Fault detection and Induction motor safety using Programmable Logic Controller and Supervisory Control and Data Acquisition system

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Abstract. Aiming at high accuracy and time consumption in classical method by eliminating the mechanical components, this work focuses on an automation process for fault detection and Induction motor safety using PLC and SCADA. The software of the system uses RS Logix 500 English to construct a ladder logic program and In-touch to design the operation process taking place in Induction motor. The communication between these two software is achieved by Dynamic Data Exchange. The problems such as voltages, currents, over speed, vibration alert and temperature sensing values of the Induction motor are monitored. By communicating the Programmable Logic Controller (PLC) to Supervisory Control and Data Acquisition System (SCADA) the warning messages are displayed on the computer screen. This PLC and SCADA system based protection method provides a visual environment to analyze and rectify the faults occurring in a three phase induction motor comparing to a Programmable Integrated Circuit (PIC) based protection system.

Keywords. Programmable integrated circuit, Programmable logic controller, Supervisory control and data acquisition system, Dynamic data exchange, Visual environment.

1. Introduction

Induction motors are baffling electro–mechanical devices which are used as actuators in 90 percent of industries at the present automation world. Faults are likely to happen in the motors when there are any abnormal conditions. To detect the faults at initial stage and to clear them immediately is the fast emerging technology in induction motor operating process. The major faults occurring in an induction motor are mechanical and electrical hassles. The mechanical faults arise due to over-load and sudden changes in load which generates bearing faults and breakage in rotor bars. The electrical faults arise due to power supply given to an induction motor from the adjustable speed AC drives also, known as Variable Frequency Drive (VFD) [1-3]. Induction motors when supplied by AC drives, are more susceptible to faults. While being robust induction machines, they are exposed to some undesirable stresses, triggering some failures [4-5]. The problems occurring in an induction motor such as high-voltage, high-current, heavy load, high-temperature and over or under voltage can be monitored by classical method using components such as timers, contractors, voltage and current relays. The
computerized conservation method requires an analog to digital conversion device and a Programmable Integrated Circuit based safety method and it does not visualize the electrical parameters that are measured [6]. Security requires the implementation of a redundant feature that should detect a failure and lead to an appropriate solution. It is used in most industrial applications due to the recent development in Programmable Logic Controller technology [7-9]. Along with their efficiency and robustness, faults occurring in the motor and protection system are also most considerable to bring out an efficient production system accompanied by time-management system [10]. The electrical parameters and physical parameters are analyzed to check out the reason for fault occurrence and proper working of the motor.

This paper provides an alternative and novel solution for manual operation and control by implementing the automation trend such as Programmable Logic Controller which requires less time to respond. The PLC is interfaced with Supervisory Control and Data Acquisition System to provide the required visual environment.

2. Variable Frequency Drive

An electric motor can be driven by variable frequency drive, a type of motor scrutinizer which supplies the motor with varying frequency and voltage [11-12]. The variable frequency drive provides lowest inrush current compared to other type of starters and it is the ideal soft starter type. The frequency from VFD can be used to limit the power and current supplied to the motor. By delivering power at low frequency, the VFD will start the motor. A high level of current is not required to the motor, at this low frequency. The VFD increases the frequency and motor speed incrementally until the desired velocity is met. The current engine level rarely reaches the engine's full-load ampere rating at any point during its start or operation. In addition to benefitting from low starting current, engine designs can now be designed for high frequency. Engine manufacturers are facing difficulties with choices in design. The designs are optimized based on the option for low starting current which often sacrifices performance, power factor, size and cost. The line – starting of induction motor is accompanied by inrush currents up to 7-10 times greater than constant current and the initial torque should be 3 times greater than the constant torque. The machine leads to reduced life service due to the mechanical stress arising due to increased torque. A voltage drop can occur when large quantities of current drawn on transformers, which adversely affects other equipment on the same electrical system. Some applications sensitive to voltage can even trip off line. Research engineers are trying to propose a new method for reducing the starting current of large induction motors. The ideal application of AC electrical motor is that it works at fixed speed by delivering a constant output. The motor frequency is always directly proportional to the motor speed (rpm). The motor speed can be controlled by varying the frequency in VFD. No wear and tear as in mechanical drives. Their maintenance cost is very less when compared to mechanical drive and speed can be varied from 0% to 100%.

\[
\text{Speed(rpm)} = \text{frequency(Hertz)} \times \frac{120}{\text{No.of Poles}}.
\]  

(1)
3. Programmable Logic Controller

The Programmable Logic Controller is designed and can be well implemented in an industrial environment to monitor and control the operations automatically by eliminating the man power [13-15]. The basic structure of PLC is given in Figure 1.

![Figure 1. Basic structure of PLC](image)

The Programmable Controller has been implemented in various manufacturing processes and its control namely robotic devices and assembly lines, which require high-reliability control and ease of programming and fault diagnosis. The structure of a typical PLC Micrologix 1200 is given in Figure 2.

