



PLC & SCADA based Condition Monitoring of Three Phase Induction Motor

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ABSTRACT: Three phase induction motors are mostly used AC motors in industry for various operations. Here the implementation of condition monitoring system for the 3-phase induction motor based on programmable logic controller (PLC) & SCADA technology is described. Also the implementation of a hardware and software for speed control, direction control, parameter monitoring on SCADA screen 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 monitoring data will be taken to a personal computer by SCADA Software Wonderware InTouch via PLC for further analysis.

KEYWORDS: PLC, SCADA, VFD, Induction Motor etc.

I.INTRODUCTION

Many factories use PLCs in automation processes to diminish production cost and to increase quality and reliability. In any industry the induction motor plays an important role due to its low cost and simplicity. By implementing a monitoring and control system for the speed of motor, the induction motor can be used in high performance variable-speed applications. To control the speed of these motor, a motor drive and control system with different methods can be used. Here we present 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. Synchronous speed given by $N_s = (120 \cdot F) / P$ Where, F= supply frequency P= poles Synchronous speed is directly proportional to the supply frequency. Hence, by changing the output frequency, the synchronous speed and motor speed can be control below and above the normal full-load speed. For this now a days the variable frequency drive is using. The traditional variable-frequency drive (known as volts per hertz (V/Hz) changes the motor's frequency and voltage using solid-state control units. The modern strategy for controlling the AC output of such a power electronic converters is the technique known as Pulse Width Modulation (PWM), which varies the duty cycle of the converter switches at a high switching frequency to achieve a target average low frequency output voltage or current, SCADA is an important application that allows a utility operator to monitor and control processes that are distributed among various remote sites.

II.RELATED WORK

As per Zhang P, in various systems or process control system mostly electrical motors are used, especially the induction motors, because of their suitability in system design in industry and many other advantages like energy, time, and sensitivity [1]. In research work of Chaitanya N. Jibhakate and Mrs. Vijaya Huchchein investigates the speed control performance of single-phase induction motor using microcontroller. The complete design is modelled and tested using MATLAB simulation and hardware implementation to control the speed. Single phase induction motor has been control by frequency And Voltage control method by using SPWM control circuit and H-bridge inverter [2] As per Shweta hugar, Basavaraj Amarapurto protect an Induction motor easily, a microcontroller based fault detection and protection of Induction motor proposed. This system tends to develop for protection of three phase induction motor from over voltage and under voltage, over current, over speed, temperature, Line frequency and phase failure with their sensing circuits[3] Mahendra Bodkhe & K N Pawar explains Parameter monitoring of an induction motor by Zigbee protocol. Zigbee is mostly used in industries in various ways because it supports devices having low cost, intelligent network topologies and energy saving[4] Snehal Lande, Pooja Jaiswal, Priyanka Rajgure used GSM Technology for Protection of induction motor against possible problems such as overvoltage , overcurrent , overspeed , overtemperature , three-phase unbalanced occurs in course of it's operation. Experimental results shows that the

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parameters of induction motor can be monitored using GSM which costs less, provides higher accuracy as well as safe and motor gets fully protected.[5] Arfat Siddique, G.S.Yadava and Bhim Singh define various techniques used to monitor faults in an induction motor. These techniques can be classified into the following categories using different parameters like Temperature, Magnetic flux, Vibration, Power, Current, Induced voltage, Instantaneous Angular speed, Air-Gap Torque, Partial discharge, Surge current, Gas analysis, Motor circuit analysis, Stator Current Monitoring, Visual monitoring.[6] Alberto Bellini, Fiorenzo Filippetti, Carla Tasoni, And Gerard-Andre Capolino classify diagnosis procedure for an induction motor into three classes as model based, signal based & data based[7] A R Al-Ali et al. proposed a power factor controller for a three-phase induction motor using PLC to improve the power factor of a three-phase induction motor[8]

Because of noisy surrounding, critical environmental condition like excessive temperature, humid weather etc. sometime microcontroller are not suitable for industrial environment, microcontroller may fail in its operation. With the use of GSM based parameter monitoring system, it was possible to observe motor status on Mobile screen, but it is not possible to keep record of all parameter with respect to time. The Signal Processing based approach of fault diagnosis may not be effective in online condition monitoring of an induction motor.

But the use of a PLC can be the right choice if it is considered in an automation system in order not to use extra microprocessor. Nowadays, the most widely used area of PLC & SCADA based system is the control circuits of industrial automation systems.

