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FAULT IDENTIFICATION AND MITIGATION IN SEVEN LEVEL CASCADED H BRIDGE INVERTER FOR VEHICULAR APPLICATION

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ABSTRACT

National efforts to improve air quality in heavily populated urban communities-by reducing vehicular tailpipe emissions-have rekindled interest in the development of electric vehicle technology and infrastructure. Electric vehicles make ideal urban-commuter vehicles, for driving to and from. To fulfill increasing demand for higher dependability in power semiconductor converters applicable in electrical vehicles, fault detection (FD) and mitigation is a very important. During this study, a model-based on open semiconductor switch fault and closed semiconductor switch fault designation methodology is conferred for a voltage-source electrical inverter (VSI) supply a Squirrel Induction motor drive. To understand this goal, a model-based designed by using Simulink. After that, the model is studied with and while not of each open and short faults. Afterwards, the planned FD technique identifies the faults within the H-bridge cell. The conferred FD technique is easy and fast; additionally, it's able to sight multiple open switch or open faults in distinction to standard ways. On the opposite aspect, so as to mitigate the occurred faults, the fault occurred switch leg of the cell has been shorted.

Keywords: H-bridge cell, open and short fault, fault detection and mitigation.

INTRODUCTION

A well functioning and economical transport sector may be a demand for economic and social development, delivery individuals along and enabling the trade and exchange of products and concepts. However, the transport sector is additionally to hold responsible for variety of negative social and environmental effects, as well as a major contribution to world gas emissions and pollution. a world shift to a greener, low carbon economy would require important improvement within the ways that within which energy is created and used. The transport sector uses over 1 / 4 of the world's energy and is to blame for a comparable share of world carbonic acid gas emissions from fuel combustion. This may need each general and additional specific technological solution, such as: sensible growth urban designing for fewer motorized visits, hyperbolic modal share of non-motorized and transport, shifting incentives to additional economical and fewer polluting modes and technologies, and taking advantage of best on the market and most fuel and energy economical technologies.

Currently there's a major effort being done toward obtaining advanced electrical vehicles. In such drives totally different motors area unit used. Thanks to the advancement in power electronic semiconductor technology DC motors replaced by a lot of economical AC motors, like squirrel cage induction machine.

Induction motor is presently one among the most affordable and most 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 (SIEMENS). The higher efficiency of the motors with cooper cage comes from decreasing of rotor, mechanical and stray losses. in addition the operation temperature for copper cage motor is lower as compared to motors with metal cage providing the reduction of the motors dimensions. The motor size reduction is very necessary within the electrical vehicles applications. Power converter as well control method of induction motors are significantly more complicated compared to those of DC motor drives. According to fast development in power electronics technologies this complexity is no more an obstacle for the development of AC electric vehicle drives. To control the electric vehicle drive inverter works efficiently. Inverters and converters combined into one unit manage the power and recharging circuits in hybrids and electric vehicles (EVs).

Some conventional 2- level high frequency pulse width modulation (PWM) electrical inverter for automotive drives will have issues related to their high voltage varying rates (dv/dt) that produces a common mode (CM) voltage across the motor windings. High frequency change will make worse many times this common mode voltage is affected upon the motor every cycle. PWM controlled inverters suffer from problem of fault particularly at diode, gate and switch. All the issues essential within the switch fault as open fault and short fault of the switch. From this paper, to mitigate the faults of the switches within the cascaded H-bridge, the fault occurred switch leg can short.

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MULTI LEVEL INVERTER FOR ELECTRIC VEHICLE

Multilevel inverters include an array of power semiconductors and capacitor voltage sources, the output of which generate voltages with stepped waveforms. The commutation of the switches permits the addition of the capacitor voltages, which reach high voltage at the output, while the power semiconductors must withstand only reduced voltages [1],[2],[3]. Figure-1 shows a schematic diagram of three phase inverter with 7 levels, for which the action of the power semiconductors is represented by an ideal switch with several positions. The general function of the multilevel inverter is to synthesize a desired voltage from several levels of dc voltages. For this reason, multilevel inverters can easily provide the high power required of a large EV or HEV drive.

As the number of levels increases, the synthesized output waveform has more steps, which produces a staircase wave that approaches the desired waveform. Also, as more steps are added to the wave from, the harmonic distortion of the output wave decreases, approaching zero as the number of levels increases. The structure of the multilevel inverter is such that no voltage sharing problems are encountered by the active devices. Using multi level inverter as drives for automotive electric motors is a much different application than for the utility applications for which they were originally developed.

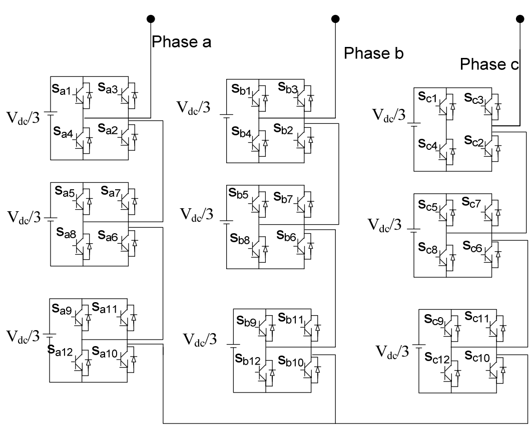

Figure-1. Cascaded H-bridge seven level inverter.

