WOLKITE UNIVERSITY

COLLEG OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

STREAM: INDUSTRIAL CONTROL ENGINEERING

Title: - Design and impelimentation of dc motor speed control using PLC

Final year thesis in Partial fulfillment of the requirements for the awards of bachleor of science in electrical and computer engineering

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Declaration

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Approval

This is to verify that the project title Design and implementation of speed control for dc motor using programmable logic controller (PLC) carried out by our group has been read and approved for meeting part of the requirements and regulations governing the ward in Electrical and Computer Engineering (stream of industrial control Engineering)

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Abstract

Direct current (DC) motor has already become an important drive configuration for many applications across a wide range of powers and speeds. In industries, it is very much required to maintain speed of DC motor accurately or precisely for some applications like drills, lathes, spinning and weaving, elevators, cranes etc. This thesis is concerned on design and implementation of DC motor speed control using Programmable Logic Controller (PLC). It is a closed-loop real time control system, where proximity sensor is placed near to the motor shaft to provide the feedback speed signal to controller. PLC and DC Drive makes major role in maintaining the speed of DC motor. PLC gets feedback signals form motor by means of proximity sensor which sends pulse signals, to PLC and PLC accept pulse signals from proximity sensor which will monitor the gating pulses to check the speed, where function blocks are available in PLC to convert these gating pulses to speed of motor. Then PLC will direct to dc drive to correct the speed by changing armature voltage by means of PWM techniques to maintain the motor at constant speed. The PWM is used to control duty cycle of DC motor drive. Through thesis, it can be concluded that PLC can control motor speed at desired speed although there is a variation of load.

Keywords: DC Motor, PLC, DC Drive, PWM, Ladder Logic

List of Abbreviation

DC--Direct current

AC--Alternating current

PLC--Programmable logic controller

PWM--Pulse width modulation

SISO--Single input single output

PI--Proportional integral

PID---Proportional integral derivative

LQG--Linear Quadratic Gaussian

BLPM---Brush less permanent magnet

CPU--Central processing unit

CCW---Connected component workbench

FLC--Fuzzy logic controller

RPM--Revolution per minute

EMF--Electromagnetic field

PC--Personal computer

I/O---Input output

PC--Personal computer

NC---Normally close

NO---Normally open

LQG---Linear quadratic Gaussian

LQ--Linear quadratic

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CHAPTER ONE

1. Introduction

Motors are electro-mechanical devices which converts electrical energy to mechanical energy. They are classified by their functions as servomotors, gear motors, and so forth. They can also be classified based on their electrical configuration as Direct current (DC) and Alternating current(AC) motors.

In today's industries demand process automation in all sectors, because automation results in better quality, increased production and reduced costs. The variable speed drives which can control the speed of AC/DC Motors are indispensable controlling elements in automation systems. Depending on the application some of them are fixed speed and some of them are variable speed drives.

1.1 Background

DC motor controls has been used for variable speed and position applications for many decades and historically were the first choices for speed and position control applications. DC motor is an electro-mechanical device that convert electrical energy into mechanical energy. This is done by way of two interacting magnetic fields--one stationary, and another attached to a part that can move. DC motors have the potential for very high torque capabilities (although this is generally a function of the physical size of the motor), are easy to miniaturize, and can be "throttled" via adjusting their supply voltage. DC motors are also not only the simplest, but the oldest electric motors.

The basic principles of electromagnetic induction were discovered in the early 1800's by Oersted, Gauss, and Faraday. By 1820, Hans Christian Oersted and Andre Marie Ampere had discovered that an electric current produces a magnetic field. The next 15 years saw a flurry of Cross-Atlantic experimentation and innovation, leading finally to simple DC rotary motor. A number of men were involved in the work, so proper credit for the first DC motor is really a function of just how broadly you choose to define the word "motor.

The versatile characteristics of DC motor can provide high starting torque which is required for drive application. DC motors provide excellent control of speed for acceleration and deceleration. The power supply of a DC motor connects directly to the field of the motor which allows for precise voltage control, and is necessary for speed and torque control applications.

DC motors have a long tradition of being used as adjustable speed machines and a wide range of options have evolved for control purpose. Cooling blowers and inlet air flanges provide cooling air for a wide speed range at constant torque. DC regenerative drives are available for applications requiring continuous regeneration for overhauling loads.

The methods of speed control of DC motors are simpler and less expensive than those of alternating current (AC) Motor.

Important speed–related requirements for efficient and intelligent dc motor speed control include maintaining constant speed with variation of load, varying the running speed to suit particular needs, for energy saving, soft starting and stopping to increase motor reliability and availability. Direct current (DC) motors have variable characteristics and are used extensively in variable-speed drives. DC motor can provide a high starting torque and it is also possible to obtain speed control over wide range.

DC motor plays a significant role in modern industrial. These are several types of applications where the load on the DC motor varies over a speed range. These applications may demand high-speed control accuracy and good dynamic responses. In home appliances, washers, dryers and compressors are good examples. In automotive, fuel pump control, electronic steering control, engine control and electric vehicle control are good examples of these.

D.C motor is considered a SISO (Single Input Single Output) system having torque/speed characteristics compatible with most mechanical loads. This makes a DC motor controllable over a wide range of speeds by proper adjustment of the terminal voltage. Now days, Induction motors, Brushless D.C motors and Synchronous motors have gained widespread use in electric traction system. Even then, there is a persistent effort towards making them behave like dc motors through innovative design and control techniques. Hence dc motors are always a good option for advanced control algorithm because the theory of dc motor speed control is extendable to other types of motors as well.

This thesis is about controlling the speed of DC motor by using Programmable Logic Controller. The controller has more advantages than conventional control circuits. The benefits can be noted such as reducing the size of the control panel, very low energy consumption, Durable

Equipment, Proper operation in the worst cases. Using PLC for controlling industrial systems is initiated in 1968 and, its development has been greatly accelerated in recent years.

1.2 Statement of problem

This thesis is intended to solve the problems faced in different controllers, electrical and electromechanical method to control the speed of DC motor. Such as

Field rheostat control: In this method speed variation is accomplished by means of a variable resistance inserted in series with the shunt field. this has limitations of

- Top speeds only obtained at reduced torque
- speed is maximum at minimum value of flux, which is governed by the demagnetizing armature reaction on the field.

In PI controller: the response is sluggish at the high value of integral time and the control loop may oscillate at the small value of integral time.

PID controller: has initially overshot which is undesired. This undesired overshoot leads to undesired results and negatively impacts DC motor. And also fast response and good stability cannot be achieved simultaneously i.e. the fast response has worse stability and the better stability has slower response.

Generally, this problem could be solved by using programmable logic controller (PLC) which provides higher efficiency, greater reliability, good stability and quick response.

1.3 Objective of the thesis

1.3.1 General objective

The main objective of this project is to design and implement speed control of DC motor using PLC.

1.3.2 Specific objectives

- To design PLC ladder program
- In order to make DC motor to run with desired speed
- In order to study about PWM.
- In order to study mathematical model of DC motor

1.4 Significance of the thesis

- Provide excellent speed control for acceleration and deceleration
- Easy to understand design.
- Simple, cheap drive design.

1.5 Scope of the thesis

The scope of this thesis work is up to achieving the required speed of the DC motor. The speed of the DC motor will be based on the duty cycle set by the program in the PLC. So that the motor will operate only by the program already set by the programmer. As a result, users can only operate the motor within the specified range.

1.6 System development methodology

Our methods of work are organized and accomplished through a sequence of stages. Prior to all, we have reviewed related literatures. Then we have made the general block diagram for our system that enables us to easily analyze each components of the system shown figurative expression. We will carefully analyze the block diagram and do for their type identification and specification explained in chapter 3. After identifying such specification and working principles, we finally designed the controlling part of the general block diagram and ladder diagram simulation and finally implement it.

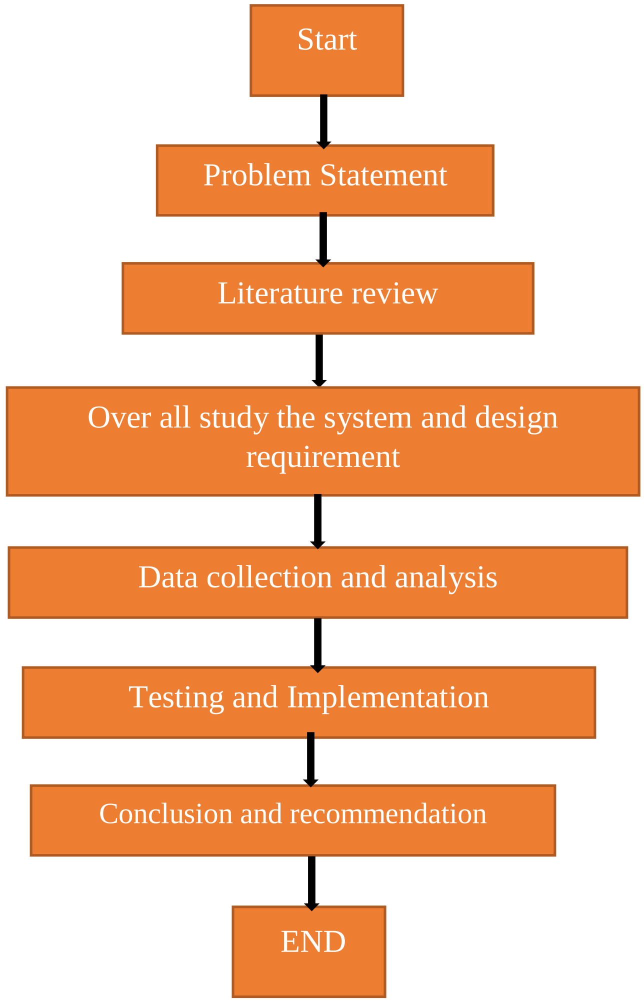


Figure 1-1 Flow chart of project methodology

1.7 Organization of the thesis

This thesis consists five chapters. Each chapter is different from the other and is described along with the necessary theory required to comprehend it.

