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FAULT LEVEL DETECTION OF A THREE PHASE INDUCTION MOTOR USING MATLAB SIMULINK

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Abstract:

This paper present a MATLAB based fault level detection of a three phase induction motor. Because of their simple and durable structure, as well as low production costs, three phase induction motors are employed in a wide range of applications. When it is in use, it is vulnerable to damage due to the defects that may occur. Overcurrent, unbalanced, overvoltage, undervoltage, single phasing, are examples of faults. Induction motors are employed in a wide range of industrial applications. THD (Total harmonic distortion) is also a problem for electrical engineers as it leads to heavy power loss in AC induction motors. These losses in AC induction motors leads to excessive heating, which happens because of additional copper losses and iron losses (eddy current and hysteresis losses) in the stator winding, rotor circuit, and rotor laminations. This causes lots of electrical equipment failure in the plants. The proposed scheme is simulated using MATLAB Simulink. MATLAB simulation results show that the well trained protest scheme is able to detect all types of internal faults and THD at different location.

Keywords: three phase induction motor, fault classification, Proteus environment, THD.

CHAPTER 1

INTRODUCTION

1.1 Overview:

Three phase induction motor are used in many application because of simple and robust structure, and low production cost. It confronts to a damage when it is working, because the faults that may be happen to it. These fault may be overcurrent, unbalanced, overvoltage, under voltage, single phasing, overheat. Induction motors are used in many industrial applications because of their simple and robust structure as well as low production costs. More features are versatility and good self – starting capability. The reliability of an induction motor is of great importance as the motors are frequently exposed to different hostile environments, mis operation and manufacturing defects which results in failures causing industrial production losses. Avoiding the unexpected shutdowns is important task for industries. A fault tolerant control systems to avoid unexpected shutdowns implies early detection and correct diagnosis and classification of fault in early stages. A huge variety of motors are employed for various purposes in our environment, ranging from household appliances to industrial machine tools. In many industries, the electric motor has become a necessary and indispensable source of power. These motors are required to execute a wide range of functions. IM are the most commonly used motor for appliances, induction control, and automation; as a result, they are quiet, dependable, and long-lasting.

Undervoltage, overvoltage, overheating, single phasing, and phase reversal are all common problems with three phase induction motors. The windings of the motor become heated as a result of this electrical problem, which causes insulation failure and reduces the motor's life span. When a three-phase induction motor receives a higher voltage than it is rated for, the motor becomes overheated. When the supply voltage is lower than the rated voltage, the voltage drop across the resistance is greater than the voltage drop across the resistance that protects the motor from this problem. When the supply voltage is lower than the specified value, the voltage drop across the resistance is lower, and the motor fails to start. When supply is only one phase, this is single phasing problem and supply voltage fall the rated and once again motor fails to start. It is highly desired that 3 phase induction motor works freely from the seal types' of faults. This fault is generated in induction motor due to variation in induction motor parameters. When three phase induction motor runs continuously, it is necessary to protect the motor from these anticipated faults.

Harmonic distortion has always been a problem for electrical engineers as it leads to heavy power loss in AC induction motors. These losses in AC induction motors leads to excessive heating, which happens because of additional copper losses and iron losses (eddy current and hysteresis losses) in the stator winding, rotor circuit, and rotor laminations. This causes lots of electrical equipment failure in the plants. At a frequency of 300 Hz and above, these losses increase further high due to skin effect, and the leakage magnetic fields caused by harmonic currents produce additional stray frequency eddy current dependent losses. This considerable amount of iron losses can also be produced in induction motors with skewed rotors due to high-frequency-induced currents and rapid flux changes i.e. due to hysteresis in the stator and rotor.

Excessive heating can worsen the bearing lubrication and complete bearing collapse. Besides, harmonic currents can result in bearing currents, which can be prevented by the use of an insulated bearing which is a very common practice used in AC variable frequency drive-fed AC motors. Overheating imposes significant limits on the effective life of an induction motor. For every 10°C rise in temperature above the rated temperature, the life of motor insulation may be reduced by as much as 50%. Squirrel cage rotors can generally withstand higher temperature levels as compared to wound rotors.

CHAPTER 2

INDUCTION MOTOR DRIVE

Introduction

An induction motor is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding. An induction motor can therefore be made without electrical connections to the rotor. An induction motor's rotor can be either wound type or squirrel-cage type.

Three-phase squirrel-cage induction motors are widely used as industrial drives because they are rugged, reliable and economical. Single-phase induction motors are used extensively for smaller loads, such as household appliances like fans. Although traditionally used in fixed-speed service, induction motors are increasingly being used with variable-frequency drives (VFDs) in variable-speed service. VFDs offer especially important energy savings opportunities for existing and prospective induction motors in variable-torque centrifugal fan, pump and compressor load applications. Squirrel cage induction motors are very widely used in both fixed-speed and variable-frequency drive (VFD) applications.

