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MICROCONTROLLER BASED FAULT DETECTION AND PROTECTION OF THREE PHASE INDUCTION MOTOR AGAINST ABNORMAL CONDITIONS

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Abstract
The three phase induction motor is a very important electrical device in the present period of automation. These motors are commonly used in industrial drive because they are simple to construct, reliable, cheap and easy to operate. However, the induction motors experience electrical faults like over voltage, overcurrent, under voltage, overload, unbalanced voltage, phase reversing and single phasing. These electrical faults result in the heating of the motor's windings which leads to reduction in its efficiency and life span. The motor needs to be protected against these electrical faults in order to prevent it from being damaged. In this paper, a new technique for the protection of three phase induction motor, using a microcontroller is introduced. A self-diagnosis which informs that a problem has occurred and by which parameter is implemented. Experimental results show that microcontroller based hardware system provides higher accuracy. And when compared with conventionally protected induction motor, the motor efficiency and power factor showed improvement.

Key words: Induction Motor, Microcontroller, Overvoltage, Overcurrent

I. INTRODUCTION

Because the induction motor is rugged in construction and its operation is easy, it is employed in most manufacturing industries to drive loads. But, the three phase induction motor generally suffers from under voltage, overvoltage, overheating, single phasing and phase reversal problems. The life of the motor may be reduced by 50% if it is allowed to reach and operate at a temperature above its maximum rating [1]. The life of electric motor is considered to be about 20 years.

Overloads: overload will result in overcurrent, and if allowed to continue for a long time will cause the temperature of the motor to rise. The result will be the eventual failure of the insulation of the motor.

Single phasing: single phasing is said to occur when there is supply in only one phase and the supply voltage is lower than the specified value. The motor will not start on this value of voltage.

Under-voltage / Over-voltage Protection: Electric motors are designed to operate within a specific voltage range, and any voltage outside that range will cause problems that shorten their service life.

It is required that three phase induction motor works be well protected against all types of faults. Therefore, they are equipped with a protection circuit immediately disconnects the equipment if the voltage outside the range the motor is designed for.

The methods for detection and protection of induction motors are many. Among such methods are artificial neural network and programmable logic controller (PLC) based systems [4]. The objective of this paper is to develop a cheap and reliable microcontroller based protection system since parametric monitoring using microcontroller eliminates the use of additional sensors unlike the some condition monitoring controls like vibration monitoring, thermal monitoring, chemical monitoring etc, which requires specialized tool and sensors which are costly.

This microcontroller based protection system detects and controls the three phase induction from electrical faults.

II. PRINCIPLE OF OPERATION OF THREE PHASE INDUCTION MOTOR

An induction motor consists of two parts: the stator and the rotor. The stator core is built of sheet-steel laminations that are supported in a frame [5].

The windings are placed in the stator slots 120 electrical degrees apart. Windings may be connected in “star” (or wye) or delta configuration [5].

A Cutaway of a typical 3-phase AC motor is shown in Fig.1.

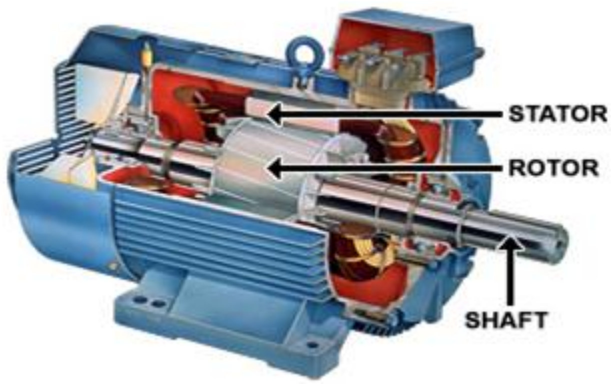

Fig.1. Cutaway of a Typical 3-Phase AC Motor

The rotor of the induction motor is made of a laminated core with conductors placed parallel to the shaft. The rotor conductors are embedded in the surface of the core, and are insulated from the core, because rotor currents follow the "least resistance" path. The rotor conductors are shorted by end rings at both ends [1]. Rotor of a Squirrel Cage Motor is shown Fig.2.

