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Design and Implementation of SCADA Based Induction Motor Control

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ABSTRACT
The introduction of Supervisory Control and Data Acquisition (SCADA) system has been discussed in details. Network components, functionality, generation and features of SCADA has been discussed in details in this paper. Application and uses of SCADA system in different fields of engineering have also been mentioned. Also the working of the software components and development in SCADA has been explained with merits and demerits of the software.
Programmable Logic Controller (PLC) has been discussed in detail which includes features, working and automation purposes of PLC in this paper. Architecture, memory organization, addressing words, input/ output modules and programming of a PLC with all its components such as programming devices, consideration of programming and program control instructions has been studying for this paper. Working of the project with SCADA and PLC has been also discussed. Programming development has also been explained. A systematic approach of control system design using programming logic controller has been discussed in details with ladder logic diagram designing. PLC program development and programming with ladder diagram has been explained with the assignment of SCADA control screen. Also the SCADA screen developed has been shown at the different operation conditions of the processing system in this paper.
Experimental setup and performance analysis explains the actual wok which has been adopted for the project.

I. INTRODUCTION

SCADA is an acronym for Supervisory Control and Data Acquisition. SCADA systems are used to monitor and control a plant or equipment in industries such as telecommunications, water and waste control, energy, oil and gas refining and transportation. These systems encompass the transfer of data between a SCADA central host computer and a number of Remote Terminal Units (RTUs) and/or Programmable Logic Controllers (PLCs), and the central host and the operator terminals. A SCADA system gathers information (such as where a leak on a pipeline has occurred), transfers the information back to a central site, then alerts the home station that a leak has occurred, carrying out necessary analysis and control, such as determining if the leak is critical, and displaying the information in a logical and organized fashion. These systems can be relatively simple, such as one that monitors environmental conditions of a small office building, or very complex, such as a system that monitors all the activity in a nuclear power plant or the activity of a municipal water system. Traditionally, SCADA systems have made use of the Public Switched Network (PSN) for monitoring purposes. Today many systems are monitored using the infrastructure of the corporate Local Area Network (LAN)/Wide Area Network (WAN). Wireless technologies are now being widely deployed for purposes of monitoring.

SCADA not a full control system, but rather focuses on the supervisory level. As such, it is a purely software package that is positioned on top of hardware to which it is interfaced, in general via Programmable Logic Controllers (PLCs), or other commercial hardware modules.

SCADA systems are used not only in industrial processes: e.g. steel making, power generation (conventional and nuclear) and distribution, chemistry, but also in some experimental facilities such as nuclear fusion. The size of such plants range from a few thousands to several 10 thousands input and output (I/O) channels. However, SCADA systems evolve rapidly and are now penetrating the market of plants with a number of I/O channel of several 100K.

SCADA systems consist of:

- One or more field data interface devices, usually Remote Terminal Units, or Programmable Logic Controls, which interface to field sensing devices and local control switchboxes and valve actuators.
- A communications system used to transfer data between field data interface devices and control units and the computers in the SCADA central

host. The system can be radio, telephone, cable, satellite, etc., or any combination of these.

- A central host computer server or servers (sometimes called a SCADA Centre, master station, or Master Terminal Unit (MTU).
- A collection of standard and/or custom software [sometimes called Human Machine Interface (HMI) software or Man Machine Interface (MMI) software] systems used to provide the SCADA central host and operator terminal application, support the communications system, and monitor and control remotely located field data interface devices.

1.1 TYPICAL SCADA SYSTEM

The figure below shows a typical diagram of a SCADA system describing different components.

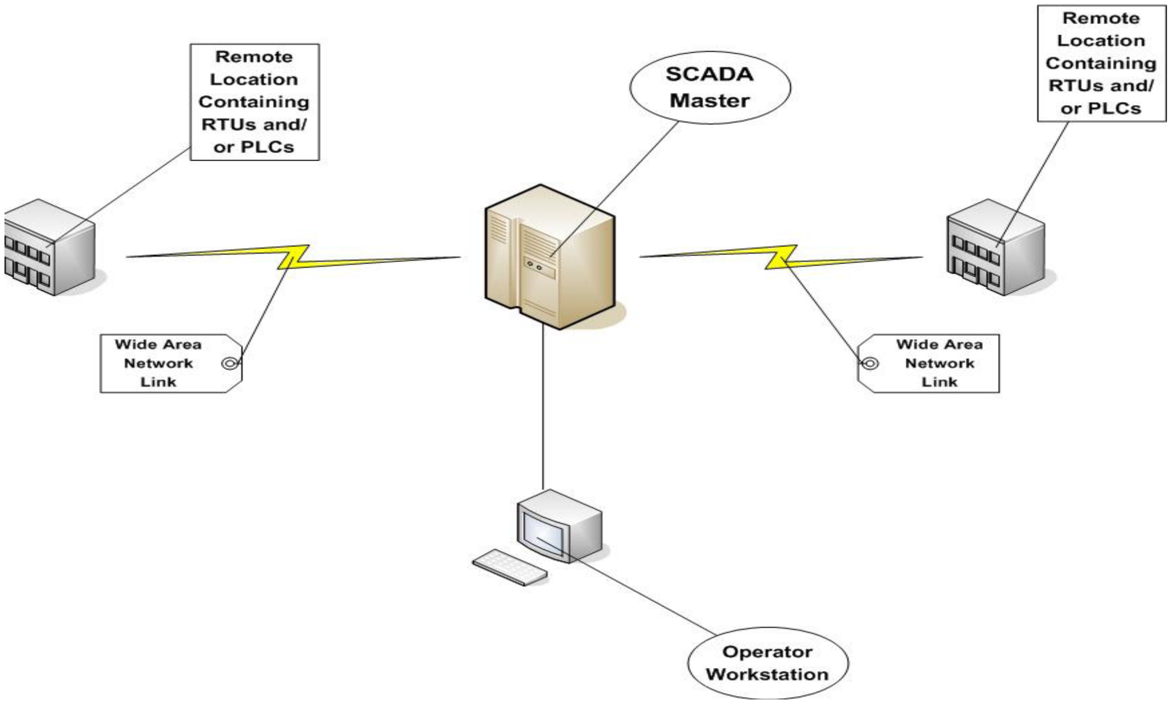

Figure1: Typical SCADA system

1.2 APPLICATION OF SCADA

A typical SCADA application requires several low cost distributed RTUs, controlled by a central station/master. Common applications for SCADA systems typically include water and waste treatment, petroleum and hydro carbon processing, power generation, food processing, steel manufacturing, remote telecommunications and plant machinery maintenance. Unlike in plant process control systems, SCADA systems typically include a remote telecommunication link. Real-time measurements and controls at remote stations are transferred to a CPU through the communication link. Large systems can monitor and control 10-2000 remote sites, with each site containing as many as 2000 I/O points.