Principle of operation

In both induction and synchronous motors, the AC power supplied to the motor's stator creates a magnetic field that rotates in synchronism with the AC oscillations. Whereas a synchronous motor's rotor turns at the same rate as the stator field, an induction motor's rotor rotates at a somewhat slower speed than the stator field. The induction motor stator's magnetic field is therefore changing or rotating relative to the rotor. This induces an opposing current in the induction motor's rotor, in effect the motor's secondary winding, when the latter is short-circuited or closed through external impedance. The rotating magnetic flux induces currents in the windings of the rotor; in a manner similar to currents induced in a transformer's secondary winding(s).

The induced currents in the rotor windings in turn create magnetic fields in the rotor that react against the stator field. Due to Lenz's Law, the direction of the magnetic field created will be such as to oppose the change in current through the rotor windings. The cause of induced current in the rotor windings is the rotating stator magnetic field, so to oppose the change in rotor-winding currents the rotor will start to rotate in the direction of the rotating stator magnetic field. The rotor accelerates until the magnitude of induced rotor current and torque balances the applied mechanical load on the rotation of the rotor. Since rotation at synchronous speed would result in no induced rotor current, an induction motor always operates slightly slower than synchronous speed. The difference, or "slip," between actual and synchronous speed varies from about 0.5 to 5.0% for standard Design B torque curve induction motors.[30] The induction motor's essential character is that it is created solely by induction instead of being separately excited as in synchronous or DC machines or being self-magnetized as in permanent magnet motors.

For rotor currents to be induced the speed of the physical rotor must be lower than that of the stator's rotating magnetic field (ns); otherwise the magnetic field would not be moving relative to the rotor conductors and no currents would be induced. As the speed of the rotor drops below synchronous speed, the rotation rate of the magnetic field in the rotor increases, inducing more current in the windings and creating more torque. The ratio between the rotation rate of the magnetic field induced in the rotor and the rotation rate of the stator's rotating field is called "slip". Under load, the speed drops and the slip increases enough to create sufficient torque to turn the load. For this reason, induction motors are sometimes referred to as "asynchronous motors".

An induction motor can be used as an induction generator, or it can be unrolled to form a linear induction motor which can directly generate linear motion.

Synchronous speed

An AC motor's synchronous speed, ns, is the rotation rate of the stator's magnetic field,

$n_s=2f/p$. Where f is the motor supply's frequency, where p is the number of magnetic poles and where ns and f have identical units. For f in unit Hertz and ns in RPM, the formula becomes

For example, for a four-pole three-phase motor, p = 4 and ns 120f/4 = 1,500 and 1800, RPM synchronous speed, respectively, for 50 Hz and 60 Hz supply systems.

The two figures at right and left above each illustrate a 2-pole 3-phase machine consisting of three pole-pairs with each pole set 60º apart.

Slip

Slip, s, is defined as the difference between synchronous speed and operating speed, at the same frequency, expressed in rpm, or in percentage or ratio of synchronous speed. Thus

$S = (n_S - n_r)/n_s$

Where ns is stator electrical speed, nr is rotor mechanical speed. Slip, which varies from zero at synchronous speed and 1 when the rotor is at rest, determines the motor's torque. Since the short-circuited rotor windings have small resistance, even a small slip induces a large current in the rotor and produces significant torque. At full rated load, slip varies from more than 5% for small or special purpose motors to less than 1% for large motors. These speed variations can cause load-sharing problems when differently sized motors are mechanically connected.

What is Total Harmonic Distortion?

Total harmonic distortion is a complex and often confusing concept to grasp. However, when broken down into the basic definitions of harmonics and distortion, it becomes much easier to understand. Imagine a power system with an AC source and an electrical load . Power System with AC source and electrical load Now imagine that this load is going to take on one of two basic types: linear or nonlinear. The type of load is going to affect the power quality of the system. This is due to the current draw of each type of load. Linear loads draw current that is sinusoidal in nature so they generally do not distort the waveform. Most household appliances are categorized as linear loads. Non-linear loads, however, can draw current that is not perfectly sinusoidal . Since the current waveform deviates from a sine wave, voltage waveform distortions are created.

Waveform distortions can drastically alter the shape of the sinusoid. However, no matter the level of complexity of the fundamental wave, it is actually just a composite of multiple waveforms called harmonics. Harmonics have frequencies that are integer multiples of the waveform's fundamental frequency. For example, given a 60Hz fundamental waveform, the 2nd, 3rd, 4th and 5th harmonic components will be at 120Hz, 180Hz, 240Hz and 300Hz respectively. Thus, harmonic distortion is the degree to which a waveform deviates from its pure sinusoidal values as a result of the summation of all these harmonic elements. The ideal sine wave has zero harmonic components. In that case, there is nothing to distort this perfect wave. Total harmonic distortion, or THD, is the summation of all harmonic components of the voltage or current waveform compared against the fundamental component of the voltage or current wave

THD effect on Induction Motor

Harmonics distortion raises the losses in AC induction motors in a similar way as in transformers and cause increased heating, due to additional copper losses and iron losses (eddy current and hysteresis losses) in the stator winding, rotor circuit and rotor laminations. These losses are further compounded by skin effect, especially at frequencies above 300 Hz. Leakage magnetic fields caused by harmonic currents in the stator and rotor end winding's produce additional stray frequency eddy current dependent losses. Substantial iron losses can also be produced in induction motors with skewed rotors due to high-frequency-induced currents and rapid flux changes (i.e., due to hysteresis) in the stator and rotor.

