EE-6491: Industrial Power Laboratory (Credits:2)

M.Tech-Industrial Power and Automation

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Significance of Industrial Power Lab

Electrical engineering is the largest field in the Engineering profession, approximately one thirds of the worlds engineers belong to electrical engineering. The current industrial scenario for an Electrical Engineer demands to have a detailed knowledge about Modern Electric drives, Process control methodology, SCADA systems, Plant Automation, Load / Power factor controllers etc. used in industries as it is a necessity for integrating these devices and systems with Electric Power Control.

This laboratory contains equipments which provide the students adequate exposure in industries. Industrial Power Laboratory consists of six laboratories. Embedded Applications lab consists of embedded controllers like DSP, FPGA, Microcontroller and VFD that are commonly used for various motion control applications in an industry. Process Automation lab consists of Supervisory Control And Data Acquisition (SCADA) and Programmable Logic Controllers (PLC) setups which are very essential for automating industrial processes. Distributed Control System lab consists of the prototypes of common industrial processes like conveyor system, material handling or Multiple Input Multiple Output Process System and other process control strategies which are to be controlled in real time via Distributed Control System Modules through Industrial Softwares. Distributed Energy Research Labs consists of STATCOM and FACTS setups that are used to regulate the voltage and power factor required for proper and efficient functioning of electric power in an industry. The power to the above setups is supplied via Solar-Wind Panel through a hybrid power controller. In addition to that Wind Simulator laboratories and Energy Labs are also a part of Industrial Power Labs.

The experiments on the laboratory setups are a part of curriculum for M.Tech Industrial Power and Automation. These experiments are also performed by other programmes in Electrical Engineering like M.Tech Power System, M.Tech Instrumentation and Control Systems and M.Tech Power Electronics as according to the relevance in their curriculum.

CONTENTS

1. VARIABLE FREQUENCY DRIVE

INTRODUCTION

A **variable-frequency drive (VFD)** is a system for controlling the rotational speed of an alternating current (AC) electric motor by controlling the frequency of the electrical power supplied to the motor. A variable frequency drive is a specific type of adjustable-speed drive. Variable frequency drives are also known as adjustable frequency drives (AFD), variable-speed drives (VSD), AC drives, micro drives or inverter drives. Since the voltage is varied along with frequency, these are sometimes also called VVVF (variable voltage variable frequency) drives. Variable-frequency drives are widely used. For example, in ventilations systems for large buildings, variable-frequency motors on fans save energy by allowing the volume of air moved to match the system demand. Variable frequency drives are also used on pumps, conveyor and machine tool drives.

OPERATING PRINCIPLE

The synchronous speed of an AC motor is determined by the frequency of the AC supply and the number of poles in the stator winding, according to the relation:

$$\text{RPM} = \frac{120 \times f}{P}$$

Where RPM = Revolutions per minute, *f* = AC power frequency (hertz), *p* = Number of poles (an even number).

The constant, 120, is 60 cycles per minute multiplied by 2 poles per pole pair. Sometimes 60 is used as the constant and p is stated as pole pairs rather than poles. By varying the frequency of the voltage applied to the motor, its speed can be changed. Synchronous motors operate at the synchronous speed determined by the above equation. The speed of an induction motor is slightly less than the synchronous speed.

An inverter is an electronic power unit for generating AC power. By using anInverter type AC drive, the speed of a conventional AC motor can be varied through a wide speed range from zero through the base (60 Hz) speed and above (often to 90 or 120 hertz). When the frequency applied to an induction motor is reduced, the applied voltage must also be reduced to limit the current drawn by the motor at reduced frequencies. (The inductive reactance of an AC magnetic circuit is directly proportional to the frequency according. Variable speed AC drives will maintain a constant volts/hertz relationship from 0 – 60 Hertz. To calculate this ratio divides the motor voltage by 60 Hz. At low frequencies the voltage will be low, as the frequency increases the voltage will increase. (Note: this ratio may be varied somewhat to alter the motor performance characteristics such a providing a low-end boost to improve starting torque.) Depending on the type of AC Drive, the microprocessor control adjusts the output voltage waveform, by one of several methods, to simultaneously change the voltage *and* frequency to maintain the constant volts/hertz ratio throughout the 0 - 60 Hz range. On most AC variable speed drives the voltage is held constant above the 60 hertz frequency. The diagram below illustrates this voltage/frequency relationship.

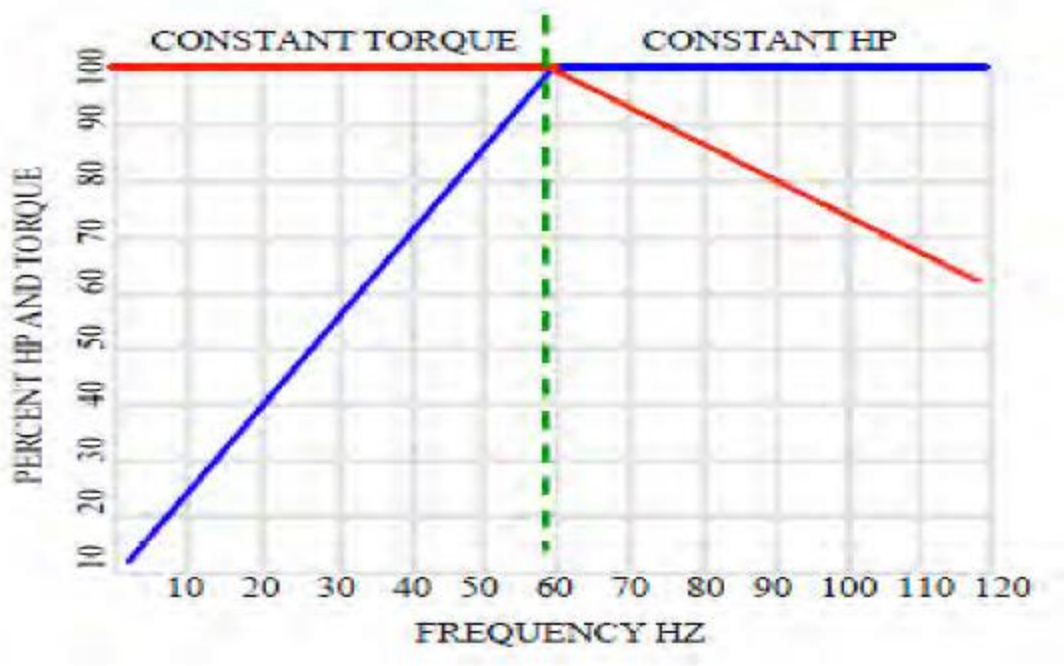


Figure 1.1 Operating Regions of VFD

In Constant Torque Area - VFD supplies rated motor nameplate voltage and motor develops full horsepower at 60 hertz base frequency. In Constant Horsepower Area – VFD delivers motor nameplate rated voltage from 60 Hertz to 120 hertz (or drive maximum). Motor horsepower is constant in this range but motor torque is reduced as frequency increases.

Initially standard AC motors were employed on inverter drives. Most motor manufacturers now offer Inverter Duty Motors which provide improved performance and reliability when used in Variable Frequency Applications. These special motors have insulation designed to withstand the steep-wave-front voltage impressed by the VFD waveform, and are redesigned to run smoother and cooler on inverter power supplies.

VARIABLE VFD TYPES

All VFDs use their output devices (IGBTs, transistors, thyristors) only as switches,turning them only on or off. Attempting to use a linear device such as transistor in its linear mode would be impractical, since power dissipated in the output devices would be about as much as power delivered to the load. Drives can be classified as: Constant voltage, Constant current, Cycloconverter. In a constant voltage converter, the intermediate DC link voltage remains approximately constant during each output cycle. In constant current drives, a large inductor is placed between the input rectifier and the output bridge, so the current delivered is nearly constant. A Cycloconverter has no input rectifier or DC link and instead connects each output terminal to the appropriate input phase. The most common type of packaged VF drive is the constant-voltage type, using pulse width modulation to control both the frequency and effective voltage applied to the motor load.

VFD SYSTEM DESCRIPTION

A variable frequency drive system generally consists of an AC motor, a controller and an operator interface.

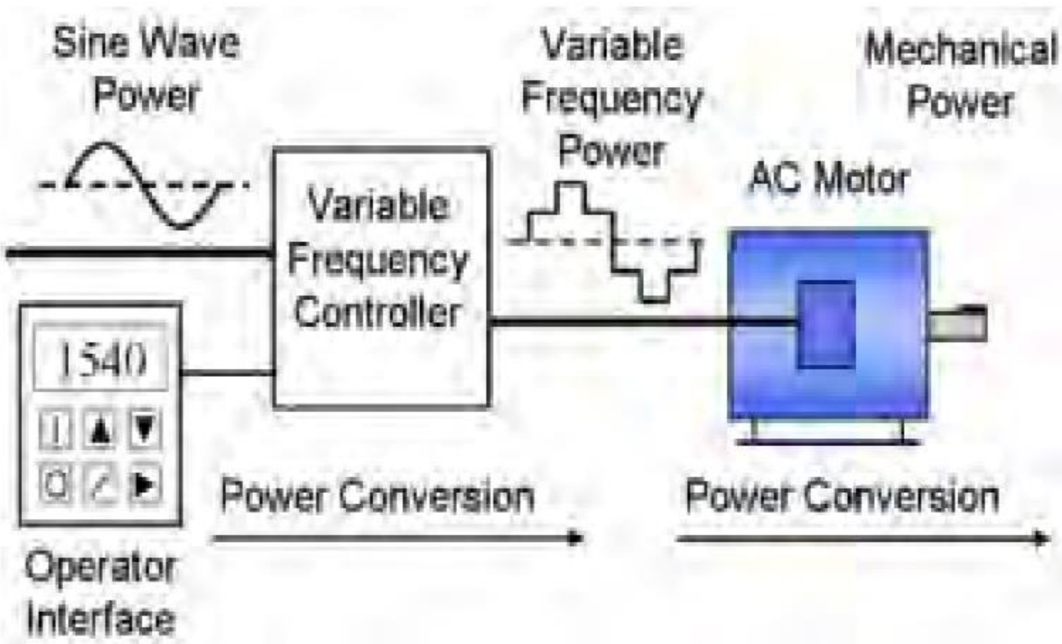


Figure 1.2 Power Flow via VFD to AC Motor

VFD MOTOR

The motor used in a VFD system is usually a three-phase induction motor. Some types of single-phase motors can be used, but three-phase motors are usually preferred. Various types of synchronous motors offer advantages in some situations, but induction motors are suitable for most purposes and are generally the most economical choice. Motors that are designed for fixed speed mains voltage operation are often used, but certain enhancements to the standard motor designs offer higher reliability and better VFD performance.

VFD CONTROLLER

Variable frequency drive controllers are solid state electronic power conversion devices. The usual design first converts AC input power to DC intermediate power using a rectifier bridge. The DC intermediate power is then converted to quasi-sinusoidal AC power using an inverter switching circuit. The rectifier is usually a three-phase diode bridge, but controlled rectifier circuits are also used. Since incoming power is converted to DC, many units will accept single-phase as well as three-phase input power (acting as a phase converter as well as a speed controller); however the unit must be derated when using single phase input as only part of the rectifier bridge is carrying the connected load. As new types of semiconductor switches have been introduced, these have promptly been applied to inverter circuits at all voltage and current ratings for which suitable devices are available. Introduced in the 1980s, the insulated gate bipolar transistor (IGBT) became the device used in most VFD inverter circuits in the first decade of the 21st century. AC motor characteristics require the applied voltage to be proportionally adjusted whenever the frequency is changed in order to deliver the rated torque. For example, if a motor is designed to operate at 460 volts at 60 Hz, the applied voltage must be reduced to 230 volts when the frequency is reduced to 30 Hz. Thus the ratio of volts per hertz must be regulated to a constant value (460/60 = 7.67 V/Hz in this case). For optimum performance, some further voltage adjustment may be necessary, but nominally constant volts per hertz are the general rule. This ratio can be changed in order to change the torque delivered by the motor

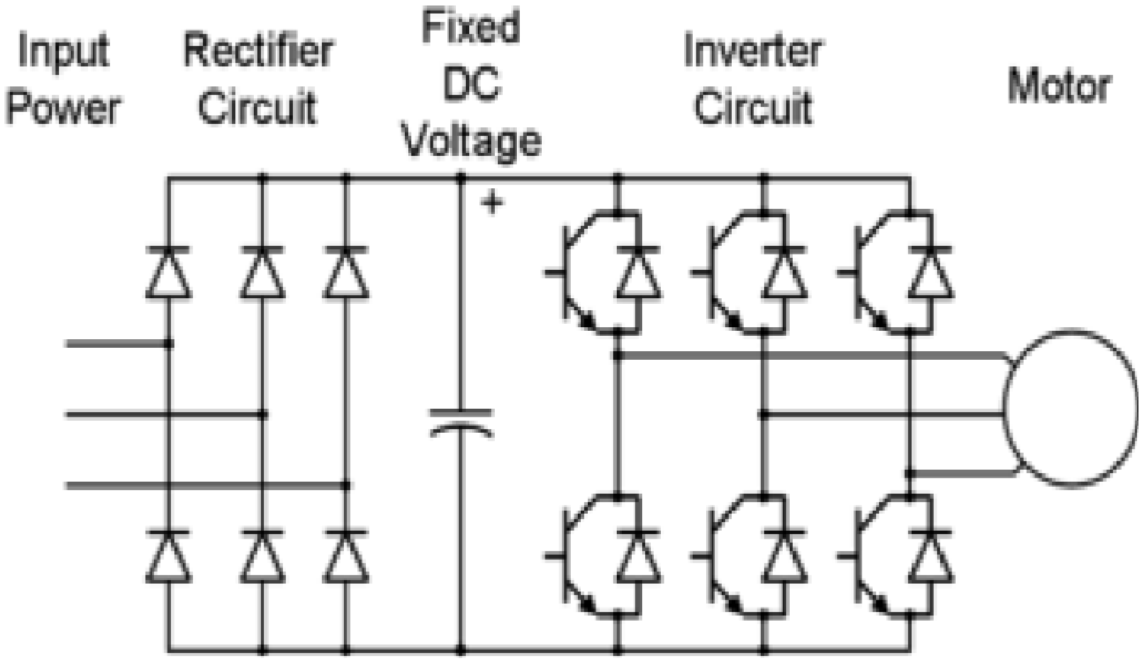


Figure 1.3 Drive Circuit for Induction Motor

The usual method used for adjusting the motor voltage is pulse-width modulation(PWM). With PWM voltage control, the inverter switches are used to divide the quasi-sinusoidal output waveform into a series of narrow voltage pulses and modulate the width of the pulses. Operation at above synchronous speed is possible, but is limited to conditions that do not require more power than nameplate rating of the motor. This is sometimes called "field weakening" and, for AC motors, is operating at less than rated volts/hertz and above synchronous speed.

Example, a 100 hp, 460 V, 60 Hz, 1775 RPM (4 pole) motor supplied with 460 V, 75 Hz (6.134 V/Hz), would be limited to 60/75 = 80% torque at 125% speed (2218.75 RPM) = 100% power.

An embedded microprocessor governs the overall operation of the VFD controller. Themain microprocessor programming is in firmware that is inaccessible to the VFD user. However, some degree of configuration programming and parameter adjustment is usually provided so that the user can customize the VFD controller to suit specific motor and driven equipment requirements. At 460 Volts, the maximum recommended cable distances between VFDs and motors can vary by a factor of 2.5:1. The longer cables distances are allowed at the lower Carrier Switching Frequencies (CSF) of 2.5 kHz. The lower CSF can produce audible noise at the motors. The 2.5 kHz and 5 kHz CSFs cause less motor bearing problems than caused by CSFs at 20 kHz. Shorter cables are recommended at the higher CSF of 20 kHz. The minimum CSF for synchronize tracking of multiple conveyors is 8 kHz.

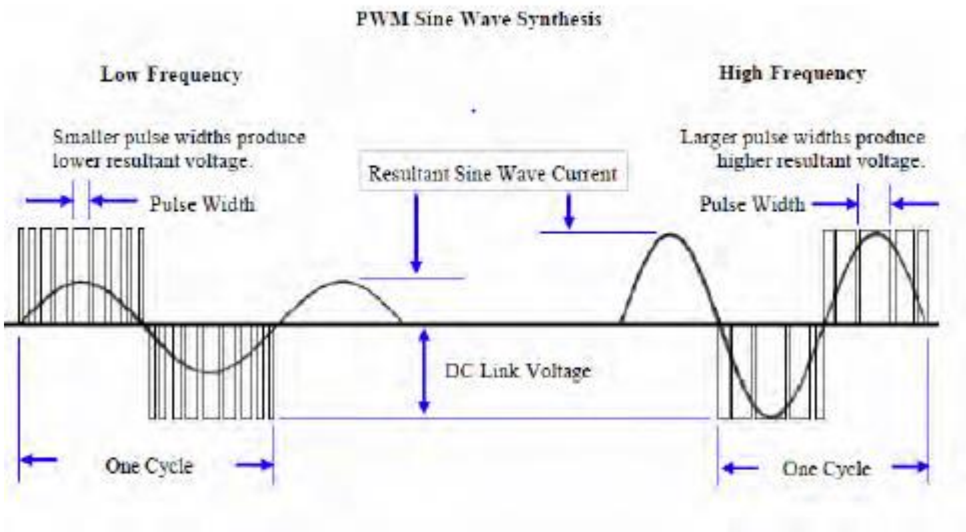


Figure 1.4 PWM Sine Wave Synthesis

VFD OPERATOR INTERFACE

The operator interface, also commonly known as an HMI (Human Machine Interface), provides a means for an operator to start and stop the motor and adjust the operating speed. Additional operator control functions might include reversing and switching between manual speed adjustment and automatic control from an external process control signal. The operator interface often includes an alphanumeric display and/or indication lights and meters to provide information about the operation of the drive. An operator interface keypad and display unit is often provided on the front of the VFD controller. The keypad display can often be cable connected and mounted a short distance from the VFD controller. Most are also provided with input and output (I/O) terminals for connecting pushbuttons, switches and other operator interface devices or control signals. A serial communications port is also often available to allow the VFD to be configured, adjusted, monitored and controlled using a computer.

VFD OPERATION

When a VFD starts a motor, it initially applies a low frequency and voltage to the motor. The starting frequency is typically 2 Hz or less. Starting at such a low frequency avoids the high inrush current that occurs when a motor is started by simply applying the utility (mains) voltage by turning on a switch. When a VFD starts, the applied frequency and voltage are increased at a controlled rate or ramped up to accelerate the load without drawing excessive current. This starting method typically allows a motor to develop 150% of its rated torque while drawing only 50% of its rated current. When a motor is simply switched on at full voltage, it initially draws at least 300% of its rated current while producing less than 50% of its rated torque. As the load accelerates, the available torque usually drops a little and then rises to a peak while the current remains very high until the motor approaches full speed. A VFD can be adjusted to produce a steady 150% starting torque from standstill right up to full speed while drawing only 50% current.

With a VFD, the stopping sequence is just the opposite as the starting sequence. The frequency and voltage applied to the motor are ramped down at a controlled rate. When the frequency approaches zero, the motor is shut off. A small amount of braking torque is available to help decelerate the load a little faster than it would stop if the motor were simply switched off and allowed to coast. Additional braking torque can be obtained by adding a braking circuit to dissipate the braking energy or return it to the power source.

APPLICATION CONSIDERATIONS

The output voltage of a PWM VFD consists of a train of pulses switched at the carrier frequency. Because of the rapid rise time of these pulses, transmission line effects of the cable between the drive and motor must be considered. Since the transmission-line impedance of the cable and motor are different, pulses tend to reflect back from the motor terminals into the cable.
If the cable is long enough, the resulting voltages can produce up to twice the rated line voltage, putting high stress on the cable and eventual insulation failure. Because of the standard ratings of cables, this phenomenon is of little concern for 230 volt motors, may be a consideration for long runs and 480 volt motors, and frequently a concern for 600 v motors.

AVAILABLE VFD POWER RATINGS

Variable frequency drives are available with voltage and current ratings to match the majority of 3-phase motors that are manufactured for operation from utility (mains) power. VFD controllers designed to operate at 110 volts to 690 volts are often classified as low voltage units. Low voltage units are typically designed for use with motors rated to deliver 0.2 kW or ¼ horsepower (hp) up to at least 750 kW or 1000 hp. Medium voltage VFD controllers are designed to operate at 2400/4160 volts (60 Hz), 3000 Volts(50 Hz) or up to 10 kV. In some applications a step up transformer is placed between a low voltage drive and a medium voltage load. Medium voltage units are typically designed for use with motors rated to deliver 375 kW or 500 hp and above. Medium voltage drives rated above 7 kV and 5000 or 10000 hp should probably be considered to be one-of-a-kind (one-off) designs.

A FEW CONSIDERATIONS WHILE SELECTING VFD FOR SPEED CONTROL

- Motors operated by VFD’s run hotter than motors operated across the line. Heat deterioratesmotor insulation over time. When supplying motors for variable frequency operation,manufacturers typically use more expensive motors with a higher insulation class than motorsused in a similar non-drive application.
- The motor manufacturer should be consulted for operational limitations. Most variablefrequency drives restrict the minimum continuous speed to some percentage of the nameplatespeed. Below this minimum speed, temperature rise may damage the motor. Every 10ºC riseabove the rated temperature in a motor reduces the insulation life by half.The motor manufacturer should be consulted before applying a VFD to an existing motor. Inaddition to higher temperatures, non-VFD motors may have component natural frequenciesthat will conflict with the drive output frequencies, resulting in noise, vibration, and prematurefailure.
- Explosion proof motors must be rated as certified for VFD operation before they can be usedwith a VFD. Qualified motors will state on the nameplate that they are certified as explosionproof for VFD operation, as well as any operational limitations.
- Variable frequency drives should be placed near the motor. A large distance between the driveunit and the motor may result in increased motor voltages and temperatures that stress theconductor insulation. Special inverter duty motors are available that are made to withstandthese higher voltages. When installing long cables, special filters may be required to reducethese effects.
- Another problem that has come to light in recent years is stray electrical currents induced intothe motor shaft by the variable frequency drive output signal. These stray currents causeelectrostatic discharges across the bearings, resulting in bearing damage. To avoid

thisproblem, brushes or slip rings are applied to provide a different path to ground for these currents.

- Some centrifugal pumps have integral shaft driven circulation devices to support bearing ormechanical seals. The pump manufacturer should be consulted regarding the minimum speed at which these devices will operate properly. This newsletter touches just a few of the issuesthat should be considered when applying a variable frequency drive. All of these potentialproblems are avoidable by working closely with the manufacturer in the selection andapplication of the drive and motor. Variable frequency drives provide very economical andreliable control when selected properly and applied to the right applications.

COMPARISON OF PERFORMANCE OF CENTRIFUGAL PUMP BY THROTTLING AND VARIABLE FREQUENCY DRIVES

AIM:

To compare and study the performance of centrifugal pump by throttling and variable frequency drives.

OBJECTIVE:

1. To operate the pump to give different discharges using throttling with a valve
2. To operate the pump to give different discharges using a variable frequency drive.
3. To compare the performance of the pump with valve operation and variable frequency drive.

APPARATUS REQUIRED:

1. Centrifugal pump with starter
2. Variable Frequency Drive
3. Throttling valve
4. Power analyzer for input measurement.

MOTOR NAME PLATE DETAILS:

0.7kW, 415 V, 2870 rpm, 50 Hz, 3 phase, 6/22.5 m Head.

TANK DIMENSIONS:

Length: 1.35m, Breadth: 0.68m, Height: 0.34m, Head: 2.8m.

THROTTLING:
Keep the valve at different position and run the pump at rated frequency. Observe and measure the required parameters for efficiency calculation.

VARIABLE FREQUENCY DRIVE (VFD):
Run the pump at different frequency using VFD by keeping valve fully opened position. Observe and measure the required parameters for efficiency calculation.
Calculate the efficiency for both the cases and compare the result by plotting the efficiency curve.

OBSERVATION

Throttling

Sl.no	Valve position	Initial height (cm)	Final height (cm)	Time (sec)	Discharge $m^3/\sec$	Head (m)	o/p (w)	I/p (w)	Efficiency (%)
1.	Fully opened								
2	Quarter closed								
3	Half closed								
4	Quarter opened								

Variable Frequency Drive

Sl.no	Frequency (Hz)	Initial height (cm)	Final height (cm)	Time (sec)	Discharge $m^3/\sec$	Head (m)	o/p (w)	I/p (w)	Efficiency (%)

Sample Calculation:

Discharge = Volume of water pumped/ Time
= (Final Height-Initial Height) * Base Area of the tank / Time
= ……..m3/sec
Output = Water Density * Discharge * g * Head= ……….watts
Input = …… watts
Efficiency = (Output power) / (Input power) x 100 %

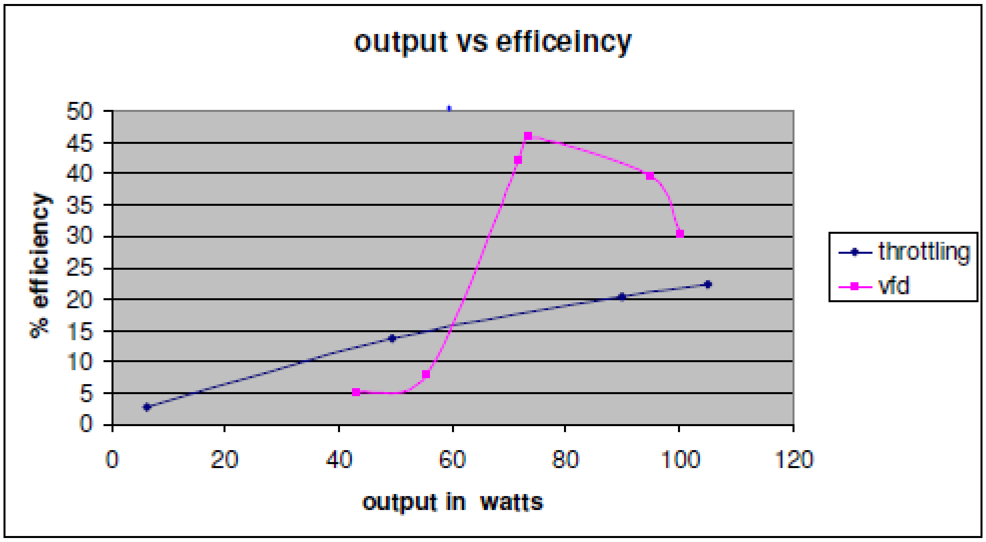


Figure 1.5 Efficiency Curve of Induction Motor Under Various Operating Conditions

<u>RESULT:</u>

The performance of the centrifugal pump with throttling and variable frequency drive is studied.

2. SCADA EXPERIMENTS

INTRODUCTION

Electrical power is one of the most important infrastructure inputs necessary for the rapid economic development of a country. The ever-rising demand of electrical energy has led to the installation and incorporation of a large number of electrical power generation units, with increased capacities in a common power grid, making the operation of the entire system sensitive to the prevailing conditions. Therefore, the extensive and complex power systems have become unmanageable using the conventional instrumentation and control schemes. Intelligent systems based on microprocessors and computers have been employed for online monitoring and control of modern large-scale power systems, in generation, transmission and distribution, thereby overcoming the complexities and drawbacks of the conventional instrumentation schemes.

THE TERM “AUTOMATION”

Automation is the use of scientific and technological principles in the manufacture of machines that take over work normally done by humans. This definition has been disputed by professional scientists and engineers, but in any case, the term is derived from the longer term “automatization” or from the phrase “automatic operation”. Delmar S. Harder, a plant manager for General Motors, is credited with first having used the term in 1935.

History of Automation

Ideas for ways of automating tasks have been in existence since the time of the ancient Greeks. The Greek inventor Hero (fl. about A.D. 50), for example, is credited with having developed an automated system that would open a temple door when a priest lit a fire on the temple altar. The real impetus for the development of automation came, however, during the Industrial Revolution of the early eighteenth century. Many of the steam-powered devices built by James Watt, Richard Trevithick, Richard Arkwright, Thomas Savery, Thomas Newcomen, and their contemporaries were simple examples of machines capable of taking over the work of humans. One of the most elaborate examples of automated machinery developed during this period was the draw loom designed by the French inventor BasileBouchon in 1725. The instructions for the operation of the Bouchon loom were recorded on sheets of paper in the form of holes. The needles that carried thread through the loom to make cloth were guided by the presence or absence of those holes. The manual process of weaving a pattern into a piece of cloth through the work of an individual was transformed by the Bouchon process into an operation thatcould be performed mindlessly by merely stepping on a pedal.

Automation Applications

Manufacturing companies in virtually every industry are achieving rapid increases in productivity by taking advantage of automation technologies. When one thinks of automation in manufacturing, robots usually come to mind. The automotive industry was the early adopter of robotics, using these automated machines for material handling, processing operations, and assembly and inspection. Donald A. Vincent, executive vice president, Robotic Industries Association, predicts a greater use of robots for assembly, paint systems, final trim, and parts transfer will be seen in the near future. One can break down automation in production into basically three categories: fixed automation, programmable automation, and flexible automation. The automotive industry primarily uses fixed automation. Also known as "hard automation," this refers to an automated production facility in which the sequence of processing operations is fixed by the equipment layout. A good example of this would be an automated production line where a series of workstations are connected by a transfer system to move parts between the stations. What starts as a piece of sheet metal in the beginning of the process, becomes a car at the end. Programmable automation is a form of automation for producing products in batches. The products are made in batch quantities ranging from several dozen to several thousand units at a time. For each new batch, the production equipment must be reprogrammed and changed over to accommodate the new product style. Flexible automation is an extension of programmable automation. Here, the variety of products is sufficiently limited so that the changeover of the equipment can be done very quickly and automatically. The reprogramming of the equipment in flexible automation is done off-line; that is, the programming is accomplished at a computer terminal without using the production equipment itself. Computer numerical control (CNC) is a form of programmable automation in which a machine is controlled by numbers (and other symbols) that have been coded into a computer. The program is actuated from the computer's memory. The machine tool industry was the first to use numerical control to control the position of a cutting tool relative to the work part being machined. The CNC part program represents the set of machining instructions for the particular part, while the coded numbers in the sequenced program specifies x-y-z coordinates in a Cartesian axis system, defining the various positions of the cutting tool in relation to the work part.

SCADA

SCADA is an acronym that stands for Supervisory Control and Data Acquisition. SCADA refers to a system that collects data from various sensors at a factory, plant or in other remote locations and then sends this data to a central computer which then manages and controls the data. SCADA is a term that is used broadly to portray control and management solutions in a wide range of industries. SCADA generally refers to an industrial control system: a computer system monitoring and controlling a process. The process can be industrial, infrastructure or facility based as described below:

- Industrial processes include those of manufacturing, production, power generation, fabrication, and refining, and may run in continuous, batch, repetitive, or discrete modes.
- Infrastructure processes may be public or private, and include water treatment and distribution, wastewater collection and treatment, oil and gas pipelines, electrical power transmission and distribution, civil defence siren systems, and large communication systems.
-Facility processes occur both in public facilities and private ones, including buildings, airports, ships, and space stations. They monitor and control HVAC, access, and energy consumption.

SCADA as a System

There are many parts of a working SCADA system. A SCADA system usually includes signal hardware (input and output), controllers, networks, user interface (HMI), communications equipment and software. All together, the term SCADA refers to the entire central system. The central system usually monitors data from various sensors that are either in close proximity or off site (sometimes miles away).

For the most part, the brains of a SCADA system are performed by the Remote Terminal Units (sometimes referred to as the RTU). The Remote Terminal Units consists of a programmable logic converter. The RTU are usually set to specific requirements, however, most RTU allow human intervention, for instance, in a factory setting, the RTU might control the setting of a conveyer belt, and the speed can be changed or overridden at any time by human intervention. In addition, any changes or errors are usually automatically logged for and/or displayed. Most often, a SCADA system will monitor and make slight changes to function optimally; SCADA systems are considered closed loop systems and run with relatively little human intervention. One of key

processes of SCADA is the ability to monitor an entire system in real time. This is facilitated by data acquisitions including meter reading, checking statuses of sensors, etc that are communicated at regular intervals depending on the system. Besides the data being used by the RTU, it is also displayed to a human that is able to interface with the system to override settings or make changes when necessary. SCADA can be seen as a system with many data elements called points. Usually each point is a monitor or sensor. Usually points can be either hard or soft. A hard data point can be an actual monitor; a soft point can be seen as an application or software calculation. Data elements from hard and soft points are usually always recorded and logged to create a time stamp or history.
A SCADA System usually consists of the following subsystems:
- A Human-Machine Interface or HMI is the apparatus which presents process data to a human operator, and through this, the human operator monitors and controls the process.
-A supervisory (computer) system, gathering (acquiring) data on the process and sending commands (control) to the process.

- Remote Terminal Units (RTUs) connecting to sensors in the process, converting sensor signals to digital data and sending digital data to the supervisory system.
- Programmable Logic Controller (PLCs) used as field devices because they are more economical, versatile, flexible, and configurable than special-purpose RTUs.
- Communication infrastructure connecting the supervisory system to the Remote Terminal Units

There is, in several industries, considerable confusion over the differences between SCADA systems and Distributed control systems (DCS). Generally speaking, a SCADA system usually refers to a system that **coordinates**, but does not **control** processes in real time. The discussion on real-time control is muddied somewhat by newer telecommunications technology, enabling reliable, low latency, high speed communications over wide areas. Most differences between SCADA and DCS are culturally determined and can usually be ignored. As communication infrastructures with higher capacity become available, the difference between SCADA and DCS will fade.

System Concept

The term SCADA usually refers to centralized systems which monitor and control entire sites, or complexes of systems spread out over large areas (anything between an industrial plant and a country). Most control actions are performed automatically by remote terminal units ("RTUs") or by programmable logic controllers ("PLCs"). Host control functions are usually restricted to basic overriding or *supervisory* level intervention. For example, a PLC may control the flow of cooling water through part of an industrial process, but the SCADA system may allow operators to change the set points for the flow, and enable alarm conditions, such as loss of flow and high temperature, to be displayed and recorded. The feedback control loop passes through the RTU or PLC, while the SCADA system monitors the overall performance of the loop.

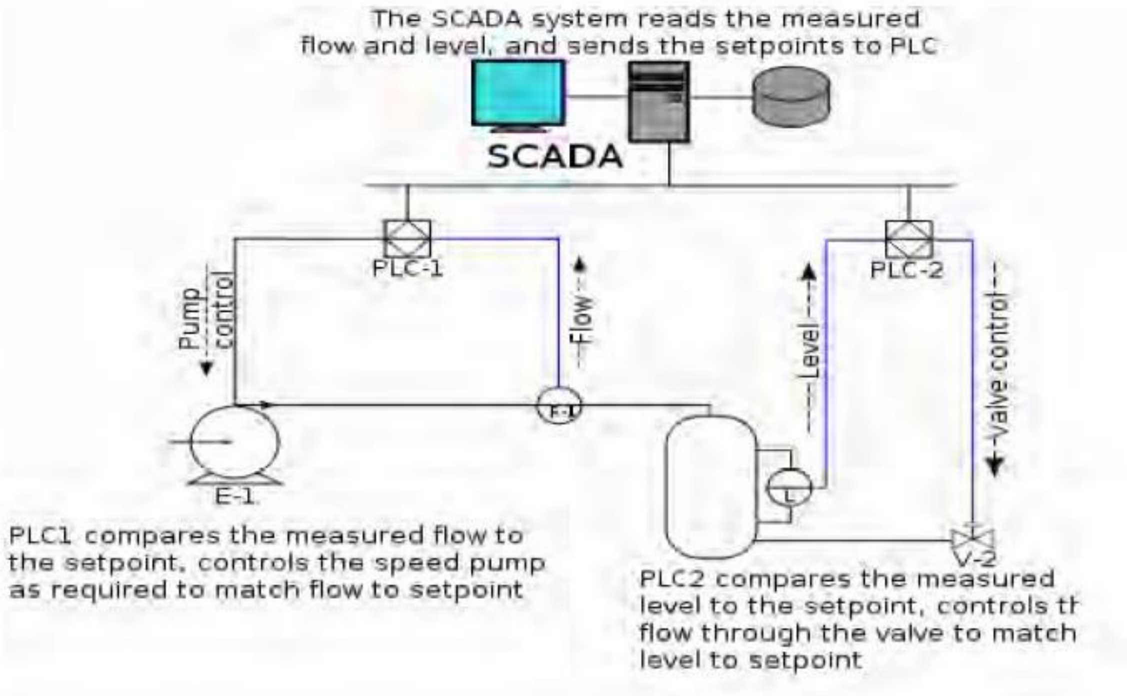


Figure 2.1 SCADA System for Level Control

Data acquisition begins at the RTU or PLC level and includes meter readings and equipment status reports that are communicated to SCADA as required. Data is then compiled and formatted in such a way that a control room operator using the HMI can make supervisory decisions to adjust or override normal RTU (PLC) controls. Data may also be fed to a Historian, often built on a commodity Database Management System, to allow trending and other analytical auditing. SCADA systems typically implement a distributed database, commonly referred to as a *tag database*, which contains data elements called *tags* or *points*. A point represents a single input or output value monitored or controlled by the system. Points can be either "hard" or "soft". A hard point represents an actual input or output within the system, while a soft point results from logic and math operations applied to other points. (Most implementations conceptually remove the distinction by making every property a "soft" point expression, which may, in the simplest case, equal a single hard point.) Points are normally stored as value-timestamp pairs: a value, and the timestamp when it was recorded or calculated. A series of value-timestamp pairs gives the history of that point. It's also common to store additional data with tags, such as the path to a field device or PLC register, design time comments, and alarm information.

Substation Automation with SCADA

The substation SCADA system provides a common interface for various types of Equipments/devices used in the substation. Display & Database tools are used to configure the interfaces used for controlling & monitoring the different equipment and the settings required for protection, regulation or loading limits. The usage of alarm management systems prompts various warning tags, control interlock logics relating to the current/past operations. The graphical screens provide current information on all critical parameters. All the equipments can be controlled & monitored through a single computer. Parameters such as actual & reactive power, Energy, transformer temperature, Tap positions, Voltage, Current, Frequency, Power factor, relay status & protection settings etc are collected and displayed in a user friendly graphical format. Substation automation can give adequate self checking, diagnostic features which helps in providing proactive measures to establish a healthy system. The functions like Voltage regulation, load management are implemented in substation software which reduces the usage of complex components.

SCADA Lab Setup

The SCADA lab setup comprises of the following

Transmission Model (400/220 kV)

1. **Panel 1: Station Model** (415 V/110 V 3- transformer 1 KVA, Protection Relay Class-1, 3- Energy Meters, PLC)
2. **Panel 2: Transmission Line Model** (Resistors, Inductors & Capacitors), Series Compensators.
3. **Panel 3: Load Model for Transmission Line** (Dimmer, Resistors & Inductors) Shunt Compensators, 3- Energy Meter

Distribution Model (11 kV)

4. **Panel 4: Distribution Model** (415 V/110 V 1- transformer 1 KVA, Protection Relay Class-1, 3- Energy Meters, PLC, Dimmers, Resistors, Inductors & Capacitors).

The system consists of 400/220 kV transmission model & 11kV distribution substation model, metering, protection and control devices, and a multi-tier SCADA system with scalable distributed architecture. The proposed solution is based on the latest international standards in substation communication and automation such as IEC 61850 and IEC 60870-5. The module consists of RTU, protection relay, circuit breakers and energy meter for control, protection and metering functions. PC based SCADA server/workstation is provided for local operation, data logging, metering and sequence of events. The substation automation system is built on IEC 61850 open standard communication architecture. The software supplied is flexible and

Compatible with above system to control entire substation modules and interfaces, simulate power system distribution and network with single line diagrams. The SCADA software monitors, communicates and operate RTUs, breakers and relays. Display for kWh, kVA, V, I, Hz, Pf and kVar is provided. The Control centre consists of remote SCADA system for operation, training & monitoring of the electrical network. The system communicates with Transmission model in IEC 870-5-101 standard protocol.

Transmission Line Model

1) The model consists of 400/220 kV receiving substation with a 220 kV out going line.
2) One typical 220 kV transmission line also is modelled for a distance of 200 km.
3) The Communication System is built on the newest substation CommunicationArchitecture of IEC 61850.

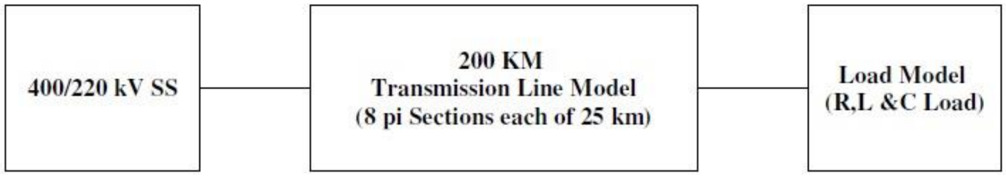


Figure 2.2 SCADA Transmission Substation Model

<u>Single Line Diagram</u>:

Communication Architecture:

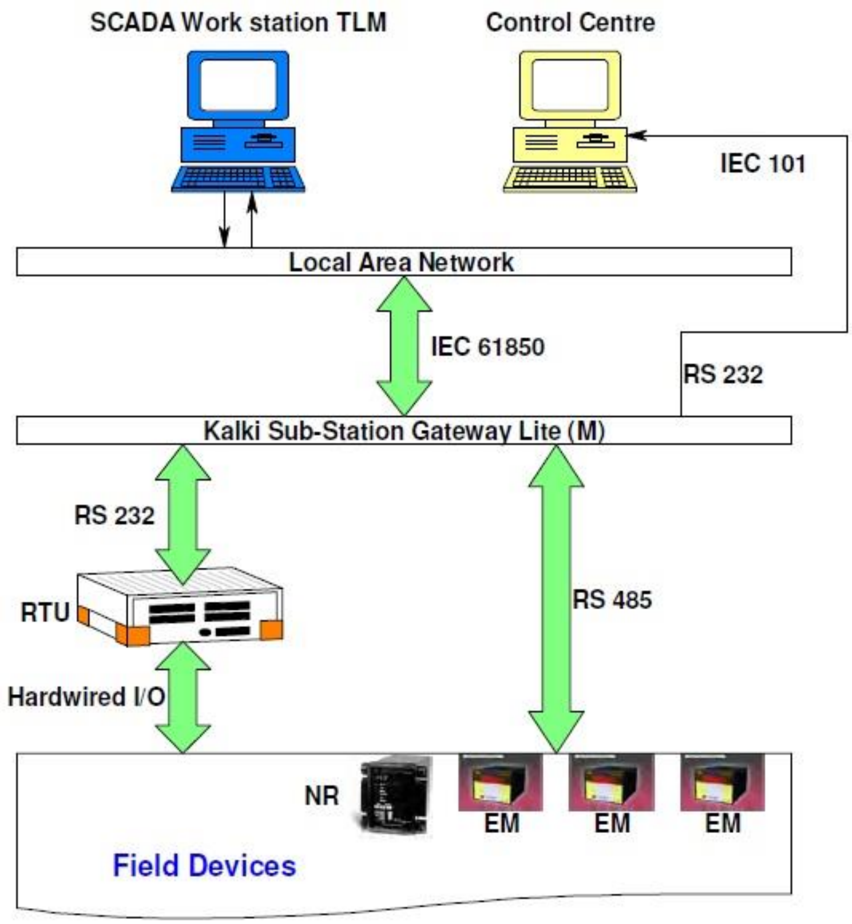


Figure 2.3 Architecture of SCADA Systems

Distribution Model

The model consists of 11 kV substations with four outgoing feeders and a capacitor bank, each feeder is designed as RL load. The Communication System is built on the newest substation Communication Architecture of IEC 61850.

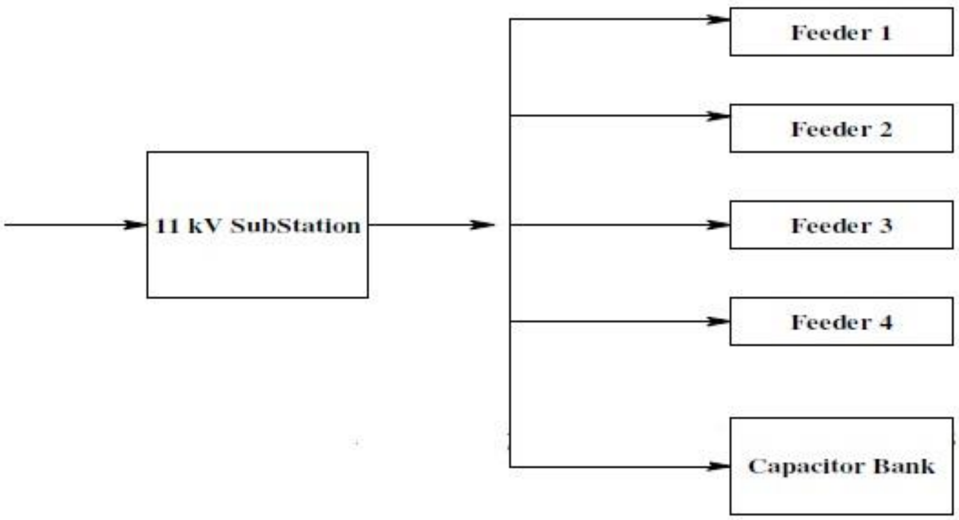


Figure 2.4 SCADA Distribution Model

Single Line Diagram:

11 KV Distribution Model:

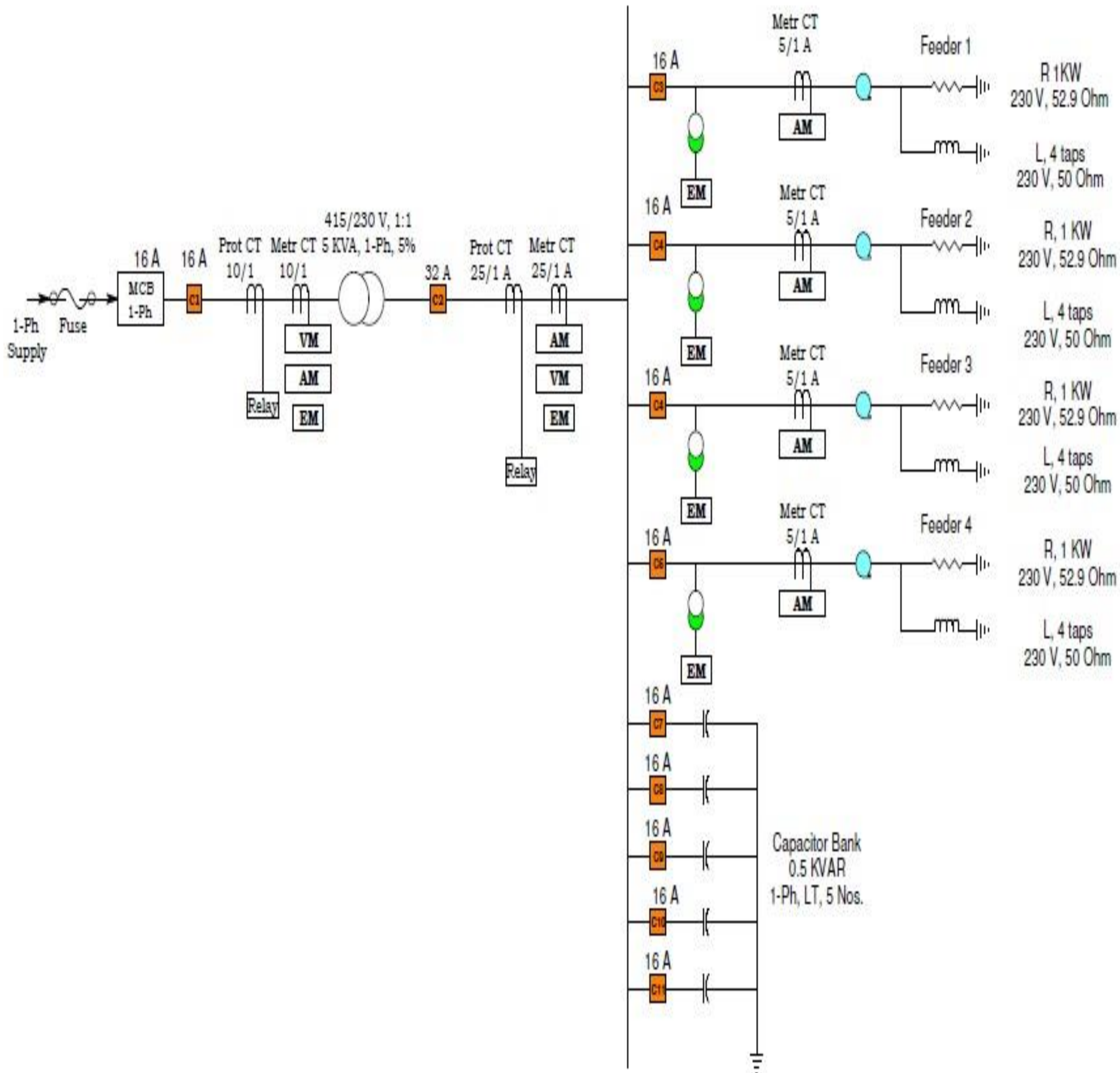


Figure 2.5 11 kV Distribution Model

EXPERIMENTS ON TRANSMISSION MODULE

Experiment Setup - Transmission Module:

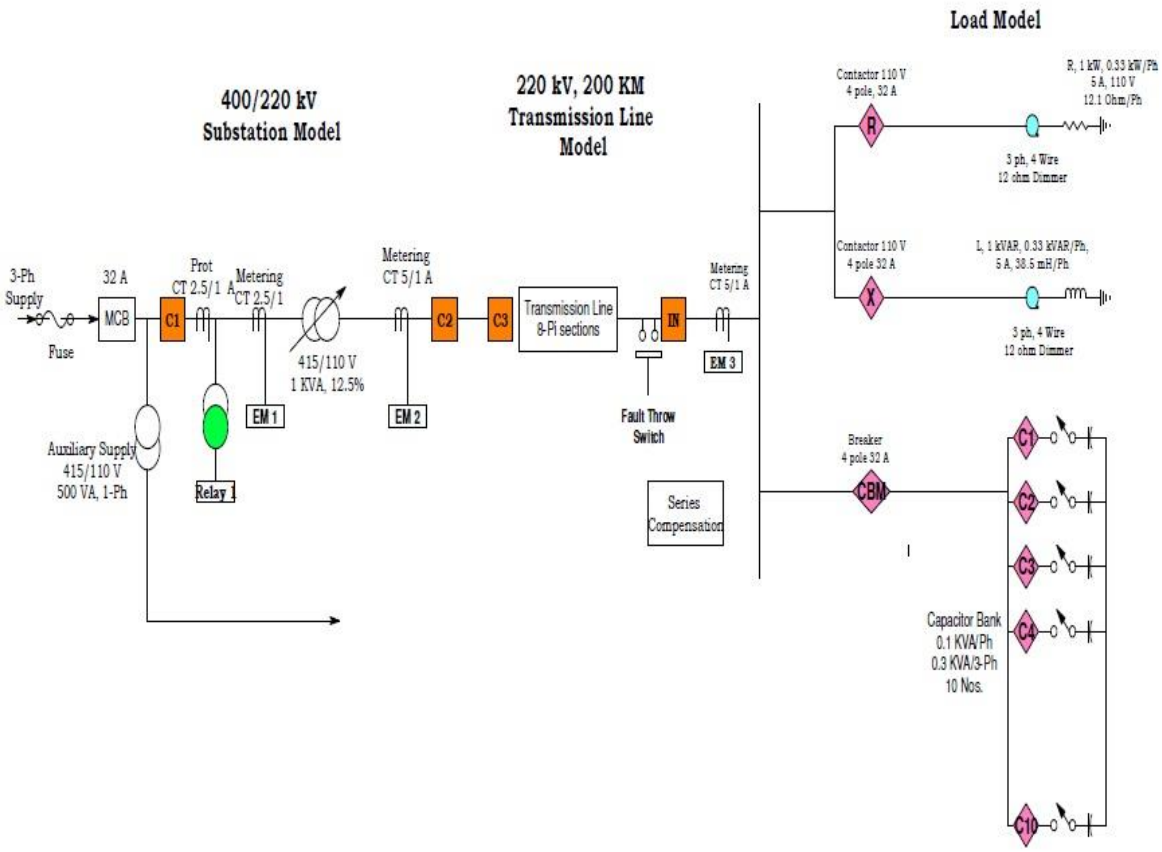


Figure 2.6 SCADA Transmission Module

Precautions:

1. Once an experiment is selected in the SCADA system until it is completed and stopped by clicking the stop button we shouldn't click the main screen.
2. While closing the Circuit breaker make sure that the status of the breaker icon is updated before going to close the next breaker (Vertical line on the breaker will be changed to horizontal line)
3. Whenever a question mark (?) appears on the breaker icons, wait till the status is updated without disturbing it, because it's the problem of communication.
4. Always click the STOP button before going to the next experiment.