Chapter one, introduction and background knowledge of speed of Dc motor, it also discusses about the objective, problem statement, significant and scope of this project as long as methods of works.

Chapter two, it discusses more on theory and literature reviews that have been done. It discusses about how to measure speed of DC motor and speed controlling technique that can be used to control the speed of the motor.

Chapter three, the discussion is on PLC, on DC motor modeling, component description, flow chart, working principle or methodology of work flow and specification the component.

Chapter four, the discussion is on the software simulation and hardware implementation.

Chapter five, contain conclusion and recommendation.

1.8 Limitations

- ✓ Rockwell Automation micro 850 PLC doesn't have pulse width modulation instruction block in order to vary duty cycle (so there is difficulty of changing speed of dc motor automatically).
- ✓ Difficulty of getting material such as motor driver (which leads to difficulty to control magnitude of supply voltage).
- ✓ We can't find materials that we select in laboratory (i.e. we are restricted with materials which only present in laboratory).

Due to the above mentioned cases hardware implementation or prototype is not fully automatic

CHAPTER TWO

2. Literature review

Literature review was an ongoing process throughout the whole process of the project. It is very essential to refer to the variety of sources in order to gain more knowledge and skills to complete this project. These sources include reference books, thesis and also the materials obtained from internet. This chapter describes previous work that has been done by different controllers. Many researchers have proposed in the field of DC motor control listed below.

2.1 Related works

Dc motor are used in so many applications like electric trains and robotic manipulators.in order to realize this systems dc motor should be controlled.in this work dc motor speed controlled by Fuzzy controller using Matlab (George, 2000) Dc motor provide high performance, because speed of the motor can be adjusted in wide range. Fuzzy logic is best to where system is nonlinear and difficult to calculate mathematical equations. As known Fuzzy logic control based on human experience and linguistic definitions of the system [1].

(Filter, 2003) Kalman filter was used to estimate the speed without noise interference. The result from the estimated speed was compared with the reference speed and the speed error will be used by the controller to control the linear amplifier. The final output was the constant speed of the DC motor. Even though the load of the DC motor changed, the speed of the DC motor remains constant under the control. The results illustrate that the Kalman filter can reject the noise from the system and estimate the speed of the DC motor with a high accuracy. The estimated speed will be feedback to control the system for constant speed. Sampling rate is a major limitation while converting continuous signal to discrete signal. [2]

(Chinnaiyan V.Kumar, 2004) have proposed the speed and direction control of DC servo motor when the current is the only one measurement. A LQG (Linear Quadratic Gaussian) controller is designed by assembling an integral LQ state. Its robustness and performances are discussed and experimentally tested. A control design was presented that performs well the compromise between speed control performances, robustness and current limitation of a dc-motor as no mechanical sensor is available. Especially good results were experimentally obtained when the motor parameters were identified at the starting of the motor. Limitation is that, accurate speed control without mechanical sensor includes on-line identification of the resistance which is slowly varying and also the use of adaptive control. [3]

(George, 2004) Designed a Brushless Permanent Magnet BLPM motor drive might serve as a potential alternative to existing servo industrial AC motor, especially in a small frame size, for variable speed drives. [7]

(Weber, 2010) have proposed a Pulse Width Modulation (PWM) based DC motor control to control the speed of a DC series field motor at different required torque levels by adjusting the voltage applied to the motor. For any constant voltage, the motor speed was determined solely by the torque requirements and top speed is reached under minimum torque conditions. Voltage to the motor is controlled to fit the various torque requirements of grades, speed and load. The common method of varying the speed of the motor is by inserting resistance R in series with motor to reduce the supplied power. This type of motor speed control is very inefficient due to the wasteful of battery power due to the I2R loss, especially under high current and high torque conditions. [10].

(Chinnaiyan V.Kumar, 2004) have proposed a methodical approach based on switched quadratic regulators for designing an efficient DC motor speed controller. This control strategy is compared with two cascade control design methods in terms of performances, robustness and complexity. Switched LQ (Linear Quadratic) regulators were particularly well suited to manage the performance robustness trade off. The performance robustness has been proved for the strategies, in spite of large parametric uncertainties. Stability analysis of the system was not carried out to demonstrate whether the system is stable or not. [3].

(Sanjay, 2011) have implemented the speed and direction control of a separately excited

DC motor using fuzzy logic control (FLC) based on LabVIEW. The results of experiment on the real plant demonstrate that the fuzzy logic controller is sensitive to variations of the reference speed attention. It was shown that the controller gains optimal performance and overcomes the disadvantage of the conventional control of sensitiveness to inertia variation and variation of the speed with drive system of DC motor. A limitation is that the load disturbances are not taken into account while designing the controller. [5]

(Ogbuka, 2014) Speed controller system based on controller had been successfully developed and it was found able to regulate the speed well above the rated values. K.-H. Kim et.al [6].

The application notes in (George, 2004) demonstrated the use of NXP Semiconductors LPC2101 controller for bi-directional brushed DC motor control. A. S [7].

(W.Bolton, 2015) presented a simplified approach for speed control of a separately excited DC motor using Programmable Logic Controller PLC designed a high-performance low-cost low-loss wireless DC motor speed control unit. [8]. The principles of PWM and Hall sensor have been introduced by W. Wang [9]. He proposed the designing strategy of DC motor speed control system based on single chip controller with integrated circuits.

A. K. Dewangan [10] investigated an implementation of the ATmega8L microcontroller for PWM speed control of Permanent Magnet DC motor fed by a DC chopper with speed feedback through a taco generator. (T.George, 2017) [11] designed circuit for controlling the voltage across the DC motor by varying the duty cycle with PWM scheme.

CHAPTER THREE

3. Methodology

This chapter will describe the materials required and method that will be used for this project in order to achieve the desired objectives.

Our methods of work are organized and accomplished through a sequence of stages. Prior to all, we have reviewed related literatures. Then we have made the general block diagram for our system that enables us to easily analyze each components of the system.

For this thesis work we follow the following procedures:

First, we select an instrument or a system that we wish to control. Automated system can be a machine or a process and can also be called a process control system. Function of a process control system is constantly watched by input devices (sensors) that give signals to a PLC controller. In response to this, PLC controller sends a signal to external output devices (operative instruments) that actually control how system functions in an assigned manner (for simplification). Finally, program is entered into the PLC controller memory. When finished with programming check-up is done for any existing errors in a program ladder and, if an entire operation is simulated. Before this system is started, check once again whether all input and output instruments are connected to correct inputs or outputs. By bringing supply in, system starts working possible.

3.1 Block diagram of the system

The block diagram (system model) of speed control of DC motor using PLC is shown below.

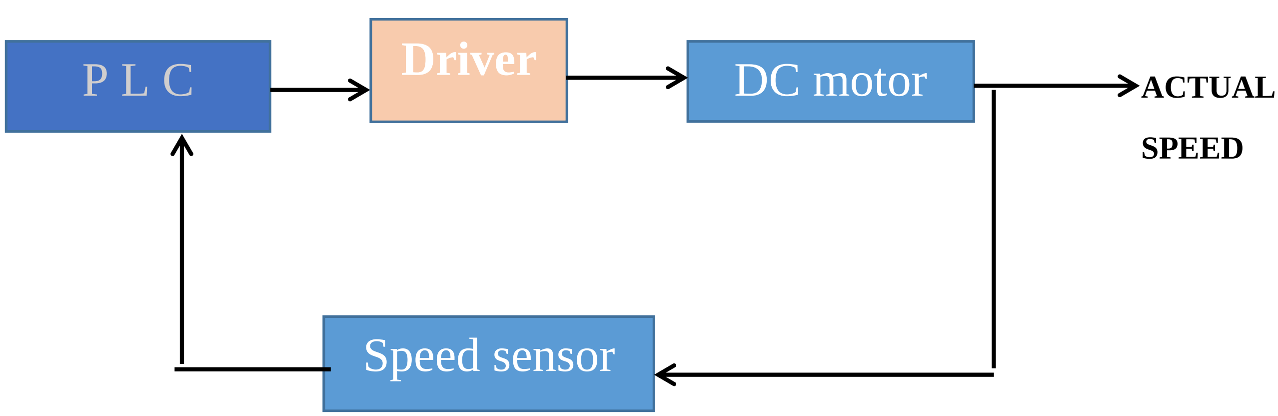


Figure 3-1 block diagram of the thesis

The basic principle behind DC motor speed control is that the output speed of DC motor can be varied by controlling armature voltage for speed below and up to rated speed keeping field voltage constant. The output speed is compared with the reference speed and error signal is fed to speed controller. Controller output will vary whenever there is a difference in the reference speed and the speed feedback.

The output of the speed controller is the control voltage Ec that controls the operation duty cycle of (here the converter used is a Chopper) converter. The converter output give the required Va required to bring motor back to the desired speed. Proximity sensor is placed near to the shaft of the motor to measure speed of DC motor.

