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A MODERN TECHNIQUE FOR FAULT DIAGNOSIS AND PROTECTION OF INDUCTION MOTOR

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ABSTRACT

Three phase Induction Motors are the "workhorses" of industry and single phase Induction Motors are the "workhorses" of home (or for commercial purpose). Thus, we can say that Induction Motors are widely used motors but these motors faces various problems (faults) during it's course of operation. Since IM's are "workhorses" of industry and of commercial purpose, therefore, our aim is to protect it from these faults. In this paper we are dealing with problems, such as overvoltage, over current , over temperature , over speed and inrush current which are being faced by IM's during it's course of operation. There are various methods for fault detection and protection of IM. Some of them are On-line fault detection, Stator fault monitoring techniques, Microcontrollers based protection system, Programmable Integrated Circuit (PIC) based protection system and Programmable Logic Controller (PLC) based protection system. In this study, we are working on PLC based protection system of IM.

Keywords: Workhorses, PLC, PIC, Fault diagnosis, Computer controlled system, computerized monitoring

I. INTRODUCTION

Because of their wider applications in electromechanical energy conversion, mainly due to their low cost, reasonably small size, ruggedness, low maintenance, and operation with an easily available power supply, IM's are the main workhorses of industrial prime movers and of commercial use. Although Induction machines are reliable, they are subjected to some undesirable stresses, causing them some faults resulting in failures. Researchers have studied a variety of machine faults and have come to a conclusion that machine failures include mechanical and insulation faults.

(A) INSULATION SYSTEM FAILURE

Insulation system failure plays an important role in electrical machine failure. The major insulation failures are caused by moisture and overtemperature.

(B) MECHANICAL FAILURE

The major faults in this category can be broadly classified as

(1) Stator faults.

(2) Broken rotor bars

(3) Static and/or dynamic air gap irregularities

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(4) Misalignment

(5) Bearing and gear box failures.

The possible detection methods to identify the motor faults are listed as follows

(a) Vibration monitoring

(b) Electromagnetic field monitoring using search coils

(c) Chemical analysis

(d) Temperature measurement

(e) Speed measurement

(f) Voltage measurement

(g) Current measurement

(h) Radio frequency emission monitoring

(i) Acoustic noise measurement

(j) Partial discharge method

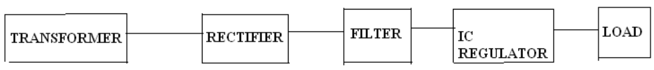

FIG. BLOCK DIAGRAM (POWER SUPPLY)

II. WHAT NEEDS TO BE MONITORED?

The critical components of an IM that need to be monitored include the stator winding temperature, bearing temperature, value of voltage, current and speed. The monitoring methods and degree of protection can vary significantly. Normally, the rotor temperatures are not directly measured, but rather the stator or bearing temperatures provides an indirect measurement of the rotor performance. For the direct measurement of rotor temperatures, a radio frequency telemetry system is required which is somewhat expensive, uncommon and in most cases unnecessary.

III. WAYS TO MONITOR AN IM

There are various methods to protect an IM and these methods have came into picture after having a deep research over it. Firstly, the protection of IM by means microcontroller was invented. After that the protection of IM by using PIC was came into picture. But both these methods of monitoring an IM has some defects which were eliminated in further research. The new method of monitoring an IM which has eliminated the defects of previous two methods is the protection of IM using PLC.

IV. METHOD WHICH WE ARE USING

This paper explains a PLC based protection and monitoring of three phase IM. The basic structure of PLC is shown in fig.1. From fig.1, the PLC systems are equipped with special I/O units appropriate for direct usage in automation systems. The I/O components, such as voltage sensor, current sensor, temperature sensor etc, can directly be connected to the input. The driver components of the control circuit such as contactors and solenoid valves can directly be connected to output. The new solutions for various faults of the voltages, currents, speed and temperatures of an IM occuring in operation have been achieved with the help of a PLC.