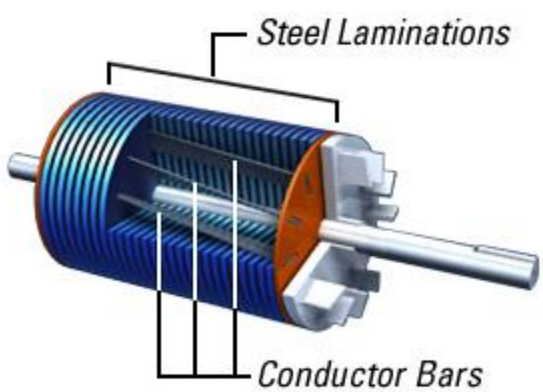

Fig.2. Rotor of a Squirrel Cage Motor

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When the stator windings of an induction are connected to a three-phase power, a rotating magnetic field ensues as a result of current through it coils in a speed that corresponds to the frequency of the supply voltage connected to the stator. If the rotating magnetic field creates a pair of poles (N, S) on the stator surface, this corresponds to one cycle of the alternative current AC. In this case the number of pole pairs (P) equals

$$f_1 = \frac{n_1}{60} \qquad (1)$$

If the stator has a number of pole pairs (P>1), then the rotating magnetic field frequency will be larger by a factor of (P) [3]. This means that the axis of the rotating magnetic field will revolve 360 degrees for every (P) number of the AC cycle as shown in the equations 2 and 3

$$f_1 = \frac{p \text{ x } n_1}{60} \qquad (2)$$

Then

$$n_1 = \frac{60 \text{ x } f_1}{p} \qquad (3)$$

The rotating magnetic field passes through the stator and the rotor windings, inducing electromotive forces (E_1, E_2). Since the rotor windings are connected to form a closed circuit, a current (I_2) passes through those windings [3].

As a result of the interaction between I_2 and the rotating magnetic field, mechanical forces and electromagnetic torques comes into existence. These forces and torques revolve the motor at a speed n (rpm), which has the same direction as the magnetic field created by the flow current through the stator windings [3].

The values of E_2 and I_2 and their frequencies depend on the speed of the interaction between the rotating magnetic field and the rotor windings. The speed (n) is less than (n_1) due to the losses in the rotating magnetic field spent to overcome the various losses in the machine.

The frequency of (E_1, E_2) depends on the deference between the synchronous speed (n_1) and the motor speed (n) which is called the slip (S) as shown in the equation 4

$$S\% = \frac{n_1 - n}{n_1} \text{ x } 100\% = \frac{\omega_1 - \omega}{\omega_1} \text{ x } 100\% \qquad (4)$$

Where:

($\omega 1$) is the electrical angular speed of the magnetic field rotation and is given by

$$\omega_1 = \frac{2\pi n_1}{60} \text{ x P } = 2\pi \text{ x} f_1 \quad (5)$$

ω is the electrical angular speed of the rotor . Therefore

$n = (1 - s)\, n_1$ (6)

$\omega = (1 - s)\, \omega_1$ (7)

The rotor does not revolve synchronically with the magnetic field ($n \neq n1$) hence is called Asynchronous motors. This type of motor is also called "induction motor because the current that passes through the rotor is created in an inductive way that is not given from an external source [7].

III. MOTOR PROTECTION OVERVIEW

Any motor failure will have the following cost contributors: repair or replacement, removal, installation and loss of production. Most of the motor failure contributors and failed motor components are related to motor overheating. Thermal stress can potentially cause the failure of all the major motor parts: stator, rotor, bearings, shaft and frame [8].

When motor is overhead, the two main risks are stator windings insulation degradation and rotor conductor melting. When motor operating temperature exceeds its thermal limit by 10^0C the insulation lifetime of the motor decreases by half [3]. Many factors can lead to the damage of three induction motors. These damage are consequences of operating conditions or internal and external faults. Some of the external faults and operation conditions are undervoltage, asymmetrical loading, phase and ground faults on the motor feeder and overloading during starting and running operation. While Internal faults include: ground faults, faults between windings and inter-turn faults [3].

IV. MOTOR FAILURE RATE AND COST

Motor failure rate is conservatively estimated as 3-5 % per year [8]. A motor failure divides in three groups.

