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Class notes on

Advanced Automation Systems

Programme: Automation and Robotics (AO4I)

Course code:22475

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Course Outcomes(CO's)

1. Compare Different SCADA systems based on given parameters.
2. Use the relevant Network communication protocol for specific SCADA applications.
3. Develop SCADA based applications in integration with PLC.
4. Use the HMI Panel for given applications.
5. Use the SCADA system to develop the given industrial applications.

Teaching and Examination scheme:

Teaching Scheme			Credit (L+T+P)	Examination Scheme												
				Theory							Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
4	-	2	6	3	70	28	30*	00	100	40	25#	10	25	10	50	20

Contents

Chapter 1

Basics of SCADA System

1.1 Industrial automation Hierarchy:

The industrial automation hierarchy takes on a pyramid form of communications where information gets aggregated as it moves from a low level (sensor level) to high level (Server or enterprise level) and there is a direct correlation between the levels of the hierarchy in that improved communications between levels of the hierarch lead to direct efficiency increases of the overall manufacturing systems. In fact, this is the basis of Industry 4.0.

Industrial automation systems are made up of large devices that synchronize and work with other industrial automation technologies. As such, they can be complex in nature. Industrial automation systems consist of different hierarchy levels as explained below.

Field level The field level is the lowest automation hierarchy level and is made up of field devices such as actuators and sensors. The field devices have a core task of transferring machines and processes data to the next level for monitoring and analysis. Actuators are used to control the process parameters. In most cases, this level is dubbed the arms and eyes of an automated industrial process. Real time process parameters such as level, flow, temperature, and pressure are converted into electrical signals by the field level sensors. Data collected from the sensors is transferred to the controller for further monitoring and analysis of the real time parameters. Sensors include; proximity sensors, flow meters, thermocouple, RTDs among others. Actuators include; pneumatic actuators, flow control valves, relays, solenoid valves, servo motors, and Dc motors among others.

The control level The control level is made up of automation devices such as PLCs and CNC machines that derive ideal process parameters from the different sensors. Industrial automated controllers trigger the actuators as per the processed sensor signals, control techniques, or programs. PLCs (programmable logic controllers) are widely used as industrial controllers of choice because they can deliver automatic control functionalities as per sensors? inputs. PLCs allow industrial automation operators to program control functions to execute automatic process

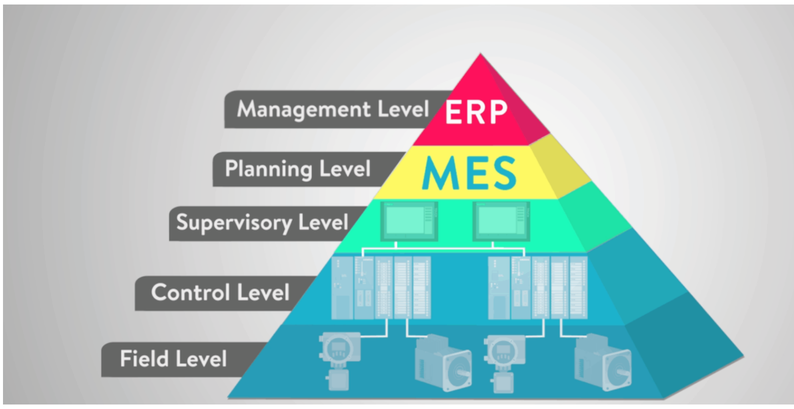

Figure 1.1: Automation Pyramid

operations. PLCs are made of different modules such as; digital I/O, communication modules, analog I/O and CPU.

Production control and supervising level At this level, automatic monitoring systems and devices are used to facilitate the intervention and control of functions such as; setting of production targets, supervising different parameters, supervisory control and data acquisition (SCADA), setting machine start and stop periods, and Human Machine Interface (HMI).

Planning or MES Level A Manufacturing Execution System (MES), is an information system which monitors and tracks the process of producing manufactured goods on the factory floor. The overall goal of MES is to make certain that manufacturing operations are effectively executed to improve production output. That goal is achieved by tracking and gathering real-time and accurate data about a complete production lifecycle.

MES is the comprehensive system that controls all the activities occurring on the shop floor. It begins with all the various orders from customers, the MRP system, the master schedule, and other planning sources; and then builds the products in the most effective, low cost, expedient, and high- quality way possible. A comparative example occurs in the construction business where the construction team (MES) builds a tower from the architectural plans (inputs from MRP, Master schedule, etc.)

Enterprise or information level Often referred to as Enterprise Resource Planning (ERP), this is the top industrial automation hierarchy level that is tasked with management of the entire industrial automation system. Tasked executed at this level include; market and customer analysis, sales, orders, and production planning just to mention a few. Evidently, this level is geared towards supporting commercial industrial activities as opposed to technical industrial aspects. Note that, all industrial automation hierarchy levels comprise of industrial communication networks that transfer information from one hierarchy level to another. As such, they ensure continuous flow of information but the communication networks can vary from one hierarchy level to the other.

1.2 Typical SCADA Architecture:

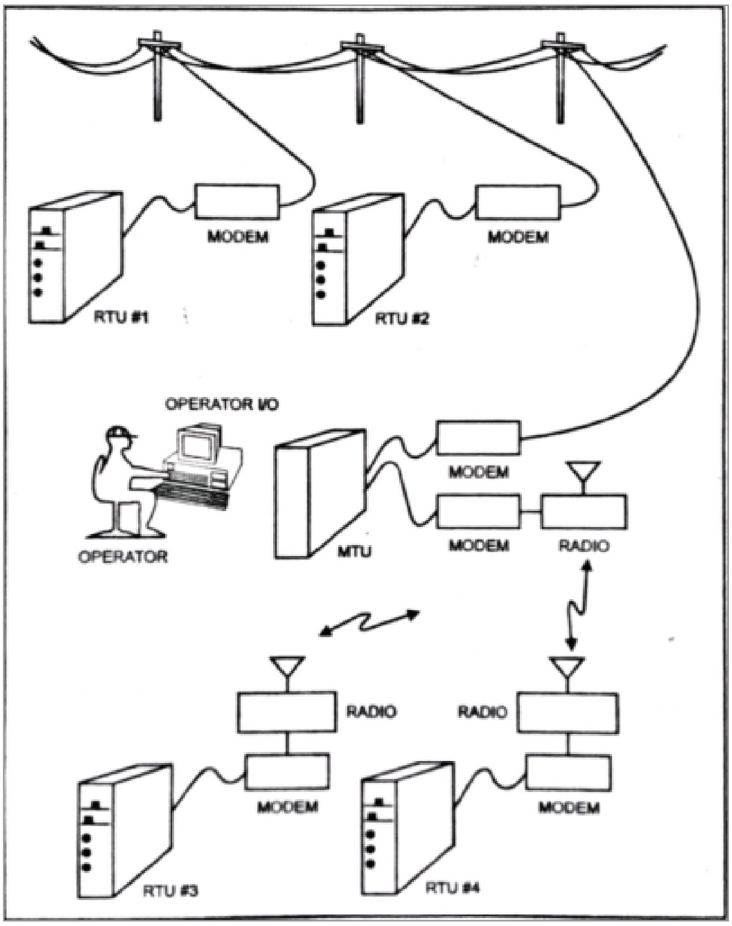

Figure1.2 Concept Of SCADA System

Scada is an acronym that stands for Supervisory Control And Data Acquisition. Generally, SCADA is a system that acquires (or collects) data (or signal) from various field devices at a factory, plant or in the remote locations and then sends this data to a master computer which then manages and controls the data and entire system.

SCADA Technology is suitable to the processes that are spread over large area (in several miles). Using SCADA, such systems become relatively simple to control and monitor and it reduces the frequent visits of an operator to remote locations. Table in figure 1.9 shows the names of different vendors (Manufacturers) of SCADA and their brand names.

Figure 1.2 above shows the basic concept of SCADA system. At the centre of every SCADA system is the operator, which interfaces with Master terminal unit (MTU) which is host computer or master computer through operator interface (HMI).

Based on the command given or programmed by the operator, MTU communicates with different units, which are placed at remote locations. A SCADA system may have as few as one RTU or as many several hundred.There are two common media of communication, as shown in following fig. i.e. Land line, which is in the form of optical fiber cable or electrical cable and radio. In both cases, a modem, which Modulates and Demodulates a signal on the carrier is required.

RTU or Remote terminal units are used to receive signal from MTU through communication link and delivering this signal to various field input and output devices. RTU contains inbuilt processor, memory, communication port and I/O port.

1.3 Components of SCADA system:

Figure 1.3 below shows the typical architecture or functional block diagram for SCADA system which can be explained as follows:

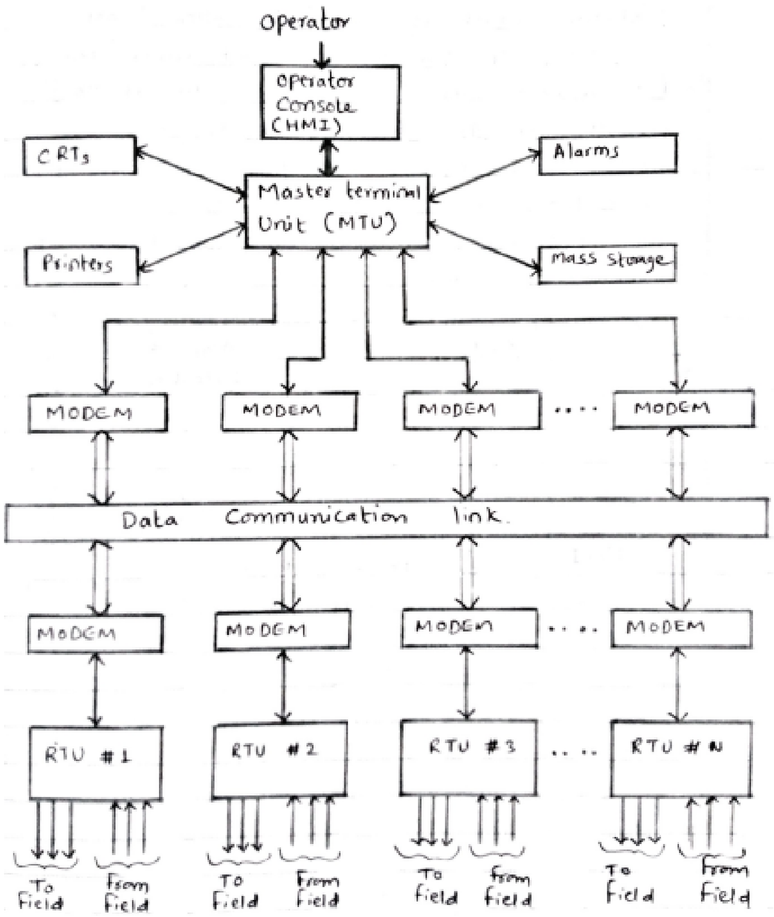

Figure1.3 Functional block diagam of SCADA

1.3.1 Master Terminal Unit (MTU)

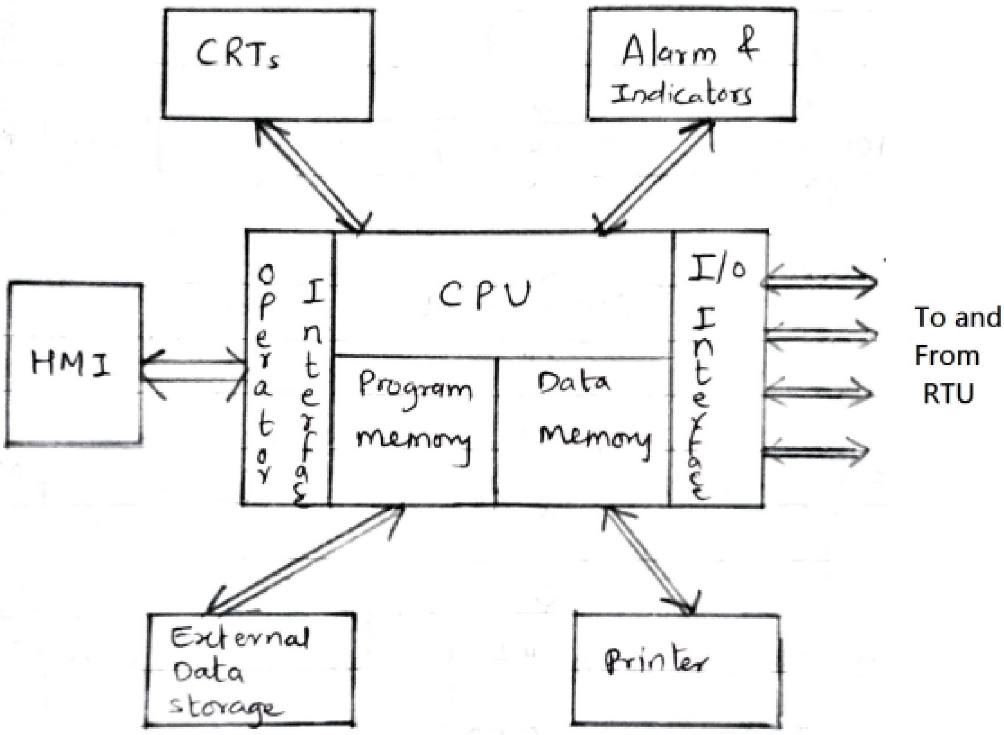

Figure1.4 Block diagram of MTU

Master terminal unit (MTU) is a system controller , which is sometimes called 'host computer'. It can monitor and control the field devices even when the operator is not present. It does this by means of a built in scheduler that can be programmed to repeat instructions at set intervals.Figure 1.4 shows the block diagram of MTU: Generally, MTU receives the signal from operator interface and after processing, this signal will be given to RTU for control of various field devices. It also receives the signal from RTU, which is received by RTU from field devices. This received signal is stored and processed by MTU according to program given by operator.

