MONITORING AND CONTROL SYSTEM FOR THREE PHASE INDUCTION MOTOR FED BY INVERTER DRIVE USING PLC AND SCADA

Adarsh.R.J[*]

Narsimpur Tushar.S[**]

Sujatha.M.S[***]

Abstract—

Induction motors has increased tremendously since the day of its invention. They are being used as actuators in various industrial processes, robotics, house appliances and other similar applications. The reason for its day by day increasing popularity can be primarily attributed to its robust construction, simplicity in design and cost effectiveness. Modern industrial processes which involve multimotor drives require a co-ordinated sequential control through PLC and SCADA system. An integrated system comprising of a Workstation (PC), the PLC (SIEMENS S7 300), SIEMENS MM420 DRIVE, Three phase INDUCTION MOTOR and the software for Supervisory Control and Data Acquisition system are configured and developed in co-ordination with each other to ultimately control the three phase induction motor drive in multiple ways. The Induction motor is configured and controlled during normal operation and trip conditions, an effort is made to monitor the induction motor runtime variables like speed, voltage, temperature and current. The necessary Communication protocols are established between PC-PLC-DRIVE to ensure flawless communication. The real time Performance of the three phase induction motor is experimentally verified and captured on the Drive software. Various virtual animated screens are developed to explain the three phase induction motor speed control applications.

IndexTerms—Programmable Logic Controller, SCADA, Inverter Drive, Induction Motor.

[*] M.Tech in Computer Application, in Industrial Drives,Department of EEE, MSRIT, Bangalore, India.

[**] Assistant Professor, Department of EEE MSRIT, Bangalore, India.

[***] Manager, M/s Vasundara Automation & Engg Solutions Pvt. Ltd, Bangalore, India

A PLC-based system for the control and monitoring of a Three-Phase Induction motor showed the efficiency and speed regulation increased by using a PLC as compared to the conventional V/f control system Maria G Ioannides et.al **[3].** A control program has been developed, in accordance of which PLC continuously monitors the inputs and activates the outputs accordingly. A speed sensor is employed for speed feedback. Protection scheme to protect induction motors against possible failures thereby increasing reliability, efficiency and performance of the system. The proposed approach is a sensor-based technique, therefore, currents, voltages, speed and temperature values of the induction motor were measured with sensors and whenever any fault is detected during operation of the motor, PLC controlled on-line operation system activates immediately. The motor protection achieved is much reliable than classical techniques and can be applied even to larger motors **[2].**A power factor controller for a 3-phase induction motor, utilizing Programmable Logic Controller. This focuses on the implementation of a model for a PLC based power factor controller to improve the power factor of a 3-phase induction motor. Voltage to frequency ratio has been maintained constant to obtain maximum toque. The power factor controller hardware comprises of S7-PLC, a 3-phase squirrel cage induction motor coupled with a dc shunt generator and an electronic conditioning circuit **[4].** An industrial PLC used for controlling five-axis rotor position, direction and speed, thereby decrementing circuit components and cost and at the same time enhancing reliability. Ladder diagram has been used to control robot through PLC. The robustness of the PLC controller has been achieved by rotating the motor in both clockwise as well as counter-clockwise directions. Consequently, the PLC controller proves to be a simple tool for controlling robot by extremely simple algorithm **[5].**Recent advances in DSP and ASIC technology, plus the theoretical concepts developed for Direct Torque Control combines the benefits of direct flux and direct torque control into sensor less variable frequency drive that does not require a PWM modulator. The theory of DTC for three phases Induction Motor Drive is developed. The mathematical model of the drive is developed and simulated. From the simulation transient and steady state performance of the drive is obtained **[6].**By considering efficient monitoring & control & customized application product development for a induction motor drive automation leads to this present work carried out, which was intended to configure and develop an easy control strategy for induction motor speed control with the help of PLC, and also simple monitoring available in automation industry with the help of SCADA.

