International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 06 | June-2017 www.irjet.net p-ISSN: 2395-0072

MRA ANALYSIS FOR FAULTS INDENTIFICATION IN MULTILEVEL INVERTER

Dr. R.A.Keswani[1], Prof. U.E.Hiwase [2]

[1] *Associate Professor, Department of Electrical Engineering, Priyadarshini College of Engineering, Nagpur, Maharashtra, India*
[2] *Assistant Professor, Department of Electrical Engineering, Priyadarshini College of Engineering, Nagpur, Maharashtra, India*

---***---

Abstract - *Multilevel Inverters (MLI) are widely used in various fields and industrial applications. This paper proposes a wavelet analysis for detection and identification of switch* fault *in diode clamped multilevel inverter feeding an induction motor drive. A fast and novel fault identifier is designed to identify various abnormal conditions (faults) by analyzing the performance of the system using wavelet based multi-resolution analysis (MRA). The switch* fault in inverter, *resulting in variation* in *the details of level of wavelet transform of various signals. The voltage and current signals were used as input for wavelet analysis to develop suitable feature vector containing signatures to discriminate faulty system from healthy one.*

Key Words: *Multilevel inverter, faults, wavelet analysis, multi-resolution analysis, feature vector, switch fault identification.*

1. INTRODUCTION:

The requirement of industrial applications is higher power apparatus. Some motor drives and utility applications require medium voltage and megawatt power level. Use of one power semiconductor switch directly for a medium and high voltage grid is troublesome. So, a multilevel power converter is used as an alternative in high power and medium voltage situations. In multilevel converters, higher power is achieved with the use of series of power semiconductor switches with several lower voltage dc sources to perform the power conversion by synthesizing a staircase voltage waveform. Capacitors, batteries, and renewable energy voltage sources can be used as the multiple dc voltage source [1]. A multilevel converter has several advantages over a conventional two-level converter that uses high switching frequency pulse width modulation (PWM). With the increase in levels, the synthesized output waveform approaches the sinusoidal wave with minimum harmonic distortion. But, the numbers of achievable voltage level are limited due to voltage unbalance problems. Also, number of power semiconductor switches are required. Although lower voltage rated switches can be utilized in a multilevel converter, each switch requires a related gate drive circuit. This may cause the overall system to be more expensive and complex. The topologies of multilevel inverters are i) Diode Clamped, ii) Flying Capacitor, iii) Cascade inverters [3]. The diode clamped MLI are mostly used. The switch arrangement for one phase of 5-Level Diode Clamped inverter is as shown in Fig. 1

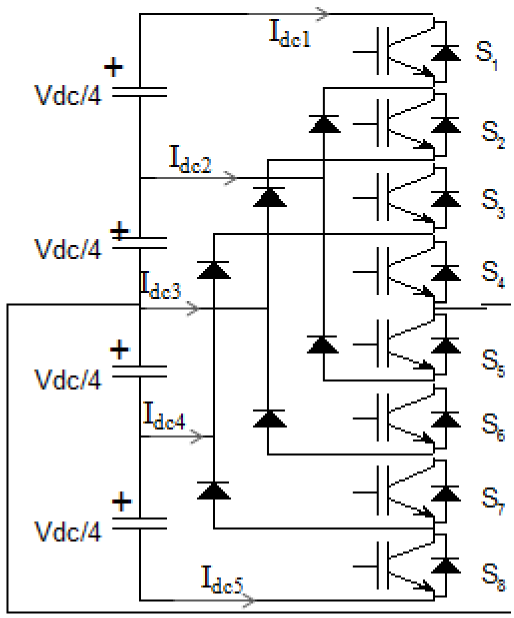

Fig 1 MLI Switch arrangement for one phase

2. FAULTS IN THE CONVERTER SYSTEM:

Multilevel converters are becoming increasingly popular for medium- and large-capacity power application areas [2]. Industrial application uses induction motors and their inverter systems for process control. As multilevel inverter systems are utilized in high power applications, the reliability of the power electronics equipment is very important. In order to maintain continuous operation for a multilevel inverter system, knowledge of fault behavior, fault prediction, and fault diagnosis are necessary. Faults need to be detected as soon as possible after they occur, because if a motor drive runs continuously under abnormal conditions, the drive or motor may quickly fail. As the Multilevel inverters have a high number of power semiconductors, and consequently, the possibility of a failure is much higher. Hence, the identification of possible faults and the operation under faulty conditions are of importance. Due to the high number of components, the detection of a fault can be complicated. Switching device failure [5,6] is often a cause of circuit dysfunction. Many factors can lead to power switch failure, and the disabled device can be either short circuit or open circuit depending on different causes and device types.