The system configuration of an EV motor drive using the cascaded inverter is shown in Figure-2. In the motoring mode, power flows from the batteries through the cascade inverter to the motor. In the charging mode, the cascaded converters act as rectifiers, and power flows from the charger to the batteries. The cascade converter can also act as rectifiers the kinetic energy of the vehicle if regenerative braking is used. The cascade inverter can also be used in parallel HEV configurations.

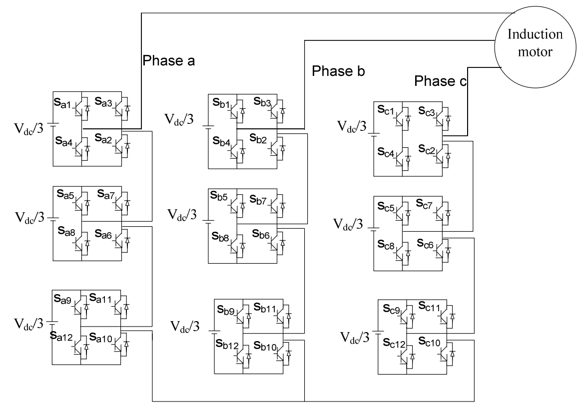

Figure-2. Cascaded H-bridge seven level inverter based induction motor drive.

FAULT ANALYSIS

It is estimated that among all types of faults in variable speed ac drives in industry, about 38% of the faults are due to failures of power devices. Most of these inverters use insulated gate bipolar transistors (IGBTs) as the power device because of their high voltage and current ratings and ability to handle short-circuit currents for periods exceeding 10 μs. But they suffer failures due to excess electrical and thermal stress that are experienced in many applications. IGBT failures can be broadly classified as diode open- faults, diode short-circuit faults, intermittent gate-misfiring faults, switch open and switch short fault.

The open fault in switch S1 is introduced by opening its Diode.

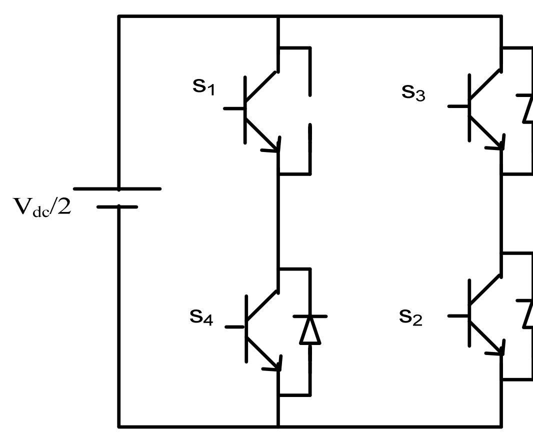

Figure-3. The fault occurred due to the diode in open condition.

The short fault can occur with diode in short condition of switch S1.

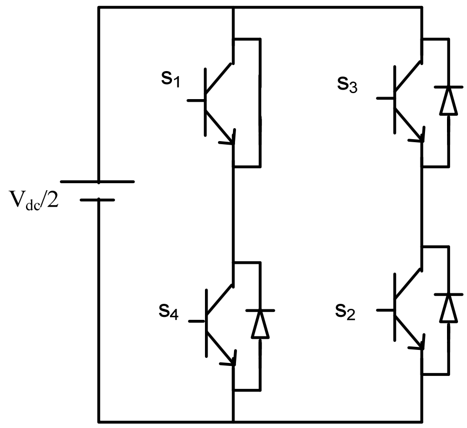

Figure-4. The fault occurred due to the diode in short condition.

The open fault in switch S1 is introduced by opening the gate pulse

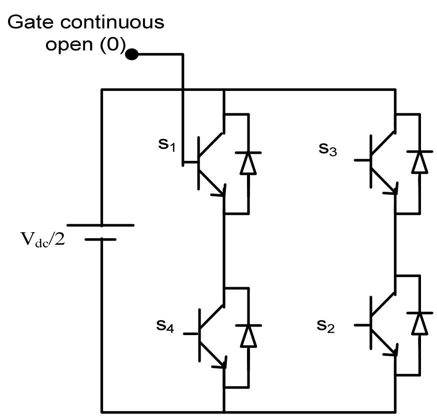

Figure-5. The fault occurred due to the Gate in open condition.

The short fault can occur with the gate in short condition of switch S1.

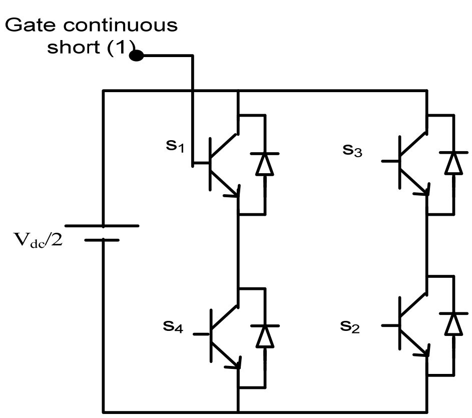

Figure-6. The fault occurred due to the Gate in Short condition.