Excessive heating can degrade the bearing lubrication and result in bearing collapse. Harmonic currents also can result in bearing currents, which can be however prevented by the use of an insulated bearing, a very common practice used in AC variable frequency drive-fed AC motors. Overheating imposes significant limits on the effective life of an induction motor. For every 10°C rise in temperature above rated temperature, the life of motor insulation may be reduced by as much as 50%. Squirrel cage rotors can normally withstand higher temperature levels compared to wound rotors. The motor windings, especially if insulation is class B or below, are also susceptible to damage due high levels of dv/dt (i.e., rate of rise of voltage) such as those attributed to line notching and associated ringing due to the flow of harmonic currents.

CHAPTER 3

FAULT DETECTION USING MATLAB SIMULINK PROGRAM

MATLAB program using to analysis the type of fault and what affective of faults in motor and to get a familiarity of it's behave and value. Then use these values as indictors for fault to do the protection system. In this simulation we do all types of electrical fault that may happen in motor. The simulation blocks built is shown in figure . The three phase squirrel cage induction motor under test has the following specifications as shown in table .1.

Table 1: Data and parameters of three phase induction motor

Power rating	2.2 KW	Rated Speed	1440 rpm	Stator Resistance (r_s)	0.435 pu
Line Voltage	400V	Connection	Delta	Rotor Resistance (r_r)	0.816 pu
Rated current	4.6A	Class	E	Mutual Inductance (Xm)	26.13 pu
Frequency	50 Hz	Number of Poles	4poles	Stator and Rotor Leakage Reactance (X_{ls}), (X_{lr})	0.754pu