3. FAULT DIAGNOSIS:

Earlier the conventional fault protection systems used are passive devices such as fuses, overload relays, and circuit breakers [7].These protection devices will disconnect the power sources from the multilevel inverter system whenever a fault occurs, stopping the operated process. Several mathematical techniques such as small signal state space averaging, Fourier technique, Time domain methods, Short-Time Fourier Transform (STFT), wavelet analysis can be used to analyze the performance of switched power converter. But the most powerful tool is wavelet as it gives time-frequency behavior of finite energy signal. Wavelet analysis [8,9]finds application in various disciplines as data compression; signal processing, image analysis, statistics and modeling of non-linear dynamic processes. It also have wide range of applications in electrical engineering fields such as measurement of harmonics in power lines under non-steady state conditions, disturbance evaluation, de-noising in signal processing, fast transient analysis like lightening induced disturbances, fault identification & diagnostics in electrical machine, power electronic problems as harmonic analysis, or noise in switched mode power supply. The valuable information in the voltage and current signals are used to diagnose faults and their locations. The diagnosis solutions found in the literature has been divided into two main groups: i) Switch measurement, ii) output waveform analysis. MLID systems consist of many switching devices and their system complexity has a nonlinear factor. Therefore, neural network (NN), Genetic Algorithm or Fuzzy Logic based classification system can be applied for the fault diagnosis of a MLID system.

4. WAVELET ANALYSIS

Wavelet analysis is a mathematical tool that enables estimation of a signal in time(space) and scale (frequency). Analysis of the signal at various resolutions is accomplished by decomposition into elementary functions that are well localized both in time and frequency domains. This enabling the extraction of features that varies with time. Thus, Wavelet analysis [7,8]consists of decomposing a signal or an image into a hierarchical set of approximations and details. The levels in the hierarchy often correspond to those in a dyadic scale.

In Multi-resolution analysis (MRA) [10], wavelet functions and scaling functions are used as building blocks to decompose and reconstruct the signal at different resolution levels. The wavelet functions will generate the detail version of the decomposed signal and the scaling function will generate the approximated version of the decomposed signal. MRA refers to the procedures to obtain low-pass approximations and high-pass details from the original signal. An approximation contains the general trend of the original signal while a detail embodies the high-frequency contents of the original signal. Approximations and details are obtained through a succession of convolution processes. The maximum number of wavelet decomposition level is determined by the length of the original signal and the level of detail required. A low pass filter removes the high frequency components, while the high pass filter picks out the high-frequency contents in the signal being analysed.

5. RESULTS:

The complete scheme of 3-phase 5 level DCMLI model using PWM technique feeding a 3HP induction motor is simulated in MATLAB Simulink. The various conditions under which the signatures obtained were: switch shorted, switch opened, sudden increase in load (torque increased), line-line fault. The signals used for analysis were phase voltage, line current, DC bus current and switch voltages. The signatures obtained using Multi-resolution analysis (MRA) from norm plot at 7th and 8th resolution levels and Wavelet Modulus Maxima (WMM) are studied and the fault identifier was developed.

The MRA analysis for 2 cycles of the phase voltage at a sampling frequency of 1000 KHz has been done and the results obtained are as shown in Fig.2

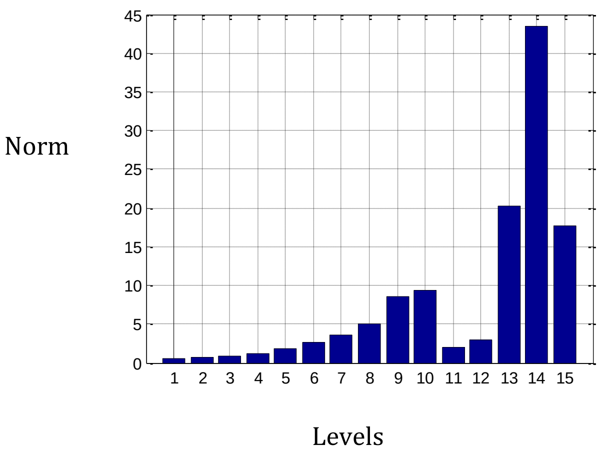

Fig.2 MRA analysis (Norm Plot) of phase voltage under normal condition

The signals used for analysis were phase voltage, line current, DC bus current and switch voltages. The signatures are obtained using Multi-resolution analysis from norm plot at 7th and 8th resolution levels is studied and the conclusions drawn are tabulated in table 1.

