

## Speed Control of Induction Motor Using PLC and SCADA System

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### ABSTRACT

Automation or automatic control is the use of various control systems for operating equipment such as machinery, processes in factories, boilers and heat-treating ovens, switching in telephone networks, steering and stabilization of ships, aircraft and other applications with minimal or reduced human intervention. Some processes have been completely automated. The motor speed is controlled via the driver as an open loop control. To make a more precise closed loop control of motor speed we will use a tachometer to measure the speed and feed it back to the PLC, which compares to the desired value and take a control action, then the signal is transferred to the motor – via driver – to increase / decrease the speed. We will measure the speed of the motor using an incremental rotary encoder by adjusting parameters (PLC, driver) and also we need to reduce the overall cost of the system. Our control system will be held using the available Siemens PLC. In addition, we will monitor motor parameters via SCADA system.

*Keywords-* Variable Frequency Drive, Programmable Logic Controller, Supervisory Control and Data Acquisition, Incremental rotary encoder, Simatic manager software V5.5, WINCC explorer software V7.2

### I. INTRODUCTION

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. An induction motor's speed enables affected by the supply frequency, change the number of motor stators, adjust the power input. In an induction motor, there is no electrical connection to the rotor, but currents are induced in the rotor circuit. The rotor conductors carry current in the stator magnetic field and thereby have a force exerted upon them tending to move them at right angles to the field. When the stator winding of a three phase AC supply, a rotating magnetic field is established and rotates at synchronous speed. The direction of rotation of the field can be reversed by interchanging the connection to the supply of any two leads of a three phase induction motor. [1]

The control of equipment has been performed through the use of computers. Most equipment's use programmable logic controllers (PLC) to connect with computers to monitor each load and electricity consuming devices. A PLC interacts with the external world through its inputs and outputs. Especially in manufacturing companies, an automaton network concept developed under the name of Totally Integrated Automation (TIA). TIA includes actuator sensor level, field level, cellular level and process level control, which makes use of actuator-sensor

interface, PROFIBUS and industrial Ethernet respectively. Through TIA, it is possible to view or control all the levels all the way to the actuators from process control level. In recent years, many companies started opening divisions in many countries around the world, and wanted to connect and control any device from another or any place around the world (Distributed Management).

Distributed management can be realized through Supervisory Control and Data Acquisition (SCADA) system. It is a common process control application that collects data from sensors on the shop floor or in remote locations and sends them to a central computer for management and control. A SCADA system includes input/output signal hardware, controllers, Human Machine Interface (HMI), networks, communication, database and software. The term SCADA usually refers to a system with a central unit that monitors and controls a complete site or a system spread out over a long distance. The bulk of the site control is actually performed automatically by a Remote Terminal Unit (RTU) or by a Programmable Logic Controller (PLC). [2, 3]

A PLC-SCADA based monitoring and control system for a Variable Frequency Drive system was developed which controls a three-phase induction motor. The integration of PLC and SCADA for industrial automation comprises of: a human-machine interface which is the device presenting processed data to a human operator, who monitors and controls the process; a Remote Terminal Unit collects the information by connecting to sensors in the process, converting sensor signals to digital data and sending

digital data to the supervisory system after which that information is displayed on a number of operator screens; PLC used as field devices for their economical, versatile, flexible and configurable attributes.

### 1.1 PROGRAMMABLE LOGIC CONTROLLER (PLC)

Control engineering has evolved over time. In the past humans was the main Method for controlling a system. More recently, electricity has been used for control and early electrical control was based on relays. These relays allow power to be switched on and off without a mechanical switch. It is common to use relays to make simple logical control decisions. The development of low cost computer has brought the most recent revolution, the Programmable Logic Controller (PLC). advantages of PLC include Cost effective for controlling complex systems; Flexible and can be applied to control other systems quickly and easily; Computational abilities allow control that is more sophisticated; Troubleshooting aids make programming easier and reduce downtime; Reliable components make these likely to operate for years before failure. [4]

A PLC based control system was set up comprising of a Siemens PLC.

### 1.2 VARIABLE FREQUENCY DRIVE (VFD)

A Variable Frequency Drive is used for applications wherein speed control is of an essential importance due to load changes wherein the speed needs to be increased or decreased accordingly. operating variable-speed drives with inverters offers a range of advantages compared to operation directly on the mains circuit: Prevents inrush current from occurring, as the inverter increases the frequency from 0 Hz instead of delivering a surge current of 50 Hz at motor startup; Any required degree of soft start and braking can be obtained by specifying the acceleration and deceleration time; If a different delivery rate is required for conveying liquid or gases, there is no need for the motor to work in its full capacity, thus leading to energy savings.