Following are the general functions of MTU:

- Collects the data from different RTU's placed at remote locations.
- Stores required information into internal and external storage devices.
- Passes other information on to the associated system.
- Interfaces with the people which operator the process.
- ssues commands or control signal to various RTU's.

1.3.2 Remote Terminal Unit (RTU)

RTU stands for Remote terminal unit. Modern RTU's are essentially microcomputer or programmable controllers (PLC) which is interfaced with the MTU and various field devices.

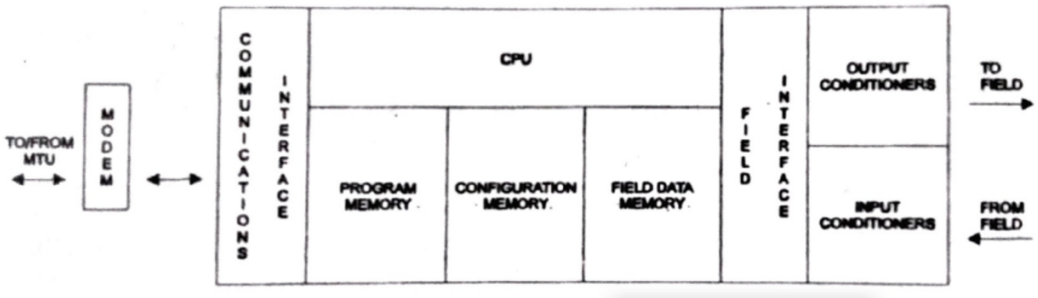

Figure1.5 Block diagram of RTU

Figure 1.5 shows the general block diagram of Remote terminal unit.RTU gathers information from the field . i.e. analog values, various ON-OFF status signals etc.. It keeps this information in the memory until the MTU asks for required information, it then codes and transmits the information using modem through communication link to the MTU.

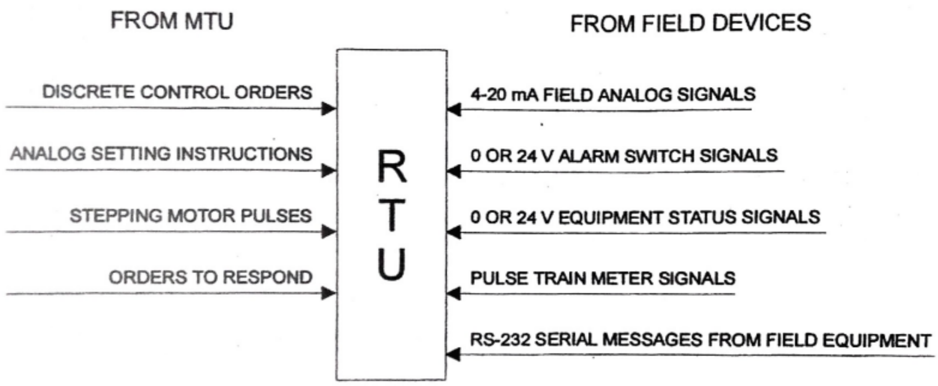

Figure1.6 Signals coming into RTU

When master terminal unit sends the control signal, RTU receives that signal and follows the commands given by MTU. Following diagram shows the various signals that are entering and leaving the Remote terminal unit.

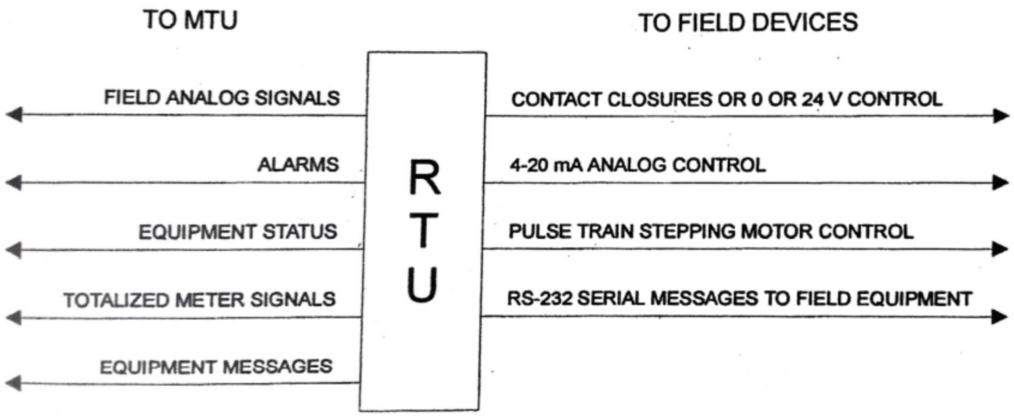

Figure1.7 Signals leaving out of the RTU

1.3.3 HMI-Operator Interface

At the centre of every SCADA system is the operator, who accesses the system by means of an operator interface device, which is sometimes called an 'operator console' or 'Human Machine Interface (HMI)'. The operator console functions as the operator's window to the process plant. Figure 1.8 shows the typical operator interface for SCADA system-

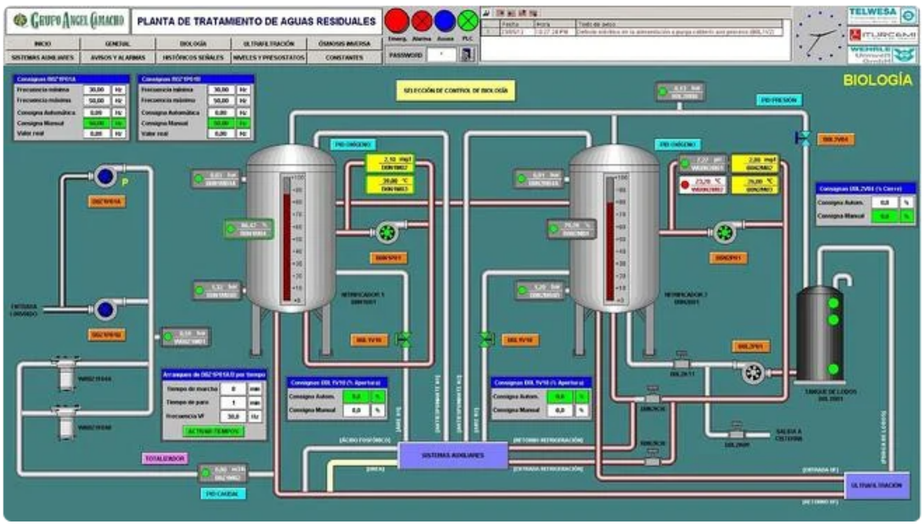

Figure1.8 Typical SCADA operator interface sceen.

Operator interface consists of a video display unit (VDU) or computer touchscreen (as shown in fig.1.8) that displays real time data about the process and a keyboard for inputting the operator's command to the process. Other cursor positioning device such as mouse, touch screen, may also be used.

1.3.4 Communication Interface

In SCADA system, communication is required to be established between MTU and different RTU's. The MTU must send information to each RTU. It almost always uses the same medium that the RTU uses to send information to it.

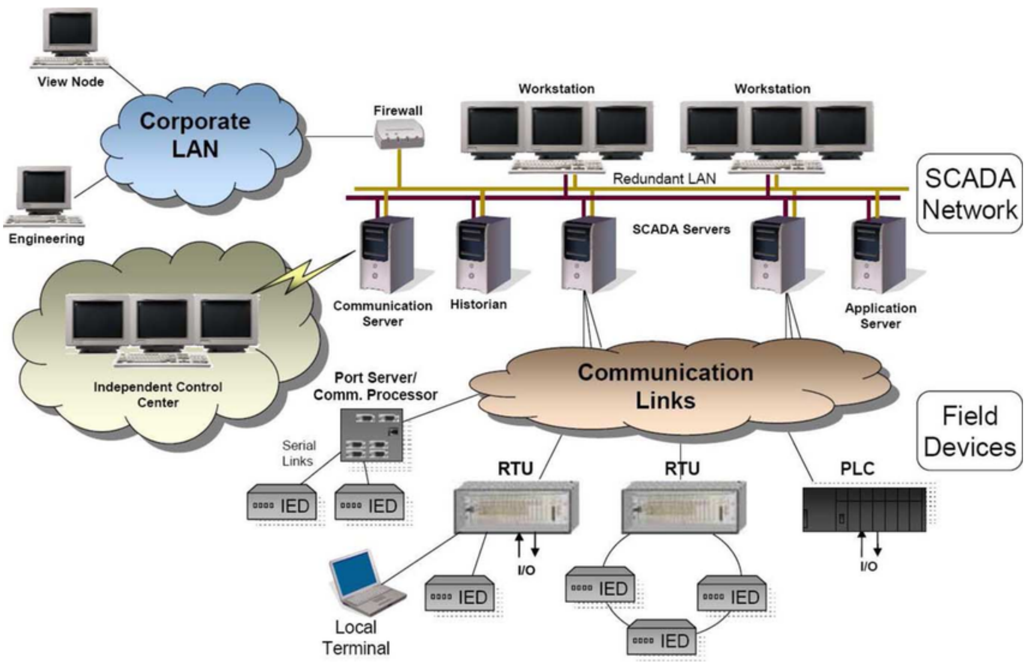

Figure1.9 SCADA Network

There are two common mediums of communications in Scada system. i.e. Land line communication and radio communication. Land line communications uses optical fiber cables or electrical cables, which are also called as industrial communication buses. But SCADA system do not communicate with just simple electrical signals. In SCADA , data is encoded in protocol format. In old days SCADA was depended on propreitory protocols. But today open or standard protocols are used.

Some of the most popular Industrial communication buses based on diff. protocol are listed below:

- Modbus
- Foundation Fieldbus
- Profibus
- Ethernet TCP/IP
- Device net
- Control net

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1.4 Commercially available SCADA Softwares :

Sr. No.	Developer (company)	SCADA Software Name
1.	Allen Bradley	RSVIEW32
2.	Schneider Electric	Vijeo Citect
3.	Siemens	WinCC
4.	Wonder ware	In Touch
5.	Ellipse software (Canada)	Elipse
6.	General Electric	Intellution iFIX
7.	G E Fanuc	Cimplicity
8.	ABB	SCADA vantage Micro SCADA
9.	Honey well	SCAN 3000 SCADA Plantscape

Figure1.10 Commercial SCADA Manufacuters

Above figure 1.10 shows the list of leading commercially available SCADA softwares along with their developers name. Features, specifications of some SCADA softwares ae given below:

1.4.1 InTouch

InTouch from Wonderware is advanced SCADA software for monitoring and backing up large-area production process data. Devices managed from a single workstation can be connected with OPC client, S7 MPI, S7 PPI, Profinet (S7 1200), Modbus RTU, Modbus TCP / IP, Host Link Protocol (Omron), Mewtocol Protocol (Panasonic)). Historical data related to the process of our SCADA system is recorded in the database.

The InTouch Scada software consists of two parts: development and execution and has the following important features /Specifications:

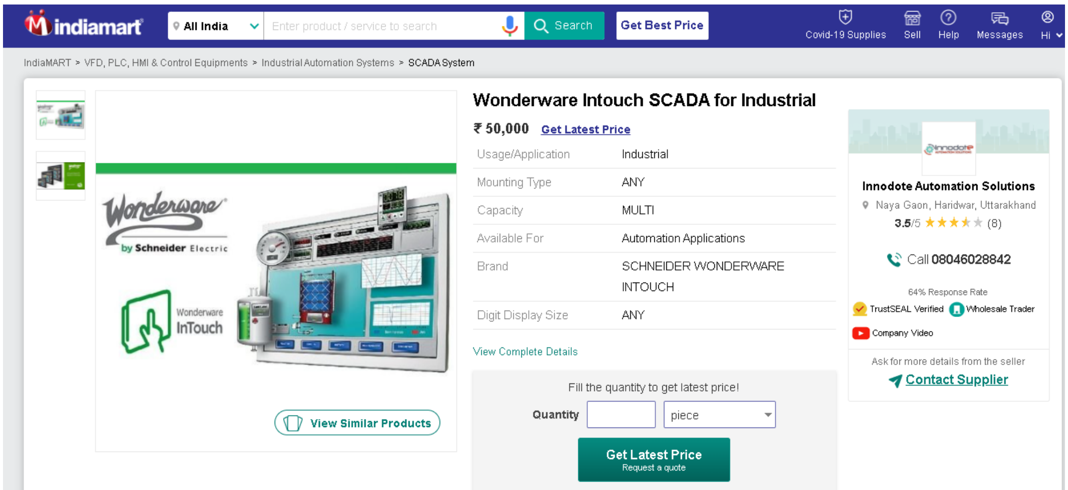
- Alarms and warnings can be defined for process values. When an alarm or warning occurs, you can monitor it in real time on the screen and notify recipients of emails and SMS.
- Easily create detailed reports based on historical data and save them in Excel or PDF format.
- Using recipes, you can send previously saved tag values to the device with just one click.
- To create an advanced screen interface includes: Symbol Factory contains 4000 industrial symbols in different category (real time, history, pie charts, lines, bars, 3D etc.)

- Microsoft .NET Framework Buttons, Check Boxes, Radio Buttons, Combo Boxes, NumericUpDown, Horizontal Scroll Bar, Vertical Scroll Bar, Progress-Bar, Datagridview, DateTimePicker, TabControl, GroupBox, PictureBox, TextBox, Toolstrip objects.

- Visual Basic and C scripts have unlimited flexibility. Use Microsoft SQL Server (2005, 2008, 2012) for the database. Limited to 4 GB, unlimited tables, each table is limited to 950 labels.

- By using the "Server-Client" option, the WinTr station can operate synchronously via the Internet and can monitor the screen on a remote computer via an Internet browser (such as Internet Explorer).

Cost of Intouch available on online purchase:



1.4.2 Vijeo Citect

Vijeo Citect SCADA is a Supervisory Control and Data Acquisition (SCADA) solution from Schneider Electric which is used to manage and monitor processes in manufacturing, primary production, utilities delivery, and facilities management.

