Diagnosis of Various Faults in MLI Fed Induction Drive Using Fuzzy Logic

Y. Krishna Priya, M. Vijaya Kumar

Abstract*−Multilevel inverters (MLI) are massively used in numerous fields. Among the various Multi level Inverters, the Three-Level Neutral Point-Clamped (NPC) inverter was widely used in medium and high voltage power conversions. Its use in low-voltage applications has increased. The three-level inverters have problems due to faulty switches. Failures of the components in static energy conversion systems results into severe and widespread damages in the converter. The system effects are more severe in switch short than in switch open, if no protective measures are taken in time. In order to provide protection from the faults there is a need to find which fault is occurring and respective mitigation techniques should be applied. In this paper, we are identifying the faults using a fuzzy approach. Here the type of the fault can be diagnosed based on the voltage and total harmonic distortion at the respective faults. This identification process was studied using MATLAB/SIMULINK software through simulations.

Index Terms: Fuzzy logic, induction motor drive, Neutral point clamped multilevel inverter, open and shortfaults.

I. INTRODUCTION

DC motors are retrieved by many cost-effective AC motors as a result of advances in electronic semiconductor technology,such as Asynchronous machines. Currently, Induction machines are among the most affordable and reliable electrical machines. Because of absence of wearing elements this motor is maintenance free machine. Induction motor characterizes high efficiency in wide operation just in case of rotor metal cage or higher for motors with rotor copper cage. The higher efficiency of copper cage motors is due to reduced rotor, mechanical and stray lossesIn addition the operation temperature for copper cage motor is lower as compared to motors with metal cage providing the reduction of the motors dimensions. In comparison to DC motor drives, Power converter and induction motor control method are substantially moretroublesome. This complexity is no longer a barrier to the development of AC drives, as power electronics technologies developing rapidly Some conventional 2- level high frequency pulse width modulation (PWM) inverter for drives will have problems with their high voltage varying rates (dv/dt) resulting in a common mode (CM) voltage across the motor windings[1]-[3]. There is a chance of fault in PWM controlled inverters,especially at diode,gate ,switch. All the key issues within the switch are open fault and short fault. [4]- [6]. This paper presents a fuzzy based approach to identify the type of fault based on the voltage and total harmonic distortion.

Revised Manuscript Received on June 05, 2019

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II. MULTI LEVEL INVERTER

Fig.1.shows a three-phase three-level inverter. It has three arms. There are four switches in each arm.Each switch is connected to a diode in anti parallel .This paragraph describes howFig.1opeartes one of the legs shown. The Vao voltage between phase "a" and the point O is completely defined by the position of switches (0 'open' or 1'closed'). The [Sa1, Sa3], and [Sa2, Sa4] switch sets have additional positions. When [Sa1, Sa3] are open [Sa2, Sa4] are closed. The three-levelNPC inverter is mainly used [10] inhigh-power applications of medium voltages. The number of switching sequences (seq) in this converter is equal to2^4= 16. Where 4 is the number of switches per arm and 2 is the state number per (0, 1). V_{dc} is the DC-bus voltage. Only three sequences of commutation are possible. Below displays the inverter arm configurations corresponding to the three possible switching sequences:

- Sequence 1: S_{a1}, S_{a2} conduct and S_{a3}, S_{a4}open, Va0=+Vdc/2.
- Sequence 2: S_{a2}, S_{a3}conduct and S_{a1}, S_{a4} open, Va0 = 0.
- Sequence 3: S_{a3}, S_{a4} conduct and S_{a1}, S_{a2} open, Va0 =-Vdc/2.

Sequences 1, 2 and 3 are applied periodically in this order. The switches are controlled by a pulse width modulation.

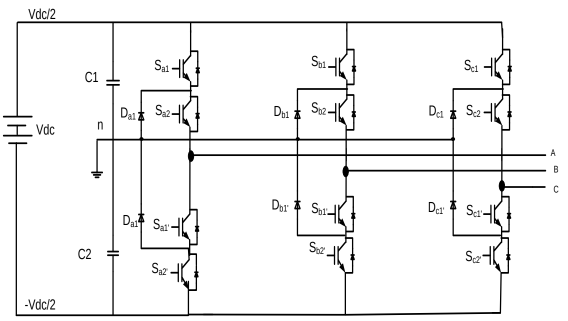

Fig.1. Neutral Point Clamped Multi level Inverter.