Experiments overview – Transmission Model

The following experiments can be done using the Transmission Model both in Local and Remote mode.

1. Fault Test

- **a.** Line to Line Faults (LL)
- **b.** Line to Ground Faults (LG)
- **c.** Line to Line to Line Fault (LLL)
- **d.** Line to Line to Ground Faults (LLG)

2. Ferranti Effect

3. Transmission Line Loading

- **a.** Resistive Loading (R Load)
- **b.** Inductive Loading (L load)
- **c.** Resistive & inductive Loading (R & L Load)

4. Transformer Loading

- **a.** Resistive Loading (R Load)
- **b.** Inductive Loading (I load)
- **c.** Resistive & Inductive Loading (R & L Load)

5. VAR Compensation

- **a.** Shunt Compensation
- **b.** Series compensation
    - **i.** Mid Point Compensation
    - **ii.** Sending End Compensation
    - **iii.** Receiving End Compensation

6. Operation of OLTC (Tap changing of transformer)

7. Sudden Load rejection

Common Procedure to All Experiments

1. Assemble S/S panel, Station Model, Transmission model & Load model.
2. Keep the Local/Remote selector in proper Position.
3. Keep all the Emergency Push buttons in released condition.
4. In the station model connect the energy meter & relay through the cables provided to the corresponding pins.
5. Interconnect Station model & Transmission model using power cable
6. In the transmission model Connect the 3 Phase supply (R-Y-B) to the corresponding Input pins of pin no. 4(4th pie section) & connect the O/p of 4th Pie to 5th pie & so on up to 8th Pie O/p to the end pins of the pie section using cables provided. (Note: Phase lines should not be interchanged).
7. Connect the transmission model & load Model using the power cable.
8. Change the phase current setting of the relay based on the load
9. Switch on the SCADA system & enter your login ID
10. Click ON the experiments screen.

LOCAL MODE EXPERIMENTS

FERRANTI EFFECT (LOCAL MODE)

AIM:

Simulating Ferranti effect in SCADA setup and observe the results

PROCEDURE:

1. Close the Incomer C1 by pressing the ON push button
2. Close the Breaker C2 by pressing the ON push button
3. Close the Breaker C3 incomer for transmission line model by pressing the ON push button.
4. Close the Breaker C3 for load model by pressing the ON push button
5. Check the Energy meter voltage of Energy meter 2 & Energy Meter 3.
6. Observe the Voltage at receiving end (EM3) and sending end (EM2) of the transmission line.
7. After completing the experiment please de-energize/open all the breakers by pressing the OFF push button of the corresponding contactors.

OBSERVATION:

Sl No.	Description	Energy Meter 2	Energy Meter 3
1	Voltage (V)		
	Current (A)		
2	Voltage (V)		
	Current (A)		
3	Voltage (V)		
	Current (A)		

RESULT:

Ferranti effect is observed in the experiment.

TRANSMISSION LINE LOADING (LOCAL MODE)

RESISTIVE LOADING

AIM:

Load the transmission line by a resistive load and observe voltage and current profile.

PROCEDURE:

1. Close the Incomer C1 by pressing the ON push button
2. Close the Breaker C2 by pressing the ON push button
3. Close the Breaker C3 for transmission line model by pressing the ON push button
4. Close the Breaker C3 of the load model by pressing the ON push button
5. Close the breaker R by pressing the ON push button of the variable resistance.
6. Increase the load by rotating the dimmer check the current value in the screen and in the EM3 for the receiving end parameters.
7. Click the test results & note the values as shown in the tabular column
8. Repeat the experiment for various current values. (Max up to 3A)
9. After completing the experiment please de-energize/open all the breakers by pressing the OFF push button of the corresponding contactors.

OBSERVATION:

Sl No.	Description	Energy Meter 2	Energy Meter 3
1	Voltage (V)		
	Current (A)		
2	Voltage (V)		
	Current (A)		
3	Voltage (V)		
	Current (A)		

RESULT:

Resistive loading of transmission line for 200km is conducted and observed the voltage and current profiles.

INDUCTIVE LOADING

AIM:

Load the transmission line by an inductive load and observe voltage and current profile.

PROCEDURE:

1. Close the Incomer C1 by pressing the ON push button
2. Close the Breaker C2 by pressing the ON push button
3. Close the Breaker C3 for transmission line model by pressing the ON push button
4. Close the Breaker C3 of the load model by pressing the ON push button
5. Close the breaker R by pressing the ON push button of the variable resistance.
6. Increase the load by rotating the dimmer check the current value in the screen and in the EM3 for the receiving end parameters.
7. Click the test results & note the values as shown in the tabular column
8. Repeat the experiment for various current values. (Max up to 3A)
9. After completing the experiment please de-energize/open all the breakers by pressing the OFF push button of the corresponding contactors.

OBSERVATION

Sl No.	Description	Sending end Measurements	Receiving end Measurements
1	Voltage (V)		
2	Current (A)		
3	Power (W)		
4	VAR		
5	Power Factor		

RESULT:

Inductive loading of transmission line for 200km is conducted and observed the voltage and current profiles.

RESISTIVE AND INDUCTIVE LOADING

AIM:

Load the transmission line by resistive and inductive loads and observe voltage and current profile.

PROCEDURE:

1. Close the Incomer C1 by pressing the ON push button
2. Close the Breaker C2 by pressing the ON push button
3. Close the Breaker C3 for transmission line model by pressing the ON push button
4. Close the Breaker C3 of the load model by pressing the ON push button
5. Close the breaker R by pressing the ON push button of the variable resistance.
6. Increase the load by rotating the dimmer check the current value in the screen and in the EM3 for the receiving end parameters.
7. Click the test results & note the values as shown in the tabular column
8. Repeat the experiment for various current values. (Max up to 3A)
9. After completing the experiment please de-energize/open all the breakers by pressing the OFF push button of the corresponding contactors.

OBSERVATION:

Sl No.	Description	Sending end Measurements	Receiving end Measurements
1	Voltage (V)		
2	Current (A)		
3	Power (W)		
4	VAR		
5	Power Factor		

RESULT:

Inductive loading of transmission line for 200km is conducted and observed the voltage and current profiles.

VAR COMPENSATION (LOCAL MODE)

SERIES COMPENSATION

AIM:
Study of series VAR compensation at different points of transmission network and observe the comparison

PROCEDURE:

1. Close the Breaker C1 by pressing the ON push button
2. Close the Breaker C2 by pressing the ON push button
3. Close the Breaker C3 of the load model by pressing the ON push button
4. Close the breaker R by pressing the ON push button of the variable resistance.
5. Close the breaker X by pressing the ON push button of the variable Inductance
6. Increase the load by rotating the dimmer for inductance &resistance; check the current value in the screen for the receiving end energy meter.
7. Click the test results & note the values as shown in the tabular column
8. Open the Breaker C3 for Transmission line model by pressing the ON push button

For Sending End compensation

9. In the transmission model Connect the 3 Phase supply (R-Y-B) to the corresponding Input pins I1, I2, I3 respectively & connect the O/p O1, O2, O3 to the input pins of the 1st pie section using cables provided. (Note: Phase lines should not be interchanged).

For Receiving End compensation

10. In the transmission model Connect the 3 Phase supply (R-Y-B) to the corresponding Input pins of 1st pie section & connect the O/p of 4th Pie to 5th Pie I/p & so on up to 8th Pie O/P. Connect the 8th Pie O/p to input pins I1, I2, I3 respectively& connect the O/p O1, O2, O3 to the 3 Phase output pins of the PI section using cables provided. (Note: Phase lines should notbe interchanged)

For Mid Point compensation

11. In the transmission model Connect the 3 Phase supply (R-Y-B) to the corresponding Input pins of 1st PI section & connect the O/p of 4th Pie to input pins I1, I2, I3 respectively & connect the O/p O1, O2, O3 to 5th Pie I/p and all 12. other PI sections should be connected in series & so on up to 8th Pie O/P & to the end pins of the pie section using cables provided. (Note: Phase lines should not be interchanged).

12. Close the Breaker C3 of the transmission line model by pressing the ON push button.
13. Compare the values for different compensations without changing the load.
14. Click the test results & note the values as shown in the tabular column
15. After completing the experiment please de-energize/open all the breakers by pressing the OFF push button of the corresponding contactors.

OBSERVATIONS:

S No.	Description	Before Compensation		Sending end Compensation		Mid point Compensation		Receiving End compensation	
		Sending	Receiving	Sending	Receiving	Sending	Receiving	Sending	Receiving
1	Voltage (V)								
2	Current (A)								
3	Power (W)								
4	VAR								
5	Power Factor								

RESULT:

VAR compensation at different of transmission line is simulated and observed the voltage and current profiles.

SHUNT COMPENSATION (REGULATION OF BUS VOLTAGE)

AIM:

Study of shunt Var compensation at different points of transmission network and observe the bus voltage.

PROCEDURE:

1. Close the Breaker C1 by pressing the ON push button
2. Close the Breaker C2 by pressing the ON push button
3. Close the Breaker C3 of the load model by pressing the ON push button
4. Close the breaker R by pressing the ON push button of the variable resistance.
5. Close the breaker X by pressing the ON push button of the variable Inductance and vary the corresponding dimmer so that the energy meter shows a lagging PF (i.e. 0.8 and less).
6. Close the breaker Capacitor Bank main of the capacitor bank main by pressing the ON push button.
7. Close the breakers CB1, CB2 in the branch carefully one by one until the power factor is compensated for a value up to .99 lagging (i.e. unity power factor) (Note: Don't close all the capacitance breakers simultaneously as it will imbalance the complete system).
8. Click the test results & note the values as shown in the tabular column. After completing the experiment please de-energize/open all the breakers by pressing the OFF push button of the corresponding contactors.

OBSERVATION

S No.	Description	Receiving end Measurements	
		Before	After
1	Voltage (V)		
2	Current (A)		
3	Power (W)		
4	VAR		
5	Power Factor		

RESULT:

Shunt Var compensation is simulated in the system and bus voltage profile is observed.

FERRANTI EFFECT (REMOTE MODE)

AIM:

Simulating Ferranti effect in SCADA setup and observe the results

PROCEDURE:

1. Click the experiments screen & select the Ferranti effect button
2. Click the back button after configuring & go to the main screen
3. Close the Incomer C1 by clicking the Breaker icon in the SLD & follow the Instructions.
4. Close the Breaker C2 by clicking the Breaker icon in the SLD & follow the Instructions.
5. Close the Breaker P2 for panel 2 by clicking the Breaker icon in the SLD & follow the instructions.
6. Close the Breaker C3 by clicking the Breaker icon in the SLD & follow the Instructions.
7. Check the Energy meter voltage of Energy meter 2 & Energy Meter 3.
8. Observe the Voltage at receiving end (EM3) and sending end (EM2) of the transmission line.

OBSERVATIONS:

Sl No.	Description	Energy Meter 2	Energy Meter 3
1	Voltage (V)		
	Current (A)		
2	Voltage (V)		
	Current (A)		
3	Voltage (V)		
	Current (A)		

RESULT:

Ferranti effect is observed in the experiment.

TRANSMISSION LINE LOADING (REMOTE MODE)

RESISTIVE LOADING

AIM:

Load the transmission line by a resistive load and observe voltage and current profile

Procedure:

1. Click the experiments screen & select the Transmission line loading button & select the resistive load button
2. Click the back button after configuring & go to the main screen
3. Close the Incomer C1 by clicking the Breaker icon in the SLD & follow the instructions
4. Close the Breaker C2 by clicking the Breaker icon in the SLD & follow the instructions
5. Close the Breaker P2 for panel 2 by clicking the Breaker icon in the SLD & follow the instructions
6. Close the Breaker C3 of the load model by clicking the Breaker icon in the SLD & follow the instructions
7. Close the breaker C4 in the SLD which shows a variable resistance.
8. Increase the load by rotating the dimmer check the current value in the screen for the receiving end energy meter
9. Click the test results & note the values as shown in the tabular column
10. Repeat the experiment for various current values.

OBSERVATIONS:

Sl No.	Description	Sending end Measurements	Receiving end Measurements
1	Voltage (V)		
2	Current (A)		
3	Power (W)		
4	VAR		
5	Power Factor		

RESULT:

Resistive loading of transmission line for 200km is conducted and observed the voltage and current profiles.

INDUCTIVE LOADING

AIM:

Load the transmission line by an inductive load and observe voltage and current profile

PROCEDURE:

1. Click the experiments screen & select the Transmission line loading button & select the inductive loading button
2. Click the back button after configuring & go to the main screen
3. Close the Incomer C1 by clicking the Breaker icon in the SLD & follow the instructions
4. Close the Breaker C2 by clicking the Breaker icon in the SLD & follow the instructions
5. Close the Breaker P2 for panel 2 by clicking the Breaker icon in the SLD & follow the instructions
6. Close the Breaker C3 of the load model by clicking the Breaker icon in the SLD & follow the instructions
7. Close the breaker C5 in the SLD, which shows a variable Inductance.
8. Increase the load by rotating the dimmer for inductance & check the current value in the screen for the receiving end energy meter
9. Click the test results & note the values as shown in the tabular column
10. Repeat the experiment for various current values

OBSERVATION

Sl No.	Description	Sending end Measurements	Receiving end Measurements
1	Voltage (V)		
2	Current (A)		
3	Power (W)		
4	VAR		
5	Power Factor		

RESULT:

Inductive loading of transmission line for 200km is conducted and observed the voltage and current profiles.

RESISTIVE AND INDUCTIVE LOADING

AIM:
Load the transmission line by resistive and inductive loads and observe voltage and current profile

PROCEDURE:
1. Click the experiments screen & select the Transmission line loading button & select the R & L button
2. Click the back button & after configuring go to the main screen
3. Close the Incomer C1 by clicking the Breaker icon in the SLD & follow the instructions
4. Close the Breaker C2 by clicking the Breaker icon in the SLD & follow the instructions
5. Close the Breaker P2 for panel 2 by clicking the Breaker icon in the SLD & follow the instructions
6. Close the Breaker C3 by clicking the Breaker icon in the SLD & follow the instructions
7. Close the breaker C4 in the SLD, which shows a variable Resistance.
8. Close the breaker C5 in the SLD which shows a variable Inductance
9. Increase the load by rotating the dimmer for inductance & resistance, check the current value in the screen for the receiving end energy meter
10. Click the test results & note the values as shown in the tabular column
11. Repeat the experiment for various current values. (Max up to 3 A)

OBSERVATIONS:

Sl No.	Description	Sending end Measurements	Receiving end Measurements
1	Voltage (V)		
2	Current (A)		
3	Power (W)		
4	VAR		
5	Power Factor		

RESULT:
Resistive and inductive loading of transmission line for 200km is conducted and observed the voltage and current profiles.

VAR COMPENSATION (REMOTE MODE)

SERIES COMPENSATION

AIM:

Study of series Var compensation at different points of transmission network and observe the comparison

PROCEDURE:

1. Click the experiments screen & select the VAR compensation button & select the Series compensation
2. Click the back button & after configuring go to the main screen
3. Close the Incomer C1 by clicking the Breaker icon in the SLD & follow the instructions
4. Close the Breaker C2 by clicking the Breaker icon in the SLD & follow the instructions
5. Close the Breaker P2 for panel 2 by clicking the Breaker icon in the SLD & follow the instructions
6. Close the Breaker C3 by clicking the Breaker icon in the SLD & follow the instructions
7. Close the breaker C4 in the SLD, which shows a variable Resistance.
8. Close the breaker C5 in the SLD which shows a variable Inductance
9. Increase the load by rotating the dimmer for inductance & resistance, check the current value in the screen for the receiving end energy meter
10. Click the test results & note the values as shown in the tabular column
11. Open the Breaker P2 for panel 2 by clicking the Breaker icon in the SLD & follow the instructions *For Sending End compensation*
12. In the transmission model Connect the 3 Phase supply (R-Y-B) to the corresponding Input pins I1, I2, I3 respectively & connect the O/p O1, O2, O3 to the input pins of the 1st pie section using cables provided. (Note: Phase lines should not be interchanged) *For Receiving End compensation*
13. In the transmission model Connect the 3 Phase supply (R-Y-B) to the corresponding Input pins of 1st pie section & connect the O/p of 4th Pie to 5th Pie I/p & so on up to 8th Pie O/P. Connect the 8th Pie O/p to input pins I1, I2, I3 respectively & connect the O/p O1, O2, O3 to the 3 Phase output pins of the PI section using cables provided. (Note: Phase lines should not be interchanged)

For Mid Point compensation

14. In the transmission model Connect the 3 Phase supply (R-Y-B) to the corresponding Input pins of 1st PI section & connect the O/p of 4th Pie to input pins I1, I2, I3 respectively & connect the O/p O1, O2, O3 to 5th Pie I/p and all other PI sections should be connected in series & so on up to 8th Pie O/P & to the end pins of the pie section using cables provided. (Note: Phase lines should not be interchanged)
15. Close the Breaker P2 by clicking the Breaker icon in the SLD & follow the instructions after connecting the cables by selecting any of the compensations
16. Compare the values for different compensations with out changing the load.
17. Click the test results & note the values as shown in the tabular column.

OBSERVATIONS:

S No.	Description	Before Compensation		Sending end Compensation		Mid point Compensation		Receiving End compensation	
		Sending	Receiving	Sending	Receiving	Sending	Receiving	Sending	Receiving
1	Voltage (V)								
2	Current (A)								
3	Power (W)								
4	VAR								
5	Power Factor								

RESULT:

Var compensation at different of transmission line is simulated and observed the voltage and current profiles.

SHUNT COMPENSATION (REGULATION OF BUS VOLTAGE)

AIM:

Study of shunt Var compensation at different points of transmission network and observe the bus voltage.

PROCEDURE:

1. Click the experiments screen & select the VAR Compensation button & select the Shunt Compensation
2. Click the back button & after configuring go to the main screen
3. Close the Incomer C1 by clicking the Breaker icon in the SLD & follow the instructions
4. Close the Breaker C2 by clicking the Breaker icon in the SLD & follow the instructions
5. Close the Breaker P2 for panel 2 by clicking the Breaker icon in the SLD & follow the instructions
6. Close the Breaker C3 by clicking the Breaker icon in the SLD & follow the Instructions
7. Close the breaker C4 in the SLD, which shows a variable Resistance.
8. Close the breaker C5 in the SLD which shows a variable Inductance and vary the corresponding dimmer so that the energy meter shows a lagging PF
9. Close the breaker C6 in the SLD which shows a mains capacitance branch with 10 breakers
10. Close the breakers in the branch carefully one by one until the power factor is compensated for a value up to .99 lagging (ie. unity power factor) (Note: Don’t close all the capacitance breakers simultaneously as it will imbalance the complete system)
11. Click the test results & note the values as shown in the tabular column
12. Repeat the experiment for various current values. (Max up to 3 A)

OBSERVATION

S No.	Description	Receiving end Measurements	
		Before	After
1	Voltage (V)		
2	Current (A)		
3	Power (W)		
4	VAR		
5	Power Factor		

RESULT:

Shunt Var compensation is simulated in the system and bus voltage profile is observed.

EXPERIMENTS ON DISTRIBUTION MODULE

Experiment Setup - Distribution Module
11 KV Distribution Model

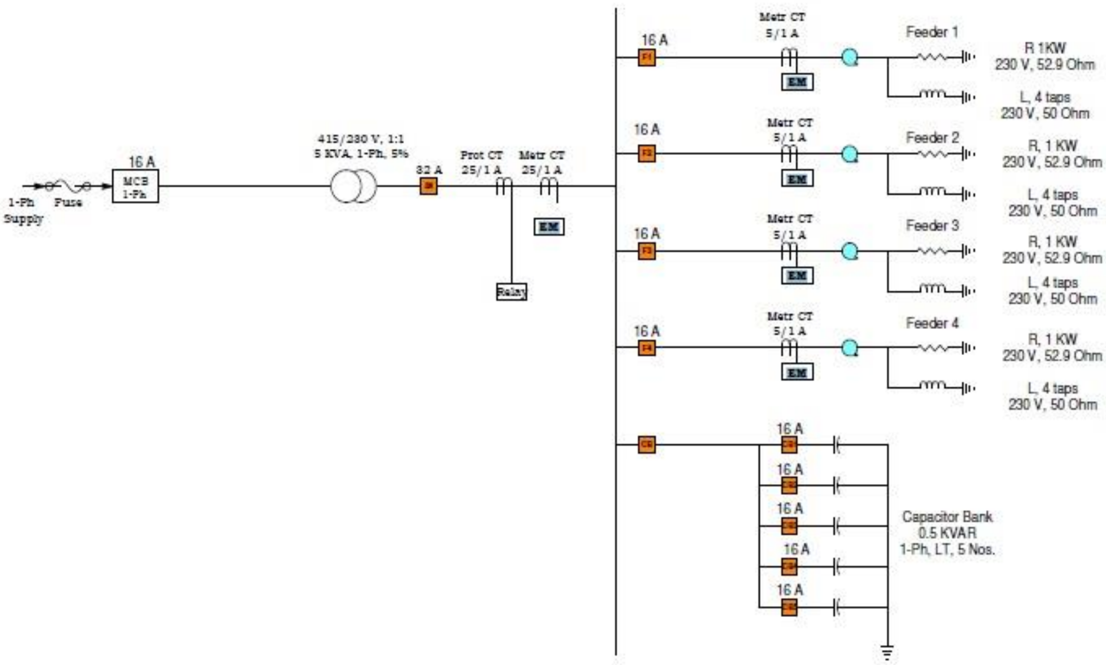


Figure 2.7 11 kV Distribution Model

Overview- Distribution Model
The following experiments can be done using the Distribution Model
1. Relay Coordination
2. PF Control\Voltage Regulation
3. Transformer Loading
4. Demand side management

These experiments can be done in two modes i.e., Remote Mode and Local Mode.

Common Procedure to All Experiments:
1. Assemble Distribution Model.
2. Keep the Local/Remote selector in Local Position.
3. Keep the Emergency Push buttons in released condition.
4. Switch on the supply to the module by closing the MCB
5. Configure the Incomer relay for the current setting, time multiplier and curve number for Phase current & Earth fault current.
6. Configure the Feeder relay for the current setting, time multiplier and curve number for Phase current & Earth fault current
7. Switch on the SCADA system & enter your login ID for observing the real Trends
8. Click the real trend icon on the main screen and select the parameters to observe with the select pen option provided at the right side of the screen.

Precautions:

1. Once an experiment is selected in the SCADA system until it is completed and stopped by clicking the stop button we shouldn't click the main screen.
2. While closing the Circuit breaker makes sure that the status of the breaker icon is updated before going to close the next breaker (Vertical line on the breaker will be changed to horizontal line)
3. Whenever a question mark (?) appears on the breaker icons, wait till the status is updated without disturbing it, because it's the problem of communication.
4. Always click the STOP button before going to the next experiment.

LOCAL MODE

PF CONTROL/VOLTAGE REGULATION (LOCAL MODE)

AIM:

Observe the voltage profile & PF at incomer and feeder side

PROCEDURE:

1. Close the Sec contactor C1 (main incomer) by pressing the ON push button.
2. Close the Feeder contactor F1 by pressing the ON push button.
3. Close the Feeder contactor F2 by pressing the ON push button.
4. Close the Feeder contactor F3 by pressing the ON push button.
5. Close the Feeder contactor F4 by pressing the ON push button.
6. Increase the load by varying the dimmer positions slowly for all the feeders & monitor the load current in the energy meter as well as in the SCADA.
7. Close the Capacitor Bank Contactor by pressing the ON push button of Capacitor bank main
8. Note the PF & Voltage of the secondary side energy meter & the feeders
9. Close the Capacitor Bank branch Contactor one by one by pressing the ON push button of CB1, CB2, CB3, CB4, and CB5. (Note: don't switch on all the capacitor banks, check the Pf profile accordingly switch on the capacitor banks based on the load)
10. The test results will display the details regarding Current, Voltage & PF
11. Repeat the experiment for various Load currents
12. Click the test results & note the values as shown in the tabular column
13. Repeat the experiment for various current values. (Max up to 3 A)
14. After completing the experiment please de-energize/open all the breakers by pressing the OFF push button of the corresponding breakers.

OBSERVATIONS:

S No.	Description	Incomer Measurements	Feeder (1,2,3,4) Measurements	Remarks
1	Voltage (V)			
2	Current (A)			
3	Power (W)			
4	VAR			
5	Power Factor			
6	VA			

RESULT:

By using capacitor banks, pf can be adjusted and voltage regulation can be obtained

REMOTE MODE EXPERIMENTS

AIM:

Configure the protection relays to trip the circuit during overloading

PROCEDURE:

1. Click the experiments screen & select the Relay coordination, Configure the system
2. Click the back button after configuring & click the start button
3. Close the Sec contactor C1 by clicking the Breaker icon in the SLD & follow the instructions
4. Close the Feeder contactor C2 by clicking the Breaker icon in the SLD & follow theinstructions.
5. Close the Feeder contactor C3 by clicking the Breaker icon in the SLD & follow theinstructions
6. Close the Feeder contactor C4 by clicking the Breaker icon in the SLD & follow theinstructions
7. Close the Feeder contactor C5 by clicking the Breaker icon in the SLD &follow theinstructions
8. Increase the load by varying the dimmer positions slowly for all the feeders & monitor the load current in the energy meter.
9. The relay will trip the Line depending on the time setting set on the relay & the overload.
10. The relay which have the lower current setting will trip first
11. The time settings can be synchronized in such a way that the feeder relay will pick up for over load & the secondary relay will trip based on the overload condition
12. The test results will display the details regarding the fault current & Nature of fault
13. Repeat the experiment for various time settings in the relay.
14. Note the Fault current, Voltage & time to trip for various settings
15. Plot the current vs. time graph
16. After completing the experiment, click close button to close the experiment

OBSERVATIONS:

Sl No	Current (%)	Time(sec)	Voltage
1			
2			
3			

RESULT:

Relay co-ordination is simulated and observed.

PF CONTROL/VOLTAGE REGULATION (REMOTE MODE)

AIM:

Observe the voltage profile & PF at incomer and feeder side

PROCEDURE:

1. Click the experiments screen & select the PF\ Voltage Regulation, Configure the system
2. Click the back button after configuring & click the start button.
3. Close the Sec contactor C2 by clicking the Breaker icon in the SLD & follow the instructions
4. Close the Feeder contactor C3 by clicking the Breaker icon in the SLD & follow theinstructions
5. Close the Feeder contactor C4 by clicking the Breaker icon in the SLD & follow theinstructions
6. Close the Feeder contactor C5 by clicking the Breaker icon in the SLD & follow theinstructions
7. Close the Feeder contactor C6 by clicking the Breaker icon in the SLD & follow theinstructions
8. Increase the load by varying the dimmer positions slowly for all the feeders & monitor the load current in the energy meter
9. Close the Capacitor Bank Contactor by clicking the Breaker icon in the SLD & follow the instructions
10. Note the PF & Voltage of the secondary side energy meter & the feeders
11. Close the Capacitor Bank branch Contactor one by one by clicking the Breaker icon in the SLD & follow the instructions. The test results will display the details regarding Current, Voltage & PF. Click the test
12. Repeat the experiment for various current values. (Max up to 3 A)

OBSERVATIONS:

S No.	Description	Incomer Measurements	Feeder (1,2,3,4) Measurements	Remarks
1	Voltage (V)			
2	Current (A)			
3	Power (W)			
4	VAR			
5	Power Factor			
6	VA			

RESULT:

By using capacitor banks, pf can be adjusted and voltage regulation can be obtained

TRANSFORMER LOADING (REMOTE MODE)

AIM:

Load the transformer by increasing the feeder loads and observe voltage and current profile

PROCEDURE:

1. Click the experiments screen & select the Transformer loading, Configure the system
2. Click the back button after configuring & click the start button.
3. Close the Sec contactor C1 by clicking the Breaker icon in the SLD & follow the instructions
4. Close the Feeder 1 contactor C2 by clicking the Breaker icon in the SLD & follow theinstructions
5. Close the Feeder 2 contactor C3 by clicking the Breaker icon in the SLD & follow theinstructions
6. Close the Feeder 3 contactor C4 by clicking the Breaker icon in the SLD & follow theinstructions
7. Close the Feeder 4 contactor C5 by clicking the Breaker icon in the SLD & follow theinstructions
8. Increase the load by varying the dimmer positions slowly for all the feeders & monitor theload current in the energy meter
9. Repeat the experiment for various Load currents
10. Click the test results & note the values as shown in the tabular column
11. Repeat the experiment for various current values. (Max up to 3 A)
12. After completing the experiment please click close button to close the experiment

OBSERVATIONS:

S No.	Description	Incomer Measurements	Feeder (1,2,3,4) Measurements	Remarks
1	Voltage (V)			
2	Current (A)			
3	Power (W)			
4	VAR			
5	Power Factor			
6	VA			

RESULT:

Transformer is loaded with the feeder and voltage and current profiles are observed.

3. PROGRAMMABLE LOGIC CONTROLLER (PLC)

The programmable logic controller (PLC) is a solid state electronic device designed to replace electromechanical relays, timers, counters and sequences, by using a programmable memory for the internal storage of user oriented instructions for implementing specific functions such as logic sequencing timing, country and arithmetic control through digital or analog inputs and outputs, various types of machines or processes.

Major advantages of using PLC are as follows:

1.The PLC is a hardened industrial computer designed to withstand the harsh factory environment.

2. PLCs are reusable they contain a changeable program that eliminators extensive andcomponent changes and that makes them cost effective

3. PLCs offer easy troubleshooting

4. PLCs feature easy installation and small size.

5. Increase productivity.

6. Ease of programming.

7. Ability to communicate with computer.

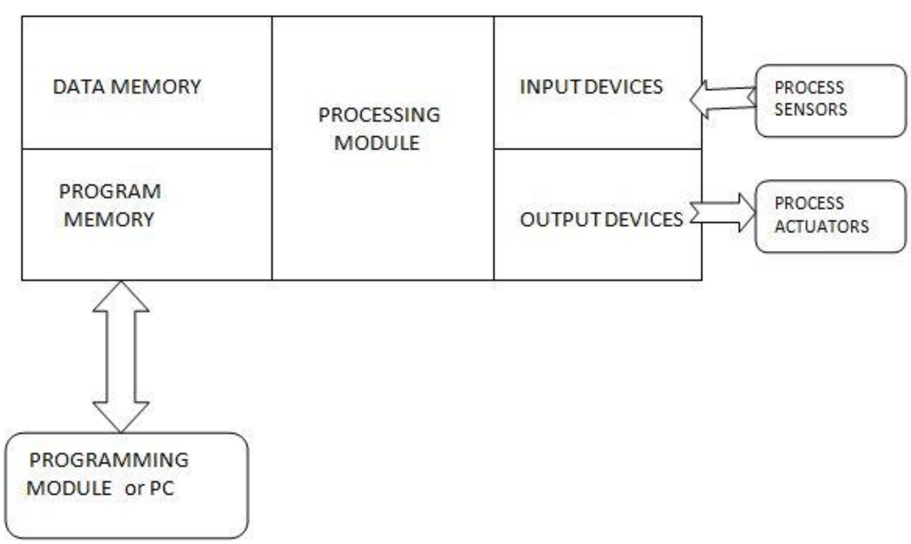


Figure 3.1 Architecture Of PLC

WATER LEVEL CONTROLLER USING PROGRAMMABLE LOGIC CONTROLLER

AIM:

To control the water level of a tank using programmable logic controller.

APPARATUS REQUIRED:

1. Level control trainer kit
2. PLC (Allen Bradley Micro logix 1500 LRP series C
3. PC with Versapro Software
4. RS232 cable
5. Patchchords

PROCEDURE:

1. Load the RS logix software to thePC
2. Open the RS logix software
3. Switch On the PLC trainer
4. Connect PLC with level control kit.
5. Open the New folder and draw the ladder logic program
6. Select the correct hardware configuration.
7. Store the Program toPLC
8. Run theprogram
9. Verify the performance of the water level control using PLC.

PROCESS DESCRIPTION:

Liquid level control is a basic and necessary process for all the process industry. Here the level of liquid is to be maintained inside the tank to a specific height.

Here there is a water reservoir from which the water needs to be pumped out to the process tank. In the process tank there are two sensors connected around the edges of the tank according to the required heights i.e., one sensor is connected at the near bottom end of the tank called as lower level sensor and another one on the near top edge of the tank called as higher level tank. To let the water out of the tank there is a pipe connected at the bottom of the tank with a valve. This valve is to be used by user for the process application.

The level sensor is a magnetic sensor and when the liquid level is above the high level sensor a HL (high level) signal is sent to the PLC. When the liquid level goes down the low level sensor LL (low level) signal is sent to the PLC. The PLC checks the signals sent by these sensors through its input port and give the proper signals through its output port as per the ladder logic program.

Sequence of process control actions done by the PLC:

1. When the water level in the tank is less than the lower level then the lower level sensor senses and turns the motor on to fill the tank.
2. Then the tank is filled up until it reaches the higher level where the higher level sensor senses and makes the motor off and filling of water stops.

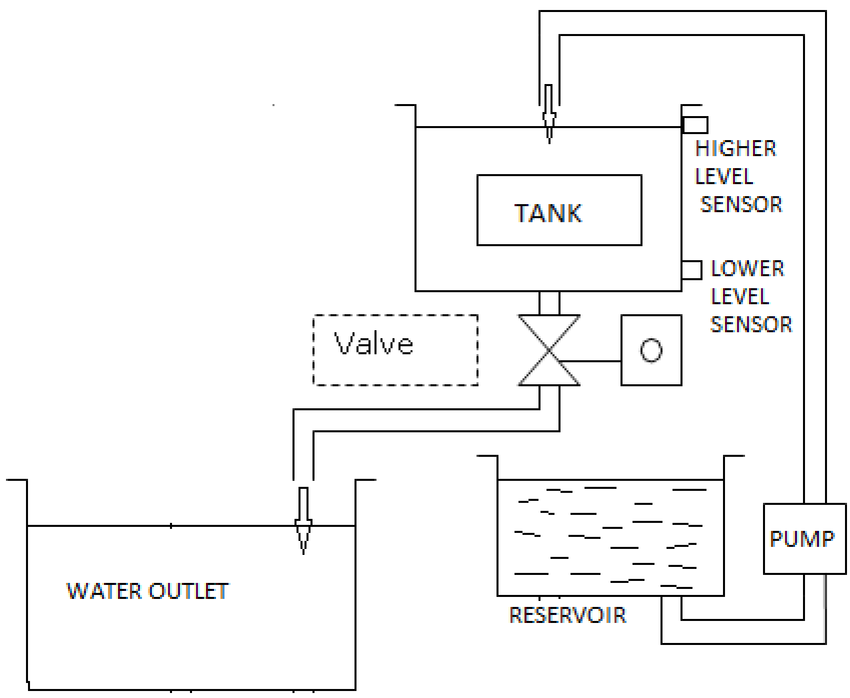
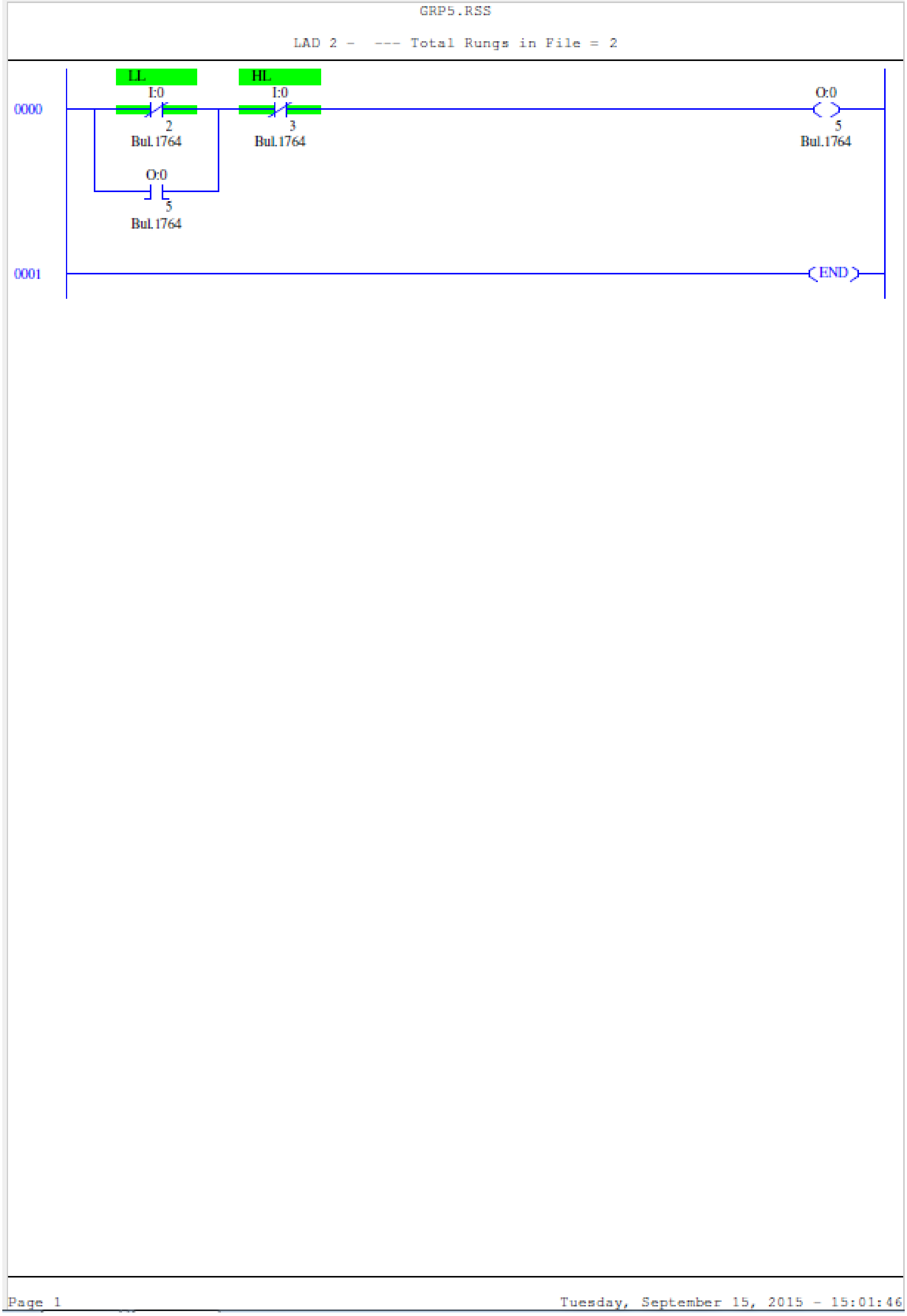


Figure 3.2 Block Diagram Of Liquid Level Setup



<u>RESULT</u>:

The liquid level trainer kit was set up and liquid level was controlled by using PLC ladder logicprogram.

BATCH PROCESS REACTOR USING PROGRAMMABLE LOGIC CONTROLLER

AIM:

To control the batch process reactor (VPAT 05) using programmable logic controller.

APPARATUS REQUIRED:

1. Batch process trainer kit
2. PLC (Allen Bradley Micrologix 1500 LRP seriesC)
3. PC with Versapro Software
4. RS232 cable
5. Patch chords

PROCEDURE:

10. Load the RS Logix Software to the PC
11. Open the RS Logix Software
12. Switch On the PLC trainer and lift control system
13. Connect PLC with Batch process control kit.
14. Open the New folder and draw the ladder logic program
15. Select the correct hardware configuration.
16. Store the Program to PLC
17. Run the program
18. Verify the performance to the Batch process control.

PROCESS DESCRIPTION:

Batch process reactor is a blending process, where two liquids are mixed together to get the output mixture. The programmable logic controller is used to control the whole process. The process tanks 1 & 2 consist of two liquids, which are blended in process tank 3. The process tank 1 & 2 consists of a low liquid level sensor and a high liquid level sensor. The liquids are pumped to the process tanks using respective pumps.

The two liquids are mixed in the process tank 3 using a stirrer. Heater is used to heat the mixture. The solenoid valves provide the liquids to the process tank 3 when the mixture level is low. Solenoid valve 3 is connected to the output of the process tank 3, which feeds mixed liquid to a vessel when it is sensed by the vessel proximity sensor. The container is fed through a conveyor belt run by stepper motor. Two solenoid valves 1 & 2 control the flow of two liquids to the tank 4. The level sensors sense the level in the process tanks1 and 2.The level sensor is a magnetic sensor and when the liquid level is above the high level sensor a HL (high level) signal is sent to the PLC. When the liquid level goes down the low level sensor LL (low level) signal is sent to the PLC. The PLC checks the signals send by these sensors through its input port and give the proper signals through its output port as per the ladder logic program.

Various process control actions done by the PLC are

1. When the low level sensor is sensed respective pump is on.
2. When the high level sensor is sensed respective pump is off
3. When both the tanks reached two higher level than the respective solenoids open and allows two liquids two mix in the 3rd one for 10 seconds.
4. Then the heater gets energized and heats the mixture for 10 seconds.
5. Then the stirrer gets on and stirring process continues for next 10 seconds.
6. A stepper motor is made ON to run the conveyor belt
7. When the proximity sensor senses a container, solenoid valve 3 is made on for a particular time as set in the program.
8. This process goes on for filling up of 20 bottles and then the total process starts from the beginning by filling up the two overhead tanks.

BATCH PROCESS REACTOR T RAINER (VPAT05)

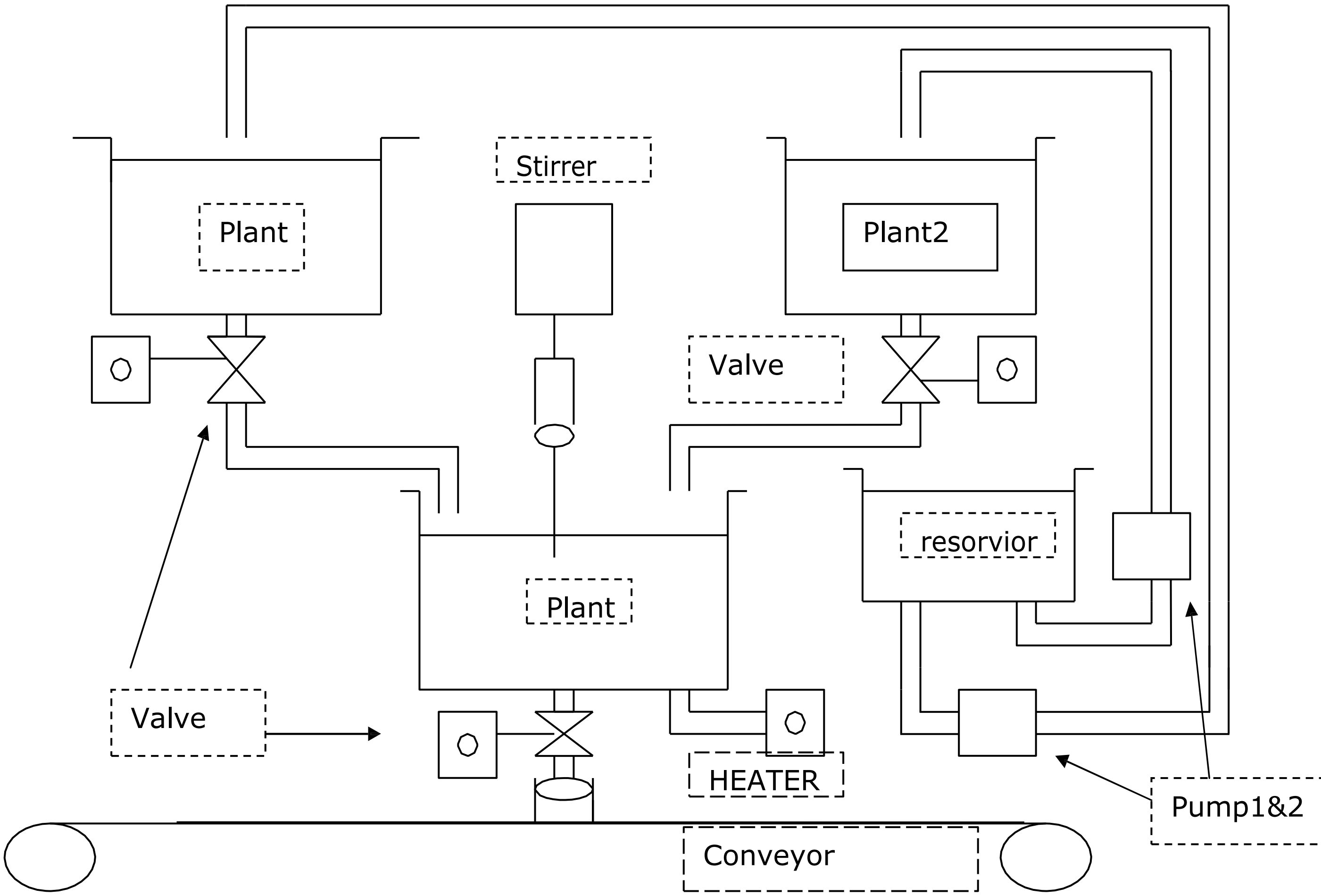
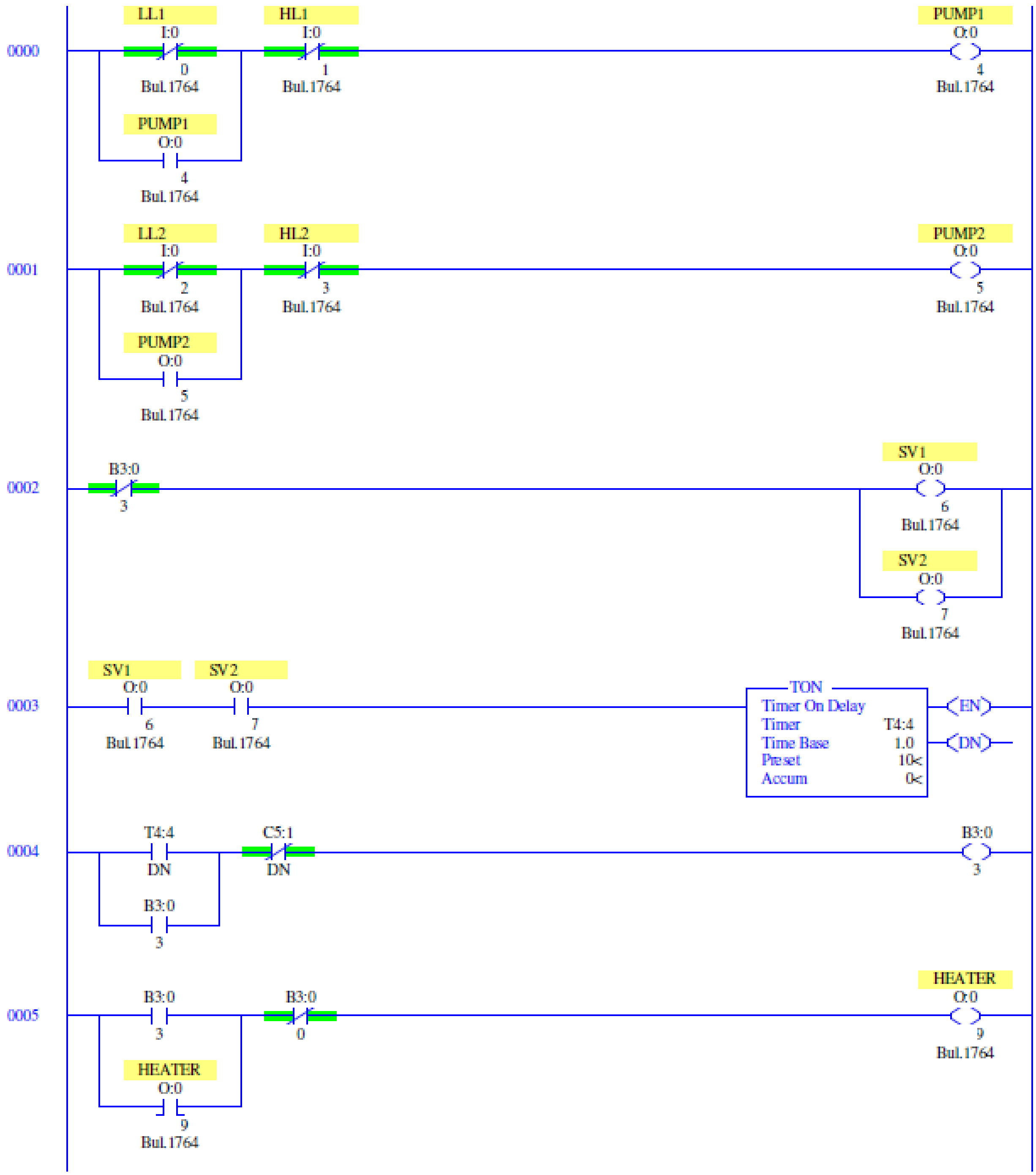
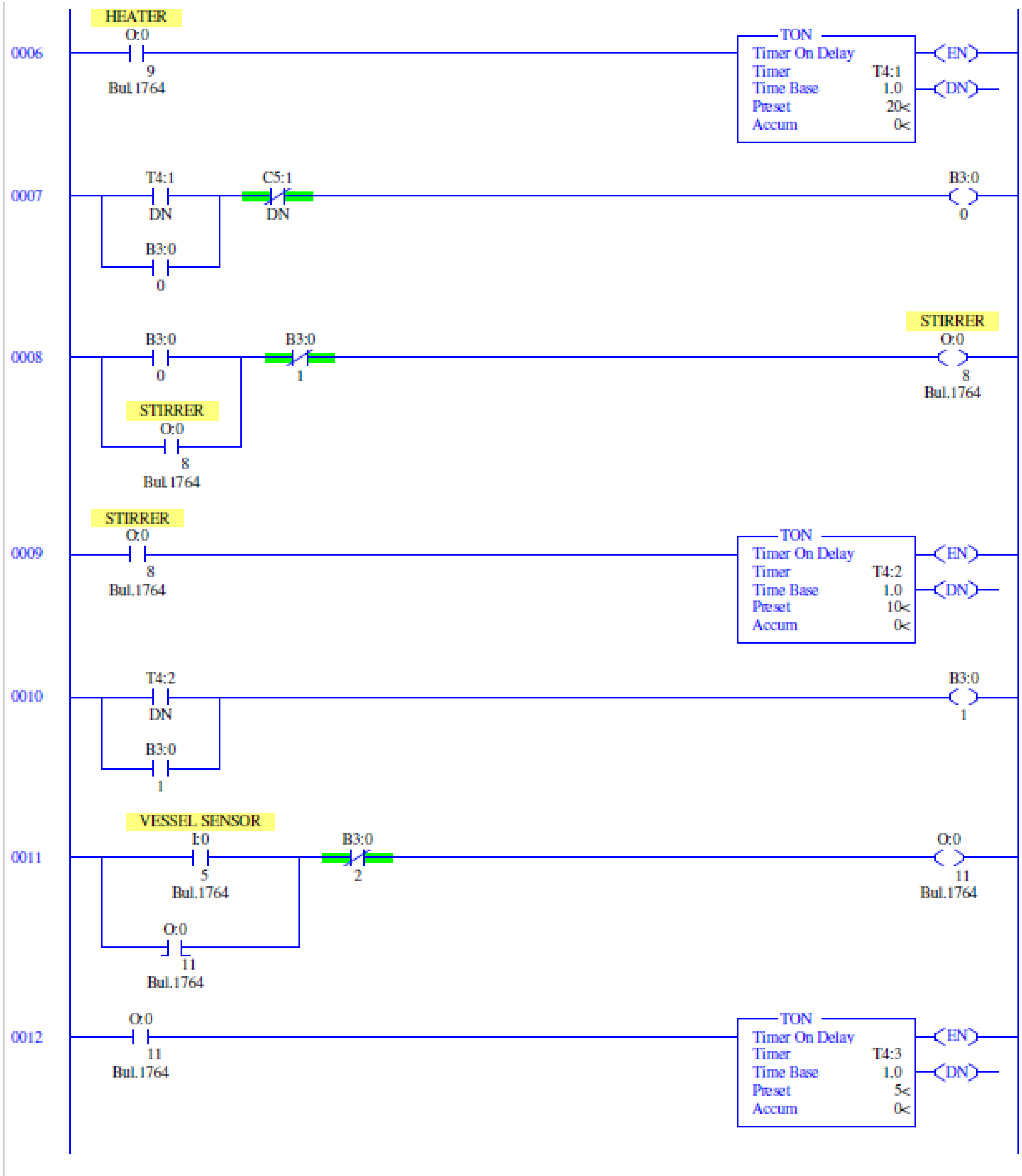


Figure 3.3 Batch Process Reactor

BATCH PROCESS.RSS

LAD 2 - --- Total Rungs in File = 24





0006
HEATER
O:0
9
Bul.1764
TON
Timer On Delay
Timer T4:1
Time Base 1.0
Preset 20<
Accum 0<
EN
DN
0007
T4:1
DN
C5:1
DN
B3:0
0
B3:0
0
0008
B3:0
0
B3:0
1
STIRRER
O:0
8
Bul.1764
STIRRER
O:0
8
Bul.1764
0009
STIRRER
O:0
8
Bul.1764
TON
Timer On Delay
Timer T4:2
Time Base 1.0
Preset 10<
Accum 0<
EN
DN
0010
T4:2
DN
B3:0
1
B3:0
1
0011
VESSEL SENSOR
I:0
5
Bul.1764
B3:0
2
O:0
11
Bul.1764
O:0
11
Bul.1764
0012
O:0
11
Bul.1764
TON
Timer On Delay
Timer T4:3
Time Base 1.0
Preset 5<
Accum 0<
EN
DN

SPEED CONTROL OF AC SERVO MOTOR USING PROGRAMMABLE LOGIC CONTROLLER

AIM:

To control the speed of an AC servomotor by implementing pi controller using PLC ladder

Logic Program.

