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FAULT ANALYSIS IN PARALLEL INVERTER TOPOLOGY FOR INDUCTION MOTOR DRIVE

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ABSTRACT

This paper presents the investigation of performance in inverters and induction motor with fault condition when the system is framed as two parallel inverters feeding a single induction motor. The two inverters share the total load current drawn by induction motor such that the rating of power devices used in inverters gets reduced. Diode clamped multi-level inverter consists of power switches and switch faults takes place very often due to many reasons in circuit behavior. Diode clamped inverter is controlled using asymmetrical PWM technique. Presence of open type of switch fault makes inverter malfunction and might cause load characteristics to disturb. Examination was carried out in this paper for line currents, line voltages and phase voltages of both parallel placed inverters along with characteristics of induction motor with fault in inverter switch. Proposed work was carried out using MATLAB/SIMULINK software and results were presented.

Keywords: shunt APF, compensation, harmonics, linear, non-linear, load.

INTRODUCTION

Motor drive system can replace human efforts and increase the process output. Motor with a speed control unit is termed as motor drive. Induction motor having fine speed-torque characteristics with robust construction is widely used motor drive in many applications since it also requires less maintenance and more vulnerable to operate under polluted regions. Induction motor speed can be regulated by regulating the terminal voltage and supply frequency of induction motor. Speed of induction motor is directly proportional to supply frequency and terminal voltage [1-4]. Varying both terminal voltage and supply frequency but keeping the terminal voltage to frequency ratio constant makes efficient speed control method of induction motor. This variable speed drive application of induction motor can be made possible by driving an induction motor with a front-end power electronic converter called inverter [5-7].

Inverter is a type of converter based on power electronic components class of converting DC to AC. The input DC type of supply is converted to output of AC type with desired value of output voltage and output frequency of inverter depends on the switching frequency of power switches in inverter [8-10]. The output voltage and frequency of the output can be obtained as desired by the user and when the same inverter output is fed to the induction motor, can be run at desired speeds. A simple schematic arrangement of inverter fed induction motor drive is shown in Figure-1.

The schematic arrangement consists of a diode bridge rectifier, diode clamped inverter and induction motor. The induction motor speed is controlled with inverter. For this, inverter is to be fed with a DC supply but the available grid supply is of AC type. A simple diode bridge rectifier converts available grid AC supply to DC and feeds inverter. Diode clamped inverter inverts DC supply to AC producing output voltage of required level in stepped multi-level form with desired supply frequency depending on switching frequency. The produced output of the inverter is fed to induction motor to run at desired speeds.

Parallel inverters topology can be very handy in reducing the current rating of the power switching devices in inverter. Parallel inverters share the load current present at the output with same voltage rating. For induction motor drive application, two inverters placed in parallel shares the total current drawn by induction motor with same voltage rating as a result reducing the switch rating of inverter and as a result switching losses.

Diode clamped inverters consists of power electronic static switches and static switches are subjected to faults very often due to circuit conditions. During circuit fault conditions, the output of the inverter distorts and the corresponding induction motor characteristics are also distorted giving distorted speed [11-14]. Distortions in speed can create vibrations and disturbs the mounting of the machine and also affects the coupling of the motor. With the presence of parallel inverter, fault in one inverter can hardly affect the overall performance of the induction motor.

This paper presents the fault analysis of diode clamped inverter fed induction motor drive with parallel inverter topology sharing load. Performance characteristics of induction motor and inverters were studied for open type of switch fault condition in any one of the two parallel inverters and also for fault condition in both the parallel inverters. Inverter Examination was carried out in this paper for line currents, line voltages and phase voltages of both parallel placed inverters along with characteristics of induction motor with fault in inverter switch. Proposed work was carried out using MATLAB/SIMULINK software and results were presented.

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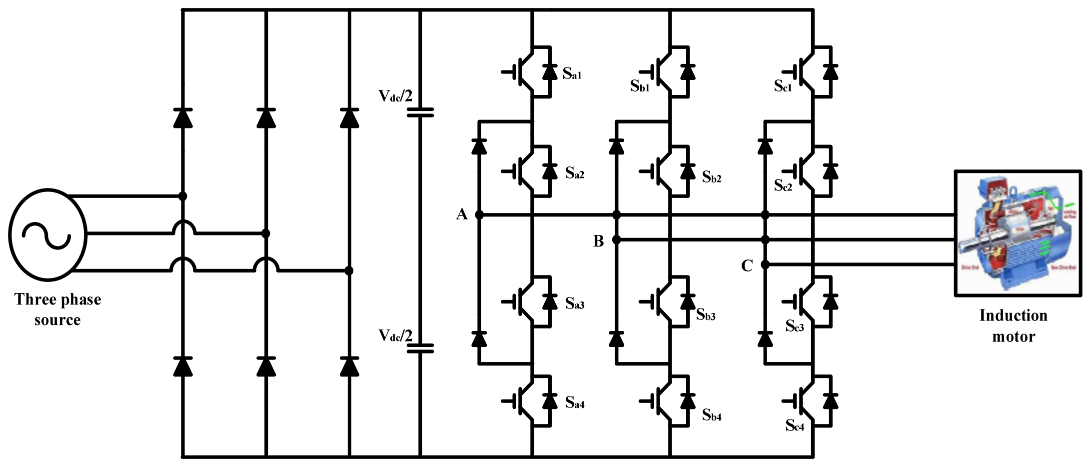

Figure-1. Conventional diode clamped inverter fed induction motor.