Electrical 33%

Mechanical 31%

Environmental, maintenance and others 36%

The summary of motor failure rate and cost is given in table 1

IEEE STUDY		EPRI STUDY		AVERAGE
FAILURE CONTRIBUTOR	%	FAILED COMPONENT	%	%
Persistent overload	4.20%	Stator Ground Insulation	23.00%	Electrical related failure 33%
Normal Deterioration	26.40%	Turn insulation	4.00	
		Bracing	3.00	
		Core	1.0	
		Cage	5.0	
Electrical Related Total	30.60%	Electrical Related Total	30.00%	
High Vibration	15.50%	Sleeve Bearings	16.00	Mechanical Related Failure 31%
Poor Lubrication	15.20%	Antifriction Bearings	8.00	
		Trust Bearings	5.00	
		Rotor Shaft	2.00	
		Rotor Core	1.0	
Mechanical Related Total	30.70%	Mechanical Related Total	30.00%	
High Ambient Temperature	3	Bearing seals	6.00	Environmental, maintenance and others Reasons Related Failures 36%
Abnormal moisture	5.8	Oil Leakage	3.00	
Abnormal Voltage	1.5	Frame	1.00	
Abnormal Frequency	0.6	Wedge	1.00	
Abrasive Chemicals	4.2			
Poor Ventilation Cooling	3.0			
Other Reasons	19.7	Other Reasons	31	
Environmental Related & Other Reasons: Total	38.70%	Environmental Related & Other Reasons: Total	32.00%	

Source: Craig Wester GE Multilin: Motor Protection Principles.

V. THE PROPOSED SYSTEM

The hardware requirements of this project include op-amps, resistors, capacitors, diodes, thermistor, transformers, relays, microcontroller. The protection system for 3-phase induction motor is represented by the block diagram in Fig.3.

