Design and Implementation of PLC-Based Monitoring Control System for Induction Motor

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***Abstract:* - Single phase Induction motor is the mostly used in industrial & domestic applications because of its high robustness, reliability, low cost. In spite of this popularity, the induction motor has two inherent limitations: (1) the standard motor is not a true constant-speed machine, its full-load slip varies less than 1 % (in high-horsepower motors). And (2) it is not inherently capable of providing variable-speed operation. In this paper a new monitoring control method using a programmable logic controller (PLC) has been introduced. The PLC correlates the operational parameters to the speed requested by the user and monitors the system during normal operation and under trip conditions. Tests of the induction motor system driven by inverter and controlled by PLC prove a higher accuracy in speed regulation as compared to a conventional V/ f control system. Also the efficiency of PLC based speed control is increased at high speeds up to 95% of the synchronous speed.**

Key words: **Design, variable frequency drives, speed control, induction motor (IM), programmable logic Controller.**

1. INTRODUCTION

The single phase induction motor is widely used in sector of the manufacturing & domestic appliances. This is because it offers simple and rugged construction, less maintenance and cost-effective pricing. Hence induction motor has been used widely for the industrial applications requiring variable speed. The speed control of Induction Motor must be done through a controller providing maximum torque with minimum loss. Although induction motors are reliable, they are subjected to some undesirable stresses, causing faults resulting in failure. Monitoring of an IM is a fast emerging technology for the detection of initial faults. It avoids unexpected failure of an industrial process. Monitoring techniques can be classified as the conventional and the digital techniques [2].

Nowadays, the programmable logic controller (PLC) is widely is used for industrial automation systems. Many factories use PLC in automation processes to reduce production cost and to increase quality and reliability. It also helps to reduce human interference and hence human errors. The PLC systems comprise with special Input & output cards which are appropriate for direct usage in industrial automation systems. The input components, such as the pressure, the level, the voltage, the current and the temperature sensors, can be connected to the input. The driver components of the control circuit such as contactors and solenoid valves can directly be connected to the output. Few papers are published about the control of induction motors using Programmable Logic Controller. One of them is about power factor controller for a induction motor that utilizes a PLC to improve the power factor and to keep its voltage-to-frequency ratio constant over the entire control range. Another paper published is about protection of induction motor using PLC against different faults [2]. The vector control integrated circuit uses a complex programmable logic device (CPLD) and integer arithmetic for the voltage or current regulation of three-phase pulse-width modulation (PWM) inverters [2].

Since different technology for motion control of electric drives is available, here we have introduced the use of programmable logic controller with power electronics for speed control in electric. This use offers advantages such as lower voltage drop when turned on and the ability to control motors and other equipment with a virtually higher power factor. Other applications include machine tools with improved precision computerized numerical control (CNC) due to the use of PLCs. To obtain accurate industrial electric drive systems, it is necessary to use PLCs interfaced with power converters, personal computers, and other electric equipment. Nevertheless, this makes the equipment more sophisticated, complex, and expensive [3].

II. PROGRAMMABLE LOGIC CONTROLLER

Following figure (Fig.1) shows the Basic Structure of the PLC. A PLC or a programmable Logic controller is a small computer used for automation of real-world processes. A PLC is consisting of CPU, Input module, Output Module. A PLC can be programmed to sense, activate, and control industrial equipment. Hence, a PLC incorporates a number of Input / Output points, to interface different electrical signals. Input & output components of the processes are connected to the PLC; and the control program is loaded on the PLC memory [6].

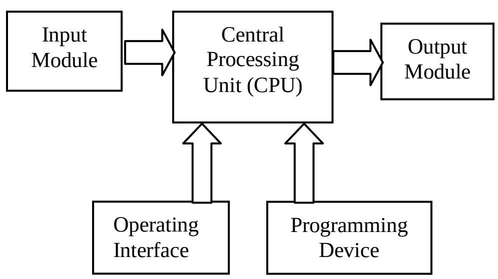

Fig 1: Basic structure of the PLC [6]

Table: 1. Difference between Microprocessor & PLC [6]

PARTS	Microprocessor Control	PLC
Inputs	3-5V	Higher rating
Input condition	Non-isolated I/O	Isolated I/O
Programming	µC Programming of is complicated	Programming of PLC is easy
Environment	µC is affected by noise	Noise can't affected the PLC
Outputs	Fast and it may vary because of disturbance	Rugged outputs

III. SYSTEM DESCRIPTION

In this study, the PLC is used to measure the speed, the voltage, and the current of an induction motor through analog inputs & sensors, such as current transformer, voltage transformer & speed sensor. In addition, it continuously monitors the inputs and activates the outputs according to the program.

A. Hardware:

The system used in this study consists of a 1 HP /1400 r/min Single phase Induction motor, one voltage transformers with transformation ratio of 250/5 V, one current transformers with current ratio of 1000:1, and an incremental encoder with 360 pulse per revolution used for measuring the rotor speed, a true rms to dc conversion card, a Allen Bradley PLC – micrologix – 1400 is used [2].

The current and the voltage of the motor in the protection system were measured using the measurement card including of current transformer and voltage transformer. This card includes an amplifier with op-amps, 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 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 pulse width modulation (PWM) is converted to dc voltage value using conversion circuit.