The system configuration of a motor drive with the clamped inverter Neutral point is shown in Fig.2. In the motor mode, power flows from the batteries via the inverter clamped Neutral point to the motor. The Neutral point clamped converters act as rectifiers in the charging mode, and power flows from the charger to the batteries. The Neutral point clamped converter can also act as rectifiers the kinetic energy of the vehicle when regenerative braking is used. In parallel HEV configurations, the neutral point clamped inverter can also be used.

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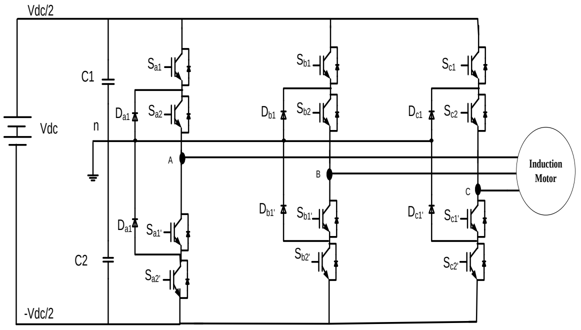

Fig .2. Neutral Point Clamped 3-level Inverter based Induction motor drive.

III. FUZZY LOGIC IMPLEMENTATION

Fuzzy logic is another form of artificial intelligence (AI), an engineering branch that deals with the development of computer programs based on human intelligence and human thinking [7]-[9]. It is argued that human thinking does not always follow crispy 'yes' or 'no' logic (or '1' or '0' in Boolean logic), but is often vague, uncertain indecisive, or fuzzy. Basedon this, Dr. LoftiA.Zadeh, a computer scientist at the University of California, Berkeley, originated in 1965 the 'Fuzzy logic' or fuzzy set theory that gradually emerged as AI discipline. Recently Fuzzy logic has been applied in process control, modeling, estimating, identification, diagnostics, stock market prediction, agriculture, military science etc. The fuzzy logic approach is based primarily on decisions that contain imprecise, vague, and inaccurate information.While fuzzy logic deals with imprecise information, it may be mentioned that it is based on sound quantitative mathematical theory that has been advanced in recent years. So we choose fuzzy logic to identify the type of faults mentioned above in the circuit using the voltage, total harmonic distortion and clock as input variables and open or short faults as output variables.

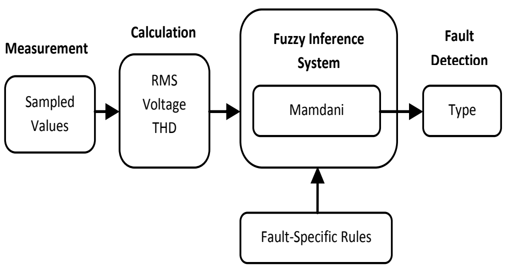

Fig.3: Schematic of fuzzy-based model for fault

The schematic diagram of fuzzy-based approach is shown in Fig.3. The sampled values of total harmonic distortion and RMS values of phase voltages in the faulted leg are considered. Thecorollary values can be used for the fuzzy inference system showing the fault type as the output as a function of time. The use of Fuzzy sets can provide better information than the fixed thresholds in case of high measuring inaccuracies.

Fig. 4 shows the membership function of input voltage variable. Here the membership function is divided based on the RMS values of voltage according to open and short faults.

Fig. 5 shows the total harmonic distortion and it includes three ranges like small positive (PS), moderate positive (PM) and large positive (PB).

Fig. 6 shows the input clock pulse representing the transient and steady state periods of the model.

Fig.7 shows the output variable representing the total faults whether it is open, short, as well as no fault conditions.