The faulty phase is analysed from the norm plot of phase voltage. The norm plot of line current indicates the switch failure type i.e either shorted or opened. The norm plot of DC bus current shows increase at 7th & 8th resolution levels for any type of fault. Hence, DC bus currents indicate the existence of fault but could not classify the fault. Similarly, the faulty switch can be identified by observing the norm plot of switch voltage. In case of Line to Line (A-B) fault, the norm values of the phase voltages of A and B shows variations. Thus an attempt was made to diagnose the fault in a MLID from MRA analysis of output voltage and currents waveform.

Table 1: Signatures from norm plot of various signals

Type	levels	$V_{ph}A$	$V_{ph}B$	$V_{ph}C$	I_{LA}	I_{LB}	I_{LC}	I_{dc}
S1 Short	7th level	$\|d_7\|_f > \|d_7\|_{nf}$	$\|d_7\|_f \approx \|d_7\|_{nf}$	$\|d_7\|_f \approx \|d_7\|_{nf}$	$\|d_7\|_f > \|d_7\|_{nf}$	$\|d_7\|_f > \|d_7\|_{nf}$	$\|d_7\|_f \approx \|d_7\|_{nf}$	$\|d_7\|_f > \|d_7\|_{nf}$
	8th level	$\|d_8\|_f > \|d_8\|_{nf}$	$\|d_8\|_f \approx \|d_8\|_{nf}$	$\|d_8\|_f \approx \|d_8\|_{nf}$	$\|d_8\|_f > \|d_8\|_{nf}$	$\|d_8\|_f > \|d_8\|_{nf}$	$\|d_8\|_f < \|d_8\|_{nf}$	$\|d_8\|_f > \|d_8\|_{nf}$
S1 open	7th level	$\|d_7\|_f < \|d_7\|_{nf}$	$\|d_7\|_f \approx \|d_7\|_{nf}$	$\|d_7\|_f \approx \|d_7\|_{nf}$	$\|d_7\|_f > \|d_7\|_{nf}$	$\|d_7\|_f > \|d_7\|_{nf}$	$\|d_7\|_f \approx \|d_7\|_{nf}$	$\|d_7\|_f > \|d_7\|_{nf}$
	8th level	$\|d_8\|_f < \|d_8\|_{nf}$	$\|d_8\|_f \approx \|d_8\|_{nf}$	$\|d_8\|_f \approx \|d_8\|_{nf}$	$\|d_8\|_f < \|d_8\|_{nf}$	$\|d_8\|_f < \|d_8\|_{nf}$	$\|d_8\|_f < \|d_8\|_{nf}$	$\|d_8\|_f > \|d_8\|_{nf}$
T increase	7th level	$\|d_7\|_f \approx \|d_7\|_{nf}$	$\|d_7\|_f \approx \|d_7\|_{nf}$	$\|d_7\|_f \approx \|d_7\|_{nf}$	$\|d_7\|_f \approx \|d_7\|_{nf}$	$\|d_7\|_f \approx \|d_7\|_{nf}$	$\|d_7\|_f \approx \|d_7\|_{nf}$	$\|d_7\|_f \approx \|d_7\|_{nf}$
	8th level	$\|d_8\|_f \approx \|d_8\|_{nf}$	$\|d_8\|_f \approx \|d_8\|_{nf}$	$\|d_8\|_f \approx \|d_8\|_{nf}$	$\|d_8\|_f \approx \|d_8\|_{nf}$	$\|d_8\|_f \approx \|d_8\|_{nf}$	$\|d_8\|_f \approx \|d_8\|_{nf}$	$\|d_8\|_f \approx \|d_8\|_{nf}$
L-L(A-B) fault	7th level	$\|d_7\|_f < \|d_7\|_{nf}$	$\|d_7\|_f < \|d_7\|_{nf}$	$\|d_7\|_f \approx \|d_7\|_{nf}$	$\|d_7\|_f < \|d_7\|_{nf}$	$\|d_7\|_f < \|d_7\|_{nf}$	$\|d_7\|_f \approx \|d_7\|_{nf}$	$\|d_7\|_f > \|d_7\|_{nf}$
	8th level	$\|d_8\|_f > \|d_8\|_{nf}$	$\|d_8\|_f < \|d_8\|_{nf}$	$\|d_8\|_f \approx \|d_8\|_{nf}$	$\|d_8\|_f > \|d_8\|_{nf}$	$\|d_8\|_f < \|d_8\|_{nf}$	$\|d_8\|_f \approx \|d_8\|_{nf}$	$\|d_8\|_f > \|d_8\|_{nf}$

6. CONCLUSION

Wavelet analysis is used for short circuit fault, open circuit fault, increase in torque and line to line fault diagnosis in 5-level Diode Clamped multi-level inverter feeding the Induction motor. The signals from the GUI model were used as input for Wavelet analysis to develop suitable feature vector that will act as signature to detect fault in converter. The wavelet results by MRA analysis for various types of faults of multilevel converter are obtained by simulating the models in MATLAB Simulink. The faulty switch is identified by signatures obtained from phase voltage, line current and switch voltage.

