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Simulation Analysis of Three Phase & Line to Ground Fault of Induction Motor Using FFT

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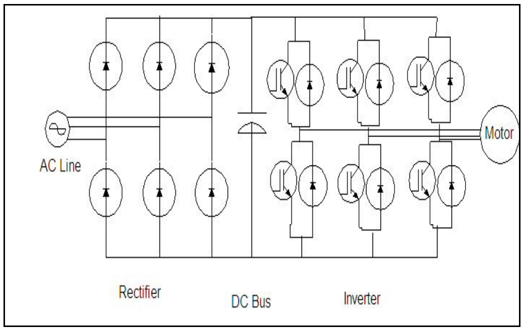
Abstract:
This paper represents the simulation analysis of induction motor drive system. Main objective of this paper is analysis of three phase and line to ground fault of induction motor and harmonic analysis. For control of induction motor number of pulse width modulation scheme are used to for variable voltage and variable frequency supply. Variable frequency Voltage Source Inverters (VSI's) are widely used to control the speed of three phase squirrel cage Induction Motors (IM) over a wide range by varying the stator frequency. In particular the VSI's are widely preferred in industries for individual medium to high power variable speed drive systems, driving a group of motors connected in parallel at economic costs. Here present modeling and simulation of induction motor drive in MATLAB/SIMULINK software. The results of total harmonic distortion (THD), fast Fourier transform (FFT) of motor current obtained in MATLAB/Simulink software.

Keywords*: VSI, FFT, THD*

1. Introduction

Due to rugged, reliable and economical the three-phase squirrel-cage induction motors are widely used in industrial drives and industrial applications. Single-phase induction motors are used for smaller loads. In this research work, detection of common faults of induction motor using signal processing techniques is used. From last few decades, the induction motor has developed gradually from being a constant speed motor to a variable speed, variable torque motor. Its gradual development was challenged by the easiness of controlling a DC motor at low power applications. The induction motor is used, when we required large amount of power and torque application. Now a day the use of an induction motor has increased using variable voltage, variable frequency drives (VVVF). Variable frequency Voltage Source Inverters (VSI's) are widely used to control the speed of three phase squirrel cage Induction Motors (IM) over a wide range by varying the stator frequency. In particular the VSI's are widely preferred in industries for individual medium to high power variable speed drive systems, driving a group of motors connected in parallel at economic costs. Most modern variable frequency drives operate by converting a three-phase voltage source to DC using rectifier. After the power flows through the rectifiers it is stored on dc bus. The dc bus contains capacitors to accept power from the rectifier, stores it, and later deliver that power through the inverter section. The inverter contains transistors that deliver power to the motor. The “Insulated Gate Bipolar Transistor” (IGBT) is a common choice in modern VFDs. The IGBT can switch on and off several thousand times per second and precisely control the power delivered to the motor. The IGBT uses “pulse width modulation” (PWM) technique to simulate a sine wave current at the desired frequency to the motor.



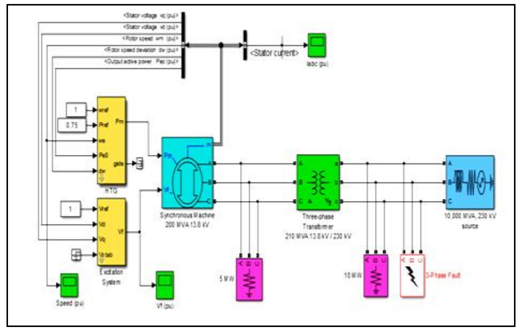
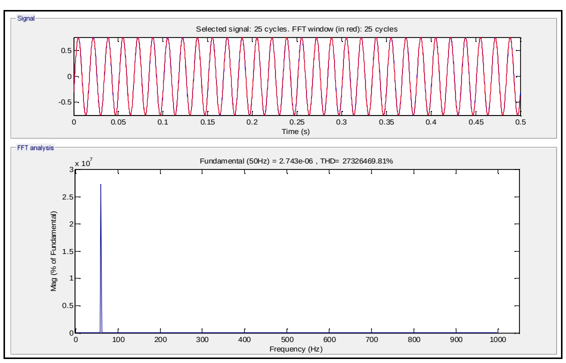


Figure 1: Block diagram of induction motor drive system
Figure 2: Validation of Simulation Model

Present investigations are mainly concerned with constant 'V/f' control operation, which excites the three phase stator winding of induction motor. A simulation model of such induction motor drive system is developed and its dynamic response is verified by observing current, torque and speed responses to establish acceptability of the model. Then a series of simulations are carried out for two different post fault conditions which are: line to ground fault at one of the motor phase terminals and three phase fault. Under these fault conditions time domain and frequency domain analyses are performed for healthy and faulty motor drive. Figure 1 shows block diagram of induction motor drive system [Biswas B. et. al, 2009]. Figure 2 shows the validation of simulation model.