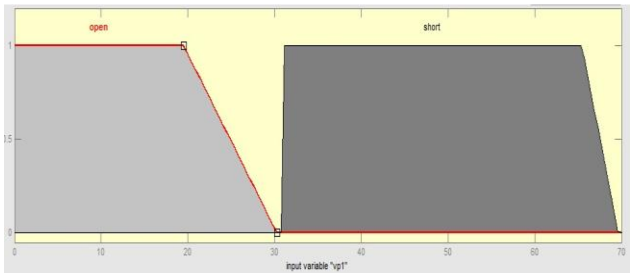

Fig. 4: Voltage Membership Feature

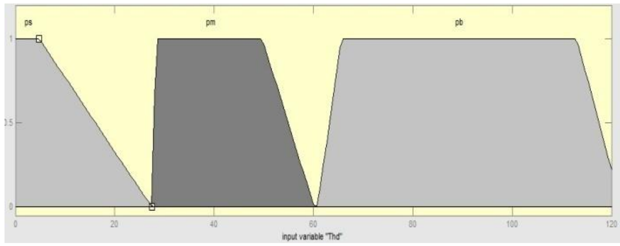

Fig. 5: THDMembership Feature

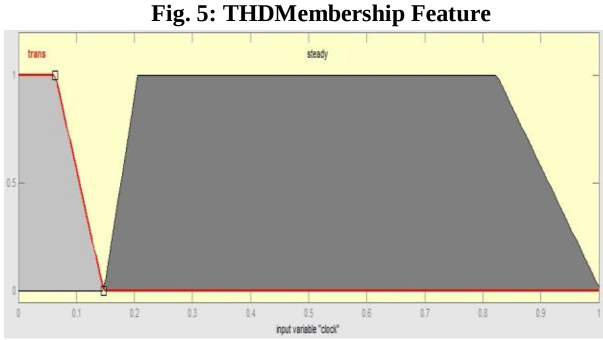

Fig. **6: ClockMembership Feature**

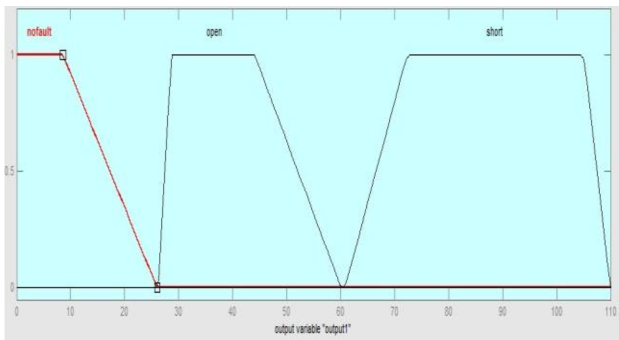

Fig. 7: OutputMembership Feature

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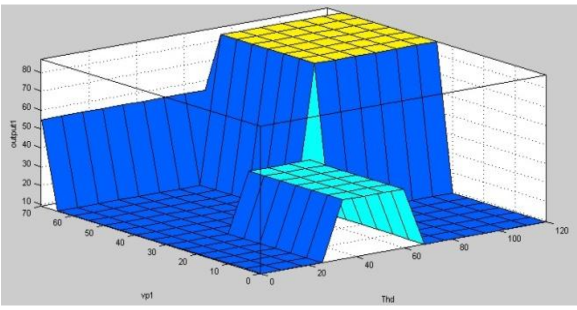

Fig.8: Three dimensional view of the fuzzy inference system

Fig. 8. Shows the output values of the fuzzy operations applied to system. It is a three dimensional structure where the lower surface represents the open type faults and top surface represents short type of faults.

IV. MATLAB/SIMULINK ANALYSIS

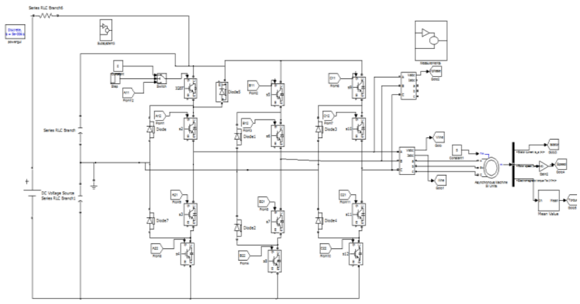

Fig.9:3-level NPC inverter Simulink model withswitch fault

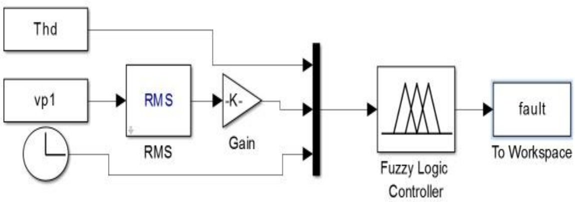

Fig.10: Simulink model for identifying the type of fault

The simulink model of three level NPC inverter with switch fault is shown in Fig.9. AndFig. 10 shows simulink model for identifying the type of fault. The input variables here considered are phase voltage RMS values and total harmonic distortion along with the clock pulse. Since voltage is independent of load is considered as one input and to distinguish the type of faults total harmonic distortion is considered. From the reference studies it is found that open type faults have the total harmonic distortion will be greater than 25% and for short type faults it is greater than 60%. Using the models shown in Fig.9and Fig. 10 one after the other we can easily identify the type of fault as mentioned above.