THEORY:

Proportional Control

The controller is proportional; it will produce a control signal, which is proportional to the input error signal, i.e., signal proportional to the difference between actual level and desired level. When the error is high the controller will send the signal according the error. In the graph we can see the same. When it is in position control, the control signal is almost a straight line and has no relation with error but in P- controller we can see that the controller output is varying according the error. Let the signal be u (t) which is proportional to the input error signal, e (t). Then we can obtain a relation

$$u\ (t) = k_p e\ (t)$$

Where Kp proportional gain (or) constant

Hence, we can say that the proportional controller amplifies the error signal by an amount Kp. Also the introduction of the controller on the system increases the loop gain by an amount Kp. The increase in loop gain improves the steady state tracking accuracy, disturbance signal rejection and the relative stability and also makes the system less sensitive to parameter variations. But increasing the gain to very large values may lead to instability of the system. The demerit of P-controller is that it leads to a constant steady state error.

Proportional + Integral Controller

The integral (or) reset action combine with proportional control gives us a controller which will always act to maintain the control variable as its desired value (set point). The proportional mode provides a stabilizing influence while the integral mode will help to overcome the OFFSET. Integral controller will provide corrective action as long as there is a deviation in the controlled variable from the set point value. Integral control has a phase lag of 900 proportional controls. This lagging feature of reset will result in a slow response & oscillation will come in to picture.The proportional & integral controller produce an output signal consisting of 2-terms, one is proportional to error signal & the other proportional to the integral of the error signal.

The advantage of both P & I controller are combined in P-I controller, the proportional action increased the loop gain & makes the system less sensitive to variations of system parameters. The integral action eliminates (or) reduces the steady state error. The integral action is adjusted by varying the integral time. The inverse of integral time T is called the reset value

Proportional + Integral + Derivative Control

When the all three control effects are combined together we obtain the benefits of each control action & more over the effect duplicates the action of good human operator on a control application. A three controller contains the stability of P- controller and the ability to eliminate offset because of reset control and ability to provide an immediate corrective action for the

magnitude of a disturbance because of rate control.

APPARATUS REQUIRED:

1. AC servomotor kit
2. PLC (Allen Bradley Micro Logix 1500 LRP series C)
3. PC with RX Logix Software
4. RS232 cable
5. Patch chords

PROCEDURE:

1. Load the RX Logix software to the PC
2. Open the RX Logix software
3. Switch on the PLC trainer and lift controls system
4. Connect PLC with AC servomotor kit.
5. Open the New folder and draw the ladder logic program
6. Select the correct hardware configuration.
7. Store the Program to PLC

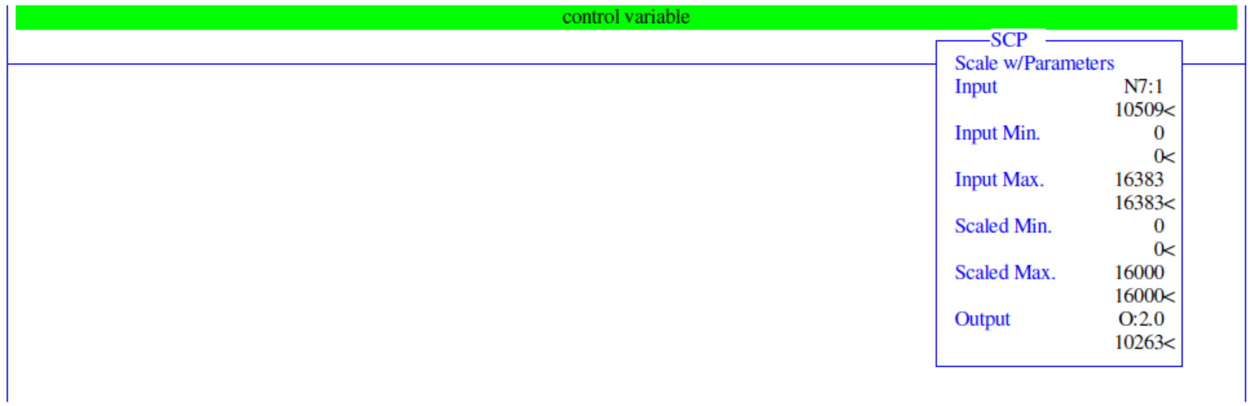
8. Run the program

9. Verify the performance to the control AC servomotor.

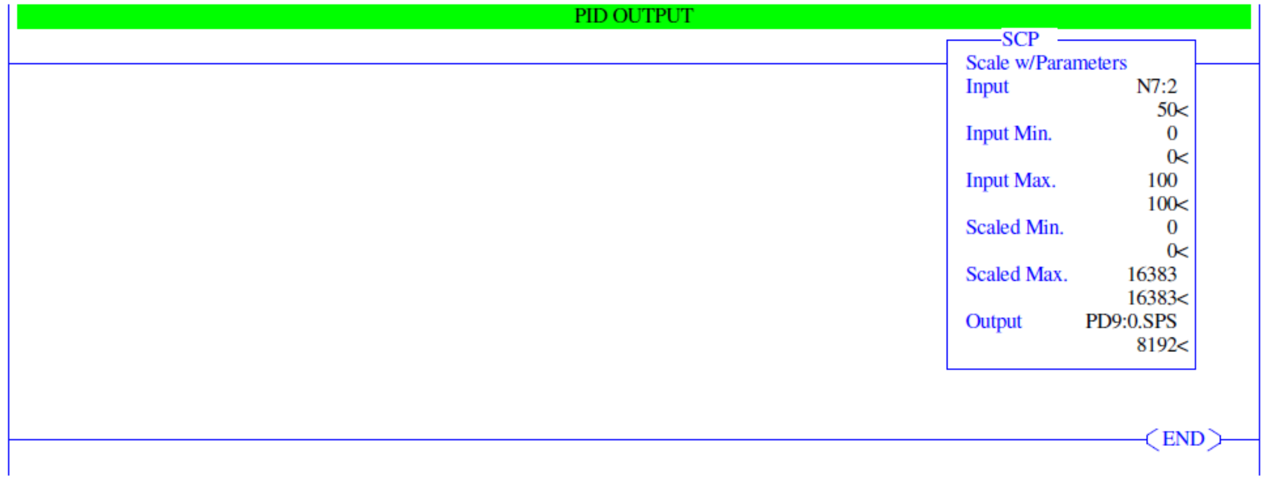
DESCRIPTION:

Applying different voltages can control speed of the AC servomotor. For this purpose AC voltage controller has been used. Accordingly triggering angle control for this circuit has accomplished by plc ladder logic program. For measurement of speed an opto coupler is used in conjunction with a square geared wheel connected to the shaft of the motor. The opto coupler measures speed of motor by noting the number of tooth that it encountered in a fixed time. The opto coupler output is given to the analog input port of plc kit. Then control algorithm will compare this value with the default set point value, which give an error signal. This error signal is used in manipulating the firing angle of thyristor circuit to control applied voltage to the servomotor. Ladder logic program also facilitates the user to tune the controller parameters to change the performance of the controller and to set desired speed value.

PLC PROGRAM


control variable
SCP
Scale w/Parameters
Input N7:1
10509<
Input Min. 0
0<
Input Max. 16383
16383<
Scaled Min. 0
0<
Scaled Max. 16000
16000<
Output O:2.0
10263<


process variabl
2
SCP
Scale w/Parameters
Input I:2.0
7808<
Input Min. 0
0<
Input Max. 16000
16000<
Scaled Min. 0
0<
Scaled Max. 16383
16383<
Output N7:0
7995<
3
SCP
Scale w/Parameters
Input N7:0
7995<
Input Min. 0
0<
Input Max. 16000
16000<
Scaled Min. 0
0<
Scaled Max. 100
100<
Output N7:3
50<



OBSERVATIONS:

What do you infer from the controller output oscillations? By varying the proportional gain, integral gain, what would be the merits and demerits?

What do you infer from the controller output oscillations? By varying the proportional gain,

Integral gain, what would be the merits and demerits?

LIFT CONTROL SYSTEM using PLC

AIM:

To control the lift plant model using programmable logic controller.

APPARATUS REQUIRED:

1. Lift control system
2. PLC (Allen Bradley micrologix 1500 LRP series C)
3. PC with RXlogix Software
4. RS232 cable
5. Patch chords

PROCEDURE:

1. Load the RX Logix software to the PC
2. Open the RX Logix software
3. Switch On the PLC trainer and lift controls system
4. Connect PLC with Lift control system kit.
5. Open the New folder and draw the ladder logic program
6. Select the correct hardware configuration.
7. Store the Program to PLC
8. Run the program
9. Verify the performance to the lift control system

PROGRAM DESCRIPTION:

I1, I2, I3 - Requisition switch.

I4, I5, I6 - Sensor Inputs.

Q2, Q3, Q4, Q5 - Output for stepper motor.

1. I1, I2, I3 are requisition switches I4, I5, I6 are the sensor placed in each floor. The other coils used in the program are the set coil, reset coil, positive transition coil, negative transition coil are in memory location.
2. The timer functions are used to produce the required time delay.
3. Bit sequence functions used to drive the stepper motor.
4. Whenever the requirement switch I1, is pressed the set coil M1 is energized and bit sequence outputs are enabled then the stepper motor rotates.
5. When the motor reaches the respective floor, the switch I4 gets closed and energizes both positive transition coil & negative transition coil.
6. The positive transition coil energizes one more set coil, which is used to enable the timer.
7. This is used to give time delay for the lift in each floor.
8. The negative transition coil, which was energized, is used to reset the requisition.
9. The above functions are repeated in each floor.

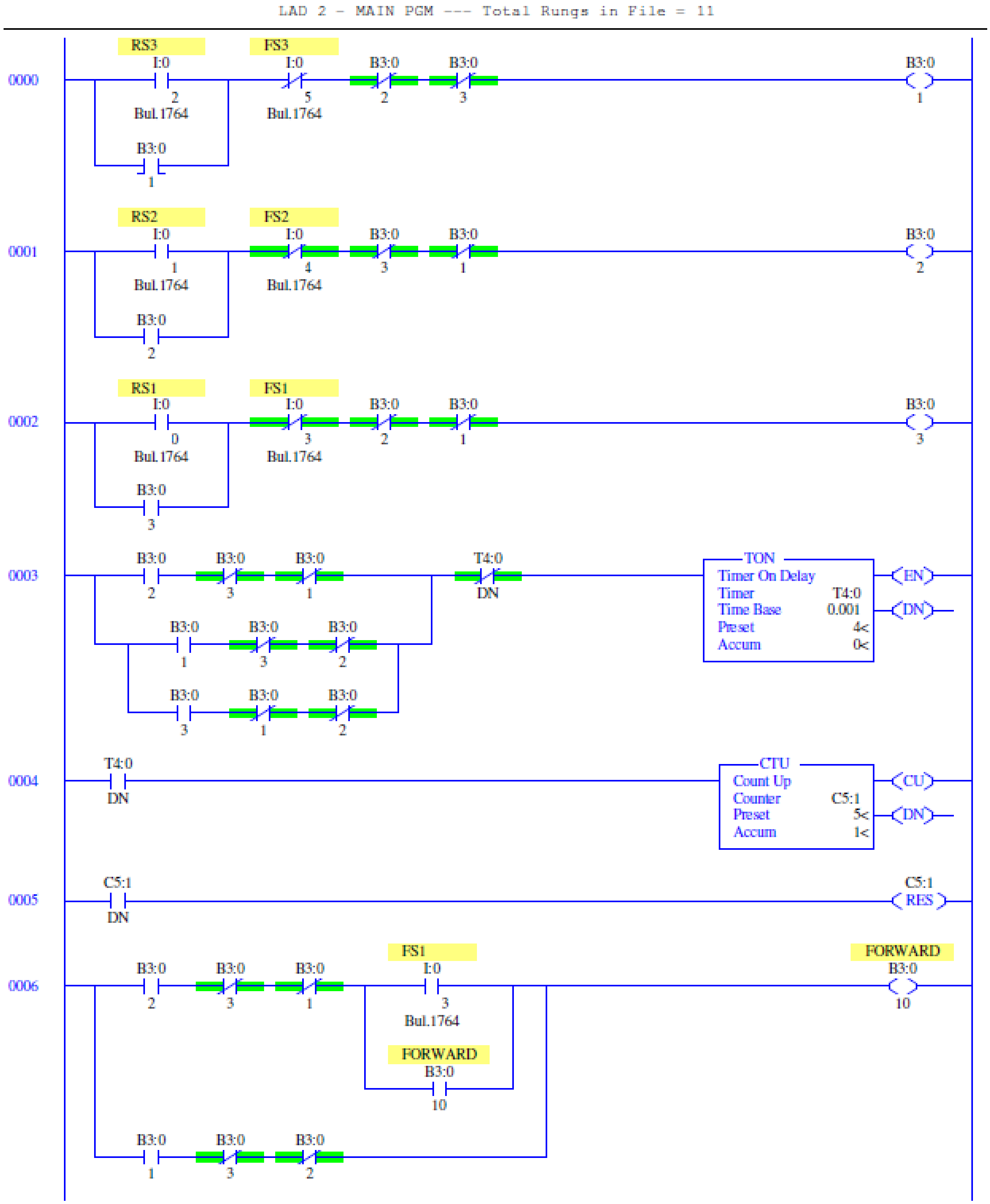
CONDITIONS FOR ROTATION OF MOTOR:

1. Consider the lift is in ground floor, when the requisition is given from first floor or second floor the motor has to move forward.

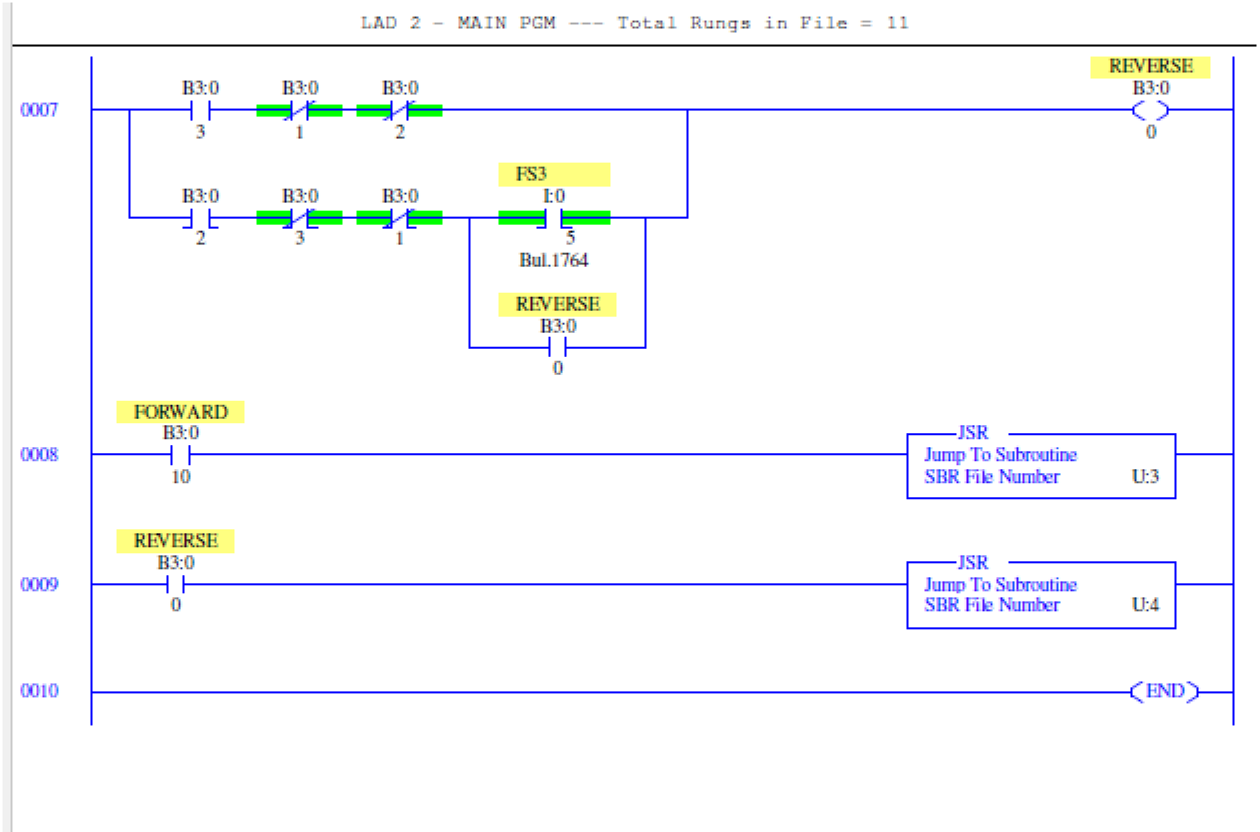
2. If the lift is in top floor then it has to move in the reverse direction.

3. If the lift is in middle floor then according to the requisition, lift will move in forward or reverse direction.

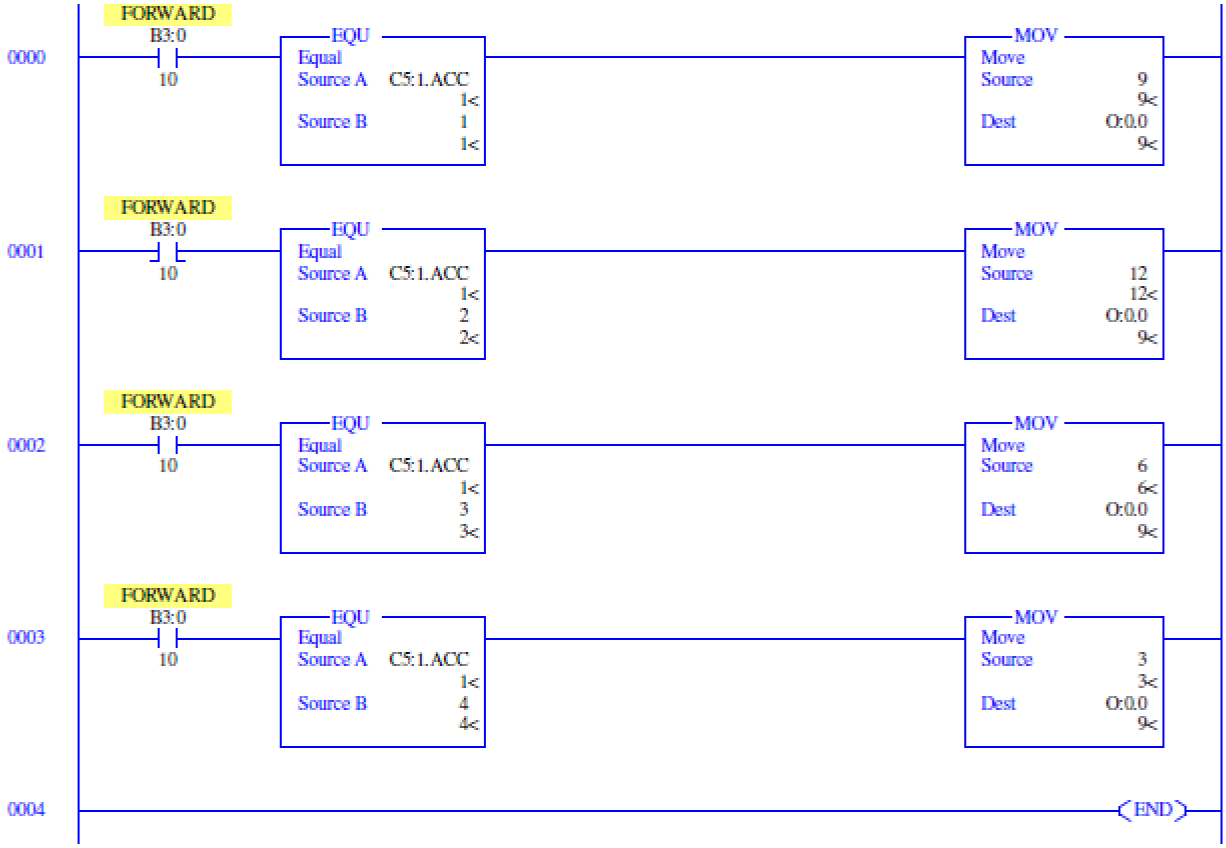
PROGRAM

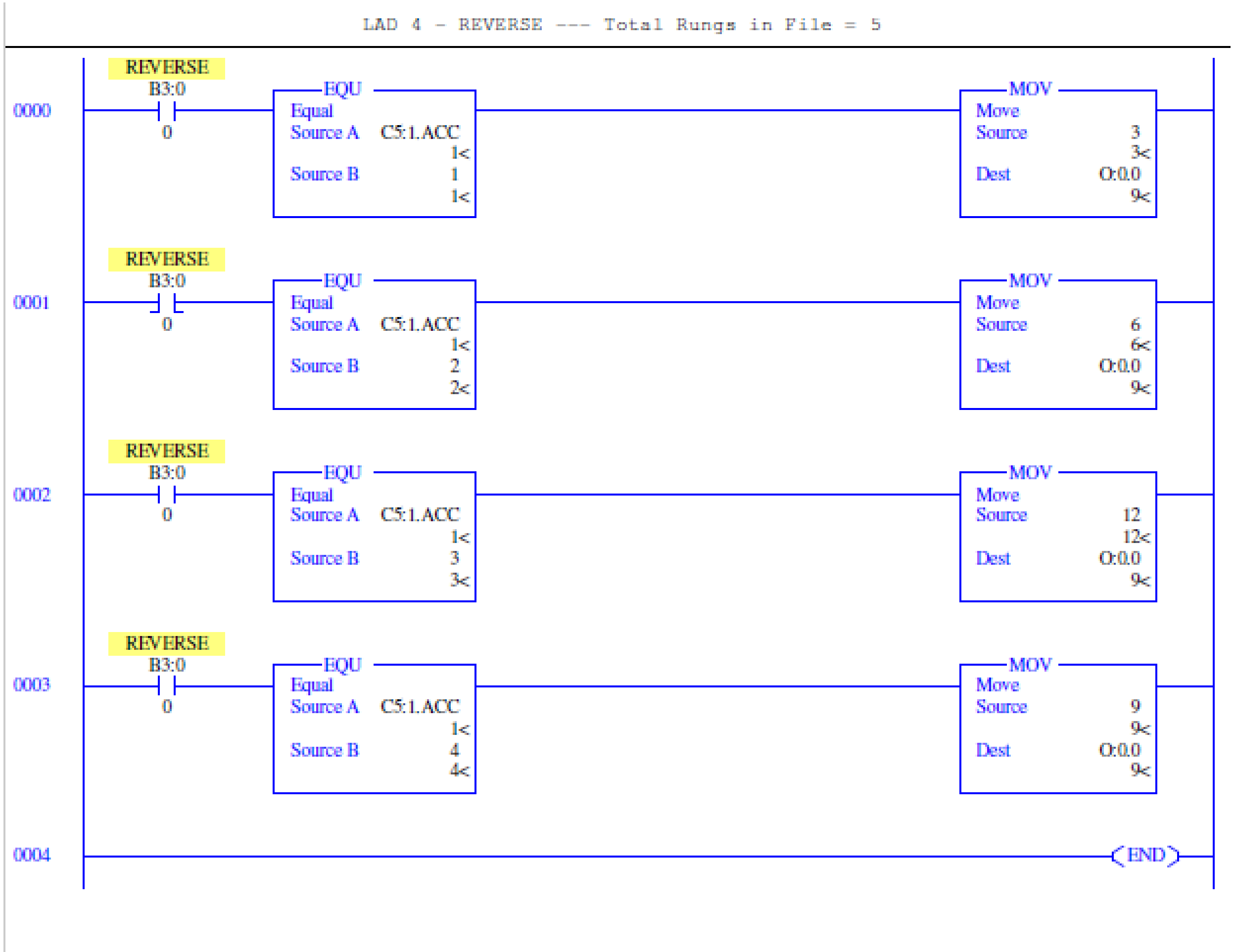


LAD 2 - MAIN PGM --- Total Rungs in File = 11
0000
RS3
I:0
2
Bul.1764
FS3
I:0
5
Bul.1764
B3:0
2
B3:0
3
B3:0
1
B3:0
1
0001
RS2
I:0
1
Bul.1764
FS2
I:0
4
Bul.1764
B3:0
3
B3:0
1
B3:0
2
B3:0
2
0002
RS1
I:0
0
Bul.1764
FS1
I:0
3
Bul.1764
B3:0
2
B3:0
1
B3:0
3
B3:0
3
0003
B3:0
2
B3:0
3
B3:0
1
B3:0
1
B3:0
3
B3:0
2
B3:0
3
B3:0
1
B3:0
2
T4:0
DN
TON
Timer On Delay
Timer T4:0
Time Base 0.001
Preset 4<
Accum 0<
EN
DN
0004
T4:0
DN
CTU
Count Up
Counter C5:1
Preset 5<
Accum 1<
CU
DN
0005
C5:1
DN
C5:1
RES
0006
B3:0
2
B3:0
3
B3:0
1
FS1
I:0
3
Bul.1764
FORWARD
B3:0
10
B3:0
1
B3:0
3
B3:0
2
FORWARD
B3:0
10


LAD 2 - MAIN PGM --- Total Rungs in File = 11
0007
B3:0
3
B3:0
1
B3:0
2
REVERSE
B3:0
0
B3:0
2
B3:0
3
B3:0
1
FS3
I:0
5
Bul.1764
REVERSE
B3:0
0
0008
FORWARD
B3:0
10
JSR
Jump To Subroutine
SBR File Number U:3
0009
REVERSE
B3:0
0
JSR
Jump To Subroutine
SBR File Number U:4
0010
END

LAD 3 - FORWARD --- Total Rungs in File = 5





RESULT:

It is observed that lift is controlled smoothly by using programmable logic controller.

STAR DELTA STARTER using PLC

AIM:

The objective of the product is to start a 3・ squirrel cage induction motor in star-delta method using PLC.

APPARATUS REQUIRED:

1. Personal computer
2. PLC.
3. PLC programming software
4. RS 232 communication cable
5. PLC based star to delta star starter module (VPAT-15).
6. Power supply -220 volt 3ΦAC 50 Hz.
7. 3Φvariable transformer.
8. Patch Chords.

STAR-DELTA STARTER

The Star/Delta starter is probably the most commonly used reduced voltage starter. The Star/Delta starter requires a six terminal motor that is delta connected at the supply voltage. The Star Delta starter employs three contactors to initially start the motor in a star connection, then after a period of time, to reconnect the motor to the supply in a delta connection. While in the star connection, the voltage across each winding is reduced by a factor of the square root of 3. This results in a start current reduction to one third of the DOL start current and a start torque reduction to one third of the DOL start torque. If there is insufficient torque available while connected in star, the motor can only accelerate to partial speed. When the timer operates (Set normally from 5 - 10 seconds), the motor is disconnected from the supply and then reconnected in Delta resulting in full voltage start currents and torque. The transition from star connection to delta connection requires that the current flow through the motor is interrupted. This is termed “Open Transition Switching” and with an induction motor operating at partial speed (or full load speed), there is a large current and torque transient produced at the point of reconnection. This transient is far worse than any produced by the

DOL starter and can cause severe damage to equipment and the supply. If there is insufficient torque produced by the motor in star, there is no way to accelerate the load to dull speed without switching to delta and causing those severe current and torque transients. These must be allowed-for in the design of the motor and its starting system if they are to have an economic useful life.

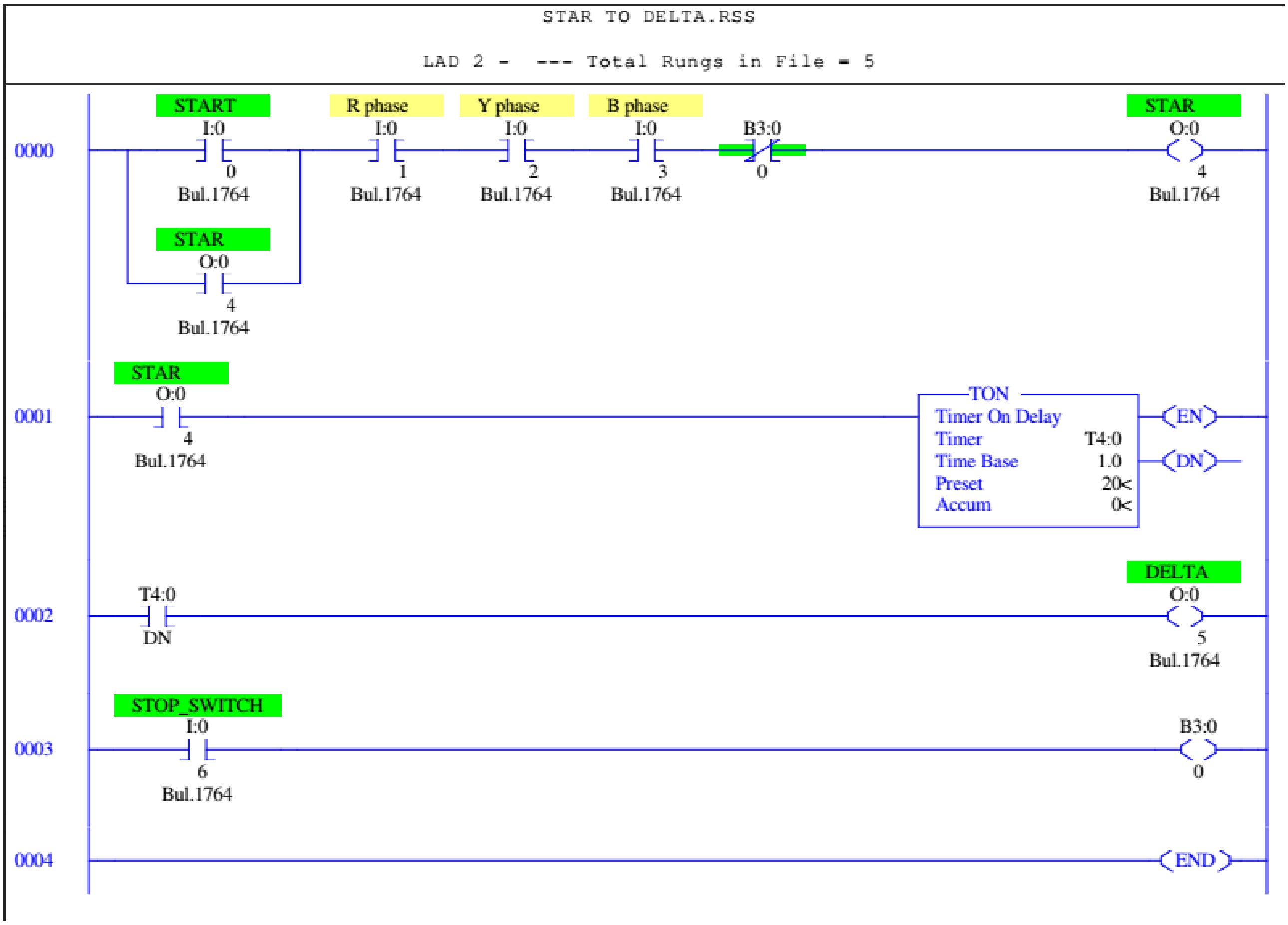
This type of starter is used in the case of motors which are built to run normally with a delta connected stator winding. It consists of a two - way switch which connects the motor in star for starting and then in delta for running. The usual connections are shown. When star-connected, the applied voltage over each motor phase is reduced by a factor of $1/\sqrt{3}$ and hence the torque developed becomes $1/\sqrt{3}$ of that which would have been developed if motor were directly connected in delta. The line current is reduced to $1/\sqrt{3}$. Hence, during starting period when motor is Y-connected, it takes 1/3rd as much stating current and develops 1/3rd as much torque as would have been developed were it directly connected in delta.

It is clear that the star-delta switch is equivalent to an auto-transformer of ratio $1/\sqrt{3}$ .or 58% approximately. This method is cheap and effective provided the starting torque is required not to be more than 1.5 times the full-load torque. Hence, it is used for machine tools, pumps and motor-generators etc.

PROCEDURE:

1. First program the ladder logic for star-delta starter with required protection sequence.
2. Connect the personal computer & PLC by RS 232 communication cable.
3. Clear the PLC content using clear command.
4. Download the ladder logic program from PC to PLC.
5. Make proper connection to PLC, motor & starter.
6. By selecting the run mode the PLC is ready for action.
7. Output of the PLC is given to PLC based starter & Motor starts to run in star connection.
8. After a preset time the motor winding change into delta connections.
9. Now the motor take high current compared to star.
10. After any fault like single phasing, over current comes the PLC starter automatically sense & cut off the power supply to the motor.
11. After the power supply cut off we have to reset the starter for next starting action.

PROGRAM



PROGRAM EXPLANATION:

1. The first rung consists of Start and Stop switch, R, Y and B phase and Memory contact.

Start or Stop Switch is used for Emergency OFF purpose. When switch is ON start switch

Enable, switch is OFF stop switch Enable.

2. When the power supply is given, R, Y and B phase in normally open and Memory contact is normally closed. At the time motor will start rotate in Star connection.

3. In second rung, the output of Star is given to the TIMER. At particular time delay, it will

give output.

4. In third rung, output of the Timer s given to Delta, Now, the motor start to rotate in delta connection.

5. In fourth rung, CURRENT SENSOR is used to sense the current. When the actual current Reaches above the set current, it will set the memory contact and motor stop.

6. In fifth rung, RESET switch is used to return to the normal position.

7. In sixth rung, END is used to stop the operation.

RESULT:

4. FACTS AND STATCOM EXPERIMENTS

HYBRID MICROGRID SETUP

The setup consists of a hybrid micro-grid with sources as solar energy and wind energy. Solar panels and a wind turbine are installed on the roof top whose terminals are available at the solar-wind wiring panel. The rating of the solar panels and wind turbine is given below.

Solar Panel: 1 kW, 450 V, 25 panels

Wind Turbine: 1 kW, 24 V (line to line), PMSG.

Apart from the wind turbine at the rooftop, a wind turbine generator is provided in the wind simulator lab, where the turbine is run using the artificial wind generated by the wind simulator for testing purposes. An uncontrolled rectifier converts the AC output of the wind turbine generator into DC and the voltage is stepped up by a DC boost converter. The output of both the wind turbines and the solar panels is then fed to the hybrid power controller which is a buck-boost converter with MPPT algorithm and dsPIC based PWM generator. By varying the modulation index of the PWM signal generated by dsPIC based PWM generator, maximum power point can be obtained. The output of the hybrid power controller is then connected to the battery bank with the rating of 300 V, 42 Ah.

The DC link voltage of the battery bank is converted into three phase 110V, 50Hz AC voltage using an intelligent power module (IPM) which is basically a voltage source inverter. The output of this IPM is then fed to an equivalent pi transmission line model with FACTS devices (STATCOM and SSSC) on the receiving end of which different AC loads can be connected. The 300 V DC output of the battery bank is also fed to a 300 V DC bus where different DC loads can be connected.

As a future expansion, researches are being going on in order to connect this micro-grid setup to utility grid.

FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS)

The increase in the loading of the transmission lines sometimes can lead to voltage collapse due to the shortage of reactive power delivered at the load centres. This is due to the increased consumption of the reactive power in the transmission network and the characteristics of the load (such as induction motors supplying constant torque).

Flexible AC Transmission Systems (FACTS) refers to alternating current transmission systems incorporating power electronics-based controllers to enhance the controllability and increase power transfer capability. The FACTS technology opens up new opportunities for controlling both active and reactive powers and enhancing the usable capacity of present transmission systems. The possibility that power through a line can be controlled enables a large potential of increasing the capacity of lines. This opportunity is arises through the ability of FACTS controllers to adjust the power system electrical parameters including series and shunt impedances, current, voltage, phase angle, and damping of oscillations etc.

The FACTS controllers can be classified as

1. Shunt connected controllers
2. Series connected controllers
3. Combined series-series controllers
4. Combined shunt-series controllers

Depending on the power electronic devices used in the control, the FACTS controllers can be classified as

A. Variable impedance type
B. Voltage Source Converter (VSC) based.

The variable impedance type controllers include:

i. Static VAR Compensator (SVC), (shunt connected)
ii. Thyristor Controlled Series Capacitor or compensator (TCSC), (series connected)
iii. Thyristor Controlled Phase Shifting Transformer (TCPST) of Static PST (combined shunt and series)

The VSC based FACTS controllers are:

i. Static synchronous Compensator (STATCOM) (shunt connected)
ii. Static Synchronous Series Compensator (SSSC) (series connected)
iii. Interline Power Flow Controller (IPFC) (combined series-series)
iv. Unified Power Flow Controller (UPFC) (combined shunt-series)

Some of the special purpose FACTS controllers are

a) Thyristor Controller Braking Resistor (TCBR)
b) Thyristor Controlled Voltage Limiter (TCVL)
c) Thyristor Controlled Voltage Regulator (TCVR)

d) Interphase Power Controller (IPC)
e) NGH-SSR damping

The FACTS controllers based on VSC have several advantages over the variable impedance type. For example, a STATCOM is much more compact than a SVC for similar rating and is technically superior. It can supply required reactive current even at low values of the bus voltage and can be designed to have in built short term overload capability. Also, a STATCOM can supply active power if it has an energy source or large energy storage at its DC terminals.

The only drawback with VSC based controllers is the requirement of using self-commutating power semiconductor devices such as Gate Turnoff (GTO) Thyristor, Insulated Gate Bipolar Transistors (IGBT), and Integrated Gate Commutated Thyristors (IGCT). Thyristors do not have this capability and cannot be used although they are available in higher voltage ratings and tend to be cheaper with reduced losses. However, the technical advantages with VSC based controllers coupled will emerging power semiconductor devices using silicon carbide technology are expected to lead to the wide spread use of VSC based controllers in future.

BENEFITS WITH THE APPLICATION OF FACTS CONTROLLERS

Primarily, the FACTS controllers provide voltage support at critical buses in the system (with shunt connected controllers) and regulate power flow in critical lines (with series connected controllers). Both voltage and power flow are controlled by the combined series and shunt controller (UPFC).

The power electronic control is quite fast and this enables regulation both under steady state and dynamic conditions (when the system is subjected to disturbances). The benefits due to FACTS controllers are listed below.

1. They contribute to optimal system operation by reducing power losses and improving voltage profile.

2. The power flow in critical lines can be enhanced as the operating margins can be reduced due to fast controllability. In general, the power carrying capacity of lines can be increased to values up to the thermal limits (imposed by current carrying capacity of the conductors).

3. The transient stability limit is increased thereby improving dynamic security of the system and reducing the incidence of blackouts caused by cascading outages.

4. The steady state or small signal stability region can be increased by providing auxiliary stabilizing controllers to damp low frequency oscillations.

5. FACTS controllers such as TCSC can counter the problem of Sub-synchronous Resonance (SSR) experienced with fixed series capacitors connected in lines evacuating power from thermal power stations (with turbo-generators).

6. The problem of voltage fluctuations and in particular, dynamic over voltages can be overcome by FACTS controllers.

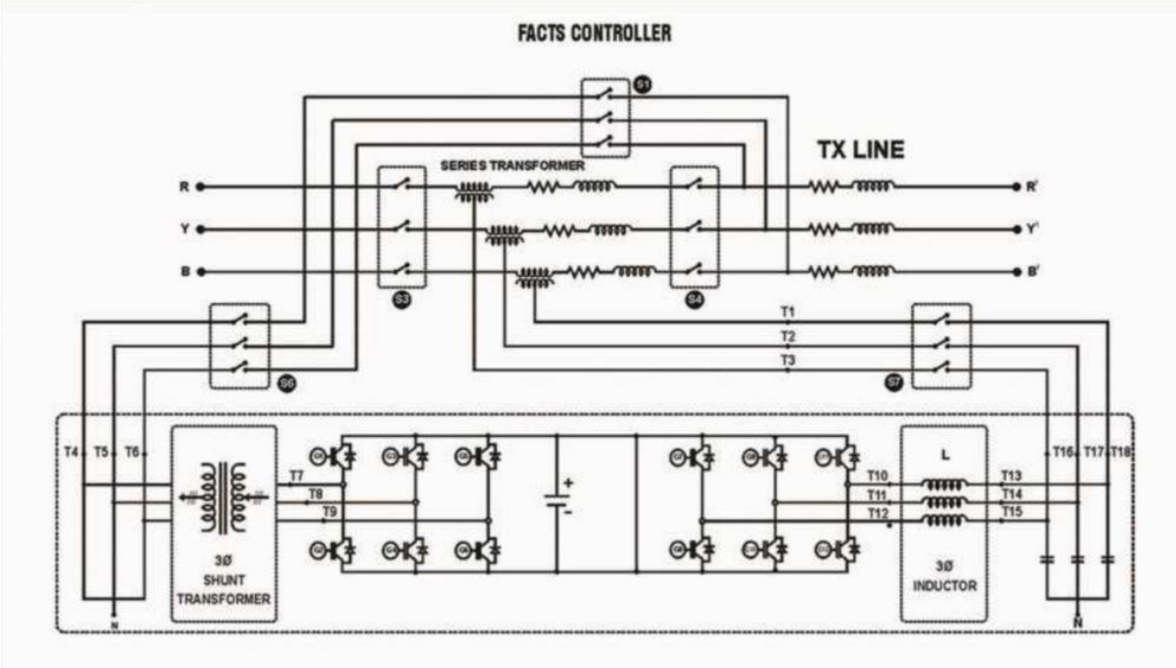


Figure 4.1 FACTS Transmission Line Model

APPLICATION OF FACTS CONTROLLERS IN DISTRIBUTION SYSTEMS

Although the concept of FACTS was developed originally for transmission network; this has been extended since last 10 years for improvement of Power Quality (PQ) in distribution systems operating at low or medium voltages.

In the early days, the power quality referred primarily to the continuity of power supply at acceptable voltage and frequency. However, the prolific increase in the use of computers, microprocessors and power electronic systems has resulted in power quality issues involving transient disturbances in voltage magnitude, waveform and frequency. The nonlinear loads not only cause PQ problems but are also very sensitive to the voltage deviations.

In the modern context, PQ problem is defined as "Any problem manifested in voltage, current or frequency deviations that result in failure or mal operation of customer equipment". The PQ problems are categorized as follows

1. Transients
    a. Impulsive
    b. Oscillatory
2. Short-duration and Long-duration variations
    a. Interruptions
    b. Sag (dip)
    c. Swell
3. Voltage unbalance
4. Waveform distortion
    a. DC offset
    b. Harmonics
    c. Inter-harmonics
    d. Notching

e. Noise

STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

A STATCOM is comparable to a Synchronous Condenser (or Compensator) which can supply variable reactive power and regulate the voltage of the bus where it is connected. The equivalent circuit of a Synchronous Condenser (SC) is shown in Fig. below, which shows a variable AC voltage source I whose magnitude is controlled by adjusting the field current. Neglecting losses, the phase angle (δ) difference between the generated voltage I and the bus voltage (V) can be assumed to be zero. By varying the magnitude of E, the reactive current supplied by SC can be varied. When E = V, the reactive current output is zero. When E > V, the SC acts as a capacitor whereas when E < V, the SC acts as an inductor. When δ = 0, the reactive current drawn (I_r) is given by

$$I_r = \frac{V - E}{X'}$$

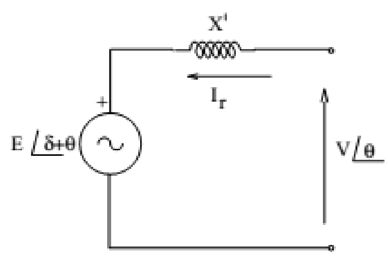


Figure 4.2 STATCOM Equivalent Circuit

A STATCOM (previously called as static condenser (STATCON)) has a similar equivalent circuit as that of a SC. The AC voltage is directly proportional to the DC voltage (V_{dc}) across the capacitor

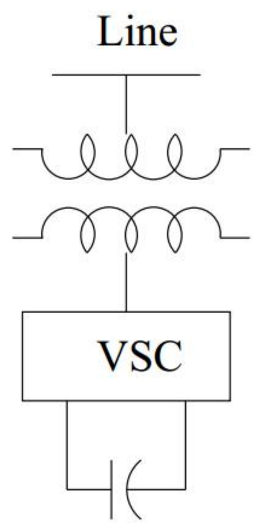


Figure 4.2 Block Diagram of VDC Connected Across Line

If an energy source (a battery or a rectifier) is present on the DC side, the voltage V_{dc} can be held constant. The self-commutated switches T_1 and T_2 (based on say GTOs) are switched on and off once in a cycle.

Unlike in the case of a SC, the capacitors can be charged from the AC side and there is no need of an energy source on the DC side if only reactive current is to be provided in steady state. The losses in the STATCOM can be met from the AC source. The advantages of a STATCOM over a SC are:

a. The response is much faster to changing system conditions.
b. It does not contribute to short circuit current.
c. It has a symmetric lead-lag capability.
d. It has no moving parts and hence the maintenance is easier.
e. It has no problems of loss of synchronism under a major disturbance.

STATIC SYNCHRONOUS SERIES COMPENSATOR

The Static Synchronous Series Compensator (SSSC) is a series connected FACTS controller based on VSC and can be viewed as an advanced type of controlled series compensation, just as a STATCOM is an advanced SVC. A SSSC has several advantages over a TCSC such as

a. Elimination of bulky passive components – capacitors and reactors
b. Improved technical characteristics
c. Symmetric capability in both inductive and capacitive operating modes
d. Possibility of connecting an energy source on the DC side to exchange real power with the AC network.

However, a SSSC is yet to be installed in practice except as a part of UPFC or Convertible Static Compensator (CSC

The schematic of a SSSC is shown in figure below.

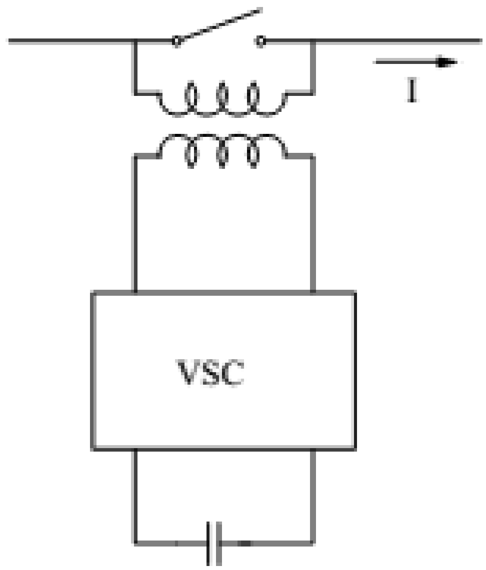


Figure 4.3 Block Diagram Of SSC Across Line

UNIFIED POWER FLOW CONTROLLER

The Unified Power Flow Controller (UPFC) proposed by Gyugyi is the most versatile FACTS controller for the regulation of voltage and power flow in a transmission line. The UPFC is a device which can control simultaneously all three parameters of line power flow. Such "new" FACTS device combines together the features of two "old" FACTS devices:

1. STATCOM
2. SSSC

These two devices are two Voltage Source Inverters (VSI's) connected respectively in shunt with the transmission line through a shunt transformer and in series with the transmission line through a series transformer, connected to each other by a common dc link including a storage capacitor.