An open-circuit fault in inverter is introduced by removing its IGBT.

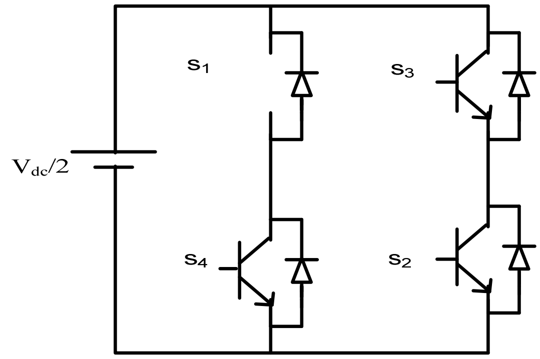

Figure-7. The fault occurred due to the IGBT in open condition.

The short-circuit fault in inverter is introduced by shorting the switch S1.

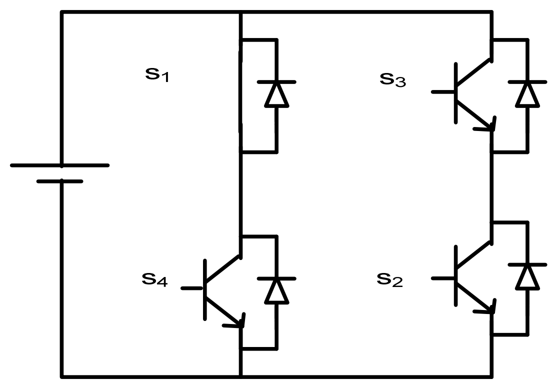

Figure-8. The fault occurred due to the IGBT in short condition.

It is discussed 6 different types of faults; among all these cases in this paper only cases have been discussed. In the mitigation process if these two faults have been mitigated remaining four types of problems also can be reduced.

a) IGBT open-circuit fault.

b) IGBT short-circuit fault.

In open circuit fault condition, the IGBT falls in the off state and remains in this situation regardless of the gate voltage value.

In short circuit fault condition, the IGBT falls in the on state and remains in this situation regardless of the gate voltage value.

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FAULT DETECTION

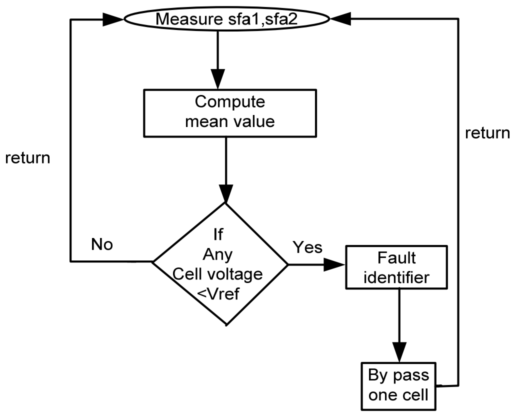

Figure-9. Fault detection algorithm.

In the fault detection the average voltage of the cell is measured, to compare with Vref. If the cell $V_{avg}<V_{ref}$ no fault has been occurred. If the cell $V_{avg}>V_{ref}$ the fault has been detected. To mitigate occurred fault, pulses given to short the leg.

FAULT MITIGATION

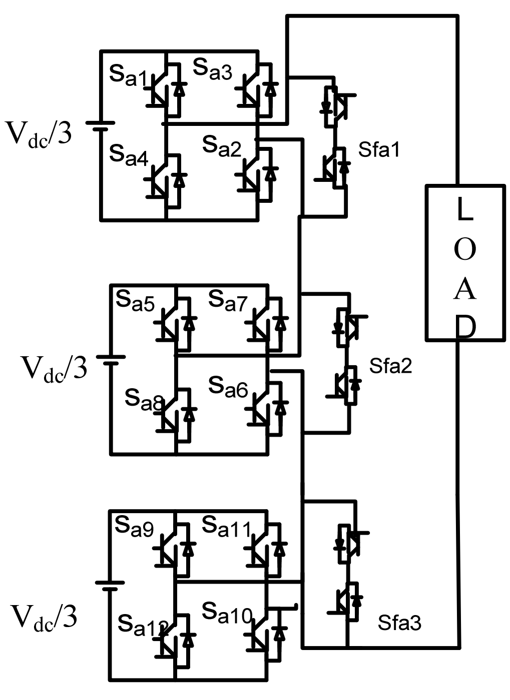

Figure-10. Mitigation of fault in Single phase cascaded H-bridge.

To mitigate the fault for each cell in the H-Bridge bi-directional switches has been connected, represented as S_{fa1}, S_{fa2} and S_{fa3} pulses developed from the Fault Detection will operates these switches to short the leg of the fault occurred switch.

Below shows the mitigation of the three phase seven level multi level inverter fed Induction motor based Electric vehicle.