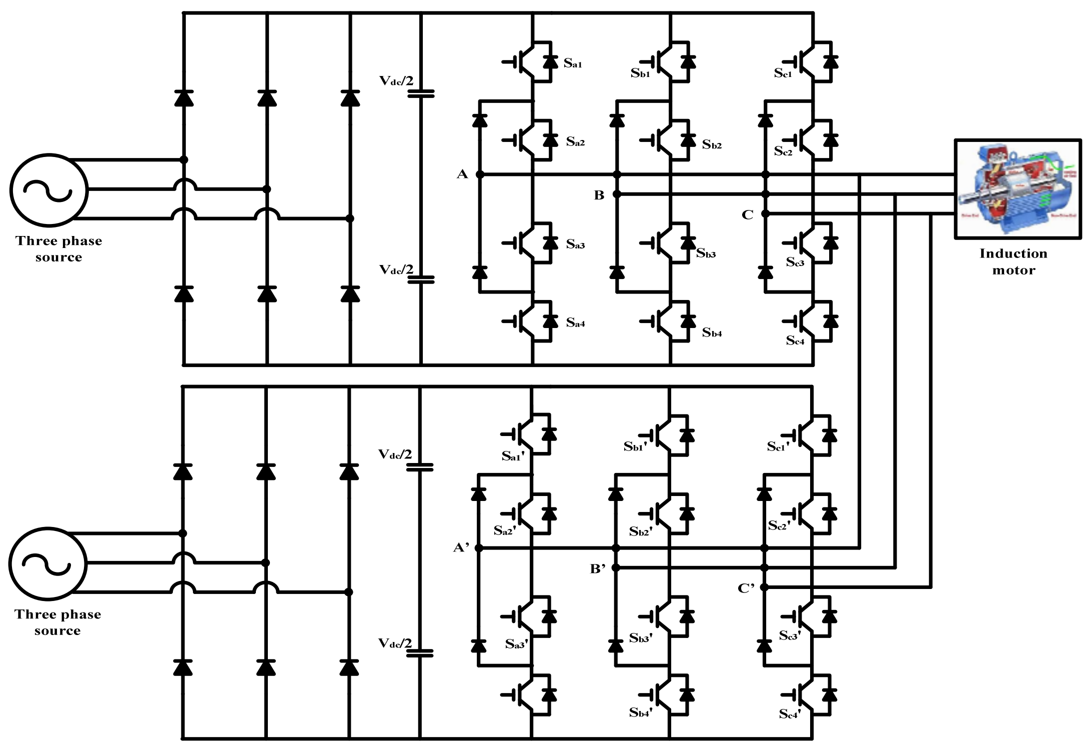

Figure-2. Proposed topology of induction motor drive fed from two parallel inverters.

INDUCTION MOTOR FED FROM TWO PARALLEL INVERTERS

The schematic circuit arrangement if induction motor fed from two parallel inverters is shown in Figure-2.

The grid AC source is fed to two parallel paths and each individual parallel path consists of a diode bridge rectifier and a diode clamped inverter. The total induction motor load current is been distributed among two parallel paths of the circuit arrangement and each parallel path of the circuit arrangement carries only half of the total load current but the voltage rating of the two parallel paths remains same in magnitude. Each parallel path supplied from a AC grid supply is rectified to DC feeding inverter using a diode bridge rectifier and then inverted to AC to produce required output using diode clamped multi-level inverter. The output frequency of both the parallel paths should be same.

FAULT ANALYSIS IN PARALLEL INVERTER TOPOLOGY FED INDUCTION MOTOR

Fault analysis for two parallel placed diode clamped inverters to feed induction motor were examined for switch open type of fault in one of the switching cell in only upper inverter as shown in figure 3, with switch open

VOL. 12, NO. 22, NOVEMBER 2017 ISSN 1819-6608
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type of fault in one of the switching cell in only lower inverter as shown in Figure-4 and switch open type of fault in one switching cell in both upper and lower inverters as shown in Figure-5. Diode clamped inverter (DCMLI) consists of four number of switches in each of the phase and performance characteristics were analyzed for open type of fault in one of the switching cell in one phase of inverter circuit.