I. INTRODUCTION

Automation of electric machines helps in precise control of industrial processes with higher productivity and product quality. The combinational use of both PLC and SCADA systems helps in continuous monitoring, supervising and controlling process plants, has led to new heights in the field of automation for ac machines and processes., The development of the microprocessor from the mid 1970's have allowed them to take on more complex tasks and larger functions as the speed of the processor increased. SCADA which is actually the combination of telemetry and data acquisition involves the collection of the information via Remote Terminal Unit (RTU), transferring it back to the central site, carrying out any necessary analysis and control and then displaying that information on a number of operator screens or displays. The required control actions are then conveyed back to the process. The overall system set up which forms an integral part of this dissertation work aims to provide a fairly good platform for developing the concepts, methodologies and the complete understanding of an industrial automated system comprising of the commonly used components like PLC, SCADA, Drive and Motor along with SCADA. The PLC proves to be a very versatile and effective tool in the control of the Three Phase induction motor drive.

The experimental setup consists of a 0.75KW Three Phase Induction Motor, Siemens MM420 AC drive, PG/PC and Siemens PLC. The Induction motor is fed through a PWM based Siemens drive, which provides high frequency controlled voltage to stator windings of motor. The feedbacks like speed, current, temperature and voltage of induction motor are fed back to the PLC.Initially Ladder logic programming is performed according to the customised logic using S7 Simatic Manager software platform on a PC offline, and then it is made online by running the developed program in the PLC. Similarly for SCADA using WinCC Explorer software platform.

II. SYSTEM OPERATION

Main control program is developed on PLC programming space using S7 Simatic Manager (SIEMENS). In this control method application specific PLC ladder logic programsare written in software tool and are communicated to PLC through industrial Ethernet or MPI cable. This software integrates all the modules of PLC as well as the devices connected to its networking module. Block diagram of Experimental setup is shown in Fig 1.The following sections briefs about Induction motor closed loop feedback technique and role of PLCs in induction motor automation.

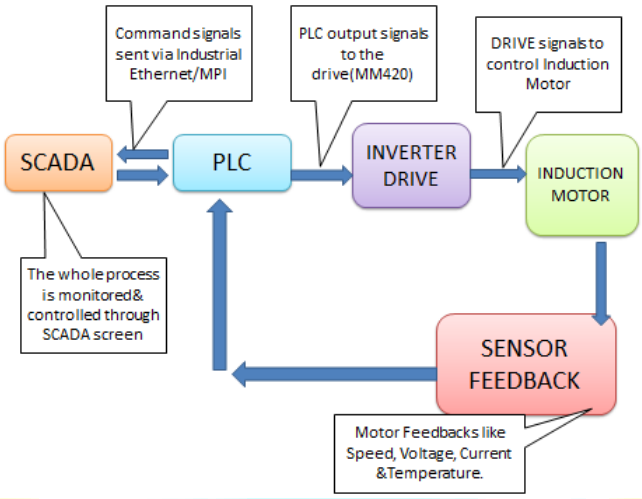

Fig 1 Block Diagram of Experimental setup

A. CLOSED LOOP FEEDBACK TECHNIQUE

Because of self adjusting nature, closed loop control systems are more complex in design. In induction motor closed loop control, feedback sensors can return data to the input stage, i.e. the control element generally PLC, which can self adjust itself based on the information received. For efficient and accurate control operations, the system should be a closed loop system, requiring feedback information signals to be satisfied according to PLC Input module standards. The feedback signal here provides information about actual speed, voltage, temperature and current drawn by motor. This obtained feedback information is signal conditioned to match the PLC input module ranges. If the PLC detects a difference between the obtained and desired values, an Alarm is generated and if it crosses the limits, it just trips of the PLC outputs. When inverter drives are used for motor control, the feedback signals are the important issue. If an error occurs the controller should react to it and take actions as per the program and guide the Inverter Drive, inturn Drive will control the motor operation. The user must know the limitations of the process and the motor conditions and design the exact program for controller. This signal conditioning circuits alters the actual sensed input signals to the desired form to match I/O module ranges. The address used in PLC program(ladder logic) and taken as tags in SCADA software and assigned to the design elements and developed screen acts as the graphical representation and human machine interface.