A SCADA system for small applications

SCADA is not a new technology by any means, but innovations and significant improvements have been made since its introduction. Until recently, SCADA technology was often viewed as a luxury item by small industrial companies. The technology was deemed unobtainable because of high association with that systems could not be fully used because of their massive I/O capacities.

1.3 ADVANTAGES AND DISADVANTAGES OF SCADA TECHNOLOGY

Advantages of SCADA system include Wide area connective and pervasive; routable; parallel polling; redundancy and hot standby ; large addressing ranges; integration of I.T to automation and monitoring net works; standardization; reduce down time; limit the frequency of accidents; improve record; increase through put.

Disadvantages of SCADA Technology include IP performance over head; web enabled SCADA hosts users to remotely monitor, control remote sites via a web browser; security concerns.

II. PROJECT OVERVIEW

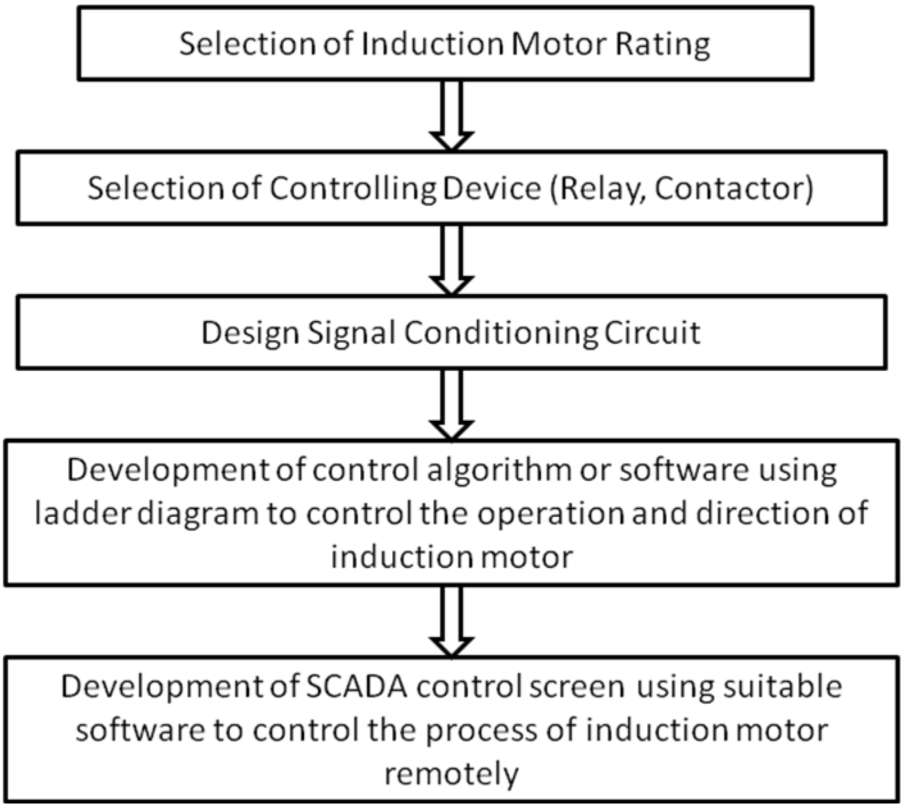

Figure2: Method of Project Implementation

In this section, it will discuss an overall overview of "Design and Implementation of SCADA based Induction Motor Control" project. The introduction to system task will also briefly explain in this chapter. Finally, the entire decision making will be addressed in this section. Basically, software and hardware design will be used in order to implement this project. In addition, there some methods must be executed to keep this project implemented successfully as shown in Figure2.

III. 2. HARDWARE DESIGN

In the hardware design part, overall component such as Pulley, Belt, motor, and load on pulley will be integrated to form the complete prototype. The hardware components are the backbone of the system. More detailed information of each section will be discussed in the following sections.

2.1 THREE PHASE INDUCTION MOTOR

The three-phase induction motors are the most widely used electric motors in industry. They run at essentially constant speed from no-load to full-load. However, the speed is frequency dependent and consequently these motors are not easily adapted to speed control. We usually prefer dc motors when large speed variations are required. Nevertheless, the 3-phase induction motors are simple, rugged, low-priced, easy to maintain and can be manufactured with characteristics to suit most industrial requirements.

2.2 BASIC CONSTRUCTION AND OPERATING PRINCIPLE

Like most motors, an AC induction motor has a fixed outer portion, called the stator and a rotor that spins inside with a carefully engineered air gap between the two. Virtually all electrical motors use magnetic field rotation to spin their rotors. A three-phase AC induction motor is the only type where the rotating magnetic field is created naturally in the stator because of the nature of the supply. DC motors depend either on mechanical or electronic commutation to create rotating magnetic fields. A single-phase AC induction motor depends on extra electrical components to produce this rotating magnetic field.

Two sets of electromagnets are formed inside any motor. In an AC induction motor, one set of electromagnets is formed in the stator because of the AC supply connected to the stator windings. The alternating nature of the supply voltage induces an

Electromagnetic Force (EMF) in the rotor (just like the voltage is induced in the transformer secondary) as per Lenz's law, thus generating another set of electromagnets; hence the name induction motor. Interaction between the magnetic fields of these electromagnets generates twisting force, or torque. As a result, the motor rotates in the direction of the resultant torque.

2.3 STATOR

The stator is made up of several thin laminations of aluminum or cast iron. They are punched and clamped together to form a hollow cylinder (stator core) with slots as shown in Figure. Coils of insulated wires are inserted into these slots. Each grouping of coils, together with the core it surrounds, forms an electromagnet (a pair of poles) on the application of AC supply. The number of poles of an AC induction motor depends on the internal connection of the stator windings. The stator windings are connected directly to the power source. Internally they are connected in such a way, that on applying AC supply, a rotating magnetic field is created.