Case 1: Analysis of Three Level inverter performance with **"Switch Open"** fault.

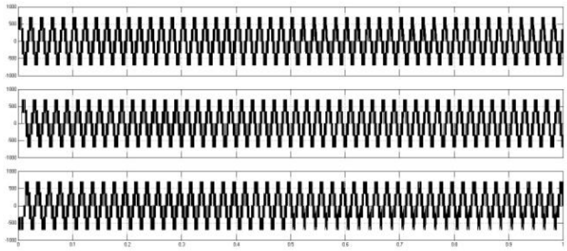

Fig.11: Simulated waveform of Line Voltage of the NPC Inverter

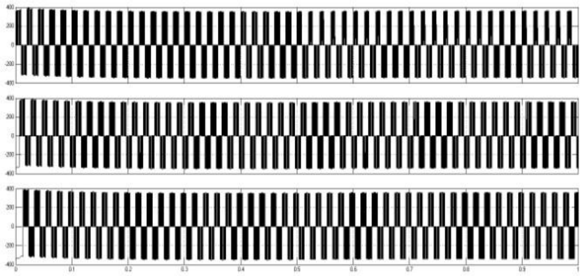

Fig.12: Simulated waveform of Phase voltage of the NPC Inverter

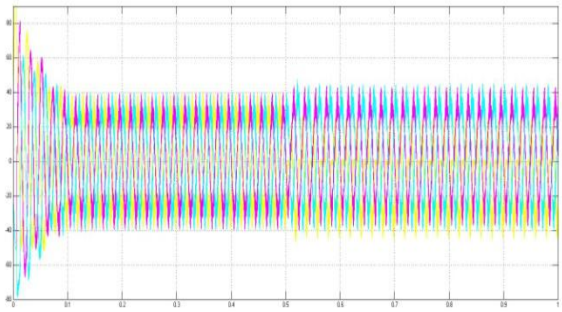

Fig.13: Simulated waveform of Line Current of the NPC Inverter

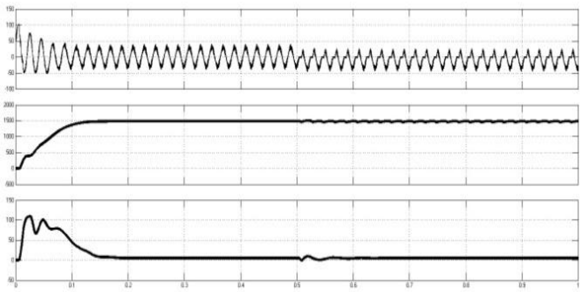

Fig.14: Performance characteristics of Current, Speed and Torque

From Fig.11, and Fig. 12 it is clear that at 0.5sec, distortion of the line voltage and phase voltage is observed due to occurrence of open fault. Fig. 13 shows the rise of line current which can damage the stator coils. Fig. 14 shows the reduction of stator current in the faulted phase and ripples in torque.

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Case 2: Analysis of Three Level inverter performance with **“Switch Short”** fault