III. OVERVIEW OF PROPOSED WORK METHODOLOGY

The proposed system is to monitor motor parameter on SCADA Screen. The drawbacks of the previous work are sometime microcontroller not suitable for industrial environment, motor parameters were not possible to show on PC and motor control from PC was not possible.

This system configuration of parameter monitoring of an induction motor system is shown in figure 3.1. This system consists of different working arrangements which mainly consist of induction motor, current sensor, VFD, PLC and PC and figure shows the detail blocks which describe the working of the parameter monitoring of an induction motor system. As seen from above figure Induction motor is last element whose parameter we have to monitor on SCADA. Induction motor receives AC main power through AC Drive or VFD. To see current consumed by an induction motor on SCADA screen, we use CT which is connected in between motor and PLC. Output of CT is given to PLC through which value of current is shown on SCADA screen. VFD plays a vital role in protecting motor from various faults like overload, overvoltage, over current, etc. Whenever faults occur, VFD indicates the same on its display. By referring code user will be able to find solution same within a short period of time. Here the system is set to sense motor parameters, to show them on SCADA screen also to control motor from SCADA. Once the parameters are sensed, PLC will decide whether measured parameters are within limit or not. If the parameter crosses the limit set by user, SCADA screen will give warning message on its screen. So at supervisory level, user will be able to see motor condition, its parameters whether they are crossing threshold or not. User also will be able to control motor.

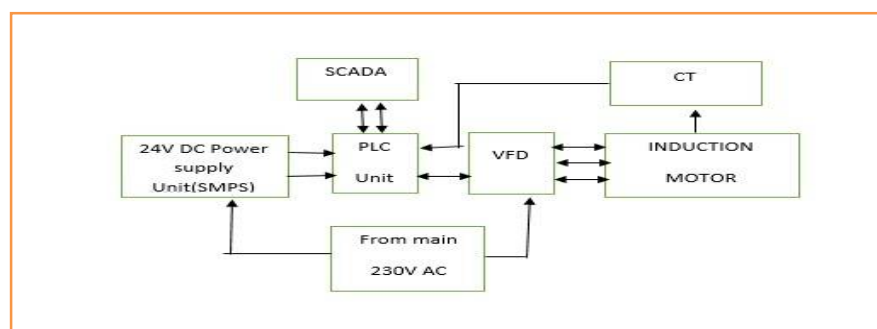


Figure 3.1: System Overview

3.1 PLC UNIT

Here for controlling operation of induction motor, that suits system requirement, we have to develop logic. It is also necessary to take motor parameters as an input and to send them as an output to SCADA system along with decision making capabilities. Hence we use Allen Bradley PLC with following specifications given in table 3.1



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Model	Micrologix-1200
Series	C
Maker	Allen Bradley
Input/output (Digital)	14/10
Input/output (Analog)	4/0
Supply Voltage	24 volts Dc

Table 3.1 PLC Specifications

3.2 VFD UNIT/ ELECTRICAL DRIVE SYSTEM:

In this system we require to handle high power devices operating electronically to control and protect the induction motor and we also require high input to the VFD. A VFD is useful for applications wherein speed control is of an essential importance due to load changes wherein the speed needs to be increased or decreased accordingly. To provide these requirements we used VFD with the specification of the VFD as shown table 3.2

Model	Powerflex 40
Series	A
Maker	Allen Bradley
Input Frequency	50 Hz
Rated Power	0.5 Hp

Table 3.2: VFD Specification

The output parameters from the motor and PLC input requires a proper isolation that means the proper range of the voltage. Hence to provide the isolation between PLC control circuit and high voltage motor, motor control and protection, VFD is used. A Variable Frequency Drive (VFD) is a type of motor controller that drives an electric motor by varying the frequency and voltage supplied to the electric motor. Other names for a VFD are variable speed drive, adjustable speed drive, adjustable frequency drive, AC drive, microdrive, and inverter. VFDs are used in applications ranging from small appliances to the largest of mine mill drives and compressors. VFD system basically consist of three main sections namely, Converter, DC Bus & Inverter. Converter section converts AC mains into DC, DC Bus that further rectifies and carries dc signal and finally Inverter section which again converts DC to AC but in PWM form.

3.3 SCADA SYSTEM:

SCADA stands for Supervisory Control and Data Acquisition. SCADA refers to a system that collects data from various sensors at a factory, plant or in other remote locations and then sends this data to a central computer which then manages and controls the data. SCADA is a term that is used broadly to portray control and management solutions in a wide range of industries. One of key processes of SCADA is the ability to monitor an entire system in real time.

