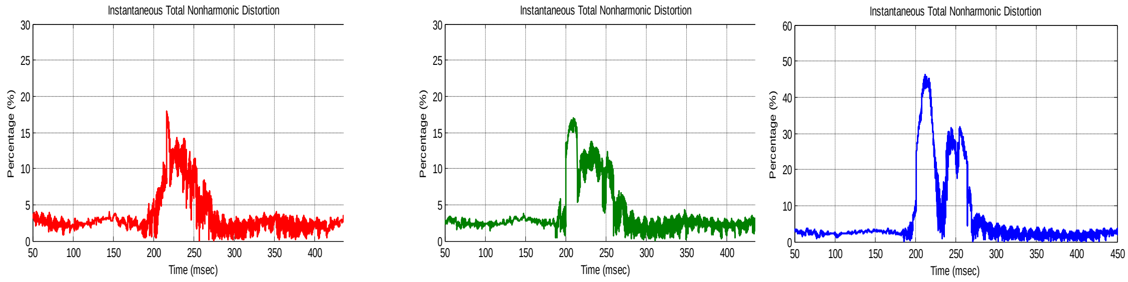


Fig. 1.13: Instantaneous THD Displayed on System



(a) (b) (c)

Fig. 1.14: Instantaneous TnHD Current by Simulation. (a) Phase *a*, (b) Phase *b* and (c) Phase *c*

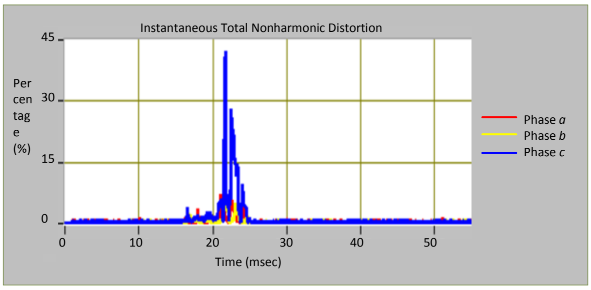
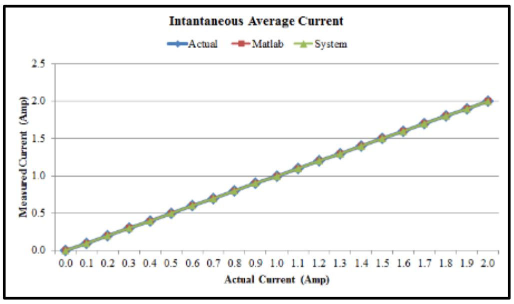


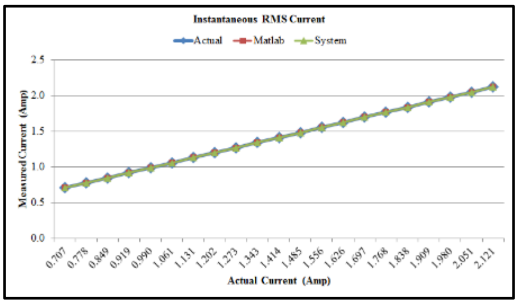
Fig. 1.15: Instantaneous TnHD Displayed on System

Figure 1.16 (a) and (b) present the average current and the RMS current comparison between actual, simulation and the proposed system. From the graph, it clearly, shows that there are very small that errors which is (0.01%) for actual, simulation and the proposed system. Figure 1.17 shows the fault duration for open and short circuit switches faults. The fault duration are tested with actual simulation and the proposed system. From the observation, there are minor error between actual, simulation and the proposed system. However, the actual, simulation and the proposed system in TWD, THD and TnHD give 100% accuracy between actual and measured values as shown in Figure 1.18.

Australian Journal of Basic and Applied Sciences, 9(12) Special 2015, Pages: 144-151

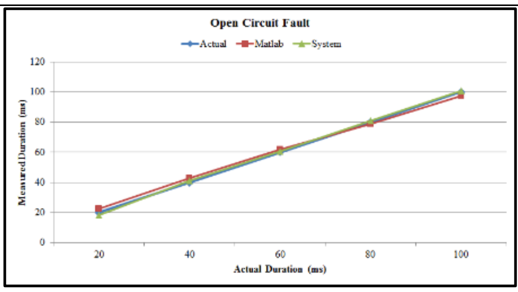


(a)

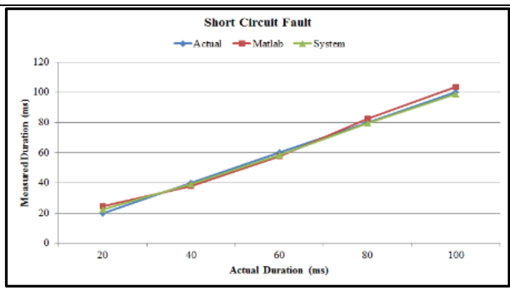


(b)

Fig. 1.16: Comparison between Actual, Simulation and System. (a) Instantaneous AverageCurrent and (b) Instantaneous of RMS Current

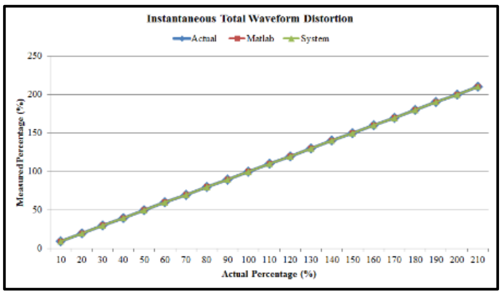


(a)