Features/Specifications of Vijeo Citect Vijeo Citect SCADA offers the following features:

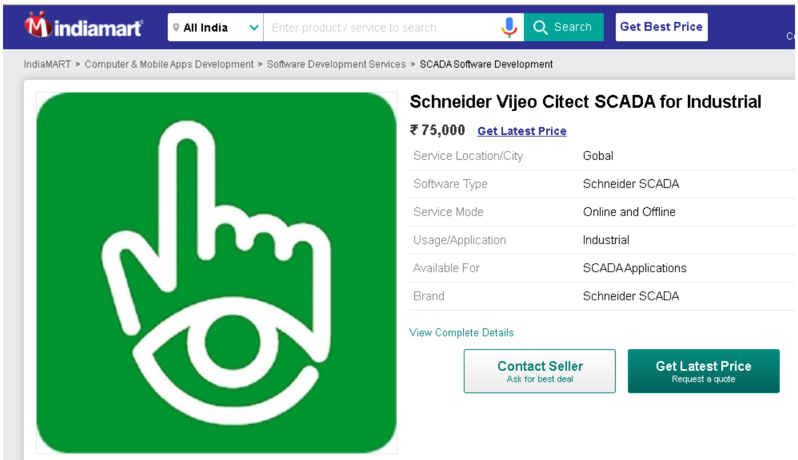
- **Scalabel Architechture**: One can start out with small system and expand it to large size as requirement changes(From 10's of I/O's to hundreds of thounsands).

- **Flexible Architechture**: Single site,multiple sites,distributed control, local control, discrete control, safety control, batch control, process control all within one system.

- Vijeo Citect provides the flexibility to access data from anywhere via its range of client interfaces and delivery systems.

- Supports OPC coomunication with third party devices.
- Easy to configure and use.
- Economical solution for monitoring remote trend, alarm and tag information.
- Vijeo Citect's comprehensive security features are integrated into all interface elements, helping to ensure a secure runtime system.
- Rich Graphics allow you to create a realistic, intuitive operator interface. For example, you could configure a tank that can be filled, heated, or rotated.
- Process Analyst feature allows operators and process engineers to analyze the cause of process disturbances by bringing together trend and alarm data, which are traditionally stored separately. With Process Analyst, users can simply view them all on a single integrated display.
- Vijeo Citect's distributed trending system handles large numbers of variables without compromising performance or data integrity. Choose from a selection of pre-configured trend pages that provide clear data representation with customizable views.
- An efficient alarm system allows you to quickly isolate and identify faults,reducing the amount of downtime. The Vijeo Citect alarm system is fast and reliable, providing you with detailed alarm information in formats that are clear and legible.
- With real-time video display in Vijeo Citect, operators can live video on their screens direct from IP cameras located across remote, as well as central, locations.

Cost of Vijeo Citect available on online purchase:



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1.4.3 Rsview32

RSView32 is an integrated, component based HMI for monitoring and controlling automation machines and processes. RSView32 expands your view with open technologies that provide unprecedented connectivity to other Rockwell Software products, Microsoft products, and third party applications. Language substitution and capabilities in English, Chinese, French, German, Italian, Japanese, Portuguese, Korean, and Spanish create further versatility satisfying users in global regions.

Features/specifications of Rsview32:

- The configuration interface for RSView 32 is easy to navigate for anyone with a SCADA or HMI background, even if they are unfamiliar with the product.*i.e.*It's very user friendly and easier to use each and every setups and tools
- Is a good SCADA/HMI software for industry use when the PLC installed are from Rockwell Automation. Has the capability to licence up to 1500 tags, supports OPC, Visual Basic for Applications (VBA), ActiveX Controls, data trends, configurable alarms, connection to databases,
- Support OPC standards as both a server and a client for fast, reliable communications with a wide variety of hardware devices
- Language tag substitution giving users the ability to create a spreadsheet of string tag values in different languages and then select the values in a particular language during runtime saving development time.
- **Powerful Graphic Editor :**Design high-level graphics for even the most complex application using the RSView32 drawing environment.
- **Graphic Import/Export Wizard:** The Graphics Import/Export Wizard in RSView32 lets you export complete graphic displays as XML (Extensible Markup Language) files.
- **Customize the look of Graphic Display:** RSView32 offers a full set of display setup features, including background color, highlight color, input field text and fill colors, scaling, window size and position, security code, and startup and shutdown commands. You can also set default values so that all graphic displays in a project share similar characteristics.
- **Comprehensive Alarms Editor:** RSView32 offers a complete, flexible alarm system. Display alarm messages on the screen, in an alarm log viewer, or export the .DBF alarm log data to any ODBC-compliant database program.

Cost of Rsview32 available on online purchase:

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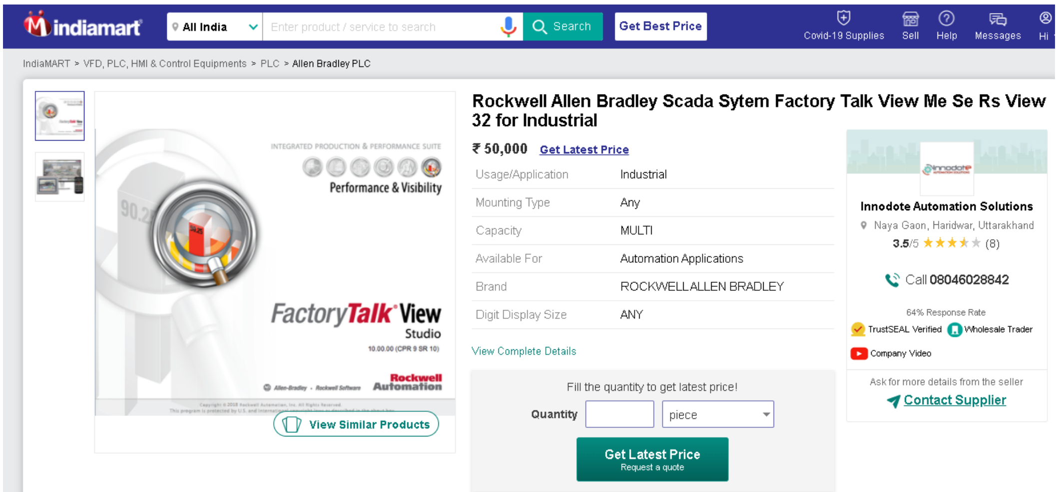

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Chapter 2

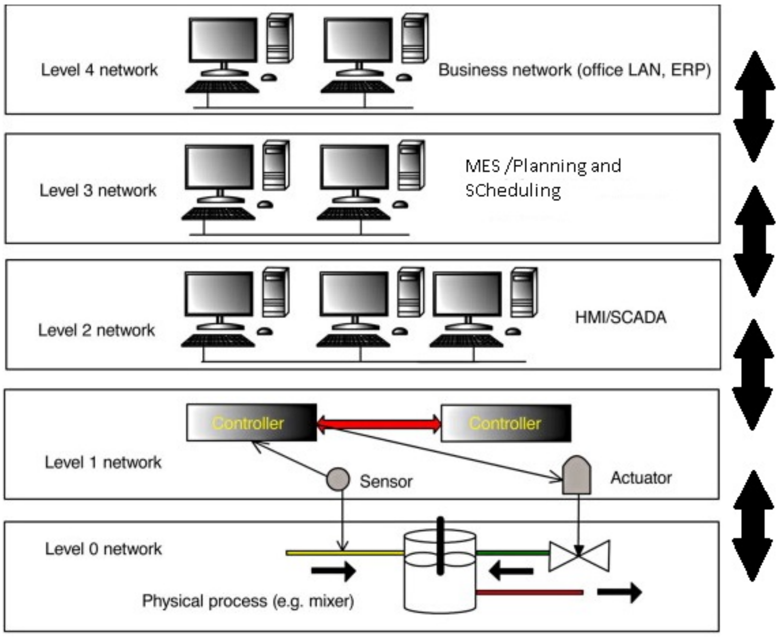
SCADA Network Communication

2.1 Network topologies and Cables

What is an Industrial Networking?

Industrial Networking refers to the networks that deal with transfer of real time 'Process data' on a **large scale**. Industrial network of Protocol communication buses allows to connect various devices available in automation environment (such as - field I/O's,PLCs, SCADA, MES, ERP etc.)

In context with Industrial Automation Pyramid Industrial Networks are generally studied and available between different levels of automation hierarchy such as:



- **Field control Network:** Allows communication between field devices (level 0) and Control devices such as PLC's (level 1).
- **Process Control Network:** Allows communication between Field devices (level 0) and Supervisory netwrok (Level 2).

- **Supervisory Network:** Allows Communication between Proces Controllers-PLC's(Level 1) and Manufacturing planning level- MES (Level 3).
- **Industrial Networks for manufacturing execution:** Allows communication between Supervisory controllers-SCADA (Level 2) and Enterprise level (Level 4)
- **Industrial Networks in Enterprises:** Allows communication between Manufacturing planning level- MES (Level 3) and enterprise network or corporate network (level 4).

Industrial Network Components :

In larger industrial and factory networks, a single cable is not enough to connect all the network nodes together. We must define network topologies and design networks to provide isolation and meet performance requirements. In many cases, because applications must communicate across dissimilar networks, we need additional network equipment. The following are various types of network components and topologies:

- **Repeaters** - a repeater, or amplifier, is a device that enhances electrical signals so they can travel greater distances between nodes. With this device, we can connect a larger number of nodes to the network. In addition, we can adapt different physical media to each other, such as coaxial cable to an optical fiber.
- **Router** - a router switches the communication packets between different network segments, defining the path.
- **Bridge** - with a bridge, the connection between two different network sections can have different electrical characteristics and protocols. A bridge can join two dissimilar networks and applications can distribute information across them.
- **Gateway** -a gateway, similar to a bridge, provides interoperability between buses of different types and protocols, and applications can communicate through the gateway.

2.1.1 Network Topology

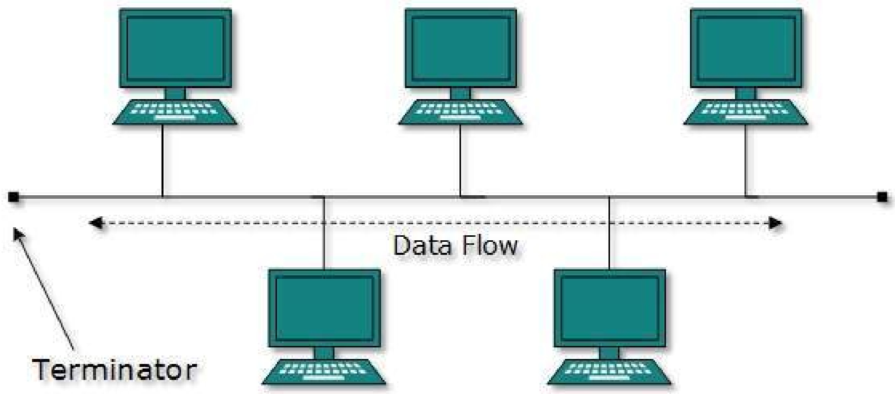
Industrial systems usually consist of two or more devices. As industrial systems get larger, we must consider the topology of the network. The **Network topology** tells us how various nodes, devices and components on your network are physically arranged in relation to each other using cables or communication protocol Bus. The design and structure of a network are usually shown and manipulated in a topology diagram.

The Most Common Types of Network Topologies are given Below:

1. **Point-to-Point:**

Point-to-point networks contains exactly two hosts such as computer, switches or routers, servers connected back to back using a single piece of cable. Often, the receiving end of one host is connected to sending end of the other and vice-versa.

2. **Bus Topology:**



In case of Bus topology, all devices share single communication line or cable. Bus topology may have problem while multiple hosts sending data at the same time. Therefore, Bus topology either uses CSMA/CD technology or recognizes one host as Bus Master to solve the issue. It is one of the simple forms of networking where a failure of a device does not affect the other devices. But failure of the shared communication line can make all other devices stop functioning.

Both ends of the shared channel have line terminator. The data is sent in only one direction and as soon as it reaches the extreme end, the terminator removes the data from the line.

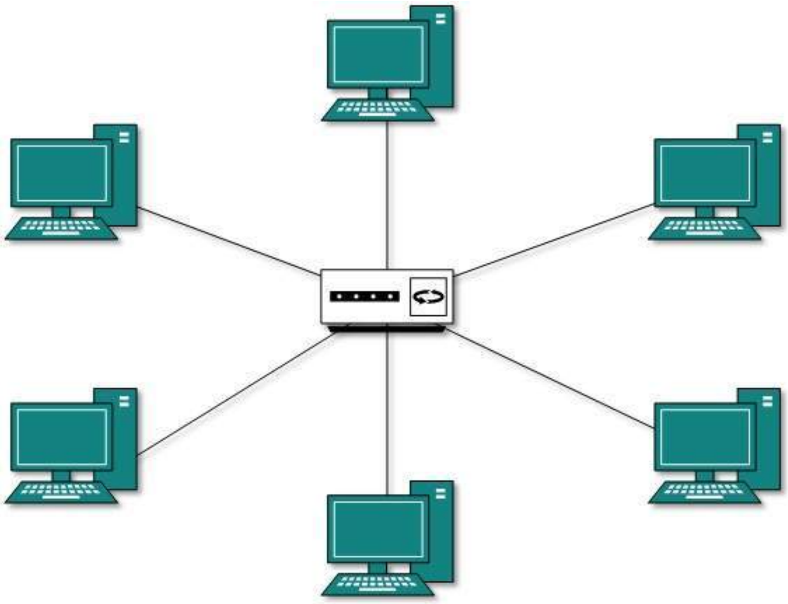
Advantages of Bus Topology :

- Bus topologies are a good, cost-effective choice for smaller networks because the layout is simple.
- If needed, more nodes can be easily added to the network by joining additional cables.