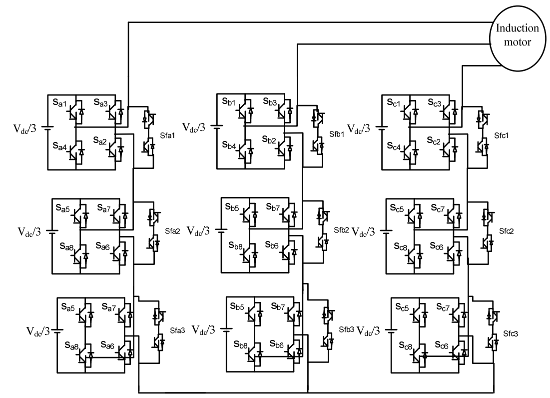

Figure-11. Mitigation of fault in three phase cascaded H-bridge.

MATLAB/SIMULINK RESULTS

Case-1: Without Fault Cascaded H-Bridge Inverter based Induction motor.

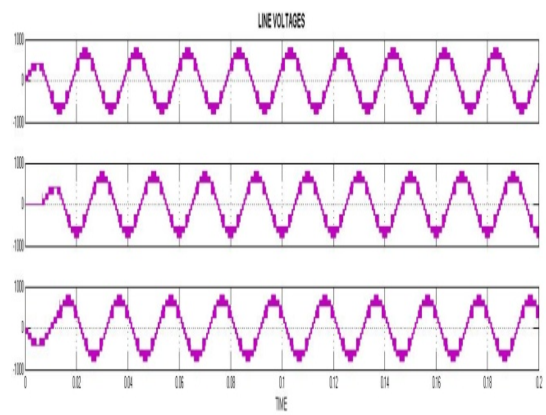

Figure-12. Inverter line voltage at healthy condition.

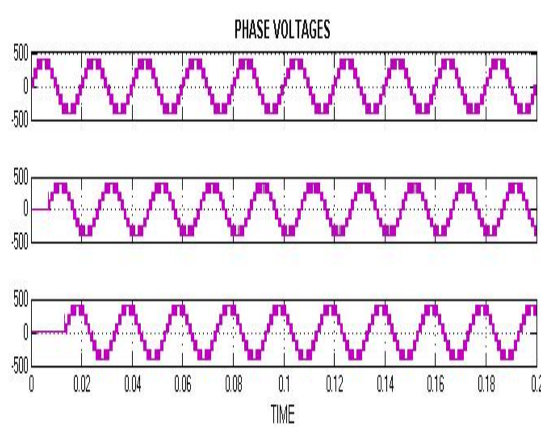

Figure-13. Inverter phase voltages at healthy condition.

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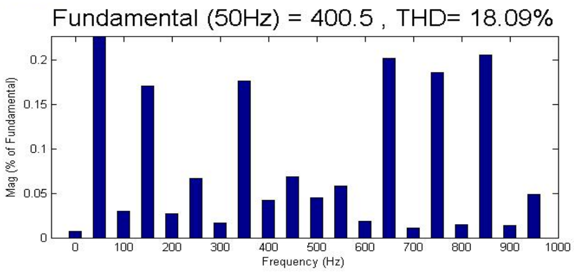

Figure-14. Total Harmonic Distortion of phase voltage shows 18.09% at healthy condition.

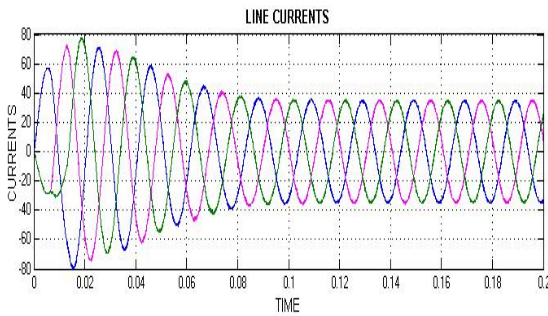

Figure-15. Inverter line currents at healthy condition.

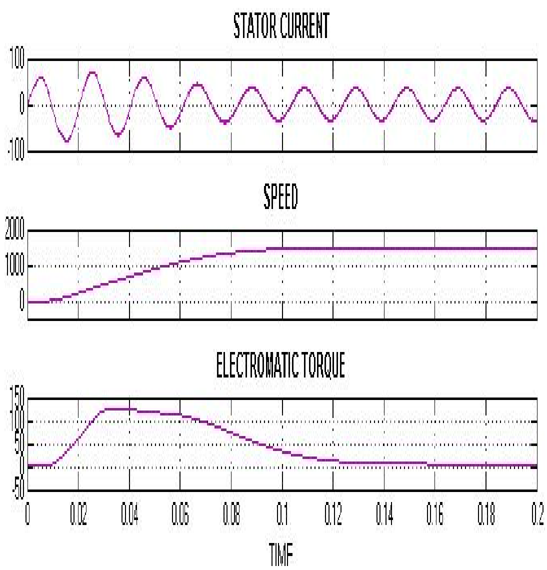

Figure-16. Stator current, speed and torque characteristics of motor at healthy condition.