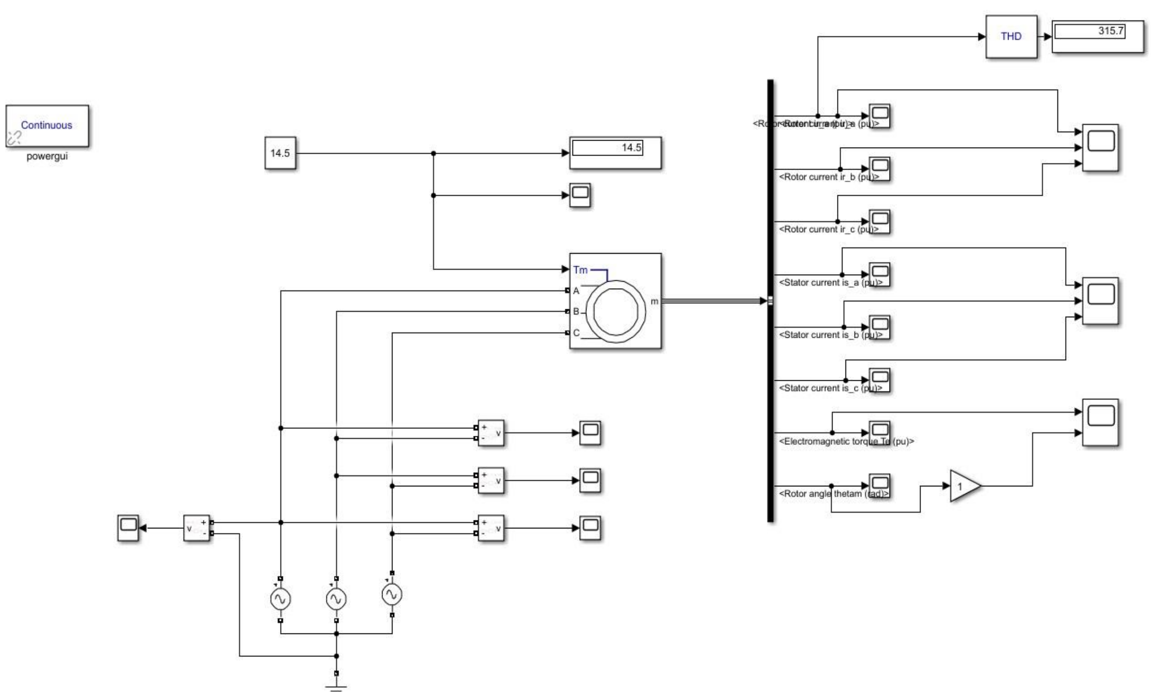

Figure (1): Simulation of induction motor to test the over voltage fault and THD

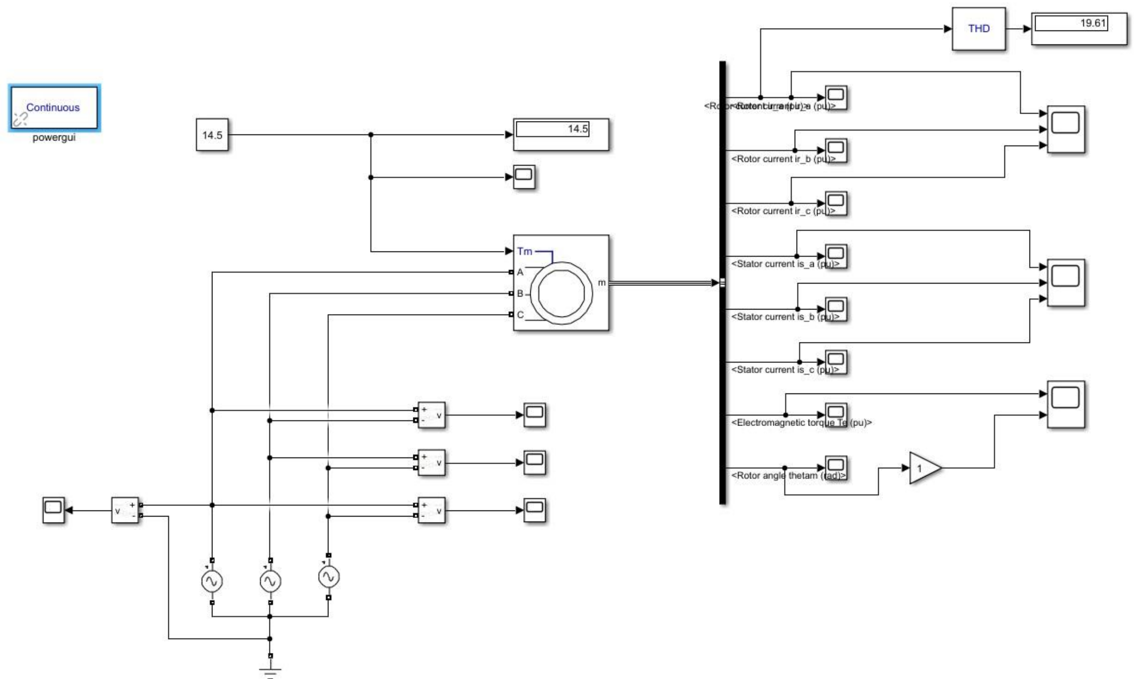

Figure (2): Simulation of induction motor to test the under voltage fault and THD

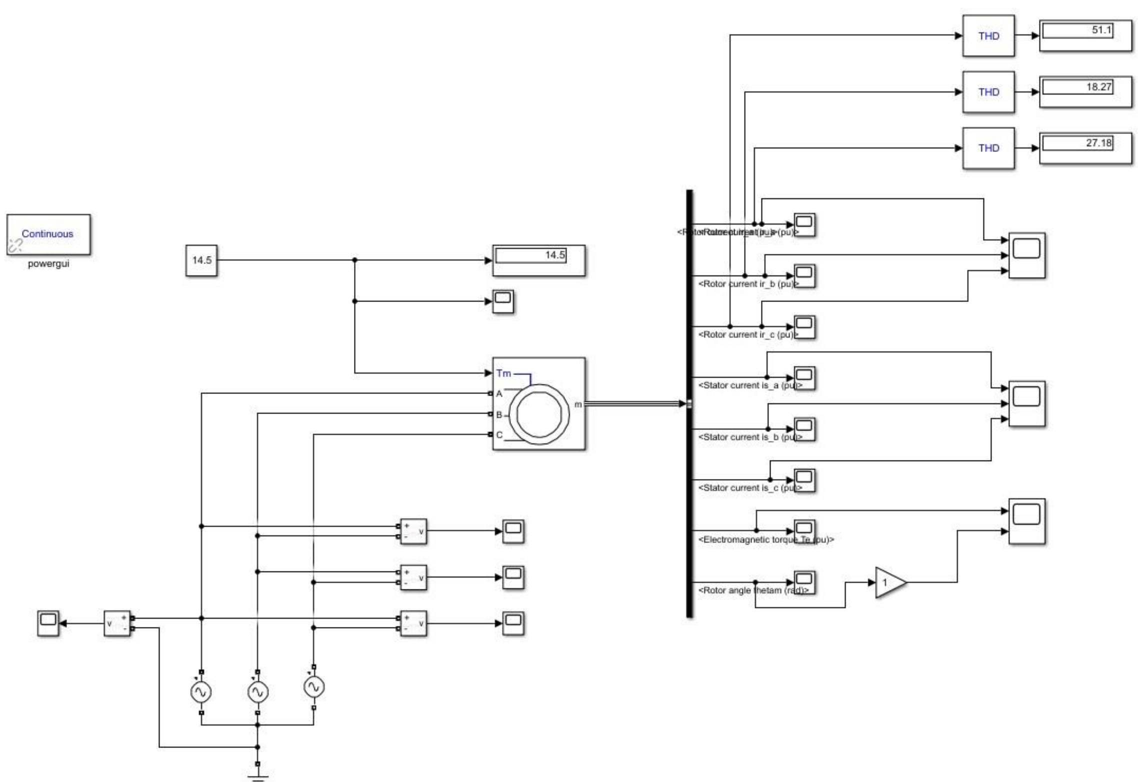

Figure (3): simulation of induction motor to test the single phasing fault and THD at different phases

Important Facts Related to Fault Detection Methods :

i) Balanced over and under voltages

• Efficiency of induction motor decrease with reduced voltages on the induction motor even though all the three phases are balanced.