2.4 ROTOR

The rotor is made up of several thin steel laminations with evenly spaced bars, which are made up of aluminum or copper, along the periphery. In the most popular type of rotor (squirrel cage rotor), these bars are connected at ends mechanically and electrically by the use of rings. Almost 90% of induction motors have squirrel cage rotors. This is because the squirrel cage rotor has a simple and rugged construction. The rotor consists of a cylindrical laminated core with axially placed parallel slots for carrying the conductors. Each slot carries a copper, aluminum, or alloy bar. These rotor bars are permanently short-circuited at both ends by means of the end rings, as shown in Figure. This total assembly resembles the look of a squirrel cage, which gives the rotor its name. The rotor slots are not exactly parallel to the shaft. Instead, they are given a skew for two main reasons.

The first reason is to make the motor run quietly by reducing magnetic hum and to decrease slot harmonics.

The second reason is to help reduce the locking tendency of the rotor. The rotor teeth tend to remain locked under the stator teeth due to direct magnetic attraction between the two. This happens when the numbers of stator teeth are equal to the number of rotor teeth.

The rotor is mounted on the shaft using bearings on each end; one end of the shaft is normally kept longer than the other for driving the load. Some motors may have an accessory shaft on the non-driving end for mounting speed or position sensing devices. Between the stator and the rotor, there exists an air gap, through which due to induction, the energy is transferred from the stator to the rotor. The generated torque forces the rotor and then the load to rotate. Regardless of the type of rotor used, the principle employed for rotation remains the same.

2.5 SPEED OF AN INDUCTION MOTOR

The magnetic field created in the stator rotates at a synchronous speed (*NS*).
In general, for P poles, the rotating field makes one revolution in P/2 cycles of current.

$$\therefore \quad \text{Cycles of current} = \frac{P}{2} \times \text{revolutions of field}$$

or $$\text{Cycles of current per second} = \frac{P}{2} \times \text{revolutions of field per second}$$

Since revolutions per second is equal to the revolutions per minute (N_s) divided by 60 and the number of cycles per second is the frequency f,

$$\therefore \quad f = \frac{P}{2} \times \frac{N_s}{60} = \frac{N_s P}{120}$$

or $$N_s = \frac{120\,f}{P}$$

Three-phase AC induction motors are widely used in industrial and commercial applications. They are classified either as squirrel cage or wound-rotor motors. These motors are self-starting and use no capacitor, start winding, centrifugal switch or other starting device. They produce medium to high degrees of starting torque. The power capabilities and efficiency in these motors range from medium to high compared to their single-phase counterparts. Popular applications include grinders, lathes, drill presses, pumps, compressors, conveyors, also printing equipment, farm equipment, electronic cooling and other mechanical duty applications.

IV. WORKING OF THE SYSTEM

Through this project, the induction motor will start running in forward direction at rated speed when we press the start button on SCADA screen. The motor will stop for a fixed interval of time as we required in between forward & reverse running of induction motor, it will automatically start to run in reverse direction at the rated speed. After that if we press the stop2 button the motor stop normally. For the safety point of view there is an emergency stop button (emergency stop) is also provided on the SCADA control screen so that the operator can stop the process if there is any problem in the process which is going on. The complete project with hardware & Software SCADA screen is shown in figure 3.

Figure3: Project with hardware & Software SCADA screen

V. SCADA DEVELOPMENT

The development of SCADA screen to access the process remotely is presented in this chapter. As per the rules, the SCADA screen is developed on the bases of Ladder diagram of the process. That would be explained in the previous chapter. On the based on the inputs and the outputs the design of SCADA screen is carried out. For that we have to assign the same address values of inputs and outputs to interface the PLC ladder logic program with SCADA and then developed the SCADA screen and also assign the values to different units of SCADA.

Assignment to Control Screen

As shown in Table1 is the values which are provide on the screen of SCADA to operate the process by control it remotely.

NAME OF INDICATOR UNIT	ADDRESS VALUE/COLOUR	COMMENT
Forward	Red	Motor is not running in forward direction
	Green	Motor is running in forward direction
Reverse	Red	Motor is not running in reverse direction
	Green	Motor is running in reverse direction
Motor	Black	Motor is at stopped condition
	Red	Motor is running in forward direction
	Green	Motor is running in reverse direction

Table1: Assignment to SCADA Screen

VI. 5. PROCESS SCADA SCREENS

A SCADA screen is design as per the requirement of the ladder logic program and also that would be clearly understood by the operator who is sitting in the control room to control the process remotely. Below figures shows the SCADA control screen at different operating conditions of induction motor as:

Figure 4: Initial SCADA Control Screen for induction motor.
Figure 5: SCADA Control Screen when induction motor runs in forward direction.
Figure 6: SCADA Control Screen when induction motor runs in reverse direction.
Figure 7: SCADA Control Screen when induction motor stopped in case of emergency.