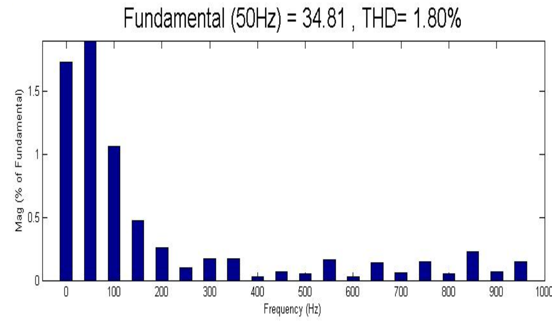

Figure-17. Total Harmonic Distortion of stator current shows 1.80% at healthy condtion.

Figure-12 shows the line voltages of inverter at healthy condition with no fault and Figure-13 shows the phase voltages of inverter. The THD in phase voltage of inverter during healthy condition is 18.09% as in Figure-14. Figure-15 shows the line currents of inverter and Figure-16 shows the stator current, speed and torque characteristics of induction motor. The THD in stator current is 1.8% as in Figure-17 during healthy condition.

Case-2: With open Fault occurred to Cascaded H-Bridge inverter based Induction motor at 0.4sec.

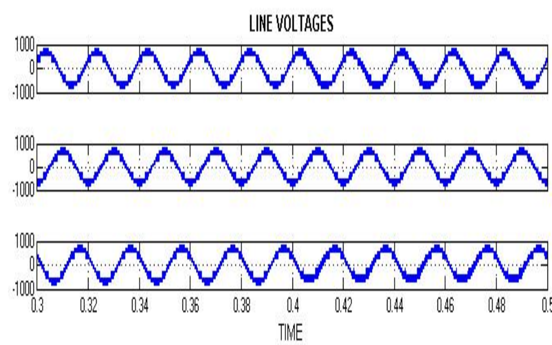

Figure-18. Inverter line voltage at Open Fault condition.

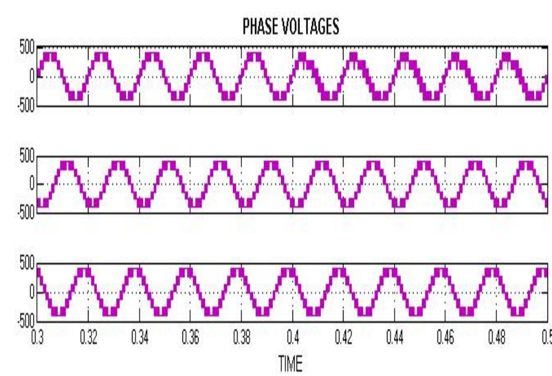

Figure-19. Inverter phase voltages at Open Fault condition.

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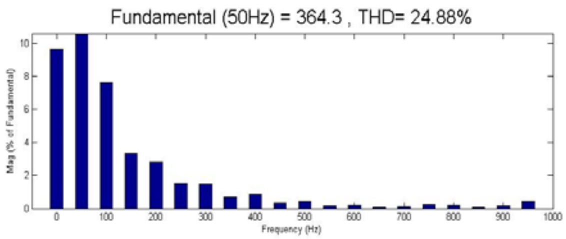

Figure-20. Total Harmonic Distortion of phase voltage shows 24.88% at Open Fault condition.

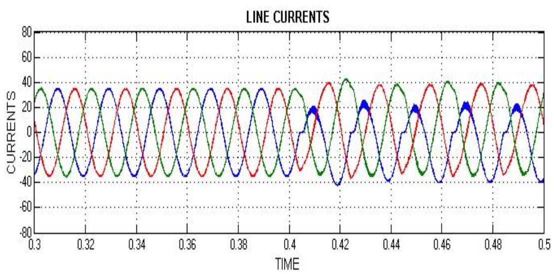

Figure-21. Inverter line currents at Open Fault condition.

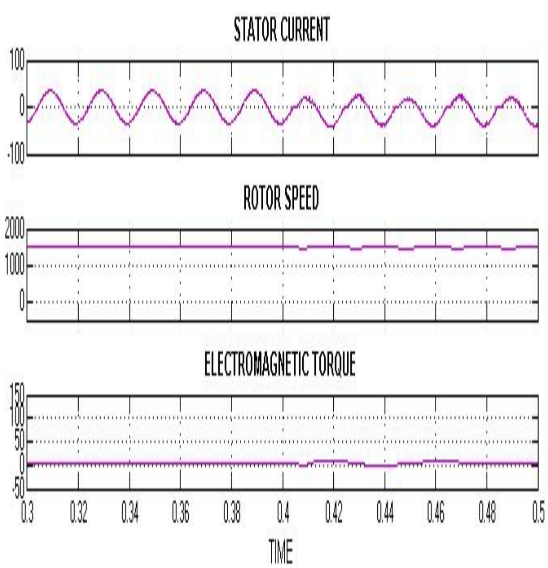

Figure-22. Stator current, speed and torque characteristics of motor at Open Fault condition.

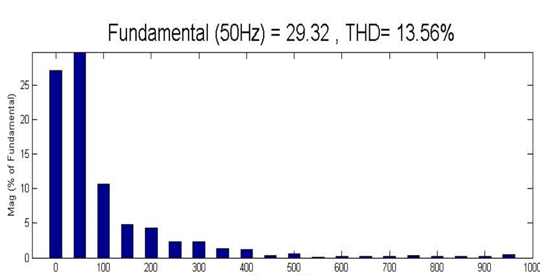

Figure-23. Total Harmonic Distortion of stator current shows 13.56% Open Fault condition.