V/f method of speed control

The motor speed can be controlled by varying the supply frequency. The voltage induced in the stator is directly proportional to product of supply frequency and air-gap flux. If stator drop is neglected, terminal voltage can be considered proportional to product of frequency and flux.  $V_1 \propto f \cdot \Phi$  Effect of supply frequency change without terminal voltage change:

1. Reduction of supply frequency without change in terminal voltage will cause an increase in the air gap flux thereby saturating the motor. This will cause the increase in magnetizing current, core loss and stator

copper loss and cause distortion in line current and voltage and produce high-pitch noise.

2. An increase of supply frequency without change in terminal voltage will cause decrease in flux, therefore leading to reduction of torque capability of the motor. A driver used in control system is Siemens (micro master 440). [5]

### 1.3 ENCODER

Controlling the speed of a motor is a basic functionality of modern electric drives. In order to precisely control the speed of an electric motor, it is necessary to measure the actual speed of the motor. This measurement can be done with various tools and methods. In most cases, it is usually done with a sensor built in the motor or mounted to its shaft externally. These sensors vary in their principle, output signal and resolution. Encoders can be used in applications, where long positions, speed or an angular position are measured. They transform mechanical movements into electrical signals and can be divided into incremental and absolute measuring systems.

Incremental rotary encoders generate pulses, where the number of pulses can be a measure of speed, length or position. In absolute encoders, every position corresponds to a unique code pattern, so that even after a power cut the actual position is recognized, when power is re-applied. We used incremental encoder instead of the encoder (Siemens) because the incremental encoder is cheaper and performs the same action as encoder (Siemens) so that we adjust the parameters of count in hardware configuration for controlling the frequency measurement and adjust the parameters of PI control to obtain the determine speed in PLC programming.

### 1.4 SUPERVISORY CONTROL AND DATA ACQUISITION SYSTEMS (SCADA)

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, number of Remote Terminal Units (RTUs), Programmable Logic Controllers (PLCs), the central host and the operator terminals.

SCADA systems consist of one or more field data interface devices, usually RTUs, or PLCs, 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, A central host computer server or servers (sometimes called a SCADA

Center, master station, or Master Terminal Unit (MTU). [6]

## II. PROJECT OVERVIEW

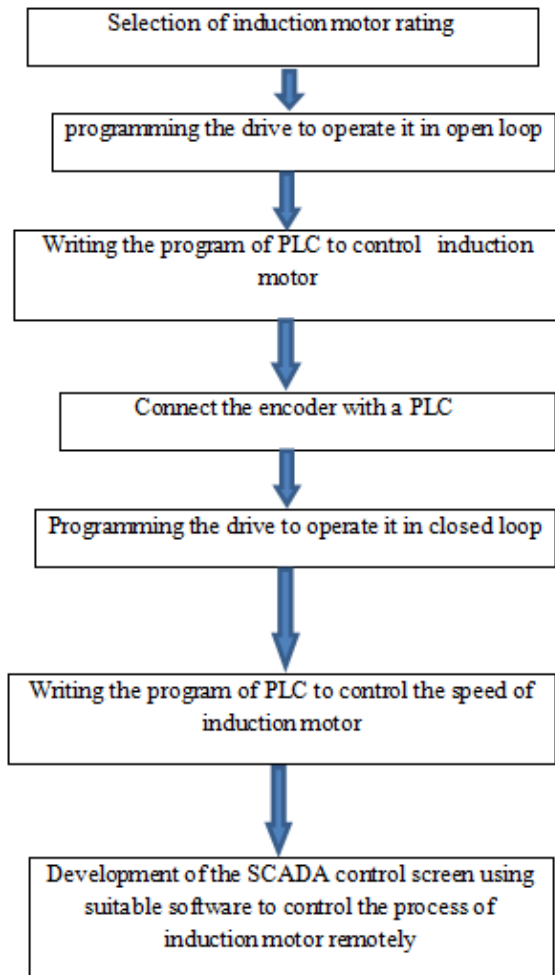


Fig.1 Method of Project Implementation

In this section, it will discuss an overall overview of “Speed Control of Induction Motor uses a PLC and SCADA system” 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 Figure1.