2. Simulation Model

Simulation modeling is the process of creating and analyzing a digital prototype of a physical model to predict its performance in the real world or is the discipline of designing a model of an actual or theoretical physical system, executing the model on a digital computer, and analyzing the execution output. Simulation model of the motor drive system developed in Matlab Simulink has been used for this study as shown in the figure 2. A three phase supply source along with source impedances to make it non-ideal has been included in the model. First stage is an uncontrolled rectifier followed by dc link capacitor and reactor. Induction motor has been controlled by an inverter made of IGBT switches sinusoidal pulse width modulator (SPWM) controller [Jung J. et. al, 2006]. To keep 'V/f' ratio constant, motor terminal voltage magnitude and frequency are adjusted by setting controller parameters. In this model induction motor is subjected to drive a constant torque load. Motor current, voltage, speed, developed electromagnetic torque along with supply main currents are sensed and analyzed [Namburi N. R. et. al, 1985). Appling FFT analysis obtained motor current in frequency domain.



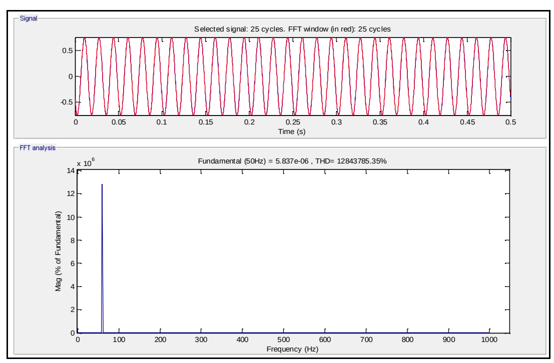
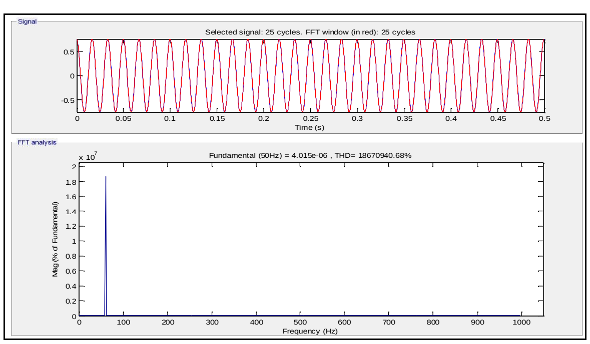


Figure 3: Magnitude vs Frequency plot of healthy induction motor for phase A.
Figure 4: Magnitude vs Frequency plot of healthy induction motor for phase B.



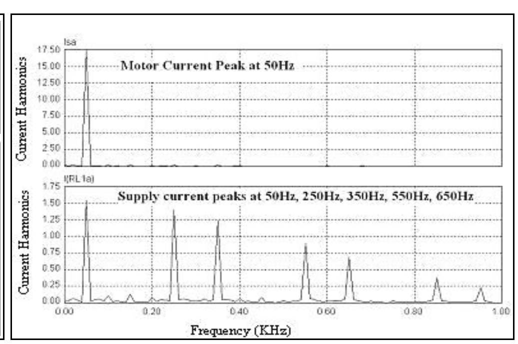


Figure 5: Magnitude vs Frequency plot of healthy induction motor for phase C.
Figure 6: FFTs of motor current and supply current of model

After simulating the model, above profiles can be concluded that the model is unambiguous. For further checking Fourier analysis of motor current and supply current can be analyzed. In the figure 6 FFTs of motor current and supply current of the model is shown. Harmonics that is multiple of two cancels out each other. The same is true for 3rd order harmonics (3rd, 6th, 9th etc.). Because the power supply is 3 phase, the third order harmonics cancel each other out in each phase. This leaves only the 5th, 7th, 11th, 13th etc. The magnitude of the harmonics produced by a VFD is greatest for the lower order harmonics (5th, 7th and 11th) and drops quickly as we move into the higher order harmonics (13th and greater).Hence the simulation model is acceptable and can be considered as a healthy motor-drive system. Figure 3, 4 and 5 shows the magnitude verses frequency plot of healthy induction motor for phase A, B and C. It is total harmonic distortion. It is observed that for healthy induction motor there is only one spike.