Figure-18 shows the line voltages of inverter at open fault condition and Figure-19 shows the phase voltages of inverter. The THD in phase voltage of inverter during open fault condition is 24.88% as in Figure-20. Figure-21 shows the line currents of inverter and Figure-22 shows the stator current, speed and torque characteristics of induction motor. The THD in stator current is 13.56% as in Figure-23 during open fault condition.

Case-3: With open Fault mitigation in Cascaded H-Bridge inverter based Induction motor at 0.6sec.

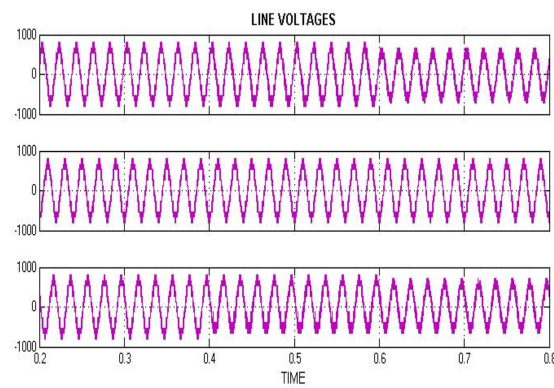

Figure-24. Inverter line voltage at Mitigation.

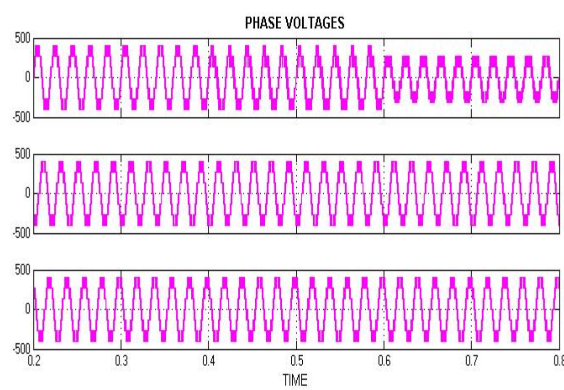

Figure-25. Inverter phase voltages at Mitigation.

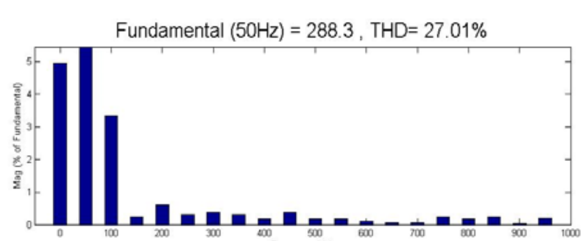

Figure-26. Total Harmonic Distortion of phase voltage shows 27.01% at Mitigation.

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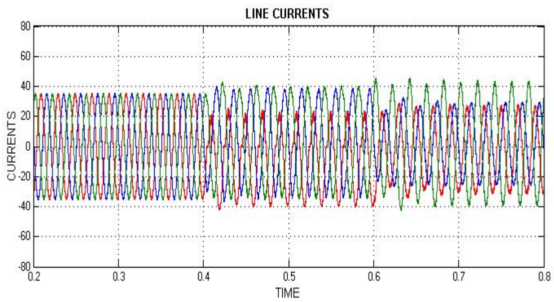

Figuire-27. Inverter line currents at Mitigation.

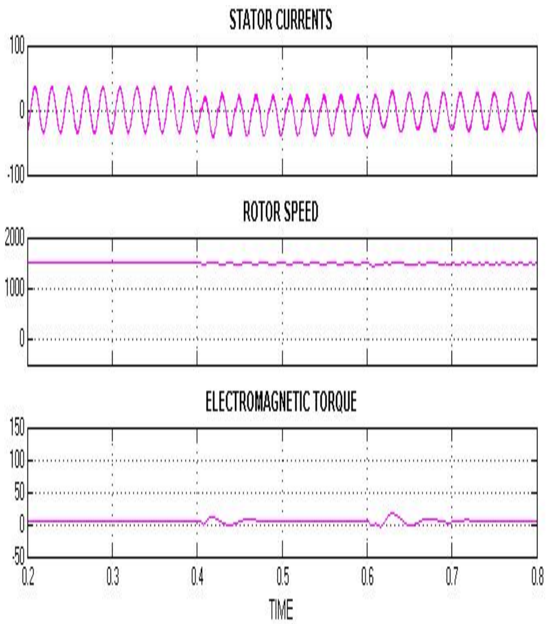

Figure-28. Stator current, speed and torque characteristics of motor at Mitigation.

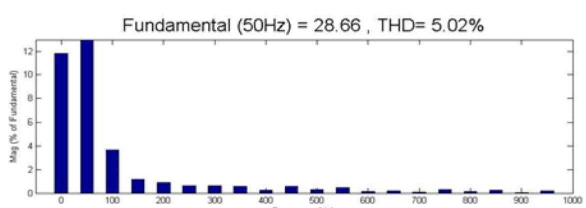

Figure-29. Total Harmonic Distortion of stator current shows 5.02% at Mitigation.