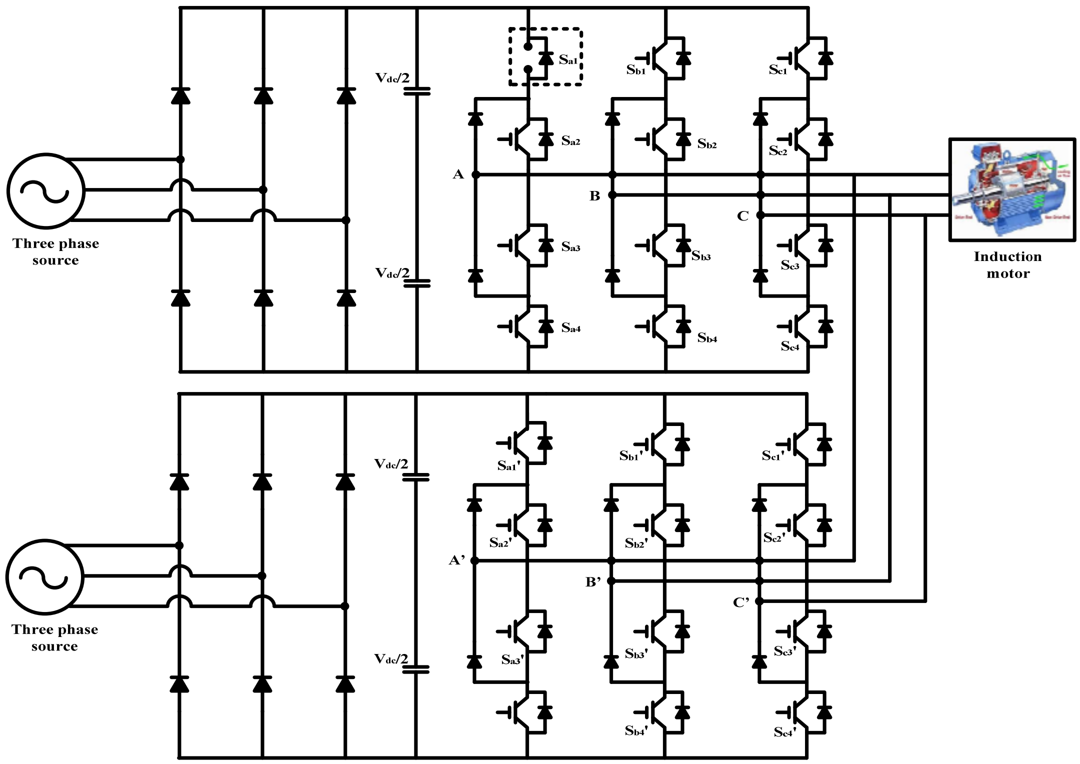

Figure-3. Induction motor drive fed from two parallel inverters with fault in upper parallel inverter.

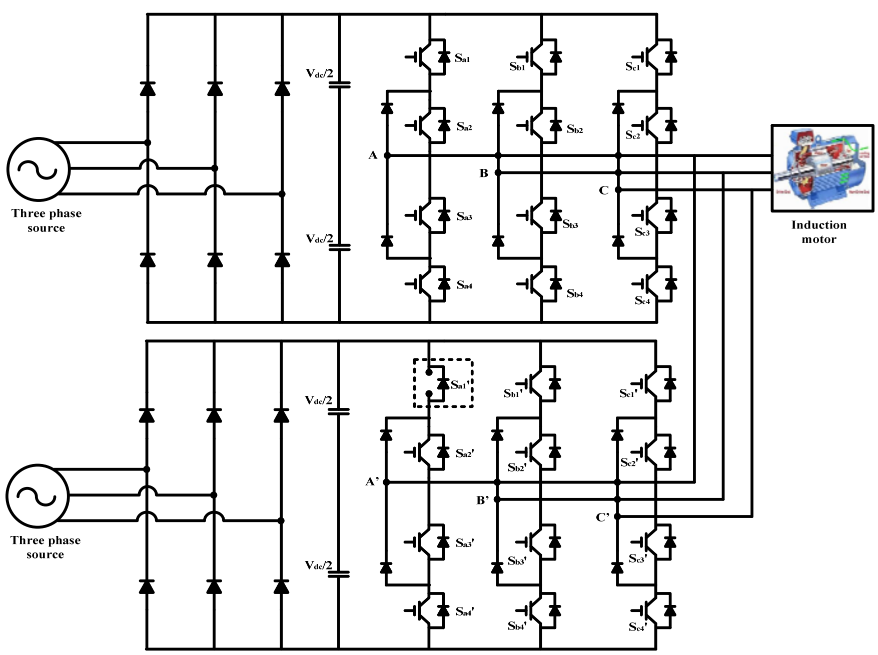

Figure-4. Induction motor drive fed from two parallel inverters with fault in lower parallel inverter.