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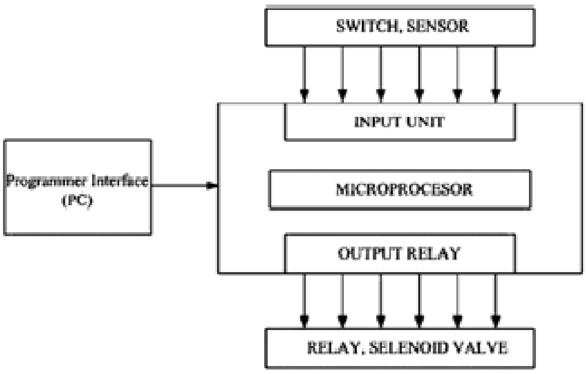

Fig.1. BASIC STRUCTURE OF PLC

Programmable logic controller

A programmable logic controller (PLC) or programmable controller is a digital computer used for automation of electromechanical processes, such as control of machinery on factory assembly lines, control of amusement rides, or control of lighting fixtures. PLCs are used in many different industries and machines such as packaging and semiconductor machines. Unlike general purpose computers, the PLC is designed for multiple inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed or non-volatile memory. A PLC is a example of real time system since output results must be produced in response to input conditions within a bounded time, otherwise unintended operation will result. There are different types of PLCs according to the type of input/output ports, they are as follows:-

(1)Fixed type and (2) Expandable PLC.

In Fixed type PLC the input/output ports cannot expand while in Expandable PLC the input/output ports can expand

VARIOUS MANUFACTURER OF PLC AND THERE SOFTWARE

COMPANY NAME	MODEL NAME	SOFTWARE	SCADA
SIEMENS	S7-200,S7-300,S7-400	MicroWin Simatic Manager	Win CC
ABB	AC 500M, AC 800M	Control Builder	SCADA Portal
AB ALLEN BRADLEY	MicroLogix 1000/1200/1500	RS Logix 500, RS Logix 5000	RS Vtec
GE Fanuc	Versa Max 90-30, 90-70/PAC	Proficy M/C Edition	Cimplicity
Crouzet Millenium	CD-10, CD-20,CD-30	Millenium3	GE Fanuc

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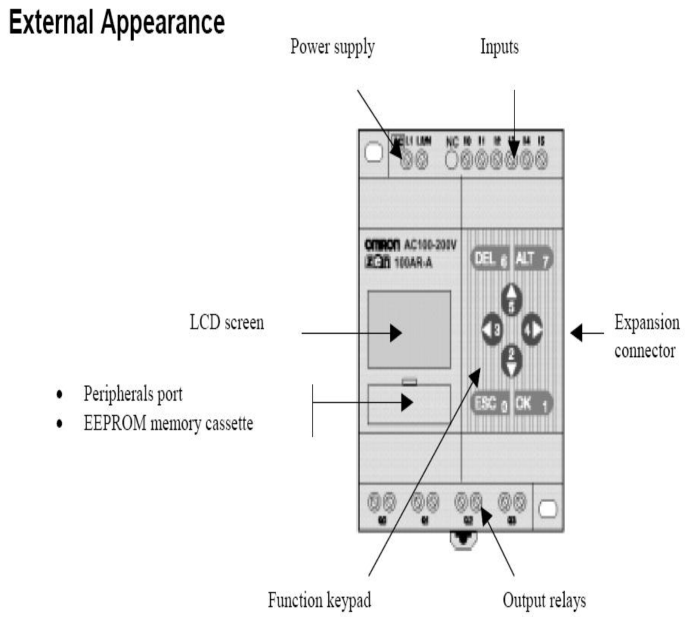
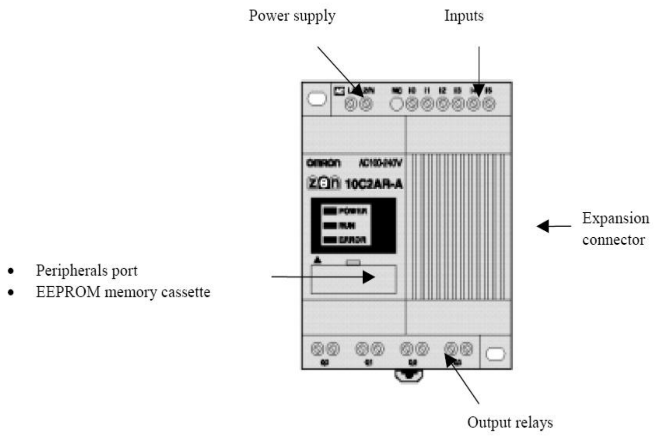
The PLC which we are using in this paper is Crouzet Millenium (CD 10) PLC. This programmable logic module provides a total of 10 I/O points (6 inputs and 4 outputs). It has two types of controllers

(1) LCD type:- with display screen and keypad

(2) LED type:- without display screen and without operating keypad.