3.2 Required Materials and descriptions

- DC motor
- Proximity sensor
- PLC
- DC Drive

3.2.1 Proximity (speed sensor)

Sensors is a device that detects the state of the environment such as energy, heat, light, magnet, supersonic, etc. and convert them to electric signals.

Proximity Sensor" includes all sensors that perform non-contact detection in comparison to sensors, such as limit switches, that detect objects by physically contacting them. Proximity Sensors convert information on the movement or presence of an object into an electrical signal.

There are three types of detection systems that do this conversion: systems that use the eddy currents that are generated in metallic sensing objects by electromagnetic induction, systems that detect changes in electrical capacity when approaching the sensing object, and systems that use magnets and reed switches.

There are different types of proximity sensors. But in our thesis we used inductive proximity sensor. Inductive proximity sensors enable the detection, without contact, of metal objects at distances of up to 60 mm.

Working principle

By applying a voltage to the oscillator coil an alternating inductive field is created in front of the active surface of the unit. When a metallic object (steel, aluminum, copper, brass etc.) enters this field from any direction and the state of the oscillator is modified until the threshold of the trigger is inverted this induces a change in the final stage and the subsequent command of an external load. The intervention distance depends on the type of metal and as described earlier, in the reduction factors. All the sensors are protected against ~~inversion~~ of polarity and electrical disturbances of inductive sources and can be supplied with short circuit protection in the D.C. version.

Their range of applications is very extensive and includes: the monitoring of machine parts (cams, mechanical stops, etc.), monitoring the flow of metal parts, counting, etc.

Advantages of inductive detection

- No physical contact with the object to be detected, thus avoiding wear and enabling fragile or freshly painted objects to be detected.
- High operating rates.
- Fast response.
- Excellent resistance to industrial environments (robust products, fully encapsulated in resin).

When a metal object is placed within the magnetic field generated by the sensor, the resulting currents induced form an additional load and the oscillation ceases.

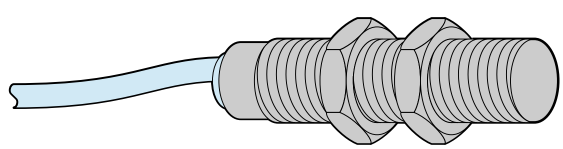


Figure 3-2 inductive proximity sensor

3.2.2 Motor Driver

If a DC motor is connected directly to the voltage supply, the constant power will be supplied to the DC motor all the time. Due to the constant power to motor, the speed of motor will slow down when the load is heavier and speed up when the load is lighter. So, DC motor drive is needed where we can control the magnitude of supply voltage in order to control the speed of DC motor. The DC motor drive that is used in this thesis is a dual full bridge driver, chip L293D. The Pin configuration of L293D is shown in Figure. The operating supply voltage of chip L293D is up to 36V and the total DC current up to 2A.

The pin diagram of L293D is shown in below figure.

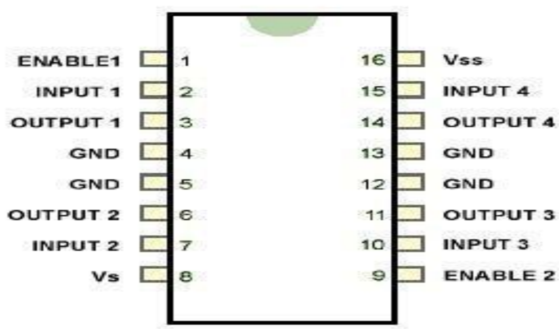


Figure 3-3 Pin diagram of L293D

3.2.3 Programmable logic controllers (PLC)

A Programmable Logic Controller (PLC) is a specialized computer used for the control and operation of manufacturing process and machinery. It uses a programmable memory to store instructions and execute functions including on/off control, timing, counting, sequencing, arithmetic, and data handling. A PLC is a very useful decision-making device in industrial applications. Serial communication is used between a PC and the PLC to download programs.

PLCs have been gaining popularity on the factory floor and will probably remain Predominant for some time to come. Most of this is because of the following general advantages they offer:

- Cost effective for controlling complex systems.
- Flexible and can be reapplied to control other systems quickly and easily.
- Computational abilities allow more sophisticated control.
- Troubleshooting aids make programming easier and reduce downtime.
- Reliable components make these likely to operate for years before failure.
- Smaller physical size than hard-wire solutions.
- Easier and faster to make changes.

- PLCs have integrated diagnostics and override functions.
- Diagnostics are centrally available.
- Applications can be immediately documented.
- Applications can be duplicated faster and less expensively

Typically, a PLC system has five basic components. These are the Processor unit, memory, the power supply unit, input/output interface Section and the programming device. Figure below shows the basic arrangement.

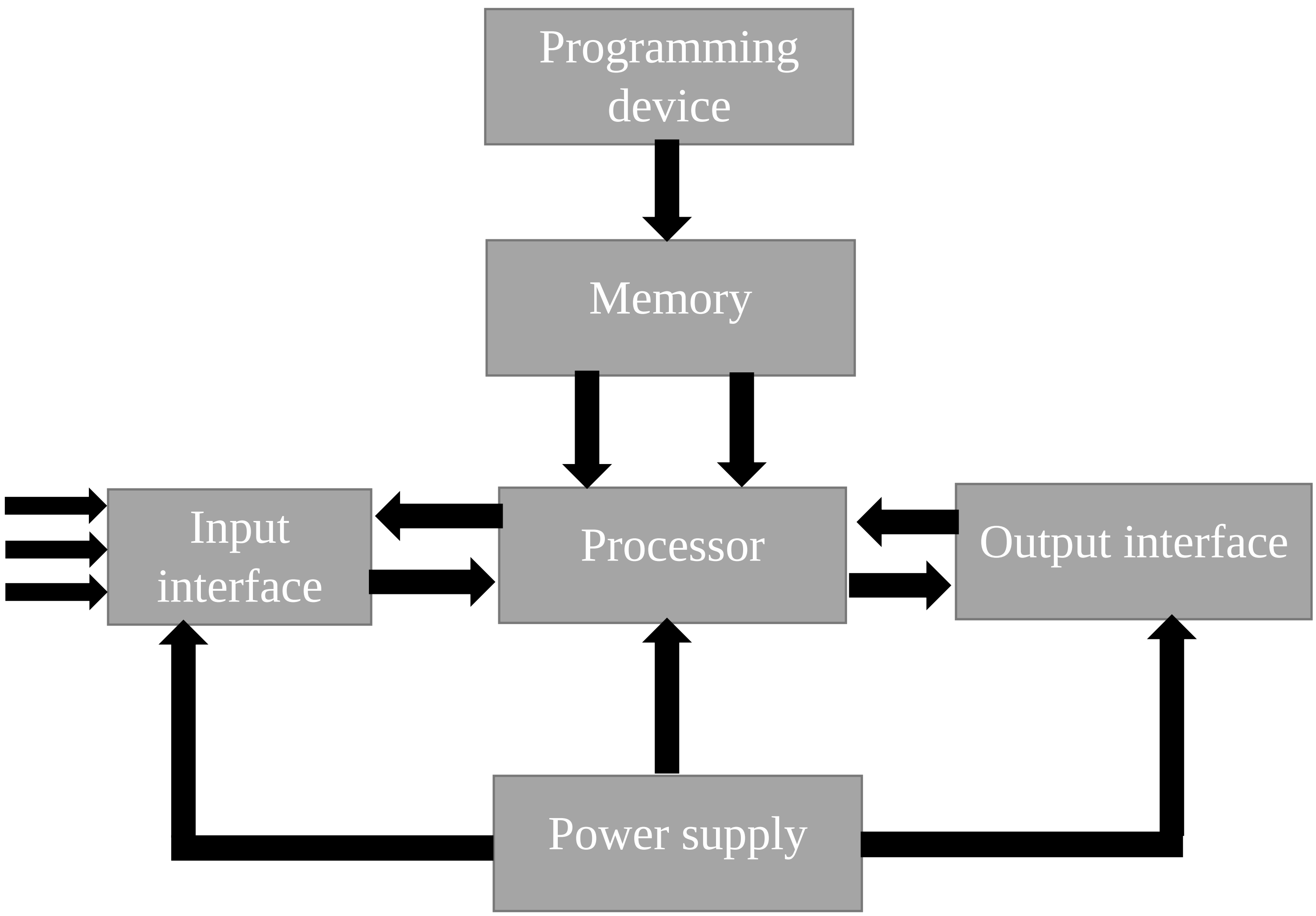


Figure 3-4 PLC system interfacing with input output and power supply

1. The processor unit or central processing unit (CPU): is the unit containing the microprocessor and this interprets the input signals and carries out the control actions, according to the program stored in its memory, communicating the decisions as action signals to the outputs.

2. The power supply unit: is needed to convert the main max.ac voltage to the low Dc voltage (24v) necessary for the processor and the Circuits in the input and output interface modules.

3. The programming device: is used to enter the required program in to the memory of the processor. The program is developed in the device and then transferred to the memory unit of the PLC.

4**. The memory unit:** is where the program is stored that is to be used for the control actions to be exercised by the microprocessor. Memory is the element that stores information, programs, and data in a PLC. Memory location refers to an address in the CPU's memory where a binary word can be stored. Each binary piece of data is a bit and eight bits make up one byte. The program is stored in the memory as 1s and 0s, which are typically assembled in the form of 16bit word.

5. The input and output sections: are where the processor receives Information from external devices and communicates information to External devices. Every input/output point has a unique address in The system. The inputs might thus be from switches, or other sensors such as photo electric cells, temperature sensors, flow sensors, etc. The out puts Might be to motor starter coils, solenoid valve, etc. to each of the I/O modules via a set of parallel conductors called the bus.