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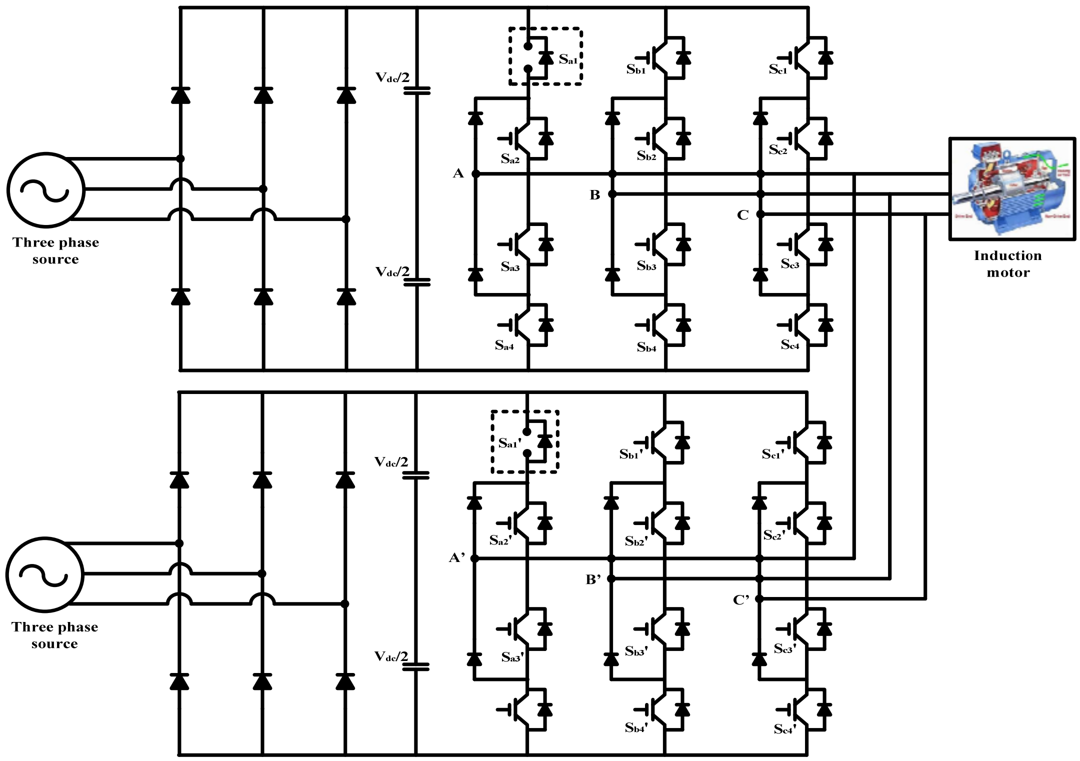

Figure-5. Induction motor drive fed from two parallel inverters with fault in both upper and lower parallel inverters.

In figure the switch open type of fault is shown with dotted box clearly indicating the switch open circuit. Open type of switch fault distorts the phase voltages and line voltages of inverter and eventually unbalances the line currents of inverter. This nature distorts the stator currents of induction motor and sped and torque of induction motor is distorted. Diode clamped inverter is controlled with asymmetrical pulse width modulation technique.

RESULTS AND DISCUSSIONS

Results were discussed for open type of switch fault condition in any one of the two parallel inverters and also for fault condition in both the parallel inverters.

A. Fault in upper inverter

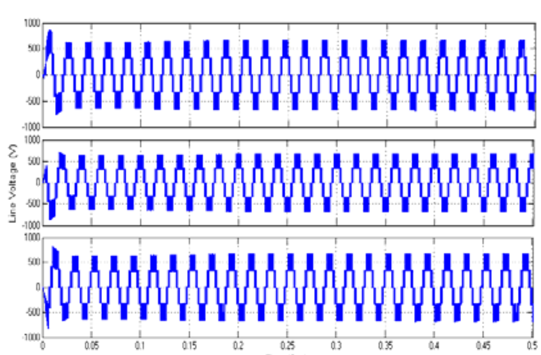

Figure-6. Line voltage of upper parallel inverter.

Three phase line voltages of upper inverter with switch open fault in phase-A of upper parallel DCMLI is shown in Figure-6. Fault is introduced at instant 0.35 seconds. Before fault instant, line voltages are normal in shape with average value equal to zero. During fault the line voltage in phase-A is disturbed.

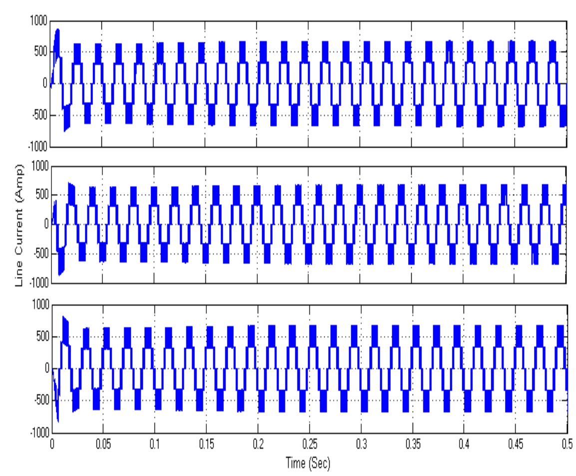

Figure-7. Line voltage of lower parallel inverter.

Three phase line voltages of lower inverter with switch open fault in phase-A of upper parallel DCMLI is shown in Figure-7. Fault is introduced at instant 0.35 seconds. Before fault instant, line voltages are normal in

VOL. 12, NO. 22, NOVEMBER 2017 ISSN 1819-6608
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shape with average value equal to zero. During fault the line voltage in phase-A is disturbed.

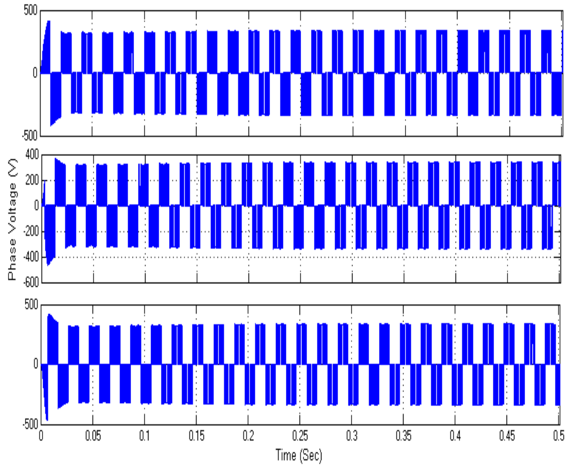

Figure-8. Phase voltage of upper parallel inverter.