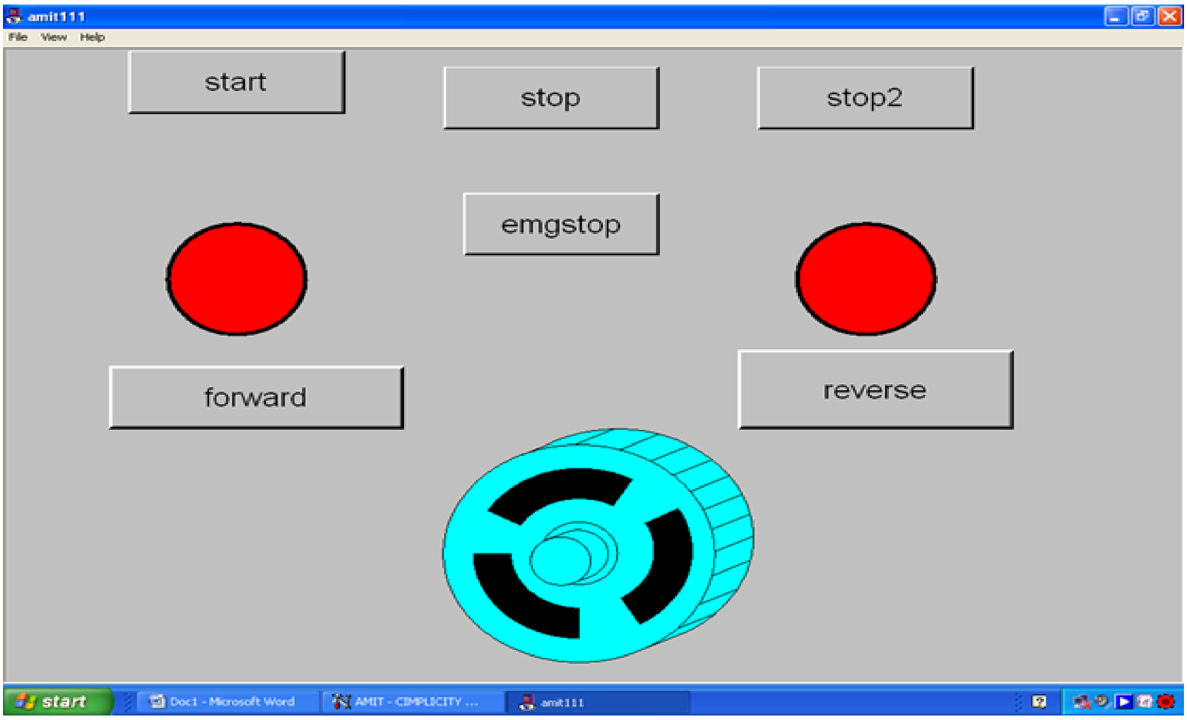

Figure 4: Initial SCADA Control Screen for induction motor

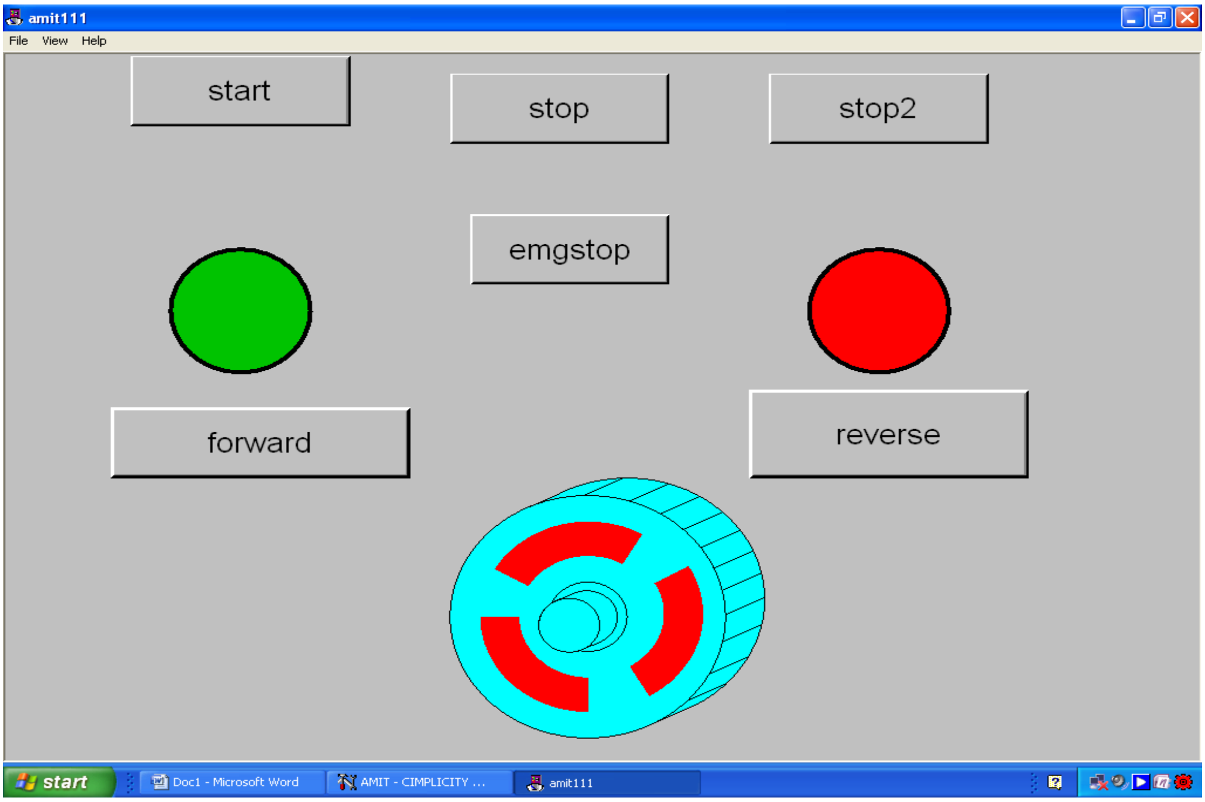

Figure 5: SCADA Control Screen when induction motor runs in forward direction

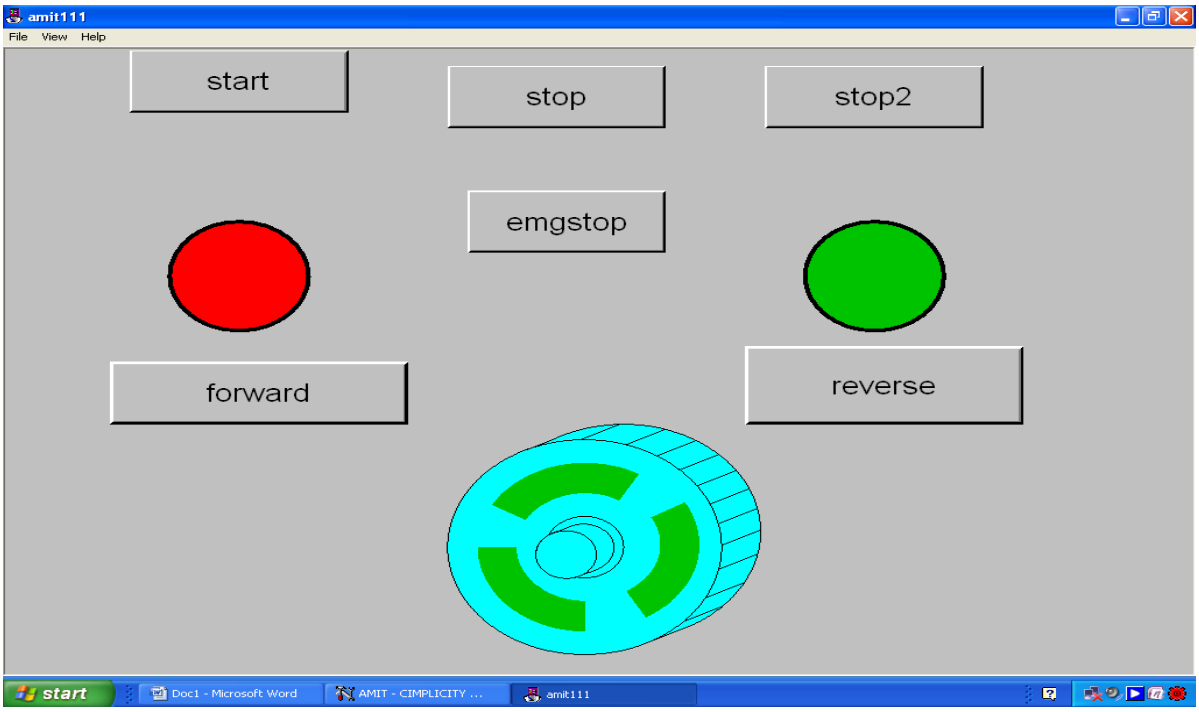

Figure 6: SCADA Control Screen when induction motor runs in reverse direction

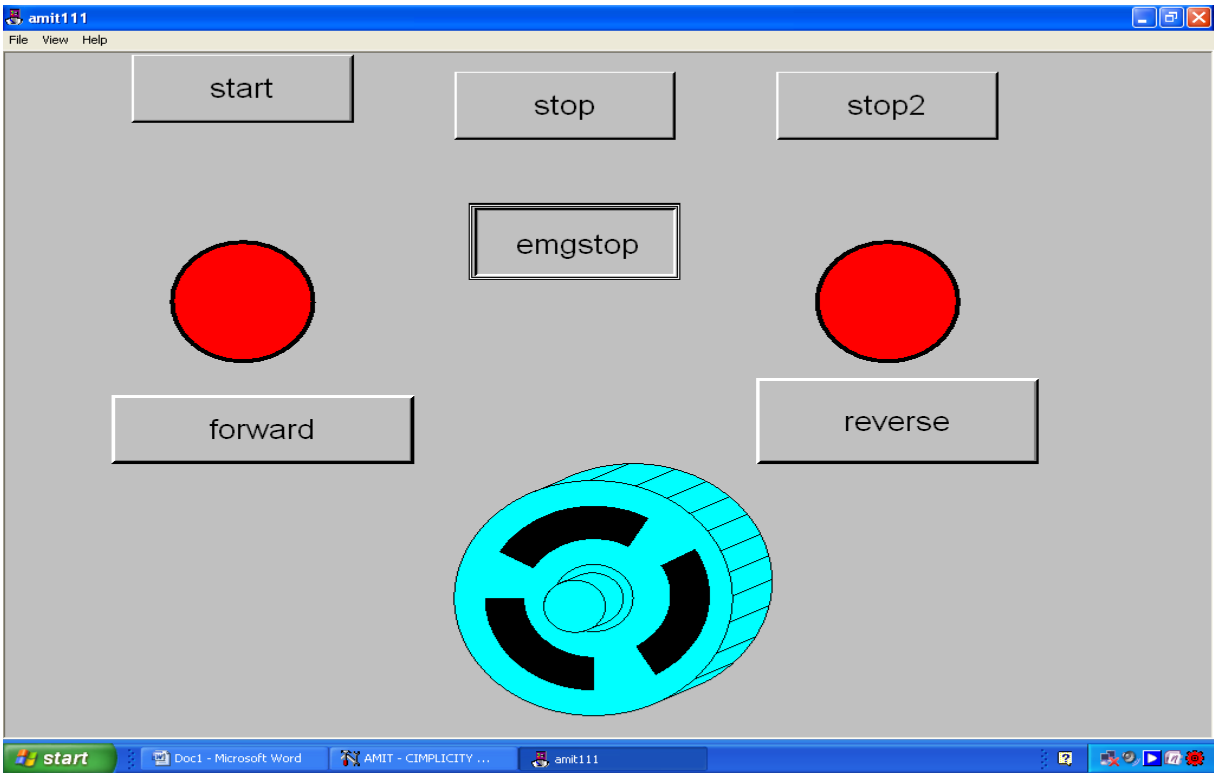

Figure 7: SCADA Control Screen when induction motor stopped in case of emergency

VII. EXPERIMENTAL SETUP

The control system is implemented and tested for squirrel cage rotor IM having technical specification given in Table2. The induction motor is attached to variable load belt and pulley. The three-phase power supply is connected to a three- phase main switch and then to contactors. The output terminal of contactors is supplied to the IM. The contactors