## III. HARDWARE DESIGN

In the hardware design part, overall component such as PLC S7-300 (Siemens), Encoder, motor, and drive micro master 440 (Siemens) will be integrated to form the complete prototype as shown in figure 2. The hardware components are the backbone of the system. More detailed information of each section will be discussed in the following sections.



Fig.2 Connections between PLC, drive and motor.

## 3.1 THREE PHASE INDUCTION MOTOR

Induction motors are the most common motors used for various equipment in the industry. Their popularity is due to their simple design, they are inexpensive and easy to maintain, and can be directly connected to an AC power source. An induction motor has two main electrical components

- A- Rotor (Squirrel-cage rotor and Wound rotor)
- B- Stator.

### 3.1.1 SPEED OF AN INDUCTION MOTOR

The magnetic field created in the stator rotates at a synchronous speed ( $N_s$ ).

$$N_s = 120 * f / p \quad (1)$$

Where:

$N_s$  = the synchronous speed of the stator magnetic field in RPM

P = the number of poles on the stator

F = the supply frequency in Hertz

The magnetic field produced in the rotor because of the induced voltage is alternating in nature. To reduce the relative speed, with respect to the stator, the rotor starts running in the same direction as that of the stator flux and tries to catch up with the rotating flux. However, in practice, the rotor never succeeds in “catching up” to the stator field. The rotor runs slower than the speed of the stator field. This speed is called the Base Speed ( $N_b$ ). The difference between  $N_s$  and  $N_b$  is called the slip. The slip varies with the load. An increase in load will cause the rotor to slow down or increase slip. A decrease in the load will cause the rotor to speed up or decrease slip. The slip is expressed as a percentage and can be determined with the following formula:

$$\%Slip = \frac{N_s - N_b}{N_s} \times 100 \quad (2)$$

Where:

$N_s$  = the synchronous speed in RPM

$N_b$  = the base speed in RPM. [7]

We controlled the speed of an AC induction motor in our application by using:-

- 1- Open loop control system.
- 2- Closed loop control system

### 3.2 CONVERTER (MICRO MASTER 440)

The MICROMASTER 440 is frequency inverters for speed control of three-phase motors. The various models available cover the performance range from 120W to 200 KW (for constant torque (CT), alternatively up to 250KW (for variable torque (VT)). The inverters are microprocessor-controlled and use state-of-the art insulated gate bipolar transistor (IGBT) technology. This makes them reliable and versatile. A special pulse- width modulation method with selectable pulse frequency permits quiet motor operation. With the factory default settings, the MICROMASTER 440 is suitable for many variable speed applications. Using the functionally grouped parameters, the MICROMASTER 440 can adapt to more demanding applications. The MICROMASTER 440 can be used in both “stand-alone” applications as well as being integrated into “automation systems”. Performance Characteristics:- Vector Control, V/f Control, Built-in DC injection brake, Compound braking to improve braking performance, Built-in braking chopper, Ramp function generator, Free Function Blocks, Positioning Ramp down.

#### 3.2.1 COMMISSIONING

In the standard version, the MICROMASTER 440 is fitted with the status display panel (SDP) with which it is possible to use the inverter with the pre-assigned factory settings for a large range of applications. If these factory settings are not suitable, you can adapt them to suit your equipment conditions using the basic operator panel (BOP) or the advanced operator panel (AOP). The BOP and AOP are available as options. We used BOP in the commissioning as shown in figure 3. [8]



Fig.3 Basic Operator Panel (BOP)

#### 3.2.2 QUICK COMMISSIONING (BASIC MODE)

Quick Commissioning is very important because it sets the correct motor and control parameters. Induction Motor Technical Specifications

V=230/400V, HZ=50, A=0.88/0.51, KW=0.12, COS  $\phi$ =0.64, RPM=645/min.