Disadvantages of Bus Topology :

- If the cable experiences a failure, the whole network goes down, which can be time-consuming and expensive to restore.
- Bus topologies are best suited for small networks and difficult to implement for larger networks.

3. **Star Topology:**



All hosts in Star topology are connected to a central device, known as hub device, using a point-to-point connection via coaxial, twisted-pair, or fiber-optic cable. That is, there exists a point to point connection between hosts and hub. The hub device can be hub, repeater, switch, bridge, router or gateway.

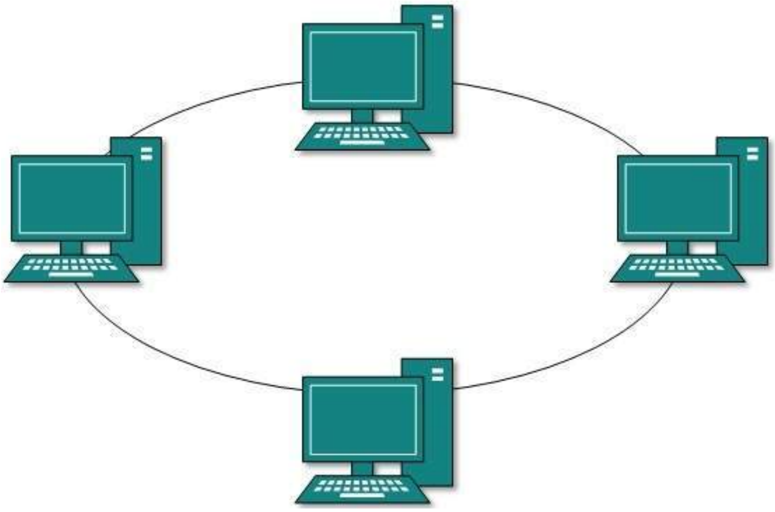
Advantages of Star Topology:

- It allow us to conveniently manage your entire network from a single location.
- Each of the nodes is independently connected to the central hub, if one goes down, the rest of the network will continue functioning unaffected, making the star topology a stable and secure network layout.

Disadvantages of Star Topology:

- If the central hub goes down, the rest of the network can?t function.
- Star topologies are expensive to set up and operate.

4. **Ring Topology:**



In ring topology, each host machine connects to exactly two other machines, creating a circular network structure. When one host tries to communicate or send message to a host which is not adjacent to it, the data travels through all intermediate hosts. To connect one more host in the existing structure, the administrator may need only one more extra cable.

Advantages of Ring Topology:

- If a large network is arranged in a ring topology, repeaters can be used to ensure packets arrive correctly and without data loss.
- Only one station on the network is permitted to send data at a time, which greatly reduces the risk of packet collisions, making ring topologies efficient at transmitting data without errors.
- Ring topologies are cost-effective and inexpensive to install.

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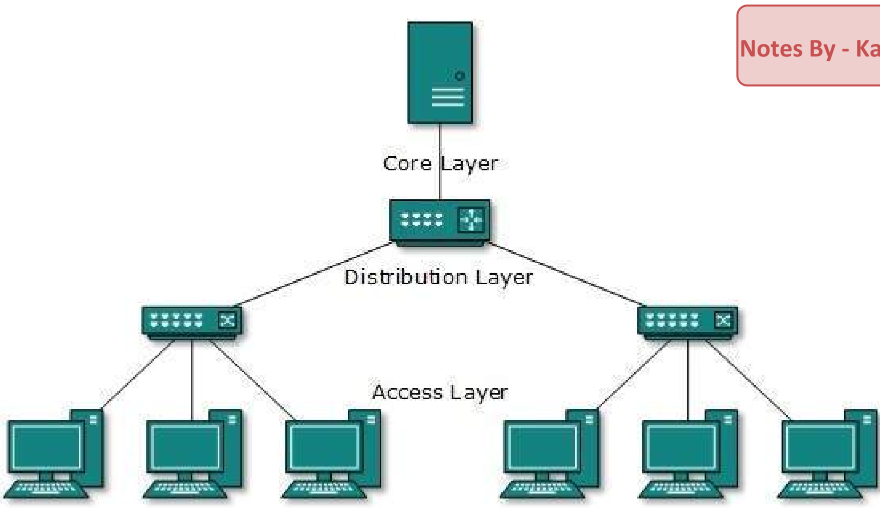
Disadvantages of Ring Topology:

- A ring topology is vulnerable to failure without proper network management, if one node goes down, it can take the entire network with it.

5. **Tree Topology:**

Also known as Hierarchical Topology, this is the most common form of network topology in use presently.This topology imitates as extended Star topology and inherits properties of bus topology.



This topology divides the network in to multiple levels/layers of network. Mainly in a Tree topology, network is bifurcated into three types of network devices. The lowermost is access-layer, The middle layer is known as distribution layer, which works as mediator between upper layer and lower layer. The highest layer is known as core layer.

Advantages of Tree Topology:

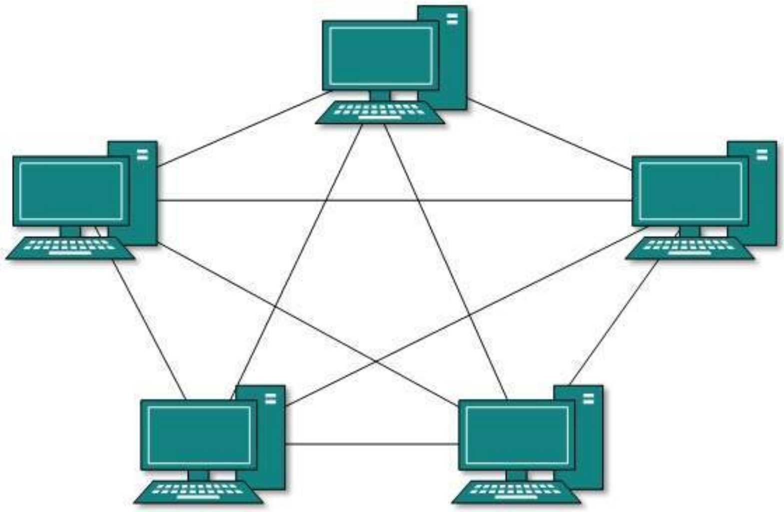
- Combining elements of the star and bus topologies allows for the easy addition of nodes and network expansion.
- Troubleshooting errors on the network is also a straightforward process.

Disadvantages of Tree Topology:

- The entire network depends on the health of the root node in a tree topology.
- If the central hub fails, the various node branches will become disconnected.

6. **Mesh Topology :**

In this type of topology, a host is connected to one or multiple hosts.This topology has hosts in point-to-point connection with every other host or may also have hosts which are in point-to-point connection to few hosts only.



Mesh networks can be full or partial mesh. Partial mesh topologies are mostly interconnected, with a few nodes with only two or three connections, while full-mesh topologies are fully interconnected.

Advantages of Mesh Topology:

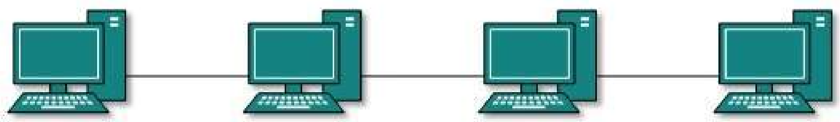
- Mesh Topologies are reliable and stable. *i.e.* complex degree of interconnectivity between nodes makes the network resistant to failure.

Disadvantages of Mesh Topology:

- Mesh topologies are incredibly labor-intensive. it is also time consuming to set up.
- Mesh topology is expensive among all other methods since cost of cabling adds up.

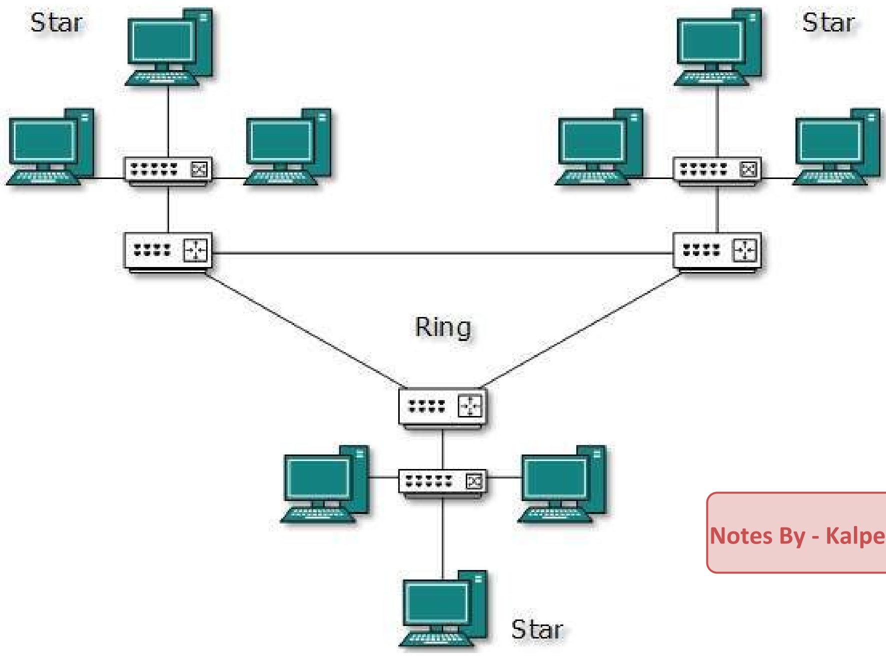
7. **Daisy Chain :**

This topology connects all the hosts in a linear fashion. Similar to Ring topology, all hosts are connected to two hosts only, except the end hosts.Means, if the end hosts in daisy chain are connected then it represents Ring topology.



8. **Hybrid Topology:**

A network structure whose design contains more than one topology is said to be hybrid topology. Hybrid topology inherits merits and demerits of all the incorporating topologies.



The above picture represents an arbitrarily hybrid topology. The combining topologies may contain attributes of Star, Ring, Bus, and Daisy-chain topologies.

Benefits of industrial networking:

Industrial networking technology offers several major improvements over existing systems. With industry-standard networks, we can select the right instrument and system for the job regardless of the control system manufacturer. Other benefits include:

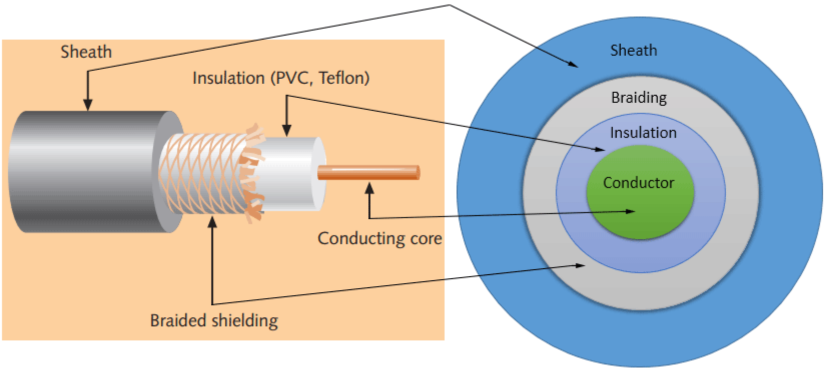
- **Reduced wiring** - resulting in lower overall installation and maintenance costs.
- **Intelligent devices** -leading to higher performance and increased functionality such as advanced diagnostics.
- **Distributed control** - with intelligent devices providing the flexibility to apply control either centrally or distributed for improved performance and reliability.
- Simplified wiring of a new installation, resulting in fewer, simpler drawings and overall reduced control system engineering costs.
- Lower installation costs for wiring, marshalling, and junction boxes

2.1.2 Network Cables

To connect two or more computers or networking devices in a network, network cables are used. There are three types of network cables; coaxial, twisted-pair, and fiber-optic.

1. **Coaxial Cables:**

This cable contains a conductor, insulator, braiding, and sheath. The sheath covers the braiding, the braiding covers the insulation, and the insulation covers the conductor.The following image shows these components.



Sheath: This is the outer layer of the coaxial cable. It protects the cable from physical damage.

Braided shield : This shield protects signals from external interference and noise. This shield is built from the same metal that is used to build the core.

Insulation : Insulation protects the core. It also keeps the core separate from the braided shield. Since both the core and the braided shield use the same metal, without this layer, they will touch each other and create a short-circuit in the wire.

Conductor: The conductor carries electromagnetic signals.

Based on conductor a coaxial cable can be categorized into two types; single-core coaxial cable and multi-core coaxial cable.

Single core coaxial cable

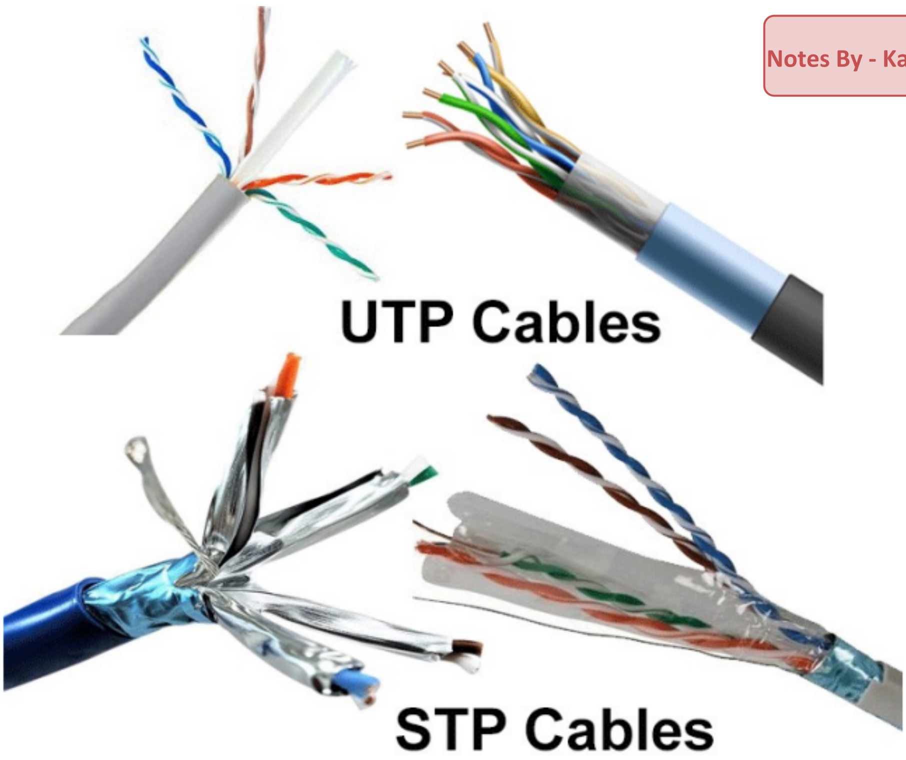
A **single-core coaxial cable** uses a single central metal (usually copper) conductor, while a **multi-core coaxial cable** uses multiple thin strands of metal wires. The above images shows both types of cable.