It consists of two voltage source converters (VSC) one shunt connected and the other series connected. The DC capacitors of the two converters are connected in parallel. If the switches 1 and 2 are open, the two converters work as STATCOM and SSSC controlling the reactive current and reactive voltage injected in shunt and series respectively in the line. The closing of the switches 1 and 2 enable the two converters to exchange real (active) power flow between the two converters. The active power can be either absorbed or supplied by the series connected converter.

The provision of a controllable power source on the DC side of the series connected converter, results in the control of both real and reactive power flow in the line (say, measured at the receiving end of the line). The shunt connected converter not only provides the necessary power required, but also the reactive current injected at the converter bus. Thus, a UPFC has 3 degrees of freedom unlike other FACTS controllers which have only one degree of freedom (control variable)

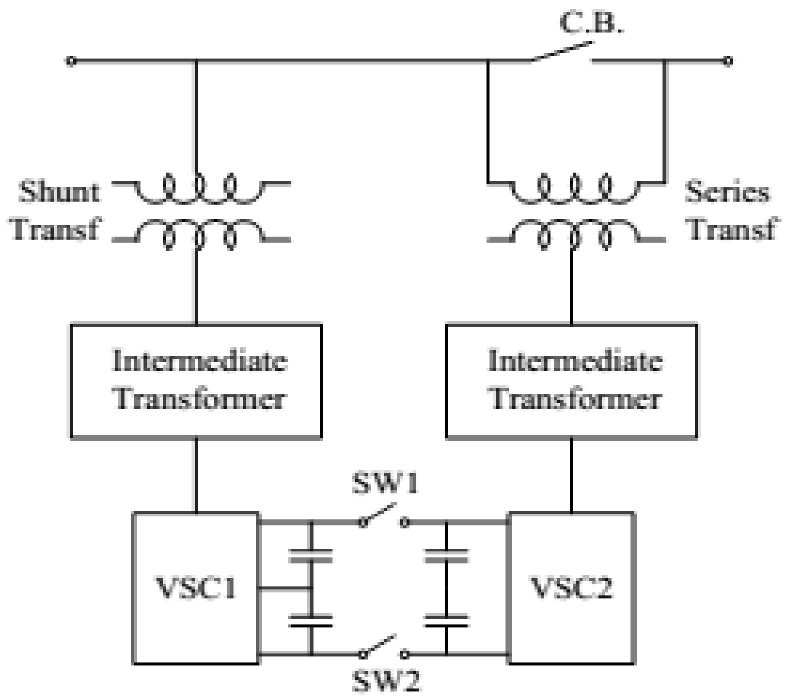


Figure 4.4 Unified Power Factor Controller

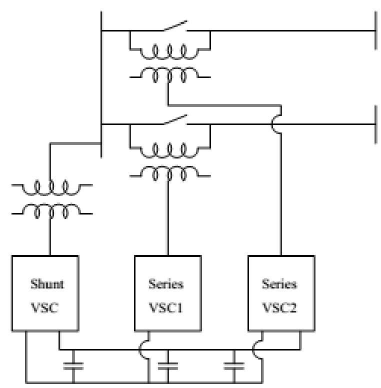


Figure 4.5 Three Converter GUPFC

The concept of combining two or more converters can be extended to provide flexibility and additional degrees of freedom. A Generalized UPFC (GUPFC) refers to 3 or more converters out of which one is shunt connected while the remaining converters are series connected

OPERATION OF A UPFC

A UPFC system can regulate the active and reactive power at same time. It has the ability to adjust the three control parameters (bus voltage, transmission line reactance, and phase angle between two buses, either simultaneously or independently). The converter 2 has the main function of the UPFC; it injects an AC voltage to the line, where magnitude and phase angle are controllable through a serial transformer. Converter 1 give or absorb the real power that the converter 2 demands.

Device	Load Flow Control	Voltage Control	Transient stability	Dynamic Stability
SVC	LESS	HIGH	LOW	MEDIUM
STATCOM	LESS	HIGH	MEDIUM	MEDIUM
UPFC	HIGH	HIGH	MEDIUM	MEDIUM

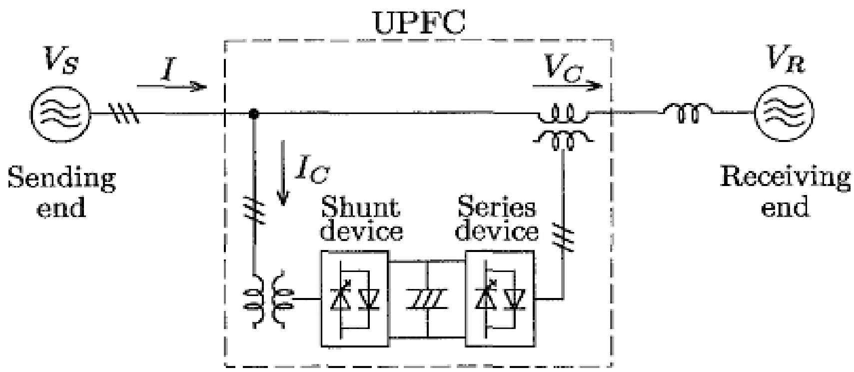


Figure 4.6 Unified Power Factor Controller Across Transmission Line

The shunt inverter is operating in such a way to inject a controllable current I_c into the transmission line.

This current consist of two components with respect to the line voltage**:**

1. Real or direct component i_d
2. Reactive or quadrature component i_q

The direct component is automatically determined by the requirement to balance the real power of the series inverter. The quadrature component, instead, can be independently set to any desired reference level (inductive or capacitive) within the capability of the inverter, to absorb or generate respectively reactive power from the line. So, two control modes are possible:

- VAR control mode : the reference input is an inductive or capacitive VAR request;
- Automatic Voltage Control mode: the goal is to maintain the transmission line voltage at the connection point to a reference value.

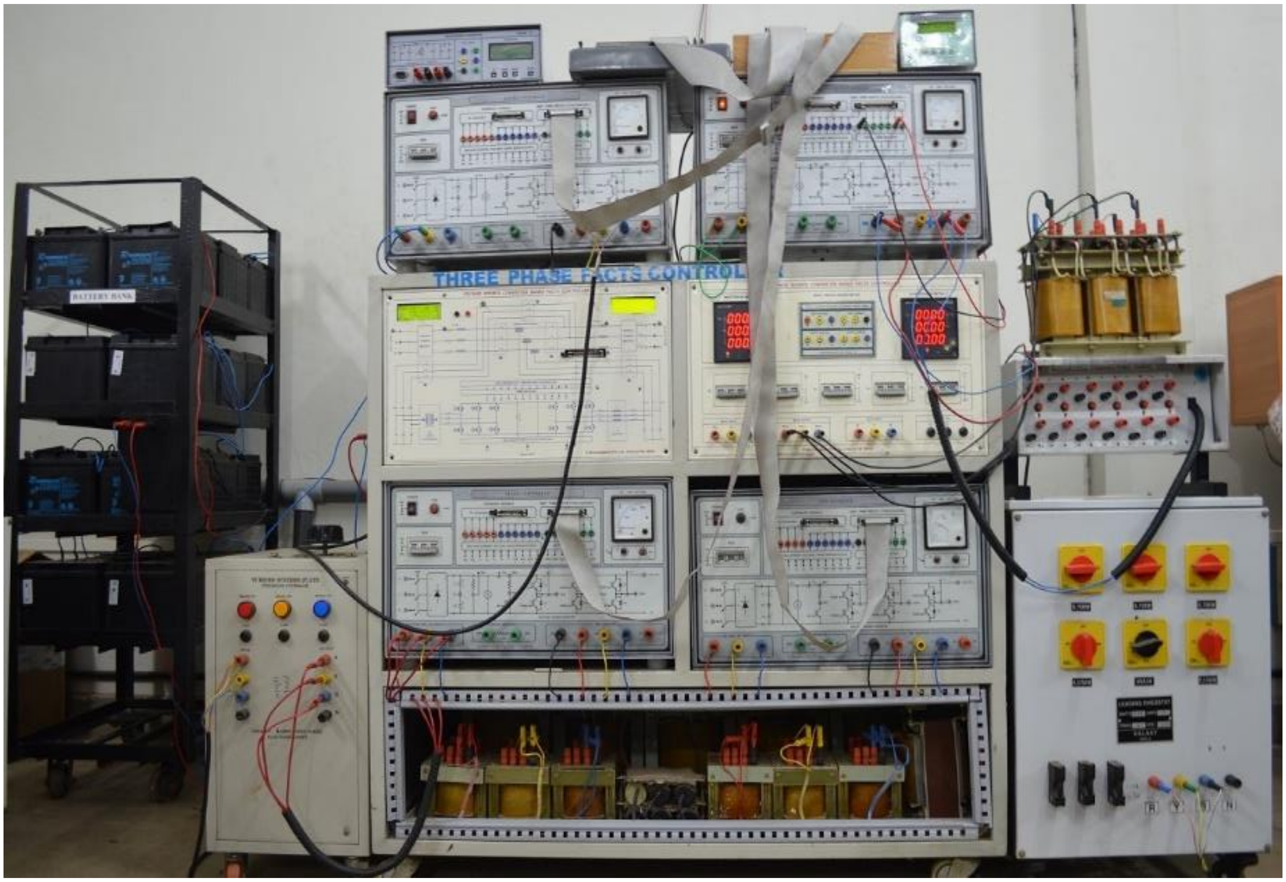
The series inverter injects a voltage, V_{se} which is controllable in amplitude and phase angle in series with the transmission line.

This series voltage can be determined in different ways:

- Direct Voltage Injection Mode: The reference inputs are directly the magnitude and phase angle of the series voltage.
- Phase Angle Shifter Emulation Mode: The reference input is phase displacement between the sending end voltage and the receiving end voltage.

- Line Impedance Emulation Mode: The reference input is an impedance value to insert in series with the line impedance.
- Automatic Power flow Control Mode: The reference inputs are values of P and Q to maintain on the transmission line despite system changes.

EXPERIMENTAL SETUP:



POWER QUALITY IMPROVEMENT OF A TRANSMISSION LINE USING FACTS

AIM:

1. To study the Flexible AC Transmission System set up for power factor compensation and voltage regulation of a transmission line module.
2. To provide combined shunt and series compensation in the transmission line using the FACTS controller to improve the receiving end power factor and zero voltage regulation for,
    i. Inductive loading.
    ii. Capacitive loading.

PROCEDURE:

For Battery Charging

1. Check the voltage rating of series connected battery bank.
2. Connect the output of the solar-wind wiring panel to the hybrid power controller. Connect the output terminals of the hybrid power controller to the battery bank through an ammeter.
3. Switch on the hybrid power controller, reset the protection circuit on it and check the DC rail voltage. Switch on the MCB on the battery charger.
4. Switch on the dsPIC based PWM generator and increase the duty ratio of PWM signal to obtain maximum power point.

STATCOM

1. Turn on the power switch of source inverter and STATCOM inverter.
2. Check whether any protection circuit is activated, and reset it.
3. Turn on the FPGA kit and select STATCOM operation.
4. Switch on MCB 1 and adjust the sending end voltage to 110 V (line to neutral) using switches SW_1 and SW_2 (select-switch upwards) on the interface board and note down the voltage, current, power factor, active power and reactive power at the sending end and receiving end for the applied load.
5. Increase the STATCOM modulation index to 95% using switches SW_1 and SW_2 (select switch downwards) on the interface board and Switch on MCB 4.
6. Adjust the angle of STATCOM using the switches SW_5 and SW_6 on the FPGA kit to make the sending and receiving end power factor to unity.
7. Note down the voltage, current, power factor, active power and reactive power at the sending end and receiving end and the STATCOM angle.
8. Switch off MCB 1 and MCB 4, reset the FPGA kit and repeat the procedure for different loading conditions.

SSSC

1. Turn on the power switch of source inverter and SSSC inverter.
2. Check whether any protection circuit is activated, and reset it.
3. Turn on the FPGA kit and select SSSC operation.
4. Switch on MCB 1 and adjust the sending end voltage to 110 V (line to neutral) using switches SW_1 and SW_2 (select-switch upwards) on the interface board and note down the voltage, current, power factor, active power and reactive power at the receiving end for the applied load.
5. Switch on MCB 2 and MCB 3, switch off MCB 1 and then switch on MCB 5.
6. Adjust the angle of SSSC using the switches SW_3 and SW_4 on the interface board to make the sending and receiving end voltage equal.
7. Note down the voltage, current, power factor, active power and reactive power at the sending end and the receiving end and the SSSC angle.
8. Switch off all the MCBs and reset the FPGA kit and repeat the procedure for different loading conditions.

UPFC

1. Turn on the power switch of source inverter, STATCOM inverter and SSSC inverter.
2. Check whether any protection circuit is activated, and reset it.
3. Turn on the FPGA kit and select UPFC operation.
4. Switch on MCB 1 and adjust the sending end voltage to 110 V (line to neutral) using switches SW_1 and SW_2 (select-switch upwards) on the interface board and note down the voltage, current, power factor, active power and reactive power at the sending end and the receiving end for the applied load.
5. Increase the STATCOM modulation index to 95% using switches SW_1 and SW_2 (select switch downwards) on the interface board and Switch on MCB 4.
6. Adjust the angle of STATCOM using the switches SW_5 and SW_6 on the FPGA kit to make the sending and receiving end power factor to unity.
7. Switch on MCB 2 and MCB 3, switch off MCB 1 and then switch on MCB 5.
8. Adjust the angle of SSSC using the switches S_3 and S_4 on the interface board to make the sending and receiving end voltage equal.
9. Note down the voltage, current, power factor, active power and reactive power at the sending end and the receiving end, STATCOM angle and the SSSC angle.
10. Switch off all the MCBs and reset the FPGA kit and repeat the procedure for different loading conditions.

RESULT:

OBSERVATIONS:

STATCOM

i. Inductive Loading = _____%

Quantity	Without STATCOM	With STATCOM
Voltage (V)		
Current (A)		
Active Power (kW)		
Reactive Power (kVar)		
Power Factor		

Phase Angle of STATCOM = _____

Reactive power supplied by STATCOM = _______ kVar.

ii. Inductive Loading = _____%

Quantity	Without STATCOM	With STATCOM
Voltage (V)		
Current (A)		
Active Power (kW)		
Reactive Power (kVar)		
Power Factor		

Phase Angle of STATCOM = _____

Reactive power supplied by STATCOM = _______ Kvar.

iii. Inductive Loading = _____%

Quantity	Without STATCOM	With STATCOM
Voltage (V)		
Current (A)		
Active Power (kW)		
Reactive Power (Kvar)		
Power Factor		

Phase Angle of STATCOM = _____

Reactive power supplied by STATCOM = _______ kVar.

SSSC

i. Inductive Loading = _____%

Quantity	Without SSSC	With SSSC
Voltage (V)		
Current (A)		
Active Power (kW)		
Reactive Power (kVar)		
Power Factor		

Amplitude of SSSC = _____

ii. Inductive Loading = _____%

Quantity	Without SSSC	With SSSC
Voltage (V)		
Current (A)		
Active Power (kW)		
Reactive Power (kVar)		
Power Factor		

Amplitude of SSSC = _____

iii. Inductive Loading = _____%

Quantity	Without SSSC	With SSSC
Voltage (V)		
Current (A)		
Active Power (Kw)		
Reactive Power (Kvar)		
Power Factor		

Amplitude of SSSC = _____

UPFC

i. Inductive Loading = _____%

Quantity	Without UPFC	With UPFC
Voltage (V)		
Current (A)		
Active Power (kW)		
Reactive Power (kVar)		
Power Factor		

Phase Angle of STATCOM = _____

Amplitude of SSSC = _____

ii. Inductive Loading = _____%

Quantity	Without UPFC	With UPFC
Voltage (V)		
Current (A)		
Active Power (kW)		
Reactive Power (kVar)		
Power Factor		

Phase Angle of STATCOM = _____

Amplitude of SSSC= _____

iii. Inductive Loading = _____%

Quantity	Without UPFC	With UPFC
Voltage (V)		
Current (A)		
Active Power (kW)		
Reactive Power (kVar)		
Power Factor		

Phase Angle of STATCOM = _____ Amplitude of SSSC = _____

STATCOM CONTROLLER

THEORY:

A static synchronous compensator (STATCOM), also known as a “static synchronous condenser” (STATCON), is a shunt connected FACTS device which uses force commutated power electronics(GTO, IGBT etc.) to inject reactive current into a power system for the purpose of controlling system voltage or power factor. It is based on a power electronics voltage source converter and can act as either a source or sink of reactive AC power to an electrical network. If connected to a source of power it can also provide active AC power.

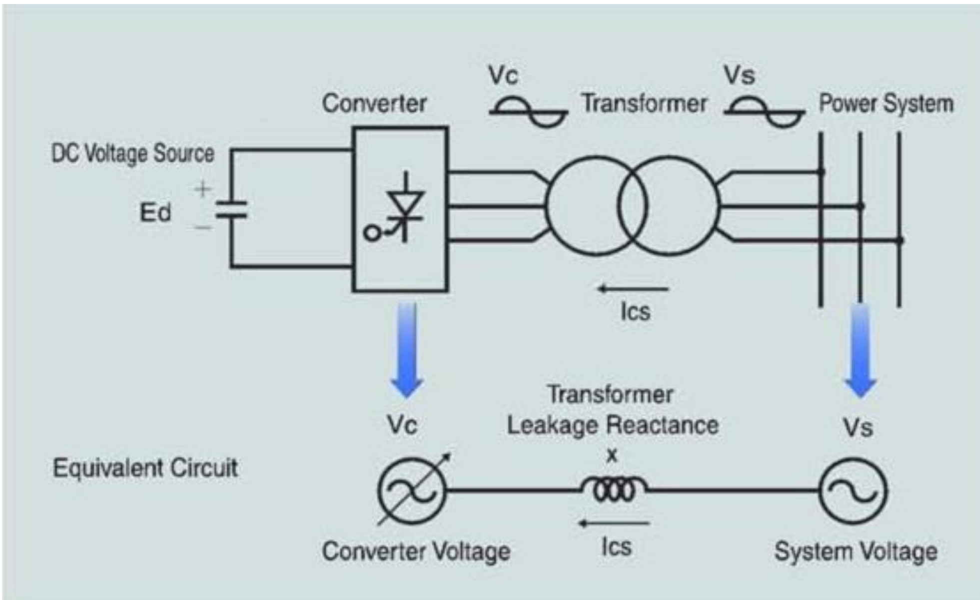


Figure 4.7 STATCOM Across Transmission Line

STATCOM is basically a voltage source converter (VSC) that converts a dc voltage at its input terminals into three phase ac voltages at fundamental frequency of controlled magnitude and phase angle. VSCs use pulse width modulation (PWM) technology, which makes it capable of providing high quality ac output voltage to the grid or even to a passive load. STATCOM provides shunt compensation in a similar way as static VAR compensator but utilizes a voltage source converter rather shunt capacitors and reactors. The basic principle of operation of a STATCOM is the generation of a controllable AC voltage source behind a transformer leakage reactance by a voltage source converter connected to a DC capacitor. The voltage difference across the reactance produces active and reactive power exchanges between the STATCOM and the power system.

Unlike SVC, STATCOM controls the output current independently of the AC system voltage, while the DC side voltage is automatically maintained to serve as a voltage source. Mostly, STATCOM is designed based on the voltage source inverter. Also, the combination of STATCOM with a different storage device or power source endows the STATCOM the ability to control the real power output.

Usually a STATCOM is installed to support electricity networks that have a poor power factor and often poor voltage regulation. The reactive power at the terminals of the STATCOM depends on the amplitude of the voltage source. For example, if the terminal voltage of the VSC is higher than the AC voltage at the point of connection, the STATCOM generates reactive current; on the other hand, when the amplitude of the voltage source is lower than the AC voltage, it absorbs reactive power. The response time of a STATCOM is shorter than that of an SVC, mainly due to the fast switching times provided by the IGBTs of the voltage source converter.

In the transmission systems, STATCOMs primarily handle only fundamental reactive power exchange and provide voltage support to buses by modulating bus voltages during dynamic disturbances in order to provide better transient characteristics, improve the transient stability margins and to damp out the system oscillations due to disturbances. The point of compensation can be sending end, midpoint or receiving end. Midpoint compensation is the most preferred one for transmission lines which results in improved voltage profile, reduced losses and increased transmission capability.

In distribution system, medium and low voltage STATCOM is employed mainly for

- Reactive power support at the load points.
- Harmonic control for nonlinear loads.

In addition, static synchronous compensators are installed in select points in the power system to perform the following:

- Voltage support and control
- Voltage fluctuation and flicker mitigation
- Unsymmetrical load balancing
- Power factor correction
- Active harmonics cancellation
- Improve transient stability of the power system

COMPONENTS OF THE SYSTEM

The lab consists of both solar panel based STSTCOM and wind generator based STATCOM. In solar panel based STSTCOM, solar panels are used for charging the battery bank while in wind generator based STATCOM, battery is charged using the wind turbine output. All other components of both the experimental setups are same, which are listed below.

i. Artificial Transmission Line Model.
   - Type : 3 Phase Pi equivalent Model.
   - Operating voltage : 220 V line to line.
   - Current Rating : 2.5 A.
   - Short Circuit Strength : 5 A.
   - Line Simulation through iron cored inductor. Each Pi section for 30km.

ii. Micro controller based charger for battery.
   - Micro controller based buck boost converter with MPPT algorithm.
   - IGBT switches.
   - Input voltage: 0-600 V.

iii. Battery Bank for 3 phase set up.
   - Low maintenance tubular batteries/ maintenance free.

- For 1 Kw: 12V/42 Ah – a set of 25 Nos.
- Total battery delivery capacity: 300 V/ 42 Ah.

iv. Source Inverter: A voltage source inverter based converter fed from battery bank with only magnitude control

v. STATCOM Inverter: A voltage source inverter with control over both magnitude and angle of injection.

vi. DSP Based Controller: PWM signals to both the source inverter and STATCOM inverter are controlled using a DSP based controller.

vii. R-L /R-C load.

BASIC PRINCIPLE OF OPERATION

In the case of two AC sources, which have the same frequency and are connected through a series reactance, the power flows will be:

- Active or Real Power flows from the leading source to the lagging source.
- Reactive Power flows from the higher to the lower voltage magnitude source.

Consequently, the phase angle difference between the sources decides the active power flow, while the voltage magnitude difference between the sources determines the reactive power flow. Based on this principle, a STATCOM can be used to regulate the reactive power flow by changing the output voltage of the voltage-source converter with respect to the system voltage.

MODES OF OPERATION

The STATCOM can be operated in two different modes:

A. Voltage Regulation

The static synchronous compensator regulates voltage at its connection point by controlling the amount of reactive power that is absorbed from or injected into the power system through a voltage-source converter.

In steady-state operation, the voltage V_2 generated by the VSC through the DC capacitor is in phase with the system voltage V_1 (δ=0), so that only reactive power (Q) is flowing (P=0)

- From a DC input voltage source, provided by the charged capacitor C_S, the converter produces a set of controllable three-phase output voltages with the frequency of the ac power system. Each output voltage is in phase with, and coupled to the corresponding ac system voltage via a relatively small (0.1-0.15 p.u.) tie reactance (which in practice is provided by the per phase leakage inductance of the coupling transformer).

- By varying the amplitude of the output voltages produced, the reactive power exchange between the converter and the ac system can be controlled in a manner similar to that of the rotating synchronous machine.

- That is, if the amplitude of the output voltage is increased above that of the ac system voltage, then the current flows through the tie reactance from the converter to the ac system, and the converter generates reactive (capacitive) power for the ac system.

- If the amplitude of the output voltage is decreased below that of the ac system, then the reactive current flows from the ac system to the converter, and the converter absorbs reactive (inductive) power. If the amplitude of the output voltage is equal to that of the ac system voltage, the reactive power exchange is zero.

Subsequently, the amount of reactive power flow is given by the equation:

$$\mathbf{Q = [V_1 (V_1 - V_2)] / X}$$

B. VAR Control

In this mode, the STATCOM reactive power output is kept constant independent of other system parameter

STATCOM V-I CHARACTERISTIC

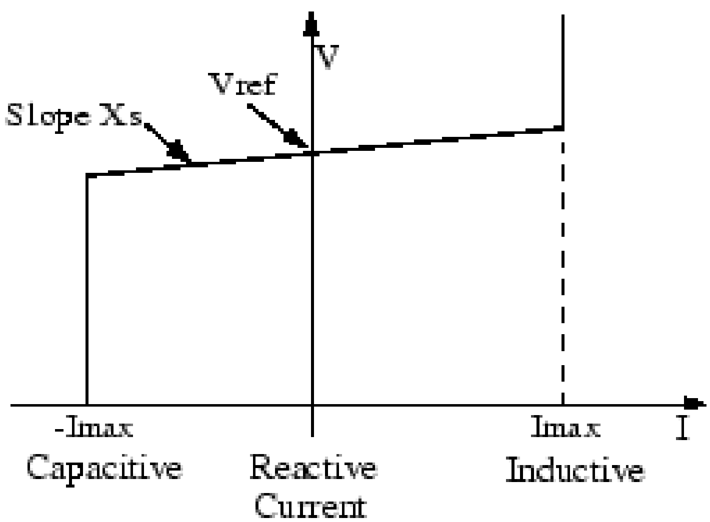
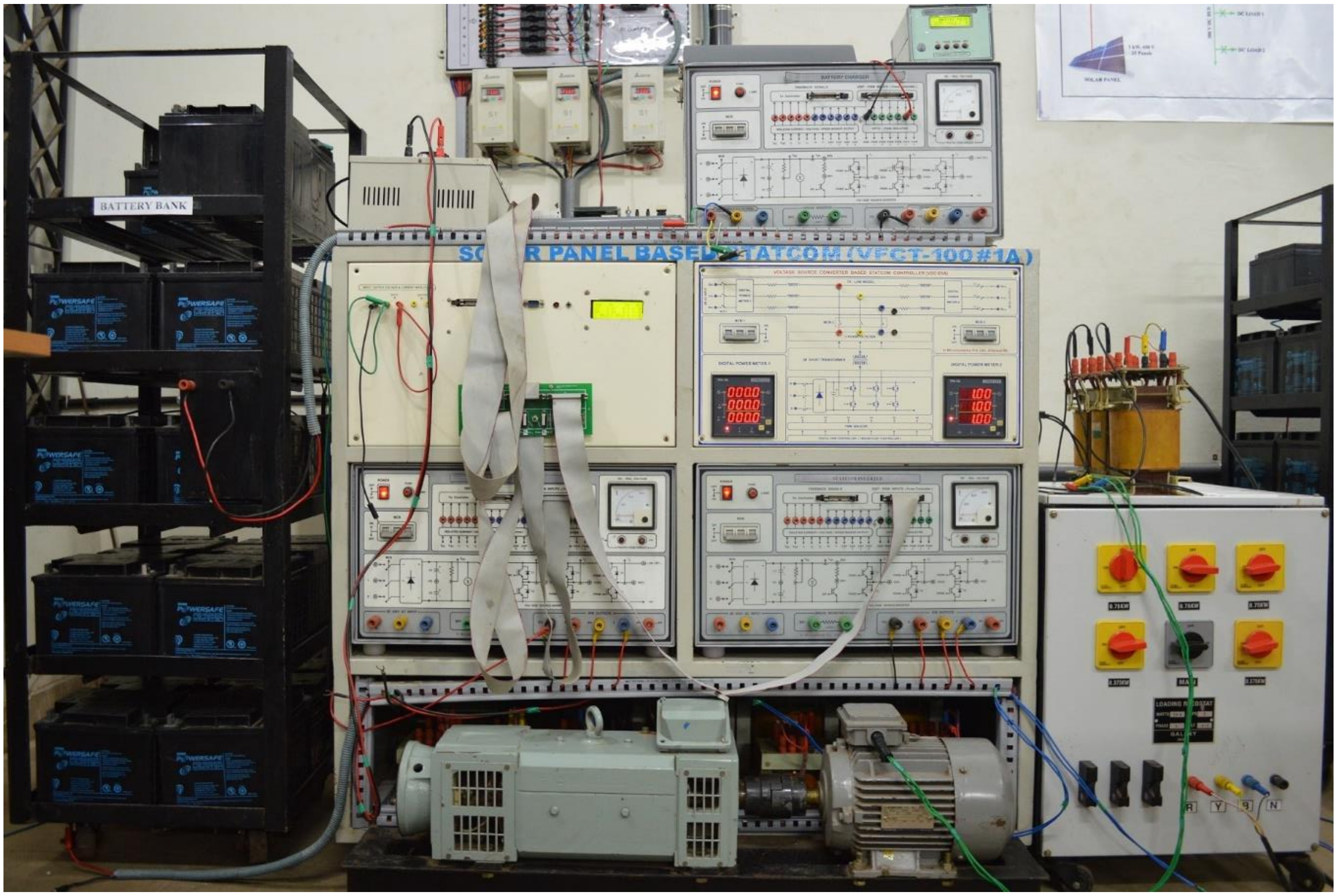


Figure 4.8 V-I Characteristics Of STATCOM Controller

Experimental Setup – Solar Panel Based STATCOM:



REACTIVE POWER COMPENSATION OF A TRANSMISSION LINE USING STATCOM

AIM:

1. To study the Solar Panel based STATCOM set up for power factor compensation of a transmission line module.
2. To adjust the midpoint compensation given by the Solar Panel based STATCOM to improve the sending end power factor of the transmission line for different loading conditions and compare the voltage regulation of the uncompensated and compensated lines.

PROCEDURE

For Battery Charging

1. Check the voltage rating of series connected battery bank.
2. From the solar-wind wiring panel, connect the required number of solar panels in series so that the total output voltage is 10 – 20% more than the voltage rating of battery bank. The voltage rating of each solar panel is 90 volts.
3. Now connect the output terminals of solar cell wiring panel to the input terminals of the battery charger. Connect the output terminals of battery charger to the battery bank through an ammeter.
4. Switch on the battery charger, reset the protection circuit on it and check the DC rail voltage. Switch on the MCB on the battery charger.
5. Switch on the DSPIC based PWM generator and increase the duty ratio of PWM signal to obtain maximum power point.

STATCOM

9. Turn on the power supply to source, battery charger and STATCOM.
10. Check whether any protection circuit is activated, and reset it.
11. Check the DC rail voltage for the battery charger.
12. Turn on the DSP kit and select STATCOM operation using the switch SW_2 on it.
13. Switch on MCB 1.
14. Adjust the sending end voltage to 110 V (line to neutral) using switches SW_1 and SW_2 on the interface board and note down the voltage, current, power factor, active power and reactive power at the receiving end for the applied load.
15. Increase the STATCOM modulation index to 80% using switches SW_3 and SW_4 on the interface board.
16. Switch on MCB 2 and note down the sending end and receiving end parameters.
17. Adjust the angle of STATCOM using the switches SW_2 and SW_3 on the DSP kit to improve the sending end and receiving end power factor.
18. Note down the voltage, current, power factor, active power and reactive power at both the ends.
19. Switch off MCB 2 and MCB 1.
20. Reset the DSP kit and repeat the procedure for different loading conditions.

RESULTS:

OBSERVATIONS:

A) Power Factor Compensation

i. Inductive Loading = _____%

Quantity	Without STATCOM	With STATCOM
Voltage (V)		
Current (A)		
Active Power (Kw)		
Reactive Power (Kvar)		
Power Factor		

Phase Angle of STATCOM = _____

Reactive power supplied by STATCOM = _______ Kvar.

ii. Inductive Loading = _____%

Quantity	Without STATCOM	With STATCOM
Voltage (V)		
Current (A)		
Active Power (Kw)		
Reactive Power (Kvar)		
Power Factor		

Phase Angle of STATCOM = _____

Reactive power supplied by STATCOM = _______ Kvar.

iii. Inductive Loading = _____%

Quantity	Without STATCOM	With STATCOM
Voltage (V)		
Current (A)		
Active Power (Kw)		

Reactive Power (Kvar)

Power Factor

Phase Angle of STATCOM = _____

Reactive power supplied by STATCOM = _______ Kvar.

iv. Inductive Loading = _____%

Quantity	Without STATCOM	With STATCOM
Voltage (V)		
Current (A)		
Active Power (Kw)		
Reactive Power (Kvar)		
Power Factor		

Phase Angle of STATCOM = _____

Reactive power supplied by STATCOM = _______ Kvar.

(B) Voltage Regulation

Sending End Voltage = 110V.

Inductive Loading	Receiving End Voltage		Voltage Regulation	
	Without STATCOM	With STATCOM	Without STATCOM	With STATCOM
100%				
80%				
60%				
40%				

5.MATLAB AND LABVIEW EXPERIMENTS

DC MOTOR SIMULATION AND ITS SPEED CONTROL USING PID, FUZZY AND FUZZY PID CONTROLLER IN LABVIEW AND SIMULINK

AIM

To use LabVIEW and Simulink to simulate the response of a dc motor based on a mathematical model derived from the physical model of the actual system. And then its speed control using PID, Fuzzy and Fuzzy PID Controller.

APPARATUS REQUIRED

PC with LabVIEW 8.5 Software and MATLAB 2013a.

DESCRIPTION

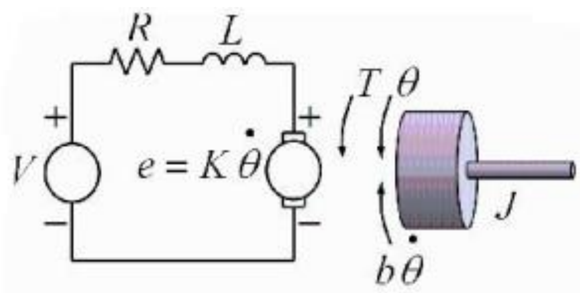


Fig 1. Mathematical model of a dc motor

Electrical Subsystem	Mechanical Subsystem
$Vapp = L\frac{di}{dt} + Ri + Eb$ $Eb = Kb * \frac{d\theta}{dt}$ $\frac{di}{dt} = \frac{(Vapp - Ri - Kb * \frac{d\theta}{dt})}{L}$	$J\frac{d^2\theta}{dt^2} + B\frac{d\theta}{dt} = T$ $T = Kt * i$ $\frac{d^2\theta}{dt^2} = \frac{(Kt * i - B * \frac{d\theta}{dt})}{J}$

J = Motor Inertia = 8.5E-6 (kg-m2)

B = Viscous damping coefficient = 3.7E-6

R = Internal resistance = 1.85(Ω)

L = Internal inductance =1.95(Mh)

Kt = Torque constant =4.24E-2 (N-m/A)

Kemf = Back emf constant =4.24E-2 (V/rad/sec)

Vapp = Applied voltage (volt)

Ɵ = Angular position of motor shaft (rad)

i(t) = Current through the motor at time t sec

PROCEDURE IN LABVIEW

Step 1:

Open the LabVIEW 8.5. Open a new project (empty project). The project window will appear then right click on "my computer"→"New"→"VI". A blank front panel will appear and behind that an empty block diagram.

Step 2:

Select the block diagram window (press control and E keys simultaneously). To view both block diagram and front panel windows simultaneously, press control +T.

Step 3:

Add a simulation loop within which the equations will be implemented. For this open LabVIEW function palette. Next click "control design and simulation" then click "simulation" and finally click the simulation loop.

Step 4:

Before implementing the equations save the VI file. Create 4 constant doubles 'Vapp', 'Kemf', 'R' and 'L' and one control "Theta dot".

Make sure each of these is set to double precision.

Step 5:

Implement the electrical subsystem

$$\frac{di}{dt}=\frac{(Vapp-Ri-Kb*\frac{d\theta}{dt})}{L}$$

This can be done by adding suitable blocks from function palette (like multiplication (3), addition (2) etc). Properly wire the blocks according to the equation given above.

Step 6:

Next we will want to encapsulate all that we have created thus far in order to reduce the complexity of the block diagram. To do this, select all of the blocks that we have placed inside the simulation loop by clicking and dragging a box around them. Then select "Edit"→"Create simulation subsystem". The blocks have now been incorporated into a separate VI. Save the VI.

Step 7:

Open a new VI. Create a simulation loop ass above and implement the equation for the mechanical portion of the system. To do this, first add three constant doubles, three multiplication blocks and one addition block. The three constants will be 'Kt', 'B' and "J". Wire them according to the equation given.

$$\frac{d^2\theta}{dt^2}=\frac{(Kt*i-B*\frac{d\theta}{dt})}{J}$$

Select the mechanical system blocks and create mechanical subsystem. Save the subsystem VI.

Step 8:

Open a new VI. Right click in the block diagram. Open a simulation loop. Click open "select a VI". Select the electrical subsystem and mechanical subsystem VI s. Interconnect the subsystems appropriately.

Add measuring blocks to graph i(t) and omega. Before running the VI, adjust the simulation parameters. Switch back to the block diagram, then right click on the simulation loop border and select "configure simulation parameters".

Change the final time to 0.1 seconds, ODE solver to "Runga-kutta1 (Euler)" and step size to 0.00001 seconds. Then click ok. Before running the completed VI, switch back to the front panel then right click on the graphs and select "chart history length". Enter 50000 for this value.

Change the ranges of X and Y axis. To do this double click the final value and change it to 0.10 for x-axis. Also change the y axis on the i(t) plot to range from 0-5 and the y-axis on the range omega plot to 0-150. Uncheck “Auto scale Y axis”. Finally click the run button to view the simulation results.

Step 9:

Replace the input voltage by a PID control block and check the system response by giving various values of the controller gains.

PROCEDURE IN MATLAB/SIMULINK

1. Model the DC Motor as according to the above equations.

2. Give load torque in the form of a STEP input.

3. Add a PID block and condition the error signal generated from the reference value, by entering different Kp, Ki and Kd values and hence check the response.

4. Open the fuzzy editor by typing fuzzy in the command prompt window.

5. Set up the membership functions for the input variables and the output variables.

6. Design a rule base for the input and the output variables and then export the editor file to the workspace.

7. Generate two input signals for the fuzzy controller, one is the error signal another change in error signal.

8. Pass the input signals through a multiplexor hence vectorizing them and hence give them as input to the fuzzy controller where the name of the editor file should be mentioned.

9. Observe the response of the fuzzy logic based speed control of DC Motor.

10. In a similar way design the fuzzy logic membership functions and rule base for Kp, Ki and Kd for implementing fuzzy-pid speed control of DC motor.

11. The output generated from the fuzzy controllers should be conditioned in such a way to generate a PID control signal.

12. Observe the response of fuzzy logic based PID controller based speed control of DC Motor.

PREREQUISITES

Study the following:

1) The mathematical model of the DC motor.
2) The speed-time and current-time curves.
3) Types of connections used for DC motors
4) Speed torque characteristics of DC motor.

EXPERIMENT ON NI COMPACT FIELD POINT

AIM:

To study and understand the Compact Field Point hardware and software configuration

PRINCIPLE:

NI Compact Field Point is a Programmable Automation Controller(PAC) which offers flexibility and ease of use of a PC and the reliability of a PLC. With Compact Field Point , powerful control and measurement systems can be developed using LABVIEW Real Time application. Thus it can be deployed on the intelligent controllers for reliable distributed I/O or standalone process control applications. In CFP, all the intelligence, advanced control and analytical capabilities of LABVIEW can be embedded in a small modular package which is suitable for industrial environment.

The Compact Field Point I/O modules can filter, calibrate and scale raw sensor signals to engineering units as well as perform self diagnostics to look for problems such as open thermocouple. Through built in net and servers, CFP interface automatically publishes measurement over Ethernet.

I/O MODULE FEATURES

Analog and Digital I/O modules for Compact Field Point are having the following features

- Direct Connectivity to sensors and actuators.
- 8 and 16 channel modules; individually configurable channels.
- Hot swappable and auto configurable.
- Programmable power up states.
- -40^{o}C to 70^{o}C operating range.

Connections Between PC and CFP

1. Connect the CFP to your PC using an Ethernet cross over cable.

2. Install and configure the CFP.

(i) Use the Measurement and Automation Explorer (MAX) to configure the CFP.

(ii) Go to remote systems. Right click on remote system and click create new.

(iii) Click on Field Point Ethernet and set the IP address.

(iv) All the CFP modules appear at that time.

Hardware Procedure

1. Connect the power supply cable to the NI Compact Field Point.

2. Connect the Ethernet cable between PC and CFP.

3. Select the respective I/O Module remove it from the backplane.

4. Make the respective wiring for input/output, power supply and common connector.

5. Place the I/O module to the backplane and lock it with the screw properly.

6. Give the analog/digital input to the respective wire or measure the output from the respective wire depending upon the applications.

Software Procedure

1. Open LABVIEW and select the Real Time Project.

2. Select the project type as "Continous Communication Architecture" and check "Application includes deterministic components". Enter the project name and the folder where it will be saved.

3. Choose the target configuration as one loop (default).

4. For selecting signal target, click browse→select "Existing device or target". From targets and devices explorer select "Real Time Field Point". Select Compact and press OK in the premium project explorer and click Finish.

5. Project Explorer will list the available analog and digital I/Os in the CFP.

6. Select the respective CFP and channel.

7. Juts drag and drop in the target window. Field Point I/O point will appear. Select the Value Pin and connect it to the system as either input/output

8. Perform the required operation and check the functionality on the respective analog/digital I/O.

EXPERIMENT ON NI MYDAQ

AIM:

To acquire Analog/Digital signal by interfacing NI myDAQ with LABVIEW

COMPONENTS REQUIRED:

1. PC with LABVIEW installed
2. NI myDAQ
3. Regulated Power Supply
4. Connecting wires

THEORY:

NI myDAQ is a portable low cost data acquisition (DAQ) device that uses NI LABVIEW software to measure and analyse real time signals. NI myDAQ is ideal for exploring and measuring real time sensor data. Combined with NI LABVIEW on the PC, acquired signals can be analysed, processed and controlled.

NI myDAQ provides analog input (AI), analog output (AO), digital input and output(DIO), audio, power supplies and digital multimeter(DMM) functions and a compact USB Device. The functions of each port of NI myDAQ is as follows

(i) Analog Input(AI): These are two analog input channels on NI myDAQ. These channels can be configured as general purpose high impedance differential voltage input or audio input.

(ii) Analog Output(AO): These are two analog output channels on NI myDAQ. These channels can be configured as either general purpose voltage output or audio output.

(iii) Digital Input/output(DIO): There are 8 DIO lines on NI myDAQ. Each line is a programmable function interface (PFI), meaning that it can be configured as a general purpose software timed digital input or output or it can act as a special function or output for a digital counter.

PROCEDURE

1. Connect NI myDAQ with PC using USB port and switch on RPS.
2. Connect positive terminal of the 0-30 V power supply to NI my DAQ(AI0+).
3. Connect negative terminal of the 0-30 V power supply to NI my DAQ(AI0-).
4. Open blank VI in LABVIEW.
5. Right click on the block diagram and obtain the DAQ assistant by clicking on Express→Input→DAQ assistant.
6. Click on the acquire signal→Analog Input→Voltage→a_i→finish

7. Now DAQ assistant window will appear select acquisition model as 1 sample (on demand) then click OK.

8. Connect a numeric indicator with data terminal of DAQ assistant block.

9. Now run the VI and observe the result.

10. Now apply the same procedure to apply input voltage supply through myDAQ to the DC Motor model in LABVIEW and observe the result.

11. Same procedure can be followed to acquire the digital input signal as well.

6. MICROCONTROLLER EXPERIMENTS

80196 MICROCONTROLLERS

ARCHITECTURE

The 80c196 is mainly based on :

1. A CPU which is turn composed of a 16-bit ALU with temporary registers, a 256-byte RAM used as 24 special registers and 232 general registers, and a micro programmed sequencer.
2. A memory controller with a 4-byte FIFO queue to pre fetch instructions and data from the program memory.
3. A set of I/O interfaces.

The CPU gets his information only through the memory controller and the special registers also called Special Function Registers (SFRs).

The ALU, is associated to a set of temporary registers (with shifter, counter, constants) and thus called RALU (Register ALU). The RALU doesn't use an accumulator but instead is able to directly work with any of the 256 special or general registers.

All I/O operations are controlled through the SFRs.

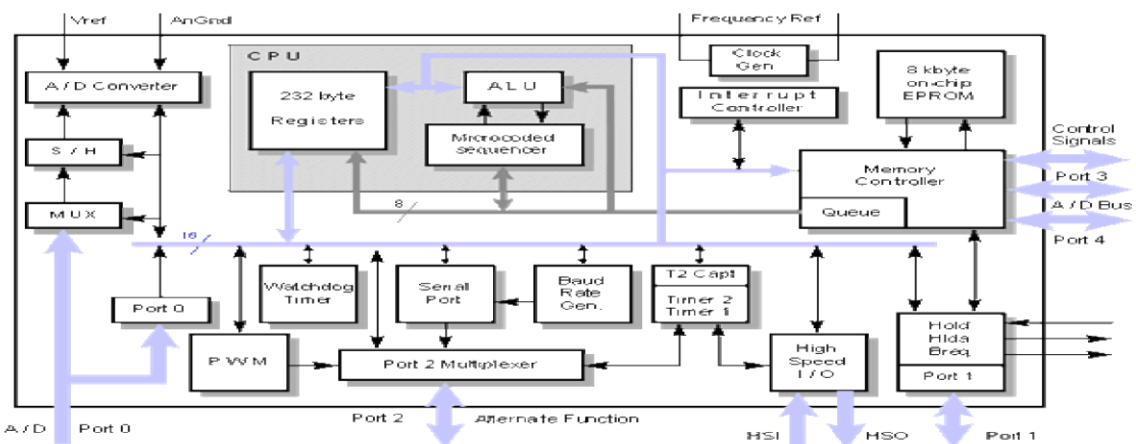


Figure 6.1 Architecture Of 80196 MicroController

MEMORY CONTROLLER

All of the program memory and external data memory are transferred to the CPU through the memory controller. The memory controller consists of a slave program counter, an instruction queue and a bus controller. The slave program counter keeps track of the instructions fetched from the program memory. Instructions fetched by the memory controller are stored in the queue. The slave program counter may be up to four bytes ahead of the main program counter (which is located in the RALU), because it is pre-fetching the instructions. The bus controller access program memory (on-chip EPROM) and external data memory and arbitrates between instruction fetches and data reads and writes. The bus controller supports both 8-bit and 16-bit external bus modes. Memory access requests to the bus controller can come from either the RALU or the queue, with priority given to the queue accesses. If the address sequence changes because of a jump interrupt, call or return, the slave PC is loaded with a new value, and the queue is flushed. Reloading the slave PC, flushing the queue and fetching the first byte of the new instruction stream takes 4 state times. This is reflected in the conditional jump taken/not taken execution times.

THE CPU

The CPU is controlled by a microcode sequencer and can perform operations on any byte, word or double-word in the 256-byte register space. Instructions to the CPU are taken from the pre fetch queue and temporarily stored in the instruction register. The sequencer decodes the instruction and generates the correct sequence of events to have the RALU perform the desired operation.

THE RALU

Most calculations performed by the 80c196 take place in the RALU. The RALU contains a 17bit ALU – Arithmetic and Logic Unit, the flag register also called PSW – Program Status Word, the main PC – Program Counter, a loop counter and three temporary registers. All registers are 16-bits or 17-bits wide. The PC has a separate incrementor as to access operands. However, PC changes due to jumps, interrupts, calls and returns are handled through the ALU. Two of the temporary registers have their own shift logic. These registers are used for the instructions which require logical shifts, including Normalize, Multiply and Divide. The upper word and lower word registers are used together for the 32-bit instructions and as temporary registers for many other instructions. Repetitive shifts are counted by the 6-bit loop counter. A third temporary register stores the second operand of two-operand instructions. To perform subtractions the output of this register can be complemented before being placed into the input of the ALU. The RALU also stores several constants such as 0, 1 and 2 to speed up certain operations like getting a 2’s complement, incrementing or decrementing.

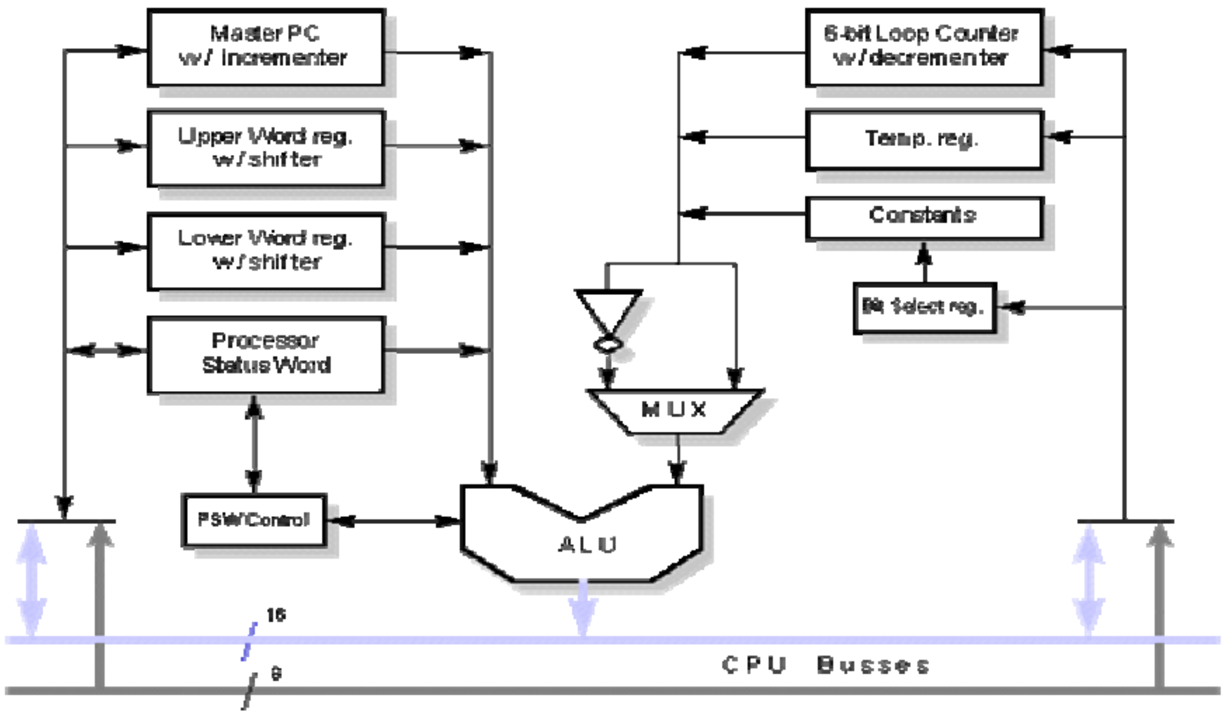


Figure 6.2 Register Arithmetic And Logic Unit

ADDRESSABLE SPACE

The addressable memory space of the 80c196 consists of 64k bytes. However, not all these addresses are available to the user. Addresses 0000H through 00FFH and 1FFEH through 207FH are reserved for special purposes. All other locations can be used for either program or data storage, or for memory-mapped I/O.

```
FFFFH +-------------------------+
      |                         |
      | External memory or I/O  |
      |                         |
4000H +-------------------------+
      | Internal ROM/EPROM or   |
      | external memory or I/O  |
2080H +-------------------------+
      |       Reserved          |
           2040H +---------------
           ----------+       | 8
           interrupt vectors    |
2030H +-------------------------+
      | ROM/EPROM security key  |
2020H +-------------------------+
      |       Reserved          |
2019H +-------------------------+
      | Chip Configuration byte |
```

```
2018H +-------------------------+
      |      Reserved         |
2014H +-------------------------+
      |  10 interrupt vector   |
2000H +-------------------------+
      |    Port 3 and port 4    |
1FFEH +-------------------------+
      | External memory or I/O  |
0200H +-------------------------+
      | 80c196KC internal RAM   |
0100H +---------------
----------+
Registers and SFRs
|
0000H +-------------------------+
   80c196 addressable space
```

REGISTERS (INTERNAL RAM)

Locations 00H through OFFH contain the 232 general registers and the 24 SFRs – Special Function Registers. The RALU can operate on any of these 256 internal register locations, but code cannot be executed from them. If attempt is made to execute instructions from locations 00H through OFFH, the instructions will be fetched from external memory. This section of external memory is generally used by the Intel development tools. Locations 018H through OFFH are the general registers. These locations can be accessed as byte, word or double-word registers, and can be essentially considered as 232 accumulators. Locations 018H and O19H contain the stack pointer. Operations to the stack cause it to be built down and the stack pointer is pre decremented, so the stack must be initialized by the user program to 2 bytes above the highest stack location. The stack pointer **must** point to a word (even) address.