B. INDUCTION MOTOR AUTOMATION USING PLC

Programmable controller is a digital computer which accepts inputs from switches and sensors, stores instructions using programmable memory, evaluates these in accordance with a

stored program, executes specific functions that include ON/OFF control, timing, counting, sequencing, etc. and generates outputs to control machines and processes involved. The PLC processor sends all the direction and information like actuating particular outputs at desired timings to the drive. It uses a programmable memory to store instructions and execute specific functions that include ON/OFF control, timing, counting, sequencing, arithmetic and data handling. The inputs are connected to the input module of the PLC and the outputs are connected to the output module of the PLC. In an automated system, a PLC controller is usually the central part of a process control system. In this project, control of three phase induction motor and monitoring of its parameters as well as evaluation based on our requirements under different condition is carried out using PLC. Based on the required application, a ladder logic program is developed and downloaded to PLC. Once the program is downloaded and PLC is in RUN mode the system works automatically on user defined instruction. Before loading program in to the PLC, inSiemens S7 300 PLC we have a simulator where logic can be verified without hardware setup and online corrections are made easy.

PLC	SIEMENS S7-300
CPU	CPU 314
INPUTS (Input Power)	SM 321; DI 16 x DC 24 V SM334; AI 4 ×8/8 Bit
OUTPUTS (Output Power)	322-1BH01-DO 16-DC 24V 1A SM334; AO2×8/8 Bit
CP	CP 343-1 LEAN

TABLE 1 :SIEMENS S7-300 series PLC Specifications

PLC based systems are cost effective and comparatively require less downtime compared to previous controls, are less manual labor intensive, can be networked together and enables “real-time” monitoring, troubleshooting, and adjustments to set points. Present day PLCs are extensively used for controlling, manufacturing and treatment processes.

C.OVERVIEW OF AC MM420 DRIVE

Figure 2 shows a three-phase Siemens AC Drive. The rectifier circuit converts 1ph or 3 ph AC voltage source into DC voltage which is then fed to three-phase inverter through a DC link (choke coil) and capacitor. The DC link capacitor removes ripples in the converted voltage.