Figure-24 shows the line voltages of inverter at open fault mitigation and Figure-25 shows the phase voltages of inverter. The THD in phase voltage of inverter during open fault mitigation is 27.01% as in Figure-26. Figure-27 shows the line currents of inverter and figure 28 shows the stator current, speed and torque characteristics of induction motor. The THD in stator current is 5.02% as in Figure-29 during open fault mitigation condition.

Case-4: With short Fault to Cascaded H-Bridge inverter based Induction motor at 0.4sec.

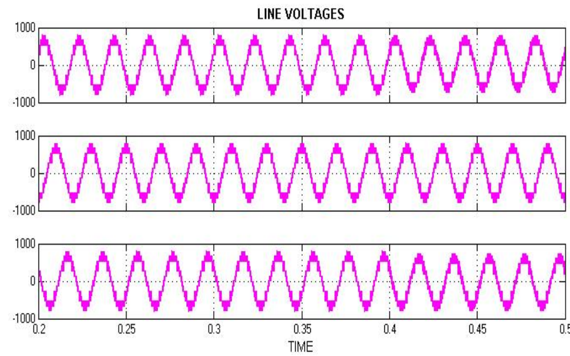

Figure-30. Inverter line voltage at Short Fault condition.

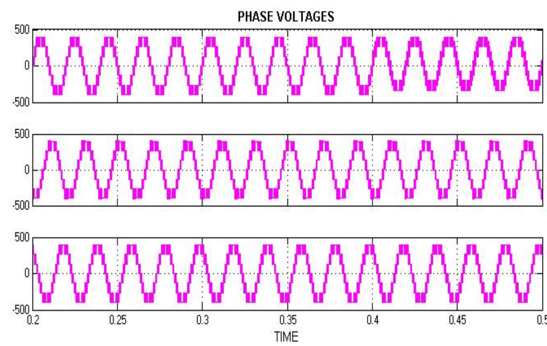

Figure-31. Inverter phase voltages at Short Fault condition.

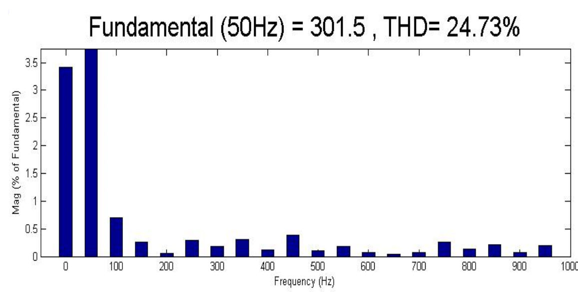

Figure-32. Total Harmonic Distortion of phase voltage shows 24.73% Short Fault condition.

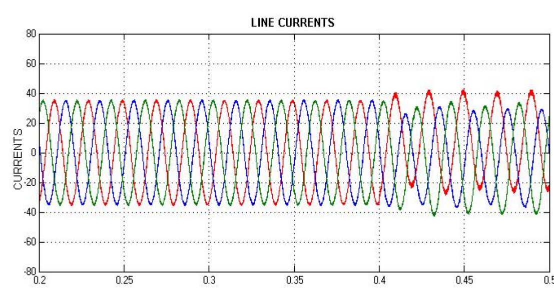

Figure-33. Inverter line currents at Short Fault condition.

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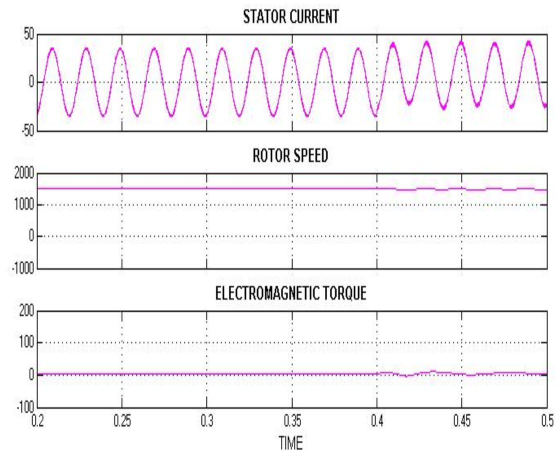

Figure-34. Stator current, speed and torque characteristics of motor at Short Fault condition.

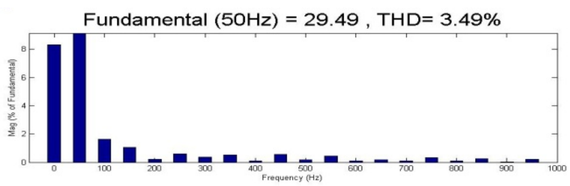

Figure-35. Total Harmonic Distortion of stator current shows 3.49% Short Fault condition.

Figure-30 shows the line voltages of inverter at short fault condition and Figure-31 shows the phase voltages of inverter. The THD in phase voltage of inverter during short fault condition is 24.73% as in Figure-32. Figure-33 shows the line currents of inverter and Figure-34 shows the stator current, speed and torque characteristics of induction motor. The THD in stator current is 3.49% as in Figure-35 during short fault condition.

Case-5: With short Fault mitigation in Cascaded H-Bridge inverter based Induction motor at 0.6sec.