In this thesis we used Rockwell Automation programmable logic controller (PLC) with software connected components workbench (CCW).

Connected Components Workbench (CCW) is the integrated design environment software package that is used to program, design, and configure your Rockwell Automation Connected Components devices such as, Micro800 programmable logic controllers, Power Flex drives, SMC soft-starters, and Panel View Component operator interface terminals.

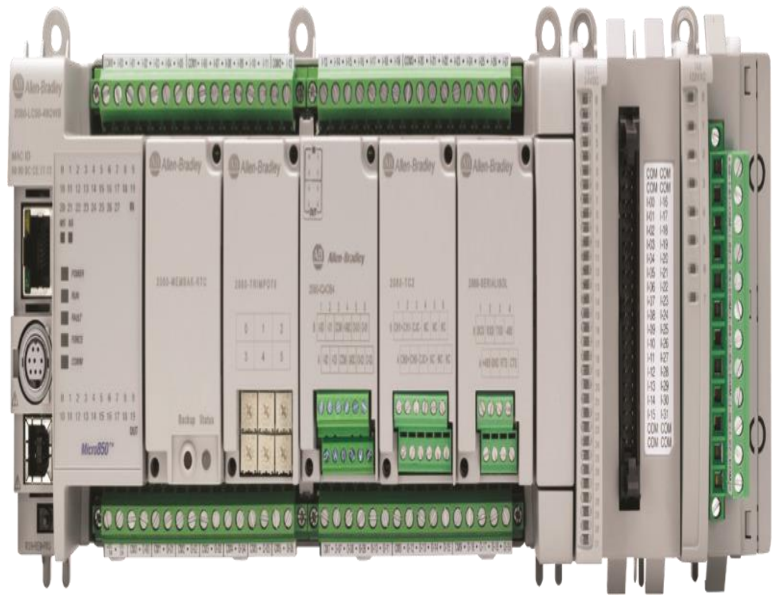


Figure 3-5 Rock well automation PLC

Features of Rock well automation micro 850 PLC

- Equipped with same form factor, plug-in support, instruction/data size and motion capabilities as Micro830® 24-pt and 48-pt controllers
- It has 13 input output pins.
- Designed for larger standalone machine applications that require higher density, higher precision analog and digital I/O as compared to Micro830 controller
- Expandable to a maximum of 132 digital I/O points on a 48-pt controller with Micro850 Expansion I/O modules
- Standard version of Connected Components Workbench software available as a free download
- Takes 24V input voltages

3.2.4 DC Motor

A direct current (DC) motor converts DC electrical energy into mechanical energy. It produces a mechanical rotary action at the motor shaft where the shaft is physically coupled to a machine or other mechanical device to perform some type of work. DC motors are well suited for many industrial applications. For example, DC motors are used where accurate control of speed or position of the load is required and can be accelerate or decelerate quickly and smoothly. Generally, a simple two pole DC motor has six basic parts which are rotor or armature, axle, stator, field magnets, commutator, dc power supply and brushes. Figure below shows the illustration of DC motor and table 3.1 shows the parts of DC motor with its explanation.

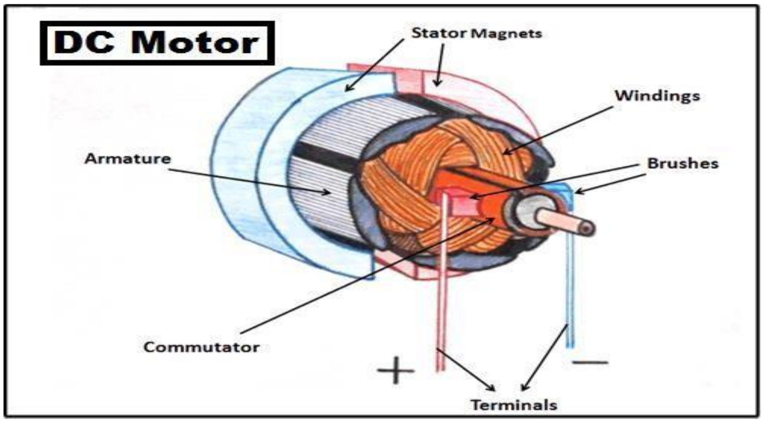


Figure 3-6 parts of dc motor

Description of DC motor parts

Table 3-1 Description of DC motor parts

Parts	Descriptions
Rotor	• Consist of windings that being electrically connected to commutator. • It is rotating together with axle and attached commutator with respect to the stator.
Axle	• Attached with commutator and rotor.
Commutator	• Composed of conductive segments which represent the termination of individual coils of wire distributed around the armature.
Stator	• Stationary part of the motor which includes the motor casing.
Brushes	• Remain stationary with the motor's housing but ride (or brush) on the rotating commutator.
Fields Magnet	• Winding that represent North and South polarization.

Types of DC Motor and Its Application

Understanding the different types of DC motors will also help you understand how they're used for different applications, and which type may apply to your application.

There are 4 main types of DC motors:

1. Permanent Magnet DC Motors

The permanent magnet motor uses a permanent magnet to create field flux. This type of DC motor provides great starting torque and has good speed regulation, but torque is limited so they are typically found on low horsepower applications.

2. Series DC Motors

In a series DC motor, the field is wound with a few turns of a large wire carrying the full armature current. Typically, series DC motors create a large amount of starting torque, but cannot regulate speed and can even be damaged by running with no load. These limitations mean that they are not a good option for variable speed drive applications.

3. Shunt DC Motors

In shunt DC motors the field is connected in parallel (shunt) with the armature windings. These motors offer great speed regulation due to the fact that the shunt field can be excited separately from the armature windings, which also offers simplified reversing controls.

4. Compound DC Motors

Compound DC motors, like shunt DC motors, have a separately excited shunt field. Compound DC motors have good starting torque but may experience control problems in variable speed drive applications.

Between the 4 types of DC motors, the potential applications are numerous. Each type of DC motor has its strengths and weaknesses. Understanding these can help you understand which types may be good for your application

Types of DC motor with advantages and disadvantages

Table 3-2 dc motor types and their advantages and dis advantages

Types	Advantages	Disadvantages
Series Coils	• High starting Torque	• Speed varies
Permanent Magnets	• Variable speed • Small and compact • Cheap	• Heavy magnets • Cannot vary magnetic field strength.
Shunt Coils	• Constant speed	• Low starting torque
Stepper motor	• Very precise speed and position control	• Expensive • Require a switching control circuit

Therefore, depending on the above explanation, we select dc shunt motor for speed controlling purpose since its speed is independent of loads.

DC SHUNT MOTOR

In a DC shunt motor the field winding is connected in parallel (shunt) to an armature with the common DC power supply. The field winding can be either separately excited or be connected to same source as that of armature. DC shunt motors have different working characteristics than that of DC series motor.

The shunt Connected motors offer good speed regulation, but does not have as much starting torque as that in DC series motor. Due to its ability of self-regulation the switching of motor from no load to full load conditions there is no considerable change in its running speed. As the load to the motor increases, the speed of the motor slows down instantaneously. Slowing down the speed reduces the back EMF, which in turn increases the current in armature branch. This results in the increase of the motor speed.

On the other hand, if load is decreased, then motor speed will rise instantaneously. This in turn will increase the counter EMF, thus reducing current to the motor. Gradually the motor will reduce its speed. As a result, the DC shunt motor is capable of maintaining a constant speed irrespective of load changes. Because of this feature, this motor is used for automotive and in industrial purposes where fine precision of the motor speed is required.

As the shunt field coil is made up of thin wire it cannot produce large current for starting like in DC series motor, this implies that DC shunt motors have extremely low starting torque. The DC shunt motors have best speed regulation.

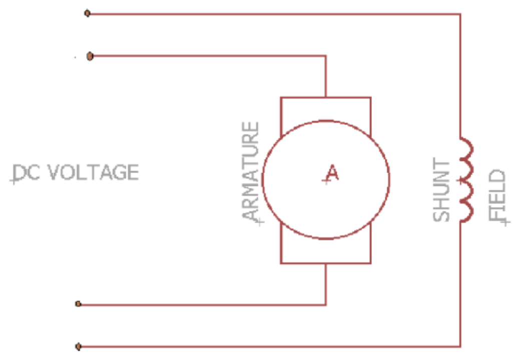


Figure 3-7 Separated Excited DC Shunt Motor

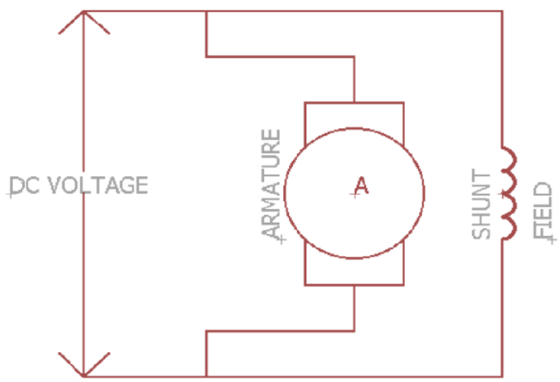


Figure 3-8 Common Source DC Shunt Motor

Modeling of separately excited dc motor

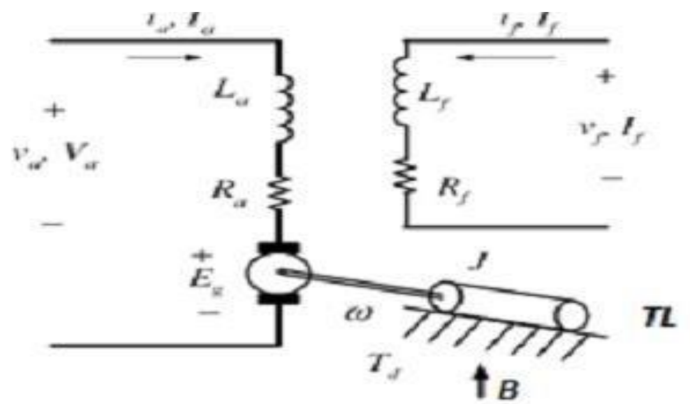


Figure 3-9 Separately Excited DC motor model

Applying KVL,

$V = Raia + \frac{ldia}{dt} + Eg$ [3.1]