(3)





V. MAIN FEATURES

The following are some of the most important features:-

(1) Capacity to carry out small scale automatic control at low cost.

(2) Ladder diagram programming directly in the LCD type CPU is possible.

(3) Upgrade upto 18 inputs and 16 outputs using 3 expansion modules.

(4) Protection against power supply faults(battery optional).

(5) Equipped with 8 configurable timers in 4 operating modes and 3 timer ranges.

(6) Direct AC input between 110 and 240 VAC.

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An analog module is primarily required for processing analog signals. Analog modules usually work in accordance with 8 or 12 bit systems. One or more than one analog sensors can be connected to the analog module in accordance with their types.

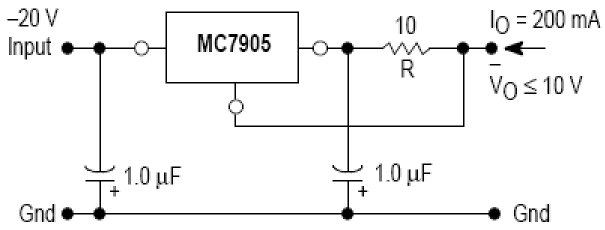

FIG. CURRENT REGULATOR

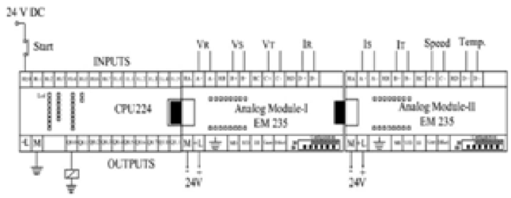

Fig.2. ANALOG AND DIGITAL MODULE

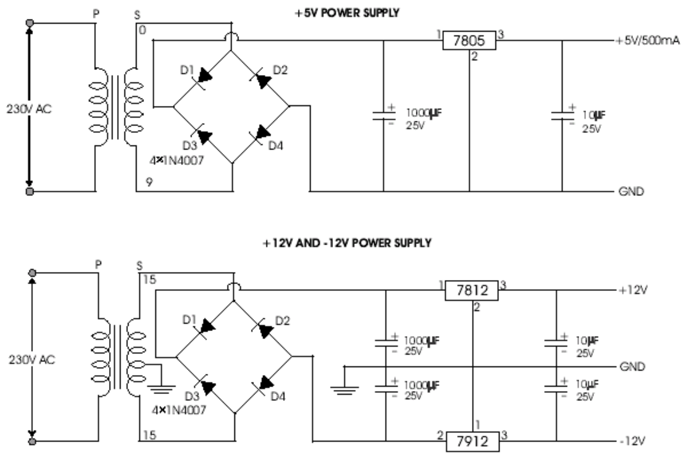

FIG. CIRCUIT DIAGRAM (POWER SUPPLY)

VI. CONTROL SYSTEM OF IM

A block diagram for the protection of IM is shown in fig.3. It consists of the measuring instruments for the measurement of the voltage, the current, the winding temperature and the rotor speed. The proposed protection system can better be understood under the following three categories as the hardware, the instrumentation and the software. The tasks of these categories are explained in the following sections.

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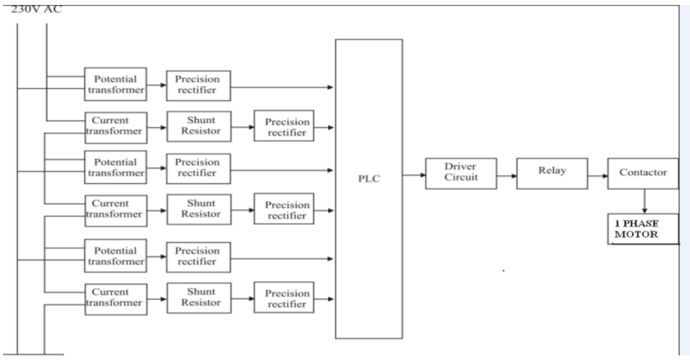
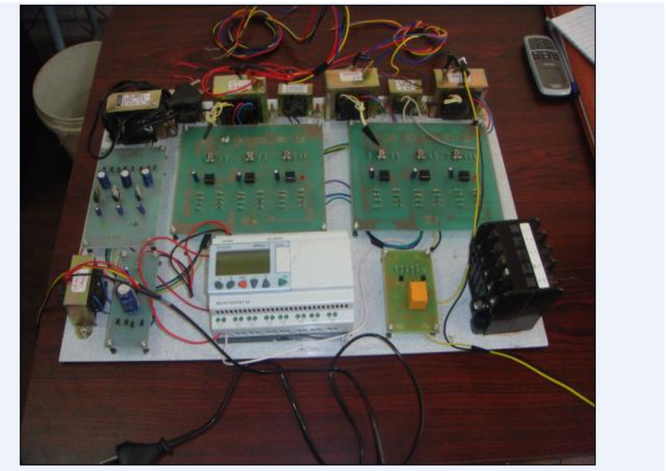