are interfaced to the PLC-based controller. As a microprocessor based system, the PLC system hardware is designed and built up with certain modules, having technical specification given in Table3.

The system consist of three phase main switch, contactors, PLC based controller signals ,lamps ,switches, & HMI are installed in control panel. Block diagram of the experimental setup is been show in Fig.8. The program is downloaded into the PLC from a personal computer with RS-232 serial interface. A HMI (Human Machine Interface) device is connected to PLC by an Ethernet cable for manual controlling of the motor in case of emergency. The status of motor is being displayed on Real time software SCADA which provides a supervisory control for the system.

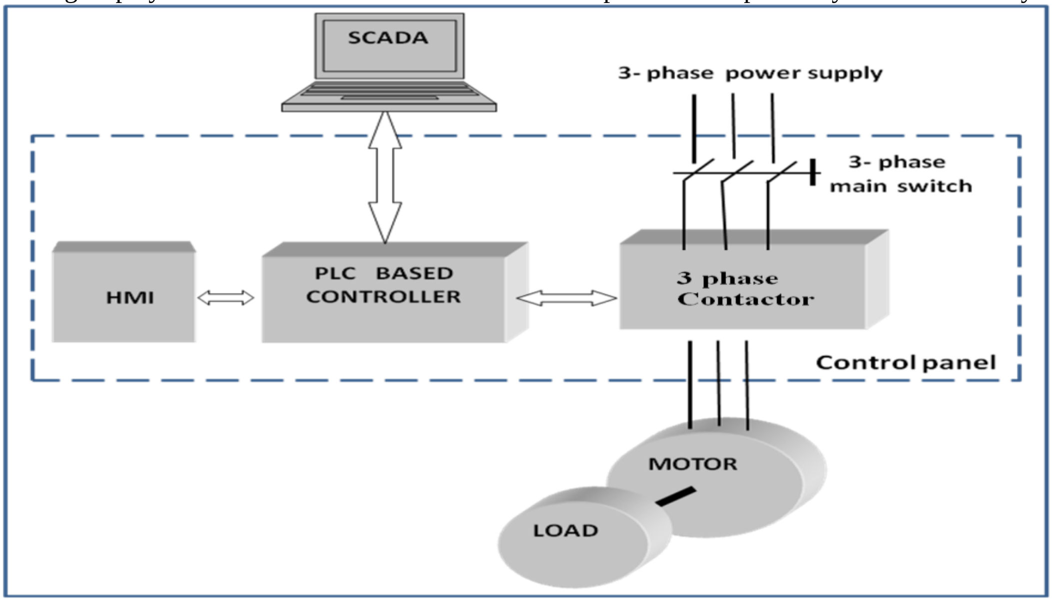

Figure8: Block diagram of experimental setup.