$Eg \propto \varphi\omega = Kb1\varphi\omega$ $(E = Kb\omega)$ Since flux and kb1 is constant, then

$Eg = \frac{Kbd\theta}{dt}$ [3.2]

$T \propto \varphi K1ia = kia$ Since field is constant flux is also constant, then

$T = Kia$ [3.3]

$T = \frac{Jd2\theta}{dt} + Bd\theta/dt$ [3.4]

In field winding,

$Vf = RfIf + \frac{LfdIf}{dt}$ [3.5]

Steady-state torque and speed

Motor speed can be easily derived by

$\omega = (V - IaRa)/K)/$ [3.6]

When Ra value is a small or when the motor is slightly loaded, Ia is very small and speed becomes

$$\omega = V/KIf$$

Take Laplace transform of equation 3.1, 3. 2, 3.3 & 3.4

$V(s) = RaIa(s) + LsIa(s) + Eg(s)$ [3.7]

$V(s) - \ Eg(s) = Ia(s)[R + SLa]$ [3.8]

$Eg(s) = KbS\theta(s)T(s) = KIa(s)$ [3.9]

$T(s) = S2J\theta(s) + BS\theta(s) \quad T(s) = \theta S(s)[SJ + B]$ d [3.10]

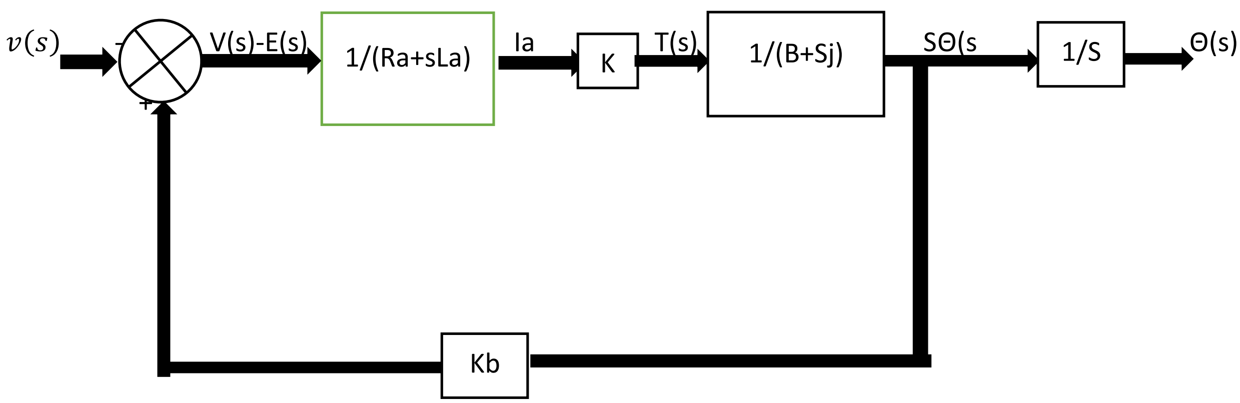


Figure 3-10 Closed loop representation of separately excited DC motor

The description for the notations used is given below:

1. V is the armature voltage in volts.
2. Egis the motor back emf in volts.
3. Ia is the armature current in amperes.
4. Ra is the armature resistance in ohms.
5. La is the armature inductance in Henry.

3.3 Pulse width modulation (PWM)

Modulation means to vary something. Pulse Width modulation means varying the width of pulses in frequency to obtain desired output voltage that makes the motor to move by the required speed. It is a method for binary signals generation, which has two signal periods (high and low). The width (W) of each pulse varies between 0 and the period (T). The main principle of this of this method is controlling the voltage by varying the duty cycle. PWM is an entirely different approach to controlling the speed of a DC motor. Power is supplied to the motor in square wave of constant voltage but varying pulse-width or duty cycle. Duty cycle refers to the percentage of one cycle during which duty cycle of a continuous train of pulses. Since the frequency is held constant while the on-off time is varied, the duty cycle of PWM is determined by the pulse width. Thus the power increases duty cycle in PWM.

The expression of duty cycle is determined by,

$$\%Duty\ cycle = \left(\frac{ton}{T}\right) * 100\% \qquad [3.11]$$

Where, $T = t1 + t2$

- Basically, the speed of a DC motor is a function of the input power and drive characteristics. While the area under an input pulse width train is measure of the average power available from such an input. The average voltage at output is given by

$$Va = \frac{1}{T}\int_0^t Vodt = \frac{t1}{T}Vo \qquad [3.12]$$

$$Va = KVs$$

- The average load current

$$Ia = \frac{Va}{R} = KVs/R \qquad [3.13]$$

Where, T is the total time period

k = t1/T is the duty cycle.

- The rms value of output voltage is Vrms = (1/T ∫ Vo^2 dt) ½ = k V_s

- The output power is given by

P = 1/T ∫$v_0$idt = 1/T ∫ V_0^2/R dt =kVs2/R

The duty cycle can be varied from 0 to 1 by varying t1, T or f. Therefore, the output voltage V0 can be varied from 0 to Vs by controlling k, and the power flow can be controlled. As the time t1 changes the width of pulse is varied and this type of control is called pulse width modulation

(PWM) control. For better understanding of PWM these diagrammatic representations can be used. These figures represent the waveforms obtained as output at different voltage requirements.

High Speed Signal (90%): The green part of the signal represents the ON time and the white part of it represents the time when it is not receiving any voltage.

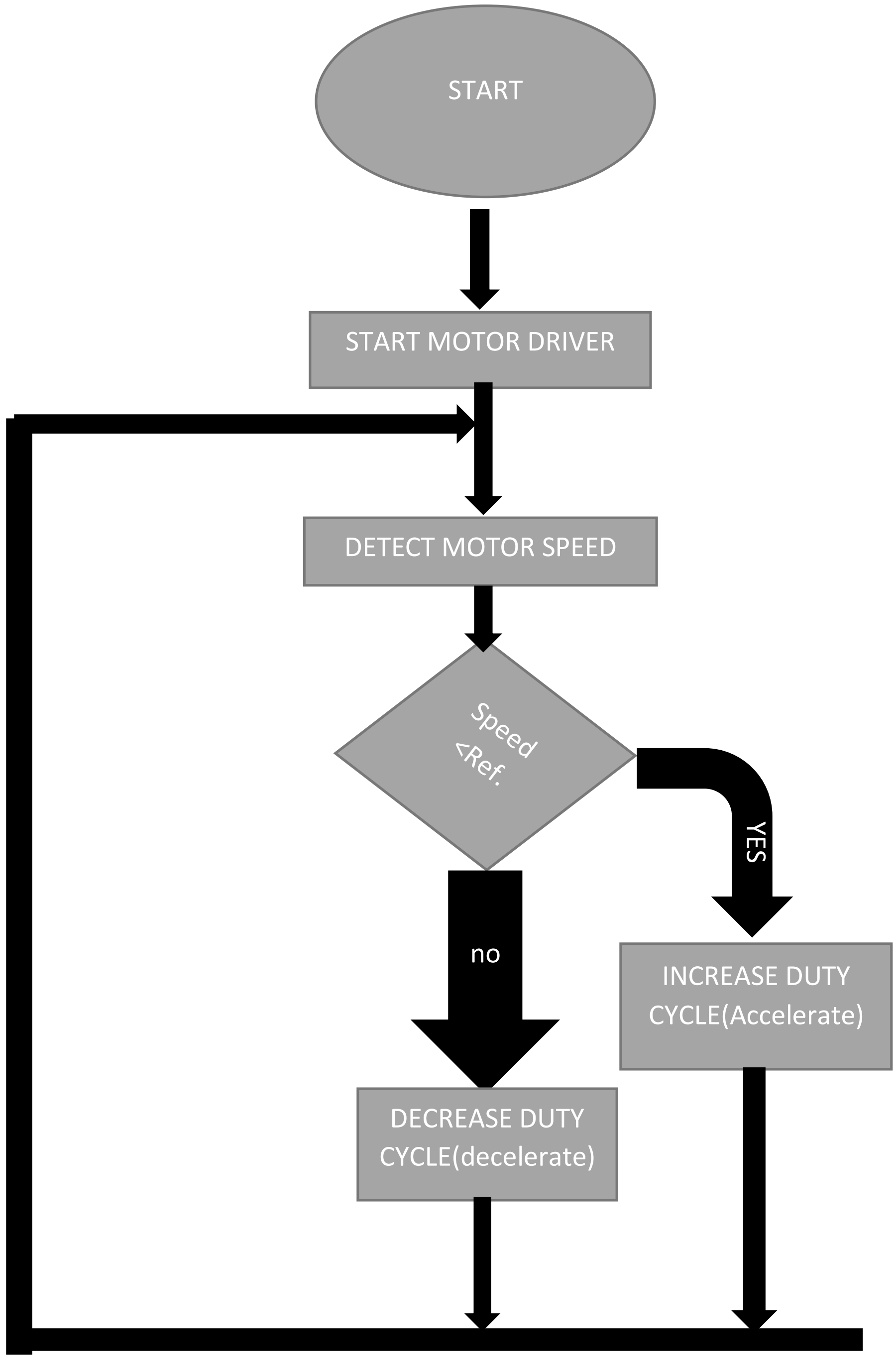
Figure 3-11 (a) High Speed Signal (90%)

Figure 3-12 (b) Signal with half voltage (50%)

Figure 3-13 (c) Signal with LOW voltage (10%)

But in rock well automation micro 850 PLC there is no PWM instruction block. PWM is only supported by Rockwell Automation 820 PLC. Therefore, in terms PWM we used timers for chopping process means that providing variable dc voltage from constant dc supply.