Three-phase voltage of upper parallel inverter with switch open fault in phase-A of upper inverter is shown in Figure-8. Fault is created at 0.35 sec and before fault phase voltages are normal and during fault, phase-A voltage is distorted

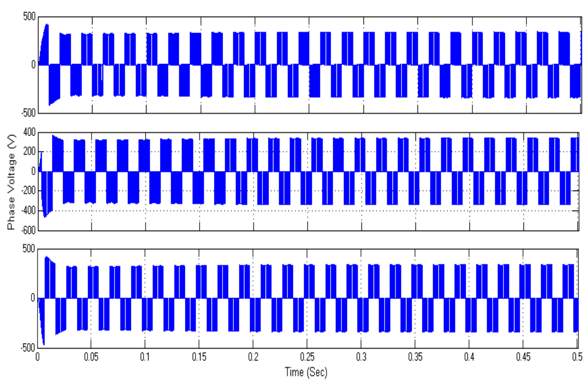

Figure-9. Phase voltage of lower parallel inverter.

Three-phase voltage of lower parallel inverter with switch open fault in phase-A of upper inverter is shown in Figure-9. Fault is created at 0.35 sec and before fault phase voltages are normal and during fault, phase-A voltage is distorted

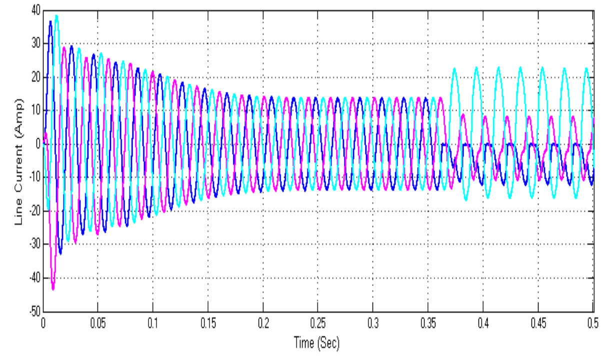

Figure-10. Line current of upper parallel inverter.

Three-phase line currents of upper parallel inverter with switch open fault in phase-A of upper inverter is shown in Figure-10. Fault is created at 0.35 sec and before fault line currents are normal and during fault, line currents becomes unbalanced in all three phases. Due to parallel connection, upper inverter carries only 15 A that is half the total value before fault but unbalanced during faulty condition.

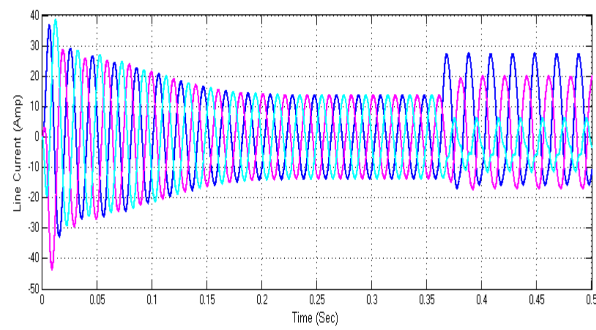

Figure-11. Line current of lower parallel inverter.

Three-phase line currents of lower parallel inverter with switch open fault in phase-A of upper inverter is shown in Figure-11. Fault is created at 0.35 sec and before fault line currents are normal and during fault, line currents becomes unbalanced in all three phases. Due to parallel connection, lower inverter carries only 15 A that is half the total value before fault but unbalanced during faulty condition.

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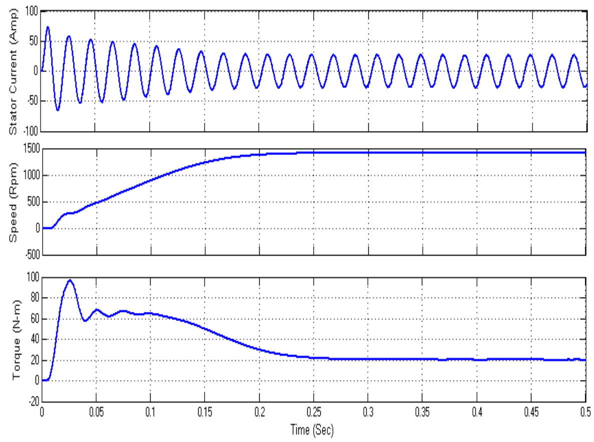

Figure-12. Induction motor characteristics with fault in upper DCMLI.

Induction motor characteristics of stator current, speed and torque characteristics were shown in Figure-12. Before fault at 0.35 seconds, stator current is maintained at constant peak of 30 A, speed at 1500 rpm and torque at 20 Nm. During fault condition the characteristics were slightly distorted.