3. Conditions under Different Cases

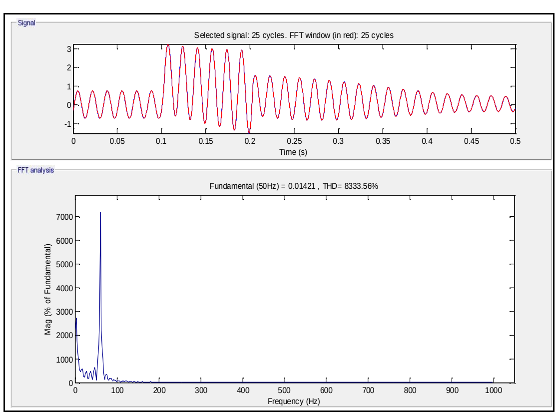
In the present work, simulation studies have been performed on a three phase induction motor. Here the fault conditions in the simulation model are created in the two following ways.

- Line to ground fault at one of the motor phase terminals
- Three phase fault.

Simulation results and analysis of above fault conditions in the simulation model are explain below:

3.1. Case – A: Line To Ground Fault At One Of The Motor Phase Terminals

In this case the analogy applied in the simulation is to make line to ground fault at one of the motor phase terminal. It is also called phase to ground fault. In this type of simulation a switch is introduced in the phase C. Initially the switch is open i.e. phase C is a healthy one. With the help of the Matlab simulink software after the transient period switch is being closed i.e. line to ground fault at Phase C is created. After creating the specified environment matching with case – a, the motor current profiles are recorded. FFT algorithm is applied to motor current profiles for the purpose of frequency domain analysis. The motor current profiles of the three phases are then recorded. First generate phase A phase to ground fault. Figure 7, 8 and 9 shows the FFTs of the induction motor phase A phase to ground fault for phase A, B and C. Similarly figure 10, 11 and 12 shows the FFTs of the induction motor phase B phase to ground fault for phase A, B and C and figure 13, 14 and 15 shows the FFTs of the induction motor phase C phase to ground fault for phase A, B and C.



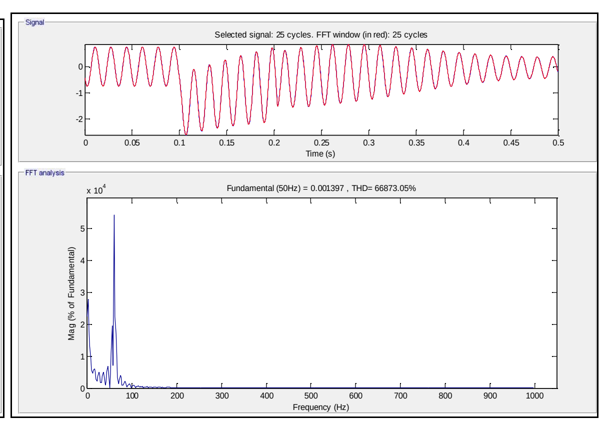
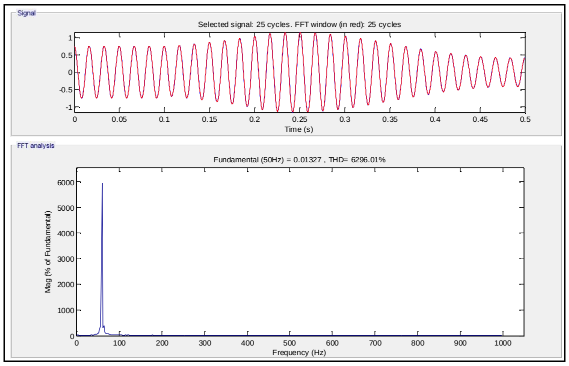