The PLC uses a programmable memory for the internal storage of instructions specified by users. In order to fetch the data and to execute supervisory Control, many PLC driver files are required. As a result, PLC requires SCADA which communicates in the same protocol environment.

![Figure 2. PLC MICROLOGIX 1200](image)
4. Software used

4.1. RS Linx classic

The Rockwell Automation Networks and Devices provides RS Linx classic which is an extensive
factory communication solution providing Programmable Logic Controller access to a wide range of
applications in Allen-Bradley software.

4.2. RS Logix 500

Allen Bradley RS Logix 500 software is used to design the ladder logic program in Programmable
Logic Controller. The ladder logic program is proposed and loaded to the run time without using any
external cables. Generally, various software’s are required for PLC programming but, the ladder logic
program is same for all implementations. The major variance in PLC software is consigning of an
element such as normally open (NO) and normally close (NC) etc.

4.3. Dynamic Data Exchange (DDE)

Dynamic Data Exchange or DDE is an interfacing system for sharing and updating data between
applications under Microsoft windows. It is still used for various applications. For example, Visual
basic access to an Allen Bradley (A-B) PLC via RS Linx. RS Linx will also support OPC interfacing,
the route is easy but, the code is more complicated to compile. The major purpose to avail Dynamic
Data Exchange (DDE) interfacing is when there is no hardware system and it will eliminate the need
of Ethernet usage.

4.4. Supervisory Control and Data Acquisition System

The Invensys Company’s programming item Wonderware In -touch provides integrity of
instrumentality in making graphical representation of the operation. Figure 3 represents the basic
structure of In-touch. A programming criterion for Human Machine Interface (HMI) implies a
graphical representation of a generating system. A human-machine interface or HMI is the system that
presents a human operator process information, and through which the technique is managed by the
human operator. HMI is usually joined to the databases and programming programs of the SCADA
System to provide information on disposition, symptoms and administration; The HMI program
usually graphically displays the data as a copy graph to the operating staff. It means that the operator
is able to see a graphical picture of the controlling farm.

SCADA system is basically a protection system, which provides a visual environment to identify the
fault location with accurate time measurement when the fault occurred on the system, and gives out
the warning message on the screen via interfacing with PLC which requires the same communication
protocol. SCADA software is implemented in industries like waste water management, gas and oil purification systems etc to execute effective monitoring and control activities.

![Image of SCADA system](image)

**Figure 3. Basic structure of In-touch**

The data is transferred between SCADA central host computer and number of remote terminal units, microcontroller terminals, PLC’s, operator terminals, and central host. The SCADA system collects the data and transfers information to centralized host, then notifies the information by logically and it is almost simple to control home station and necessary analysis.

5. Proposed Methodology

In this work, a new methodology is proposed to identify the faults occurring in an induction motor by using PLC ladder logic and interfacing it with SCADA to provide a visual environment to analyze the time, when the faults occurred in motor with exact time. The need to go for PLC is that, it can be used as a protection system and it can measure various criterions functioning as load beyond the machine’s capability, under/over voltage, temperature limit, vibrations, control in speed and temperature sensing simultaneously.

5.1. Working

The induction motor protection can be achieved easily by developing a ladder logic program in Programmable Logic Controller. To visualize the process taking place inside the industrial field, a computer interface program is written using SCADA system software called In-Touch. The program menu consists of buttons such as start, stop, fault Inputs, fault reset, alarm window. Separate switches are used in the motor for start and stop operations. Alarm switches are used to stop the motor at any type of breakdown and to intimate immediately about the danger by notifications. After recovering from failure, the motor will not start automatically. The reset icon is clicked to restart the motor, first followed by the start icon. The execution time of Programmable Logic Software is about 0.37
microseconds for each Boolean Instruction. The motor is stopped immediately by sending intimation from Programmable Logic Controller to the motor circuit control, if any faults have been occurred.

5.2. Flowchart
Figure 4 represents the flowchart to clearly indicate the methodology involved in the proposed system.

![Flowchart of the proposed system](image)

**Figure 4.** Flowchart of the proposed system

The flowchart describes the protection of induction motor using recent trends in automation technology known as Programmable Logic Controller technology. The above proposed methodology is used to completely minimize the fault rectification by eliminating the man power with time management. This method is applicable for any type of manufacturing and production industries. In case, while trying to operate the motor without rectifying the faults, the motor will not start.

5.3. Algorithmic steps
The algorithmic steps involved in control of induction motor using PLC are given here:

1. Initially start the process by giving AC power supply from 3-phase AC transformer.
2. The operation process of induction motor is continuously monitored by PLC to identify any faults in the test system.
3. If any fault is identified, the motor will be stopped immediately.
4. Rectify the faults and reset the motor.
5. Turn ON the motor to normal condition.
6. Restart the process.