REFERENCES

1. Jhi Sheng, “Multilevel Converters – A new Breed of Power Converters”, IEEE Transactions on Industry Applications, Vol. 32, No. 3, May/ June 1996.
2. Steffen Bernet, “Recent Developments of High Power Converters for Industry and Traction Applications” IEEE Transactions on Power Electronics, Vol. 15, No. 6, November 2000.
3. Takashi Ishida, Kouki Matsuse, Kiyoaki Sasagawa, and Lipei Huang, “Fundamental Characteristics of a Five-Level Double Converter for Induction Motor Drive”, IEEE transaction on Industry Applications, Vol 25, No. 7, Dec 2000.
4. Surin Khomfoi and Leon M. Tolbert, “Fault Diagnostic System for a Multilevel Inverter Using a Neural Network”, IEEE Transactions on Power Electronics, Vol. 22, No. 3, May 2007.
5. Surin Khomfoi, Leon M. Tolbert and Burak Ozpineci, “Cascaded H-bridge Multilevel Inverter Drives Operating under Faulty Condition with AI-Based Fault Diagnosis and Reconfiguration”, IEEE Transactions on Power Electronics, Vol. 22, No. 4, May 2007.
6. Debaprasad Kastha, Bimal K. Bose, “Investigation of Fault Modes of Voltage-Fed Inverter System for Induction Motor Drive”, IEEE Transactions on Industry Applications, Vol. 30, No. 4, July / August 1994.

7. Pablo Lezana, Josep Pou, Thierry A. Meynard, Jose Rodriguez, Salvador Ceballos, and Frédéric Richardeau, "Survey on Fault Operation on Multilevel Inverters", IEEE Transactions on Industrial Electronics, Vol. 57, No. 7, July 2010
8. A.P.Sakis Meliopoulos, Chien-Hsing Lee, "An Alternative Method for Transient Analysis Via Wavelets", IEEE Transactions on Power Delivery, Vol. 15, No.1, pp. 114 – 121, January 2000.
9. Andrew Bruce, David Donoho, Hong Yegao, "Wavelet Analysis", IEEE Spectrum, pp. 26 – 35, October 1996.
10. T.Lachman, A.P.Memon, T.R.Mohamad, Z.A.Memon, "Detection of Power Quality Disturbances Using Wavelet Transform Technique", International Journal for The Advancement of Science & Arts, Vol. 1, No. 1, 2010.
11. M. F. N. Tajuddin, N. H. Ghazali, M. F. Mohammed, B. Ismail, Z. M. Isa, T. C. Siong and N. Ghazali, "TMS320F2812 Digital Signal Processor (DSP) Implementation of DPWM", Student Conference on Research and Development (SCOReD 2009), UPM Serdang, Malaysia,18 Nov. 2009.
12. Abdelrahaman Yousif Eshag Lesan, Mamadou Lamine Doumbia, Pierre Sicard, "DSP-Based Sinusoidal PWM Signal Generation Algorithm for Three Phase Inverter", IEEE Electrical Power & Energy Conference, 2009.

BIOGRAPHIES

Rashmi A. Keswani received her B.E. in electrical engineering from Visvesvaraya Regional College of Engineering, Nagpur, India, in 2001 and her M. Tech. (by research) and Ph.D. in electrical engineering from Visvesvaraya National Institute of Technology, Nagpur, India, in 2008. She is working as an assosciate professor in the Department of Electrical Engineering, Priyadarshini College of Engineering, Nagpur (India). Her research interests include multi-level converters and electric drives.

Prof. Umesh E. Hiwase is a Assistant professor in Department of Electrical Engineering, Priyadarshini College of Engineering, Nagpur (MS) since last 11 years; 5 years of industrial experience and pursuing PhD in the field of Electrical Drive system. He is a stalwart of power electronics and drives. He has published more than 15 papers in various esteemed reputable International Journals. He is member of various Professional Bodies.