The main purposes for the use of a SCADA system would be to collect the needed data from remote sites and even the local site, displaying them on the monitor of the master computer in the control room, storing the appropriate data to the hard drive of the master computer and allowing the control of field devices (remote or local) from the control room. SCADA systems are equipped to make immediate corrections in the operational system, so they can increase the life-period of your equipment and save on the need for costly repairs. It also translates into man-hours saved and personnel enabled to focus on tasks that require human involvement

IV. HARDWARE MODEL

The Figure 4.1 shows overall hardware model of this project. Power supply is a reference to a source of electrical power. A device or system that supplies electrical or other types of energy to an output load or group of load is called a power supply unit or PSU.

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Figure 4.1: Overall Hardware Model

To control the speed of induction motor, a motor drive and control system with different methods can be used. The three phase induction motor is, by a very considerable margin, the most widely used AC motor in industries. The reasons are its low cost, simple and rugged construction, absence of commutator, good speed regulation. An induction motor of a medium size may have an efficiency as high as 90% and a power factor of 0.89

V.SOFTWARE DESCRIPTION

Under the IEC 61131-3 standard, PLCs can be programmed using standards-based programming languages. A graphical programming notation called Sequential Function Charts is available on certain programmable controllers. Initially most PLCs utilized Ladder Logic Diagram Programming, a model which emulated electromechanical control panel devices (such as the contact and coils of relays) which PLCs replaced. This model remains common today. The developed ladder logic is shown in figure 5.1. Power flows through these contacts when they are closed. The normally open (NO) is true when the input or output status bit controlling the contact is 1. The normally closed (NC) is true when the input or output status bit controlling the contact is 0.



Figure 5.1: Ladder Diagram

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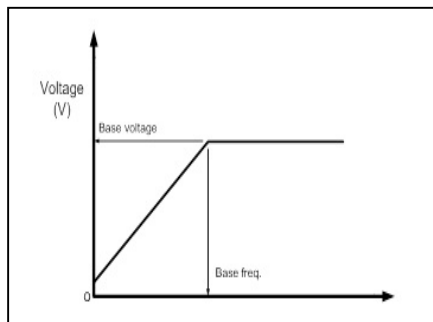
V. RESULTS

Effect of Drive Frequency: The major effect of change in supply frequency is on motor speed. If supply frequency drop by 10%, then motor speed also drop by 10%. We know that speed of three phase induction motor is given by equation $N = (120 * F) / P$ where N= Speed of Motor, F=Supply Frequency & P=No.of Pole.

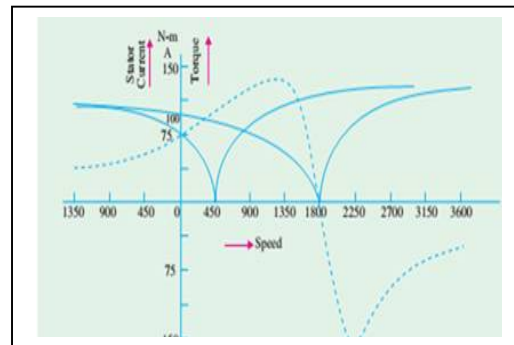
From equation it is clear that, $N \propto F$ i.e. Speed is directly proportional to Frequency

Sr No.	Drive Frequency	Speed of Motor	Current	Power
1	10	273	0.92	210
2	15	395	1.01	236
3	20	529	1.08	250
4	25	651	1.12	257
5	30	800	1.15	262
6	35	918	1.18	270
7	40	1067	1.18	275

Table 4.2: Drive Frequency Vs Speed Observation



Graph 4.1 Drive frequency Vs. Speed



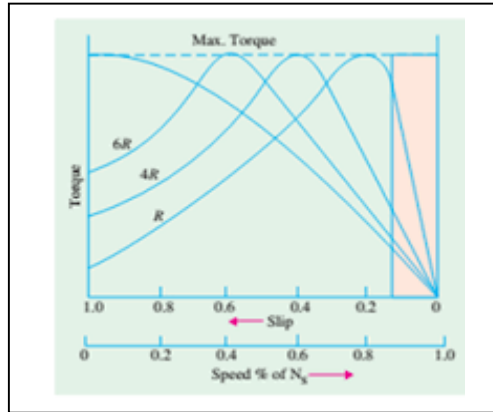
Graph 4.2 Speed Vs Current & Torque

We know that $T \propto s$, where T= Torque & s=Slip. As seen from graph 4.4, for low value of slip, torque-slip curve is approximately straight line. As slip increases (Load Increases), Torque also increases up to 'pullout' or 'breakdown' torque only. After that with increase in slip (i.e. motor speed falls), with increase in motor load. Hence, for large value of slip $T \propto (1/s)$. The corresponding relation is shown in graphical manner as shown in graph 4.4

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Graph 4.4: Torque Vs Slip characteristics

SCADA RESULTS:

To monitor motor condition, SCADA Screen was provided with various control buttons like Motor ON/OFF, Motor Forward/Reverse and associated indicators. If the condition is true, the indicator glows GREEN and if the condition is False, the indicator glows RED.