2. **Twisted-Pair cables:**

The twisted-pair cable were primarily developed for computer networks. This cable is also known as Ethernet cable. Almost all modern LAN computer networks use this cable.

This cable consists of color-coded pairs of insulated copper wires. Every two wires are twisted around each other to form pair. Usually, there are four pairs. Each pair has one solid color and one stripped color wire. Solid colors are blue, brown, green, and orange. In stripped color, the solid color is mixed with the white color.

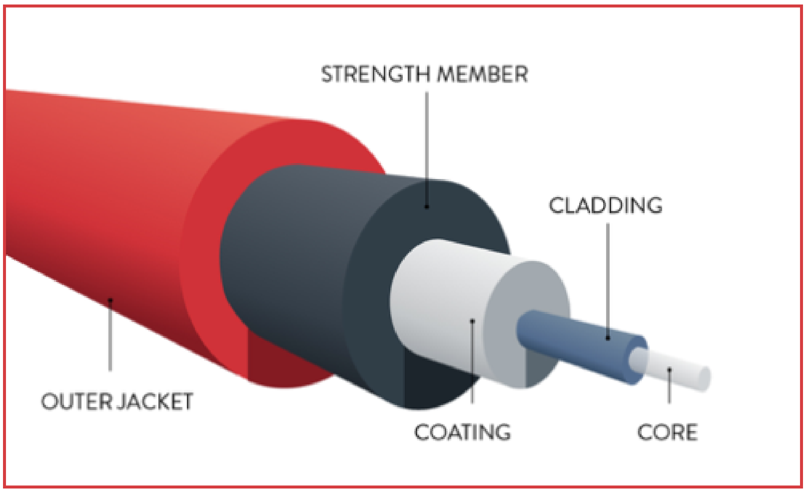
Based on how pairs are stripped in the plastic sheath, there are two types of twisted-pair cable; **UTP** and **STP**.



In the **UTP (Unshielded twisted-pair)** cable, all pairs are wrapped in a single plastic sheath whereas, In the **STP (Shielded twisted-pair)** cable, each pair is wrapped with an additional metal shield, then all pairs are wrapped in a single outer plastic sheath.

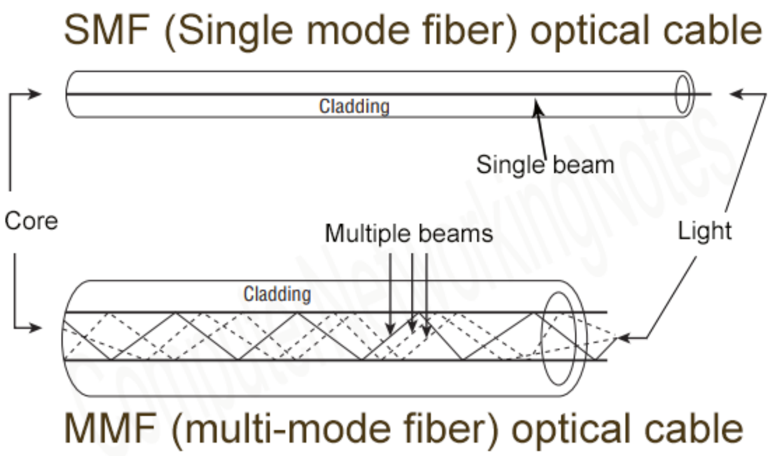
3. **Fiber-Optic cables:**

This cable consists of a core, cladding, buffer, and jacket. The core is made from thin strands of glass or plastic that can carry data over a long distance. The core is wrapped in the cladding; the cladding is wrapped in the buffer, and the buffer is wrapped in the jacket.



- Core carries the data signals in the form of light.
- Cladding reflects light back to the core.
- Buffer protects the light from leaking.
- The jacket protects the cable from physical damage.

Fiber optic uses light to send data. It reflects light from one endpoint to another. Based on how many beams of light are transmitted at a given time, there are two types of fiber optical cable; **SMF** and **MMF**.



SMF (Single-mode fiber) optical cable : This cable carries only a single beam of light. This is more reliable and supports much higher bandwidth and longer distances than the MMF cable. This cable uses a laser as the light source and transmits 1300 or 1550 nano-meter wavelengths of light.

MMF (multi-mode fiber) optical cable : This cable carries multiple beams of light. Because of multiple beams, this cable carries much more data than the SMF cable. This cable is used for shorter distances. This cable uses an LED as the light source and transmits 850 or 1300 nano-meter wavelengths of light.

2.2 Modes of Network communication

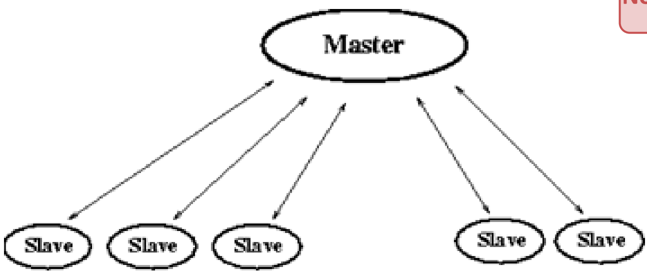
In industrial networks, data communication can be analogue or digital. Analogue data takes continuously changing values.In digital communication, the data can take only binary 1 or 0 values. The transmission itself can be **Asynchronous** or **Synchronous**, depending on the way data is sent.

In **Asynchronous mode** transmission, characters are sent using start and stop codes and each character can be sent independently at a nonuniform rate.

The **synchronous mode** transmission is more efficient method. The data is transmitted in blocks of characters, and the exact departure and arrival time of each bit is predictable because the sender/receiver clocks are synchronized.

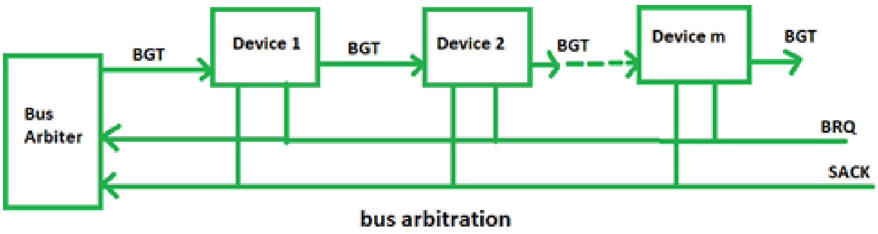
In industrial Network communications, data transmission(Asynchronous or Synchronous) takes place in different modes, such as-

1. **Master-Slave:**



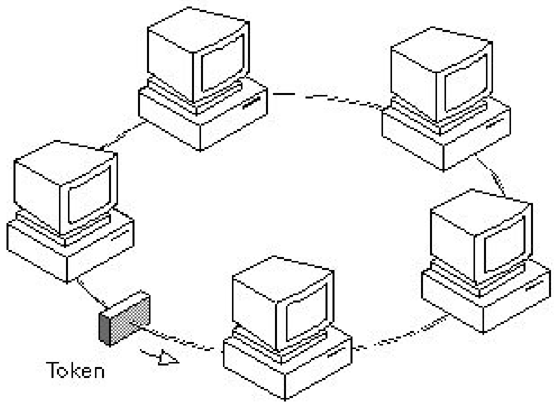
In this method one bus device is the master.The master alone possesses a continuous right to transmit.It polls (or addresses) each bus participant in turn, supplies it with data, and/or asks it to transmit its data, *e.g.*, its measured value and status. To increase the efficiency, *i.e.*, the amount of useful data to overheads, the protocol is kept as simple as possible. The security of the data depends upon the protocol structure and the error checking method used. MODBUS, PROFIBUS DP/PA, and AS-i are all protocols that use the master-slave method.

2. **Bus Arbitration:**



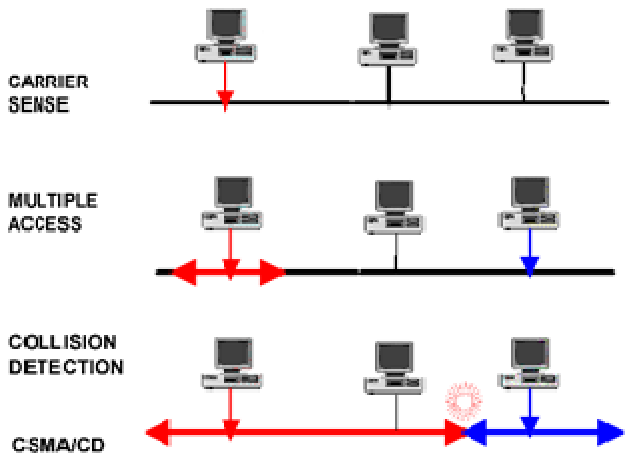
In this method, every device on the network may transmit and receive data. The right to transmit is organized by a central controller, the so called bus arbitrator. The arbitrator maintains a list containing the order in which and the length of time devices are allowed to transmit. The arbitrator works through the list, passing the right to transmit to each device in turn. If different scanning frequencies are required, the device can appear more than once in the table. It should be noted that although this is classified as centralized control, token passing is a central element. The method is used in the WorldFIP and FOUNDATION Fieldbus H1 protocols.

3. **Token Passing(Token Ring:)**



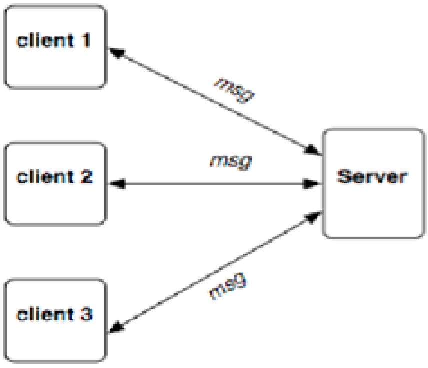
In this access method, the token, i.e., the right to transmit, is passed from device to device. This may be done on a master?slave or peer-to-peer basis. In the event of peer- to-peer passing, a so-called token ring is built, which may be real or logical. The passing sequence depends upon the application and is defined during the planning of the system. This method allows each device a fair share of the bus, since each is allowed to transmit within a preset period of time. The time taken to pass the token around the system determines the frequency of polling of the individual members. Token passing is used by FOUNDATION Fieldbus to ensure deterministic communication on the H1 layer.

4. **Stochastic or random bus access:**



There are several random access methods of which CSMA/CD is the most well known. CSMA/CD stands for Carrier Sense Multiple Access with Collision Detection. All devices on the bus have the right to transmit. Each continually listens to (or senses) the bus. If this is free, then any of the devices can transmit its data. If several devices want to transmit simultaneously, a collision is detected and all withdraw. A random generator in each of the devices then determines the time interval that must elapse before it can attempt to transmit again. The CSMA/CD bus access method is specified in the Ethernet protocol and is used in office networks and the higher levels of automation systems. At field and control levels it has to be supported by a centralized access management method because there is no strict periodicity of scanning.

5. **Client Server:**



The client transmits a request to its server communication partner. When the requested action is executed and its confirmation is necessary, the server issues a response to the client. If the client is also a server to its communication partner, the relationship is said to be peer-to-peer. Otherwise it can be considered to be master?slave.

6. **Publisher-Subscriber:**

All the devices sense the traffic on the bus continuously. The publisher broadcasts its data when it has the right to transmit. The subscribers to the data recognize that they are of interest to them and update their local copies. There is no direct confirmation of receipt. When communication is controlled by bus arbitrator, transfers can be scheduled on a precisely periodic basis. Publisher?subscriber is also known as the producer?consumer method.

2.3 Modbus

MODBUS is a industrial standard protocol developed some years ago by Gould-Modicon and is a messaging service that may run on a variety of physical layers. Its two open versions are of interest here:

Serial MODBUS, using RS-485 (or RS-422) as physical layer allows the connection of MODBUS devices to a PLC in a bus structure, whereby analog devices can be connected via gateways.

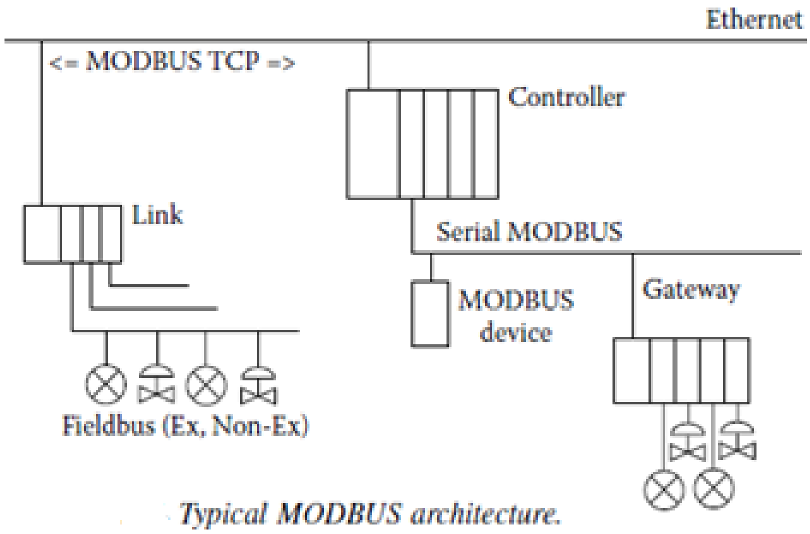
MODBUS TCP (also known as MODBUS TCP/IP), using Ethernet as physical layer, allows the exchange of data between PLCs in different networks.