• When the percentage balanced under voltage (20%), increases the speed decreases drastically with increase in load.

• During balanced over voltage condition, the increase in speed is not proportional to increase in voltage. But increase in motor's temperature

ii) Unbalanced supply voltages:

• Unbalance supply voltage causes the current flow of different magnitudes in all the three phases of induction motor. Hence heat produced in the stator windings and rotor is unequal which leads to failure of stator windings, rotor bars and bearings.

• The ripples in torque increase with increase percentage voltage unbalance (5%).

iii) Single phasing

• During single phasing condition, the losses are more.

• The heat dissipation is heavy which will damage the stator and rotor conductors.

• Also there is heavy pulsation in torque and speed.

iv) Over load

Due to over load, the current drawn by the motor is more and hence more heat dissipation in the motor.

v) Ground fault:

Ground faults produce more thermal stress on the motor and also hazards for human safety.

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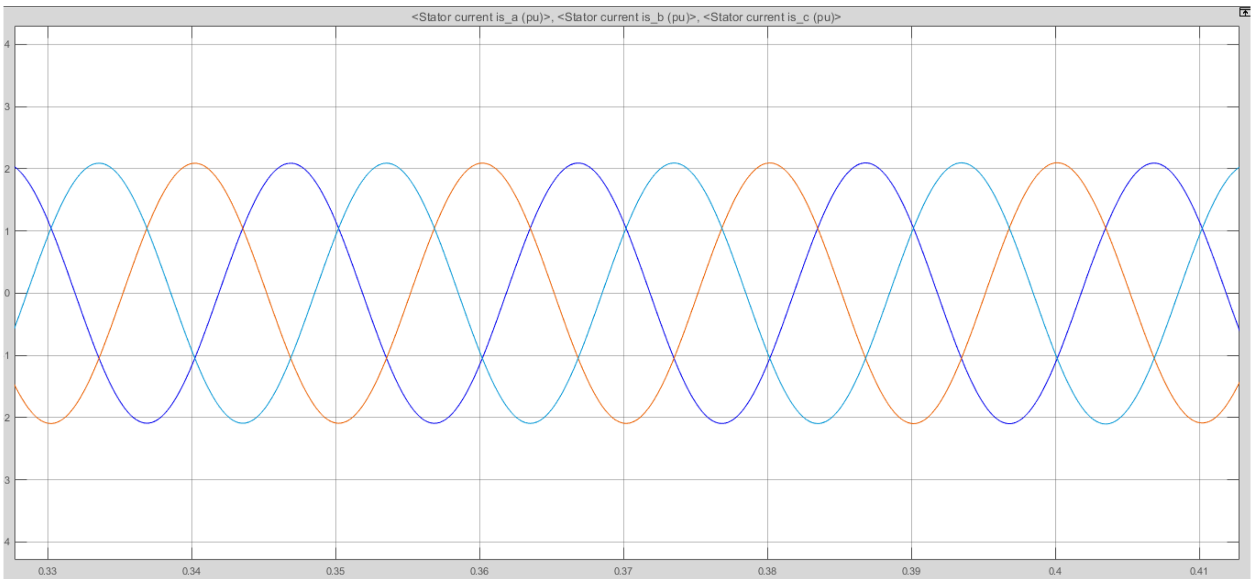
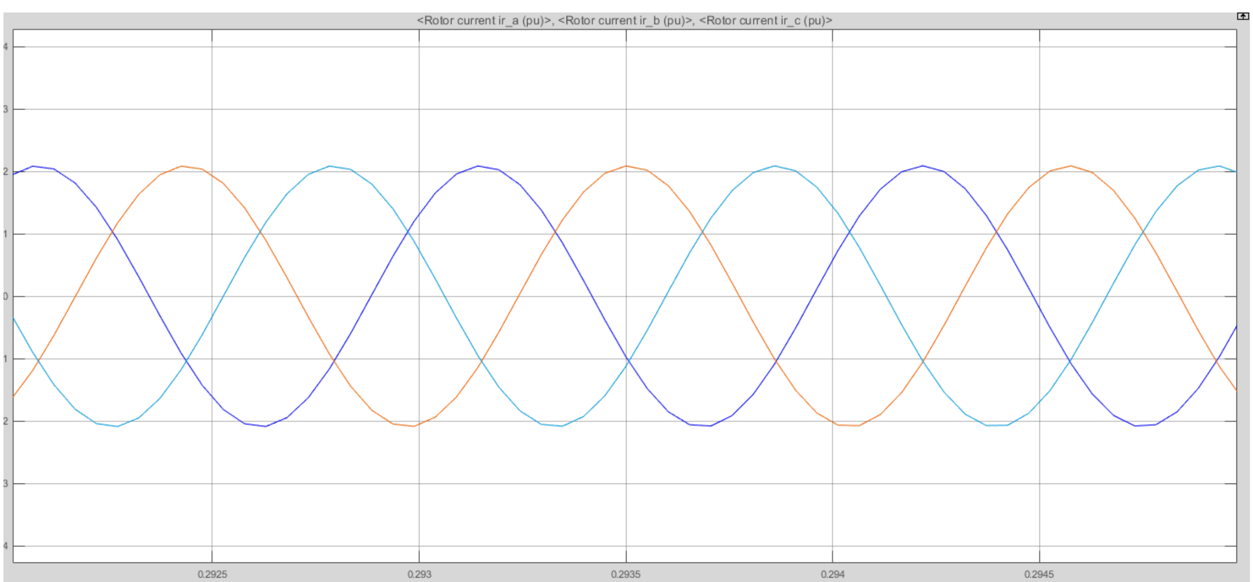
CHAPTER 4

SIMULATION RESULTS

RESULTS

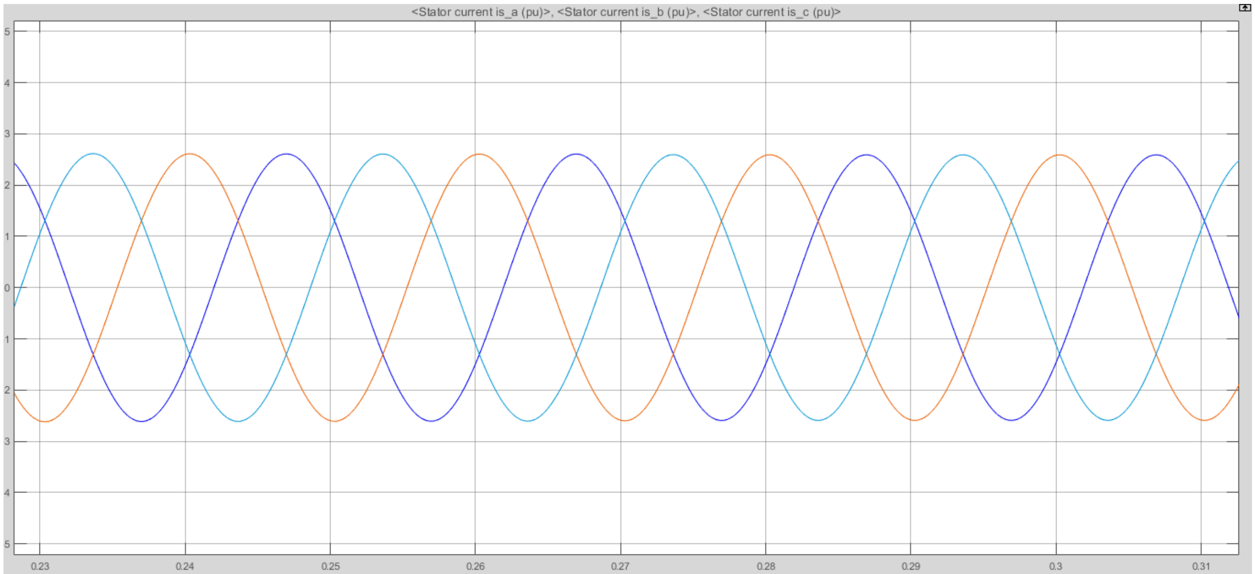


(4.a)

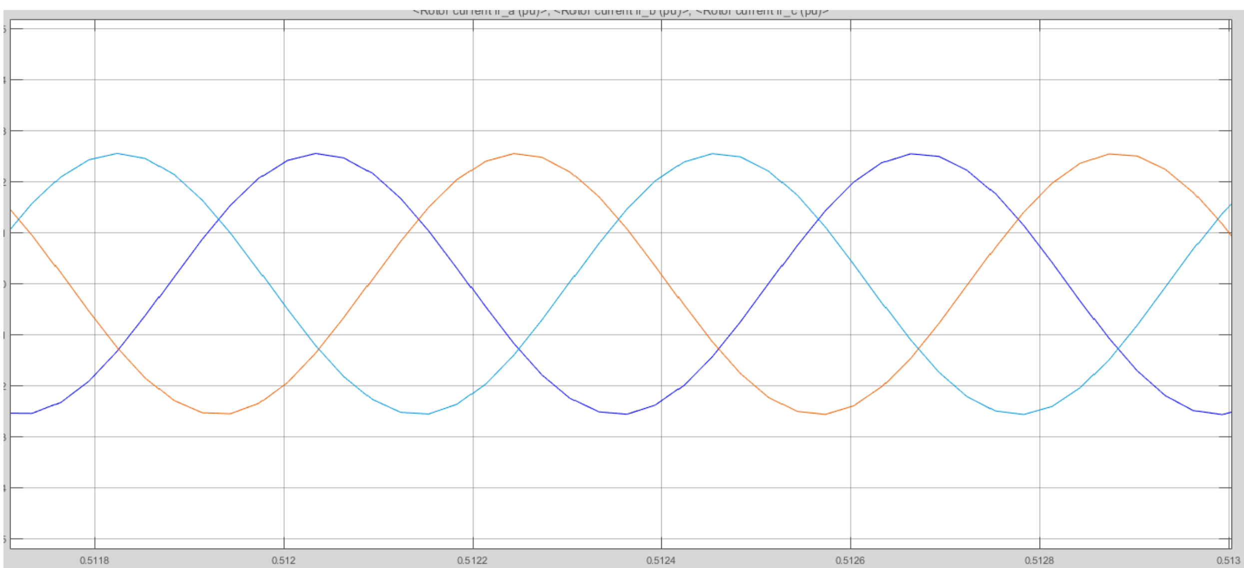


(4.b)

Figure (4): the normal condition (4.a) stator (4.b) rotor

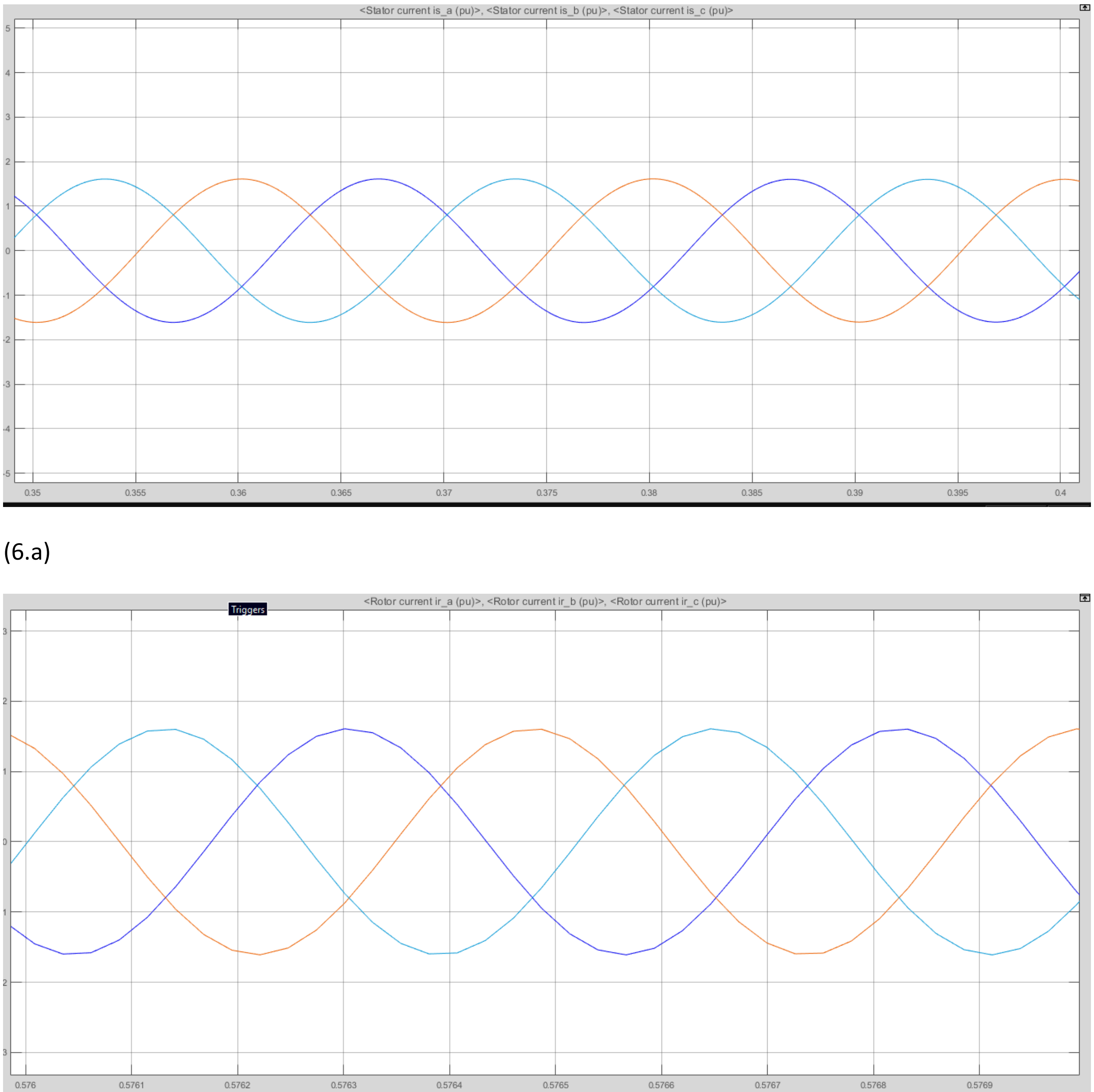


(5.a)



(5.b)

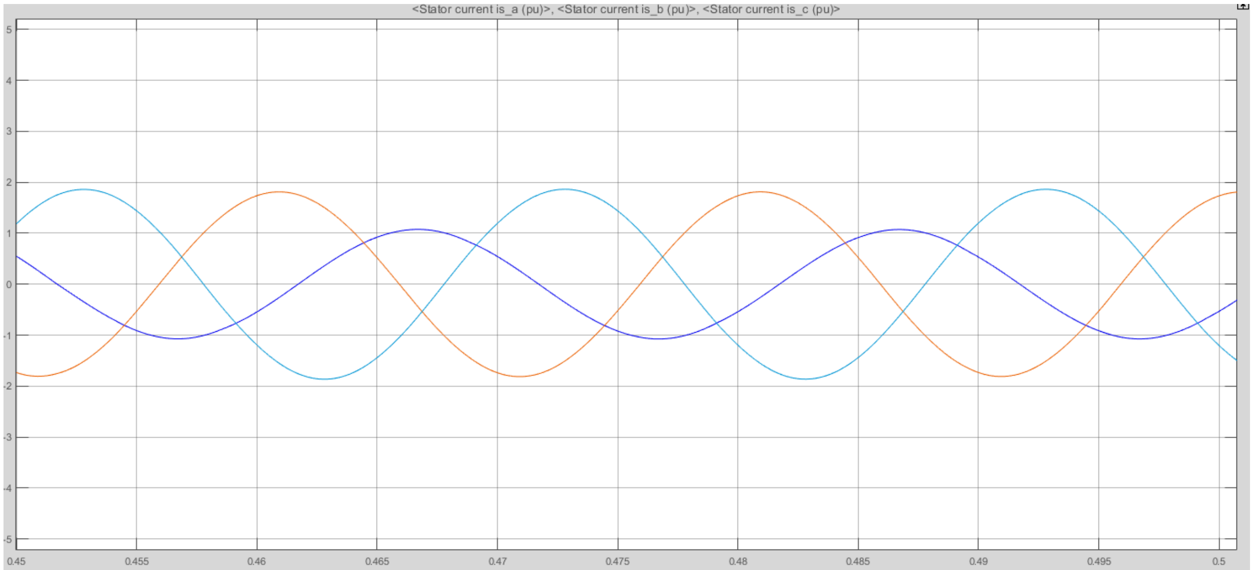
Figure (5): over voltage condition (5.a) stator (5.b) rotor



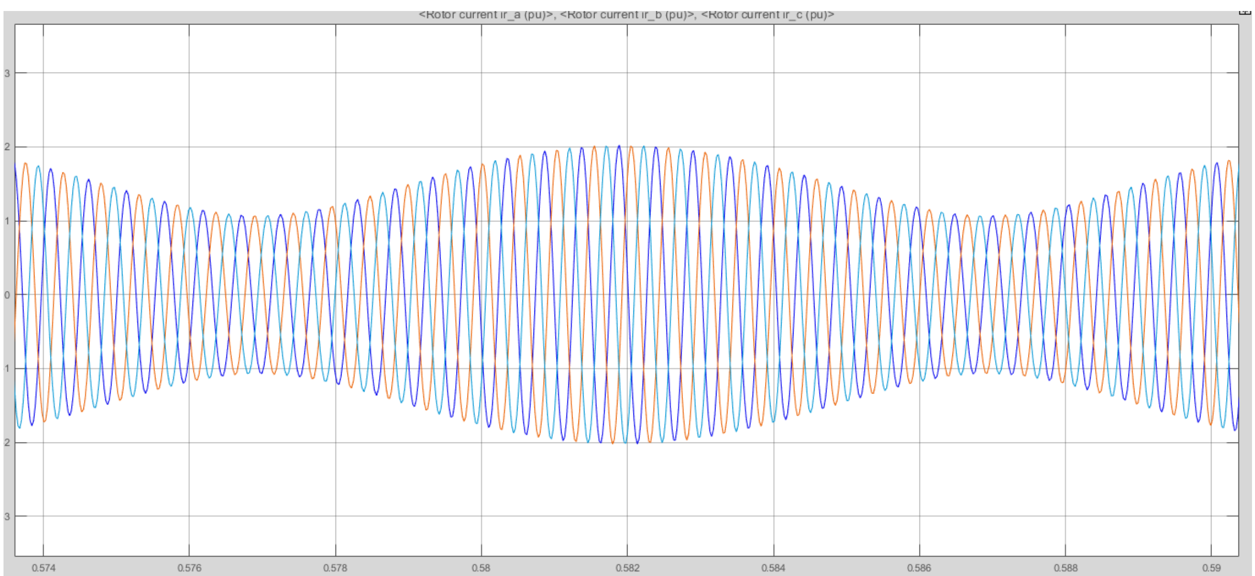
(6.a)

(6.b)

Figure (5): under voltage condition (6.a) stator (6.b) rotor



(7.a)



(7.b)

Figure (6): single phasing condition (7.a) stator (7.b) rotor

Conclusion:

Internal motor faults can cause unbalance in motor performance and failure to motor parts. MATLAB Simulink is used to detect the undervoltage, overvoltage, phasing fault(motor fault detection) and also this simulink can detect the THD at each phase.

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