B. Fault in lower inverter

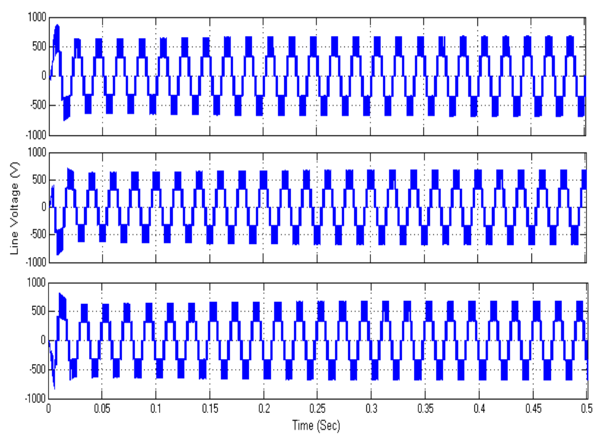

Figure-13. Line voltage of upper parallel inverter.

Three phase line voltages of upper inverter with switch open fault in phase-A of lower parallel DCMLI is shown in Figure-13. Fault is introduced at instant 0.35 seconds. Before fault instant, line voltages are normal in shape with average value equal to zero. During fault the line voltage in phase-A is disturbed.

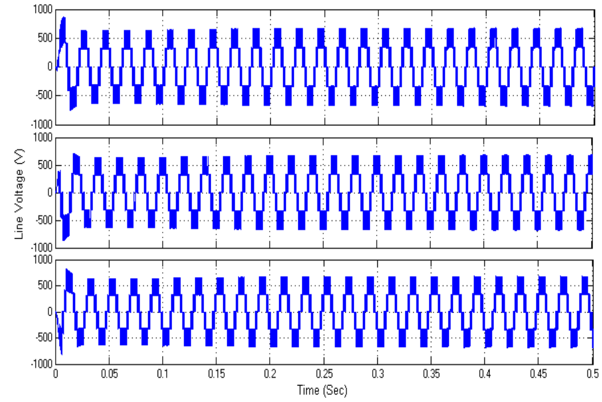

Figure-14. Line voltage of lower parallel inverter.

Three phase line voltages of lower inverter with switch open fault in phase-A of lower parallel DCMLI is shown in Figure-14. Fault is introduced at instant 0.35 seconds. Before fault instant, line voltages are normal in shape with average value equal to zero. During fault the line voltage in phase-A is disturbed.

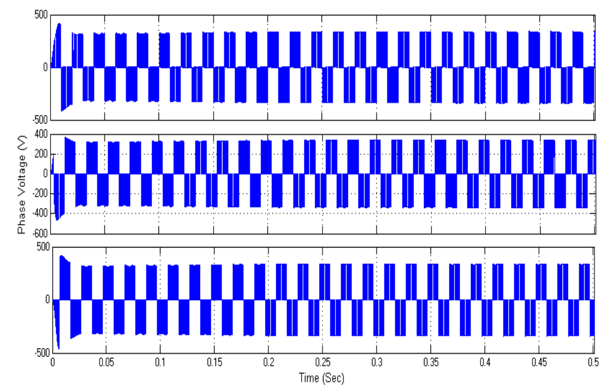

Figure-15. Phase voltage of upper parallel inverter.

Three-phase voltage of upper parallel inverter with switch open fault in phase-A of lower inverter is shown in Figure-15. Fault is created at 0.35 sec and before fault phase voltages are normal and during fault, phase-A voltage is distorted

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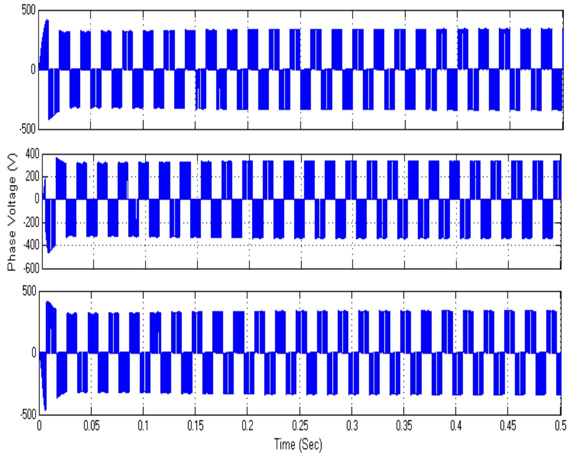

Figure-16. Phase voltage of lower parallel inverter.

Three-phase voltage of lower parallel inverter with switch open fault in phase-A of lower inverter is shown in Figure-16. Fault is created at 0.35 sec and before fault phase voltages are normal and during fault, phase-A voltage is distorted

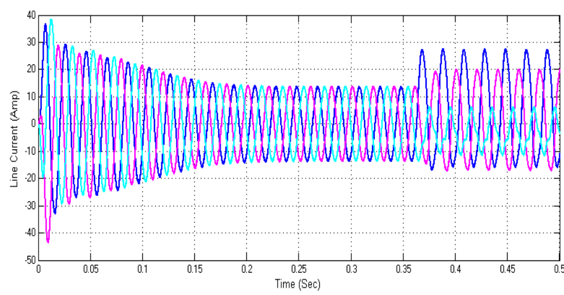

Figure-17. Line current of upper parallel inverter.