Bus Access Method:

- **Serial Modbus:** Master slave
- **TCP/IP:** CSMA/CD

(**Note:** Explain Bus Access method in detail from earlier explanation given in above notes.)

Modbus Architecture: Figure below shows typical system architecture.



Typical MODBUS architecture.

The MODBUS protocol exchanges data in a master?slave relationship. Each slave has a unique address, and the data are identified by their location in the slave address register. Certain characteristics of the MODBUS protocol are fixed, such as the frame format, frame sequences, handling of communications errors, exception conditions, and the functions performed. Other characteristics are user selectable; these include transmission medium, baud rate, character parity, number of stop bits, and transmission modes (ASCII or RTU). The contents of the data carried by the protocol are also freely selectable, i.e., nothing is said about strings, integers, floating- point numbers, etc. The MODBUS protocol controls the query and response cycle between master and slave devices. Only the master can initiate a transaction.

The data can be exchanged in two **transmission modes: ASCII** (American Standard Code for Information Interchange) and **RTU** (Remote Terminal Unit). The major differences between them are the type of error check performed on the message and the number of characters used.

MODBUS Features: Table below summarizes the principal technical data of MODBUS Protocol:

Notes By - Kalpesh Bagal

TABLE *Principal Technical Data for MODBUS*

Property	*Serial MODBUS*	*MODBUS TCP*
Standard	Industrial standard	Industrial standard
Physical layer	Not specified, but usually RS-422, RS-485	10BaseTX, 100BaseTX
Length	1200 m at 19.2 kbit/s	100 m
Transmission rate	Max. 19.2 kbit/s	10/100 Mbit/s
Bus access method	Master–slave	CSMA/CD
Participants	1 master, max 247 slaves	Logical: limited by address range only Practical: limited by response time

2.4 Profibus

PROFIBUS (Process Fieldbus) is an open fieldbus standard. It was developed in Germany and was published as national standard in 1992.European Standard EN 50170 followed roughly a year later. The application profiles **PROFIBUS DP** (Decentralized Periphery) and **PROFIBUS PA** (Process Automation), which are used in process automation, are incorporated into the IEC 61158 standard published in 2000.

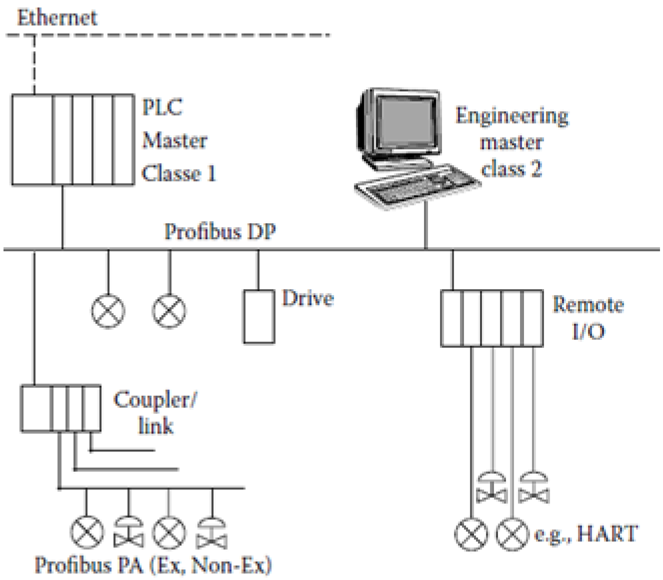
Bus Access Method:

- **Profibus PA** - Master Slave with Token Passing.
- **Profibus DP** - Master Slave with Token Passing.

(**Note:** Explain Bus Access method in detail from earlier explanation given in above notes.)

Profibus Architecture: Figure below shows a typical PROFIBUS process automation network. It can be seen that PROFIBUS DP (Version DPV1) provides the H2 control network backbone and PROFIBUS PA the H1 fieldbus.

Notes By - Kalpesh Bagal



Typical PROFIBUS architecture.

Here,

- The PLC acts as a Class 1 master and communicates cyclically or acyclically with the slaves.
- The engineering tool acts as a Class 2 master and communicates acyclically with any device, either according to its own schedule or at the request of the device.
- The medium is shared between the two masters by token passing.
- When a master has the right to transmit, it talks with its slaves in a master?slave relationship.
- The field devices, i.e., sensors and actuators, on the PROFIBUS PA segment communicate with a PROFIBUS DP master via a segment coupler or link.

Profibus Features:

An overview of the technical features of Profibus is given in below:

TABLE
Principal Technical Data of PROFIBUS PA and PROFIBUS DP Version DPV1

Property	*PROFIBUS PA*	*PROFIBUS DPV1*
Standard	DIN 19245 Part 4; EN 50170, Part 2; IEC–61158 Type 3	DIN 19245 Parts 1 to 3, Version DPV1; EN 50170, Part 2; IEC 61158 Type 3
Protocol	PROFIBUS DP	PROFIBUS DP
Physical layer	IEC 61158-2	RS-485 and/or fiber optics
Length	Max. 1900 m for safe and EEx ib areas Max. 1000 m for EEx ia	Up to 1200 m, depending upon transmission rate
Transmission rate	31.25 kbit/s	9600 bit/s to 12 Mbit/s
Bus access method	Handled from PROFIBUS-DP side	Master–slave with token passing
Participants	32 in safe areas, approx. 24 in EEx ib and approx. 10 in EEx ia	Per segment: max 32 Logical: max 126 (using repeaters), including max. 32 as masters

2.5 Foundation fieldbus

Notes By - Kalpesh Bagal

FOUNDATION Fieldbus is an open fieldbus standard to IEC 61158 and European Standard EN 50170 that was developed and is supported by the Fieldbus Foundation. It has been designed to solve the measurement and control tasks associated with process automation, aiming to provide optimum communication between programmable logic controllers (PLCs) or process control systems (PCS) and the plant equipment operating on the field level. The standard specifies two communication levels -

- **HSE(High Speed Ethernet**), on which traffic between controllers, computers, frequency converters, and other control equipment is handled. HSE (High-Speed Ethernet) is the high-speed communication specification for the FOUNDATION Fieldbus. It provides a cost-effective, high-speed backbone by using standard Ethernet technology running at a fixed rate of 100 Mbit/second.
- **H1**, on which traffic between the process sensors and actuators is handled. FOUNDATION Fieldbus H1 provides low-speed communication for field instrumentation. The FOUNDATION Fieldbus protocol is used for both HSE and H1 levels.

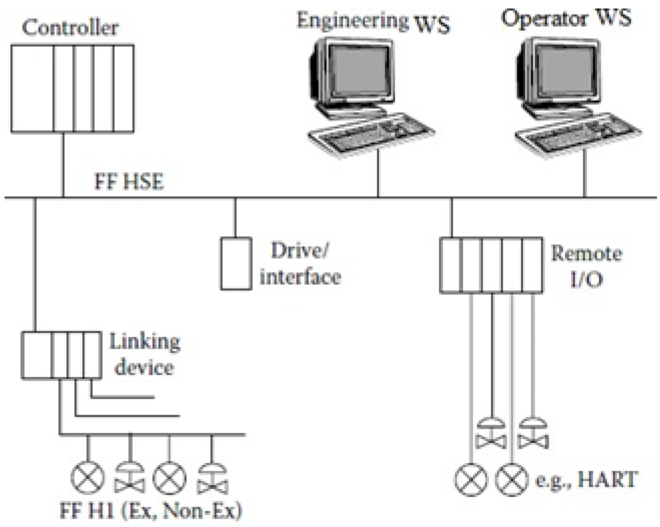
Bus Access Method:

1. HSE - CSMA/CD

2. H1 - Bus Arbitrator / Token Passing

(**Note :** Explain Bus Access method in detail from earlier explanation given in above notes)

Foundation Field Bus Architecture: Figure below shows a typical architecture of Foundation Field bus:



Typical FOUNDATION Fieldbus architecture.

Explanation:

- The process is run by one or more controllers connected to the HSE backbone. These may be separate entities or reside in the linking device. The engineering tool may be part of the system or may run on a separate workstation. Similarly, there may be a SCADA system running in parallel.
- FOUNDATION Fieldbus HSE handles the communication at the control level. Drives, remote I/Os and linking devices, etc., are connected to this bus. At this level the devices are externally powered and HSE ensures that data are quickly exchanged.
- FOUNDATION Fieldbus H1 is used at the field level. The linking device serves as interface to the HSE system. In addition, a power unit and conditioner are required to power the field devices over the bus. Depending upon power conditioner type, the H1 segment can be installed in safe or hazardous areas.

Features of Foundation Fieldbus: Following Table gives an overview of (comparison between) the main technical features of Foundation Field bus.-

TABLE *Overview of FOUNDATION Fieldbus H1 and HSE*

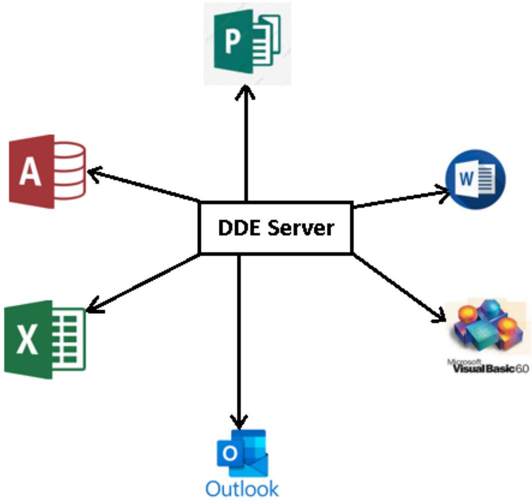
Property	*FOUNDATION Fieldbus H1*	*FOUNDATION Fieldbus HSE*
Standard	EN 50170, Part 4; IEC 61158 Type 1	EN 50170, Part 4; IEC 61158 Type 5
Protocol	FOUNDATION Fieldbus	FOUNDATION Fieldbus
Physical layer	IEC 61158-2	100BaseTX, 100Base FX
Length	Max. 1900 m for safe and Ex ib areas Max. 1000 m for Ex ia	Up to to 100 m (copper) Approx. 2 km (fiber optics)
Transmission rate	31.25 kbit/s	100 Mbit/s
Bus access method	Bus arbitrator (Token passing)	CSMA/CD
Participants	32 in safe areas, approx. 10 in Ex ia	Logical: limited by address range only Practical: limited by response time

Notes By - Kalpesh Bagal

2.6 Database and DDE connectivity

Typical DDE connectivity:

Dynamic Data Exchange (DDE) is a protocol that allows data to be shared between applications running on early versions of the Windows operating system . DDE enables two running applications to share the same data. For example, DDE makes it possible to insert a spreadsheet chart into a document created with a word processor. Whenever the spreadsheet data changes, the chart in the document changes accordingly. DDE was introduced in Windows 2.0 back in 1987 and currently used by thousands of applications such as Microsoft Word, Microsoft Excel, and Visual Basic, Outlook, Access etc.



Because attackers have taken advantage of DDE, macros and ActiveX controls to deliver malicious payloads, **Object Linking and Embedding for Process control** (OPC) has effectively replaced Dynamic Data Exchange.Some Microsoft products still support DDE.

DDE Connectivity with OPC:

Different OPC Servers (Such as Kepserver or Matrikon) are used to exchange information between an OPC Client and a DDE Server. An OPC Server for DDE provides key DDE functionality such as read and write access to all valid DDE server items, and DDE server connection status. These applications can be used by any OPC compliant application, such as an HMI or Process Historian or SCADA controller to connect to dde servers such as Microsoft Excel, as shown in above figure..

Chapter 3

SCADA System Integration

3.0.1 Introduction

SCADA is an acronym that stands for **S**upervisory **C**ontrol **A**nd **D**ata **A**cquisition. Generally, SCADA is a system that acquires (or collects) data (or signal) from various field devices at a factory, plant or in the remote locations and then sends this data to a master computer which then manages and controls the data and entire system.

SCADA System Integration is the process of integrating available SCADA software with the associated hardware/software components such as, PLCs(or RTUs), Field instruments, OPC servers, database or Historian server etc. in order to develop a real time industrial application as per the need of customer(industry).

3.1 SCADA Software

3.1.1 Creating Graphics and Object Library

Graphic pages are one of the principal components of any SCADA system. Graphics are the interface for the plant operator, and can be designed to display data as well as to accept operator input. Graphic pages are comprised of a page template, The objects drawn on the page as well as properties specified to the page objects.

Different Graphical objects are available in the graphic toolbox library(or Object library) such as -

- Free hand line,
- Rectangle,
- Ellipse,
- Polygon,
- Pipes,

- Numbers and text,
- Buttons,
- Symbol set,
- Alarms,
- Trends etc.

For these different objects available in graphic library can be programmed for different animation such as -

- Blinking,
- Filling,
- Movement,
- Movement (Horizontal/vertical),
- Sliding
- Text and Numbers

These animated graphics are created and executed in runtime Environment of SCADA.

3.1.2 Tags

A 'Tag' is a logical name for a variable in a device or in logical memory (RAM). Tags that receive data from an external source such as PLC or OPC server are referred to as 'Device tags' or 'External tags'. Whereas, tags that receive their data internally from SCADA software are referred to as 'Memory tags' or 'Local tags'. Tag values are stored in tag database.