3.4 Flowchart for the system software



y

Figure 3-14 Basic flow chart for Dc motor speed control

Operation

PLC is used for storing and running the program. The PLC receive the input through proximity sensor and plc provides control signal in order to run the motor with desired speed.

When reference speed is greater than the actual speed which is read by proximity sensor, duty cycle starts to increase. As the duty cycle increases, the on time of PWM output of PLC is high so that the average power to the motor is approximately equal with the supply voltage due to this speed of the motor increases. Also when reference speed is less than the actual speed which is read by proximity sensor, duty cycle starts to decrease and as duty cycle decreases and average power to the motor goes to zero due to this speed of the motor will decrease. In the proposed system the speed control of DC motor can be done automatically based on set time in the program. PWM pulse width is varied based on time set value. The proposed system controls the speed the motor in an efficient manner. The speed of DC motor is directly proportional to the duty cycle. When the value of voltage is low, pulse will be narrow and when the value of voltage is high, pulse width will be wide. PWM control adjusts the duty ratio of the DC motor. The average DC value of the signal can be varied by varying the duty cycle.

CHAPTER FOUR

4. Result and discussion

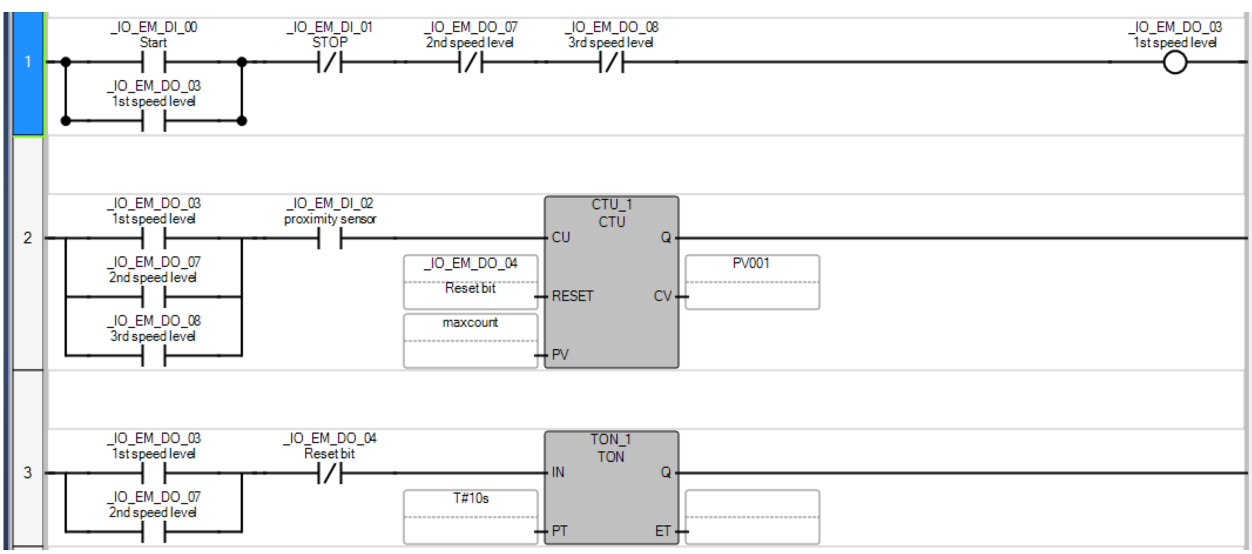
This chapter discusses on the results of the thesis including the performance of the system.

4.1 Software simulation results and discussions

We have designed and simulate the controlling program below on Rockwell Automation micro 850 plc CCW software. The simulation result shows exactly what discussed before. After downloading the program (ladder diagram) to the PLC, then PLC generates PWM (TON and TOFF) so that, by varying the duty cycle the speed of the motor can be controlled. Generally, from this project the achieved technical knowledge's are:

- Programming the PLC ladder diagram using CCW software.
- Interfacing input/output devices with Rockwell Automation PLC. Controlling the speed of the DC-motor by using PWM.