SPECIAL FUNCTION REGISTERS (SFRS)

Locations 00H through O17H are the I/O control registers or SFRs. All of the peripheral devices of the 80c196 except ports 3 and 4 are controlled through these registers. SFR functions are controlled through 3 windows. Switching between the windows is done using the WSR – Window Select Register located at address 014H. SFR windows other than WSR = 0 are out of the scope of this course. Some of the Special Function Registers have different meanings if read from or written to.

RESERVED MEMORY LOCATIONS

Locations 1FFEH and O1FFFH are used for Ports 3 and 4 respectively. Many reserved and special locations are in the memory area between 2000H and 2080H. The 18 interrupt vectors, the chip configuration byte and the security key are located in this area.

GENERATION OF PWM SIGNAL USING 80196 MICRO CONTROLLERS

AIM:

To generate PWM signals using 80196 micro controllers.

APPARATUS REQUIRED:

1. 80196 Trainer kit
2. Key board
3. CRO
4. Connecting probes Theory:

THEORY:

The Intel 80196 features quick register to register transfers. The quick transfers are made possible by the absence of and intervening accumulator that would otherwise constrict data flow. The architecture has at least 230 bytes on chip RAM that may be operated upon as bytes, words, or double words. The RAM registers can interconnect through a 16 bit bus with themselves and a 16 bit ALU with the idea that each of the 232 registers is an "accumulator". The ALU of the 80196 has two 17 bit input ports (16bits + sign) denoted as "A" and "B" respectively. Temporary "Upper T1" and "Lower T1" word registers give input to the A port while Temporary "T2" and "Constant" registers input to the B port. The "Upper" and "Lower" registers have independent shift capabilities, but may be coupled and shifted together as a 32 bit unit. These registers are used for the repeated shift and add (shift and subtract) operations of multiplication (division). In between the "Temporary" and "Constant" registers and the ALU B port is a multiplexed inverter. The inverter gives a 1's complement of the "Temporary" register. A further edition of 1 from the "Constant" register gives a 2's complement.

PROGRAM:

Address	Op-code	Label	Mnemonic	Description
		A1	EQU 1A	
8200	B0 16 1A		LDB A1,16	Load register byte
8203	91 01 1A		ORB 1A, #1	Overwrite byte
8206	C4 16 1A		STB 1A, 16	Store byte
8209	B1 7F 17		LDB 17, #7F	Load byte

8206	27 FE		SJMP 810C	Termination of program

PROCEDURE:

1. Enter the above program

2. using an oscilloscope, observe the PWM output at 12^{th} pin of the analog I/O connector P2 (now the duty cycle is 50%) Output:

OBSERVATION

Frequency:

Amplitude:

RESULT:

PWM signal is generated using 80196 micro controller kit, with 50% duty ratio.

GENERATION OF SAW-TOOTH SIGNAL USING 80196 MICRO CONTROLLERS

AIM:

To generate SAW-TOOTH signals using 80196 micro controllers.

APPARATUS REQUIRED:

1.80196 Trainer kit
2. Key board
3. CRO
4. Connecting probes Theory:

THEORY

The Intel 80196 features quick register to register transfers. The quick transfers are made possible by the absence of and intervening accumulator that would otherwise constrict data flow. The architecture has at least 230 bytes on chip RAM that may be operated upon as bytes, words, or double words. The RAM registers can interconnect through a 16 bit bus with themselves and a 16 bit ALU with the idea that each of the 232 registers is an "accumulator". The ALU of the 80196 has two 17 bit input ports (16bits + sign) denoted as "A" and "B" respectively. Temporary "Upper T1" and "Lower T1" word registers give input to the A port while Temporary "T2" and "Constant" registers input to the B port. The "Upper" and "Lower" registers have independent shift capabilities, but may be coupled and shifted together as a 32 bit unit. These registers are used for the repeated shift and add (shift and subtract) operations of multiplication (division). In between the "Temporary" and "Constant" registers and the ALU B port is a multiplexed inverter. The inverter gives a 1's complement of the "Temporary" register. A further edition of 1 from the "Constant" register gives a 2's complement.

PROGRAM:

Address	Label	Mnemonics		Description
		Operator	Operand	
		ORG	8200H	
	DACPRT:	EQU	0FF10H	

	50:	EQU	50H	
	52:	EQU	52H	
8200	START	LD	50,#FF10	Loading the AX register with FF10H location
8204		LD	52,#00	Loading the BX register with 00H location
8208		ST	52,[50]	Storing Accumulator content to BX register
820B		ADD	52,#01	Pointing BX register to next location
820F		CMP	52,#0FFFH	Comparing BX location with 0FFFH
8213		JNE	8208	Jump to location 8208H
8215		SJMP	8200	To get next cycle

PROCEDURE:

1. Enter the above program
2. Using an oscilloscope, observe the SAW-TOOTH output at the Port output:

OBSERVATION

Frequency:

Amplitude:

RESULT:

The SAW-TOOTH wave is generated using 80196 micro controller kit.

80C51 MICROCONTROLLER:-

All 80C51 devices have separate address spaces for program and data memory, as shown in Figures 1 and 2. The logical separation of program and data memory allows the data memory to be accessed by 8-bit addresses, which can be quickly stored and manipulated by an 8-bit CPU. Nevertheless, 16-bit data memory addresses can also be generated through the DPTR register. Program memory (ROM, EPROM) can only be read, not written to. There can be up to 64k bytes of program memory. In the 80C51, the lowest 4k bytes of program are on-chip. In the ROM less versions, all program memory is external. The read strobe for external program memory is the PSEN (program store enable). Data Memory (RAM) occupies a separate address space from Program Memory. In the 80C51, the lowest 128 bytes of data memory are on-chip. Up to 64k bytes of external RAM can be addressed in the external Data Memory space. In the ROM less version, the lowest 128 bytes are on-chip. The CPU generates read and write signals, RD and WR, as needed during external Data Memory accesses. External Program Memory and external Data Memory may be combined if desired by applying the RD and PSEN signals to the inputs of an AND gate and using the output of the gate as the read strobe to the external Program/Data memory.

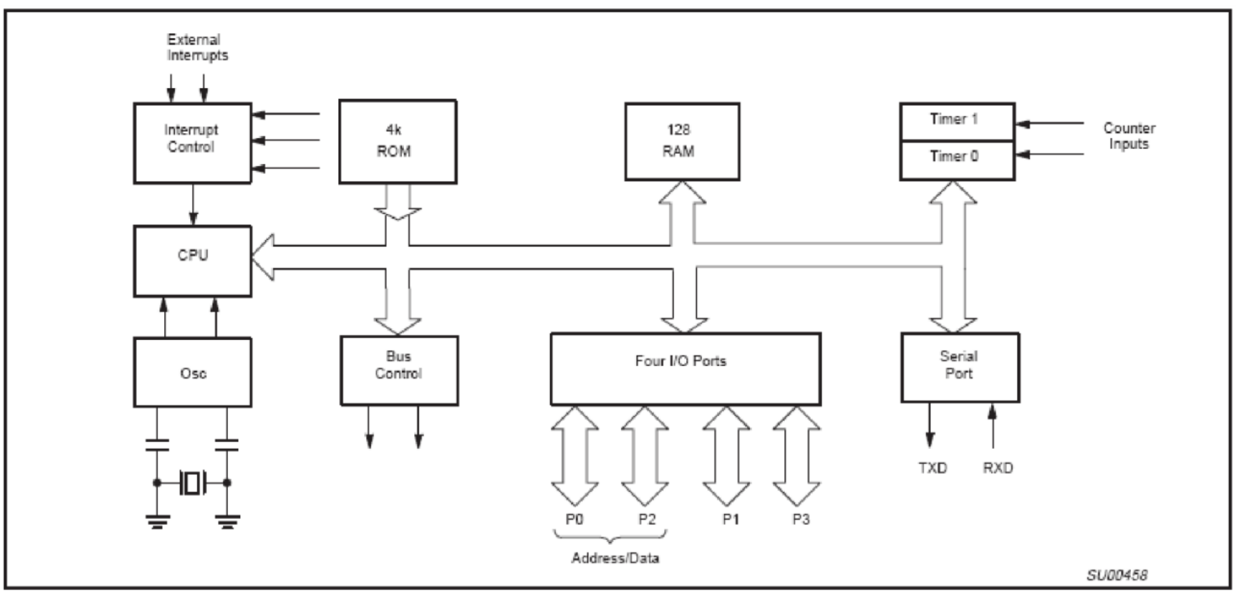


Figure 1. 80C51 Block Diagram

Figure 6.3 80C51 Block Diagram

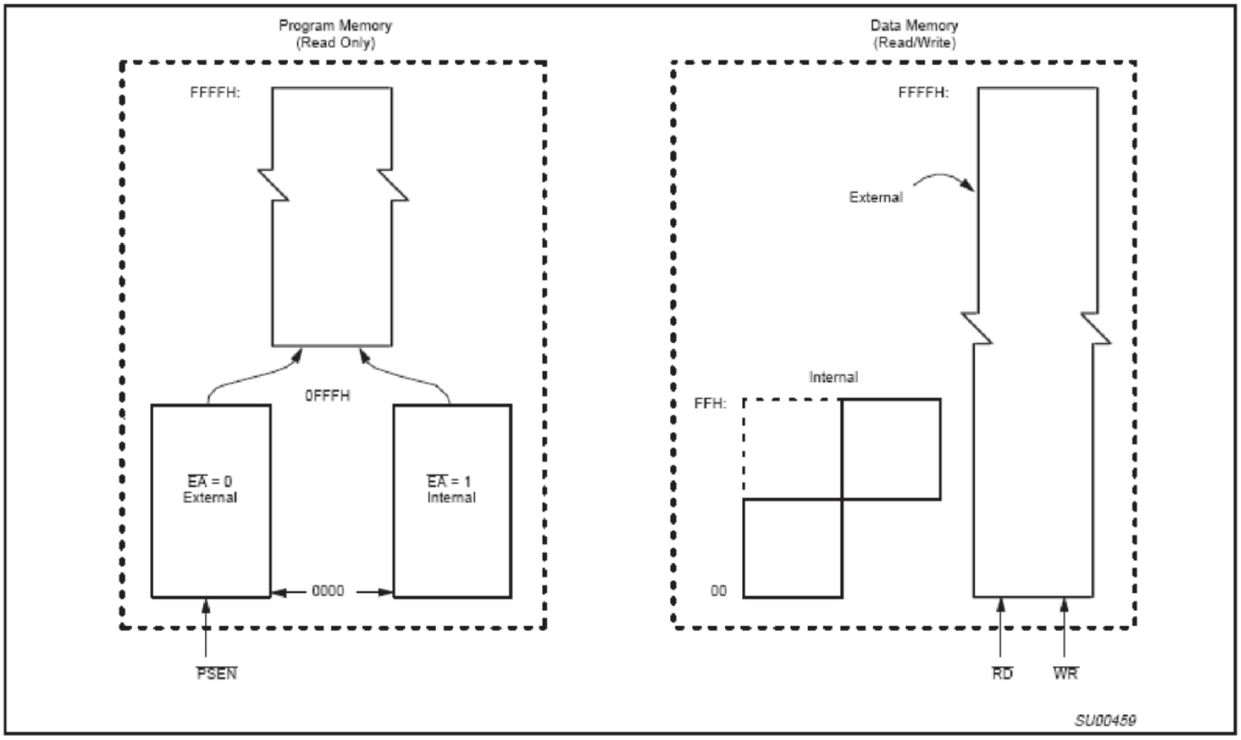


Figure 2. 80C51 Memory Structure

Figure 6.4 80C51 Memory Structure

Program Memory

Figure 3 shows a map of the lower part of the Program Memory. After reset, the CPU begins execution from location 0000H. As shown in Figure 3, each interrupt is assigned a fixed location in Program Memory. The interrupt causes the CPU to jump to that location, where it commences execution of the service routine. External Interrupt 0, for example, is assigned to location 0003H. If External Interrupt 0 is going to be used, its service routine must begin at location 0003H. If the interrupt is not going to be used, its service location is available as general purpose Program Memory.

The interrupt service locations are spaced at 8-byte intervals: 0003H for External Interrupt 0, 000BH for Timer 0, 0013H for External Interrupt 1, 001BH for Timer 1, etc. If an interrupt service routine is short enough (as is often the case in control applications), it can reside entirely within that 8-byte interval. Longer service routines can use a jump instruction to skip over subsequent interrupt locations, if other interrupts are in use.

The lowest 4k bytes of Program Memory can either be in the on-chip ROM or in an external ROM. This selection is made by strapping the EA (External Access) pin to either VCC, or VSS. In the 80C51, if the EA pin is strapped to VCC, then the program fetches to addresses 0000H through 0FFFH are directed to the internal ROM. Program fetches to addresses 1000H through FFFFH are directed to external ROM.

If the EA pin is strapped to VSS, then all program fetches are directed to external ROM. The ROM less parts (8031, 80C31, etc.) must have this pin externally strapped to VSS to enable them to execute from external Program Memory.
The read strobe to external ROM, PSEN, is used for all external program fetches. PSEN is not activated for internal program fetches. The hardware configuration for external program execution is shown in Figure 4. Note that 16 I/O lines (Ports 0 and 2) are dedicated to bus functions during external Program Memory fetches. Port 0 (P0 in Figure 4) serves as a multiplexed address/data bus. It emits the low byte of the Program Counter (PCL) as an address, and then goes into a float state awaiting the arrival of the code byte from the Program Memory. During the time that the low byte of the Program Counter is valid on Port 0, the signal ALE (Address Latch Enable) clocks this byte into an address latch. Meanwhile, Port 2 (P2 in Figure 4) emits the high byte of the Program Counter (PCH). Then PSEN strobes the EPROM and the code byte is read into the microcontroller.

Program Memory addresses are always 16 bits wide, even though the actual amount of Program Memory used may be less than 64k bytes. External program execution sacrifices two of the 8-bit ports, P0 and P2, to the function of addressing the Program Memory.

Data Memory

The right half of Figure 2 shows the internal and external Data Memory spaces available to the 80C51 user. Figure 5 shows a hardware configuration for accessing up to 2k bytes of external RAM. The CPU in this case is executing from internal ROM. Port 0 serves as a multiplexed address/data bus to the RAM, and 3 lines of Port 2 are being used to page the RAM. The CPU generates RD and WR signals as needed during external RAM accesses. There can be up to 64k bytes of external Data Memory. External Data Memory addresses can be either 1 or 2 bytes wide. One-byte addresses are often used in conjunction with one or more other I/O lines to page the RAM, as shown in Figure 5.

Two-byte addresses can also be used, in which case the high address byte is emitted at Port 2. Internal Data Memory is mapped in Figure 6. The memory space is shown divided into three blocks, which are generally referred to as the Lower 128, the Upper 128, and SFR space.

Internal Data Memory addresses are always one byte wide, which implies an address space of only 256 bytes. However, the addressing modes for internal RAM can in fact accommodate 384 bytes, using a simple trick. Direct addresses higher than 7FH access one memory space, and indirect addresses higher than 7FH access a different memory space. Thus Figure 6 shows the Upper 128 and SFR space occupying the same block of addresses, 80H through FFH, although they are physically separate entities.

The Lower 128 bytes of RAM are present in all 80C51 devices as mapped in Figure 7. The lowest 32 bytes are grouped into 4 banks of 8 registers. Program instructions call out these registers as R0 through R7. Two bits in the Program Status Word (PSW) select which register bank is in use. This allows more efficient use of code space, since register instructions are shorter than instructions that use direct addressing.

The next 16 bytes above the register banks form a block of bit-addressable memory space. The 80C51 instruction set includes a wide selection of single-bit instructions, and the 128 bits in this area can be directly addressed by these instructions. The bit addresses in this area are 00H through 7FH.

All of the bytes in the Lower 128 can be accessed by either direct or indirect addressing. The Upper 128 (Figure 8) can only be accessed by indirect addressing.

Figure 9 gives a brief look at the Special Function Register (SFR) space. SFRs include the Port latches, timers, peripheral controls, etc. These registers can only be accessed by direct addressing. Sixteen addresses in SFR space are both byte- and bit-addressable. The bit addressable SFRs are those whose address ends in 0H or 8H.

<u>STEPPER MOTOR ROTATION IN FORWARD AND BACKWARD DIRECTION BY USING 8051 MICROCONTROLLER</u>

<u>AIM: -</u>

To run a stepper motor in Forward and Backward Direction using 8051 microcontroller.

<u>APPARATUS:-</u>

1. 8051 Microcontroller.
2. Keyboard
3. Stepper Motor
4. Interfacing Kit

<u>PROCEDURE:-</u>

1. Interface the 8051 Microcontroller kit with the stepper motor.
2. Enter the program.
3. Call the program and observe the rotation of stepper motor.

<u>PROGRAM:</u>

ADDRESS	OPCODE	LABEL	MNEMONICS	COMMENTS
4100			ORG	4100H
		SMOD52		
4100	7C 33	START	MOV R4, #33H	Initialize count
4102	90 41 44	L2	MOV DPTR,#FORWARD	Initalize pointer
4105	12 41 1C		LCALL L1	Long jump to loop1
4108	DC F8		DJNZ R4,L2	Decrement R4
410A	12 41 3B		LCALL DELAY	
410D	7C 33		MOV R4,#33H	Initialize count
410F	90 41 48	L3:	MOV DPTR,#REVERSE	Initialize pointer
4112	12 41 1C		LCALL L1	Long call loop1

4115	DC F8		DJNZ R4,L3	Decrement R4
4117	12 41 3B		LCALL DELAY	Wait for subroutine
411A	80 E4		SJMP START	Short jump to start
411C	78 04	L1:	MOV R0,#04H	Move 04 to reg R0
411E	E0	LOOP:	MOVX A,@DPTR	
411F	C0 83		PUSH 83H	
4121	C0 82		PUSH 82H	
4123	90 FF C0		MOV DPTR,#FFC0H	Move FFC0 data to DPTR
4126	7A 04		MOV R2,#04H	Move 04 to reg R2
4128	79 05	L7:	MOV R1,#05H	Move 05 to reg R1
412A	7B FF	L6:	MOV R3, #FFH	Move FF to reg R3
412C	DB FE	L4:	DJNZ R3,L4	Decrement R3 go to L4
412E	D9 FA		DJNZ R1,L6	Decrement R1 go to L6
4130	DA F6		DJNZ R2, L7	Decrement R2 go to L7
4132	F0		MOVX@DPTR,A	Move A to DPTR
4133	D0 82		POP 82H	
4135	D0 83		POP 83H	
4137	A3		INC DPTR	Increment pointer
4138	D8 E4		DJNZ R0,LOOP	
413A	22		RET	

413B	7D 01	DELAY:	MOV R5,#01H	Move 01 to reg R5
413D	7A 01	L9:	MOV R2,#01H	Move 01 to reg R2
413F	DA FE	L8:	DJNZ R2,L8	Decrement R2
4141	DD FA		DJNZ R5, L9	Decrement R5
4143	22		RET	
4144	09 05 06 0A	FORWARD:	DB 09H, 05H,06H,0AH	
4148	0A 06 05 09	REVERSE:	DB 0AH,06H,05H,09H	

RUN A STEPPER MOTOR FOR REQUIRED ANGLE WITHIN 360^0 WHICH IS EQUIVALENT TO 256 STEPS.

AIM:

To run a stepper motor for required angle within 360^0 this is equivalent to 256 steps using 8051 microcontroller.

APPARATUS:-

1. 8051 Microcontroller.
2. Keyboard
3. Stepper Motor
4. Interfacing Kit

PROCEDURE:-

1. Interface the 8051 Microcontroller kit with the stepper motor.
2. Enter the program.
3. Call the program and observe the rotation of stepper motor.

PROGRAM:-

ADDRESS	OPCODE	LABEL	MNEMONICS	COMMENTS
4100			ORG	4100H
4100	7C FF		MOV R4, #FFH	Hex data for 360^0
4102	90 41 44	START:	MOV DPTR,#LOOK UP	Initalize pointer
4105	78 04		MOV R0, #04H	Move 04 to reg R0
4107	E0	JO:	MOVX A,@DPTR	
4108	C0 83		PUSH DPH	
410A	C0 82		PUSH DPL	
410C	90 FF C0	L3:	MOV DPTR,#FFC0H	Initialize pointer
410F	F0		MOVX@DPTR,A	Move A to DPTR
4110	DC 06		DJNZ R4,CALL	Decrement R4
4112	80 FE	HLT:	SJMP HLT	Short jump to HLT
4114	09 05 06 0A	LOOK UP:	DB 09H ,05H,06H,0AH	

4118	7A 03	CALL:	MOV R2, #03H	Move 03 to reg R2
411A	79 FF	DLY2:	MOV R1,#FFH	Move FF to reg R1
411C	7B FF	DLY1:	MOV R3,#FFH	Move FF to ref R3
411E	DB FE	DLY:	DJNZ R3,DLY	Decrement R3 go to DLY
4120	D9 FA		DJNZ R1,DLY1	Decrement R1 go to DLY 1
4122	DA F6		DJNZ R2,DLY 2	Decrement R2 go to DLY 2
4124	D0 82		POP DPL	
4126	D0 83		POP DPH	
4128	A3		INC DPTR	Increment pointer
4129	D8 DC		DJNZ R0, JO	
412B	80 D5		SJMP START	
412D			END	

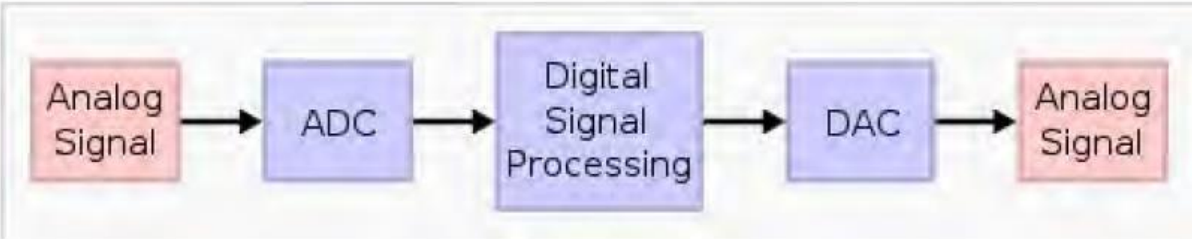
RESULT:

The stepper motor was made to rotate for required angle within 360^0 which is equivalent to 256 steps using 8051 Microcontroller.

7.DSP BASED MOTOR CONTROL

DIGITAL SIGNAL PROCESSOR

Digital signal processing algorithms require a large number of mathematical operations to be performed quickly on a set of data. Signals are converted from analog to digital, manipulated digitally, and then converted again to analog form, as diagrammed below. Many DSP applications have constraints on latency; that is, for the system to work, the DSP operation must be completed within some time constraint.



A simple digital processing system

Figure 7.1 A Digital Signal Processing System

Most general-purpose microprocessors and operating systems can execute DSP algorithms successfully. But these microprocessors are not suitable for application of mobile telephone because of power supply and space limit. A specialized digital signal processor, however, will tend to provide a lower-cost solution, with better performance and lower latency.

- DSP often use special memory architectures that are able to fetch multiple data and/or instructions at the same time:
  - Harvard architecture
  - Modified von Neumann architecture
- Use of direct memory access
- Memory-address calculation unit.

Modern signal processors yield greater performance. This is due in part to both technological and architectural advancements like lower design rules, fast-access two-level cache, IDMA circuit and a wider bus system.

APPLICATIONS OF DSP

The main applications of DSP are audio signal processing, audio compression, digital image processing, video compression, speech processing, speech recognition, digital communications, RADAR, SONAR, seismology, and biomedicine. Specific examples are speech compression and transmission in digital mobile phones, room matching equalization of sound in Hi-Fi and sound reinforcement applications, weather forecasting, economic forecasting, seismic data processing, analysis and control of industrial processes, computer-generated animations in movies, medical imaging such as CAT scans and MRI, MP3 compression, image manipulation, high fidelity loud speaker crossovers and equalization, and audio effects for use with electric guitar amplifiers.

IMPLEMENTATION OF DSP

Digital signal processing is often implemented using specialized microprocessors such as theDSP56000, the TMS320, or the SHARC. These often process data using fixed-point arithmetic although some versions are available which use floating point arithmetic and are more powerful. For faster applications FPGAs might be used. Beginning in 2007, multicore implementations of DSPs have started to emerge from companies including Free scale and Stream Processors, Inc. For faster applications with vast usage, ASICs might be designed specifically. For slow applications, a traditional slower processor such as a microcontroller may be adequate.

EXPERIMENT ON DSP BASED MOTOR SPEED CONTROL

AIM:

1. To control the speed of motor using DSP controller.
2. To study the variation in settling time and peak overshoot by the variation of the PID controller settings.

APPARATUS REQUIRED:

1. DSP Trainer Kit(TMS320F2407)
2. 3 phase induction motor (2.2Kw, 415V, 4.4A, 50Hz, 1435rpm) with speed sensor
3. 3 phase autotransformer
4. IPM based power module
5. PC with DSP software (C2407 serial Monitor software).

PROCEDURE:

1. Load the software to the PC
2. Open the software
3. Switch on the DSP trainer kit and the motor starter.
4. Connect the DSP kit and controller module
5. Open the folder and select the control required
6. Give the PID parameters
7. Run the program
8. Verify the speed response of the motor by varying the controller settings.

DESCRIPTION:

Speed of the AC induction motor can be controlled by varying the input voltage to the motor. This can be achieved by using a DSP kit to produce variable voltage. Variable voltage is produced by triggering the IGBT's in the power module at different angles. DSP processor is producing the necessary PWM gating signals for the IGBT triggering. Speed sensor will sense the speed and gives equivalent voltage signals to the power module. From power module, control, signal are fed to the DSP through ADC. PWM signals from the DSP are given back to the power module which controls the speed of the motor. Hence it is a feedback system. We can vary the PI controller settings and verify the controller performance.

OBSERVATION:

Open loop control:

P	I	D	CURRENT	% OVERSHOOT	SETTLING TIME

Closed loop control:

P	I	D	CURRENT	% OVERSHOOT	SETTLING TIME

RESULT:

Speed of AC motor is controlled by using digital signal processor. The controller settings are varied and variations are observed of the system according to the different settings.

8.LINEAR INDUCTION MOTOR

INTRODUCTION

The Linear Motor is composed of two main parts a movable vehicle and a stationary rail is a simplealuminium plate mounted on an iron support. The movable vehicle contains stator of the linear motor and the stationary rail of the rotor. This is contrary to an ordinary rotating motor in which the stator is stationary and the rotor is moving.

The stator is composed of a three-legged laminated iron core upon which are mounted three identical coils A, B, C, A cross section view is shown in Figure 1. The three coils, powered by a three-phase source, can be connected either in wye or delta (Figure 2). Unless otherwise stated,

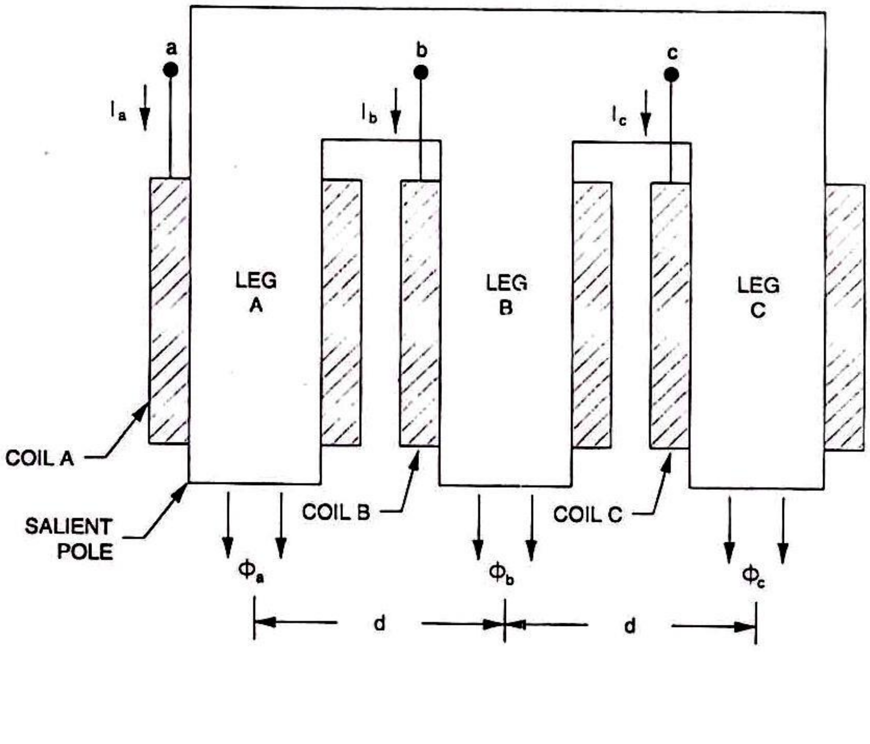


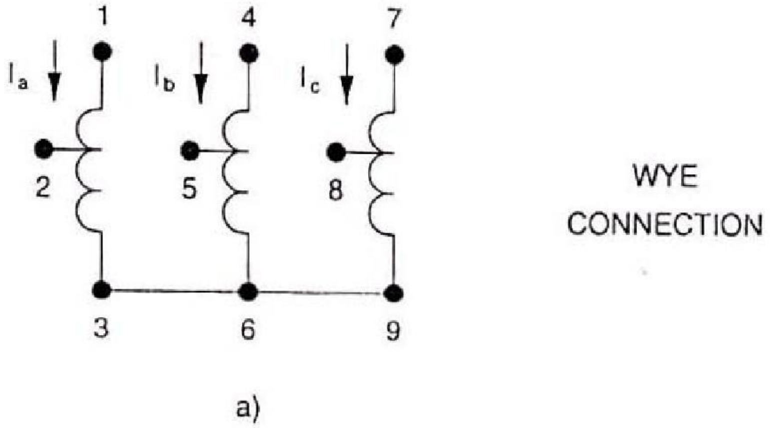
Figure 8.1 Coil Structure Of Linear Induction Motor

The coils produce in each leg and corresponding salient pole, fluxes that are 125abelled$_a$, $_b$ and $_c$. These fluxes are created by the currents l_a, l_b, l_c that flow in the respective windings; consequently, the fluxes are 120° out of phase. This phase shift means that the fluxes attain their maximum values at different times, separated by intervals of 1/3f where f is the frequency of the source. For example, if the frequency is 50Hz, and the phase sequence is A-B-C, flux $_b$ will attain its maximum value 1/150 s after $_a$. Similarly, $_c$ will reach its maximum value 1/150 s after $_b$. Thus, by referring to Figure 1, it can be seen that the flux continually shifts from left to right across the face of the salient poles. If two of the supply lines are interchanged, the phase sequence will reverse, and the flux will shift from right to left across the poles.

Frequency f is 50Hz , the linear synchronous speed is

$$V_s = 3\ d\ f = 3 \times 0.048 \times 50 = 7.2\text{m/s}$$

This corresponds to a speed of about 25.92km/h [(7.2/1000)*3600)].



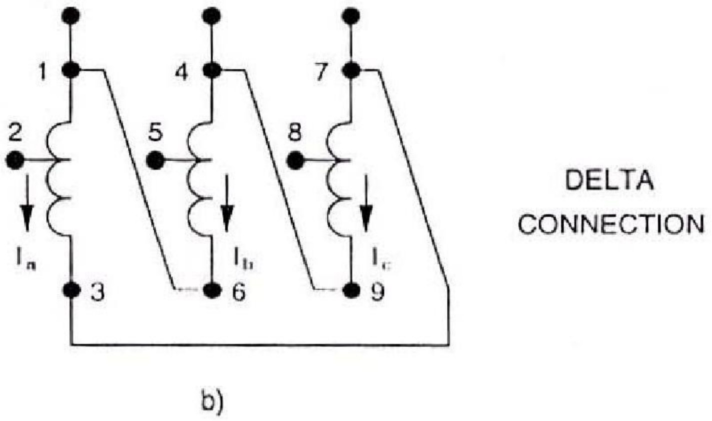


Figure 8.2 Supply Connection Schemes For Linear Induction Motor

PRINCIPLE OF A LINEAR INDUCTION MOTOR

Consider now an aluminium plate 1 mounted on a iron support 2, that faces the salient poles of the stator (figure 3). The iron support also offers a high permeability path for the magnetic flux coming from the poles. As the flux sweeps from left to right across the aluminium plate, it will induce a current according to principle of Faraday's law. This current is in the path of the very flux that created it, and so a tractive force, or electromagnetic thrust, will be exerted upon the plate, tending to drag it along with the moving flux. Therefore, if the vehicle is stationary, the plate will tend to move to the right. But if the plate is fixed, and the vehicle is free to move, the latter will start moving to the left. As the vehicle picks up speed, the flux will continue to sweep across the plate (now called a rail and the thrust would fall to zero. As a result, the vehicle would immediately begin to slow down. The final steady-state speed would be that where the friction and drag on the vehicle is exactly equal to the thrust exerted on the rail by the moving flux.

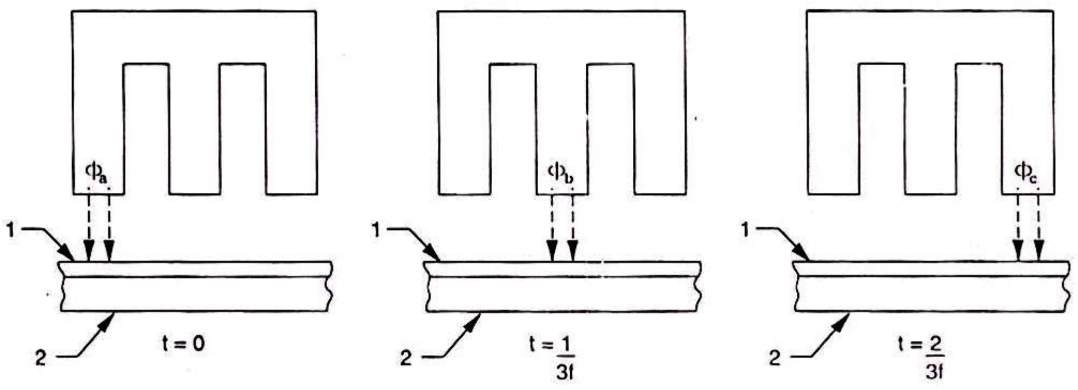


Figure 8.3 Principle Of A Linear Induction Motor

ACTIVE POWER FLOW IN A LINEAR MOTOR

It is important to observe the power aspects of the linear induction motor. Refering to Figure the active power (watts) P1 from the sources flows into the windings and a portion P2 isdissipated in the form of heat due o the I^2R copper losses.

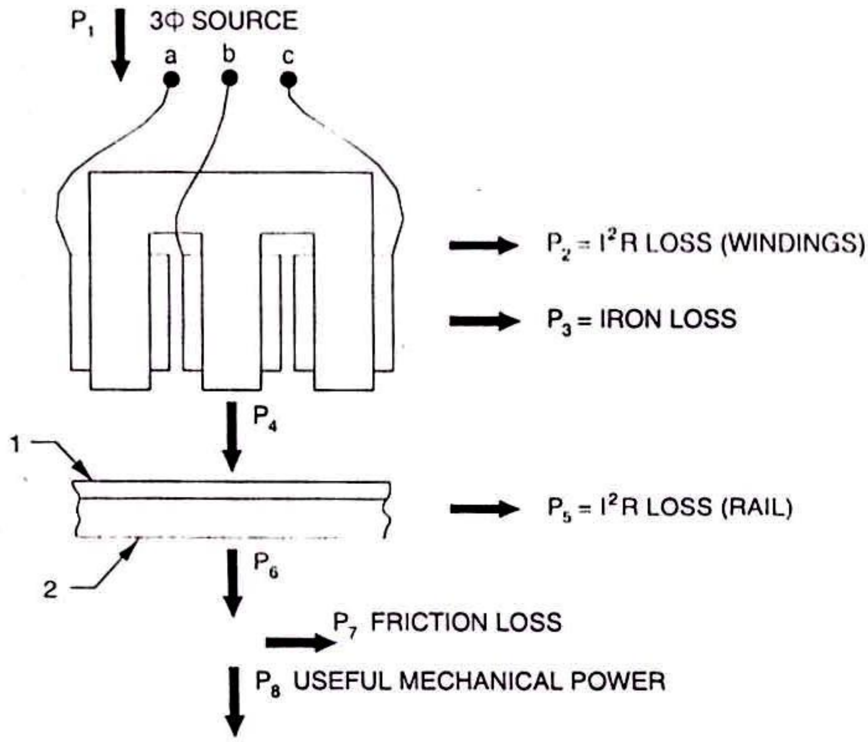


Figure 8.4 Power Flow in Linear Induction Motor

Another portion P3 id lost due to the iron losses in the laminated core. The iron losses amount to about 10 W, at rated voltage. The remaining power P4 is then transmitted across the air gap to the aluminium rail. A large portion P5 is dissipated in the form of heat, due to the I2R losses of the current induced in the rail. The power P6 that remains is the mechanical power developed by the motor. A small portion P7 is used up to overcome the friction losses, and the final amount P8 is the power that actually drives the motor.

The ratio P8/P1 is the efficiency of the motor. The efficiency of small linear motors is low, being typically of the order 10 % or less. The reason is that unlike rotating motors, the flux does not flow smoothly from one pole to the next, but cuts off sharply at the front and rear of the linear motor. Because of this “end effect”, only a fraction of the power P4 transmitted to the rail is available to produce the desired linear thrust. The thrust (in Newton) of a linear motor corresponds to the torque (in Newton meters) of a rotating motor.

In an ideal linear motor the thrust is given by the formula

Equation (2)

$$F = \frac{P4}{Vs} \quad \text{----------------------} \quad (2)$$

where in

F	=	Thrust in Newton [N]
P4	=	Power transmitted to the rail [W]
Vs	=	Synchronous speed [m/s]

In linear motors, the actual thrust is only 30% to 60% of the theoretical value given by equation
(2).

However, in the case of large linear motors of several hundred horsepower, the thrusts are close to the theoretical value. Furthermore, the efficiencies are of the order of 90%.

As mentioned previously, in addition to the active power, the linear motor draws considerable reactive power (Vars) from the 3-phase source. In small linear motors the reactive power can even exceed the active power consumed by the motor.

Dynamic behaviour

Starting from rest, how quickly will the vehicle pick up speed? To answer this question, we first have to calculate the acceleration.

The mass (m) of the vehicle is known to be 6. 9 kg

From Newton's second law of motion we know that

Equation (3)

Force F = ma, and--------------------- (3)

Equation (4)

Acceleration A = distance in meter /(time in sec) ^{2} ---------------------- (4)

To demonstrate the dynamic aspects of the linear induction motor, it can be connected as shown in figure. Power from the three-phase supply is fed into a box RS that contains a reversing switch. The output from RS is fed into the stator, as shown. When power is applied, the vehicle starts moving to the right, say. A moment before it strikes buffer 2, it trips lever S2. This reverse the switch in box RS, causing the flux in the vehicle to reverse. This slows the vehicle down before it hits the buffer. The buffer contains a spring that absorbs energy when it is compressed. When the vehicle strikes the buffer, it rapidly slows down until its speed falls to zero.

Traction Test

1. Set the gap of the vehicle to 5mm. This is the gap between the pole faces of the stator and the aluminium rail. The actual gap is equal to 5mm plus the thickness of the aluminium rail which is about 3.2mm. (By way of comparison, the gap in a rotating motor of equivalent power would be about 0.4mm).

2. Set the vehicle on the track and connect terminals R,Y,B connector to module.

3. Connect terminals R,Y,B of the Linear Motor to a variable, three phase, 50Hz source through three appropriate ac ammeters.

4. Place the vehicle in horizontal position.

]

Note that the active power P is considerably greater than when the vehicle was not coupled to the 131abelled131 rail (Table 1). The reason is that currents are induced in the rail, and so it dissipates power, causing the rail to heat up. The exciting current is also lower because the iron support underneath the aluminium rail reduces the effective length of the air gap, on account of its high permeability.

1. The synchronous speed Vs of the linear motor is given by Eq. (1),

$$V_s = 2df \qquad m/s$$

Experiments;

i. Traction Test (Air Gap = ______ mm)

S.No	Frequency –Hz	Modulation Index	Acceleration	Force-Newton	Synchronous speed
1.	15HZ				
2.	20HZ				
3.	25HZ				
4.	30HZ				
5.	35HZ				

Table 1

FEATURES OF PEC16LM01

* The iron support also offers a high permeability path for the magnetic flux coming from the poles.
* This current is in the path of the very flux that created it, and so a tractive force, or electromagnetic thrust, will be exerted upon the plate, tending to drag it along with the moving flux.
* As the vehicle picks up speed, the flux will continue to sweep across the plate (now called a rail and the thrust would fall to zero.
* The stator is the primary and the rail behaves like a single-turn secondary that is short circuited on itself.
* The air gap comprises not only the air itself, but also the thickness of the aluminium rail.
* On account of this long air gap a large magnetizing current is needed to produce the flux.

VIEW OF THE MODULE

Figure 8.5 Linear Induction Motor Controller

Figure 8.6 Linear Induction Motor On a Rail

FRONT PANEL VIEW

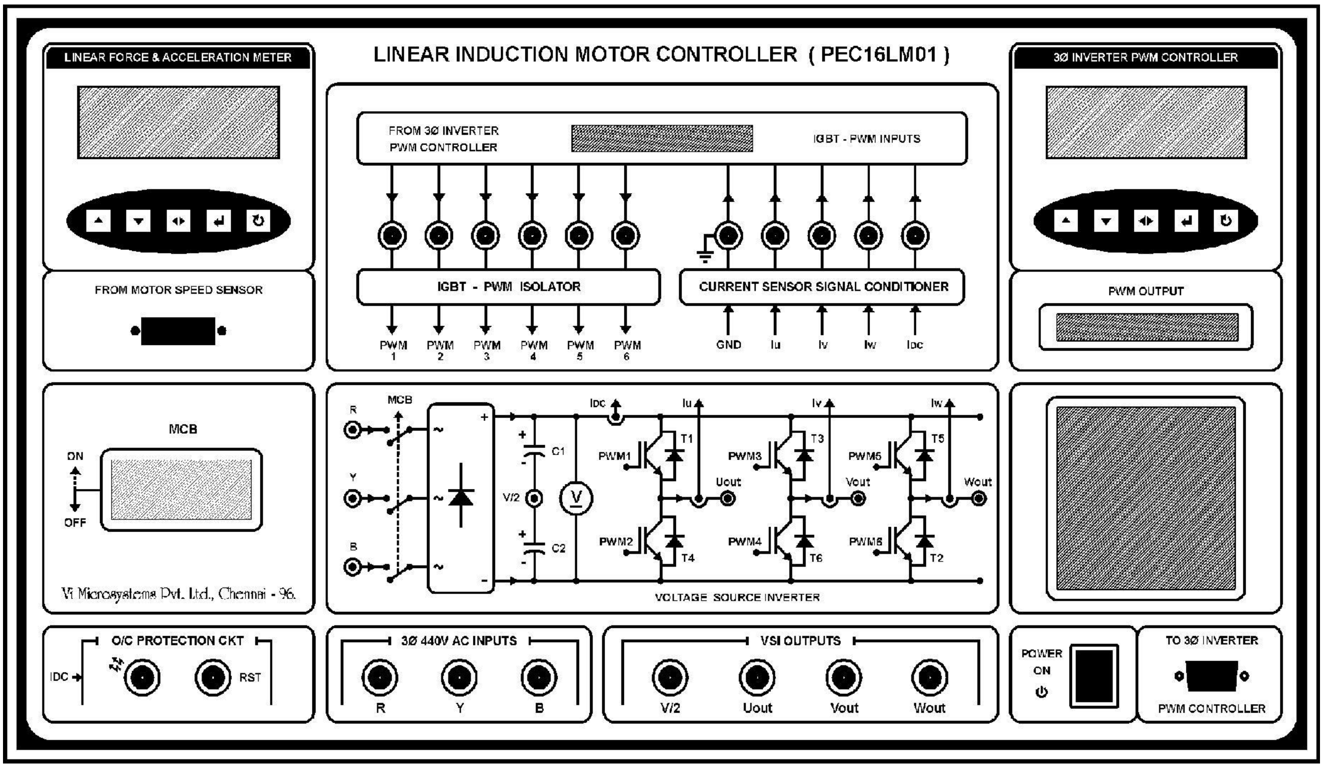


Figure 8.7 Linear Induction Motor Controller Front Panel View

FRONT PANEL DESCRIPTION OF PEC16LM01

MCB - To switch ON three phase input to the module.

R,Y,B - Terminals for three phase supply input to the module.

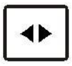
U_{out},V_{out}, W_{out} - Terminals for connecting the linear induction motor.

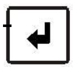
Power ON/OFF - To switch ON/OFF power to the controller module.

3 INVERTER PWM CONTROLLERS

 - To Increment the frequency value

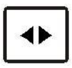
 - To decrement the frequency value

 - To Increment the modulation index value

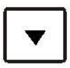
 To decrement the modulation index value

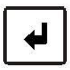
 - To reset the PWM controller.

LINEAR FORCE & ACCELERATION METER

 - Cursor movement

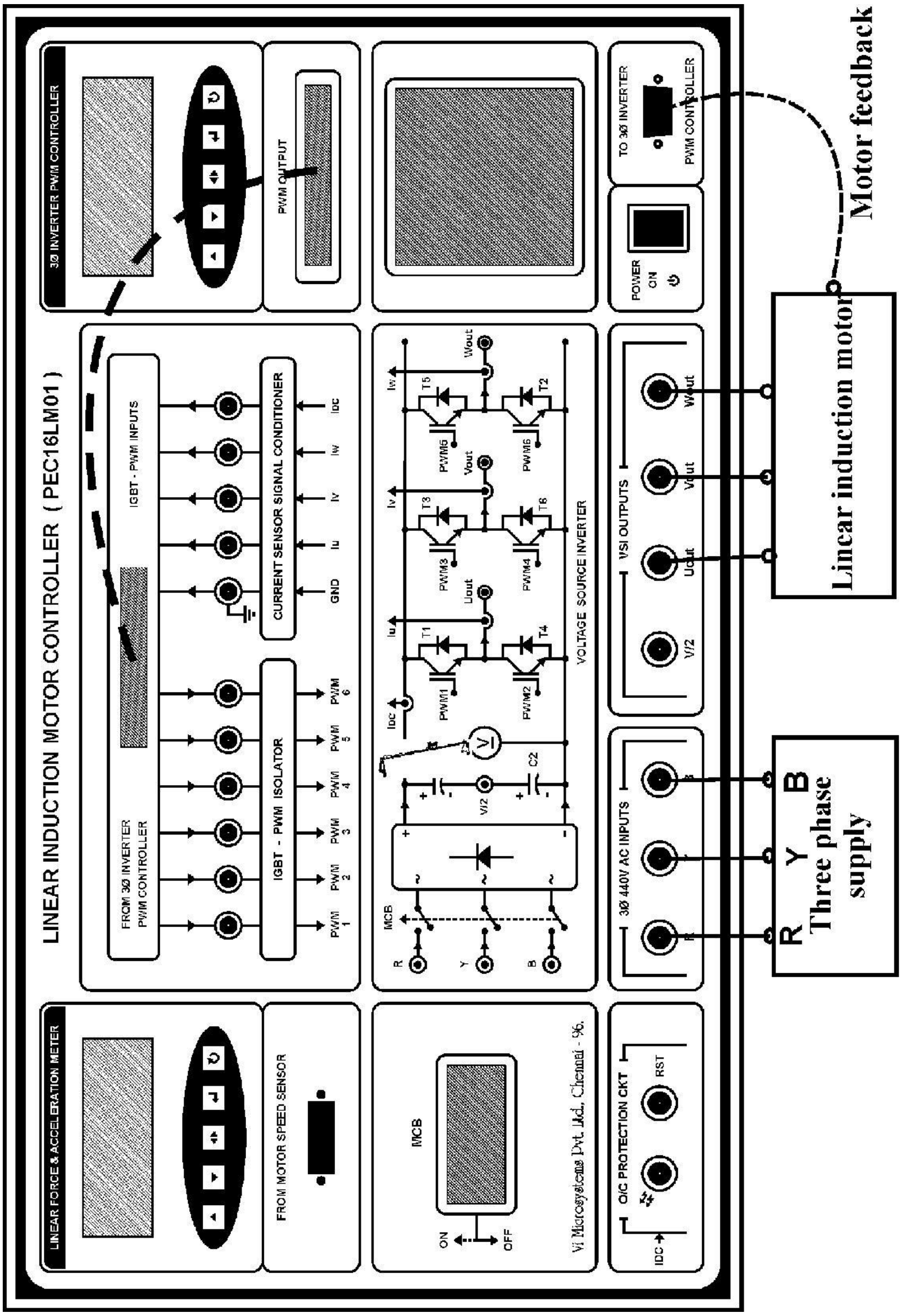
 - To incremental value

 - No connection

 - Enter key

 - Reset

CONNECTION DIAGRAM



TRACTION TEST ON LINEAR INDUCTION MOTOR

AIM:

To study the linear induction motor and perform traction test on it.

APPARATUS REQUIRED:

1. PEC16LM01 trainer.
2. Pulse cable.
3. Linear Induction Motor.

FORMULA USED:

The synchronous speed **Vs** of the linear motor is given by,

$$V_s = 3df$$

Where,

Vs = synchronous speed [m/s]
d = distance between poles [m]
f = frequency [Hz]

In this Model

d = 0.048 m (48mm)

F = Mass x Acceleration

Where,

Mass - The mass (m)of the vehicle is known to be 6.9 kg

Acceleration - Distance in meter/(time in sec)^2.

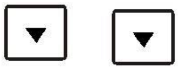
CONNECTION PROCEDURE

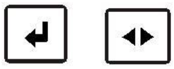
* Connect the controller module to the supply main.
* Connect 1 variable AC input supply to the controller module.
* Connect PWM output of the controller module to pwm input of the controller module using pulse cable.
* Connect linear induction motor input to the controller output (Uout,Vout,Wout) module.
* Connect motor speed feedback from motor to the feedback input of the controller module.