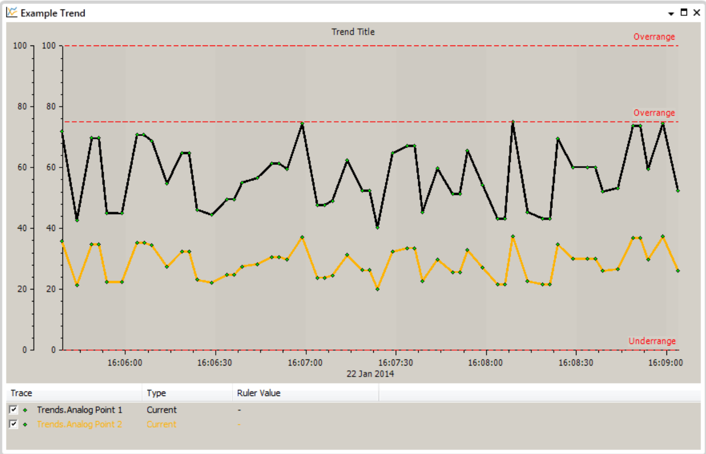
There are three types of tags:

- **Analog or Integer tags:** Analog tags store range of values. These tags represent variable states such as pressure, temperature, level, flow , position of rotary object. It represent analog variable to be measured.
- **Digital or Boolean tags:** Digital tag stores 0 or 1. these tags can represent devices that can only be ON or OFF such as, switches, lamps etc.
- **Strings tags:** String tags that stores ASCII string, Series of characters, or whole words. These tags can represent that use text.

3.1.3 Trends or Charts

In an automation systems, collecting data from the field instruments is a very important task and displaying this data on the operators screen in also very important. The data acquired form the field instruments can either be displayed as values digitally or as a Graphical chart.

Graphical Chart is one of the most convenient methods to view a group of data for anyone to identify the changes taking place instantly by looking at the waveforms. In SCADA graphical display of Data is called '**Trends**'.



A '**Trend**' as shown in above figure is a visual representation of Real time or historical tag values, They record real time data from field, retrieve historical data, and present them in graphical ways.

There are two types of Trends:

1. **Real-time trends:** As the name explains itself, these are the graphs that display the values of data in real-time and the graph updates for every instant of time we have specified.

2. **Historic trends:** As the name indicates, historic trends are used to display the data in real-time at the same time the old data can be retrieved and viewed on the run time.

3.1.4 Logs and reports

What are logs?

SCADA logs are the collection and recording of information and data from around the production process. The information is usually collected automatically, but there may also be the need for manual input points where staff can input information or add relevant comments to explain the reason for downtime, faults, or change of operator.

Data History used in Logs or reports: Within any production line there are large quantities of information that can be logged. This data is collected automatically by sensors or transducers within the production line that are set to monitor the production process. This collected data or information is then recorded (logged) in SCADA system.

This logged data can then be-

- Combined together,
- Recalculated,
- Plotted on graph,
- Compared with another data, and
- Used to take process control decisions.

Types of Logs: There are three types of logs:

1. **Event / Activity Log:** The Event or Activity log records information about various types of system activities or events such as, Tag writes, Occurrence of predefined event, System messages, occurrence of system errors and communication errors etc. To set up activity logging, activity log setup editor is used in SCADA system.
2. **Alarm Log:** The alarm log records alarm incidents, such as, when tag goes into alarm, when tag goes out of alarm, when an alarm is acknowledged. The name of the user (Operator) who acknowledges the alarm is also logged. To setup, an Alarm log setup editor is used in SCADA system.
3. **Data Log:** The data log records, specifies tag values, or data, under certain conditions. These conditions are defined by a data log model. To setup, data log setup editor is used in SCADA system.

What are Reports?

A 'SCADA report' is a document that presents the logged (or recorded) process information in an organized format for a specific operator and purpose. Although summaries of these reports may be delivered orally, complete reports are almost always in the form of written documents.

Similar to logs the reports are of three types: **Event/ activity report, Alarm report, and data report.**

Notes By - Kalpesh Bagal

3.1.5 Alarms and Events

SCADA Alarms: From an industrial process control points of view, an abnormal condition develops when the process deviates from ?normal? operating range. This abnormal condition may lead to severe or dangerous situation and may result into an accident or disaster.

If we do the analysis of these ?abnormal conditions? occurring in process industries, it is observed that in 40 percent of the cases, Human or operator has played a role in causing the accident; in 40 percent cases it is instrument failure and in 20 percent cases process itself fails.

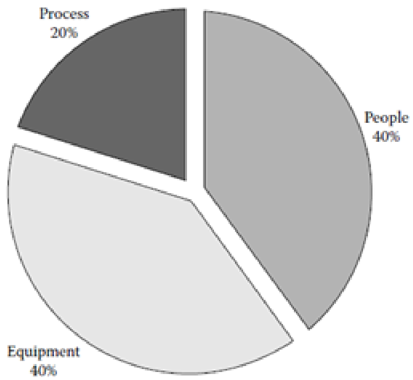


FIG. Root causes of industrial upsets and accidents.

Industrial Alarms are the indicators to the process operator about this abnormal conditions, based on the alarm, the operator may take a corrective action and try to bring process into the safe operating range and avoid abnormal situation.

Types of Alarms in SCADA system:

1. **Process Alarms:** Such alarms may be related to system efficiency or suggest equipment defects. This form of alarm is typically integrated into the system of control (usually a DCS) and uses the same sensors as the system of control.
2. **Machinery or Equipment Alarms:** Such warnings help detect equipment issues and do not directly affect the system operation.
3. **Safety Related Alarms:**Such warnings are used to alert operators to a situation that may be dangerous or detrimental to the plant. Such alarms should normally have a high priority and should be independent of the devices they monitor when they are involved in protecting against malfunction by the control system. In many instances, the security shutdown mechanism itself produces such warnings.
4. **Shutdown Alarms:** This type of alarm informs the operator that the SIS has reached and triggered an automatic shutdown case. It must be recalled, however, that shutdowns will not occur in all alarm systems. There are situations where the consequence of automatic start-up is such alarms.

5. **Other alarm systems:** The separate hardwire announcer system could incorporate the following alarms in addition to critical process safety alarms:

    - Fire
    - Spill or toxic release
    - Safety shower
    - Power system fault
    - Electrical room or Substation smoke detector
    - Ventilation failure

SCADA Events: **Events** represent normal system status messages, and do not require an operator response.An event is defined as a detectable occurrence, which may or may not be associated with an alarm.

Simple example of Event in Industrial automation can be simple logging of Operator with his user name to the SCADA application. The SCADA system can log that event in text file if configured to do so.

3.2 Electric Drives:

What is an Electric Drive?

Definition- The system which is used for controlling the motion of an electrical machine is called an electric drive. Or an electric drive is a form of machine equipment designed to convert electrical energy into mechanical energy and provides control of the processes.

n electric drive is a electro-mechanical system intended to set into motion technological equipment.The electric drive employs any of the prime movers such as diesel engines, steam turbines and electric motors for supplying mechanical energy for motion control.

3.2.1 Need of Electric drive in Robotics and Automation Industry:

- To have smooth speed control over a wide range.
- To meet good overload capacity.
- For operating in all four quadrants of the speed torque plane.
- To improve the energy efficiency.
- To save time and cost.

Function of electric drive - The electric drive operates and controls the speed, torque and direction of moving objects. The drives are generally employed for speed or motion control applications such as machine tools, Transportation robots, Fans,Pumps, Conveyors etc.

3.2.2 Types of drives

Usually, these are classified into three types such as -

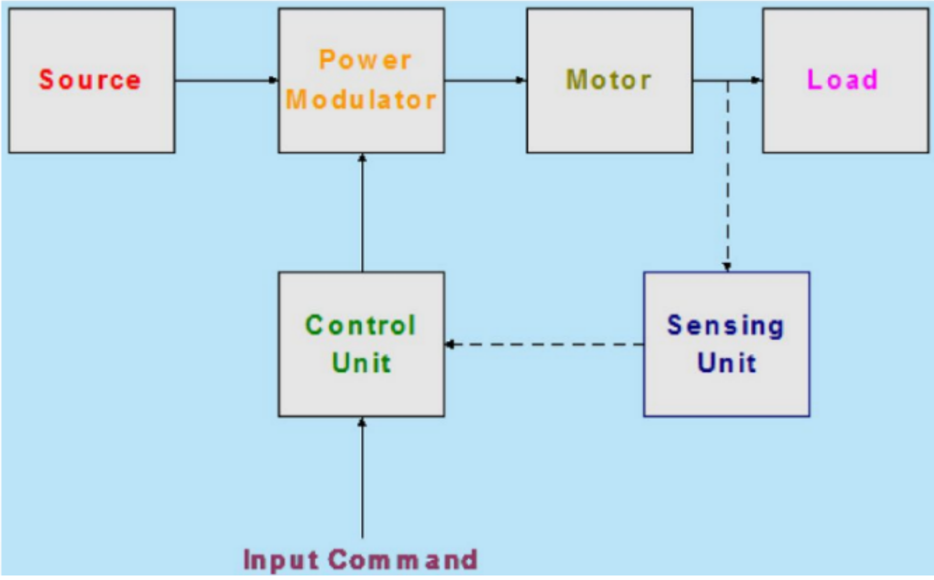
1. Group Drive
2. Individual Drive
3. Multi-Motor Drive

Additionally, these drives are further categorized based on the different parameters which are discussed below.

- Electrical Drives are classified into two types based on supply namely **AC drives** and **DC drives**.
- Electrical Drives are classified into two types based on running speed namely **Constant speed drives** and **changeable speed drives**.
- Electrical Drives are classified into two types based on a number of motors namely **Single motor drives** and **multi-motor drives**.
- Electrical Drives are classified into two types based on control parameter namely **stable torque drives** and **stable power drives**.

3.2.3 Block Diagram Of Electric drive

The block diagram of the electrical drive is shown in figure below. The electrical load like fans, pumps, Movement of robotic arm, leg, etc., consists the electrical motor. The requirement of an electrical load is determined regarding speed and torque. The motor which suited the capabilities of the load is chosen for the load drive.



The main parts of the electrical drives are power modulator, motor, controlling unit and sensing units.Their parts are explained below in detail.

Power Modulator - The power modulator regulates the output power of the source. It controls the power from the source to the motor in such a manner that motor transmits the speed -torque characteristic required by the load. During the transient operations like starting, braking and speed reversing the excessive current drawn from the source. This excessive current drawn from the source may overload it or may cause a voltage drop. Hence the power modulator restricts the source and motor current. The power modulator converts the energy according to the requirement of the motor e.g. if the source is DC and an induction motor is used then power modulator convert DC into AC. It also selects the mode of operation of the motor, i.e., motoring or braking.

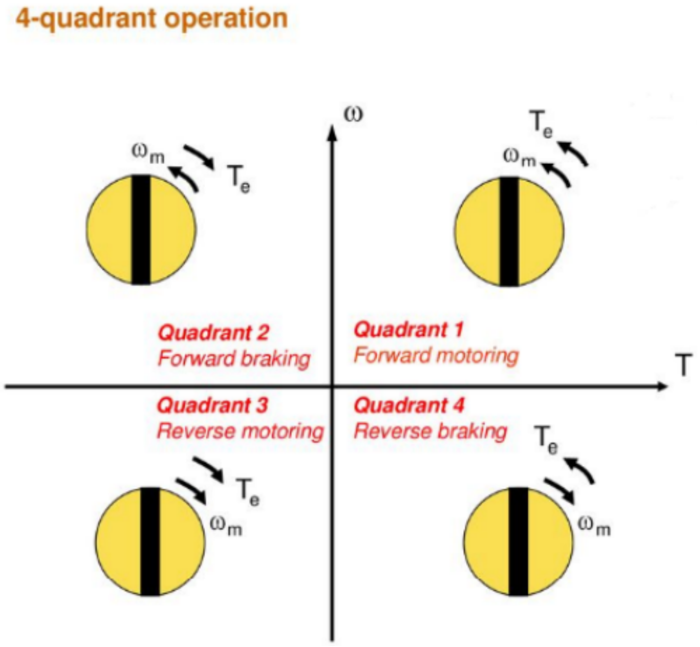
Control Unit - The control unit controls the power modulator which operates at small voltage and power levels. The control unit also operates the power modulator as desired. It also generates the commands for the protection of power modulator and motor. An input command signal which adjusts the operating point of the drive, from an input to the control unit.

Sensing Unit - It senses the certain drive parameter like motor current and speed. It mainly required either for protection or for closed loop operation.

Four Quadrant Operation of Drives:

Four Quadrant Operation of any drives means that the machine operates in four quadrants. They are Forward motoring, Forward braking, Reverse motoring and Reverse braking. A motor operates in two modes- Motoring and Braking. A motor drive capable of operating in both directions of rotation and of producing both motoring and regeneration is called a Four Quadrant variable speed drive.

In motoring mode, the machine works as a motor and converts the electrical energy into mechanical energy, supporting its motion. In braking mode, the machine works as a generator, and converts mechanical energy into electrical energy and as a result, it opposes the motion. The Motor can work in both, forward and reverse directions, i.e., in motoring and braking operations. Figure below shows the four quadrant operation of electric drive.



1. **First quadrant operation - Forward motoring:** In this quadrant the direction of rotation (speed) is positive and torque is positive so, quadrant power developed is positive and the machine is working as a 'motor', supplying mechanical energy. (Power is positive means power flow is from source to load.)

2. **Second quadrant operation - Forward Braking:** In this quadrant the direction of rotation (speed) is positive, but the torque is negative, and thus, the machine operates as a 'generator' developing a negative torque, which opposes the motion. (Power is negative means power flow is from load to source.)

3. **Third quadrant operation - Reverse motoring:** In this quadrant The motor works in the reverse direction. Both the direction of rotation (speed) and the torque are negative, while the power is positive. (Power is positive means power flow is from source to load.)

4. **Fourth quadrant operation - Reverse braking:** In this quadrant the motor works in the reverse direction. In This the direction of rotation (speed) is negative and the torque is positive, therefore, the power is negative. (Power is negative means power flow is from load to source.)