Ladder diagram for the whole system



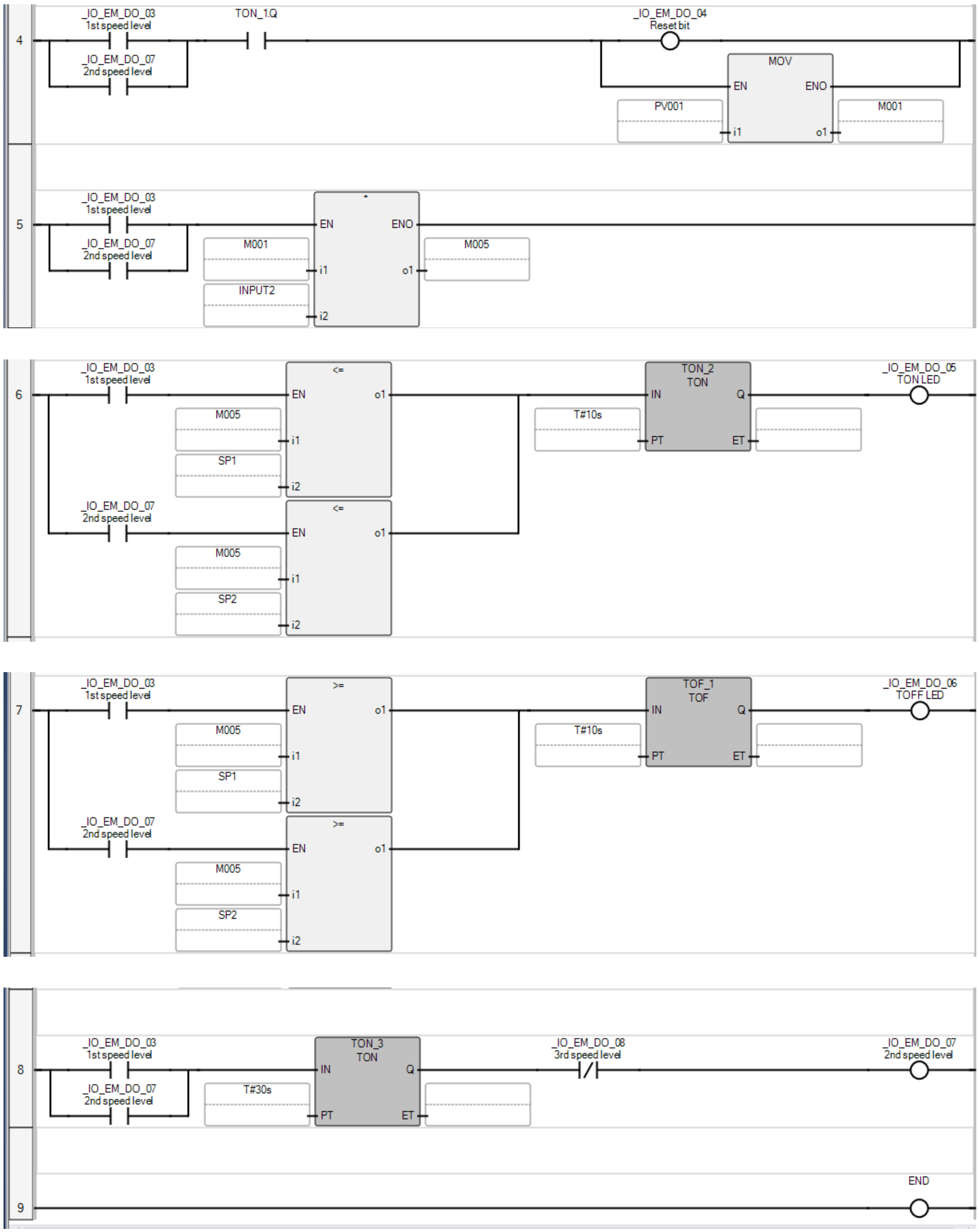


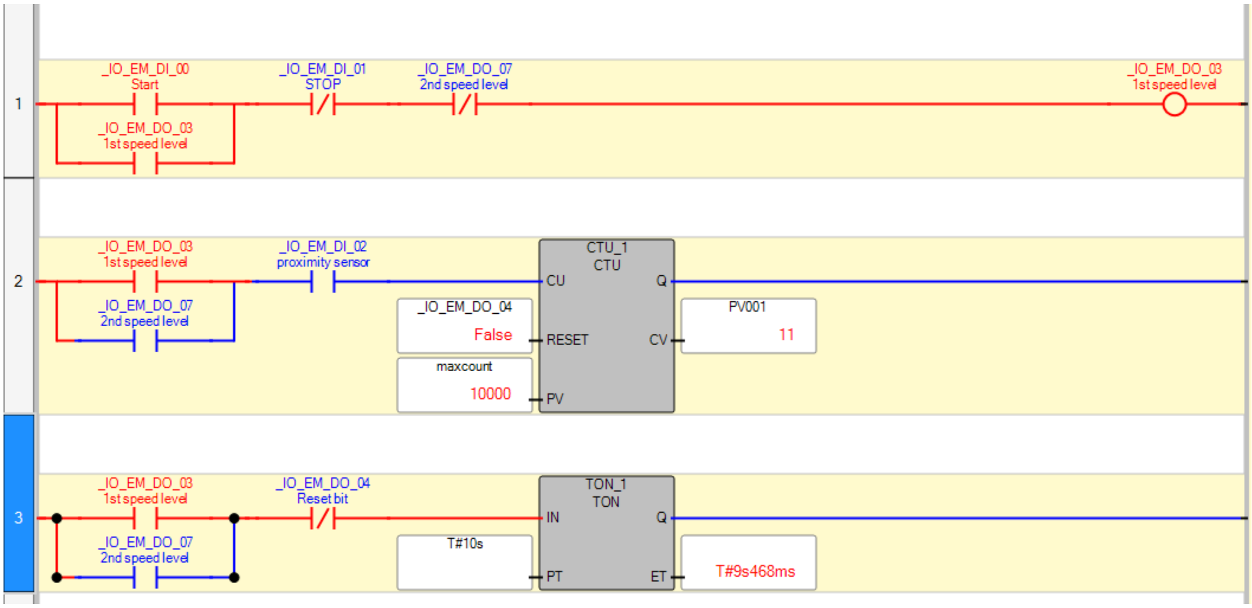
Figure 4-1 ladder diagram of the system

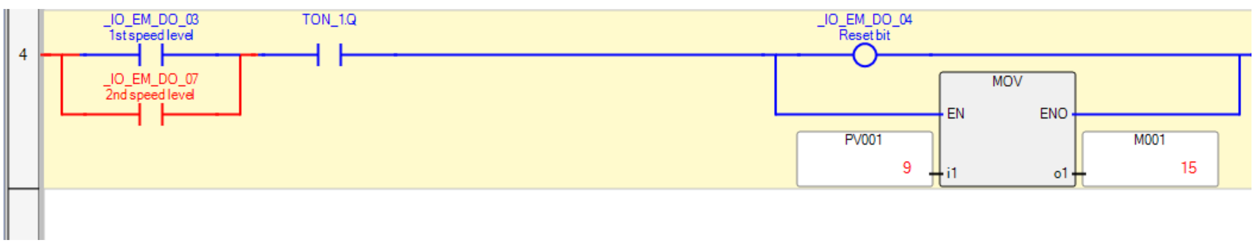
Descriptions of about the program

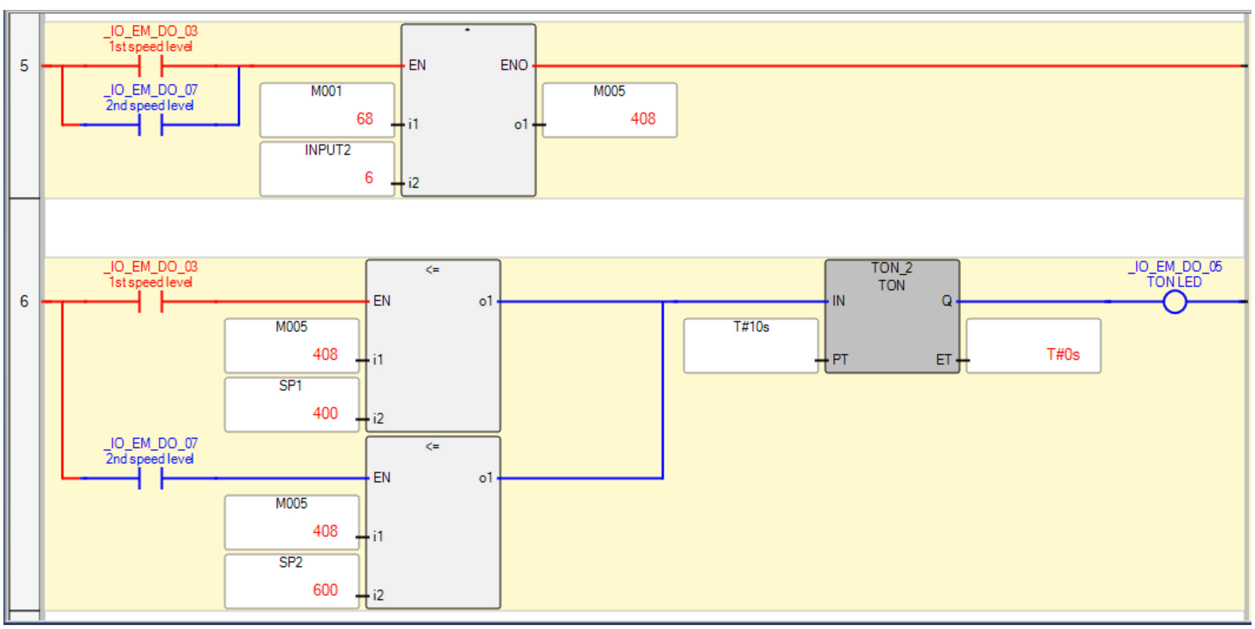
- In rung 1 there is start stop and run bit and latching bit.
- In rung 2 there is run bit, proximity sensor and counter when motor starts to run, proximity sensor activated and detects the rotation of motor provides pulse signal then counter counts the number of pulses or revolution.
- In rung 3 there is timer and reset bit. We used timer here to know how many pulses can be obtained in a set amount of time because proximity sensor couldn't read RPM rather it reads in terms of pulses or revolution and this pulse should be converted to RPM. Here in this thesis we set 10s in order to know how many pulses or revolutions could be obtained in 10s and after10s the reset bit resets the timer and counter.
- In rung 4 we used MOV instruction block in order to move counter signal to memory address since the counter count value must be converted to RPM.
- In rung 5 we used multiplication instruction block in order to convert pulses or revolutions to RPM. This pulses can be converted in a such a way that,

  Therefore, 10s is multiplied by 6 in order to convert to 60s (1 minute) and the corresponding revolution or count is also multiplied by the same factor (6) then we find the RPM of the motor.
- In rung 6 and 7 we used compare instruction to compare reference speed and actual speed of the motor. When reference speed is less than the actual speed, duty cycle decrease to decrease voltage which also decreases the speed of the motor. In other way, when actual speed less than reference speed, duty cycle increase to increase output voltage which also increases speed of the motor. But here in our thesis load is not considered. Since the motor is not loaded the speed of the motor will not vary means that the motor will continue with start speed.
- In rung 8 we used timers inter locked with speed levels to change from one speed levels to another speed levels after set time with different reference point.

At the simulation stage, the ladder diagram became;


_IO_EM_DI_00
Start
_IO_EM_DI_01
STOP
_IO_EM_DO_07
2nd speed level
_IO_EM_DO_03
1st speed level
_IO_EM_DI_02
proximity sensor
CTU_1
CTU
CU
Q
RESET
CV
PV
_IO_EM_DO_04
False
maxcount
10000
PV001
11
_IO_EM_DO_04
Reset bit
TON_1
TON
IN
PT
ET
T#10s
T#9s468ms


_IO_EM_DO_03
1st speed level
_IO_EM_DO_07
2nd speed level
TON_1.Q
_IO_EM_DO_04
Reset bit
MOV
EN
ENO
i1
o1
PV001
9
M001
15


_IO_EM_DO_03
1st speed level
_IO_EM_DO_07
2nd speed level
EN
ENO
i1
i2
o1
M001
68
INPUT2
6
M005
408
<=
SP1
400
SP2
600
TON_2
TON
IN
PT
Q
ET
T#10s
T#0s
_IO_EM_DO_05
TON LED