Figure 7: FFTs of the induction motor phase A phase to ground fault for phase A

Figure 8: FFTs of the induction motor phase A phase to ground fault for phase B



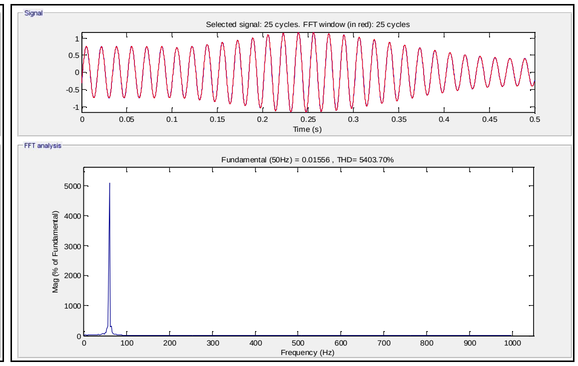
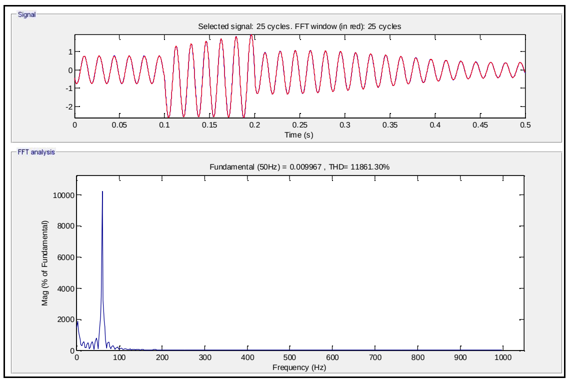


Figure 9: FFTs of the induction motor phase A phase to ground fault for phase C

Figure 10: FFTs of the induction motor phase B phase to ground fault for phase A



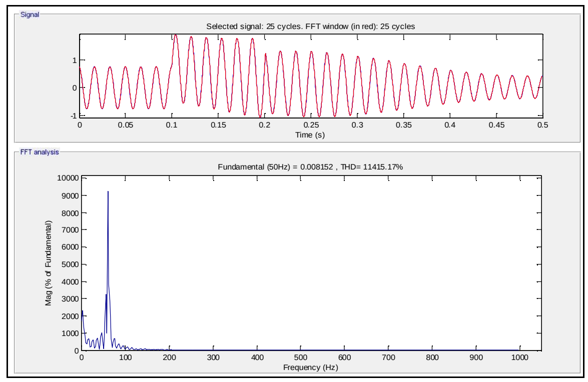
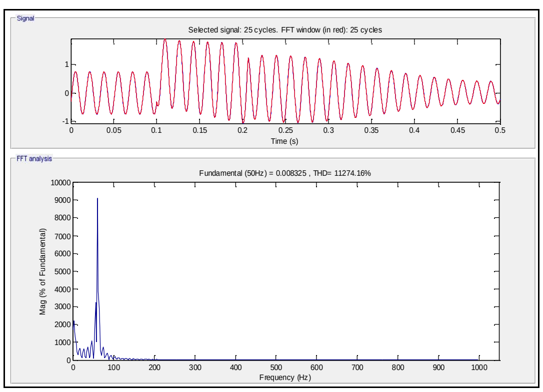


