AN OVERVIEW OF A CONTINUOUS MONITORING AND CONTROL SYSTEM FOR 3-PHASE INDUCTION MOTOR BASED ON PROGRAMMABLE LOGIC CONTROLLER AND SCADA TECHNOLOGY

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ABSTRACT

Automation is the process of handling various parameters of process like temperature, flow, etc. without presence of responsible person. In the development of automation controllers the trend has been to move towards soft controllers so as to provide better control, more flexibility and more reliability with intelligent diagnostics of machine faults. So industries have gradually moved from conventional relay logic control to programmable logic control. Three phase squirrel cage induction motors are widely used motors in industry. The implementation of monitoring and control system for the induction motor based on programmable logic controller technology is described. Also the implementation of a hardware and software for speed control and protection with the result obtained from the test on induction motor performance is provided. Variable Frequency Drives (VFD) can also use to control the motor rotation direction and rotation speed of the three phase induction motor. All the required control and motor performance data will be taken to a personal computer via PLC for further analysis.

Keywords: Computer-controlled systems, Programmable Logic Control (P.L.C.), induction motors, Personal Computer (PC), variable frequency drives, voltage control

1. INTRODUCTION

Since technology for motion control of electric drives became available, the use of programmable logic controllers (PLCs) with power electronics in electric machines applications has been introduced in the manufacturing automation [1]. AC induction motors (IMs) are used as actuators in many industrial processes. Although IMs 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. Classical monitoring techniques for three-phase IMs are generally provided by some combination of mechanical and electrical monitoring equipment. Mechanical forms of motor sensing are also limited in ability to detect electrical faults, such as stator insulation failures. In addition, the mechanical parts of the equipment can cause problems in the course of operation and can reduce the life and efficiency of a system. Almost any production line, machine function or process can be automated using a PLC. The speed and accuracy of the operation can be greatly enhanced using this type of control system. But the biggest benefit in using a PLC is the ability to change and replicate the operation or process while collecting and communicating vital information. Since there were problems related to large electrical panels with a number of electrical components and extensive wiring, people felt the need for software logic controllers, so they gave birth to Programmable Logic Controller (P.L.C) wherein the control logic is developed in ladder diagram, a software logic control, with a number of inputs taken from the environment and generating the outputs, depending on the logic programmed, to the environment. This helped to control any machine sequence with small electrical panels, less number of electrical components and less wiring with more flexibility to change machine sequence [2]. PLC provides higher accuracy as well as safe and visual environment compared with the classical, the computer, and the PIC-based protection system. Other performance parameters of three phase induction motors can also be monitored by the other control devices. Variable Frequency Drives (VFD) can also use to control the motor rotation direction and rotation speed of the three phase induction motor. Many applications of induction motors require besides the motor control functionality, the handling of several specific Analog and digital I/O signals, home signals, trip signals, on/off/reverse commands. In such cases, a control unit involving a PLC must be added to the system structure. In this paper presents a PLC-based monitoring and control system for a three-phase induction motor. It describes the design and implementation of the configured hardware and software. This configuration is interfaced on SCADA through PLC via RS232. Thus, the PLC correlates and controls the operational parameters to the speed set point requested by the user and monitors the induction motor system during normal operation and under trip conditions [3].

2. PROGRAMMABLE LOGIC CONTROLLER

A programmable logic controller is a specialized computer. Since it is a computer, it has all the basic component parts contained in any other computer, a central processing unit, memory, input interfacing, and output interfacing. PLC is a microprocessor-based control system, designed for automation processes in industrial environments. It uses a programmable memory for the internal storage of user-orientated instructions for implementing specific functions such as arithmetic, counting, logic, sequencing, and timing. A PLC can be programmed to sense, activate, and control industrial equipment and, therefore, incorporates a number of I/O points, which allow electrical signals to be interfaced. Input devices and output devices of the process are connected to the PLC and the control program is entered into the PLC memory. In our application, it controls through Analog and digital inputs and outputs the varying load-constant speed operation of an induction motor. Also, the PLC continuously monitors the inputs and activates the outputs according to the control program.
3. CONTROL SYSTEM OF INDUCTION MOTOR

In Fig. 1, the block diagram of the experimental system is illustrated. The following configurations can be obtained from this setup [3].

1) A closed-loop control system for constant speed operation, configured with speed feedback and load current feedback. The induction motor drives a variable load, is fed by an inverter, and the PLC controls the inverter V/f output.

2) An open-loop control system for variable speed operation. The induction motor drives a variable load and is fed by an inverter in constant V/f control mode. The PLC is inactivated.
3). The standard variable speed operation. The induction motor drives a variable load and is fed by a constant voltage-constant frequency standard three-phase supply [4-5]. The open-loop configuration 2) can be obtained from the closed-loop configuration 1) by removing the speed and load feedback. On the other hand, operation 3) results if the entire control system is bypassed.

4. FLOW CHART

The ladder program is then executed rung-by-rung. Scanning the program and solving the logic of the various ladder rungs determine the output states. The updated output states are stored in fixed memory locations (output image memory Q). The output values held in memory are then used to set and reset the physical outputs of the PLC simultaneously at the end of the program scan [6].

The software regulates the speed and monitors the constant speed control regardless of load variation with the help of SCADA and PLC.
5. VFD CONTROl DIAGRAM

The circuit shown in fig.4 is control the direction of rotation and speed of 3-phase induction motor by using VFD. 230 V, 50Hz, 1 Phase supply is given across NO contact of relay (terminal A and C of VFD) Terminal SD is Common to the contact input terminal and terminal FM. Common output terminal for 24VDC 0.1A power output. SD terminal is connected to the selector switch 1. Terminal R, S, T is used as input and U, V, W is used as output which is connected to motor. In this there are two control methods (1) control by Auto (2) Control by Manually. In manually control, selector switch2 is connected across STF and STR terminal of VFD which is used for changing direction of rotation. 1W2Kohm frequency setting potentiometer is connected across terminal 10, 2, 5 of VFD which is used to adjust input voltage and frequency setting of inverter. In automatic control we push the start forward push button on SCADA, relay R3 is energized and motor rotate in forward direction and pushing start reverse button on SCADA ,relay R4 is energized and motor rotate in reverse direction. Speed of motor is control by Analog output of PLC.