- 1- In the open loop system

P0100=0 USA default settings read from DIP switch, P0304 =220V Rated motor voltage, P0305 =0.88A Rated motor current, P0307=0.12KW Rated motor power, P0308=0.64 Rated motor COS PHI, P0310 =50HZ Rated motor efficiency, P0311 =645/min rated motor speed (RPM), P0700=1 From BOP (keyboard), P1000=1 MOP set point, P1080=0 Min.Frequency,P1082=50 Max.Frequency, P3900=1 Complete commissioning learns motor model

- 2- In the closed loop system

We used the same command in the open loop system except: -P0700 which means selection of command source and P1000 which means selection of frequency set point. [9]

Therefore, we putted in a closed loop system P0700=6 CB on COM link (CB= communications module), P1000=6 CB on COM link (CB= communications module)

### 3.3 INCREMENTAL ROTARY ENCODER

Figure 4 shows the incremental rotary encoder which we used it in this project to control the speed of induction motor instead of the encoder of Siemens



Fig.4 Incremental rotary encoder

Specification of Incremental rotary encoder

Mode	HE50B
Shaft external diameter	8
Pulse number per revolution	250
Phase type	3:A, B, Z
Output type	T: Totem-pole
Power voltage	24

Table 3.1 Specification of Incremental encoder

O/p type: - A, B, Z phase, Phase difference at o/p: - phase difference between A, B phase  $T/4 \pm T/8$ (cycle of phase = T), Max. Response frequency: - 300KHZ, Power voltage: - 12-24V D.C $\pm$ 5%

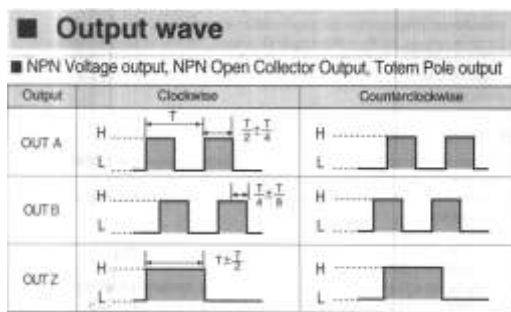


Fig.5 output wave of incremental rotary encoder

Connection method wire

- 1- The black wire OUT (A)
- 2- The white wire OUT (B)
- 3- The orange wire OUT (Z)
- 4- The brown wire +V (12-24 V D.C)
- 5- The blue wire 0 V(GND)

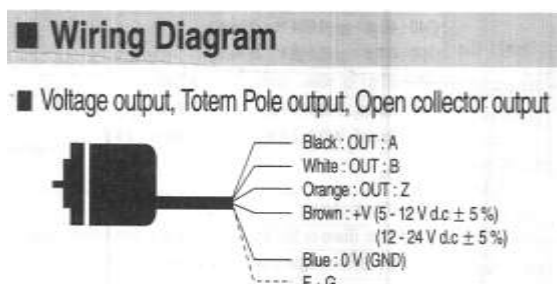


Fig. 6 wiring diagram for Incremental rotary encoder Connections between PLC and incremental rotary encoder

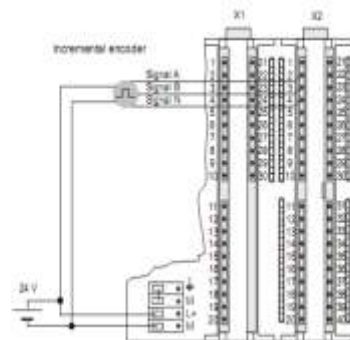


Fig. 7 Connections between PLC and encoder [10]

#### IV. WORKING OF THE SYSTEM

Through this project, Siemens S7-300 PLC, Variable Frequency Drive (Micro Master 440), a three-phase induction motor controlled by ladder logic software

Hardware Configuration of PLC

- 1- Double click on short Cut for SIMATIC Manager that is on the desktop
- 2- Open the menu file from the menu bar and select New Project
- 3- Open the menu Insert then Station and select somatic 300 stations

- 4- Open Hardware Configuration Editor and Insert Rack

From the catalog:

- 1- Click on the SIMATIC 300
- 2- Click on Rack 300
- 3- Double Click on the Rail
- 4- Selecting the CPU from the list by order number, then by version. If any product selected from the list you will find the order number and Micro Master 440 from the list PROFIBUS DP then list of SIMOVERT
- 5- Open the properties of countable and select frequency counting
- 6- Save & Compile Hardware Configuration
- 7- Downloading HW Configuration to the PLC