Figure 11: FFTs of the induction motor phase B phase to ground fault for phase B

Figure 12: FFTs of the induction motor phase B phase to ground fault for phase C



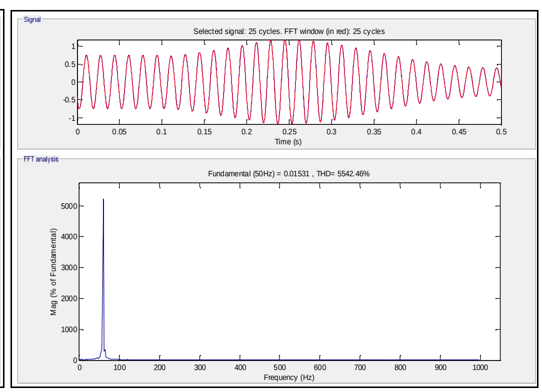


Figure 13: FFTs of the induction motor phase C phase to ground fault for phase A

Figure 14: FFTs of the induction motor phase C phase to ground fault for phase B

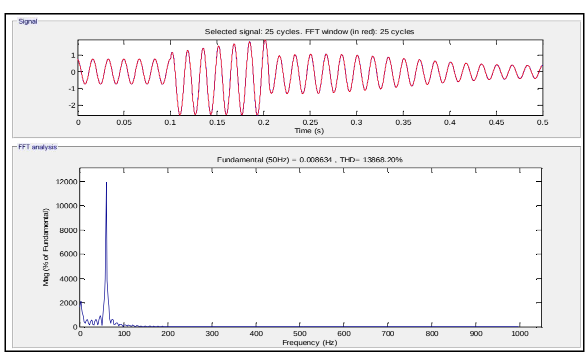
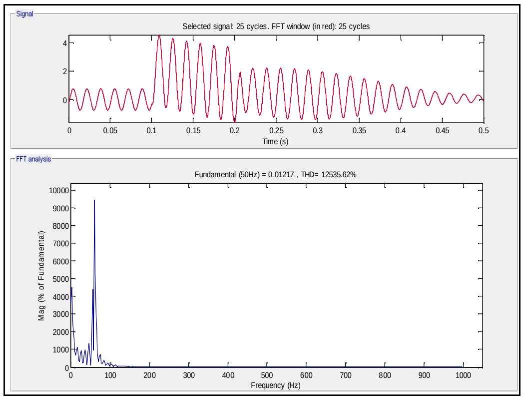


Figure 15: FFTs of the induction motor phase C phase to ground fault for phase C

3.2. Case - B: Three Phase Fault

All the three lines of the motor terminals may get open circuited while the motor is running in steady state condition. When the motor is running under set values of torque, current limit and speed conditions, it may happen that all the three lines of the motor terminals get short circuited. Figure 16, 17 and 18 shows FFTs of the induction motor where all three phase ground fault for phase A, B and C.



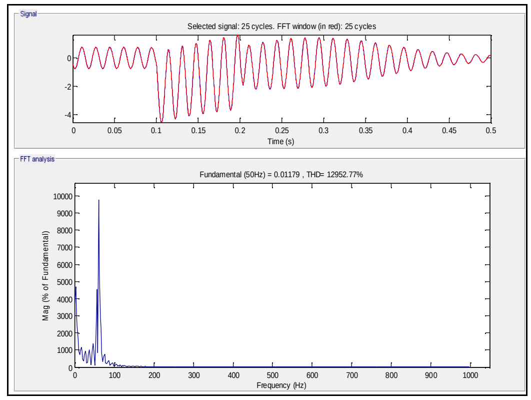


Figure 16: FFTs of the induction motor where all three phase ground fault for phase A

Figure 17: FFTs of the induction motor where all three phase ground fault for phase B

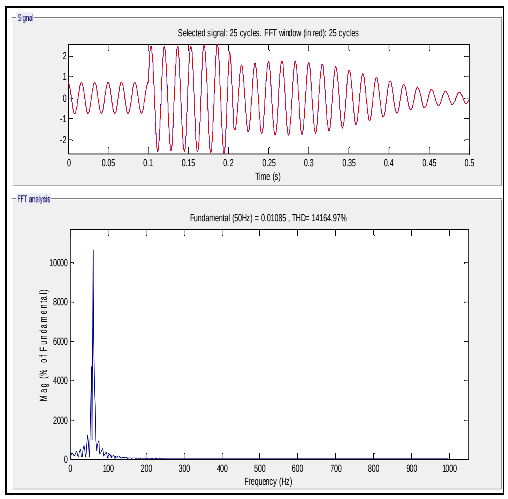


Figure 18: FFTs of the induction motor where all three phase ground fault for phase C

4. Results

Figure 7, 8 and 9 shows the FFTs of the induction motor phase A phase to ground fault for phase A, B and C. Similarly figure 10, 11 and 12 shows the FFTs of the induction motor phase B phase to ground fault for phase A, B and C and figure 13, 14 and 15 shows the FFTs of the induction motor phase C phase to ground fault for phase A, B and C. Figure 16, 17 and 18 shows FFTs of the induction motor where all three phase ground fault for phase A, B and C.

5. Conclusion

Induction motor drive system modeling and then simulation is done in MATLAB/SIMULINK R2012b. From simulation result and their FFT analysis concluded that case – a, it is cleared that for line to ground fault at one of the motor phase terminals i.e. phase B then phase A having single spike and phase B and C consist two spikes. Similarly for phase C then phase B having single spike and phase A and C consist two spikes. Case – b, three phase fault one phase consist one spike and rest of phases having two spikes. Figure 3, 4 and 5 shows FFT of the Healthy motor, which consist only one spike in all phases.

6. Acknowledgment

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7. References

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