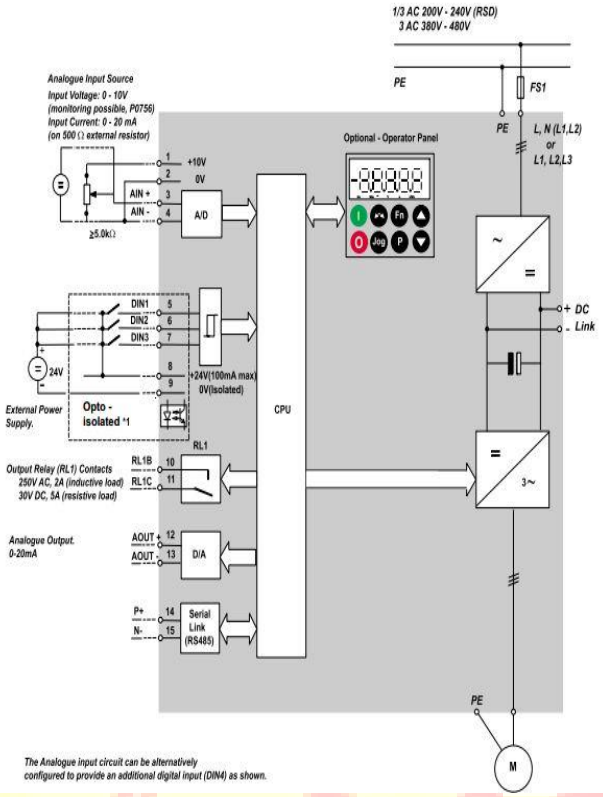

Fig 2:Block diagram of MM420 drive

The drive has a protection circuit which protects motor against under overloading, faults, etc. MM420 drive works on V/F principle... The pulses to the gate circuitry of IGBTs are controlled by gating circuits and in turn AC induction motor operation is controlled. The drive has a display screen to view and change various parameters as and when required. The commissioning of drive can be done in 3 ways i.e. using BOP (Basic Operator Panel), terminal blocks and through PG/PC.in quick commissioning the typical name plate readings should be fed in to the drive.

III. SOFTWARE REQUIREMENT FOR MONTIORING AND CONTROL OF THREE PHASE INDUCTION MOTOR

A PLC and SCADA based monitoring and control systems for induction motor have been successfully implemented and tested for application development. The drive system provides precise control and also enables an online monitoring of drive speed, voltage, temperature and current drawnetc. through SCADA System. The following software's are used in the monitoring and control of the three phase induction Motor.

SIMATIC MANAGER

This is software specially meant for SIEMENS S7 seriesPLC. The ladder logic programs are developed according to the control logic required so that same can be downloaded to the PLC, it also has the option of running in PLC offline mode where the developed ladder diagrams can be run without any PLC by simulating and running using simulator where the status of inputs and outputs can be monitored and controlled according to the requirement.

WinCC Explorer

This software is used to create SCADA screens graphically which provides user interface to control the process, creating tags in WinCC Explorer based on I/O addresses used in simatic manageris important. Different screens are developed in SCADA for monitoring and control of three phase induction motor. This makes the system/process to be controlled in an efficient manner.

COMMUNICATION PROTOCOLS

Protocols are used to communicate between PG/PC and the PLC. MPI (Multi Point Interface) and Industrial Ethernet can be used in the process as per the situation and requirements.

IV. OBJECTIVE FULFILLMENT

Following sections deals with the scope of the present work. The control schemes developed are able to control and monitoring of servo motor used for application specific requirement.

A.Development of PLC ladder logic program to control induction motor

An experimental setup comprising of a AC Three phase induction motor, PLC & PC will be designed and implemented to control Three phase induction motor for different process

applications. In this method, V/F control of Siemens MM420 Three phase drive through PLC and SCADA has been implemented. The developed ladder logic is downloaded into PLC processor and control of motor is achieved by simply activating the particular logical input involved, which ultimately results in instigation of ladder logic program developed.

In this method,control of three phase induction motor drive through PLC has been implemented. The developed ladder logic is downloaded into PLC processor and control of motor is achieved by actuating the particular logical output involved, which ultimately results in instigation of ladder logic program developed.The experimental work involves parameter grouping for monitoring feedbacks of motor like motor voltage, temperature, speed and current drawn.