EXPERIMENTAL PROCEDURE

1. Verify the connection as per the connection procedure.
2. Switch on the power on/off switch in the controller module.
3. Manually Set the frequency between 1HZ to 50HZ.
4. Manually Set the modulation index between 0% to 90%.
5. The five sensor found in rail of linear induction motor, it is used to measure the time taken by the motor to travel between any two particular sensors.
6. Select any two sensor (eg . 1& 2, 1&3, 2&4, etc,.) and measure the time.
7. The consecutive sensors are separated by a distance of 0.4m.
8. The movable part one end to another end reach .that time Automatically change to forward and reverse direction shown in display mode.
9. Now the LCD display of 3 inverter pwm controller displays the following one by one with a delay of few seconds,

FREQUENCY : 1HZ
MODULATION INDEX : 0
DIRECTION : FORWARD
END 1 : OFF   END 2 : OFF

10. Now select the frequency, by using Key 

11. Now select the modulation index, by using Key 

12. Now vary the 1 input supply by using auto transformer.

13. Now motor starts running in any one direction at the speed corresponds to the frequency & modulation index value.

14. When motor reaches are end of rail the direction in automatically **“REVERSED”** through the sensor.

15. The speed of motor can be varied. By varying the frequency and modulation index value, while the motor in motion.

16. Now reduce the 1 input supply to zero.

17. For traction test set the value as following display of linear force and acceleration meter display will show

SET LENGTH – 000
SET MASS – 000
START SENSOR – 000
END SENSOR – 000

18. Now select the set length by using key 

19. Now select the set mass by using key 

20. Now vary the single phase input supply by using single phase auto transformer.

21. The sensor sensing one end to another end and measure the time and speed should be calculated by using stop clock.

22. Repeat the same procedure of different frequency of output voltage.

NOTE:

The active power P is considerably greater than when the vehicle was not coupled to the aluminium rail the reason is that currents are induced in the rail, and so it dissipates power, causing the rail to heat up. The exciting current is also lower because the iron support underneath the aluminium rail reduces the effective length of the air gap, on account of its high permeability.

* **d = 0.048 m (48mm)**
* **The mass (m) of the vehicle is known to be 6.9 kg.**

TABULATION

1. Traction Test (Air Gap = ______ mm)

S.No	Frequency –Hz	Modulation Index	Acceleration	Force - Newton	Synchronous speed
1.	10HZ				
2.	15HZ				
3.	20HZ				
4.	25HZ				
5.	30HZ				

RESULT

Thus the linear induction motor and perform traction test has been studied.

9.INTRODUCTION TO ROBOT STUDIO

RobotStudio is a PC application for labelled, offline programming, and simulation of robot cells. Robot Studio allows you to work with an off-line controller, which is a virtual IRC5 controller running locally on your PC. This offline controller is also referred to as the virtual controller (VC). RobotStudio also allows you to work with the real physical IRC5 controller, which is simply referred to as the real controller. When RobotStudio is used with real controllers, it is referred to as the online mode. When working without being connected to a real controller, or while being connected to a virtual controller, RobotStudio is said to be in offline mode. RobotStudio offers the following installation options:

- Complete
- Custom, allowing user-customized contents and paths
- Minimal, allowing you to run RobotStudio in online mode only.

STANDARD HARDWARE:-

Hardware	**Explanation**
Robot manipulator	An ABB industrial robot
Control module	Contains the main computer that controls the motion of the manipulator. This includes RAPID execution and signal handling. One control module can be connected to 1 – 4 drive modules.
Drive module	A module containing the electronics that power the motors of a manipulator. The drive module can contain up to nine drive units, each controlling one manipulator joint. Since the standard robot manipulators have six joints, you usually use one drive module per robot manipulator.
FlexController	The controller cabinet for the IRC5 robots. It consists of one control module and one drive module for each robot manipulator in the system.
FlexPendant	The programming pendant, connected to the control module. Programming on the Flex Pendant is referred to as “online programming”
Tool	A device usually mounted on the robot manipulator to allow it to perform specific tasks, such as gripping, cutting or welding. Tool The tool can also be stationary, see below for more information

OPTIONAL HARDWARE:-

Hardware	Explanation
Track manipulator	A moving stand holding the robot manipulator to give it a larger work space. When the control module controls the motion of a track manipulator, it is referred to as a “Track External Axis”.
Positioner manipulator	A moving stand normally holding a work piece or a fixture. When the control module controls the motion of a manipulator, it is referred to as an “External Axis”.
Flex Positioner	A second robot manipulator acting as a second manipulator.
Stationary tool	A device that stands in a fixed location. The robot manipulator picks up the work piece and brings it to the device to perform specific tasks, such as gluing, grinding or welding.
Work piece	The product being worked on.
Fixture	A construction holding the work piece in a specific position so that the repeatability of the production can be maintained.

INDRODUCTION TO RAPID PROGRAMMING

Rapid language is used for robot offline programming;in this programming we will make a virtual prototype of robot.

TERMINOLOGY OF THE RAPID STRUCTURE:-

The table below describes the RAPID terminology that you may come across whenworking with RobotStudio. The concepts are listed by size, from most basic toincreasingly large.

Concept	Explanation
Data declaration	Used to create instances of variables or data types, like numortooldata.
Instruction	The actual code commands that make something happen, for Example, setting data to a specific value or a robot motion. Instructions can only be created inside a routine.
Move instructions	Create the robot motions. They consist of a reference to a targetspecified in a data declaration along with parameters that setMotion and process behavior. If inline targets are used, thePosition is declared in the move instructions.
Action instruction	Instructions that perform other actions than moving the robot,Such as setting data or sync properties.
Routine	Usually a set of data declarations followed by a set of instructionsimplementing a task. Routines can be divided into threecategories: procedures, functions and trap routines.
Procedure	A set of instructions that does not return a value.
Function	A set of instructions that returns a value.
Trap	A set of instructions that is triggered by an interrupt.
Module	A set of data declarations followed by a set of routines. Modules Can be saved, loaded and copied as files. Modules are divided into program modules and system modules.
Program module (.mod)	Can be loaded and unloaded during execution.
System module (.sys)	Used mainly for common system-specific data and routines, for example, an arcware system module that is common for all arc robots.
Program files (.pgf)	In IRC5 a RAPID program is a collection of module files (.mod) and the program file

	(.pgf.) that references all the module files. When loading a program file, all old program modules are replaced by those referenced in the .pgf file. System modules are unaffected by program load.

PROGRAMMING CONCEPT:

The table below describes the terminology and concepts that are used in robot programming.

Concept	Explanation
Online programming	Programming when connected to a real controller. This expression also implies using the robot to create positions and motion.
Offline programming	Programming without being connected to the robot or the real Controller.
True offline programming	Refers to the ABB Robotics concept of connecting a simulation Environment to a virtual controller. This enables not only program Creation, but also program testing and optimizing offline.
Virtual controller	A software that emulates a FlexController to allow the same software (the RobotWare system) that is controlling the robots To run on a PC. This gives the same behavior of the robots Offline as you get online.
MultiMove	Running multiple robot manipulators with the same control Module.
Frame	A synonym for coordinate system.
Workobject calibration	If all your targets refer to workobjects, you only need to calibrate Theworkobjects when deploying offline programs.

IRB 1200 PICK AND PLACE APPLICATION

Overview

A palletizing application aims at picking container objects like boxes and cases from one or more stations and stack them together tightly in a second station for further shipment. An important parameter in the palletizing process is the speed of the process, that is, the throughput of products in time and the efficiency to stack the products in a stable configuration.

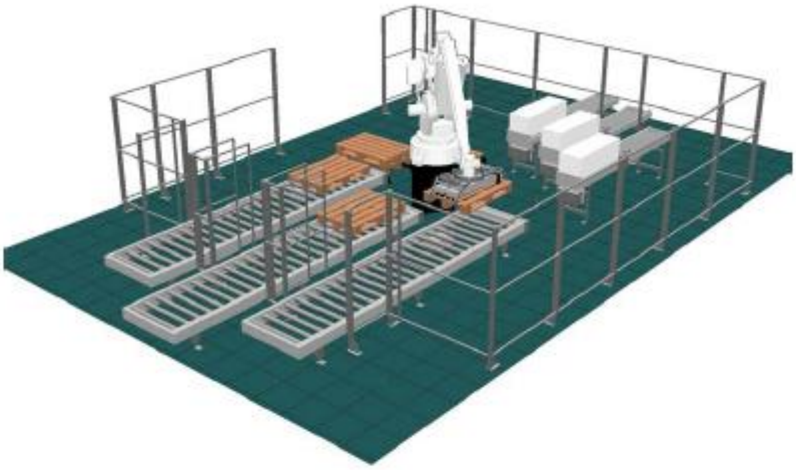


Figure 9.1 IRB 1200 Platform Base Diagram

A robot has the benefit of concentrating all palletizing to one cell where different pallet loads are produced simultaneously, for both high and low throughput demands. This makes the palletizing process flexible to adapt to different production situations. Therefore multiple in feeders and out feeders are usually gathered around the robot, which enables parallel production of many different pallet loads. The preceding figure shows a typical palletizing cell with one robot and multiple in and out feeders.

Pallet Pattern Layout:-

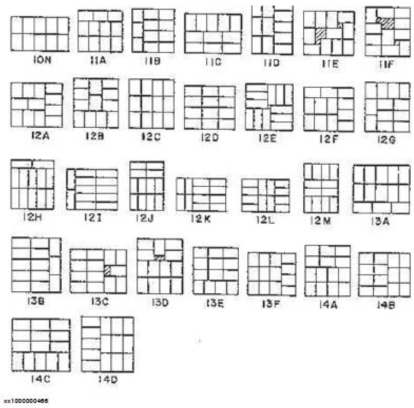


Figure 9.2 Pallet Pattern Layout

Logical Flow Control:- To achieve such a high efficiency, not having to rely on a predefined setup ofdedicated products and pallet loads to given stations, Robot Studio introduces an Intelligent logical station control concept – the concept of “Logical Flow Control” LFC with built-in, automated intelligent order sequence control. LFC sends order signals to the peripheral feeder control about what product topresent on each product feeder and to the robot, where to get the next productsfrom and where to place them. This standardized LFC-concept removes the needfor advanced PLC programs to control the robot palletizing cell.

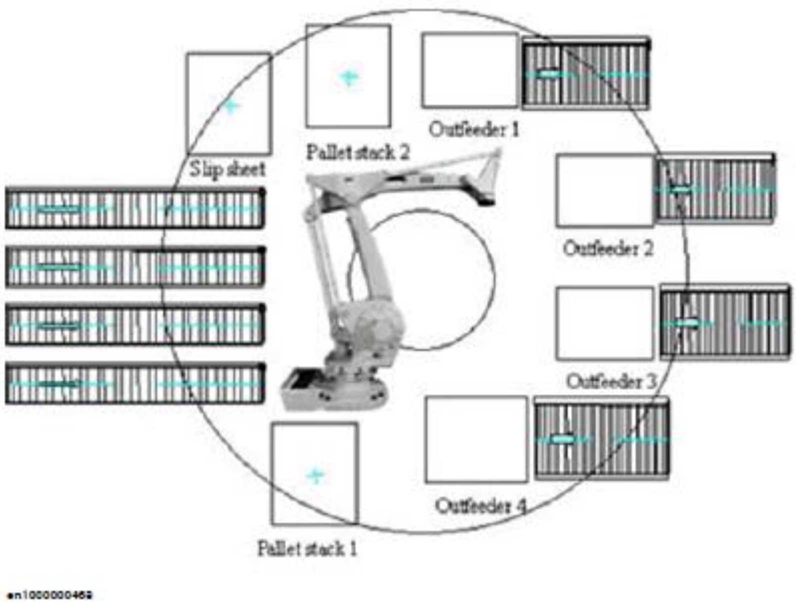


Figure 9.3 Logic Flow Control

System Overview:

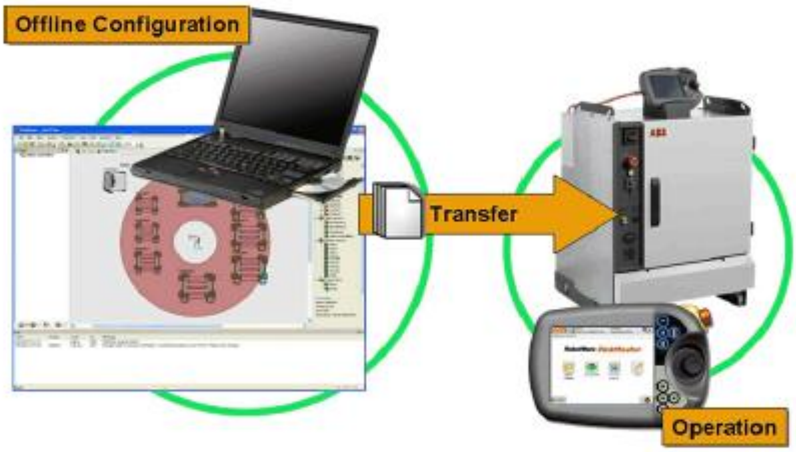


Figure 9.4 System Overview For IRB 1200

Interface Description:-During commissioning, the application is defined and edited from the PC applicationand the setup files are transferred over Ethernet to the controller. In runtime, a well-defined set of signals defines the communication with the stations. The following figures show the hardware interfaces to the Robot.

Simulation in Robot Studio:-The Robot may be simulated in runtime in Robot Studio. The Robot projectis transferred to the Virtual Controller in the same way as to the real controller andthe application is started from the Virtual FlexPendant.

10. PROCESS CONTROL EXPERIMENTS

CASCADE CONTROL EXPERIMENT

AIM:

To control the water level in a Process Tank using cascade control.

APPARATUS:

1. Cascade controller Trainer (VFLPA – 501CE).
2. GE Fanuc Proficy machine edition.
3. RS 232 cable.
4. Patch cards.

THEORY:

Applications with two or more capacities are inherently difficult to control with a single control loop due to large overshoots and unacceptable lags. The solution is a cascade of two or more control loops, each with its own input, in series forming a single regulating device.

There are two separate loops. Loop 1 is known as the primary loop, outer loop, or the master, whereas loop 2 is known as the secondary loop, inner loop, or the slave. To identify the primary and secondary loops, one must identify the control variable and the manipulated variable. In this case, the control variable is the water level of the process tank and the reference variable is the water flow rate. Hence, the primary loop (loop 1) involves the control variable and the secondary loop (loop 2) involves the reference variable.

In a double loop cascade system, the action of the secondary loop on the process should be faster than that of the primary loop. This ensures that the changes made by the primary output will be reflected quickly in the process and observed when the primary control variable is next measured. This hierarchy of information can be preserved by applying the following conditions when setting up the cascade controls.

- There must be a clear relationship between the measured variables of the primary and secondary loops.
- Response period of the primary loop has to be at least 10 times larger than the response period of the secondary loop.
- The major disturbance to the system should act in the primary loop.

Cascade control is best when the inner loop is controlling something that happens at fairly high frequency. Cascade control is designed to allow the master controller to respond to slow changes in the system, while the slave controller controls disturbances that happen quickly. If set up in reverse order, there will be a large propagation of error. Hence, it is important to maintain the hierarchy of information.

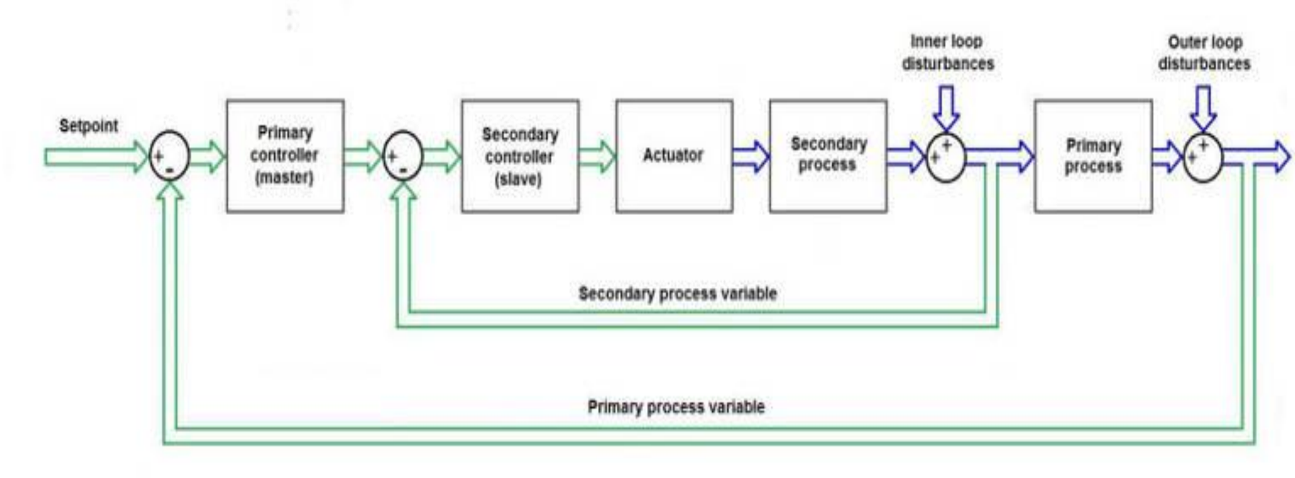


Figure 10.1 Cascade Control System Block Diagram

Level control:

In this experiment we need to control the water level in the process tank. In master loop level is measured by using capacitive transducer and in the inner loop flow rate is measured. The measured variables are compared with set point and error was given to the controller (ex Proportional, PI, PID or ON-OFF controller). The measured variables and controller output will be in the electrical form. The electrical output (4-20Ma) of controller was converted in pressure of 3-15 psi using Flapper-Nozzle current to pressure converter. This pressure will control the valve. Here in this experiment there is use of capacitive transducer for measurement of liquid level.

<u>Capacitive transducer for level measurement.</u>

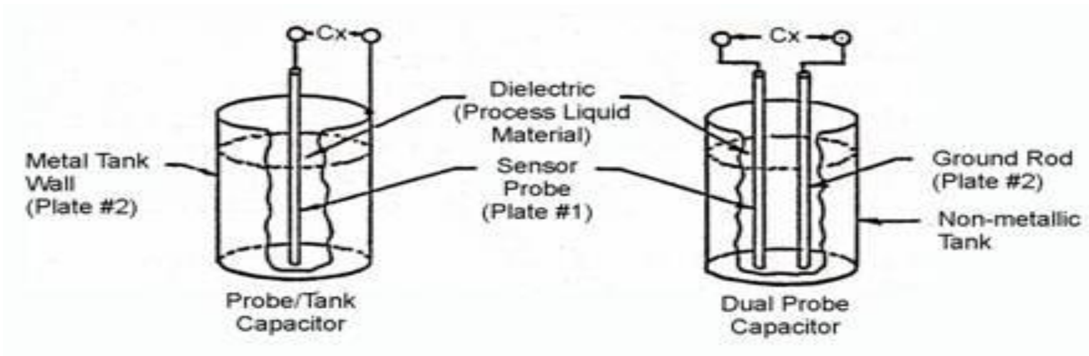


Figure 10.2 Capacitive Transducer for Level Measurement

To understand how a capacitive-based liquid sensing measurement is made, let us first take a look at the basics of capacitance sensing. For a parallel plate capacitor, the capacitance is defined as:

$$C = \varepsilon_0 \varepsilon_r A/d \qquad \text{(Equation 1)}$$

Where, 'ε_0' is permittivity of free space (8.85×10^{-12} F/m)
'ε_r' is the relative permittivity of the dielectric placed between the plates
'A' is the area of plates
'd' is the distance between plates
'C' is the capacitance

From this equation, if there is a slight change to either e_r, A, or d, the value of capacitance will change. By measuring this change in capacitance, the relation between the various parameters that caused the change in capacitance and the physical quantity with which the change occurs can be determined using Equation 1.

There are numerous methods by which capacitance can be measured. Some methods are based on absolute capacitance measurements and others are based on relative measurement. In relative capacitance measurement, only the change in capacitance, which respect to a reference capacitance value is measured. For absolute capacitance measurements, the actual sensor capacitance is used.

Controllers used:

On-off controller:

In control theory, a bang–bang controller (on–off controller), also known as a hysteresis controller, is a feedback controller that switches abruptly between two states. These controllers may be realized in terms of any element that provides hysteresis. They are often used to control a plant that accepts a binary input, for example a furnace that is either completely on or completely off. Most common residential thermostats are bang–bang controllers. The Heaviside step function in its discrete form is an example of a bang–bang control signal. Due to the discontinuous control signal, systems that include bang–bang controllers are variable structure systems, and bang–bang controllers are thus variable structure controllers

P Controller:

P controller is mostly used in first order processes with single energy storage to stabilize the unstable process. The main usage of the P controller is to decrease the steady state error of the system. As the proportional gain factor K increases, the steady state error of the system decreases. However, despite the reduction, P control can never manage to eliminate the steady state error of the system. As we increase the proportional gain, it provides smaller amplitude and phase margin, faster dynamics satisfying wider frequency band and larger sensitivity to the noise. We can use this controller only when our system is tolerable to a constant steady state error. In addition, it can be easily concluded that applying P controller decreases the rise time and after a certain value of reduction on the steady state error, increasing K only leads to overshoot of the system response. P control also causes oscillation if sufficiently aggressive in the presence of lags and/or dead time.

P-I Controller:

P-I controller is mainly used to eliminate the steady state error resulting from P controller. However, in terms of the speed of the response and overall stability of the system, it has a negative impact. This controller is mostly used in areas where speed of the system is not an issue. Since P-I controller has no ability to predict the future errors of the system it cannot decrease the rise time and eliminate the oscillations. If applied, any amount of I guarantees set point overshoot.

P-D Controller:

The aim of using P-D controller is to increase the stability of the system by improving control since it has an ability to predict the future error of the system response. In order to avoid effects of the sudden change in the value of the error signal, the derivative is taken from the output response of the system variable instead of the error signal. Therefore, D mode is designed to be proportional to the change of the output variable to prevent the sudden changes occurring in the control output resulting from sudden changes in the error signal. In addition D directly amplifies process noise therefore D-only control is not used.

P-I-D Controller:

P-I-D controller has the optimum control dynamics including zero steady state error, fast response (short rise time), no oscillations and higher stability. The necessity of using a derivative gain component in addition to the PI controller is to eliminate the overshoot and the oscillations occurring in the output response of the system. It can be used with higher order processes including more than single energy storage. In order to observe the basic impacts, described above, of the proportional, integrative.

In this experiment there is conversion of current to pressure and that is done by flapper-nozzle system.

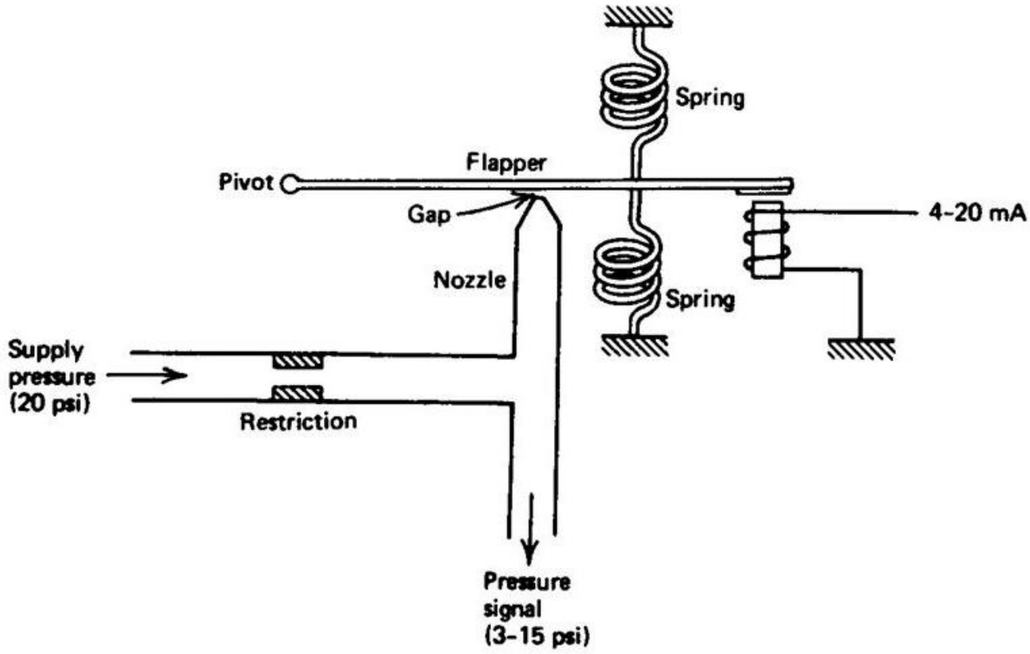


Figure 10.3 Current To Pressure Converter Using Flapper Nozzle

The operation of this type of I/P converter is similar to the one shown in this figure. It uses a magnetic coil to change the position of a balance beam that controls a small amount of pilot air pressure. The pilot air pressure controls the main air pressure that's regulated at 3-15 psi. The air supply for the I/P converter must be approximately 20 psi so that the converter can control the pressure between 3-15 psi.

PROCEDURE:

1. Switch on the power supply to the Cascade controller Trainer (VFLPA – 501CE).
2. Connect the trainer kit and PC using RS 232 Cable.
3. Set the controller variables in the GE Fanuc proficy software.
4. Observe the output level and valve positions in the graph.
5. Repeat the same for different controllers.

CONCLUSION:

The water level in the process tank is controlled by using cascade control.

SPLIT RANGE CONTROL EXPERIMENT

AIM:

To control the water level in a Process Tank using Split range control.

APPARATUS:

1. Cascade controller Trainer (VSRC – 01).
2. GE Fanuc Proficy machine edition.
3. RS 232 cable.
4. Patch cards.

THEORY:

In a split range control loop, output of the controller is split and sent to two or more control valves. The splitter defines how each valve is sequenced as the controller output changes from 0 to 100%. In most split range applications, the controller adjusts the opening of one of the valves when its output is in the range of 0 to 50% and the other valve when its output is in the range of 50% to 100%.The principle of a split range control is illustrated in the following example:

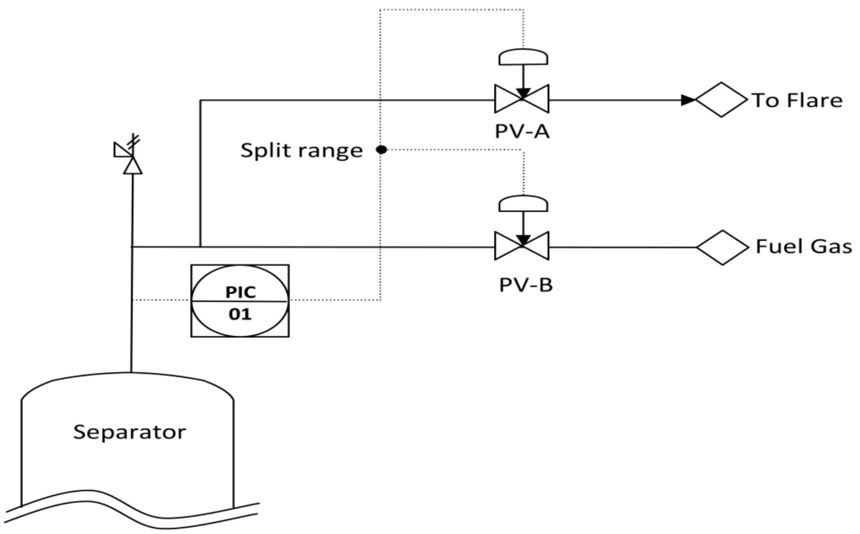


Figure 10.4 Split Range Control Scheme

In figure PIC-01 controls the pressure of the separator for liquid-vapor hydrocarbons, by mean of a split range controller with the output signal split and sent to two pressure control valves PV-A and PV-B. When pressure increases, the fluid shall be discharged to flare. When the pressure decreases, Fuel gas is introduced to compensate the pressure of the separator.

The fuel gas valve (PV-B) needs to close in response to increasing of pressure of the separator, while the flare valve (PV-A) will need to open when the pressure increases beyond set point.

When the pressure increases beyond set point in range of with 0-50% controller output, PV-B shall close from fully open to fully close and When the pressure increases beyond set point in range of with 50-100% controller output, PV-A shall open from fully close to fully open.

PROCEDURE:

1. Switch on the power supply to the Cascade controller Trainer (VSRC – 01).
2. Connect the trainer kit and PC using RS 232 Cable.
3. Set the controller variables in the GE Fanuc Proficy software.
4. Observe the output level and valve positions in the graph.
5. Repeat the same for different controllers.

CONCLUSION:

The water level in the process tank is controlled by using Split Range Control.

FEED FORWARD CONTROL EXPERIMENT

AIM:

To control the water level in a Process Tank using Feed forward Control.

APPARATUS:

1. Cascade controller Trainer (VFECT– 01).
2. GEFanuc Proficy machine edition.
3. RS 232 cable.
4. Patch cards.

THEORY:

Like cascade, feed forward requires that additional instrumentation be purchased, installed and maintained. In contrast, a feed forward controller measures the disturbance, D, while it is still distant. As shown below , a feed forward element receives the measured D, uses it to predict an impact on PV, and then computes preemptive control actions, feedforward, that counteract the predicted impact as the disturbance arrives. The goal is to maintain the process variable at set point (PV = SP) throughout the disturbance event.

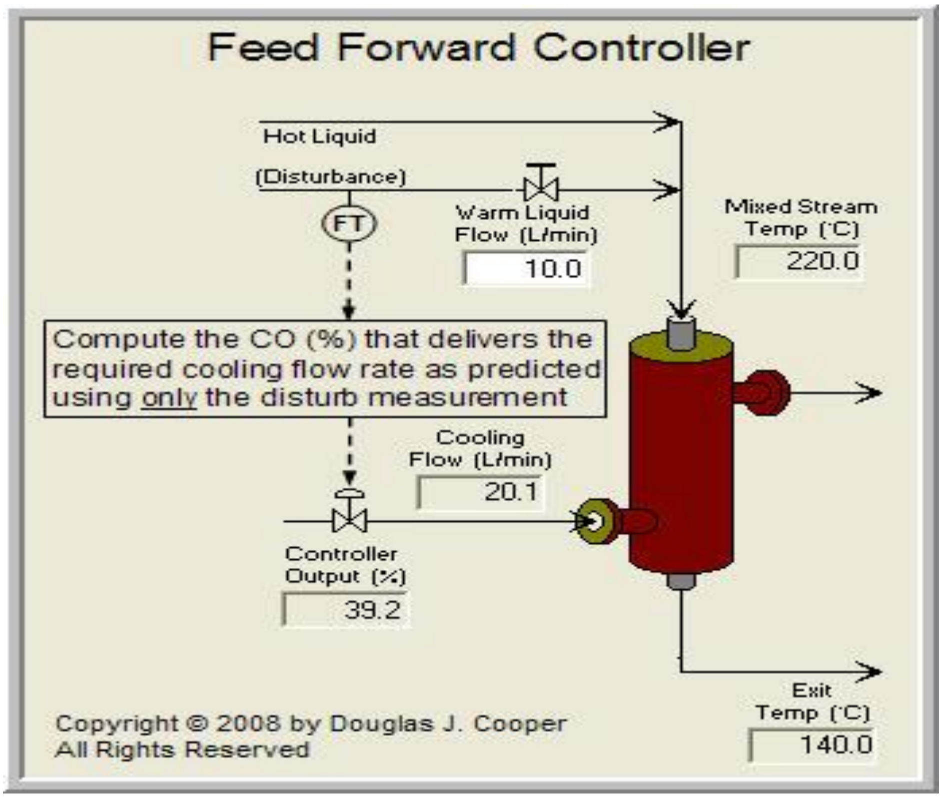


Figure 10.5 Feed Forward Controller

Where:

CO = controller output signal
D = measured disturbance variable
e(t) = controller error, SP – PV
FCE = final control element (e.g., valve, variable speed pump or compressor)
PV = measured process variable
SP = set point

PROCEDURE:

1. Switch on the power supply to the Cascade controller Trainer (VFECT– 01).
2. Connect the trainer kit and PC using RS 232 Cable.
3. Set the controller variables in the GE Fanuc Proficy software.
4. Observe the output level and valve positions in the graph.
5. Repeat the same for different controllers.

CONCLUSION:

The water level in the process tank is controlled by using feed forward control.

MULTIPLE INPUT MULTIPLE OUTPUT

In the early history of automatic process control the controller was implemented as a mechanical device often energized by compressed air. Mechanical systems (once the cheapest) can use a lever spring and a mass. Pneumatic controllers were once common, but have been largely replaced by digital electronic controllers. Electronic systems are now very cheap, and can be made by using a solid-state or electron tube amplifier, a capacitor and a resistance. Electronic analog control loops are often found within more complex systems for example, chemical process industry.

Software control of loops are the most stable because they do not wear out, and their high expense has been decreasing compare to hardware control setup. Controller can also be implemented with any physical system that can produce ratio metric 158abelled158 and integration. A controller can be purchased for industrial uses as a panel- mounted controller. These often control only one or two loops and are still applied for small stand-alone systems everywhere a controller or computer control is unnecessary. For complex system, say chemical oriented process control systems need a computer based controller.

In the chemical industry most of the processing systems are multi input multi output systems. Since the design of single input single output system is simpler. Depending on how many controlled outputs and manipulated inputs. We have in a chemical process we can distinguish the control configurations as either Single Input Single Output (SISO) or Multiple Input Multiple Output (MIMO) control systems. The basic configuration are, 1. Feed Back control configuration 2. Inferential control configuration 3. Feed forward control configuration. In every control configuration, the controller is the active element that receive the information from the measurement and takes appropriate control action to adjust the values ofthe manipulated variables.

In our unit, design point of view we are encountered that, the feedback control configuration involves one measurement (output) and manipulated variable in a single loop- There ate temperature control by sensing process temperature as a feedback signal, etc..

The controller having more than one measurement and one manipulated variable (or) one measured variable and more than one manipulated variable in such cases control systems with multiple loops, typically control configurations such as cascade controller, various types of selective control etc.

Front Panel Diagram

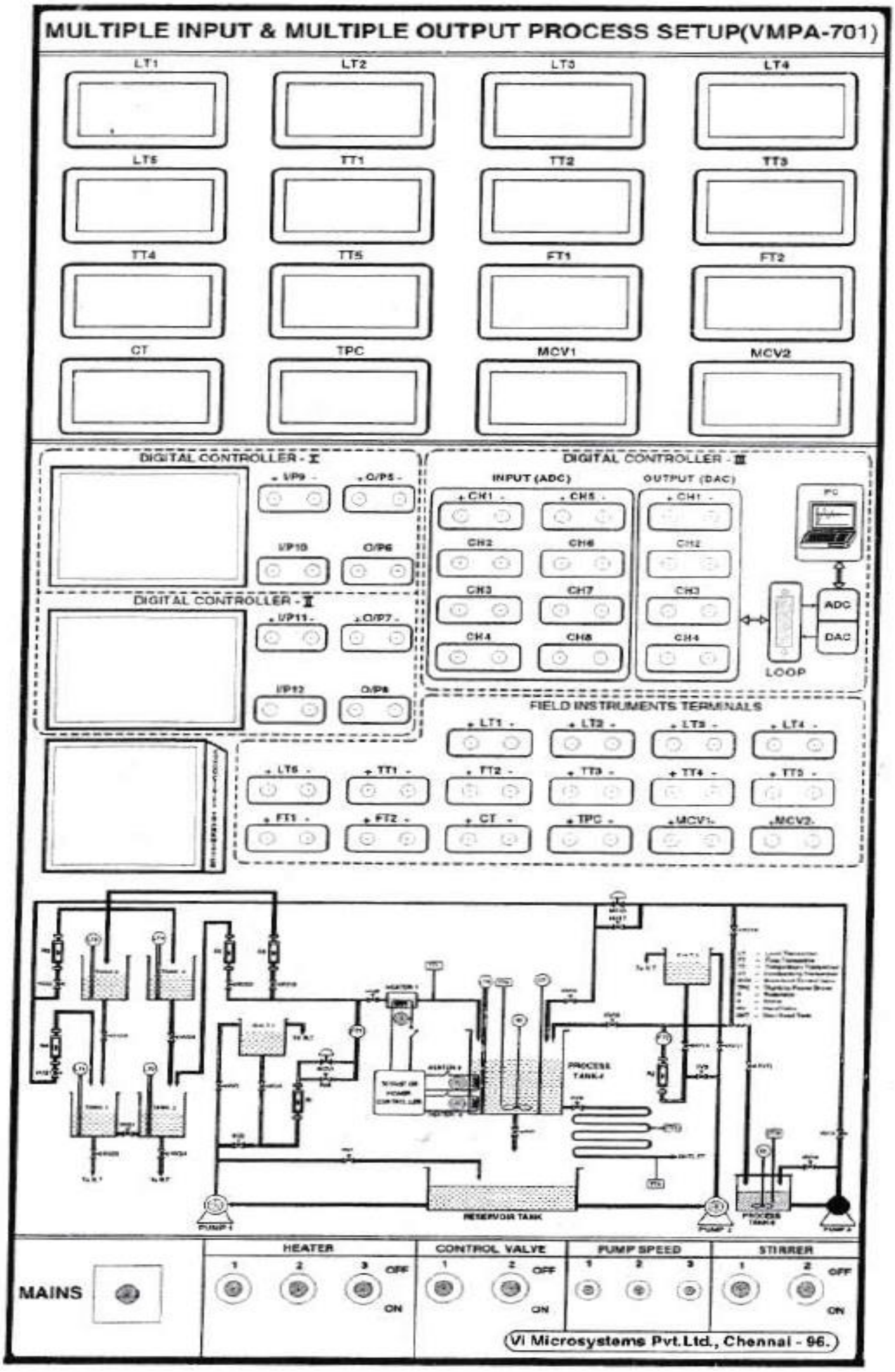


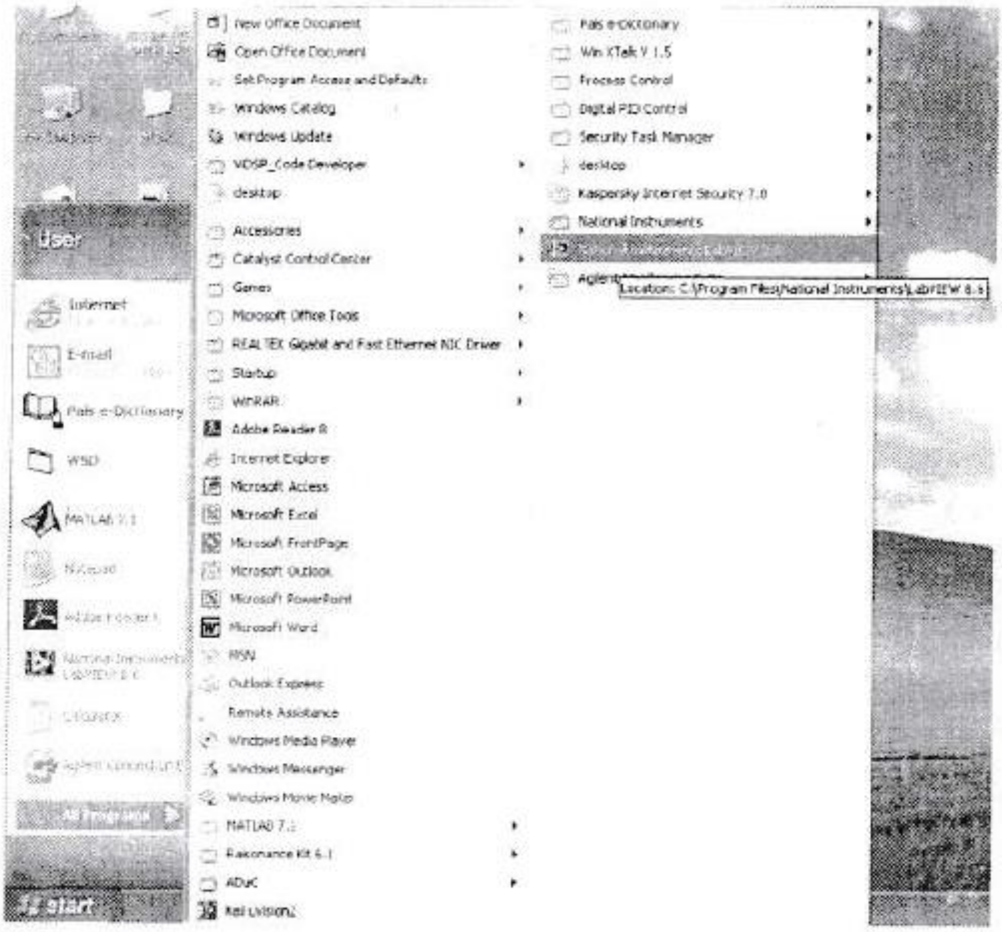
Figure 10.6 MIMO Front Panel

Front Panel Description

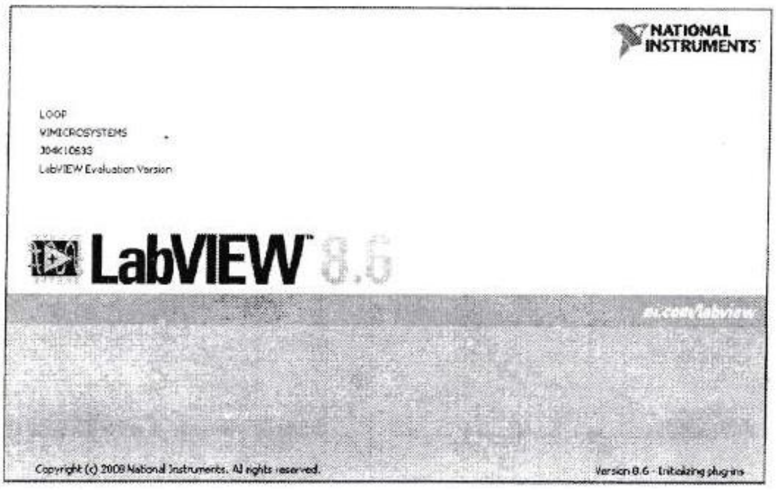
Mains ON/OFF switch	-	To switch ON/OFF the setup
Pump Speed (1,2,3)	-	To vary the speed of the pump (1,2,3).
DPM	-	It displays the current (mA) signal from sensor & actuator.
Loop	-	Process setup is directly interfaced to DAQ.
Heater ON/OFF	-	Switch ON & OFF the Heater.
Input (+)	-	In built 24V DC power supply
Input (-)	-	ADC input terminal.
LT (+)	-	Supply terminal
LT (-)	-	Load terminal (4-20)mA
TPC (+)	-	Thyristor power controller Positive terminal
TPC (-)	-	Thyristor power controller Negative terminal
MCV (+)	-	Motorized control valve Positive terminal
MCV (-)	-	Motorized control valve Negative terminal
Channel (+)	-	Inbuilt 24V DC
Channel (-)	-	DAC output terminal
Stirrer ON/OFF	-	To swith On/Off the stirrer
Control valve ON/OFF	-	To switch On/Off the control valve

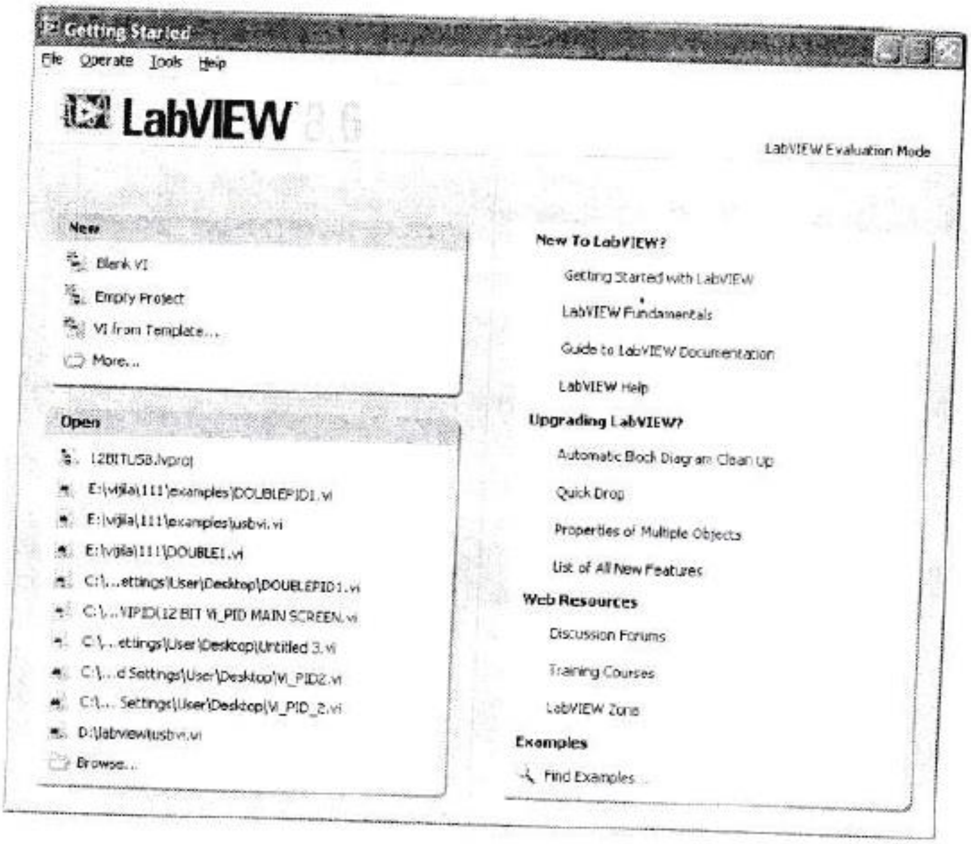
Lab View Program:

1. To open the LabView program select start – All Programs –National instruments 8.6 (Any Other version)**).**

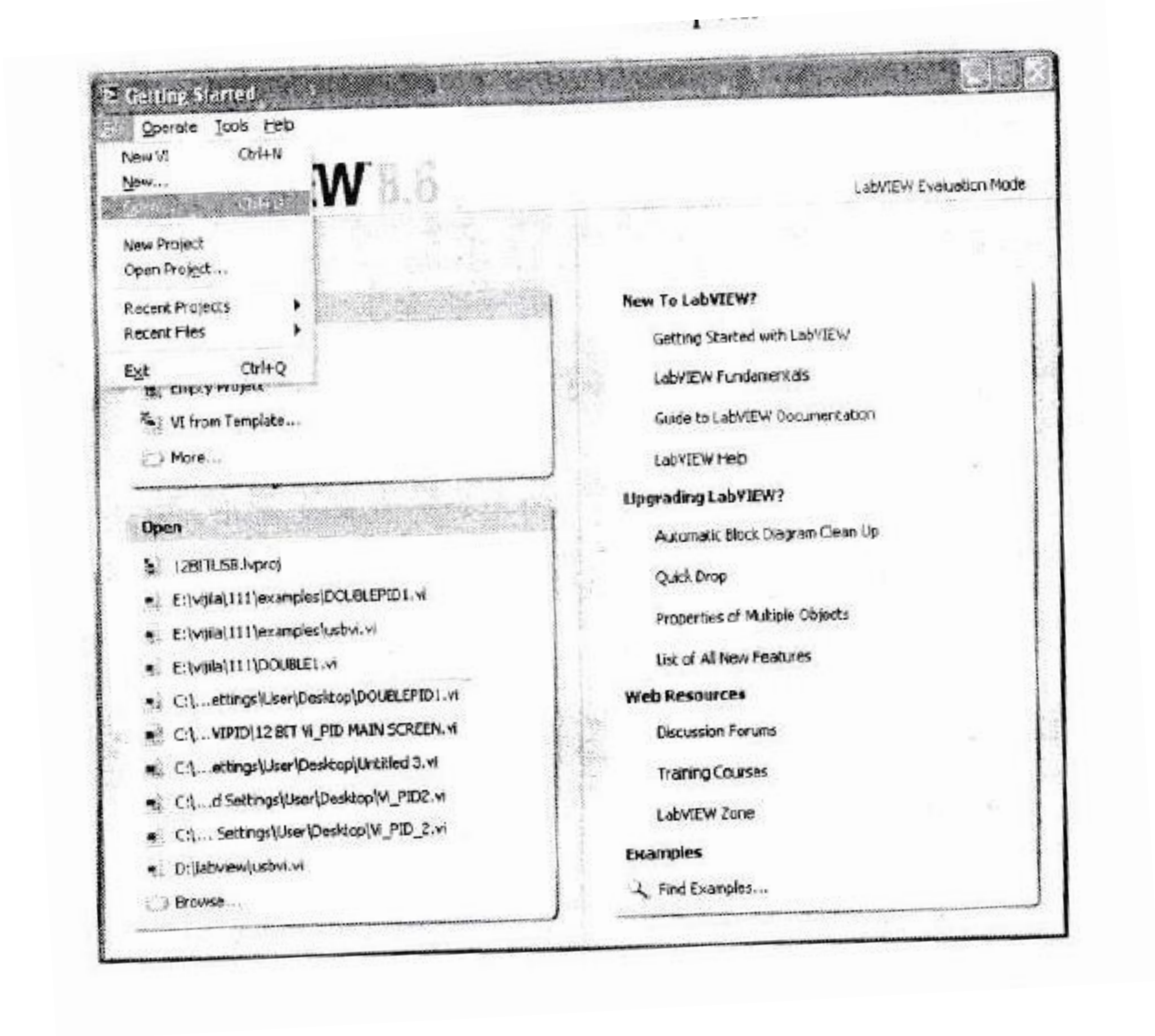


2. The following windows will appear.

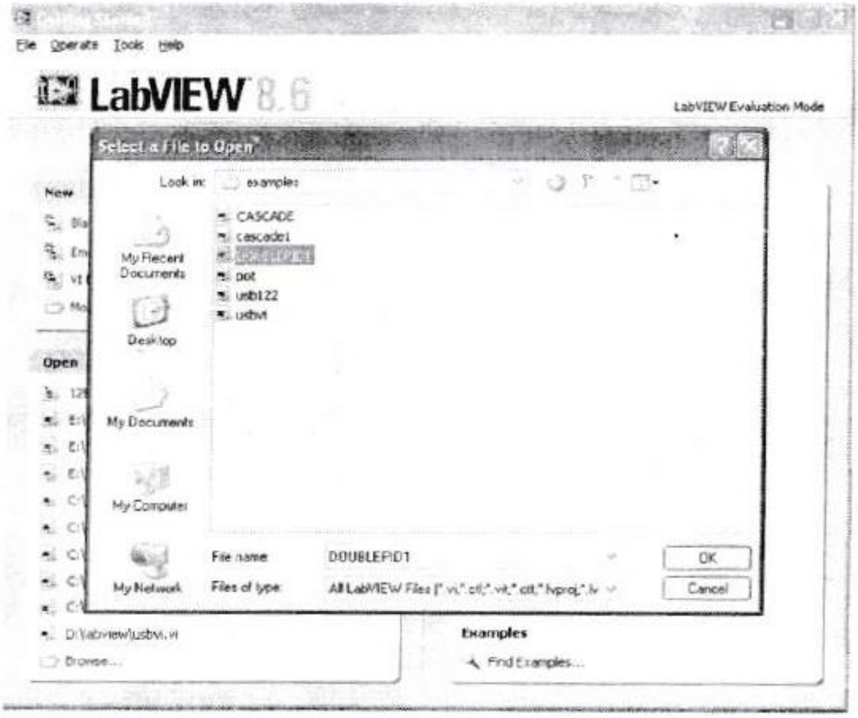




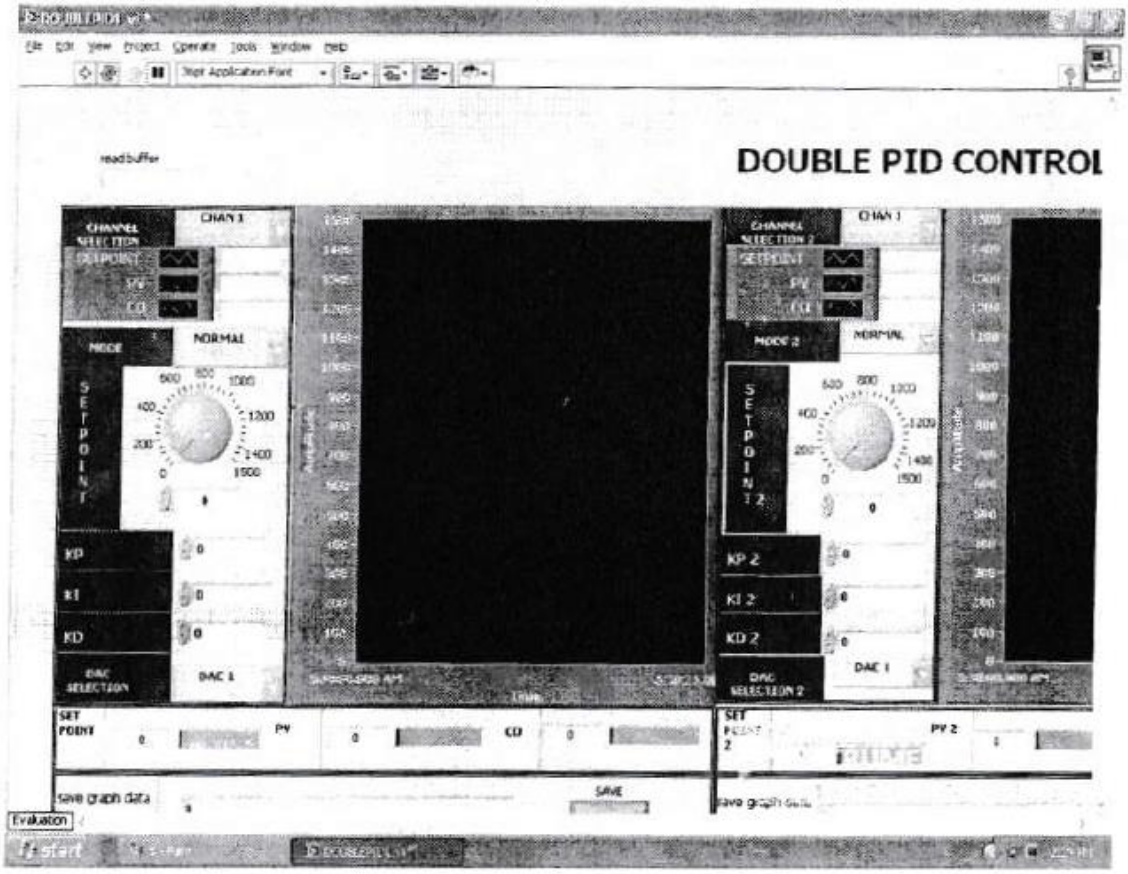
3. To open the program select file and then select open.