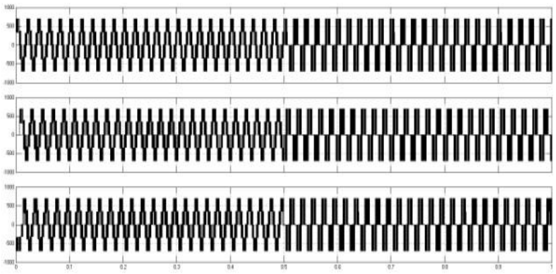

Fig.15: Simulated waveform of Line Voltage of the NPC Inverter

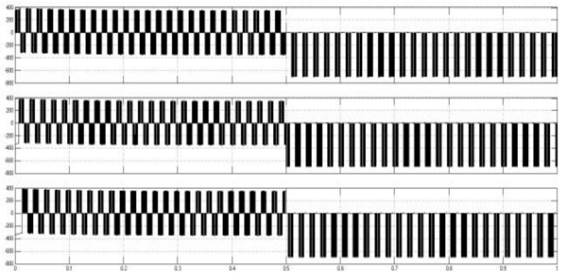

Fig.16: Simulated wave form of Phase voltage of the NPC Inverter

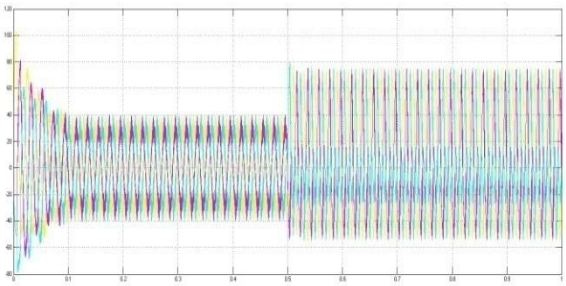

Fig.17: Simulated waveform of Line Current of the NPC Inverter

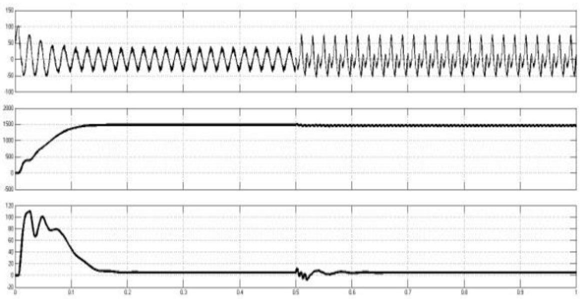

Fig.18: Performance characteristicsof Current, Speed and Torque

Fig.15 shows the distortion in line voltage. Fig. 16 it is clear that at 0.5sec, the phase voltage is shifted to complete negative peak due to occurrence of short fault. Fig. 17 shows the rise of line current which is higher than the current occurred in open fault and can damage the stator coils Fig. 18shows the reduction of stator current in the faulted phase and ripples in torque.

V. CONCLUSION

In the Converter, Component Failures in static energy conversion systems results into severe and widespread damages. The system effects of switch short are more severe than those of switch openif no protective measuresare taken in time. In order to provide protection from the faults there is a need to find which fault is occurring and respective mitigation techniques should be applied. Here the fuzzy inference system is used for detecting the type of fault. The total harmonic distortion and RMS values of phase voltages are considered as input variables and the results shows it as a simple identification than any other methods. This is because of the probabilistic approach in form of fuzzy rules.

REFERENCES

1. K. Rothenhagen and FW. Fuchs, “ *Performance of diagnosis methods for IGBT open circuit faults in voltage source active rectifiers* “, IEEE PESC proc..,2004, pp.4348-4354.
2. FW. Fuchs, “ *Some diagnosis methods for voltage source inverters in variable speed drives with induction machines-A survey” , in proc..*, IEEE India Electron.. Conf.. 2003, pp.1378-1385.
3. A M S. Mendes, A J M. Cardoso, E S. Saraiva, “ *Voltage source inverter fault diagnosis in variable speed AC drives, by the average current park’s vector approach ”* ,IEEE IEMDC Proc..,1999, pp. 704-706.
4. R L A.Ribeiro, C B. Jacobina, E R C.Silva, and A M N.Lima, “ *Fault detection of open-switch damage in voltage-fed PWM motor drive systems “*, IEEE Trans, Power Electron.., vol.18,no. 2, pp. 587-593.
5. C kral and K kafka, “ *power electronics monitoring for a controlled voltage source inverter drive with induction machine” s, in proc..*, IEEE 31 Annu.Power Electron..spec., Conf. 2000, vol. 1, pp. 213-217.
6. D Diallo M E H. Benbouzid, D Hamad and X Pierre, “ *Fault detection and diagnosis in an induction machine drive: apattern recognition approach based on Concordia stator mean current vector ”* ,IEEE Energy Conv.., vol.20, no. 3, pp.512-519, 2005.
7. E H. Mamdani, “ *Application of fuzzy algorithms for control of simple dynamic plant ”* , Proc. Of the Institution of Electrical Engineers, vol. 121, pp. 1585-1588,.1974
8. A Ferrero, S Sangiovanni, E Zappitelli, “ *A fuzzy-set approach to fault type identification in digital relaying ”* , IEEE Trans. On power delivery, vol. 10, pp. 169-175,1995
9. L A. Zadeh, *Fuzzy sets*, Information Control, 1956.

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