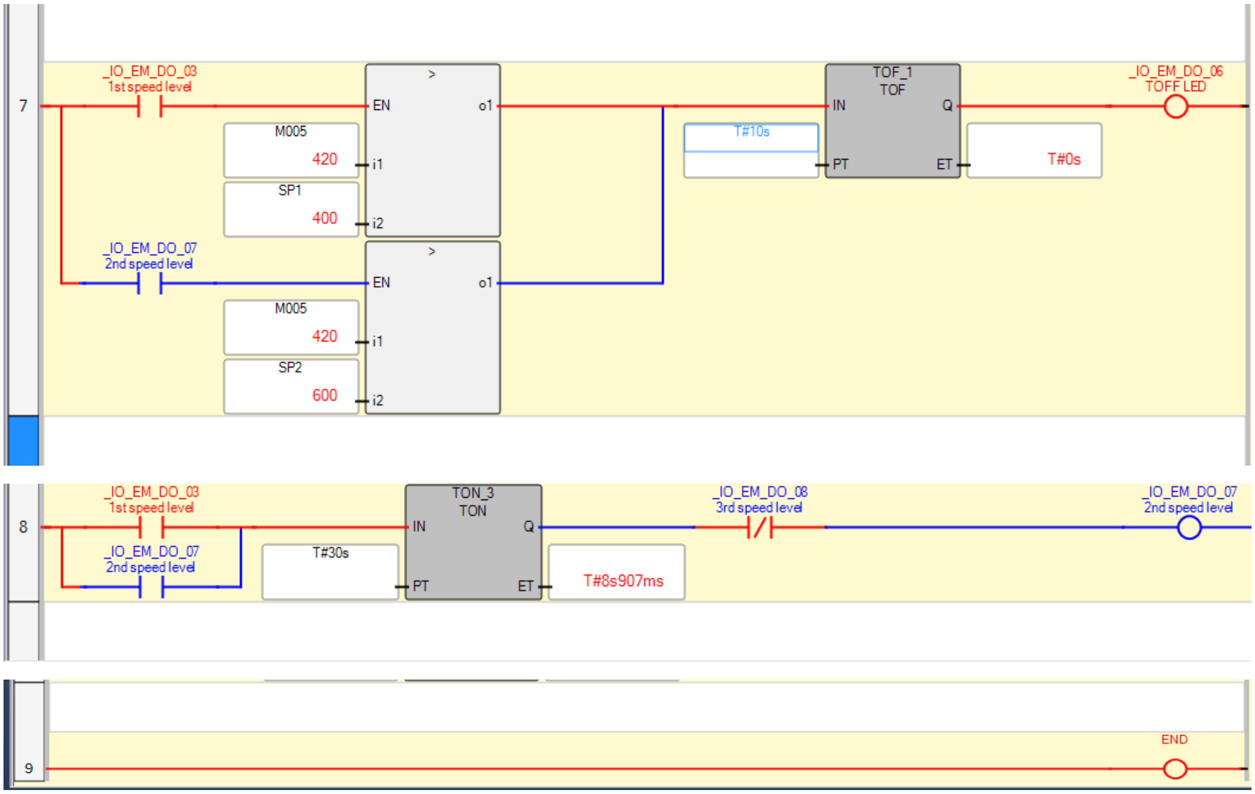


Figure 4-2 Ladder diagram at simulation stage

Descriptions

At this stage motor is rotating and proximity sensor is detecting the revolution of the shaft of the motor and counter is counting how many pulses can proximity sensor detects with in 10seconds.

This count value is (18 count as a sample) is stored to MOV instruction and later multiplied by six while converting 10 seconds into 1minute (i.e. in order to convert pulses detected in 10s to RPM,10s should be converted to minute so, the corresponding pulses is also multiplied by 6).

Here the multiplied value is (18*6) 108 which is greater than the reference value 100 so that TOF is energized to decrease duty cycle as ($duty\ cycle = \left(\frac{ton}{T}\right)$ where T=Ton+Tof) as Tof increased with constant Ton then duty cycle decreases and as the duty cycle decreases the DC voltage entering to the armature of the DC motor will decrease and so the speed of the motor will also decrease to the reference speed. The reverse is true when actual speed is less than the reference speed (i.e. as actual speed less than reference speed, Ton will be energized to increase duty cycle to increase the actual speed to reference speed).

4.2 Hardware implementation

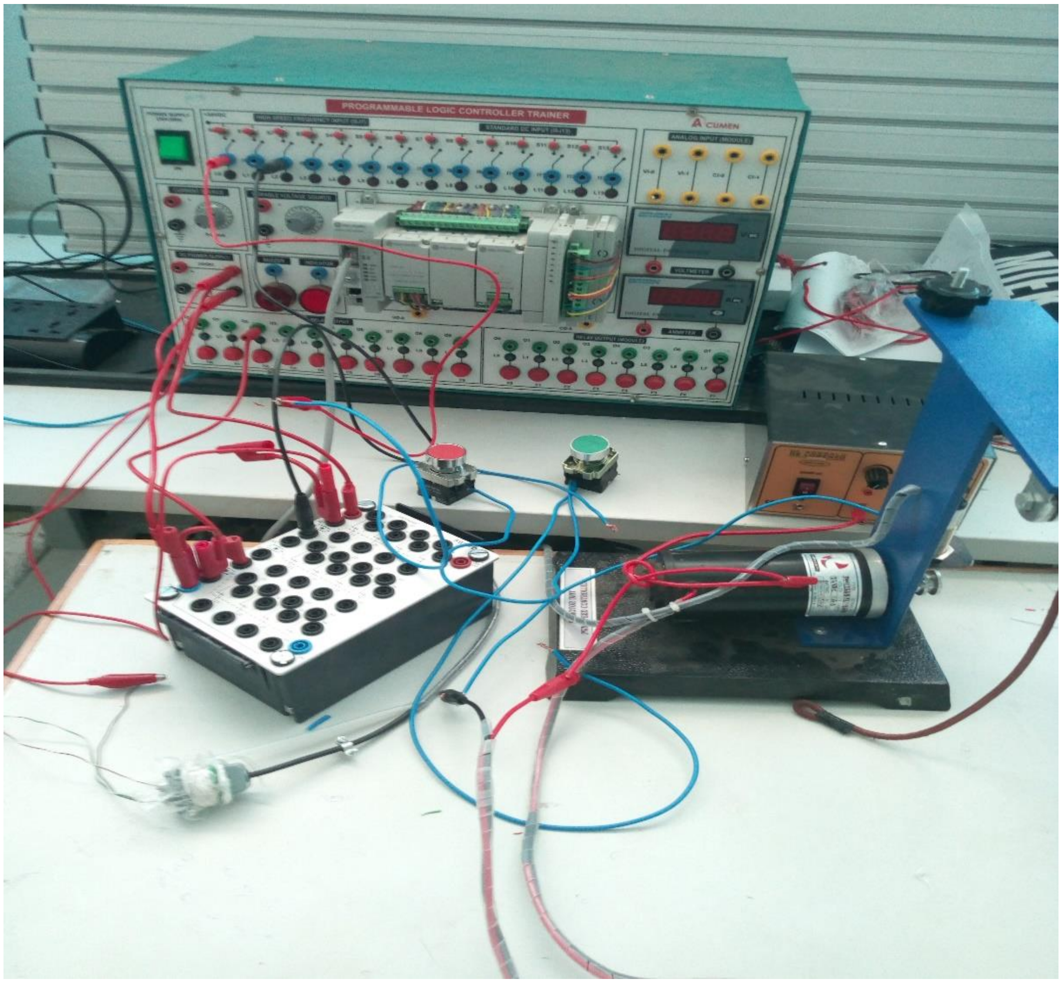


Figure 4-3 hard ware implementation of dc motor speed control

Descriptions

After the program is downloaded to the plc via communication cable from PC, then PLC stores and executes the program. When start push button is pressed, motor starts to rotate and proximity sensor starts to detect the rotation of the shaft. Then counter counts revolutions or pulses detected by proximity sensor and this revolution is converted to RPM. The converted RPM or actual speed is less or equal then dc volt is increased or decreased manually to get desired or reference speed due to the case that micro 850 PLC doesn't support or doesn't have PWM instruction that used to vary duty cycle to change dc volt.

CHAPTER FIVE

5. Conclusion and Recommendation

5.1 Conclusion

Recent developments in science and technology provide a wide range scope of applications of high performance DC motor drives in area such as medical equipment, transportation, motion control, many industrial tools and the home electric appliances require speed controllers to perform different tasks. We have designed variable speed control system for DC motor, which has reliability, precision and adaptability for different system ratting with response. By varying the duty cycle from PLC to the motor driver, motor speed is controlled back to desired value easily.

The proposed method for control reduces the number of components because PLC can integrate in one package all the functions (PLC based system requires less hardware compared to any microcontroller or microprocessor based system.). This thesis work gives a reliable, durable, accurate and efficient way of speed control of DC motors.

Generally, we have concluded that DC motor is interfaced with PLC using L293 driver and the speed of dc motor control has been designed in the system to get efficient and effective speed of motor.

5.2 Recommendation

Some small industries are still using electrical and electromechanical methods for speed controlling mechanisms. But Speed control by such kinds of mechanisms has many disadvantages. So it is better to use PLC which is more effective than other controlling mechanisms.

The PLC based DC motor speed control is such that it saves power, provide full safety and save time. This will be very helpful in the development of in the industries both financially and technically. As a result of the significant development in the working system of speed controlling method, this thesis can be further extended to meet the demands according to situation.

For the future, this thesis will extend to allow the user to enter the desired speed on keypad and the control system adjusts the duty cycle automatically to maintain the desired speed of the motor.

Someone can also can extend to develop this thesis using SCADA system because those types of systems are more reliable.

Appendix

Input and Output address of micro850 Allen Bradley PLC

Name	Alias	Data Type	Dimension	Initial Value	Comment	String Size
_IO_EM_DO_03	1st speed level	BOOL			speed level	
_IO_EM_DO_04	Reset bit	BOOL			to Reset	
_IO_EM_DO_05	TON LED	BOOL			LED	
_IO_EM_DO_06	TOFF LED	BOOL			LED	
_IO_EM_DO_07	2nd speed level	BOOL			speed level	
_IO_EM_DO_08	3rd speed level	BOOL			speed level	
_IO_EM_DO_09		BOOL				
_IO_EM_DI_00	Start	BOOL			to start the motor	
_IO_EM_DI_01	STOP	BOOL			to stop the motor	
_IO_EM_DI_02	proximity sensor	BOOL			sensor	

Local variable of the PLC Program

Name	Alias	Data Type	Dimension	Initial Value	Comment	String Size
CTU_1		CTU		...		
TON_2		TON		...		
TOF_1		TOF		...		
maxcount		DINT		10000		
PV001		DINT				
M001		DINT				
INPUT2		DINT		6		
M005		DINT				
SP1		DINT		400		
TON_1		TON		...		
END		BOOL				
TON_3		TON		...		
SP2		DINT		600		

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