B.PLC Speed Control Software

The software regulates the speed and monitors the constant speed control regardless of torque variation. The inverter is used for the power supply to the motor which is controlled by PLC's software. The inverter alone cannot keep the speed constant without the control loop with feedback and PLC. From the control panel, the operator selects the speed set point and the direction of rotation whether forward/backward. Then, by pushing the manual start push button, the motor begins the rotation. If the stop button is pushed, then the rotation stops. The corresponding input signals are interfaced to the DIM (Digital Input Module) and the output signals to the DOM (Digital Output Module). The AIM (Analog Input Module) receives the trip signal from the stator current sensor, the speed feedback signal from the tachogenerator, and the signal from the control panel. In this way, the PLC compares the requested speed and the actual speed of the motor. The difference between the requested speed by the operator and the actual speed of the motor gives the error signal. If the error signal is not zero, but positive or negative, then according to the computations carried out by the CPU, the PLC decreases or increases the V/f ratio of the inverter and, thus, the speed of the motor is corrected. The implemented control is of proportional and integral (PI) type (i.e., the error signal is multiplied by gain, integrated, and added to the requested speed). As a result, the control signal is sent to the DOM and connected to the digital input of the inverter to control variations. At the beginning, the operator selects the gain by using a rotary resistor mounted on the control panel (gain adjust) and the AIM receives its voltage drop as controller gain signal (0–10V). The requested speed is selected using a rotary resistor and the AIM reads this signal. Its value is sent to the AOM and displayed at the control panel (speed set point display). Another display of the control panel shows the actual speed computed from the speed feedback signal. A third display shows the load torque computed from the load current signal in Newton-meters (Nm). Their corresponding signals are output to the AOM.

C. PLC Monitoring Control Software

Some of the required protections are also provided by monitoring different parameters. During motor operation, it is not possible to reverse its direction of rotation by changing the switch position. Before direction reversal, the stop button must be pushed. To protect motor from overloading currents during starting and loading condition, the following commands were programmed into the software.

a. Forward/backward signal is input to DIM.
b. Speed set point signal (n_{sp}), the load current (I_L), and the speed feedback signal are input to AIM.
c. At no load ($I_s \leq 1.0$ A), if the speed set point is lower than 20% or $n_{sp} < 300$ r/min, the motor will not start.
d. At an increased load over 0.4 Nm (40% of rated torque), ($I_S > 1.3$ A) and a speed set point lower than 40% or $n_{sp} < 600$ r/min, the motor will not start.
e. If the load is increased more than 1, (Nm) (rated torque) ($I_S \geq 1.5$ A) and if the speed set point exceeds 100% or $n_{sp} \geq 1500$ r/min, the motor enters the cutoff procedure.
f. In all other situations, the motor enters in the speed control mode and the speed control software is executed.

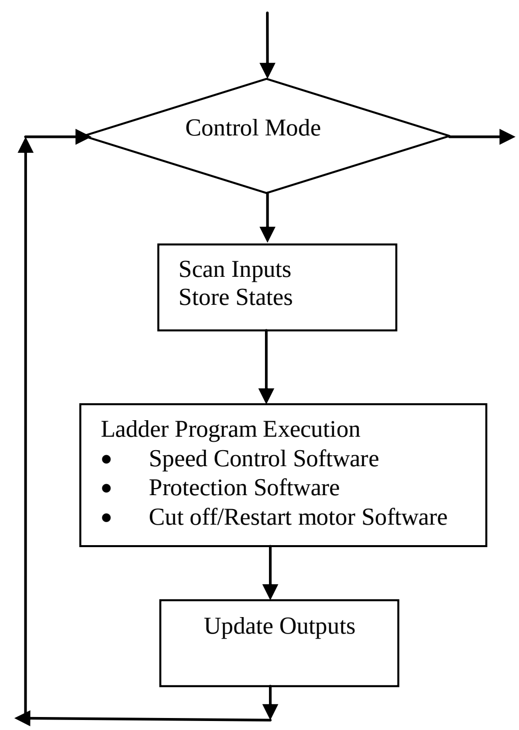

Fig 2: Flowchart of software program used

Table II: Measured Parameters

Variables	Symbol	Input	Unit
Voltage	V_1	Analog module I - input A	Volts
Current	I_1	Analog module I - input D	Ampere
Speed	n_r	Analog module II - input C	Rpm

IV. CONCLUSION

The PLC can be used in automated systems with an induction motor for monitoring control system. The monitoring control system of the induction motor driven by inverter and controlled by PLC gives high accuracy in speed regulation at constant-speed-variable-load operation. The effectiveness of the PLC-based control software is satisfactory up to 96% of the synchronous speed. The efficiency using PLC control is more as compared to the open-loop configuration of the induction motor fed by an inverter.

Despite the simplicity of the speed control method used, this system presents:

• Constant speed for changes in load torque;
• Full torque available over a wider speed range;
• Good accuracy in closed-loop speed control scheme;
• Higher efficiency;
• Overload protection.

The PLC based monitoring control system for induction motor is studied. This proposed system can be applied to different ac motors by doing small modifications in both the hardware and the software.

Thus, the PLC is a versatile and efficient control tool in industrial electric drives applications.

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