Three-phase line currents of upper parallel inverter with switch open fault in phase-A of lower inverter is shown in Figure-17. Fault is created at 0.35 sec and before fault line currents are normal and during fault, line currents becomes unbalanced in all three phases. Due to parallel connection, upper inverter carries only 15 A that is half the total value before fault but unbalanced during faulty condition.

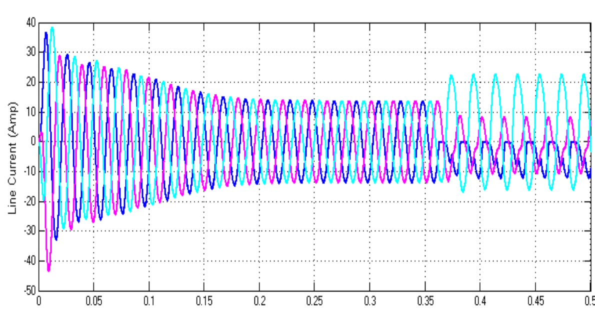

Figure-18. Line current of lower parallel inverter.

Three-phase line currents of lower parallel inverter with switch open fault in phase-A of lower inverter is shown in Figure-18. Fault is created at 0.35 sec and before fault line currents are normal and during fault, line currents becomes unbalanced in all three phases. Due to parallel connection, lower inverter carries only 15 A that is half the total value before fault but unbalanced during faulty condition.

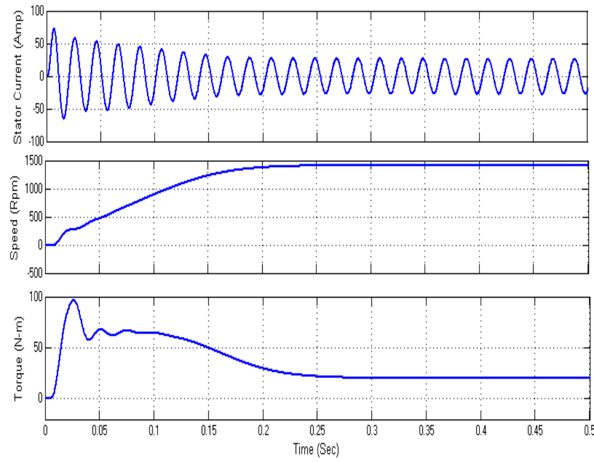

Figure-19. Induction motor characteristics with fault in lower DCMLI.

Induction motor characteristics of stator current, speed and torque characteristics were shown in Figure-19. Before fault at 0.35 seconds, stator current is maintained at constant peak of 30 A, speed at 1500 rpm and torque at 20 Nm. During fault condition the characteristics were slightly distorted.

c. Fault in both upper and lower inverters

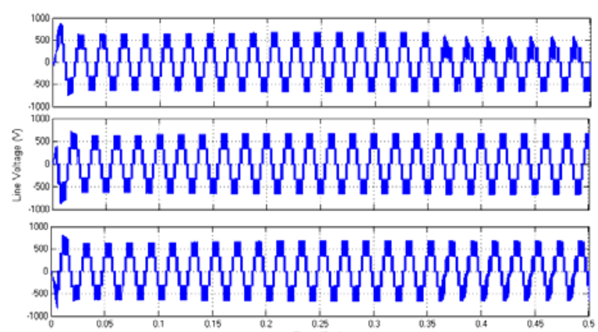

Figure-20. Line voltage of upper parallel inverter.

Three phase line voltages of upper inverter with switch open fault in phase-A of both parallel DCMLI is shown in Figure-20. Fault is introduced at instant 0.35 seconds. Before fault instant, line voltages are normal in shape with average value equal to zero. During fault the line voltage in phase-A is disturbed.

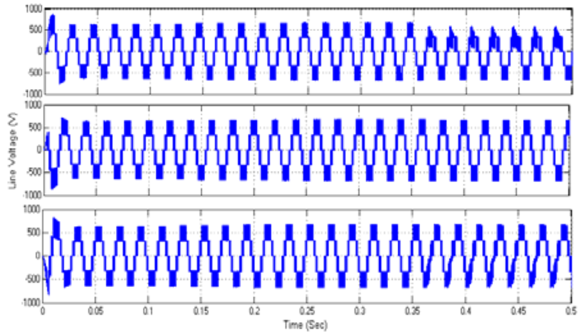

Figure-21. Line voltage of lower parallel inverter.

Three phase line voltages of lower inverter with switch open fault in phase-A of both parallel DCMLI is shown in Figure-21. Fault is introduced at instant 0.35 seconds. Before fault instant, line voltages are normal in shape with average value equal to zero. During fault the line voltage in phase-A is disturbed.

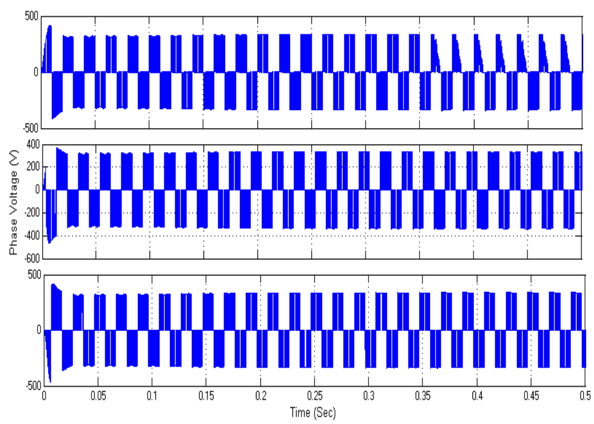

Figure-22. Phase voltage of upper parallel inverter.