5.4. SCADA program
The programming codes developed to simulate the system under study are given here.

IF R1==1 THEN S1=0;
ENDIF;
IF R2==1 THEN S2=0;
ENDIF;
IF R3==1 THEN S3=0;
ENDIF;
IF R4==1 THEN S4=0;
ENDIF;
IF R5==1 THEN S5=0;
ENDIF;
IF SW==1 THEN S=S+1;
ELSE S=0;
ENDIF;
IF SW==1 AND S>=5 THEN A=(A+5);
ELSE A=0;
ENDIF;
IF SW==1 AND S>=50 THEN A=240;
ENDIF;
IF S4==1 THEN
  A=500;
ENDIF;
IF SW==0 THEN S1=0;
ENDIF;
IF SW==0 THEN S2=0;
ENDIF;
IF SW==0 THEN S3=0;
ENDIF;
IF SW==0 THEN S4=0;
ENDIF;
IF SW==0 THEN S5=0;
ENDIF;
IF SW==1 AND S>=25 THEN
B=B+20;
ELSE B=0;
ENDIF;
IF S5==1 THEN
C=C+150;
ELSE C=0;
ENDIF;
IF S5==1 THEN B=0;
ENDIF;
IF S1==1 OR S2==1 OR S3==1 OR S4==1 THEN B=0;
ENDIF;
IF S1==1 OR S2==1 OR S3==1 OR S4==1 THEN C=0;
ENDIF

6. Simulation results
The PLC ladder logic program to execute the simulation is given in Figure 5. In the ladder logic diagram, each rung is drawn from the rail, which is the vertical member of a ladder. Every rung holds its corresponding output at the end. There are about 500 lines in the total length of PLC. The time taken by the software to execute each Boolean instruction is 0.37 µs. For every 18 ms, the PLC software developed will be scanned. The possible faults will be detected for 10 times in one second. If any fault occurred in the operation of Induction motor, the motor will be stopped immediately by sending an alarm signal to the motor constraint circuit.
The Figure 5 represents the result and analysis various kinds of faults occurring in the operation of asynchronous or induction motor. By running the PLC program, the operating condition of the motor will be initially analyzed. The status of the individual operating parts of the motor is tested. After getting the result from the system, the problem is rectified and the process will be implemented again. This initial process is repeated until all the conditions are properly monitored. The PLC ladder logic program used to monitor and control the induction motor operation. The faults arranged in the ladder logic are as per the priorities of fault occurrences.

The single–phase fault, ground/earth fault, short circuit fault, over voltage fault, over load faults have been analyzed in this PLC program. To allow the current flow in the process, Normally Open (NO) logic is used and to stop the motor normally closed (NC) is used. The memory of each fault is allocated in parallel to normally open toggle switch to find the fault location quickly for rectification.

Figure 5. PLC Ladder Logic Program

The Figure 6 represents the SCADA protection system in design format. The faults which are going to be analyzed are designed in the SCADA system for fast shut down off the system and notifications through the command window. The push buttons to start and pause the motor operation are provided to initiate and shut down the process occurring in the motor. The motor speed is set to 440V, which is
the bearing rated capacity of the motor. When the rotating speed exceeds above the rated speed of motor, it causes the temperature rise in motor. Also, vibrations are observed, when the output side is connected with heavy load. The three phase AC supply is directly given from the distribution side of transformer to AC motor operating in industrial applications. Utilizing the power supply from transformer, the motor starts its functioning.

![Image](image1.png)

**Figure 6. SCADA system in Development mode**

The Figure 7 represents the run mode of monitoring system. The run mode is achieved by developing a corresponding SCADA designing system and communicating it with to the developed program. The process will be continued smoothly until an interruption occurs. If there is any fault or disturbances taking place in motor, it will be immediately notified in command window with accurate value and time. The details can be collected by any individuals from the system, to get clearance about fault location and type of fault that has been occurred in the system.

![Image](image2.png)

**Figure 7. SCADA Protection system Run mode**

The Figure 8 represents the communication between PLC and SCADA, which can be achieved by Dynamic Data Exchange using RS Linx classic. The instructions to perform the operation will come from the programmable logic controller for switching operations either it is an ON/condition depending on its present state or other component state. The DDE plays a major role in interfacing the PLC with SCADA without the use of internet connection. By observing through monitoring screen, various values of current, voltage, temperature and speed can be recorded at determined time intervals.
7. Conclusion
In this paper, an invulnerability system for an induction motor has been made known. The induction motor faults are studied and identified by using (AB) RS Logix 500. The project is successfully implemented by PLC ladder logic program. The various physical parameters identified and analyzed in this implementation are over-load, under-voltage, over-speed, temperature and vibrations that are detected immediately. The electrical faults such as single-phase fault, earth fault, ground fault, short circuit fault, over-voltage are analyzed and rectified by the emerging PLC. If any interruptions are likely to happen in the operation, a warning message is sent to the PC, to stop the motor, automatically.

In this project, a visual environment program is provided by SCADA. The interface between PLC and SCADA gives a reliable operating condition for the system and efficient time management system. The future work will be continued by a system with unique identifiers such as computing devices, mechanical and digital machines that will be interrelated to transfer data through a wireless network communication namely Internet of Things.

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