Figure9: An experimental setup of IM Control.

Connection type	Δ
Amb. temperature	45°C
Input voltage	415volts +/-10%
Input current	4.5Amp
Rated power	2kW
Input frequency	50Hz
Pole number	4
Rated speed	1500rpm
Efficiency	0.85

Table2. Induction Motor specifications

Power Source	100-240 VAC or 125 VDC
Output Source	• 30 watts total • 15 watts 5 V • 15 watts 24 V relay 20 watts 24 V isolated • 24 VDC Output Current Capacity: 0.8

Table3: PLC Power Module specification

User Logic memory (K bytes)	240
I/O Points	10
Internal Power Used	1.4 Amps @ 5 VDC
I/O Analog Words	2048 In/512 Out
Timers/Counters	>2000
Type of memory storage	RAM, Flash
Processor Speed (MHz)	133Mhz
Built-in Ethernet Ports	Ethernet 10/100Mbit with built in switch (2 physical connections). Supports SRTP, Ethernet Global Data, no Channel support
Communications Option Modules	Serial-SNP, SNPX, RTU and CCM, LAN-Genius, Ethernet SRTP and Ethernet Modbus TCP

Field Busses/Device Networks	Ethernet, Genius, Profibus-DP, Device Net, Interbus-S, CsCAN
Built-in Communication Ports	One Ethernet port on CPU, 10/100 Mbps built-in switch, SRTP - channels (consumer only); EGD

Table 4: PLC CPU specification

Table 5: PLC Input Module specification

Power Type	DC
Input Voltage Range	0-30 VDC
Input Current (mA)	7
Number of Points	6
Response Time (ms): 7 on/7 off	7 on/7 off
Points per Common: 10	10

Power Type	:DC
Output Voltage Range	12-24 VDC
Number of Points	4
Response Time (ms)	2 on/2 off
Points per Common: 10	10

Table6: PLC Output Module specification

VIII. PERFORMANCE ANALYSIS

- **Performance of IM in Clockwise Running Condition**

Fig.10 shows the experimental performance of the 3-phase IM running in clockwise direction at different load conditions. The speed and current readings at different loads are shown in Table7 and corresponding graph is shown in drawn in figure 10. And the status of motor is being displayed on Real time software SCADA which provides a supervisory control for the system when it run in clockwise (Forward) direction as shown in figure 11.

IM in Clockwise Running Condition		**IM in Anti-clockwise Running Condition**	
Current (Amp.)	Speed (RPM)	Current (Amp.)	Speed (RPM)
1.64	1468	1.53	1480
1.68	1462	1.65	1466
1.70	1456	1.75	1458
1.80	1450	1.87	1454
1.92	1446	1.96	1450
2.00	1442	2.17	1440
2.13	1436	2.36	1432
2.31	1430	2.60	1424
2.52	1426	2.83	1414
2.66	1420	3.03	1410
2.85	1414	3.30	1398
3.02	1404	3.55	1392
3.25	1400		
3.50	1392		
3.70	1386		
3.90	1380		
4.06	1374		