Three-phase voltage of upper parallel inverter with switch open fault in phase-A of both inverter is shown in Figure-22. Fault is created at 0.35 sec and before fault phase voltages are normal and during fault, phase-A voltage is distorted

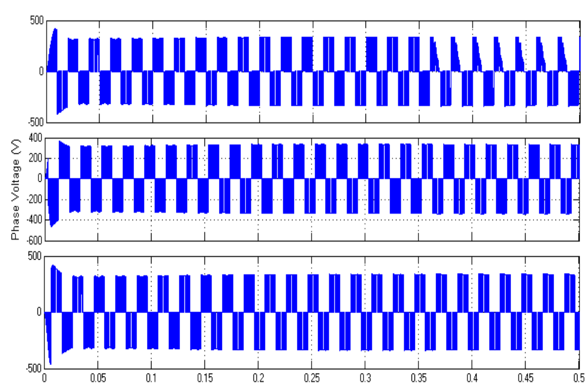

Figure-23. Phase voltage of lower parallel inverter.

Three-phase voltage of lower parallel inverter with switch open fault in phase-A of both inverter is shown in Figure-23. Fault is created at 0.35 sec and before fault phase voltages are normal and during fault, phase-A voltage is distorted

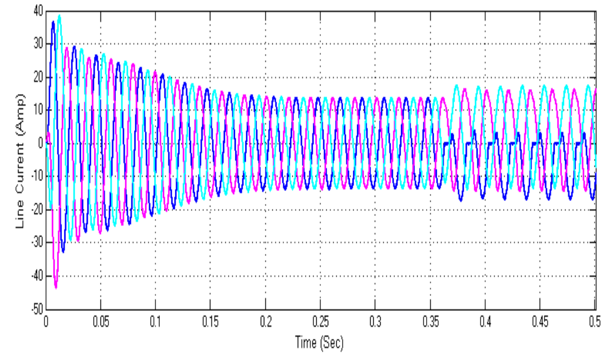

Figure-24. Line current of upper parallel inverter.

Three-phase line currents of upper parallel inverter with switch open fault in phase-A of both inverter is shown in Figure-24. Fault is created at 0.35 sec and before fault line currents are normal and during fault, line currents becomes unbalanced in all three phases. Due to parallel connection, upper inverter carries only 15 A that is half the total value before fault but unbalanced during faulty condition.

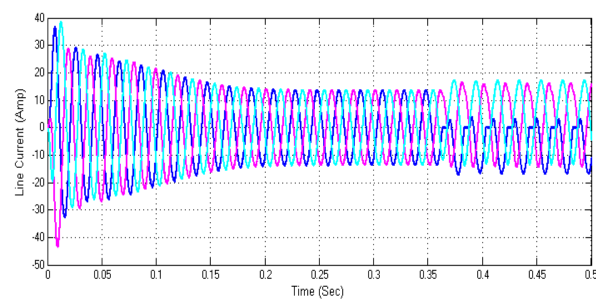

Figure-25. Line current of lower parallel inverter

Three-phase line currents of lower parallel inverter with switch open fault in phase-A of both inverter is shown in Figure-25. Fault is created at 0.35 sec and before fault line currents are normal and during fault, line currents becomes unbalanced in all three phases. Due to parallel connection, lower inverter carries only 15 A that is half the total value before fault but unbalanced during faulty condition.

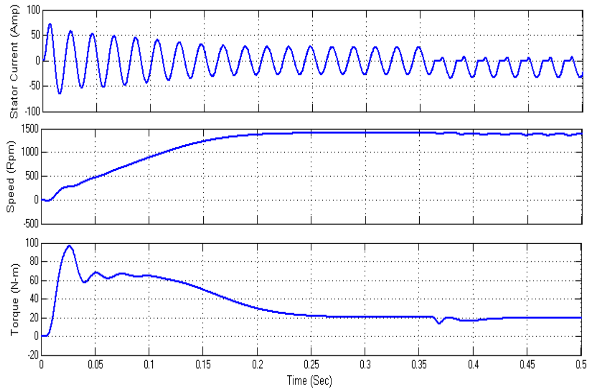

Figure-26. Induction motor characteristics with fault in both DCMLIs.

Induction motor characteristics of stator current, speed and torque characteristics were shown in figure 26. Before fault at 0.35 seconds, stator current is maintained at constant peak of 30 A, speed at 1500 rpm and torque at 20 Nm. During fault condition the characteristics were slightly distorted.

CONCLUSIONS

This paper presents the fault analysis of parallel inverter topology fed induction motor drive. Fault analysis was considered when open switch type of fault in phase-A occur in only one at a time of the two parallel inverters and also considering switch open fault in phase-A on both parallel inverters. Performance of inverter was presented along with the induction motor characteristics. During fault condition, line voltage, phase voltage and line currents of inverter are distorted due to the presence of fault condition in any of the inverter or both. Due to sharing of load, each inverter carries only half the load current which is clearly presented in results.

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