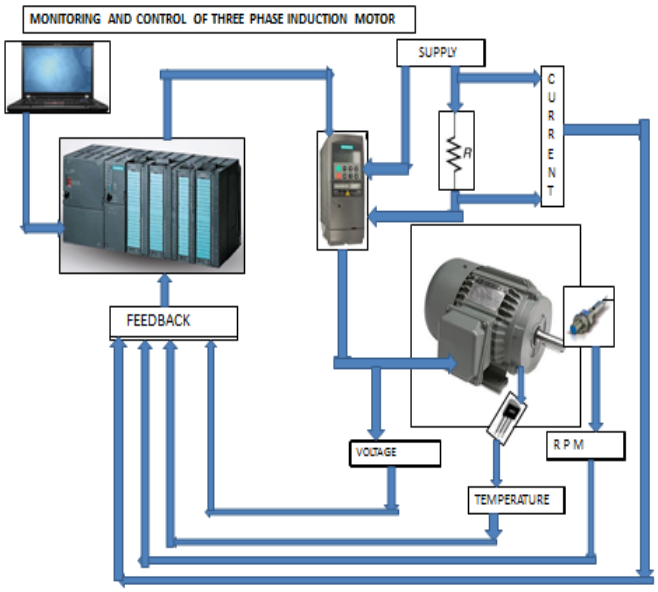

Fig 3 :Experimental setup to control induction motor using PLC

In order to provide convenient control using MM420 drive, the control mode parameters are listed, configured and commissioned in to the drive using BOP.Then the ladder logic program is developed in the PLC to satisfy the application requirement.The operational criteria and the limitations to be maintained of the process is completely written in the program logicand purely dependent on the user.

B. To read analog and digital inputs in PLC ladder logic

Micro Master 420 drive present in the system provides operation and monitoring of three phase induction motor. Simultaneously analog and digital input signals are read in data monitor window in PLC as a feedback of speed, voltage, current and temperature. This comprises of both digital and analog inputs, the analog inputs with high ranges which cannot be read directly by PLC to monitor, so an attempt has been made to overcome this problem by using signal conditioning circuits and scaling down the inputs equivalent to decimal values readable format in PLC ladder logic.

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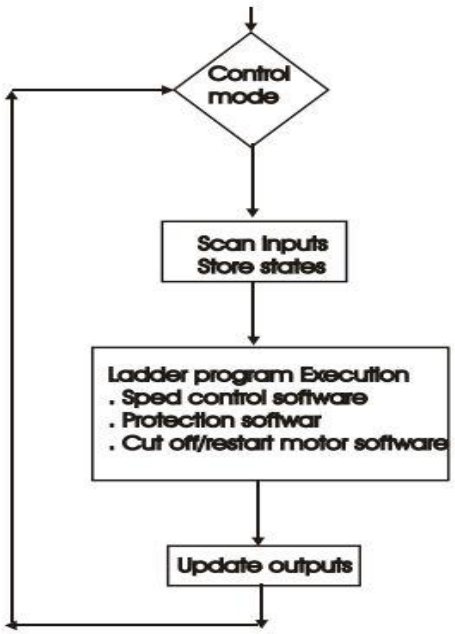
C.Interfacing of SCADA, PLC with Siemens MM420 drive

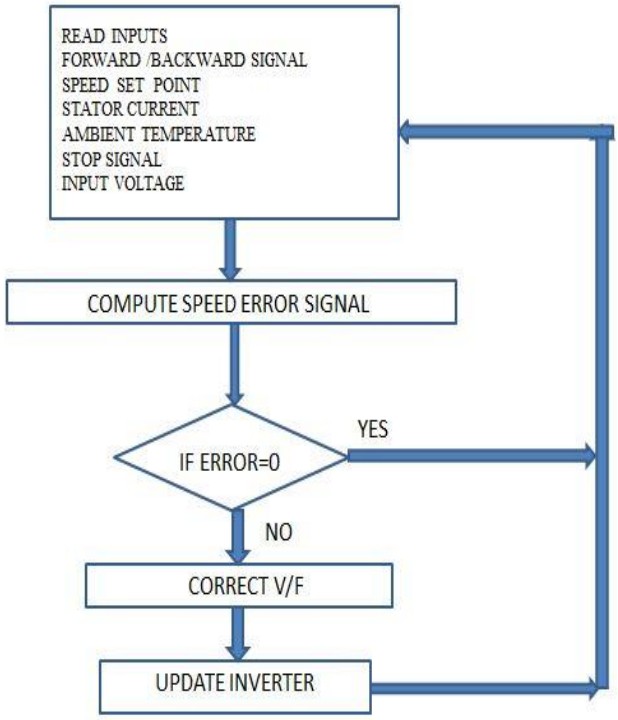
This method is meant for semi-automated control of field devices through a control panel; by designing PC monitor as SCADA screen using different graphics having the same address as that of logical inputs involved in motor control. SCADA allows control systems to be much more interactive than before. The basic purpose of SCADA is to allow easy graphical interface with control processes. SCADA allows an operator to use simple displays for determining machine parameters like Speed, voltage, temperature and current for supervising control processes.