FIG. BLOCK DIAGRAM

A. Hardware



The protection system used in this study consists of a .25kW/1500 r/min single-phase IM, three voltage transformers with transformation ratio of 220/5 V, three current transformers with current ratio of 1000:1, a temperature sensor with transformation ratio of 10 mV for each 1 ◦C increasing temperature, and an incremental encoder with 360 pulse per revolution used for measuring the rotor speed, a true rms to dc conversion card, a CPU 224, and Crouzet Millenium CD 10 series PLC. A photograph of the proposed system is demonstrated in Fig. 4.

B. Instrumentation

The currents and the voltages of the motor in the protection system were measured using the measurement card available in the laboratory including three current transformers and three voltage transformers. This card includes an amplifier with opamps, a gain potentiometer, and a filter circuit used to change the current value. The outputs of the measurement card were applied to the input port of true rms-to-dc conversion card. The AD536A integrated circuit was used for the true rms-to-dc conversion. The AD536A is a complete monolithic integrated circuit that performs true rms-to-dc conversion. It offers a good performance that is comparable or superior to that of hybrid or modular units that cost more. The AD536A directly computes the true rms value of any complex input waveform containing ac and dc components. Potentiometers and filter circuit, shown were used on the true rms-to-dc conversion card for changing the current and the voltage values. Converted current and voltage values were then transferred to the PLC analog module through the true rms-to-dc conversion card. To measure the speed of the motor, an incremental encoder was connected to motor shaft. The incremental encoder with 360 pulses per revolution was used for measuring the rotor speed. The encoder output with

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pulsewidth modulation (PWM) is converted to dc voltage value using conversion circuit. The temperature of the motor was measured with an LM-35 sensor placed between the coils. The LM-35 sensor is a linear component that can produce 10 mV voltages per 1 ◦C. The temperature signal was magnified and transferred to PLC analog module. On the nameplate of the motor, maximum ambient temperature was given as 40 ◦C. Over this value, the motor is stopped by the PLC.

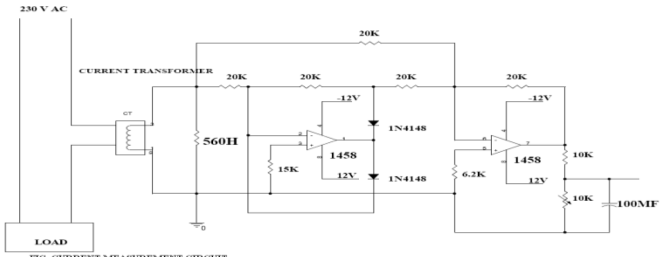

FIG. CURRENT MEASUREMENT CIRCUIT

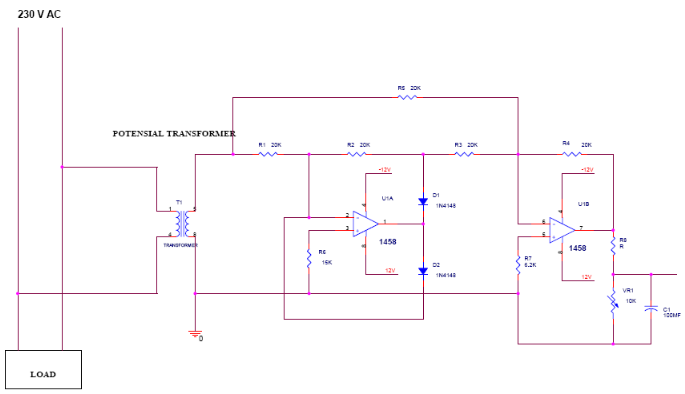

FIG. VOLTAGE MEASUREMENT

C. Developed Software

In order to achieve the protection of the IM easily, a PLC program was developed.The PLC system provides a design environment in the form of software tools running on a host computer terminal that allows LADs to be developed, verified, tested, and diagnosed. First, the high-level program is written in LADs. The LAD is then converted to binary instruction codes, so that they can be stored in RAM or erasable programmable read-only memory (EPROM). Each successive instruction is decoded and executed by the CPU. The function of the CPU is to control the operation of memory and I/O components and to process data according to the program. Each input and output connection point on a PLC has an address used to identify the I/O bit. Flowchart of the program is given in Fig. below.