Table 7: speed and current readings at different loads

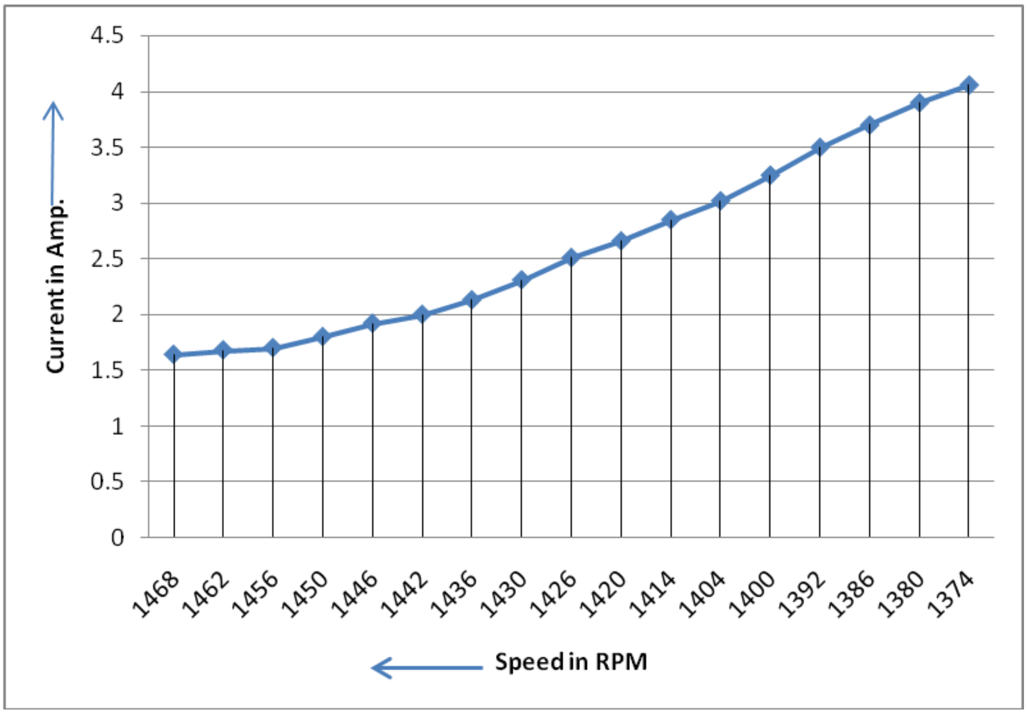

Figure 10: Performance of 3-Phase IM drive under Clockwise running Condition

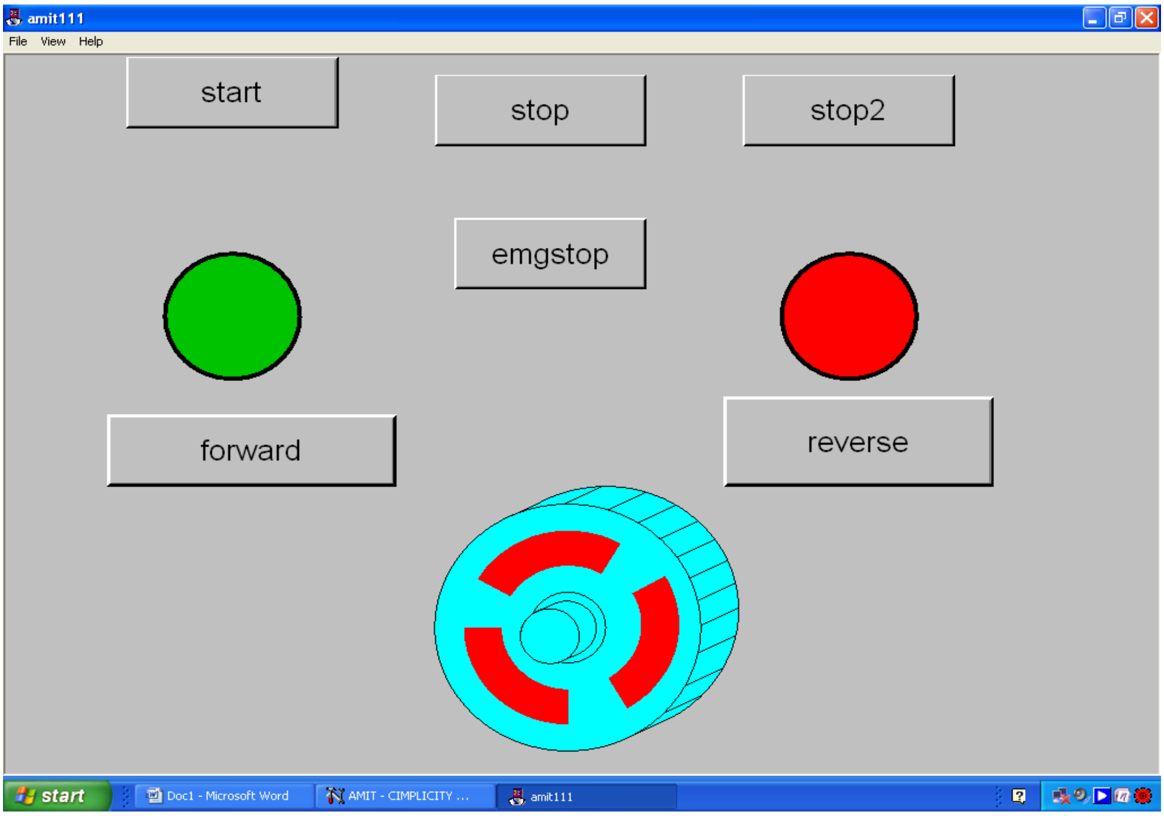

Figure11: Clockwise (Forward) direction of Rotation of IM

- **Performance of IM in Anti- clockwise Running Condition**

Fig.13 shows the experimental performance of the 3-phase IM running in anti-clockwise direction at different load conditions. The speed and current reading at different load is shown in Table 8 and corresponding graph is shown in drawn in figure12. And the status of motor is being displayed on Real time software SCADA which provides a supervisory control for the system when it rum in anti-clockwise (Reverse) direction as shown in figure 8.