1. Flow chart for the main program



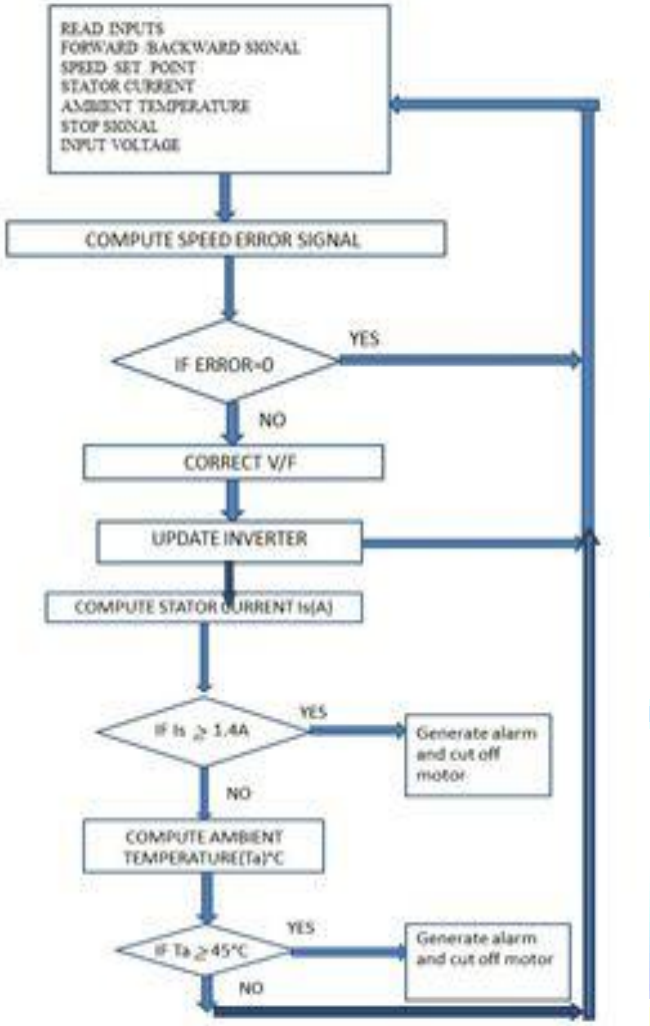
The software regulates the speed and monitors the constant speed control regardless of torque variation. The inverter being the power supply for the motor executes this while, at the same time, it is controlled by plc.'s software. The inverter alone cannot keep the speed constant without the control loop with feedback and plc. From the control panel, the operator selects the speed set point nsp and forward/backward direction of rotation. Then, by pushing the manual start pushbutton, the motor begins the rotation. If the stop button is pushed, then the rotation stops.

2.Flowchart of speed control software



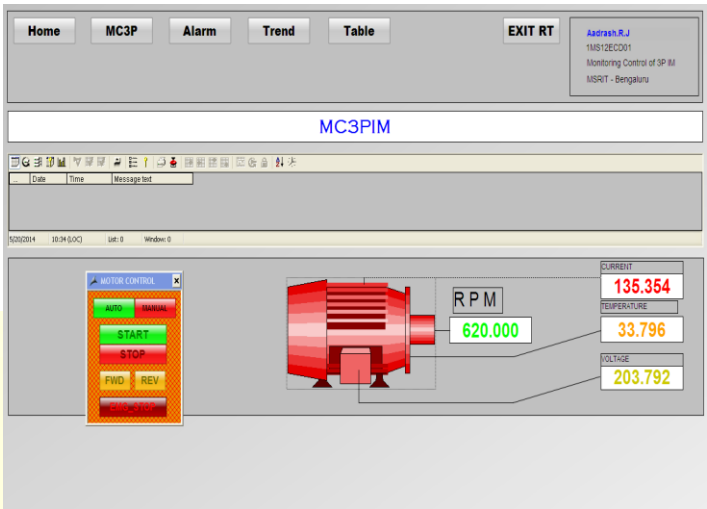
The corresponding input signals are interfaced to the DIM and the output signals to the DOM. The AIM receives the trip signal from the stator current sensor and from temperature sensor, the speed feedback signal from the speed sensor, and the signal from the control panel. In this way, the PLC reads 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 the PLC according to the computations carried out by the CPU decreases or increases the V/f of the inverter and, as a result, the speed of the motor is corrected.