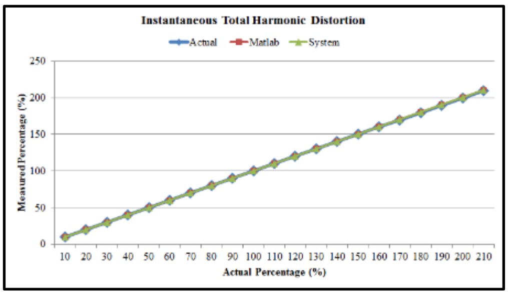


(b)

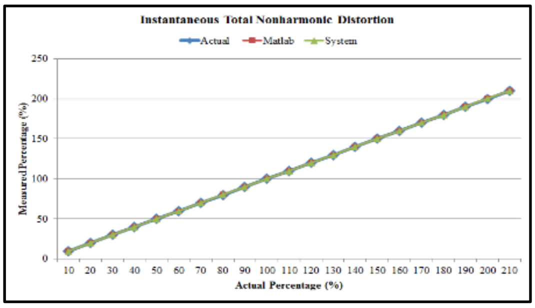
Fig. 1.17: Comparison between Actual, Simulation and System of Fault Duration. (a) Open Circuit Fault and (b) Short Circuit Fault



(a)



(b)



(c)

Fig. 1.18: Comparison between Actual, Simulation and System. (a) Instantaneous Total Waveform Distortion, (b) Instantaneous of Total Harmonic Distortion and (c) Instantaneous of Total Nonharmonic Distortion between Actual, Simulation and System

Conclusion:

This paper has presented the performance verification of VSI switches faults classification and identification system. The results, clearly, shows that the characteristic of the switches fault signals can be determined by the signal parameters estimated from the TFR. The comparison between actual, simulation and system shows that the S-transform technique provide 99.99% of accuracy which is important for high performance of VSI switches fault classification and identification system.

AKNOWLEDGEMENT

The authors would like to thank the Ministry of Education Malaysia (High Education Department) and UniversitiTeknikal Malaysia Melaka (UTeM) for providing the resources for this research. (ERGS/2013/FKE/TK02/UTEM/03/02/E00025).

REFERENCES

ALAVI, M., W. DANWEI and L. MING, 2014. Short-Circuit Fault Diagnosis for Three-Phase Inverters Based on Voltage-Space Patterns. Industrial Electronics, IEEE Transactions on, 61: 5558-5569.

BANDYOPADHYAY, I., S. DAS, P. PURKAIT, P.P. DAS and C. KOLEY, 2014. Application of wavelet transform to identify faulty IGBTs in 3-phase induction motor drives. Control, Instrumentation, Energy and Communication (CIEC), 2014 International Conference on., pp: 296-300.

BHENDE, C., S. MISHRA and B. PANIGRAHI, 2008. Detection and classification of power quality disturbances using S-transform and modular neural network. Electric Power Systems Research, 78: 122-128.

BOLLEN, M.H. and I. GU, 2006. Signal Processing of Switches faults Disturbances. *Wiley*.

FRANZ, H. and A. FRANCOIS, 2008. Time-Frequency Analysis: concepts and Methods. *Wiley*.

GAETA, A., G. SCARCELLA, G. SCELBA, S. DE CARO and A. TESTA, 2011. Inverter fault-identification for VSI motor drives. Diagnostics for Electric Machines, Power Electronics & Drives (SDEMPED), 2011 IEEE International Symposium on, pp: 413-419.

GHORPADE, S.S. and S.R. JAGTAP, 2014. Detection and identification of open circuit faults in VSI-fed induction motor drive. Advanced Communication Control and Computing Technologies (ICACCCT), 2014 International Conference on., pp: 306-308.

HUDA, N.H.T., A.R. ABDULLAH and M.H. JOPRI, 2013. Power quality signals detection using S-transform. Power Engineering and Optimization Conference (PEOCO), 2013 IEEE 7th International on., 552-557.

MENDES, A.M.S., M.B. ABADI and S.M.A. CRUZ, 2014. Fault diagnostic algorithm for three-level neutral point clamped AC motor drives, based on the average current Park's vector. Power Electronics, IET, 7: 1127-1137.

MIRAFZAL, B., 2014. Survey of Fault-Tolerance Techniques for Three-Phase Voltage Source Inverters. *Industrial Electronics,* IEEE Transactions on, 61: 5192-5202.

NGUYEN, N., F. MEINGUET, E. SEMAIL and X. KESTELYNKESTELYN, 2015. Fault-Tolerant Operation of an Open-End Winding Five-Phase PMSM Drive with Short-Circuit Inverter Fault. Industrial Electronics, IEEE Transactions on, pp: 1-1.

SMIRNOV, N. and S. TUSHEV, 2014. Two Methods of Fault Detection in the PMSM Electric Drive IGBT-Based Inverter. Manufacturing Engineering, Automatic Control and Robotics: Proceedings of the 14th International Conference on Robotics, Control and Manufacturing Technology (ROCOM'14), 1.

STOCKWELL, R.G., L. MANSINHA and R.P. LOWE, 1996. Localization of the complex spectrum: the S transform. Signal Processing, IEEE Transactions on, 44: 998-1001.

UBALE, M.R., R. DHUMALE and S. LOKHANDE, 2013. Open Switch Fault Diagnosis in Three Phase Inverter using Diagnostic Variable Method.

UI-MIN, C., F. BLAABJERG and L. KYO-BEUM, 2015. Study and Handling Methods of Power IGBT Module Failures in Power Electronic Converter Systems. Power Electronics, IEEE Transactions on, 30: 2517-2533.

YONG, Y., H. JINYANG, W. ZIYUAN and X. DIANGUO, 2014. IGBT open circuit fault diagnosis in VSI fed induction motor drives based on modified average current method. Industrial Electronics and Applications (ICIEA), 2014 IEEE 9th Conference on., pp: 1334-1338.