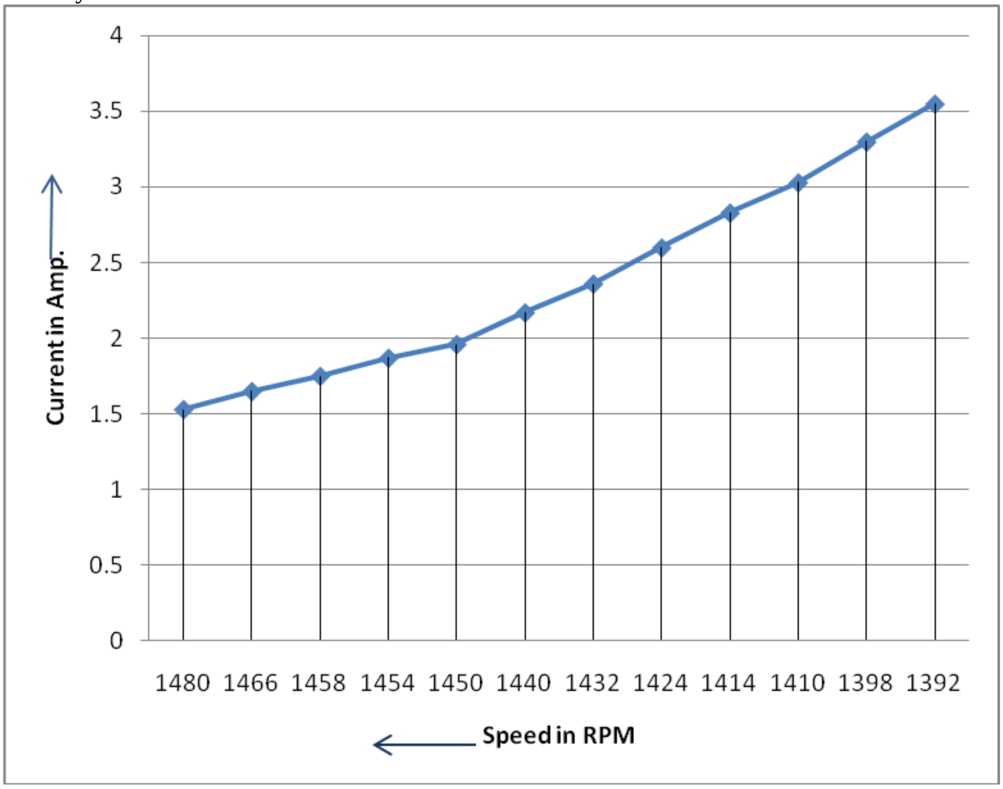

Figure12: Performance of 3-Phase IM drive under Anti-clockwise running Condition

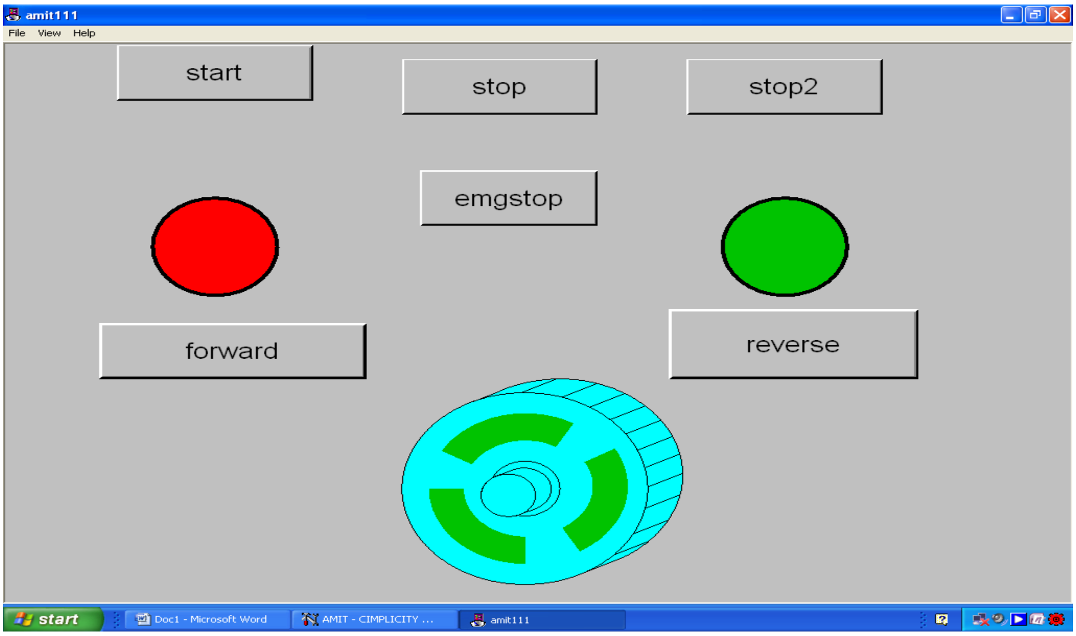

Figure13: Anti-clockwise (Reverse) direction of Rotation of IM

And figure14 shows the SCADA screen when we stop the IM in case of emergency by remote access the system from main control room.

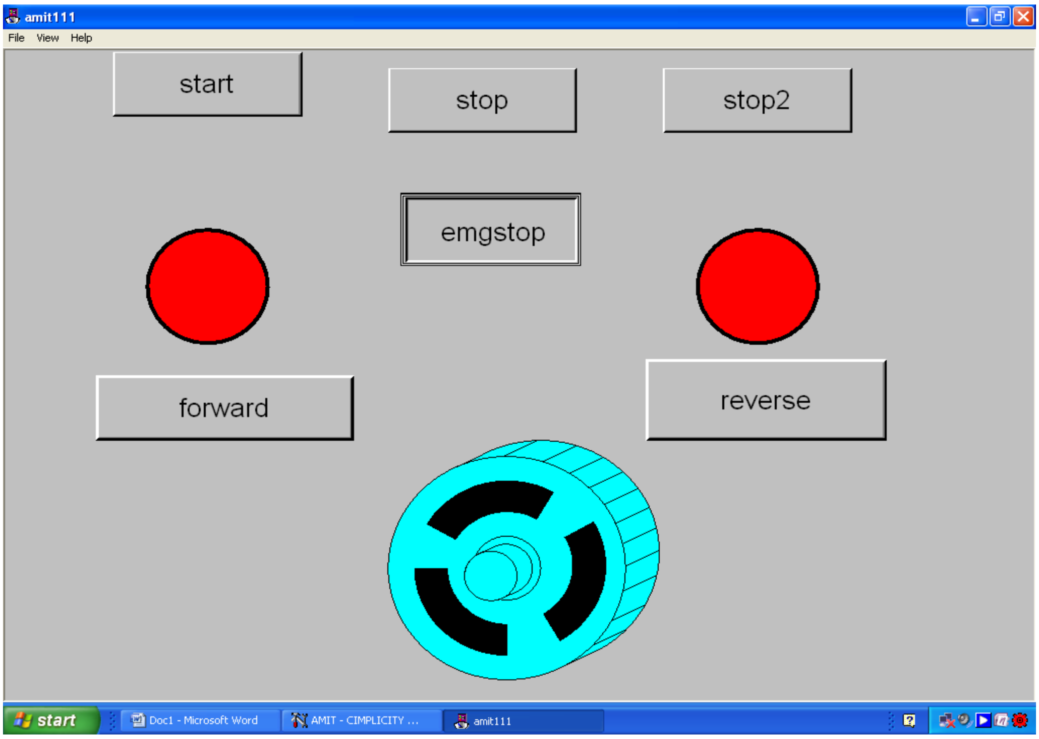

Figure14: SCADA screen to stop IM in case of emergency.

IX. CONCLUSION

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

In this project thesis monitoring and control system is designed for three phase induction motor control. The system is successfully implemented and tested. After detailed experiment it is observed that proposed system is a feasible method for controlling the IM. With the use of PLC & SCADA control the system is more reliable. The control system designed is based on the most advanced technology which gives high amount of flexibility and efficiency. Monitoring system gives facility of analyzing the operation of induction motor in online/offline mode which makes the system to be safe from any fault/error conditions. LAN connectivity of the system makes the system more flexible and reliable.

X. FUTURE RECOMMENDATION

There are various other methods for the control of IM, like Advance vector control, Direct torque control, Sensor less direct torque control. These methods can also be used as monitoring and control system of IM. The monitoring system can be connected to the web, making the system control from any place. The system would be more adaptive so that it can be configured for different type of application such as servo motors, stepper motors etc. In this project the software ROCKWELL has been successfully used. However, other types of software may be employed and comparative analysis can be done. In this project, the other parameters like power factor, harmonics etc have not been considered. So it is further suggested to consider these parameters and the design of circuit for improving power factor reduction of harmonic contents.

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CATALOUGES

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2. Chassis module series 90-30 PLC GE Fanuc, IC693CHS391.
3. Power Supply module series 90-30 PLC GE Fanuc, IC693PWR321.
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5. Digital Output module series 90-30 PLC GE Fanuc, IC693MDL740.
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