Name of Indicator Unit	Color	Comment
MOTOR ON	GREEN	YES; Motor ON
	RED	NO; Motor NOT ON
MOTOR OFF	GREEN	YES; Motor OFF
	RED	NO; Motor NOT OFF
MOTOR FWD	GREEN	YES; Motor Running in Forward Direction
	RED	NO; Motor is NOT Running in Forward Direction
MOTOR REV	GREEN	YES; Motor Running in Reverse Direction
	RED	NO; Motor is NOT Running in Reverse Direction

Table 4.1: Summary of SCADA display

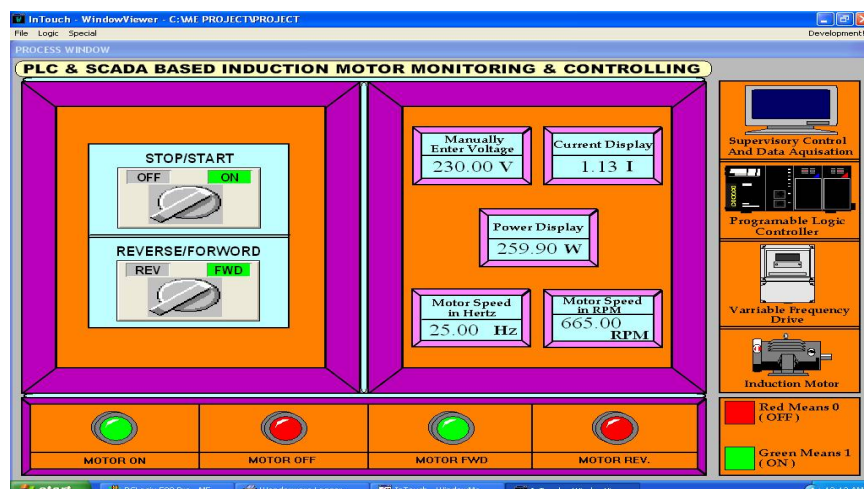


Figure: 4.1 SCADA Screenshots when motor is ON and running in Forward direction

Here Induction Motor is fed by three phase AC Supply through PWM Inverter. When Induction motor starts, it is governed by PLC through sensors. The reading from sensors is sent to PLC. PLC communicates with SCADA &



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displayed parameters of motor like Voltage, Current, Power, Speed & Drive Frequency on SCADA Screen effectively. The parameters of motor are used to compare with specified threshold values and according to control program stored in memory, certain decision is taken, like warning message are given on SCADA screen like Overload /Over current

VI. CONCLUSION AND FUTURE WORK

From the result, it is seen that with increase of load current the speed either in clockwise or anticlockwise direction, in the both case the speed decreases. This justifies the performance of induction motor. The curve drawn is almost a linear straight line which is in accordance with the performance characteristics of an induction motor. In this project, the software Rockwell has been successfully used for PLC and Wonderware InTouch for SCADA.

In this project, the monitoring and control system is designed for three phase induction motor. The system is successfully implemented and tested. After detailed experiment, it is observed that proposed system is feasible method for controlling of an induction motor. With the use of PLC & SCADA, the control system is more reliable. The control system design is based on most advanced technology which give high amount of flexibility and efficiency. Monitoring system give facility of analysing the operation of an induction motor in online/offline mode which make the system to be safe from fault/error conditions.

There are various other methods for the control of induction motor control like GSM, ZigBee based parameter monitoring which can also be used for monitoring and control system of an Induction Motor. The monitoring system can be connected to web, making the system control from any place from any corner of around the world. The system would be more adaptive so that it can be configured for different type of applications such as servo motor, stepper motor etc. In this project software Rockwell & Wonderware InTouch has been successfully used. However other type of software may also be employed & comparative analysis can be done. In this project, the other parameters like power factor, harmonics, vibration etc. have not been considered. So it is further suggested to consider these parameters and design circuit for improving power factor, reduction of harmonics contents in order to improve motor performance.

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