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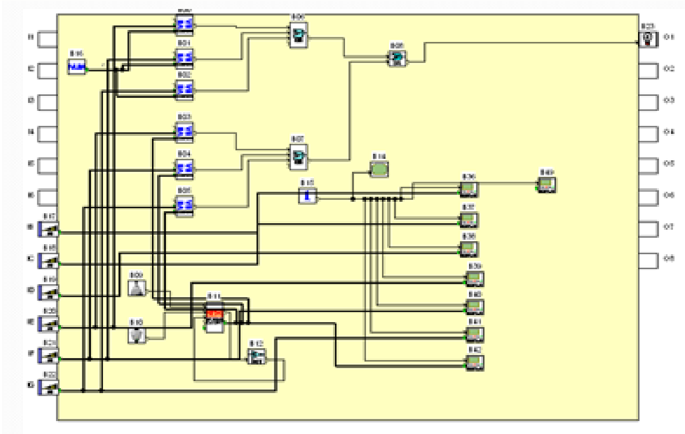

FIG. LOGIC DIAGRAM

Table 1
Motor Electrical Variables Achived On Computer

Variable	Symbol	Input	Unit
Phase voltage	V	Analog module	volt
Phase current	I	Analog module	Amp
Speed	n	Analog module	rpm
Temperature	T	Analog module	Degree

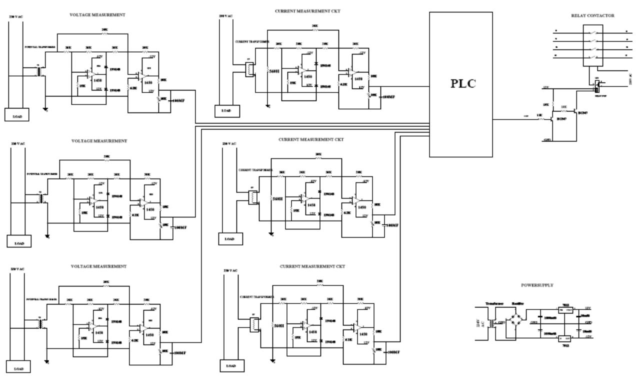

FIG. FAULT DETECTION AND PROTECTION OF IM

VII. EXPERIMENTAL RESULTS

The computer interface program has been written using package PLC software known as Millenium 3. The communication is achived between the PLC and computer and thus results are obtained. The motor electrical variables with description (symbol, unit and type of input) is given in table.1. The logic is then developed on computer screen with the help of PLC software. As we know that each and every PLC has it's own execution time. The execution time of the PLC which we are using is about 0.40 microseconds. Thus the PLC software developed is been scanned at each and every movement. According to the control procedure the data are are first read and then calculated. The transient time of the motor is defined which is continuously been controlled by the program. If the defined time is less then the transient time , the program goes to control procedure and at the same time the PLC sends a signal to the control circuit of the motor due to which the motor stops.

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The phase voltage, phase current, rotor speed and winding temperature are then directly being displayed on the computer screen with the help of the software developed. After having all these data they are controlled considering their tolerance values. The system continues to run under normal condition but in case any kind of fault occurs on the system i.e. if the value of phase voltage, phase current, rotor speed or winding temperature increases beyond it's defined value then the PLC will immediately gives signal to the control circuit of the motor and thus the motor stops.

VIII. CONCLUSION

A 0.25 kW single-phase IM has been connected to the protection system through the measuring components, as illustrated in Fig. 5. The proposed PLC-controlled protective relay deals with the most important types of these failures, which are summarizedas the phase lost, the over/undercurrent, the over/undervoltage, the unbalance of supply voltages, the overload, the unbalance of phase currents, the ground fault, and the excessive repeated starting. If any fault is observed during online operation of the motor, a warning message appears on computer and then the motor is stopped. When an undefined fault occurs, the motor stops without giving any description. In this case, the fault can be described and found by the operator. The test has been found successful in detecting the faults and in recovering them.

The results showed that a reliable PLC-based protection system including all variables of the three-phase IMs and operators have been developed.

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