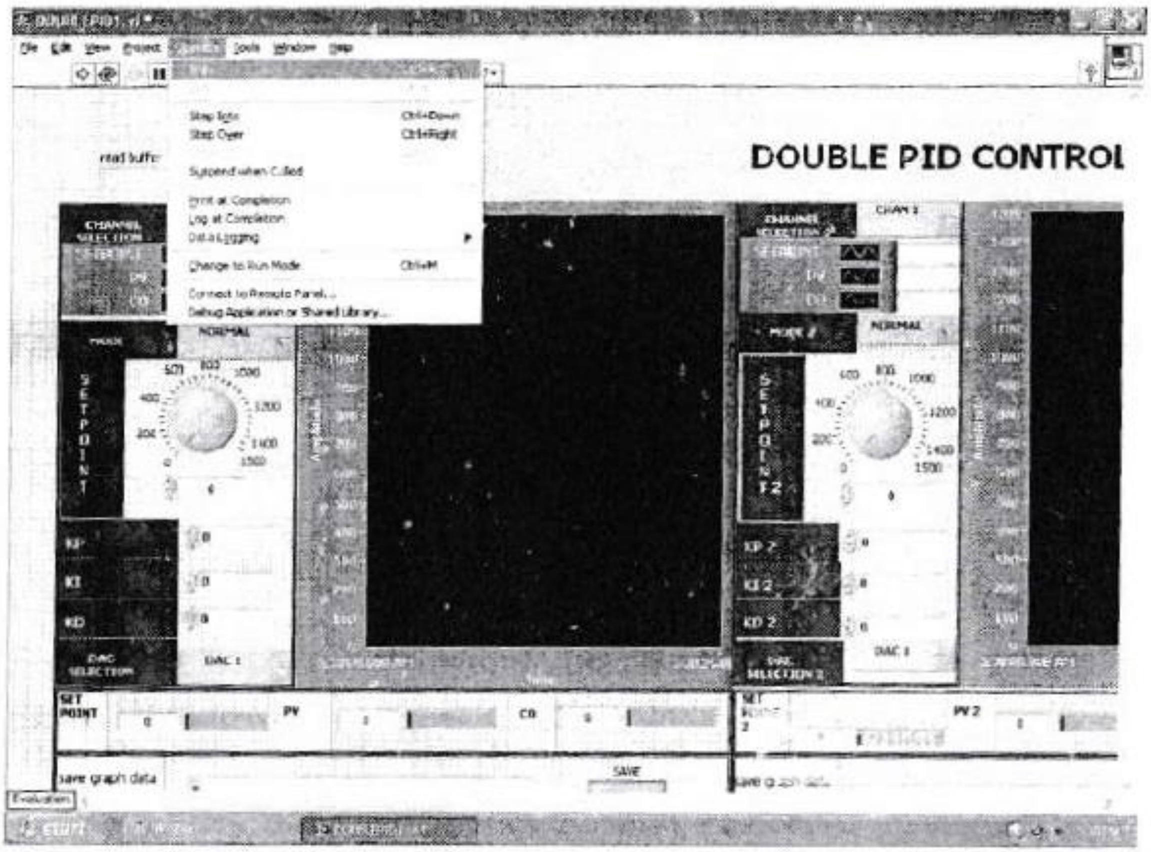
4. The following window will appear. Select file and click the OK button.



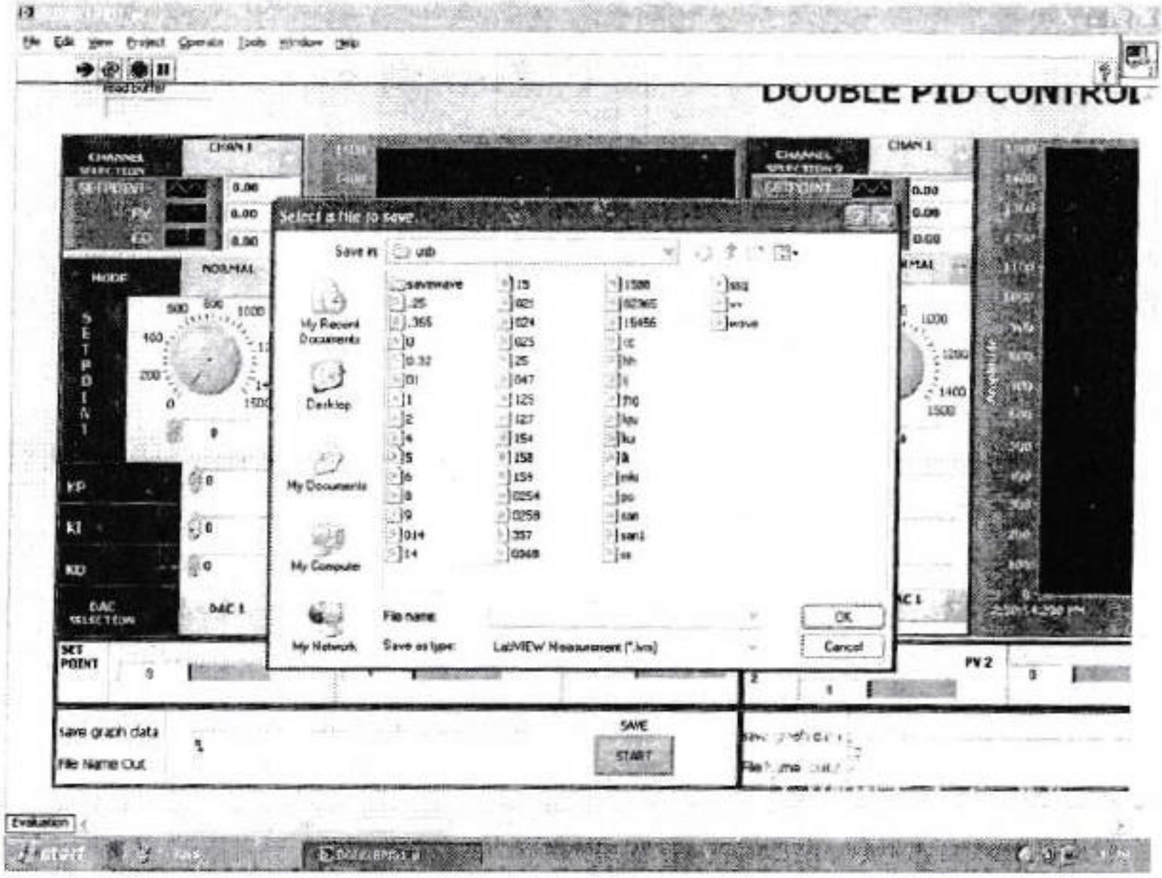
5. The following window will appear.



6. To run the program select operate and then select run. The output response will be displayed in the front panel window.



7. To save the process click the start button and give the location and file name then save response.


DOUBLE PID CONTROL
Select a file to save
Save in
My Recent Documents
Desktop
My Documents
My Computer
My Network
File name
Save as type
LabVIEW Measurement (*.lvm)
OK
Cancel
save graph data
File Name Out
START
Evaluation

EXPERIMENTAL SECTION

EXPERIMENT-1

AIM:

To study the action of “P+ I+ D CONTROL” for a Level process.

APPARATUS REQUIRED:

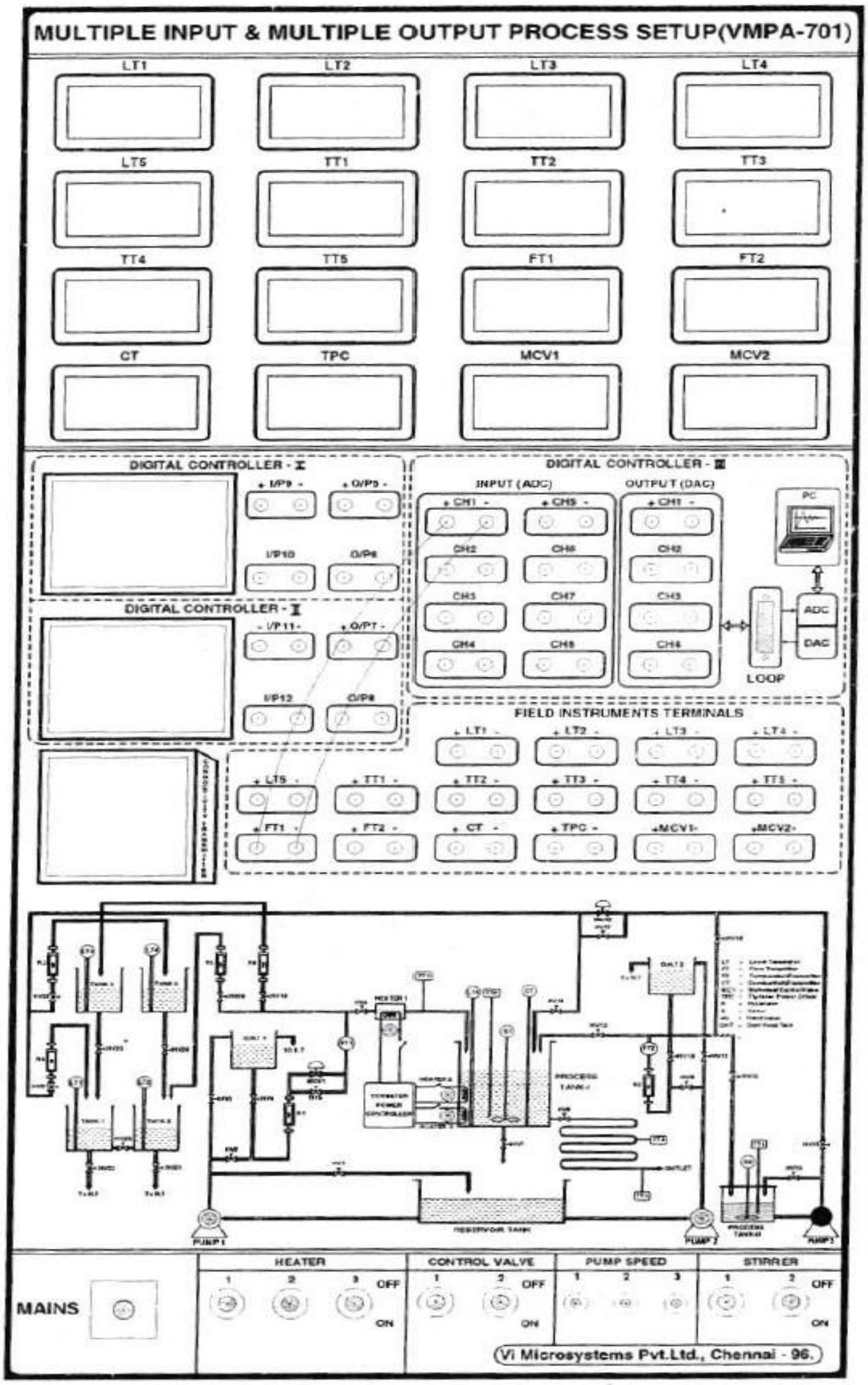
1. VMPA – 701 [Multiple input Multiple output Process setup]
2. PC
3. Data Acquisition Card (VUDAS – 100) with software
4. Patch Chords
5. Loop cable
6. 5V Adaptor
7. USB cable

PROCEDURE:

1. Electrical connections should be given as per fig 2 shown.
2. Interfacing connection should be given as per a fig.1 shown.
3. Switch ON the VMPA-701 and Data Acquisition Card (VUDAS-100).
4. Position the Hand valve
   NO – HV2, HV6
   NC – HV3. HV4, HV5, HVl9, HV20, HV8
   Partially open- HV1, HV7
5. lnvoke “LabVIEW” software in PC and select “file>> open”
6. Enter values for each parameters (i.e. Kp, Ki, Kd) & set point
7. Select “Operate >> RUN”
8. Switch ON the control valve and vary the pump speed.
9. For getting a desired response, tune the process parameter to optimum values. Tune theproportional gain to maintain the process variable within the proportional band without anyoscillation. To change the proportional gain (Kp) and Tune the integral gain (Ki) an dderivative gain (Kd) to maintain the process variable at set point.
10. Now study the response ofPID control action for various values of set point Kp. Ki. Kd.

RESULT:

Thus the characteristics and control action of PID on the Level Process was studied.


MULTIPLE INPUT & MULTIPLE OUTPUT PROCESS SETUP(VMPA-701)
LT1
LT2
LT3
LT4
LT5
TT1
TT2
TT3
TT4
TT5
FT1
FT2
CT
TPC
MCV1
MCV2
DIGITAL CONTROLLER - I
DIGITAL CONTROLLER - II
DIGITAL CONTROLLER - III
INPUT (ADC)
OUTPUT (DAC)
PC
ADC
DAC
LOOP
FIELD INSTRUMENTS TERMINALS
RESERVOIR TANK
PUMP 1
PUMP 2
MAINS
HEATER
CONTROL VALVE
PUMP SPEED
STIRRER
OFF
ON
Vi Microsystems Pvt.Ltd., Chennai - 96.

EXPERIMENT-2

AIM:

To study the action of “P+ I+ D CONTROL” for a Flow process.

APPARATUS REQUIRED:

1. VMPA – 701 [Multiple input & Multiple output Process setup]
2. PC
3. Data Acquisition Card (VUDAS-100) with software
4. Loop cable
5. Patch Chords

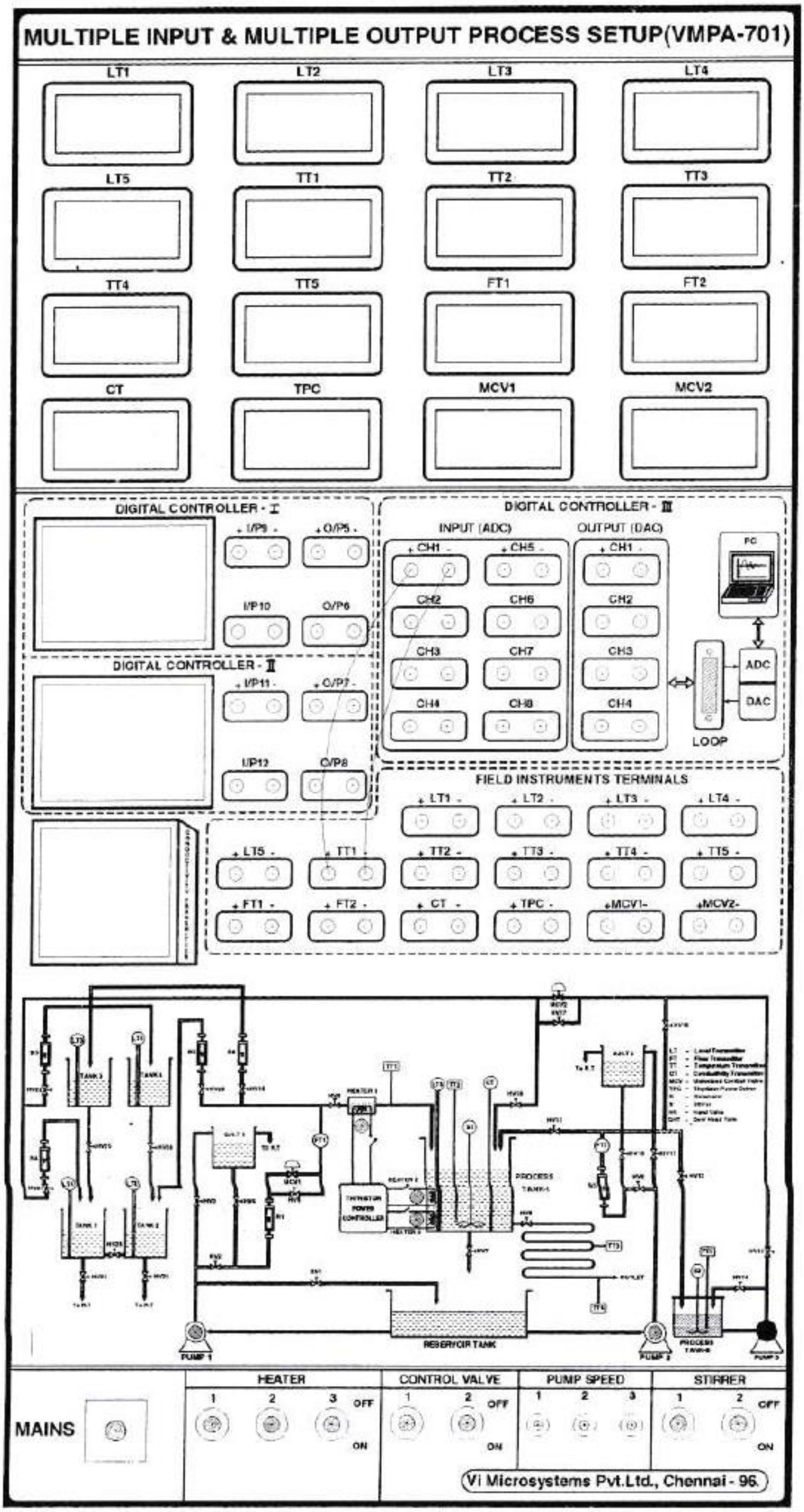
PROCEDURE:

Electrical connections should be given as per fig 2 shown.

1. Interfacing connection should be given as per a fig.1 shown.
2. Switch ON the VMPA – 701 and Data Acquisition Card (VUDAS – 100)
3. Position the Hand valve
   NO – t HV2, HV6, HV7
   NC – HV3, HV4, IrV5, HVr9, HV8, HV20
   Partially open – HVI
4. Invoke “LabVIEW’ software in PC and select “file>> open”
5. Enter values for each parameters (i.eKp, Ki, Kd) & set point
6. Select “Operate >> RUN”
7. Switch ON the control valve vary the pump speed.
8. For getting a desired response, tune the process parameter to optimum values. Tune the proportional gain to maintain the process variable within the proportional band without any oscillation. To change the proportional gain (Kp) and Tune the integral gain (Ki) and derivative gain (Kd) to maintain the process variable at set point
9. Now, study the response of PID control action for various values 169 a bell point, Kp, Ki, Kd.

RESULT:

The characteristics and control action of PID on the Flow Process has been studied.


MULTIPLE INPUT & MULTIPLE OUTPUT PROCESS SETUP(VMPA-701)
LT1
LT2
LT3
LT4
LT5
TT1
TT2
TT3
TT4
TT5
FT1
FT2
CT
TPC
MCV1
MCV2
DIGITAL CONTROLLER - I
I/P9
O/P5
I/P10
O/P6
DIGITAL CONTROLLER - II
I/P11
O/P7
I/P12
O/P8
DIGITAL CONTROLLER - III
INPUT (ADC)
OUTPUT (DAC)
CH1
CH2
CH3
CH4
CH5
CH6
CH7
CH8
PC
ADC
DAC
LOOP
FIELD INSTRUMENTS TERMINALS
PROCESS TANK-I
RESERVOIR TANK
PUMP 1
PUMP 2
THYRISTOR POWER CONTROLLER
MAINS
HEATER
CONTROL VALVE
PUMP SPEED
STIRRER
OFF
ON
Vi Microsystems Pvt.Ltd., Chennai - 96.

EXPERIMENT-3

AIM:

To study the action of' P+ I+ D CONTROL" for a Temperature process.

APPARATUS REQUIRED:

1. VMPA – 701 [Multiple input & Multiple output Process setup]
2. PC
3. Data Acquisition Card (VUDAS – 100) with software
4. Patch Chords
5. Loop cable
6. USB cable,5V Adaptor

PROCEDURE:

Electrical connections should be given as per fig 2 shown.

1. Interfacing connection should be given as per a fig. 1 shown.
2. Switch ON the VMPA – 701 and Data Acquisition Card (VUDAS – 100).
3. Position the Hand valve
   NO – HV3, HV4, HV6, HV8
   NC – HV2, HV5, HV19, HV20, HV7
   Partially open – HVI
4. Invoke "LabVIEW" software in PC and select "file>> open"
5. Enter values for each parameters (i.e. Kp, Ki, Kd) & Set point.
6. Select "Operate 2> RLN"
7. Switch ON the heater I and vary the pump speed.
8. For getting a desired response, tune the process parameter to optimum values. Tune the proportional gain to maintain the process variable within the proportional band without any oscillation. To change the proportional gain (Kp) and Tune the integral gain (Ki) and derivative gain (Kd) to maintain [the process variable at set point.
9. Now, study the response of PID control action for various values of set point, Kp, Ki, Kd.

RESULT:

Characteristics and control action of PlD on the Temperature process was studied.

NOTE:

To study the transport lag connect the TT2 – CH1.

EXPERIMENT-4

AIM:

To study the action of "CASCADE CONTROL" for a Level process.

APPARATUS REQUIRED:

1. VMPA – 701 [Multiple input & Multiple output Process setup]
2. PC
3. Data Acquisition Card (VUDAS – 100) with software
4. Patch Chords
5. Loop cable

PROCEDURE:

Electrical connections should be given as per fig 2 shown.

1. Interfacing connection should be given as per a fig.1 should.
2. Switch ON the VMPA – 701 and Data Acquisition Card (VUDAS – 100).
3. Position the Hand valve
   NO – HV2, HV6,
   NC – HV3, HV4, HV5, HVl9, HV20, HV8
   Partially open – HV1, HV7
4. Invoke "LabVIEW" software in PC and select "file>> open"
5. Enter values for each parameters (i.e.Kp, Ki, Kd) & set point.
6. Select "Operate >> RUN"
7. Switch ON the MCV 1 and vary the pump speed.
8. For getting a desired response, tune the process parameter to optimum values. Tune the proportional gain to maintain the process variable within the proportional band without any oscillation. To change the proportional gain (Kp) and Tune the integral gain (Ki) and derivative gain (Kd) to maintain the process variable at set point.
9. Now, study the response of PID control action for various values of set point, Kp, Ki, Kd.

RESULT:

Cascade control action on the level Process was studied.

11. DISTRIBUTED CONTROL SYSTEM EXPERIMENTS

MODBUS RTU –MASTER COMMUNICATIONS

Introduction

Modbus Serial line protocol is an open standard for data communication between PLCs to related PLC devices. That is sharing common registers among Programmable Logic Controllers. Modbus RTU master communication is available on the series 90-30 IC693CPU363 and versa max modular CPU models IC200CPU00l, Lc200CPU002, Lc200CPU005 and Lc200CPUE05.

Above mentioned controller supports Modbus communication in which they have RS485 ports for communicate between other controllers.

Importance of Modbus Communication:

- In order to maintain centralized operation in an Automation Industry. Modbus communication establishment is essential.
- To get all the information less than one roof. E.g.: Data from Remote terminal. Slave controller can be grabbed in master controller and vice versa.

Mode of Operation:

A Modbus RTU master device (the client) sends query messages to one or more slave devices (the servers) on a serial network. Queries may contain data request for data or status or commands. Each slave on the network has a unique device address. Any query may be addressed either to a specific slave device or to a special broadcast address. Queries addressed to the broadcast address are called broadcast queries. Queries that require a response may not be addressed lo the broadcast address.

A slave that receives a well-formed, non-broadcast query must send a response message to the master. The query/response transaction completes when the master receives a well formed response. Slaves do not respond to broadcast queries. After sending a broadcast query, the master must wait a specified time before completing the transaction and sending the next query. Some broadcast queries contain commands that require the slaves to take specified actions.

VERSA MAX PLC:

The VERSA MAX PLC features compact, reckless design and DIN rail mounting. The CPU, with its powerful programming instruction set and advanced features serves up to eight I/O and optional modules, proceeding up to 256 local I/O points

Upto eight modules can be included in the local system, power, for module operation is provided by a power supply that mounts directly on the CPU itself.

The ON state indicates that the COMMREQ did not complete successfully. If the COMMREQ specified a Modbus RTU query message, it was NOT sent from the port.

Guide To Establish Modbus Communication:

Connect the RS232 bus from PC to PLC and RS485 bus from PLC (Master) to PLC (Slave). Give supply to corresponding PLCs and check the PLCs (power, ok, run) LED will glow or not. Now connect the master PLC to PC through RS232 bus and follow the procedure in software (Proficy Machine Edition).

Master Configuration:

Start---Programs---GE Fanuc---Proficy Machine Edition---proficy machine edition

Step1---File---New project (now enter your project name as u desire, say modbus). Click ok.

Step2---In the left comer. Navigator window will open with our project name which we have given as project name. Now right click the (project name) ---Add target---GE Fanuc PLC – Versa max PLC.

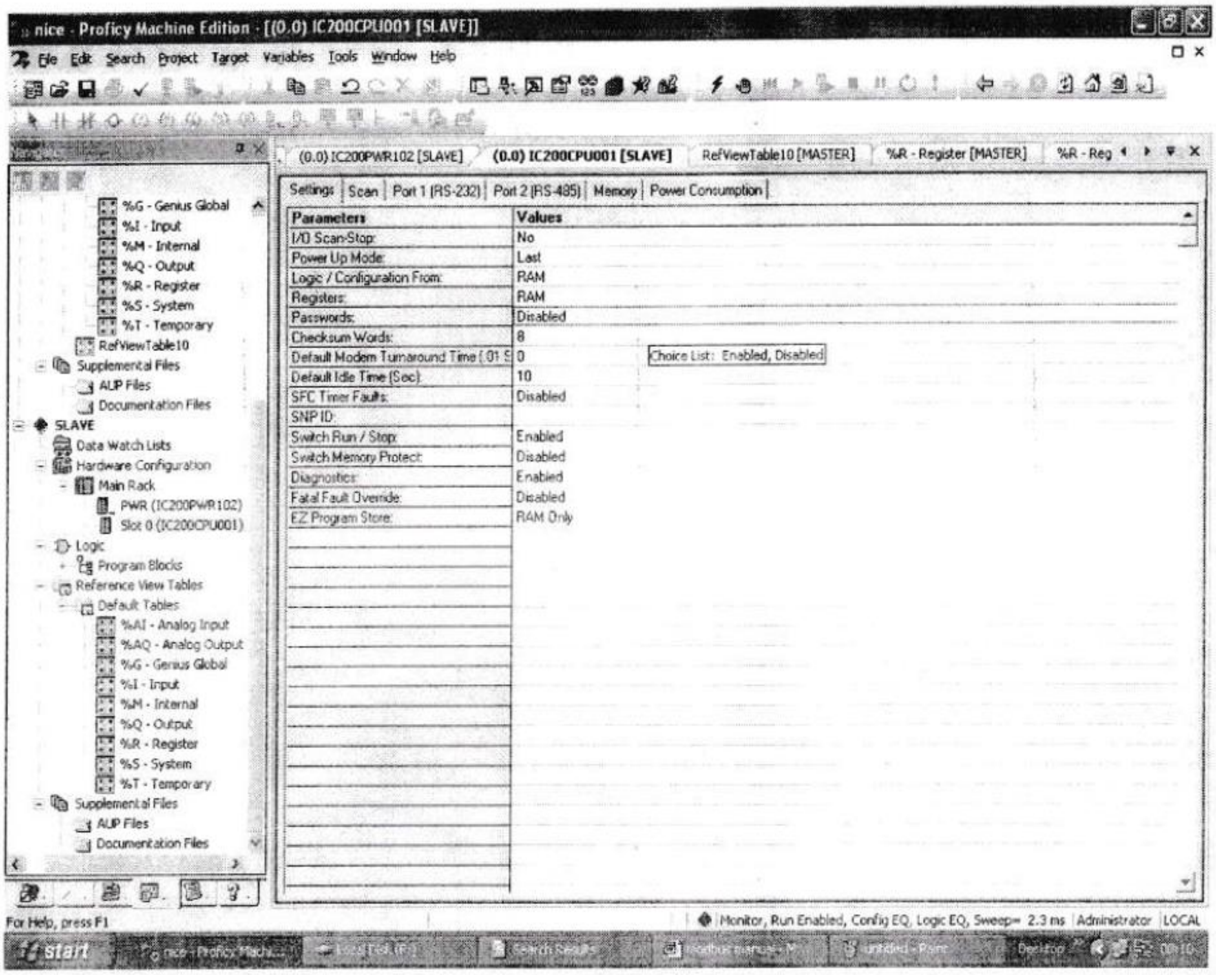
Step3---In the left corner, Navigator window will open with our project name which we have given as project name. Now right click the (project name) ---Add target---GE Fanuc PLC – Versa max PLC.

Step4---Now navigator will appear with Target, Data list, Hardware configuration, Logic, Reference View table and Supplementary Files. Right click in the Target and rename it desire, e.g.: Master.

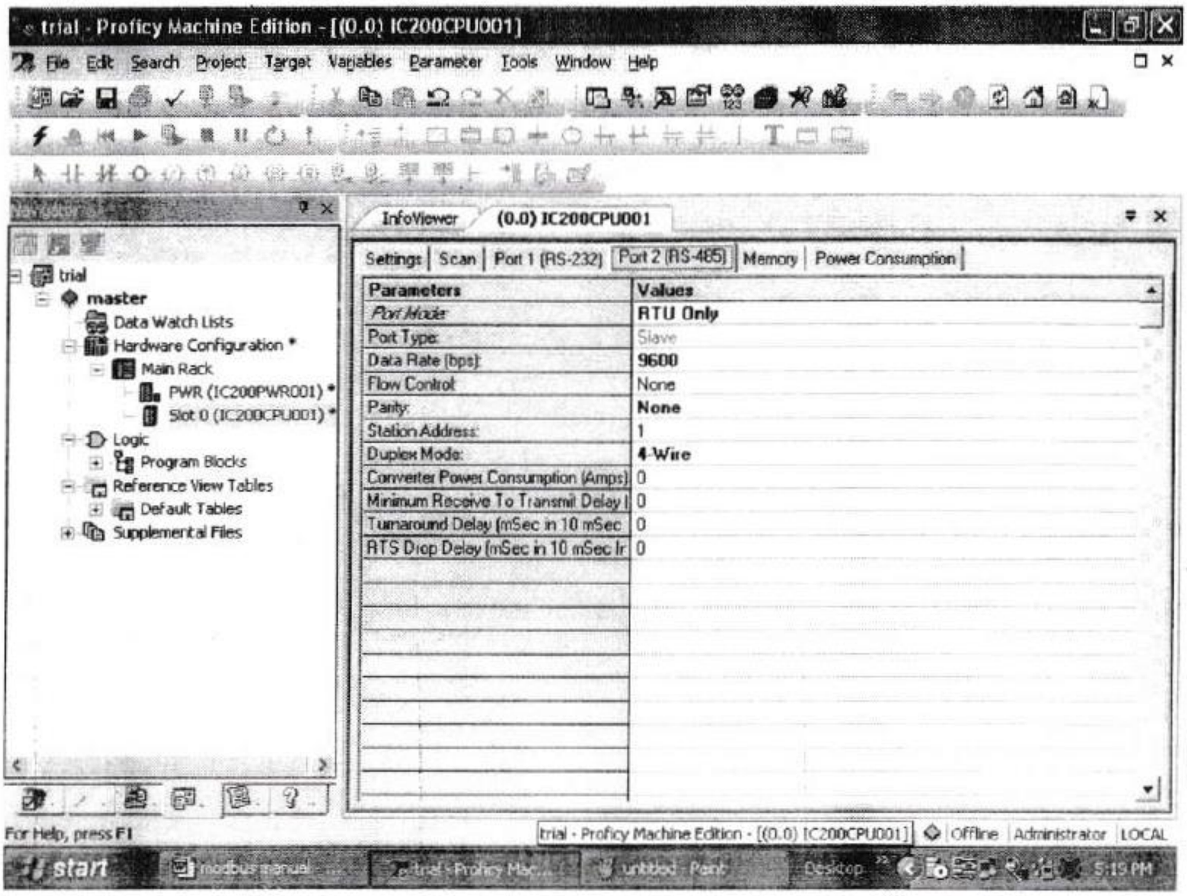
Step5---Click the + button before the Hardware configuration where it comprise pwr and slot. Right click the PWR ---REPLACE MODULE and select the required PWR Module which we are using now.

Step6---Besides right click the SLOT---REPLACE MODULE and select the requiredslot which we are using now.

Step7---Now right click –CONFICURE and set the parameters as per the following window.



Change the parameters as per the window. Important note is to change the PASSWORD tab DISABLE.lt can be done by double click the text box and choose DISABLED. If any of the parameters changed, correct it with reference to above window.



Here we should change the parameters as above window for master configuration, always keep the master station address as I and for slave change the station address as 2 which we will see while slave configuration.

After configuring the above parameters one by one, save the file. Now the star symbol above the HARDWARE CONFIGURATION will disappear.

Step8: In the NAVIGATOR window click LOGIC---PROGRAM BLOCK---MAIN (double click) to get the logic diagram window.

Step9: Now put the logics for Modbus communication .After put the programs go to Menu bar, Click TARCET---SET AS ACTIVE TARGET. Again TARGET---GO ONLINE with "master"

Step10: Then Click TARGET---DOWNLOAD AND START or Press F9.

Step 11:Check the program whether it's correct or not. It is done by monitoring the Registers. Click REFERNCE VIEW TABLES---DEFAULT TABLES---REGISTERS (double click)

Step12: A window will open with all REGISTER values. Monitor the 111^{th}

CONVEYOR SORTING SYSTEM

INTRODUCTION

Nowadays industry is increasingly shifting towards automation. The principle components of today's industrial automation are PROGRAMABLE LOGIC CONTROLLERS,

Automation has resulted in

- Increased productivity
- Decreased cost of production
- Improved quality

PROGRAMMABLE LOGIC CONTROLLERS

Several industries utilize sequential industrial processes, which are repetitive in nature. For such processes, industries have so for depended on use of relays, stepping drums, timers and controllers. Considerable difficulty is experienced in reprogramming necessitated due to changes in the nature of production. Often the entire system has to be scrapped and redesigned afresh.

This is difficulty is overcome through the use of programmable controller. Automobile industry's was the first to male use of these programmable controllers. As a result, this industry has benefited due to

- Saving time and money
- Increasedreliability
- Extensive flexibility

Now these programmable controllers are being increasingly used in various other industries to perform numerous duties such as

- Logic function
- Record keeping
- Timing
- Counting
- Sequencing
- Information handling

Conveyor Sorting System:

Conveyor sorting system deals with the colour of the material in an industrial set up. This system is transporting from production area to store.

Materials are loaded on a conveyor and the colour of the material is sensing by using a colour sensor and the position of the particular materials are used to sense by an inductive proximity sensor. We can set the values for the particular colours in the colour sensor. Whenever the particularly coloured materials are sensed the corresponding output channels of the colour sensor are enabled. For each coloured materials use separate boxes for storing. When the proximity sensor sense the material conveyor stopped until the material is pulled to corresponding boxes which is reserved for a particular colour by using a single acting cylinder.

WHY WE ARE USING PLC:

Conveyor sorting control system is used to sort the materials according to their colour by using simple program logic. But the micro controller system is very complex to programming and wiring adds complexities. Hence we are choosing the PLCS are used to control the sorting. For the complex problems PLC provides simpler solution by means of ladder-logic programs.

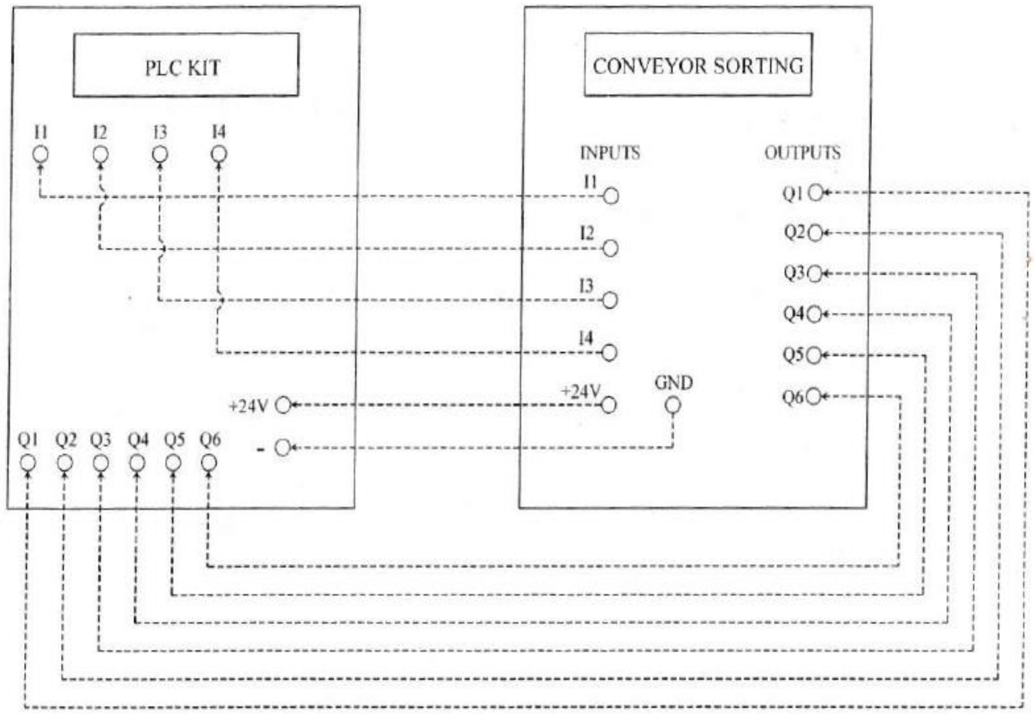
EXPERIMENTAL SECTION

AIM:

To study the conveyor sorting with colour sensing fibre unit by using the Programmable Logic Controller.

APPARATUS REQUIRED:

1. Programmable Logic Controller
2. Conveyor sorting trainer kit
3. Computer with required PLC software
4. Connecting patch cord's



DIAGRAMMATIC REPRESENTATION OF PLC AND CONVEYOR

PROCEDURE:

The Connection are made as the diagrammatic representation, 4 inputs are 4 sensors output and 2 output are 2 cylinder output and power supply as placed the appropriate patching connections. Take any colour coated material and place it in the conveyor belt. Before the want to set the threshold level of the different colour in the fibre colour sensing. Set the threshold level is OK condition. After execution the conveyor sorting program. The conveyor belt is running. The colour sensing fibre is detects the colour of the material. Depend on the material to energize the cylinder I or 2. For example, (take two colour are Red and Green) the cylinder I is energize for Red colour and cylinder 2 is energize for Green colour. When the green colour material is detected then cylinder is energize and ready to sorting the material is sensed by sensor 2 till conveyor is running. The red colour is detected means the cylinder I is energized and sensed by sensor l. Another colour material settles down in box.

Now the Red colour is stored in the box and Green colour coated material arte stored in 2nd box. This process is sorted with conveyor.

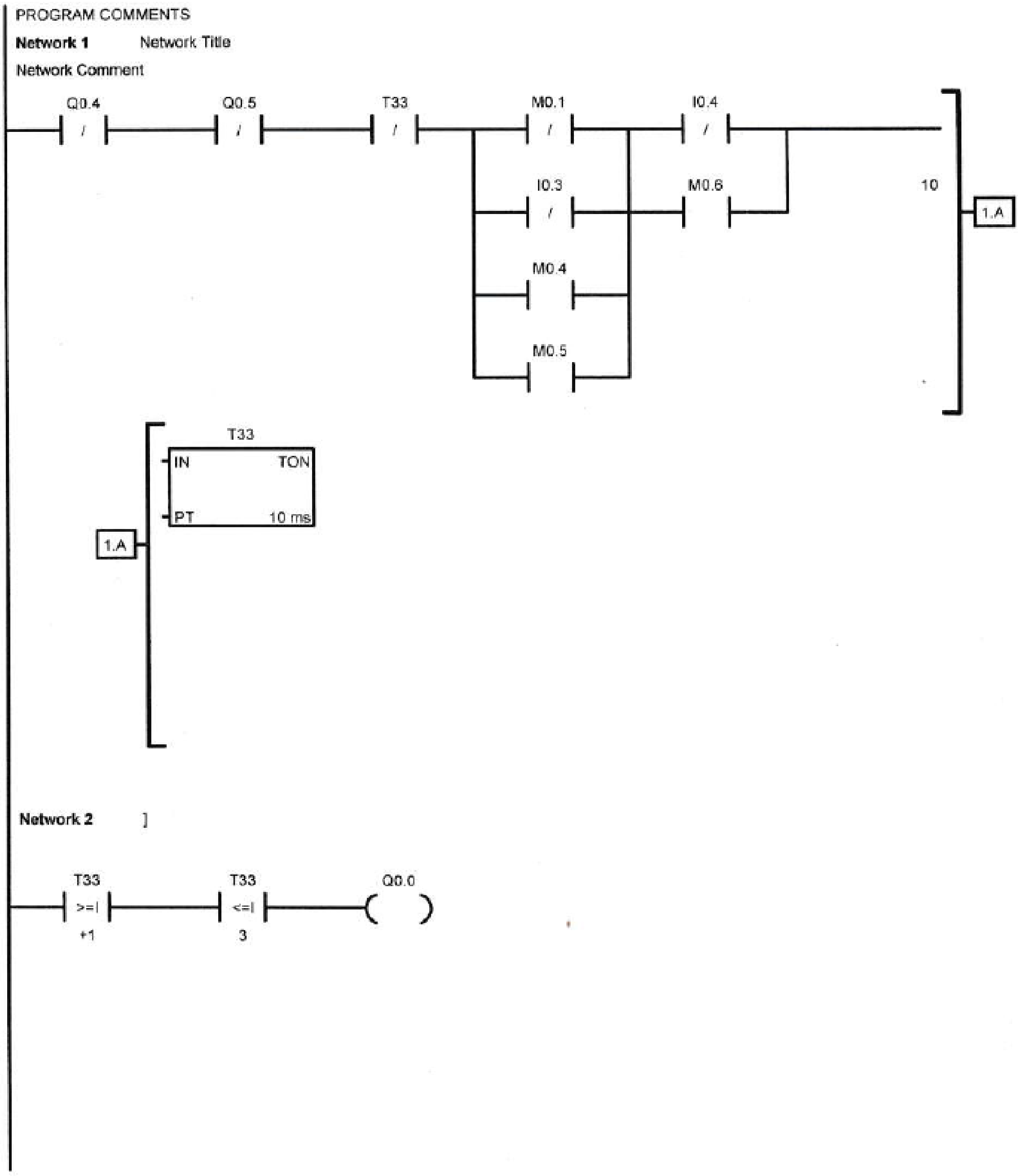
STEPS:

1. The connections are made as per in the required input sensor and output cylinder as defined in the ladder diagram program.
2. Give the +24 voltage of DC supply.
3. Take the colour coated material and placed in the conveyor belt.
4. Their three ranges are available in fibre sense the material are NEAR, OK and OVER condition.
5. Design and download the program to the Programmable Logic Controller (PLC)
6. Run the program and conveyor sorting the colour material depend on the colour.