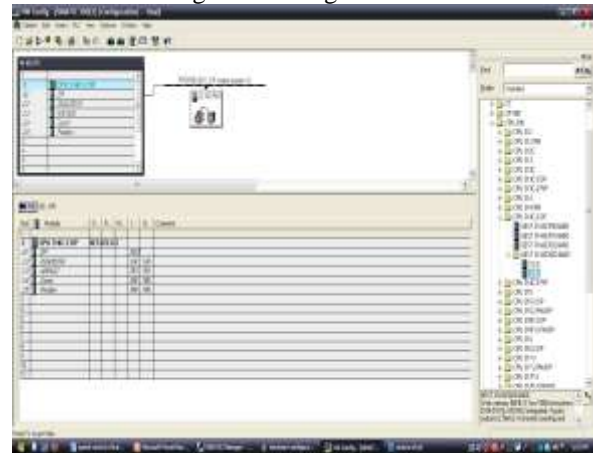


Fig. 8 Hardware Configuration

Software Configurations

The experiments were conducted based on ladder logic programming which is a software installed on a personal computer according to which the PLC takes the sensor inputs, processes them according to the program and gives the output to the VFD which again processes this input within the drive and finally controls the speed and position of the motor

Through this project, we used SFB 48 (system function block) for controlling the Frequency Measurement and Continuous Control with SFB 41 "Continues control" to control technical processes with continuous input and output variables on SIMATIC S7-300 programmable logic controllers.

In SFB 41:- We putted set point as floating-point number and adjusted the Gain so that

- 1- High-limit speed of the motor is "16000.0" equal to 50 HZ on The Micro- Master 440.
- 2- Half limit the speed of the motor is "8000.0" equal to 25 HZ on the Micro- Master 440.

- 3- Quarter limit speed of the motor is "4000.0" equal to 12 HZ on the Micro- Master 440

Fig.9 show maximum frequency when we putted set point equal to "16000.0", the frequency appeared on micro-master 440 equal to 50HZ



Fig.9 Maximum of frequency on Micro-Master

#### SCADA program output

The SCADA program was also written using ladder logic and then run simultaneously from the SCADA screen developed by using WINCC explorer program. The SCADA software enables human operator to control the entire operation away from the plant and just by using the virtual inputs designated on his computer screen. Table 4 shows the input-output address of the SCADA program.

We used two input/output fields; we have chosen the tag of gain that is linked to a PLC address (MD230) and the tag of set point that is linked to a PLC address (MD220)

In input/output field for internal setup point of PI control: We putted set point per scaling and adjusted the gain so that:-

- 1- High-limit of set point is 100% equal to 50 HZ on the micro- master 440 as shown in fig.
- 2- Half limit of set point is 50% equal to 25 HZ on the micro- master 440
- 3- Quarter limit of set point is 25% equal to 12.5 HZ on the micro- master 440.

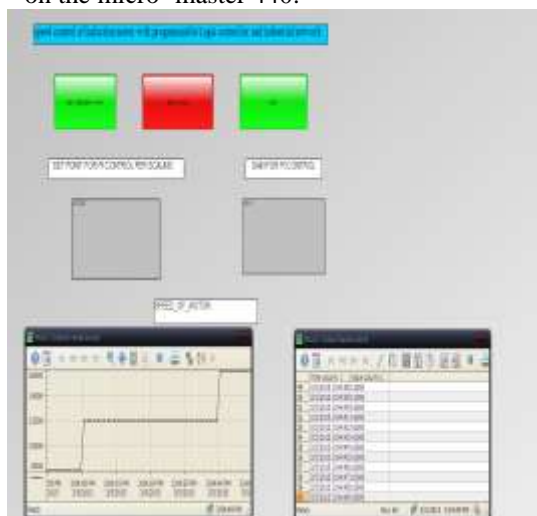


Fig.10 WINCC online trend and table control when set point change from 12000.0 to 16000.0

#### V. Conclusion

The goal of this project was motivated to control Speed of motor using PLC (Siemens) S7-300, converter micro master 440, incremental rotary encoder instead of the encoder (Siemens) because the incremental encoder is cheaper than encoder (Siemens) and performs the same action as encoder (Siemens) so that we adjust the parameters of count in hardware configuration for controlling the frequency measurement and adjust the parameters of PI control to obtain the determine the speed in PLC programming as shown in the results of the above figures. Also in this project we were motivated to monitor the speed of three phase induction motor using a SCADA system. The control system is designed based on the most advanced technology which gives a high amount of flexibility and efficiency. Monitoring system gives facility of analyzing the operation of induction motor in an online / offline mode, which makes the system to be safe from any fault/error conditions.

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