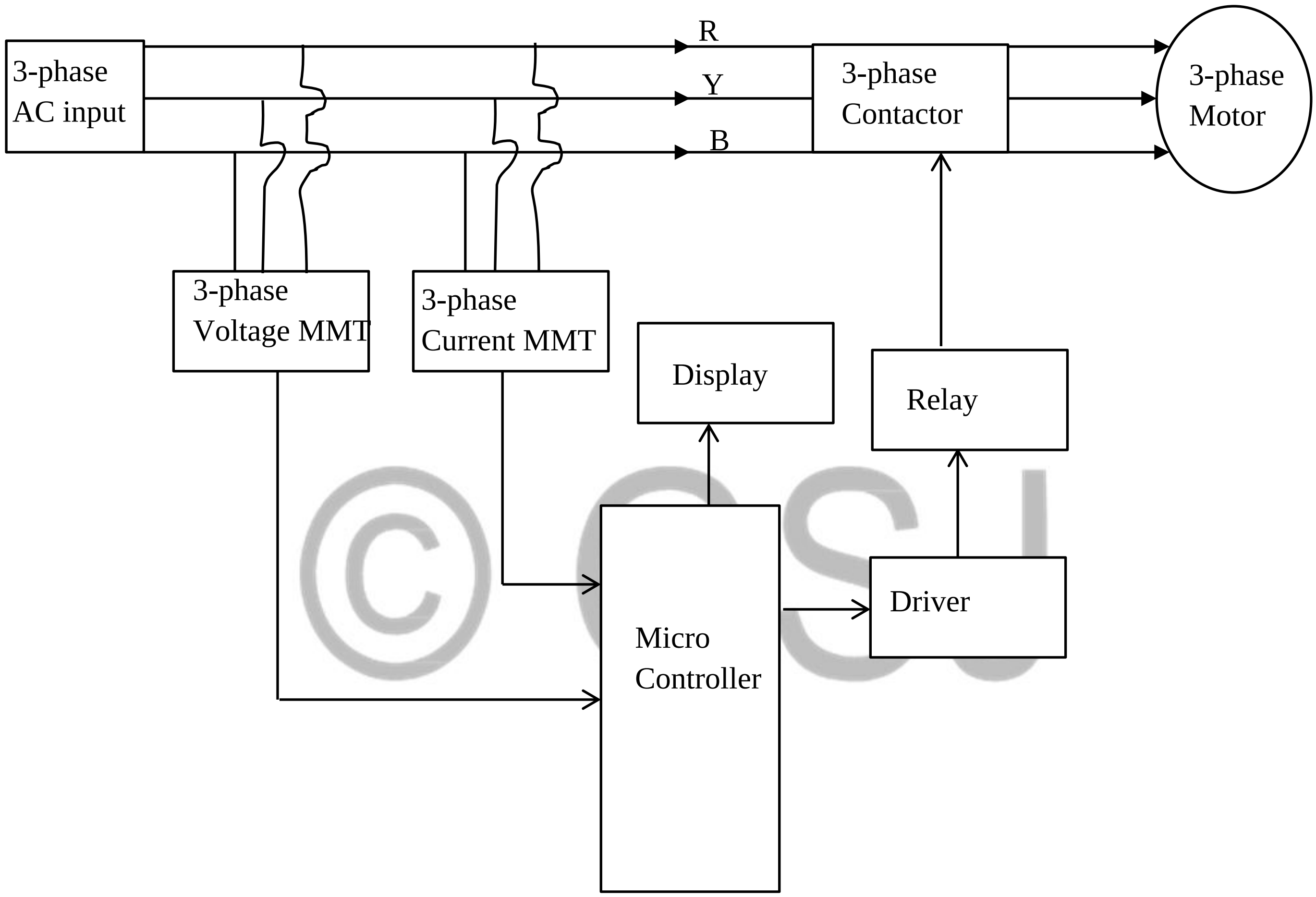

Fig.4.. Block Diagram of System

For the implementation of various protections, protection schemes are used. The values of voltage and current of the motor and the problems occurring in the motor and monitored, detected by the microcontroller, and the warning signals are displayed on the LCD. The motor will trip if any fault occurs. The faulty conditions considered are overload, overcurrent, over voltage, under voltage, unbalanced voltage, phase reversing and single phasing.

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Circuit diagram of the microcontroller is depicted in Fig.4.

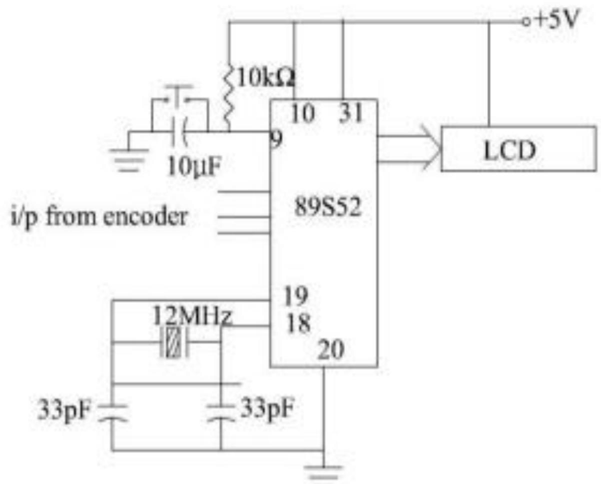

Fig.4. Circuit diagram of microcontroller

Over current protection: Over current protection protects the three phase motor when the current in the motor exceeds the rated value. The over current relay senses the current in each phase and current value exceeds the its rated value, the comparator gives signal to the microcontroller to stop the motor and the nature of the fault is display on the LCD.

Single phasing protection: If single phase supply voltage is lower than the specified voltage, the motor is unable to start. Comparator compares the single phasing supply voltage and the specified voltage and the sensed value is sent to the microcontroller to stop the motor from running.

Overvoltage protection: Over voltage protection is a power supply feature which shuts down the supply, or clamps the output, when the voltage exceeds a preset level. The protection involves setting a threshold voltage above which the control circuit shuts down the supply. The comparator sends signal to the microcontroller when the supply voltage exceeds the preset value and the supply voltage is shut down.

Undervoltage protection: If the supply voltage has low voltage than the rated voltage of the induction motor then under voltage protection section of the protection supply is applied to the motor. It has the same concept as overvoltage; as a comparator compares two voltages. Signal is sent to the microcontroller and microcontroller stops the operation of the motor, in case it is running, and will not operate, in case of starting.

VI. CONCLUSION

This paper presented a reliable, fast and efficient for induction motor protection. It is recommended for the industry in all cases of drives employing induction motors. Protection of three phase induction motor from electrical faults ensures continuous and smooth running of motor, and improves its life span. The prototype model of microcontroller based protection system is very simple in design, reliable, and cost effective and guarantees quick response.

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