3. Flow chart for monitor and protection software



In the above flow chart we have a program for controlling, monitoring and protection software. First the inputs are read by the PLC and other protection parameters like stator current and ambient temperature is sensed and checks for the errors .If there are any errors occurring the control program shuts off the motor through the output command.

4. SCADA monitoring and controlling screen



The above Screen presents the control of motor that is auto, manual, start, and stop; forward, reverse, emergency stop controlling FACEPLATE is designed. All the sensor outputs like speed, current, temperature and voltage readings of the induction motor are displayed as shown

5. SCADA TREND screen

Trend represents the speed, voltage and temperature in the form of graph.The x-axis represents the time domain and y-axis represents the speed temperature and voltage values as shown

6. RESULTS& DISCUSSIONS

Successful experimental results were obtained from the monitoring and control scheme indicating that the PLC can be used in automated systems with an induction motor. The monitoring control system of the induction motor driven by inverter and controlled by PLC and SCADA proves its high accuracy in speed regulation at constant-speed variable-load operation. Despite the simplicity of the speed control method used, this system presents

- Monitoring and control using SCADA.
- Constant speed for changes in load torque.
- Full torque available over a wider speed range.
- Very good accuracy in closed-loop speed control scheme.
- Overload protection.

7. CONCLUSION

The present work was motivated to develop an online scheme to Monitor and Control a Three Phase induction motor using PLC and SCADA. A thorough study of all the hardware components was done including their Specifications, functioning and overall performance. Two software platforms namely step 7 SIMATIC manager and WinCC explorer Software were comprehended, analyzed and implemented step by step.

A 0.75KW, 1415 rpm, three phase induction motor monitoring and control was fully automated using PLC and Siemens MM420 Drive with the help of SCADA system its remote start, stop control operations and monitoring too were demonstrated. An effort was also made to configure the PLC device and its ports in SCADA to monitor the real-time values of the three phase induction motor variables like Speed, current, voltage and temperature.

The necessary settings and software implementation of the algorithms needed for, Speed control operation of the drive were developed and tested for real-time implementation of the motor drive. The motor drive used in this set-up offered v/f control mode of motor operation. The configuration and settings to run the three phase induction motor in v/f control mode was

done systematically and its characteristics were captured on the data scope and interpreted successfully.

Other than practically implementing the above schemes an important aspect of the present work which was successfully carried out was to completely identify study and summarize the communication ports, standards and protocols used between the various components of the entire industrial set-up including the PC – PLC – Drive –Induction motor – SCADA.

A complete study and practical hands on the PLC and the drive operation have imparted a fairly good idea about the industrial automation systems.

8. FUTURE SCOPE OF WORK

The following aspects can be explored as an extension to this dissertation work. More emphasis can be given to the real-time monitoring of processes using the SCADA software to obtain complete control of a real-time process including monitoring of more variables and incorporating some error control element too. Also the Programming methodology used in this dissertation work is Ladder Programming. The STEP 7 SIMATIC manager also offers various other programming platforms like FBD, STL, IL etc. Programs can be developed using these platforms.

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