![Fig.4: VFD control wiring](image)

6. TERMINAL CONNECTION OF VFD

This is a power line diagram of experiment setup. In below table describe main and control circuit terminals when terminal PC-SD are used as 24Vdc power supply, be care full not to short them these terminals. If they are shorted, the inverter will be damaged.
Fig.5: Power line diagram of experiment setup

Table 1: Description of Main circuit terminals

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Terminal name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>R,S,T(L1,L2,L3)</td>
<td>Ac power input</td>
<td>Connect to the commercial</td>
</tr>
<tr>
<td>U,V,W</td>
<td>Inverter output</td>
<td>Connect to the squirrel cage induction motor</td>
</tr>
<tr>
<td>P(+),PR</td>
<td>Brake resistor connection</td>
<td>Connect the optional brake resistor across the terminals P-PR</td>
</tr>
<tr>
<td>P(+),N(-)</td>
<td>Brake unit connection</td>
<td>Connect optional brake unit or high power factor converter</td>
</tr>
<tr>
<td>P(+),P1</td>
<td>Power factor improving DC reactor connection</td>
<td>Disconnect the jumper from the terminals P-P1(+ - P1) and connect the optional power factor improving DC reactor</td>
</tr>
</tbody>
</table>
**Table 2: Description of Control circuit terminals**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Terminal name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>STF</td>
<td>Forward rotation start</td>
<td>Turn on the STF signal to start forward rotation and turn it off to stop.</td>
</tr>
<tr>
<td>STR</td>
<td>Reverse rotation start</td>
<td>Turn on the STR signal to start reverse rotation and turn it off to stop.</td>
</tr>
<tr>
<td>RH,RM,R</td>
<td>Multi-speed selection</td>
<td>Combined the RH, RM and RL signal as appropriate to select multiple speeds.</td>
</tr>
<tr>
<td>MRS</td>
<td>Output stop</td>
<td>Turn on the MRS signal (20ms or longer) to stop the inverter output. Used to shutoff the inverter output to bring the motor to a stop by electromagnetic brake.</td>
</tr>
<tr>
<td>RES</td>
<td>Reset</td>
<td>Used to reset the protective circuit activated. turn on the RES signal for more than 0.1 second then turn it off.</td>
</tr>
<tr>
<td>SD</td>
<td>Contact input common (sink)</td>
<td>Common to the contact input terminal and terminal FM. Common output terminal for 24VDC 0.1A power output.</td>
</tr>
<tr>
<td>PC</td>
<td>Power output and external transistor common .Contact input common (source)</td>
<td>When transistor output (open collector output) such as programmable controller (PLC) is connected, connect the external power supply common for transistor output to this terminal to prevent a fault caused by undesirable current. This terminal can be used as a 24VDC 0.1 A power output.</td>
</tr>
<tr>
<td>10</td>
<td>Frequency setting power supply</td>
<td>5V, permissible load current 10 mA</td>
</tr>
<tr>
<td>2</td>
<td>Frequency setting (voltage)</td>
<td>By entering 0 to 10VDC, the maximum output frequency is reached at 10V and I/O is proportional. Use Pr.73 to switch between 0 to 5VDC and 0to 10V, input resistance 10Kohm. Maximum permissible voltage 20V</td>
</tr>
<tr>
<td>4</td>
<td>Frequency setting (current)</td>
<td>By entering 4 to 20mA DC, the maximum output frequency is reached at 2mA and I/O is proportional. This input signal is valid only when AU signal is on. Input resistance 250 ohm. Maximum permissible current 30mA</td>
</tr>
<tr>
<td>5</td>
<td>Frequency setting input common</td>
<td>Common to frequency setting signal (terminal 2, 1 or 4). Do not connect to the earth.</td>
</tr>
<tr>
<td>A,B,C</td>
<td>Alarm output</td>
<td>Contact output indicating that output has been stopped by the inverter protective function activated. 230V AC0.3A, 30V DC 0.3A</td>
</tr>
</tbody>
</table>
7. EXPERIMENTAL RESULT

The system is tested during operation with varying loads including tests on induction motor speed control performance. The PLC monitors the motor operation and correlates the parameters according to the software. At the beginning, for reference purposes, the performance of Induction motor supplied from a standard 440 V, 50-Hz network is measured.

- Induction motor fed by the inverter and PLC
  Generator voltage = 230 V
  Rated current = 1.8 A
  Speed set point = 890 rpm

![Speed control with PID tuning](image)

**Fig.6:** Experimental speed–% load of motor characteristics with PLC and inverter

Result on SCADA at Speed set point = 890 rpm

![Experimental SCADA result](image)

**Fig.7:** Experimental SCADA result

8. CONCLUSION

Successful experimental results were obtained from the previously described scheme indicating that the PLC can be used in automated systems with an induction motor. By automation we can improve the productivity in the industry. We continuously monitor the state of input devices and make the decision based upon a custom program to control the state devices connected as output. The monitoring control system of the induction motor driven by VFD and controlled by PLC proves its high accuracy in speed regulation at constant-speed-variable-load operation. The PLC proved to be a versatile and efficient control tool in industrial electric drives applications. The effectiveness of the PLC-based control software is satisfactory up to 94% of the synchronous speed.
REFERENCES