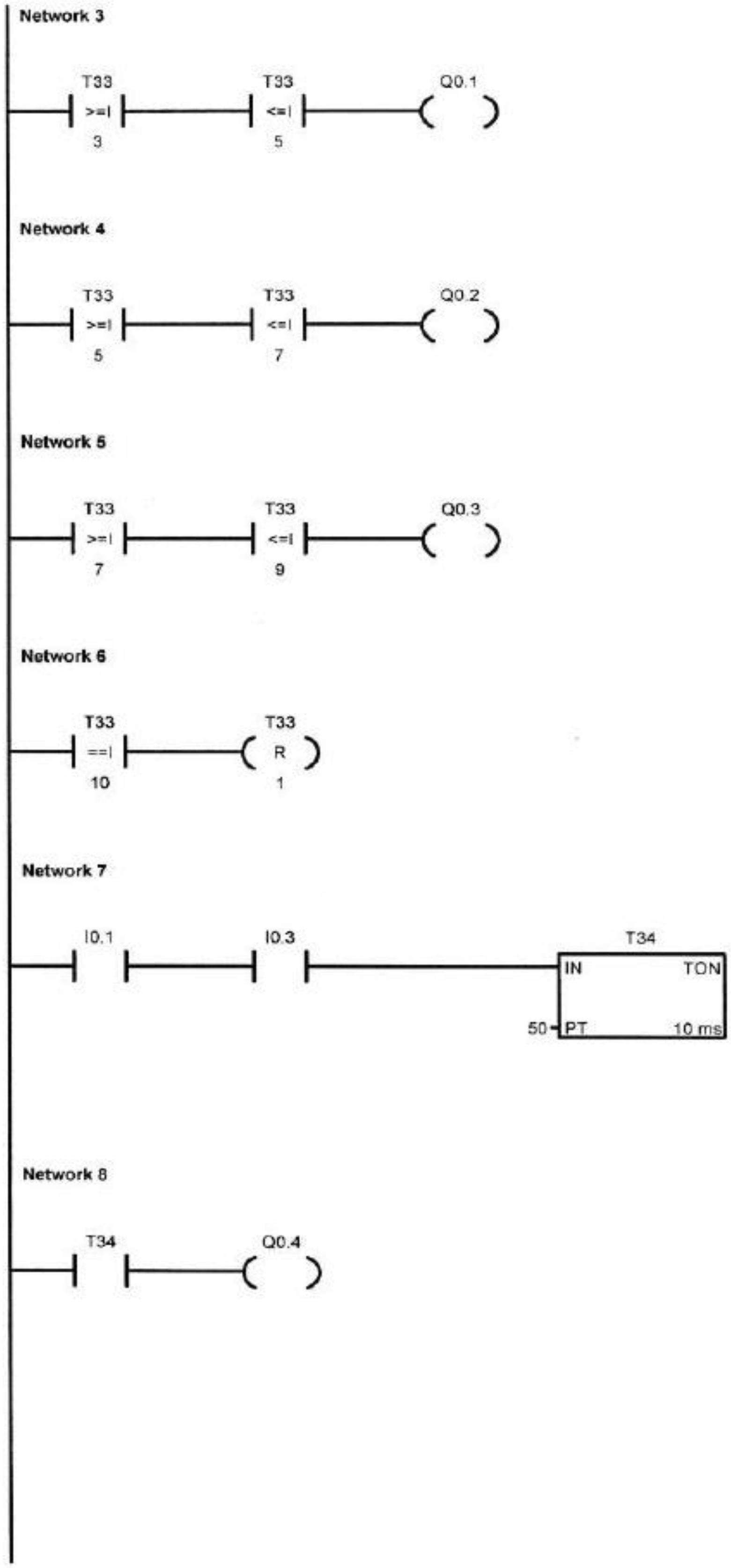
NEW SORTING / MAIN (OB1)

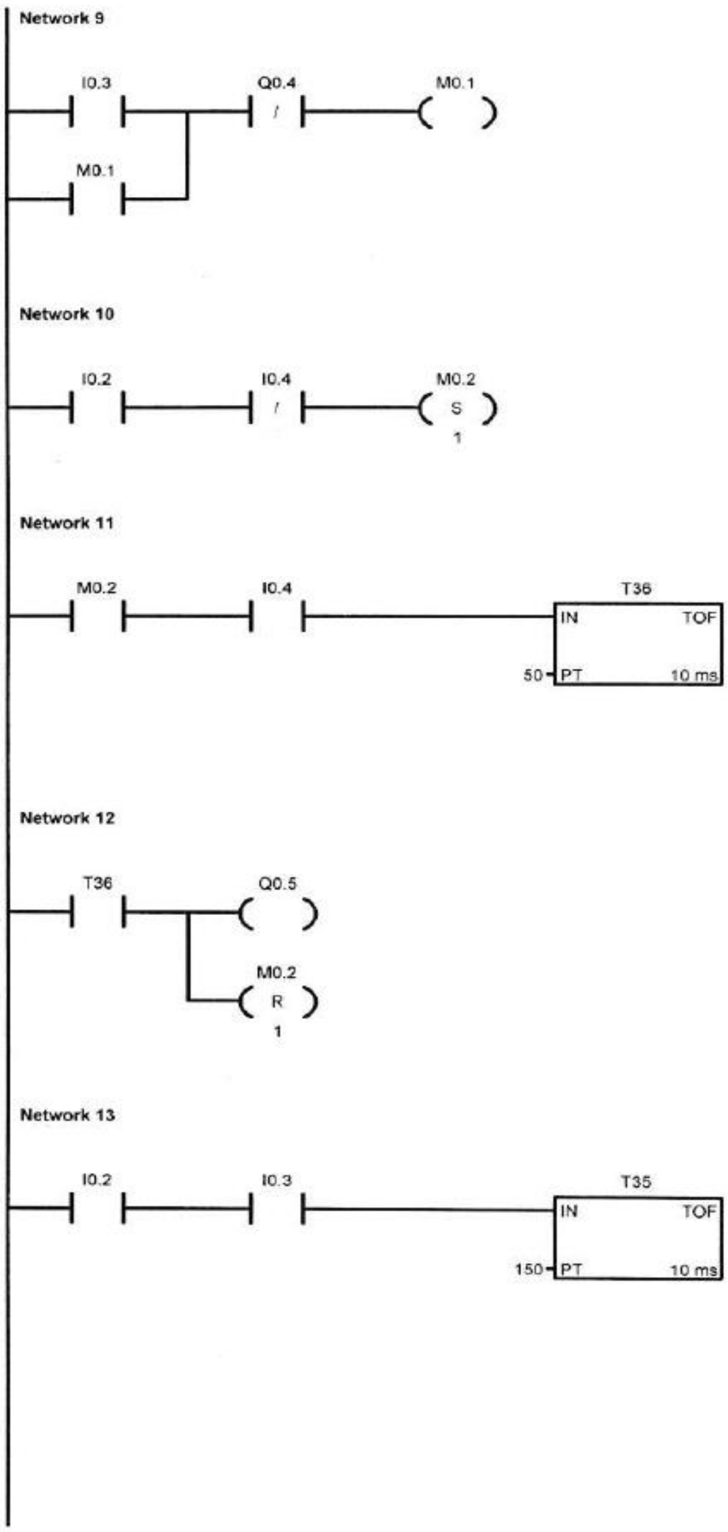
Block: MAIN
Author:
Created: 05/14/2008 10:12:13 am
Last Modified: 02/10/2010 05:21:07 pm

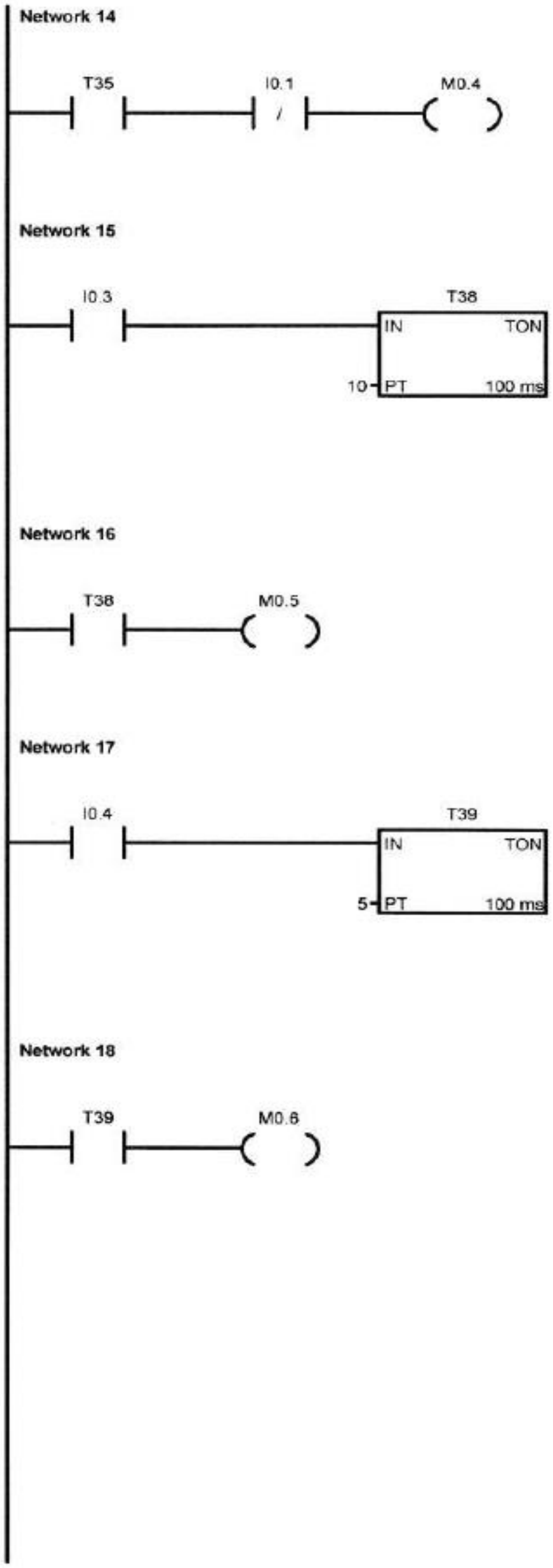
Symbol	Var Type	Data Type	Comment
	TEMP		
	TEMP		
	TEMP		
	TEMP		



NEW SORTING / MAIN (OB1)




Network 9
I0.3
Q0.4
M0.1
M0.1
Network 10
I0.2
I0.4
M0.2
S
1
Network 11
M0.2
I0.4
T36
IN
TOF
50
PT
10 ms
Network 12
T36
Q0.5
M0.2
R
1
Network 13
I0.2
I0.3
T35
IN
TOF
150
PT
10 ms


Network 14
T35
I0.1
M0.4
Network 15
I0.3
T38
IN
TON
10
PT
100 ms
Network 16
T38
M0.5
Network 17
I0.4
T39
IN
TON
5
PT
100 ms
Network 18
T39
M0.6

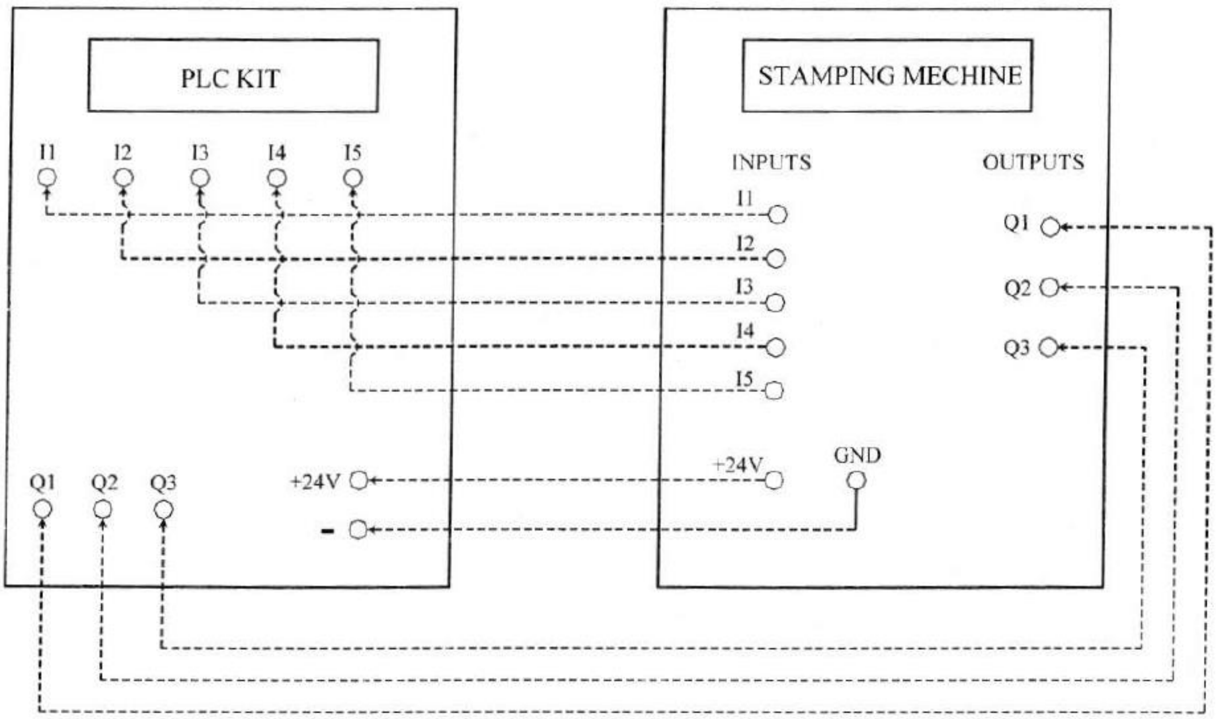
STAMPING MACHINE SYSTEM USING PLC

AIM:

To study the stamping machine by using the Programmable logic Controller.

APPARATUS REQUIRED:

1. Programmable logic controller
2. Pneumatic Stamping trainer kit
3. Computer with required software
4. Connecting patch cord's



DIAGRAMMATIC REPRESENTATION OF PLC AND STAMPING MACHINE

PROCEDURE:

The Connections are made as the diagrammatic representation given as above. In this stamping machine are widely used in the industries to labelledthe products. There are 5 inputs and 3 output piston cylinder. The wooden pieces are stored in the Store rack. When the material arc sensed by Sensors, then the piston cylinder are energized and material arc shifted to piston cylinder2. Below position of piston cylinder2 having placed the sealing patch. After sensed the material by sensor 2, then the stamping process arc done. Then piston cylinder3 are energized and shifted the material to the storing rack of the materials.

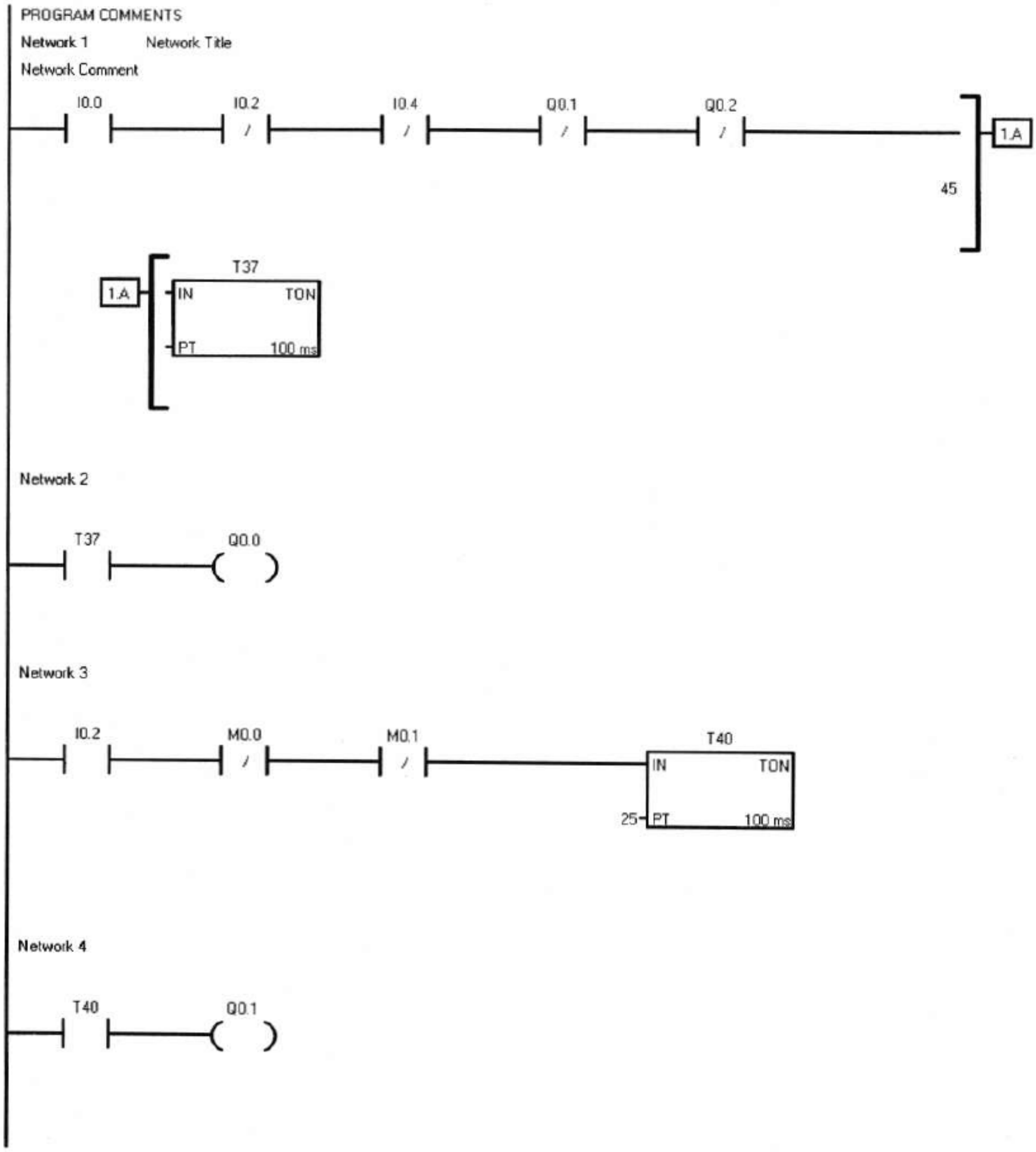
STEPS:

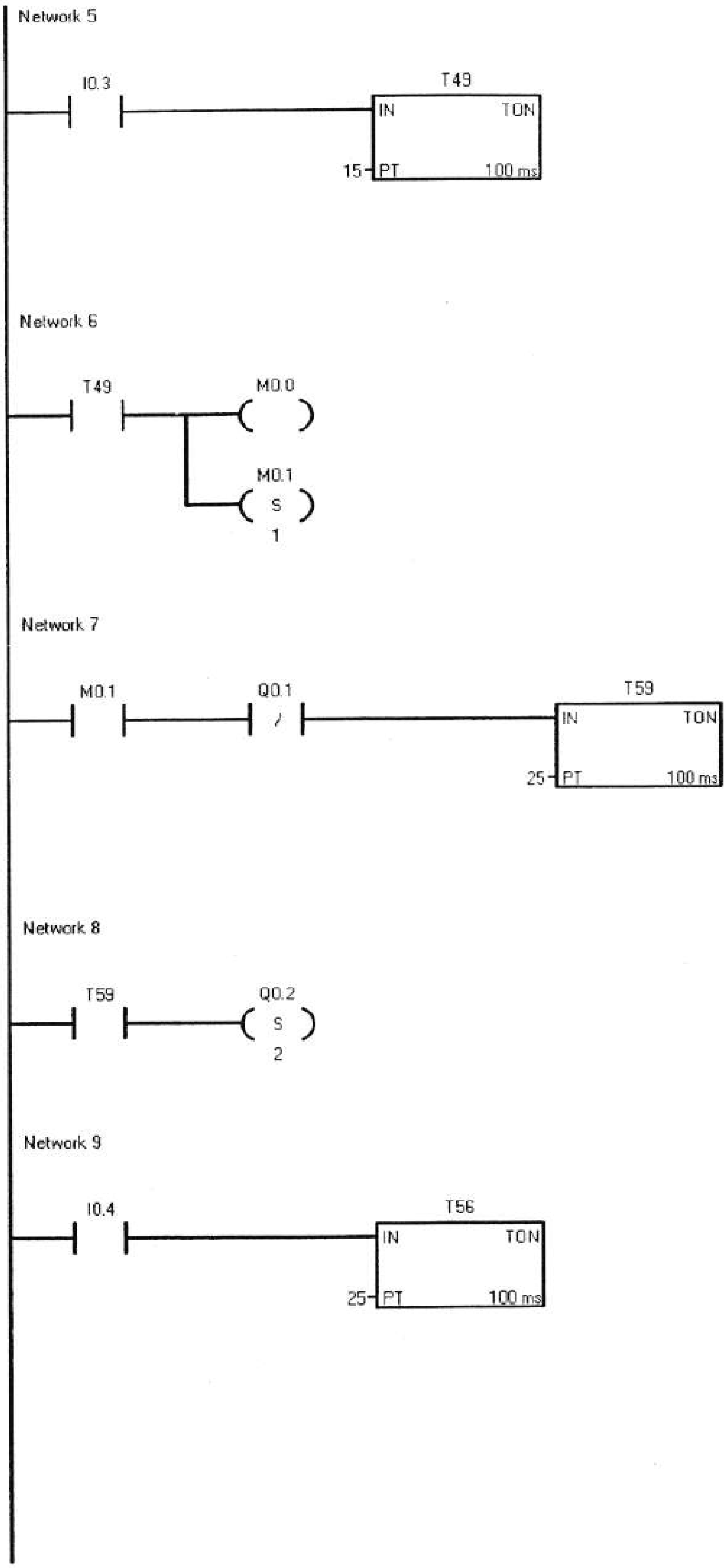
1. The connections are given as per the design of our program.
2. Give the +24v DC power to the PLC Trainer and Stamping machine application trainer kit.
3. Placed the given wooden piece to seal on the material rack.
4. Then, Download and run the program.
5. The sealed or labelled material are collected in the material store rack.

STAMPING MACHINE / MAIN (OB1)

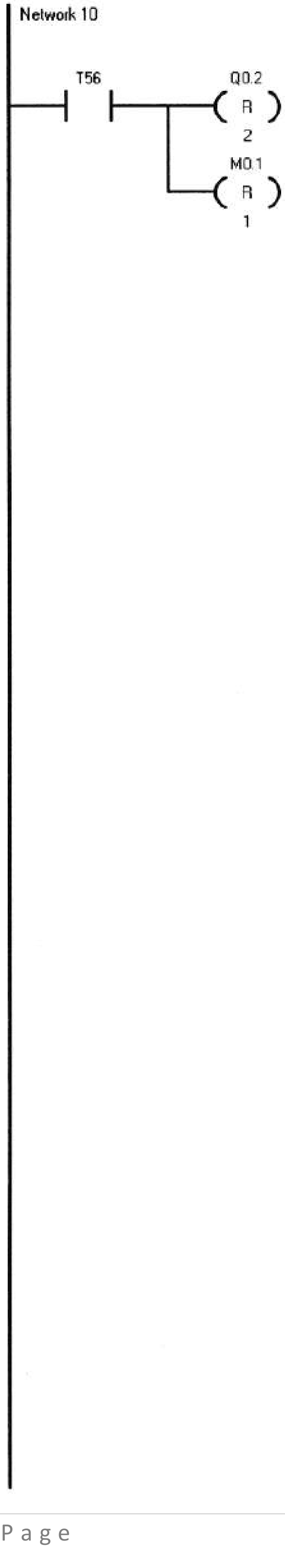
Block: MAIN
Author:
Created: 01/25/2010 04:36:52 pm
Last Modified: 01/25/2010 04:52:09 pm

Symbol	Var Type	Data Type	Comment
	TEMP		
	TEMP		
	TEMP		
	TEMP		




Network 5
I0.3
T49
IN
TON
15
PT
100 ms
Network 6
T49
M0.0
M0.1
S
1
Network 7
M0.1
Q0.1
/
T59
IN
TON
25
PT
100 ms
Network 8
T59
Q0.2
S
2
Network 9
I0.4
T56
IN
TON
25
PT
100 ms

STAMPING MACHINE / MAIN (OB1)



MATERIAL HANDLING SYSTEM

INTRODUCTION

Material handling system deals with the flow ofmaterial in an industrial setup. Beginning right from the raw material in the store to the finished product.

These are many equipment's covered in material handling system like conveyor (both powered handling & non-powered) hoist, crane, AGV (Automated Guided Vehicles), Robots and host of other.

Our trainer kit is aimed at providing a look at one of the most common & important pan of material handling system (i.e.) Conveyor and also it has electromagnet to transfer the materials.

It gives students a practical look into the components of material handling system and how they can place them in industrial setup.

CONSTRUCTION:

The material handling systems trainer consists of the following parts.

1. Conveyor
    1. Stepper motor
    2. Sensors
        a. photo electric
        b. Capacitive
        c. Inductive
2. Electromagnet
3. Limit Switches

MATERIAL HANDLING SYSTEM USING PLC

AIM:

To study the performance for the material handling system.

APPARATUS REQUIRED:

1. Material Handling System.
2. PLC
3. Step 7 lite Software
4. PC
5. MPI cable
6. Patch Chords

PROCEDURE:

1. Load the step 7 Lite software to the PLC.
2. Open the step 7 Lite software.
3. Switch ON the PLC trainer and Material handling system.
4. Connect PLC and material handling system kit.
5. Open the New folder and draw the ladder logic program.
6. Connect the PLC to PC.
7. Select the correct hardware Configuration [SL.No].
8. Store the program to PLC.
9. Run the Program.
10. Verify the performanceof the material handling system.

SPEED CONTROL OF SWITCHED RELUCTANCE MOTOR USING FPGA

AIM:

To control the speed of the switched reluctance motor using FPGA (Altium Nano board 3000).

APPARATUS REQUIRED:

1. SRM motor with hall sensors and position encoder.
2. IGBT stack module.
3. 1-Φ Auto transformer.
4. Altium Nano board with AMS card.
5. Xilinx ISE design suite.
6. Altium designer software.

THEORY:

A switched reluctance (SR) motor is a rotating electric machine where both stator and rotor have salient poles. The stator winding comprises a set of coils, each of which is wound on one pole. The rotor is created from lamination in order to minimize the eddy current losses.

SR motors differ in the number of phases wound on the stator. Each has a certain number of suitable combinations of stator and rotor poles. The motor is excited by a sequence of current pulses applied at each phase. The individual phases are consequently excited, forcing the motor to rotate. The current pulses need to be applied to the respective phase at the exact rotor position relative to the excited phase.

The inductance profile of SR motors is triangular shaped, with maximum inductance when it is in an aligned position and minimum inductance when unaligned. Figure 2 illustrates the idealized triangular-like inductance profile of both phases of an SR motor with phase A highlighted. The individual phases A and B are shifted electrically by 180 degrees relative to each other. When the respective phase is powered, the interval is called the dwell angle: $\theta_{dwell.}$ It is defined by the turn-on $\theta_{on}$and the turn-off θ_{off} angles.

When the voltage is applied to the stator phase, the motor creates torque in the direction of increasing inductance. When the phase is energized in its minimum inductance position, the rotor moves to the forthcoming position of maximal inductance. The movement is defined by the magnetization characteristics of the motor. A typical current profile for a constant phase voltage is shown in figure 2.

CONTROL OF SRM MOTOR

The SR motor is driven by voltage strokes coupled with the given rotor position. The profile of the phase current together with the magnetization characteristics defines the generated torque and thus

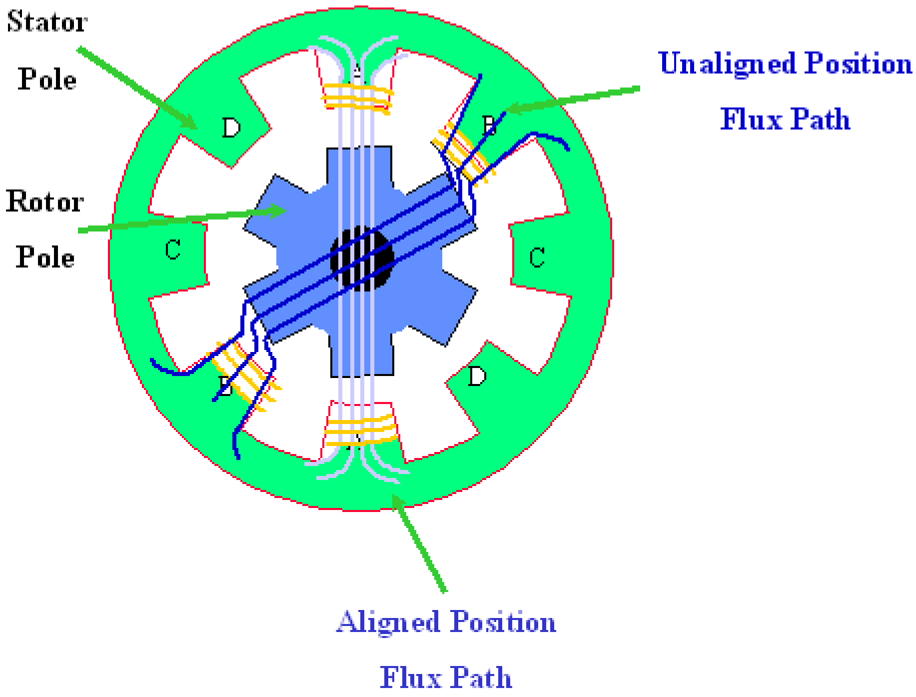


Figure 12.1: 8/6 switched reluctance motor

The speed of the motor. Due to this fact, the motor requires electronic control for operation. Several power stage topologies are being implemented, according to the number of motor phases and the desired control algorithm. The particular structure of the SR power stage defines the freedom of control for an individual phase.

There are a number of control techniques for SR motors. They differ in the structure of the control algorithm and in position evaluation. Three basic techniques for controlling SR motors can be distinguished, according to the motor variables that are being controlled.

1. Angle control
2. Voltage control
3. Current control

In angle control techniques, the constant full voltage is applied in the SR motor. The speed of the motor is controlled by changing on/off angles. The speed controller processes the speed error (the difference between the desired speed and the actual speed) and calculates the desired on/off angles. This technique is not suitable for full speed range operation since during low-speed operation the maximal voltage amplitude generates high current peaks in the motor phases. This technique is used to run the SR motor over nominal speed. At the nominal speed, the full voltage is applied on the motor phases and by properly adjusting on/off angles the motor can achieve operation over the nominal speed.

In voltage control techniques, the speed of the motor is defined by the voltage applied to the motor phases. The voltage applied to the phase is directly controlled by a speed controller. The speed controller processes the speed error (the difference between the desired speed and the actual speed) and generates the desired phase voltage. The desired voltage is generated by the SR inverter using PWM modulation. During PWM modulation, the on/off times are constant. Once the applied voltage has achieved its maximal value, the motor speed can be increased over the nominal speed by changing on/off times.

In the case of current control, there is one more control loop: inner current control loop employed in the control of the SR motor. In this type of control, the output of the speed controller defines the required current amplitude in the motor phase. Based on the required current amplitude, the new on/off times are calculated. Once the current reaches desired amplitude, the current controller keeps the phase current at the desired level.

As is apparent from the description, the SR motor requires position feedback for motor phase commutation. In many cases, this requirement is addressed by using position sensors, such as encoders and Hall sensors. The result is that the implementation of mechanical sensors increases costs and decreases system reliability. Traditionally, developers of motion control products have attempted to lower system costs by reducing the number of sensors. A variety of algorithms for Sensorless control have been developed, most of which involve evaluation of the variation of magnetic circuit parameters that are dependent on the rotor position.

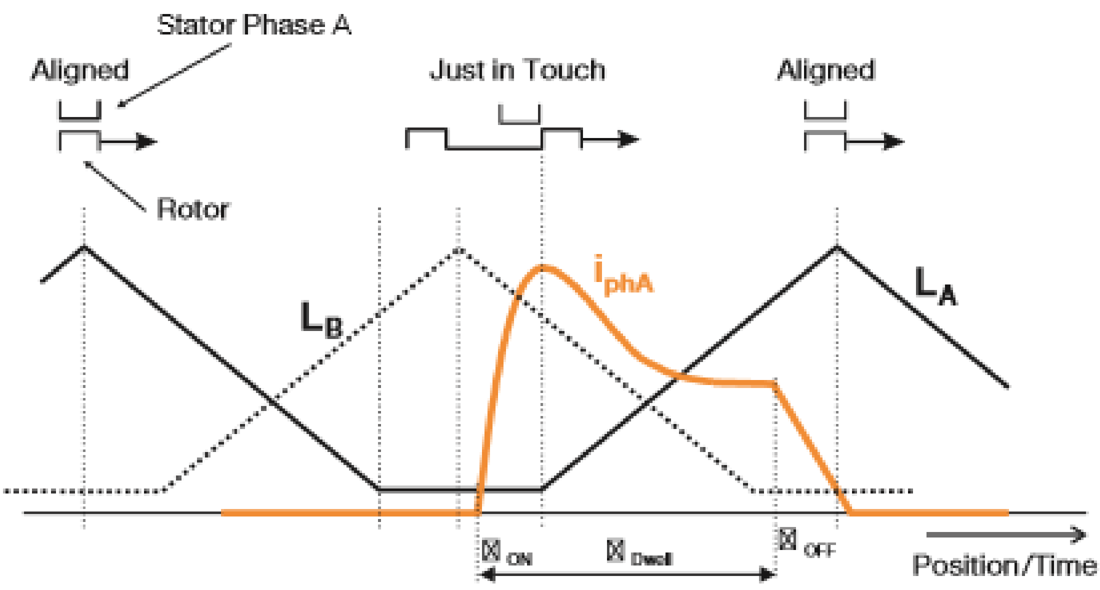


Figure 12.2: Ideal phase Inductance current profile.

SR MOTOR APPLICATIONS

The SR motor itself is a cost-effective machine of simple construction. Since high-speed operation is possible, the motor is suitable for high-speed applications, such as vacuum cleaners, fans and white goods. As discussed above, the disadvantage of the SR motor is the need for shaft position information for the proper switching of individual phases. Also, the motor structure causes noise and torque ripple. The greater the number of poles, the smoother the torque ripple, but motor construction and control electronics become more expensive. Torque ripple can also be reduced by advanced control techniques such as phase current profiling.

CONNECTION DIAGRAM

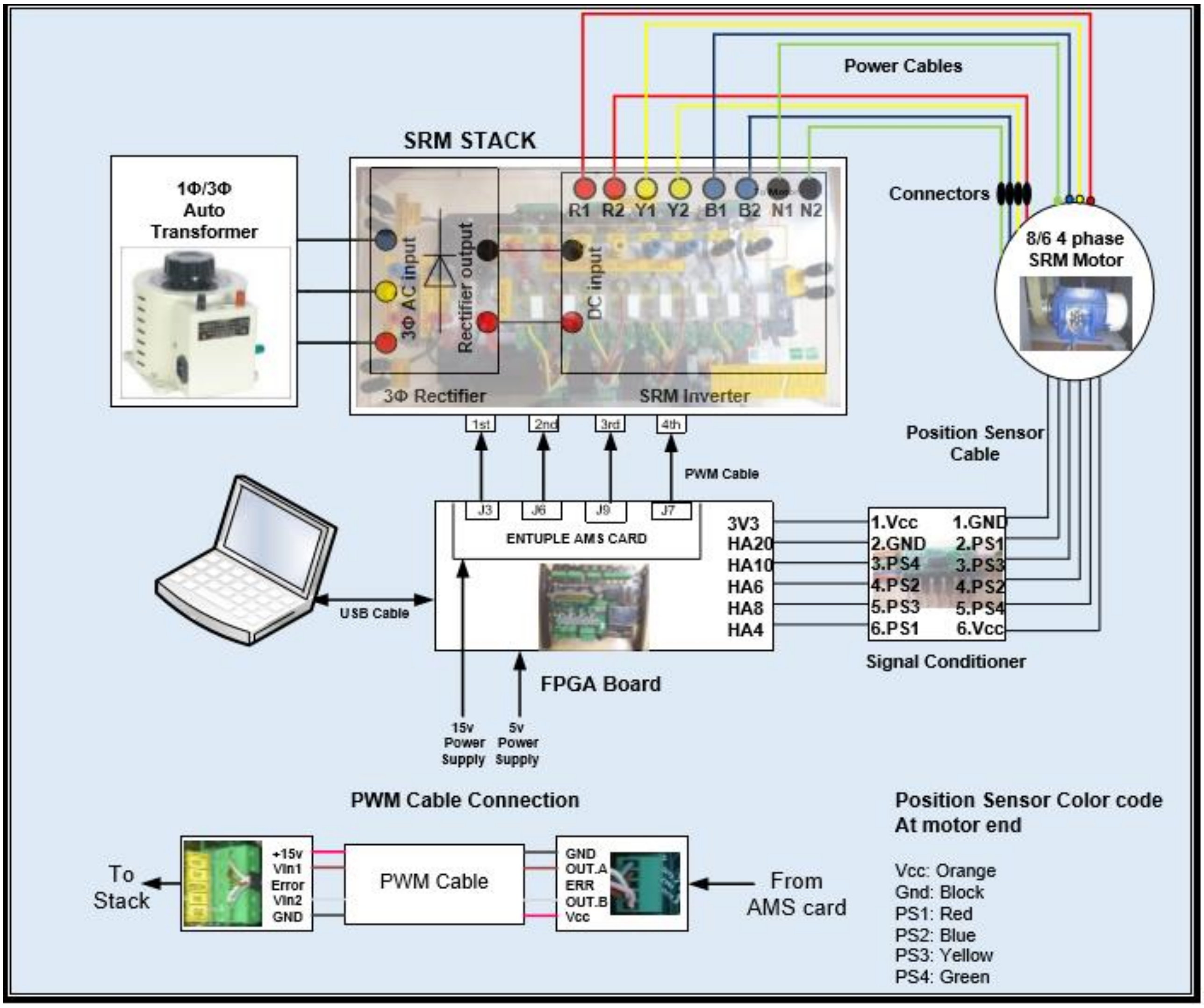


Figure 12.3 Switched Reluctance Motor Drive Connections

CONNECTION PROCEDURE

1. Connect 1φ/3φ autotransformer to AC input of SRM stack.
2. Connect DC output of rectifier to DC input of Inverter in SRM stack.
3. Using PWM cables connect j3, j6, j9 and j7 port of AMS card to 1st, 2nd, 3rd and 4th port of Stack.
4. Connect starting coil (Red, Yellow, Blue and Green wire) of motor to (R1, Y1, B1, N1) of stack using power cable.
5. Connect ending coil (Red, Yellow, Blue and Green wire with connector) of motor to (R2, Y2, B2, N2) of stack using another power cable.
6. Connect position sensor of motor to FPGA Board according to the table given below using position sensor cable.

PS – Position sensor

Position sensor colour code at motor end	
V_{cc}	White
GND	Brown
PS1	Red
PS2	Yellow
PS3	Blue
PS4	Green

Position	Signal conditioner input	Signal conditioner output	To FPGA
1	GND	V_{cc}	3V3
2	PS1	GND	HA20
3	PS3	PS4	HA10
4	PS2	PS2	HA6
5	PS4	PS3	HA8
6	V_{cc}	PS1	HA4

7. Connect 5V power supply to FPGA Board.
8. Connect 15V power supply to AMS card.
9. Connect an USB cable from USB port of FPGA Board to USB port of PC.

PROCEDURE:

1. Connect every equipment according to connection procedure.
2. Turn on power supply for FPGA Board and AMS card.
3. Monitor driver card’s LED,
   a. For SKYPER_32_PRO connection it will not glow.
   b. For SKYPER_32 connection it will glow.

4. Download the SRM program into FPGA Board by following altium instruction.
5. For testing of sensor connection rotate rotor by hand and check bottom right LED’s of FPGA (Only one or two LED should glow at one time that too in sequence).
6. Double click on digital I/O and custom instrument to see the controls and graphs.
7. Keep autotransformer at zero position and turn on power supply of SRM stack.
8. Increase the input voltage gradually using autotransformer.
9. Fill all datain digital I/O(like PI, speedtarget, motor direction) and Click on enable button.
10. Motor will run according to data input.
11. Increase the input voltage using autotransformer to make DC input to rated voltage of motor.
12. Then by changing input values on digital I/O you can visualize different controls.

RESULT:

13.VECTOR CONTROL OF THREE PHASE INDUCTION MOTOR

AIM:

Vector control of three phase Induction Motor using Altium Nano board 3000.

APPARATUS REQUIRED:

1.Three phase Induction Motor.

2.IGBT stack module.

3.3-Φ Auto transformer.

4.Altium Nano board with AMS card.

5.Xilinx ISE design suite.

6.Altium designer software.

THEORY:

Three-phase AC induction motors (ACIM) are popular in industry for a number of reasons. Their construction is extremely optimized, since they have been produced for years. They are very simple and manufacturing costs are favourable. They have no brushes and require minimum maintenance. The robustness of the motor is another strong advantage. We would find induction motors mostly in applications such as water pumps, compressors, fans and air-conditioning systems.

In order to achieve variable speed operations in a three-phase AC induction motor, a variable voltage and variable frequency needs to be supplied to the motor. Modern three-phase variable speed drives (VSD) are supplied with digitally controlled switching inverters.

The control algorithms can be sorted into two general groups. The first group is referred to scalar control. The constant Volt per Hertz control is a very popular technique representing scalar control. The other group is called vector or field oriented control (FOC). The vector oriented techniques brings overall improvements in drive performance over scalar control. Let's mention the higher efficiency, full torque control, decoupled control of flux and torque, improved dynamics, etc.

The AC induction motor is a rotating electric machine designed to operate from a 3-phase source of alternating voltage. For variable speed drives, the source is normally an inverter that uses power switches to produce approximately sinusoidal voltages and currents of controllable magnitude and frequency.

A cross-section of a two-pole induction motor is shown in Figure 1. Slots in the inner periphery of the stator accommodate 3-phase winding a,b,c. The turns in each winding are distributed so that a current in a stator winding produces an approximately sinusoidally-distributed flux density around the periphery of the air gap. When three currents that are sinusoidal varying in time, but displaced in phase by 120° from each other, flow through the three symmetrically-placed windings, a radially-directed air gap flux density is produced that is also sinusoidal distributed around the gap and rotates at an angular velocity equal to the angular frequency of the stator currents.

The most common type of induction motor has a squirrel cage rotor in which aluminium conductors or bars are cast into slots in the outer periphery of the rotor. These conductors or bars are shorted together at both ends of the rotor by cast aluminium end rings, which also can be shaped to act as fans. In larger induction motors, copper or copper-alloy bars are used to fabricate the rotor cage winding.

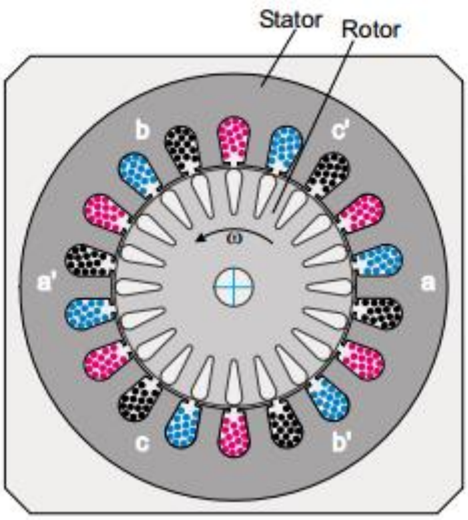


Fig 13.1: Three phase AC Induction Motor – Cross section

As the sinusoidal-distributed flux density wave produced by the stator magnetizing currents sweeps past the rotor conductors, it generates a voltage in them. The result is a sinusoidal-distributed set of currents in the short-circuited rotor bars. Because of the low resistance of these shorted bars, only a small relative angular velocity between the angular velocity of the flux wave (ω_s)and the mechanical angular velocity (ω)of the two-pole rotor is required to produce the necessary rotor current. The relative angular velocity is called the slip velocity (ω_{slip}). The interaction of the sinusoidal-distributed air gap flux density and induced rotor currents produces a torque on the rotor. The typical induction motor speed-torque characteristic is shown in Figure 2.

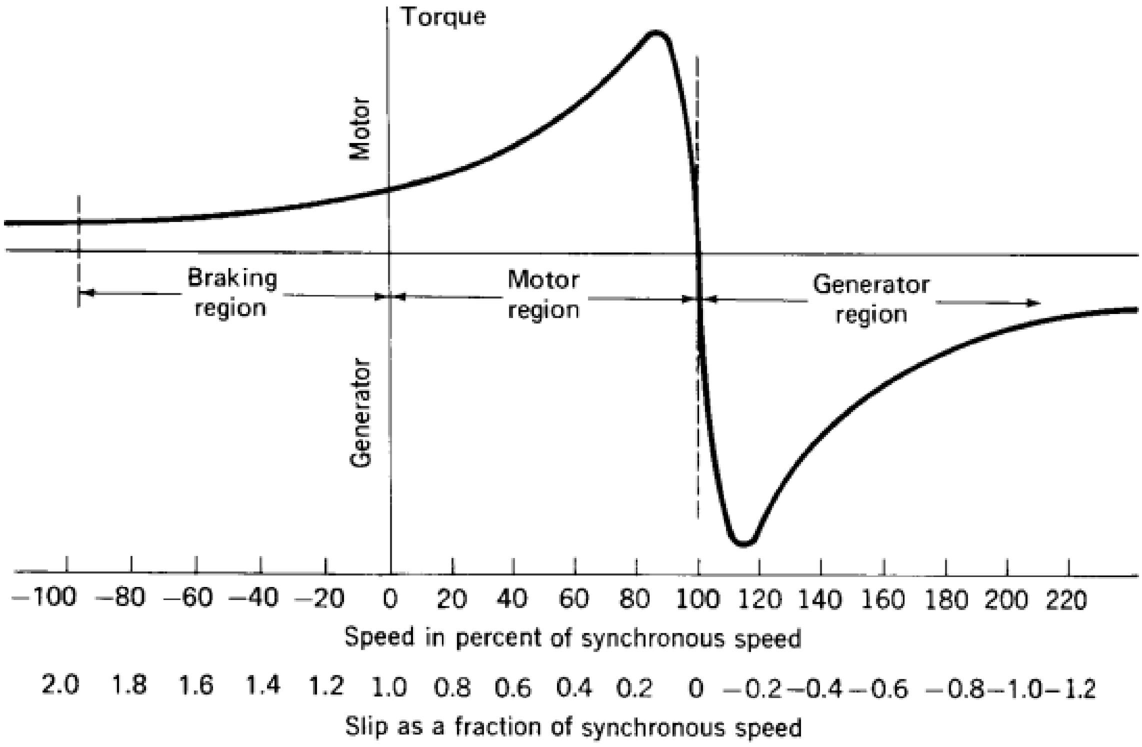


Fig 13.2: AC Induction Motor Speed – Torque Characteristics

Squirrel-cage AC induction motors are popular for their simple construction, low cost per horsepower and low maintenance (they contain no brushes, as do DC motors). They are available in a wide range of power ratings. With field-oriented vector control methods, AC induction motors can fully replace standard DC motors, even in high-performance applications.

VECTOR CONTROL OF AC INDUCTION MOTOR:

High-performance motor control is characterized by smooth rotation over the entire speed range of the motor, full torque control at zero speed, fast accelerations and decelerations. To achieve such control, vector control techniques are used for three-phase AC motors. The vector control techniques are usually also referred to field-oriented control (FOC). The basic idea of the FOC algorithm is to decompose a stator current into flux and torque producing components. Both components can be controlled separately after decomposition. The structure of the motor controller is then as simple as that for a separately excited DC motor.

Figure 3 shows the basic structure of the vector control algorithm for the AC induction motor. To perform vector control, it is necessary to follow these steps:

- Measure the motor quantities (phase voltages and currents).
- Transform them into the 2-phase system (α,β) using a Clarke transformation
- Calculate the rotor flux space-vector magnitude and position angle.

- Transform stator currents into the d-q reference frame using a Park transformation.
- The stator current torque (i_{sq}) and flux (i_{sd}) producing components are separately controlled.
- The output stator voltage space vector is calculated using the decoupling block.
- The stator voltage space vector is transformed by an inverse Park transformation back from the d-q reference frame into the 2-phase system fixed with the stator.
- Using space vector modulation, the output 3-phase voltage is generated.

To be able to decompose currents into torque and flux producing components (i_{sd},i_{sq})), we need to know the position of the motor magnetizing flux. This requires accurate velocity information sensed by a speed or position sensor attached to the rotor. Incremental encoders or resolvers are naturally used as position transducers for vector control drives. In cost sensitive applications like washing machines, Tacho-generators are widely used. In some applications the use of speed/position sensors is not desirable either. Then, the aim is not to measure the speed/position directly, but to employ some indirect techniques to estimate the rotor position instead. Algorithms which do not employ speed sensors, are called "sensorless control".

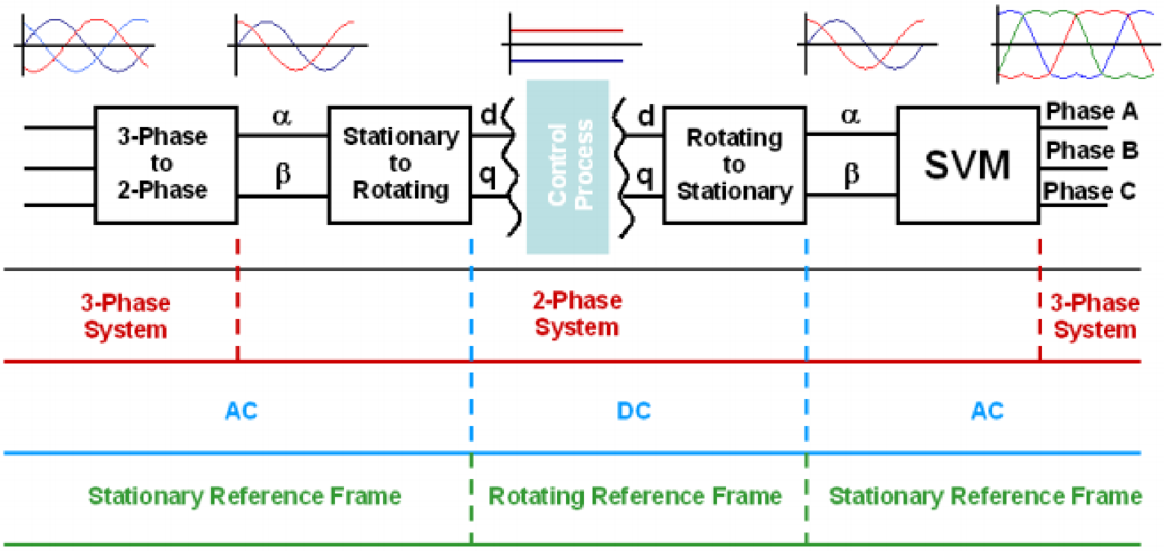
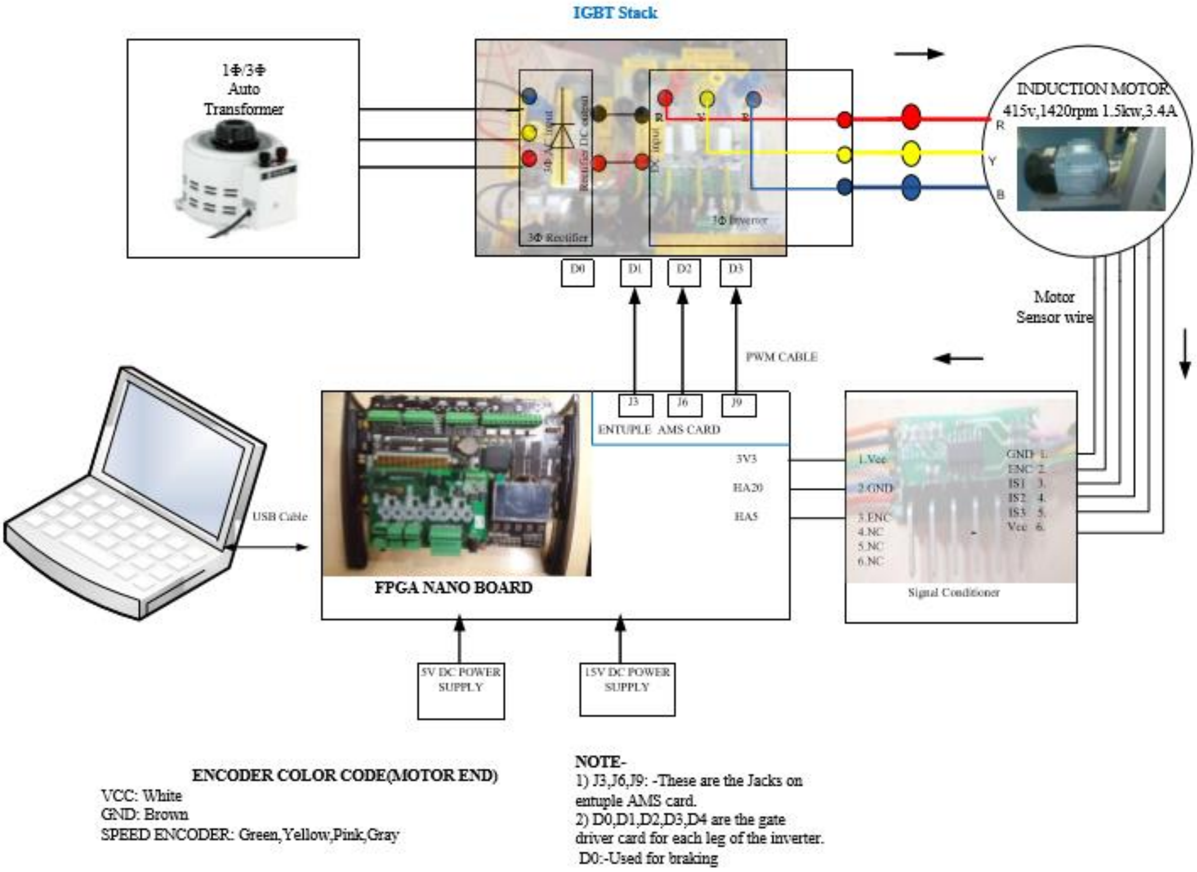


Fig 13.3: Vector Control Transformations

INDUCTION MOTOR DRIVE CONNECTION PROCEDURE



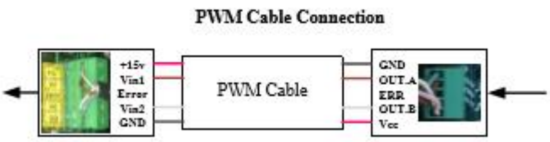


Figure 13.4 Vector Control Drive System Connection

CONNECTION PROCEDURE:

- Connect the Input of the IGBT MODULE (R,Y,B) Terminal through (3ph or 1ph). Auto Transformer from the Input supply lines. For single phase auto transformer connect any two terminals out of R Y B.
- Connect Rectifier Output to DC Link Capacitors using Connecting wire.
- Connect Motor terminals R, Y,B to IGBT Module Inverter Output of R,Y and B using power cable.
- Connect another end of PWM cables to J3, J6,J9 port of FPGA to 2nd,3rd ,4th port of IGBT Stack.

SENSOR CONNECTION:

- Connect Motor speed encoder input to Input port of speed sensor cable on input side.
- Connect speed sensor cable Output to FPGA Board.
- In sensor cable White for VCC, Brown for GROUND, Green, Yellow, Grey, Pink wires for Input Signals.
- Connect White to JP1&UH1 port of 3V3 pin, Brown to HA20, Green to HA5 in FPGA Board.

Table 1 :-(Sensor ->signal conditioner->FPGA)

Signal Name	From Motor Encoder	To sensor cable input	After Signal conditioning	To FPGA
VCC	+VE(white)	Input_PIN_6	Output_PIN_1	3V3 pin
GROUND	Ground(Brown)	Input_PIN_1	Output_PIN_2	HA20
Speed Encoder	Speed(Green, Pink,Yellow,Gray)	Input_PIN_2	Output_PIN_3	HA5

PROCEDURE:

- Connect every equipment according to the connection procedure.
- Turn on power supply for FPGA Board and AMS card.
- Burn the program into Controller Board using your PC by following the instructions.
- Open FPGA Project of Induction Motor and Click on Device View to open the device view.
- Now check live button and click on 'program FPGA' to burn the program into FPGA Board.
- Double-click on Configurable digital IO and custom instrument to see the controls and graphs.
- Keep Autotransformer at zero position. Increase the input voltage gradually using autotransformer.
- Fill all the data (m_en, speed_ref, sw_freq, kp, ki) in Configurable digital IO.
- Click on enable button.
- Motor will run according to the data value.
- Increase the input voltage using auto transformer to rated voltage of motor.
- Then by changing the data on Configurable digital IO, You can do different controls.

RESULT: