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# Protection of Three Phase Induction Motor Using Embedded System

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**Abstract:** This paper present a PIC microcontroller – based control system for the protection of a three phase induction motor.The use of microcontroller technology has enabled the design of energy efficient and cost-effective reliable control systems for induction motors. Faulttypes of induction motor likeunbalanced voltage, over voltage, under voltage, over current, phase failure, over heat and more considered in this work. Fault monitoring and diagnosis are performed using proteus environment. Fault classification is achieved through the microcontroller which includes a program for fault classification. When the fault occurs, the microcontroller sends a signal to the interfaced digital relay to trip the motor circuit and another signal to an LCD to display the type of fault. The use of microcontroller reduce the response time of the protection system and make it more suitable for real time operation. The proposed protection scheme is simulated using MATLAB Simulink. MATLAB simulation results show that the well trained proteus scheme is able to detect all types of internal faults at different locations. The microcontroller used in this work is the high performance enhanced flash PIC16F877A Microcontroller of microchip which has an on chip analogue to digital converter peripheral, among other features. The microcontroller is programmed using C and assembly language to control the function digital relay. MATLAB integrated development environment (IDE) is applied for the development of the proposed embedded applications.

**Keywords:** PIC microcontroller, three phase induction motor, fault classification, Proteus environment.

## Introduction

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 .we cannot prevent fault but we can sense it's after it happened to stop it before damage the motor.A microcontrolleris also known embedded controller, is a solitary chip microcomputer developed by VLSI fabrication. Microcontrollers comprise a central processing unit, memory and several peripherals. They are divided into categories according to their memory size, internal architecture, number of bits and instruction sets. The most universally employed sets of microcontrollers include the 8051 family, peripheral interface controller (PIC) provided by microchip technology, advanced virtual RISC microcontrollers(AVR), Among others. Microcontrollers are basically employed to control the functions of embedded systems in various applications like machines, robots, home appliance, motor vehicles or any electric appliance that stores, measures and displays information. One of the most widely used areas of microcontrollers are the parts of the control circuits in industrial automation systems. The input components, such as the sensors of pressure, of level and of temperature are interfaced as peripherals to the input. The driver components of the control circuit such as contactors and solenoid valves are interfaced to the output. Microcontrollers have the advantages of reducing the size, cost and power consumption compared to designs applying separate microprocessor and input – output devices. The features encouraged further evaluation of microcontroller - based approaches in industrial applications like protection of induction motors. 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. A voiding 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.Researchers have studied using microcontroller interfaces and integrated protection architectures to allow a reasonable approach to reduce total system cost and increase overall performancemotor control system. In the following a sample previous research work is illustrated in [1-6], protection of three phase induction motor was doneusing microcontroller, current transformer and step down transformer from single phasing, under voltage, over voltage and over current. The process was monitored by ATmega32 microcontroller. Proposed a technique to protect a three phase 2KW induction motor from single phasing using PIC16F877 microcontroller [7-9]. The values of each phase are sampled and converted to low ac voltage by means of transformer. More recent research can found by [10-12]. This work presents a PIC microcontroller – based digital protection system for three phase induction motor. Fault types of induction motordetection like unbalanced voltage, over voltage, under voltage, over current, phase failure, over heat and more considered in this work. Fault monitoring and diagnosis are performed using proteus environment.

## Fault Detection Using Matlab Simulink Program

MATALAP program using to analysis the type of fault and what affective of faults in motor and to get a familiarity of its behaver 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 blocksbuilt is shown in figure 1.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 |

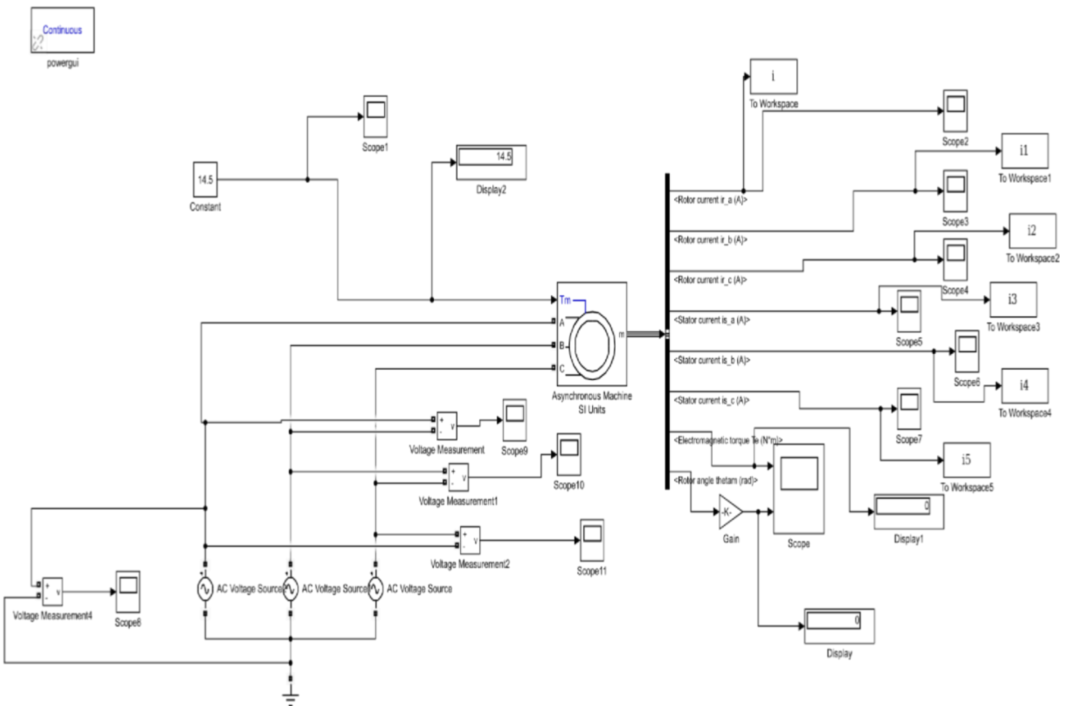
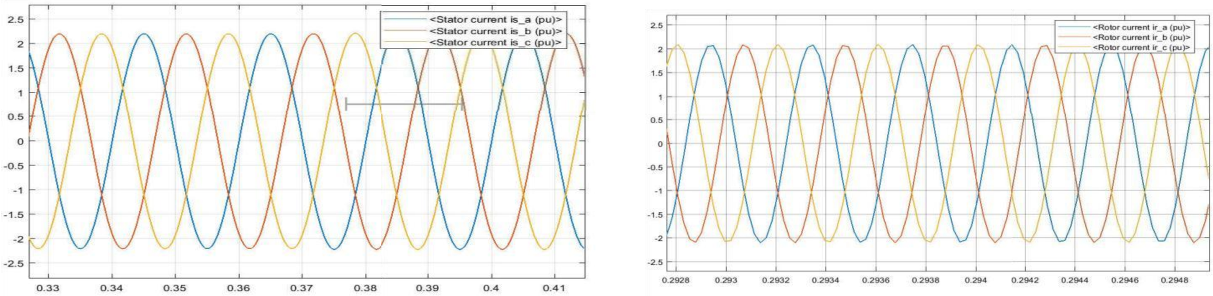


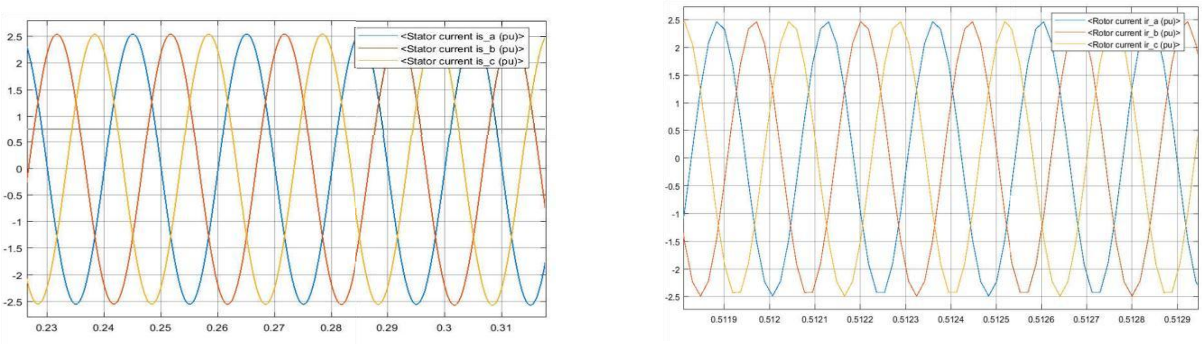

Figure (1): simulation of induction motor to test the fault in MATLAB

Figure 2 show the normal operation stator and rotor currents of induction motor




(2.a) (2.b)

Figure (2): the normal condition (2.a) stator (2.b) rotor

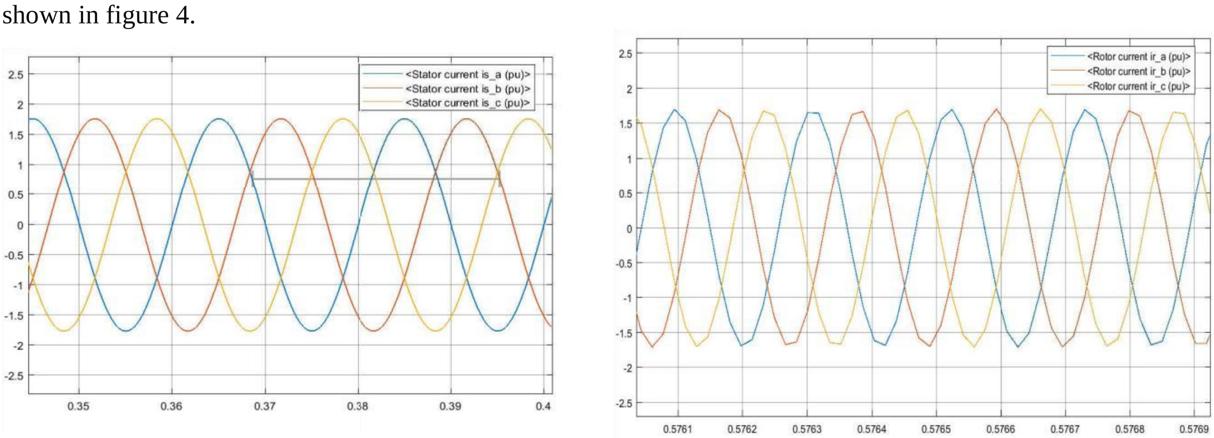



(3.a) (3.b)

Figure (3): over voltage condition (3.a) stator (3.b) rotor

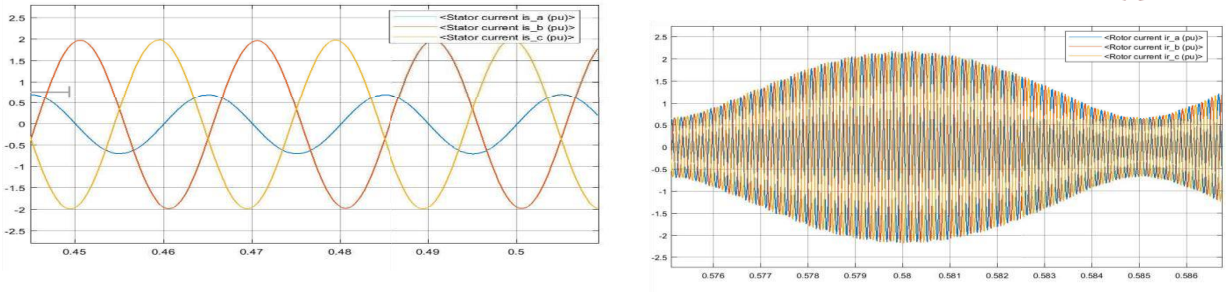
When the voltage increase above the normal operation the currents of stator and rotor are increased as shown in figure3.

When the voltage decrease under the normal operation the currents of stator and rotor are decreased as shown in figure 4.




(4.a) (4.b)

Figure (4): under voltage condition (4.a) stator (4.b) rotor




(5.a) (5.b)

Figure (5): single phasing condition (5.a)stator (5.b) rotor

When single phasing occurred in stator that affective in balanced rotation of rotoras shown in figure 4. The block diagram and schematic diagram for microcontroller based fault classification system are built in proteus Simulink program shown in Fig.6 and Fig.7, respectively. The motor starts at rated condition. The stator currents and line voltages are monitored through current and voltage transformer.

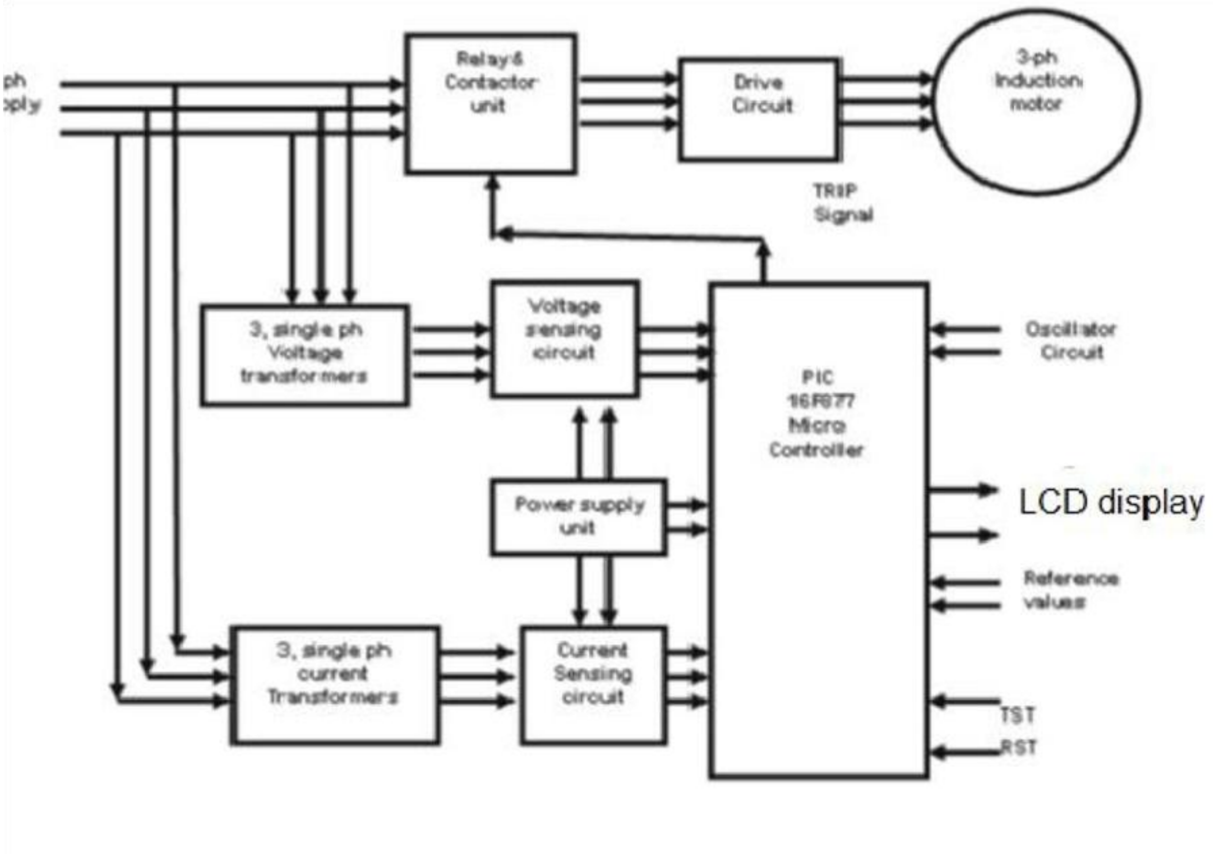



Figure (6): the block diagram for the micro controller based fault classification system.

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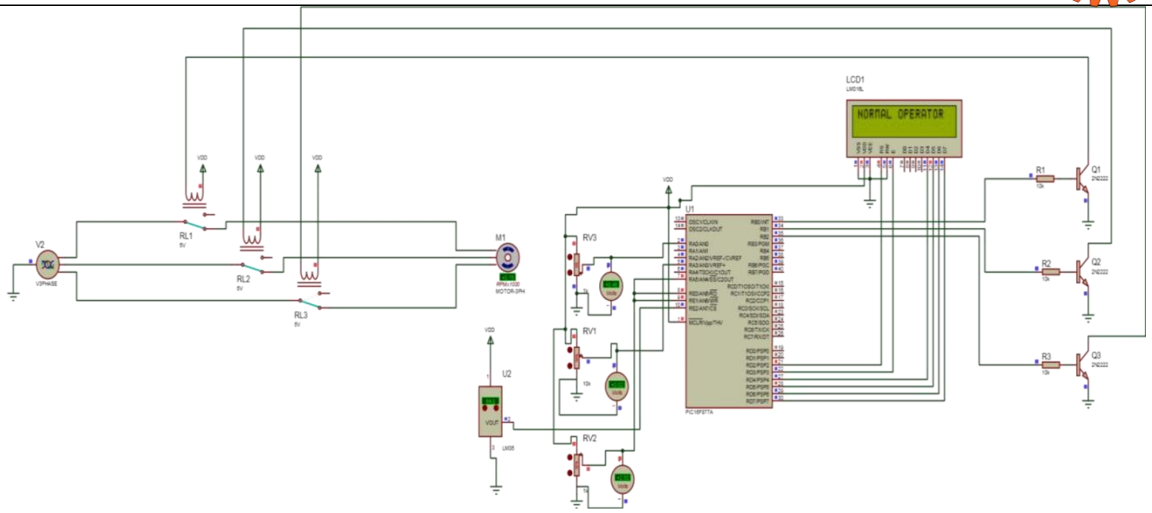



**Figure (7): the schematic diagram for the microcontroller based fault classification system**

## 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 lossesare 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.**

## Software Algorithm

After get know about value of every fault .now we will do strategy to sense the fault then use proper method to protect the motor as shown in figure 8.
A brief description for method control is given in the following:

**Step 1 :** sense the current by current sensor if the current abnormal wait two second (starting current time), then sense again if the current abnormal that mean there is fault , then send signal to circuit breaker to cut the source and show in LCD overcurrent , if the current normal go to next step. Note we start the sense current because we need the time of starting not exceed time of starting.

**Step 2:** sense the current of neutral, if it is abnormal the current cut the source and shown in LCD unbalanced. If the current normal go to next step.

**Step 3:** sense the voltage if the voltage less than 80% of rated voltage cut the source and show in LCD under voltage. if the voltage more than 110% of rated voltage the source is cut and show in LCD over voltage. If the voltage more 80% and under 110% of normal voltage go to next step

**Step 4:** sense the temperature sensor if the temperature is abnormal the source is cut and shown in LCD, if the temperature normal shown in LCD normal operation and go to first step.
By this strategy that shown in steps and figure 6 we design code in C language and load it programmable integrated circuit (PIC) to do the protection.

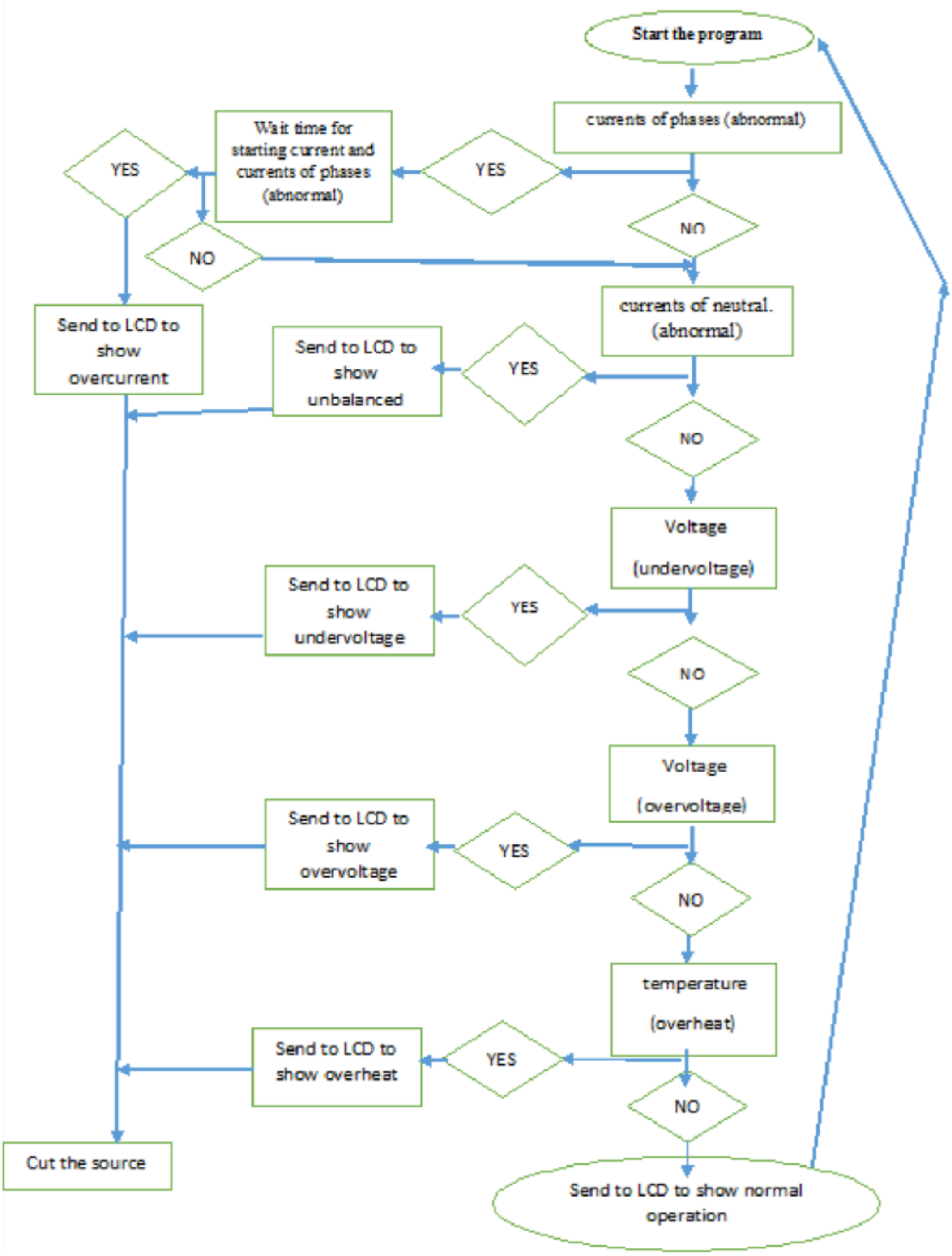



Figure (8): Flow chart of control method

## Results and Discussion

An extensive series of simulation studies have been carried out to obtain various motor faults for analysis Matlab/Simulink. The microcontroller unit performs fault classification and delivers a signal to the relay to trip the motor according to the fault conditions. It should be noted that for each protection scheme, the time delay and setting values could be individually adjusted according to rating and characteristic of the protected motor, taking into account coordination between different protection schemes.

The comparative between standers values and the values from MATLAB simulation as shown in table 2.

Table 2: observation from fault analysis in MATLAB simulation

| **Faults** | **MATLAB Value** | **Standers Value** |
|---|---|---|
| Unbalanced Supply Voltage | 1% to 5% | 1% to 5% |
| Current Unbalance | Up to 45% | Up to 40% |
| Over current | 2 Times rated current | 1.5 Times rated current |
| Single Phasing | Motor will run up to 75 % of its rated Load. | Not Permitted |
| Under Voltage | Up to 30% | Up to 20% |
| Over Voltage | Up to 20% | Up to 10% |
| Ground Fault | Up to 2A | Up to 1 A |

From table2 above when by providing different magnitude of voltages from (1%to5%)of rated value in all the three phases of supply, the Voltage unbalance is occurred, this will rise in the temperature of motor and Increase in stator and rotor copper losses.Over load is occurred when Anyone of phase current is greater than the1.5% of ratedvalue, this rising in current will doing failure in insulation of winding .Providing phase voltage less than the 20% of rated value voltage, the Under voltage is occurred that cause increase in temperature and motor heating and a reduction in overall motor performance. Providing phase voltage greater than 10% of the rated value that cause increase in current. Alsoanyone of the phase is cut down or anyone of the phase voltage is zero. The Single phasing is occurred, When the motor is single phased, the current in the remaining two phases increase to 173% of normal current.

The maximum allowable under voltage unbalance and over voltageunbalance is 5%. When the limits are exceeded, controller generates tripsignal, which in turn switch off the induction motor and display warningmessage as unbalanced voltage fault and hence induction motor is protectedfrom heavy unbalancing condition.

## Overcurrent Condition

When there is fault occurred,the current will be more normal and the protection wait two second (starting time ) and sense again if the rising in current is still the protection response as shown in figure 9.

It is observed from fig (9) the signal trip time of fault sensitivity of over current is 0.55 second. The time of fault line trip signal is (0.67+ 2) =2.67second.

Div./1.00v

Div./250ms

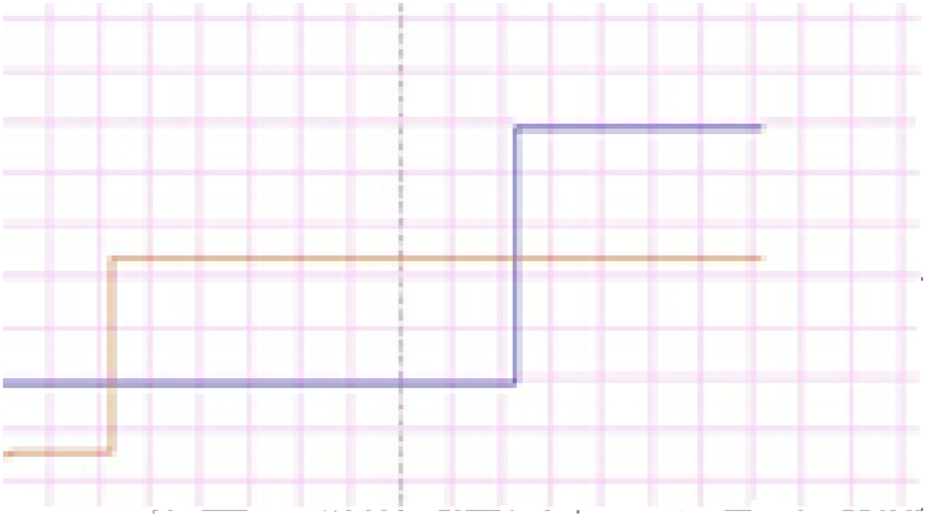
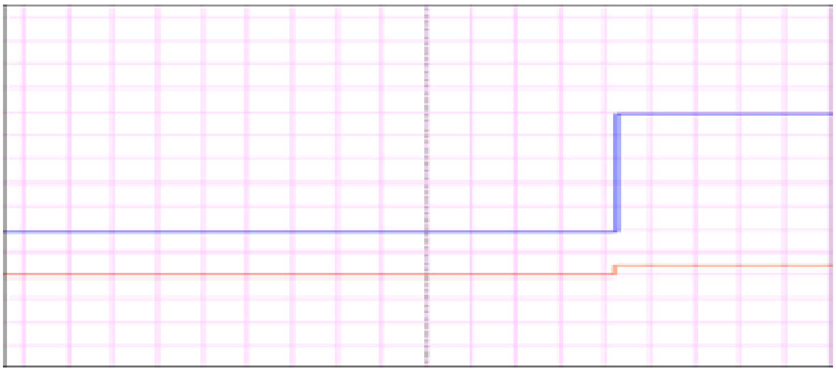


Figure (9):
overcurrent condition of signal trip (red signal sensor) and line trip(blue line sensor)

**Unbalanced Condition:**

In this condition there is currentflow inneutral more normal value theEmbedded sense fault and cut the source and show in LCD unbalanced as Shownin figure 10. Fig (10) shows that signal trip time of fault sensitivity of unbalanced is 3.4 second and the time of fault line trip signal is 3.52second.

Div./1.00v



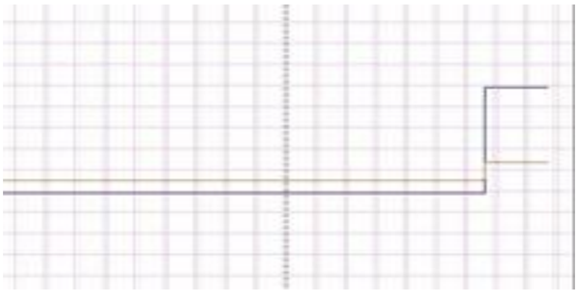
Div./250ms

**Figure (10): unbalanced condition of signal trip (red signal sensor) and line trip(blue signal sensor)**

**Overvoltage:**

In this condition there is overvoltage more normal value the embedded sense fault and cut the source and show in LCD unbalanced as shown in figure 11. Fig (11.a) shows that of signal trip that the time of fault sensitivity of overvoltage is 4 second and the time of fault line trip signal is 4.125 second.

div/1v.



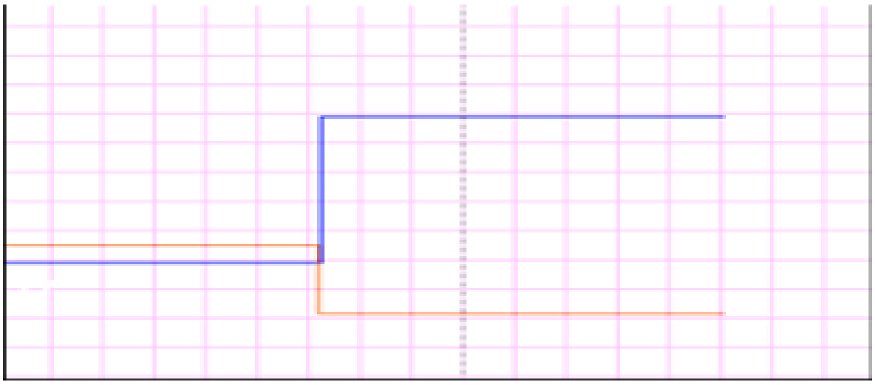
Div./250ms

Figure (11): overvoltage condition **of signal trip (red signal sensor) and line trip(blue signal sensor)**

## Under voltage:

In this condition there is under voltage more normal value the embedded sense fault and cut the source and show in LCD unbalanced as shown in figure 12.Fig (12.a) shows that signal trip that the time of fault sensitivity of under voltage is 1.55 second and the time of fault line trip signal is 1.67 second.

div./1v



Div./250ms

Figure (12): under voltage conditionof signal trip (red signal sensor) and line trip(blue signal sensor)

## Overheat:

In this condition there is temperature more normal value the embedded sense fault and cut the source and show in LCD unbalanced as shown in figure 13. ) shows that signal trip that the time offault sensitivity of overheat is 1.75 second and the time of fault line trip signal is1.87second.

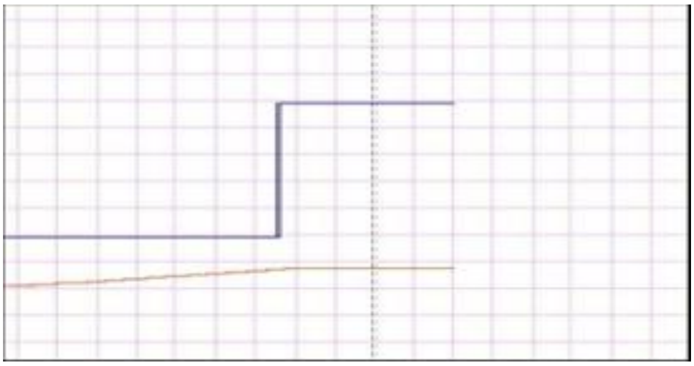


Figure (13): overheat condition of signal trip (red signal sensor) and line trip(blue signal sensor)

## Conclusion:

External motor faults can cause unbalance in motor performance and failure to motor parts. In this study, a microcontroller – based protection system for three phase induction motor during external fault condition has been proposed. MATLAB Simulink is used for motor fault detection. The monitoring and operational diagnosis of three phase induction motor was achieved by using eight output. PIC microcontroller is used for fault classification and control to tripping the motor circuit through the interfaced digital relay.The application of microcontroller decrease the response time, very fast and low cost of the protection system. The measurement of electrical quantities itself give sufficient information about the fault mode behavior of induction motor. The method is simple and reliable compared to invasive technique of fault analysis. The proposed protection system can develop in easy way be change the coding and use for wide range of motor by small change in coding. The proposed protection system works with any motor design up to 200 A at full load condition, and provides a high degree of accuracy. By providing suitable current transformers and potential transformers, the range of the relay can be extended for high capacity motors. The method is very sensitive, fast and detects faults while running and before start.

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