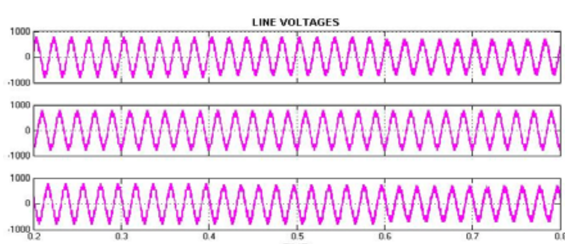

Figure-36. Inverter line voltage at Mitigation.

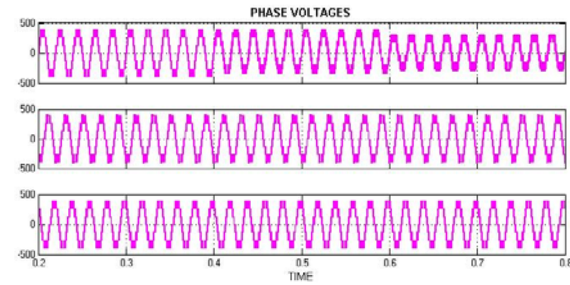

Figure-37. Inverter phase voltages at Mitigation.

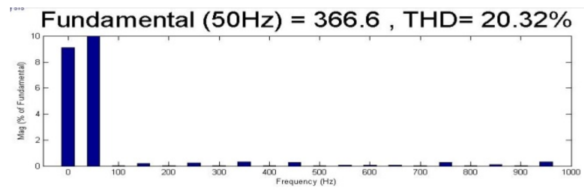

Figure-38. Total Harmonic Distortion of phase voltage shows 20.32% at Mitigation.

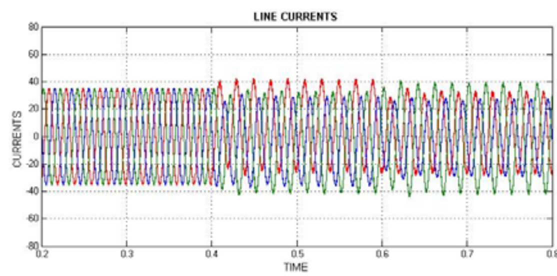

Figure-39. Inverter line currents at Mitigation.

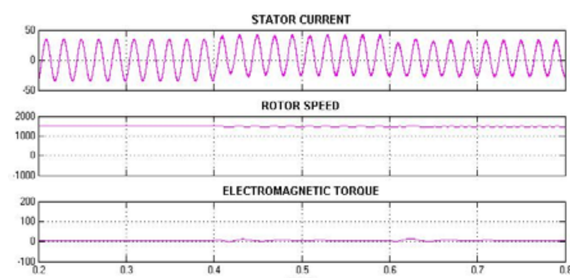

Figure-40. Stator current, speed and torque characteristics of motor at Mitigation.

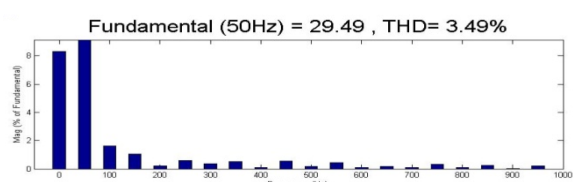

Figure-41. Total Harmonic Distortion of stator current shows 3.49% at Mitigation.

Figure-36 shows the line voltages of inverter at open fault mitigation and Figure-37 shows the phase voltages of inverter. The THD in phase voltage of inverter during open fault mitigation is 20.32% as in Figure-38. Figure-39 shows the line currents of inverter and figure 40 shows the stator current, speed and torque characteristics of induction motor. The THD in stator current is 3.49% as in Figure-41 during open fault mitigation condition. Table-1 shows the THD valuesfor phase voltages and stator currents at different conditions.

Table-1. Harmonic content in Phase voltage and Stator currents without fault, open and short faults.

Harmonics in	At healthy condition	At open circuit fault	At open circuit fault mitigation	At short circuit fault	At short circuit fault mitigation
Phase voltage	18.09%	24.88%	27.01%	28.82%	35.89%
Stator current	1.80%	13.56%	5.02%	3.49%	3.49%

CONCLUSIONS

The seven-level inverter is modeled with induction motor based electric vehicle designed by using simulink. After that, the model is studied with and without of each open and short faults. Fault Detection FD technique identifies the faults within the H-bridge cell. The identification of FD technique is easy and fast; additionally, it's able to sight multiple open switch or open faults in distinction to standard ways. The detected fault has been mitigated; the fault occurred switch leg of the cell has been shorted. This mitigation technique is employed to control multi fault in VSI controlled Induction motor based electrical vehicle drive. From the simulation analysis a table has been formed for phase voltage and stator currents which show harmonic content at healthy, fault and mitigation conditions. The harmonic content at fault condition of the phase voltage and stator currents is more when compared to healthy conditions. In mitigation condition stator harmonics are less and phase voltage harmonics are more compared to fault condition. The accuracy of the mitigation lies in the net harmonics of the both phase voltages and stator currents is less compared to the net harmonics of phase voltage and stator currents at fault condition.

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