The four quadrant operation and its relationship to speed, torque and power output are summarized below in the figure .

Function	Quadrant	Speed	Torque	Power Output
Forward Motoring	I	+	+	+
Forward Braking	II	+	-	-
Reverse Motoring	III	-	-	+
Reverse Braking	IV	-	+	-

3.2.4 Comparison of AC and DC Drives

Sr.no.	Characteristics	AC Drives	DC Drives
1	Supply	Run by AC supply	Run by DC supply
2	Maintenance	Requires less maintenance.	Requires comparatively more and Frequent maintenance.
3	Use/ Application	Are generally used for AC Motors.	Are used for DC motors normally.
4	Breaking Mechanism	Breaking and accelerating when supply frequency (F s) changes	Breaking occurs when resistance is Applied at rotor.
5	Size in terms of Power Rating	Power to Weight ratio is very Large.	Power to Weight ratio is considerably small.
6	Components	Have converter and inverter.	Have converter and chopping circuit.
7	Rectifier	There is no need of rectifier circuit	Rectifying circuit is necessary
8	Speed Control	Sped control is achieved by changing the frequency	Speed control is achieved by armature and field control
9	Motor speed	Can reach up to 10000 RPM	Can reach up to 2500 RPM
10	Starting torque	Do not produce high starting torque	Produces high starting torque
11	Battery use	Cannot be run directly by batteries without using extra circuitry	Can be run directly through batteries Without adding an extra components
12	Noise	Operation is noisy which is highly unfavourable in certain applications	They are not noisy as compared to AC Drives
13	Power consumption	Consume less power	Consume more power

3.2.5 Variable Frequency Drives (VFDs)

AC drives are used to drive the AC motor especially three phase induction motors because these are predominant over other motors in most of the industries. In industrial terms, AC drive is also called as variable frequency drive (VFD), variable speed drive (VSD), or adjustable speed drive (ASD).

Though there are different types of VFDs (or AC drives), all of them are works on same principle that converting fixed incoming voltage and frequency into variable

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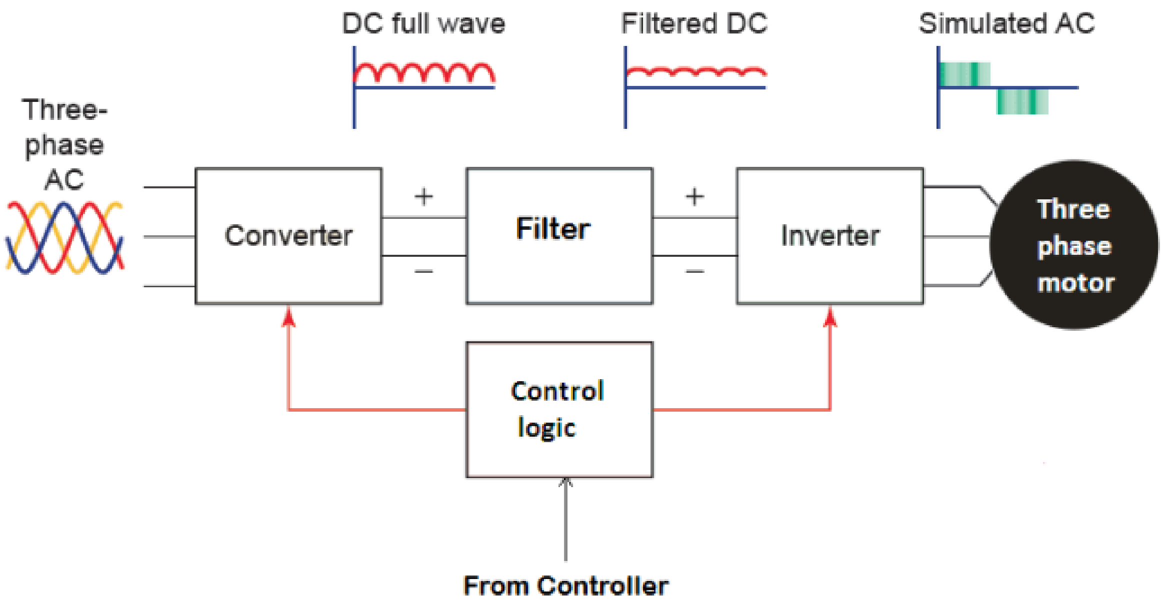
voltage and frequency output. The frequency of the drive determines the how fast motor should run while the combination of voltage and frequency decides the amount of torque that the motor to generate.

A VFD is made up of power electronic converters, filter, a central control unit (a microprocessor or micro controller) and other sensing devices. The block diagram of a typical VFD is shown in fig below. The various sections of the variable frequency drive (VFD) include:



Rectifier and Filter section converts the AC power into DC power with negligible ripples. Mostly, the rectifier section is made with diodes that produce uncontrollable DC output. The filter section then removes ripples and produces the fixed DC from pulsating DC. Depends on the type of supply number of diodes is decided in the rectifier. For example, if it is three phase supply, a minimum of 6 diodes are required and hence it is called as six pulse converter.

The **inverter** takes the DC power from the rectifier section and then converts back to the AC power of variable voltage and variable frequency under the control of microprocessor or microcontroller. This section is made with series of transistors, IGBTs, SCRs, or MOSFETs and these are turned ON/OFF by the signals from the controller. Depends on the turn ON of these power electronic components, the output and eventually the speed of the motor is determined.

The **controller** is made with microprocessor or microcontroller and it takes the input from sensor (as speed reference) and speed reference from the user and accordingly triggers the power electronic components in order to vary the frequency of the supply. It also performs overvoltage and under voltage trip, power factor correction, temperature control and PC connectivity for real time monitoring.

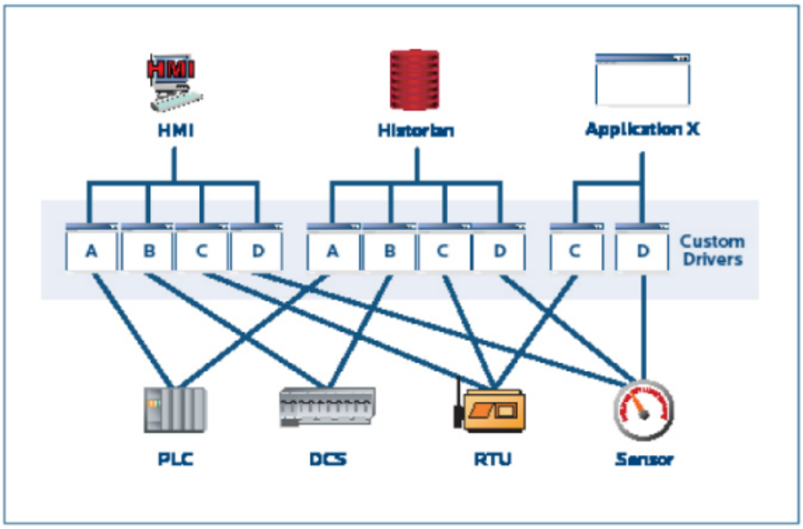
3.3 Introduction to OPC DA server

What is Automation's Data Connectivity Problem ?

Before looking at what OPC is and how it solves one of automation's biggest communications headaches, it is worth looking at what the problems were in the first place. Following is a list of factors that have traditionally caused the biggest data sharing issues:

1. **Proprietary Protocols**: Vendors often used proprietary protocols that allowed products from a particular product line to communicate among each other, but required custom drivers to communicate with other vendors? products. To make matters worse, different product lines from the same vendor often did not communicate amongst each other, which necessitated the need for additional connectors.

2. **Custom Drivers:** Every end-to-end connection required a custom driver to facilitate communications between specific endpoints. For example, if an HMI needed to communicate with a PLC, it required a custom HMI driver written for the specific protocol used by the PLC. If this PLC data was to be historized (recorded), the historian required its own driver because the HMI's custom driver could only be used to communicate with the HMI, not the historian. If a custom driver for the specific endpoints was not available, data communications were difficult and expensive to establish.



Custom Driver Problem - Each application requires a device or protocol specific driver to allow it to communicate with each respective device. Drivers are not re-usable between applications because each application uses its own data format(s).

3. **Complex Integration:** The use of custom drivers between every endpoint meant that even a small number of devices and applications quickly involved the use of many drivers. The same HMI running on multiple computers, all communicating with the same device, required multiple installations and

configurations of the same driver on each computer. If the HMIs communicated with additional devices, each HMI required its own set of custom drivers for each of the devices. This leads to complex integration of automation devices across the network.

4. **Obsolescence of Legacy Infrastructure:** As vendors release new products they eventually stop supporting older ones. When a new version of an HMI comes out, it may require its own set of device drivers that sometimes may no longer support communications with a device the previous version of the HMI supported.

What is OPC?

Open Platform Communications (OPC) is a standard defined for industrial communication. An industrial automation task force developed the original standard in 1996 under the name OLE for Process Control (Object Linking and Embedding for process control). OPC is used for the communication of real-time plant data between control devices from different manufacturers. OPC was designed to provide a common bridge for Windows-based software applications (such as SCADA and PLC sotwares from different manufacturers) and process control hardware.

What Types of Data does OPC Support?

The most common types of Automation data transferred between devices, controllers, and applications break down into three broad categories:

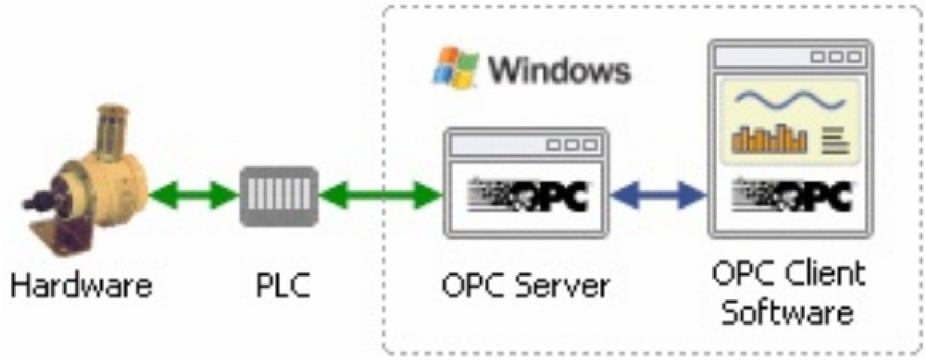
- Real-time data
- Historical data
- Alarm and Event data

Each of the above also supports a wide range of value types. Some common examples of these data types are integer, floating point, string, date, and various array types to name a few. The three types of OPC servers corresponding to the three data categories are:

1. OPC Data Access Server (OPC DA) - used to transport real-time data
2. OPC Historical Data Access Server (OPC HDA) - used to transport historical data
3. OPC Alarms and Events Specification (OPC A and E) - used to transport alarming information

OPC Architecture :

OPC works in server/client pairs. figure below shows the typical OPC architecture:



Benefits of using OPC Connectivity:

Following are some key benefits of using OPC-

1. An OPC enabled Application can freely communicate with any OPC-enabled Data Source visible to it on the network without the need for any driver software, specific to the Data Source.

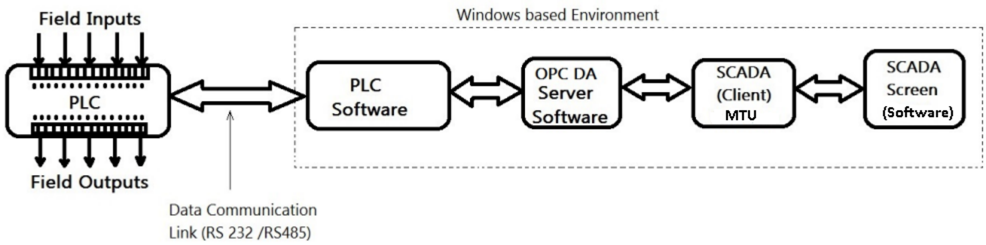
2. OPC-enabled applications can communicate with as many OPC-enabled Data Sources as they need. There is no inherent OPC limitation on the number of connections made.

3. Today OPC is so common that there's an OPC connector available for almost every modern and legacy device on the market. It's easy to get started using OPC.

4. Users are free to choose the best-suited devices, controllers, and applications for their projects without worrying about which vendor each came from and whether they will communicate with each other.

3.4 Steps in Integrating PLC (RTU) with SCADA

The communication between PLC software and SCADA is achieved through an OPC DA Server. The figure below shows the typical connection digram or interfacing diagram of PLC hardware with SCADA software. It is cleared from the below figure that a PLC hardware is operated through a appropriate PLC software(*In VES Polytechnic we have used Allen bradley Micrologix 1200 PLC with RSlogix 500 software and Vijeo Citect SCADA*).



As shown in above figure, to establish communication between PLC and SCADA, over OPC DA Server, typically we need to follow the following steps:

1. **Developing PLC based Application:**
2. **Configuring the OPC DA server:**
3. **Creating Tags:**
4. **Configuring SCADA graphics:**
5. **Executing the application in SCADA Runtime environment:**

(**Note:** Students can describe the above steps in their own words. They can refer to the practicals performed on the Integrating PLC and SCADA.)

Chapter 4

Human Machine Interface (HMI)

4.1 Introduction

What is HMI?

"HMI" stands for Human Machine Interface. These devices are also known as M an Machine Interface (MMI), Operator Interface Terminal (OIT), Local Operator Interface (LOI), Operator Terminal (OT) etc. but widely they are referred as HMIs.

An HMI is exactly what the name implies: a graphical interface that allows human users to interact with a system's machinery. HMI technology is used in almost all manufacturing industries , as well as a wide range of other companies, to interact with their machines and optimize their industrial processes. Industries using HMI include: Energy, Oil and gas, Transportation, Food and beverage,Power,Water and waste water, Manufacturing, Recycling, and many more.

Evolution of the Human-Machine Interface:

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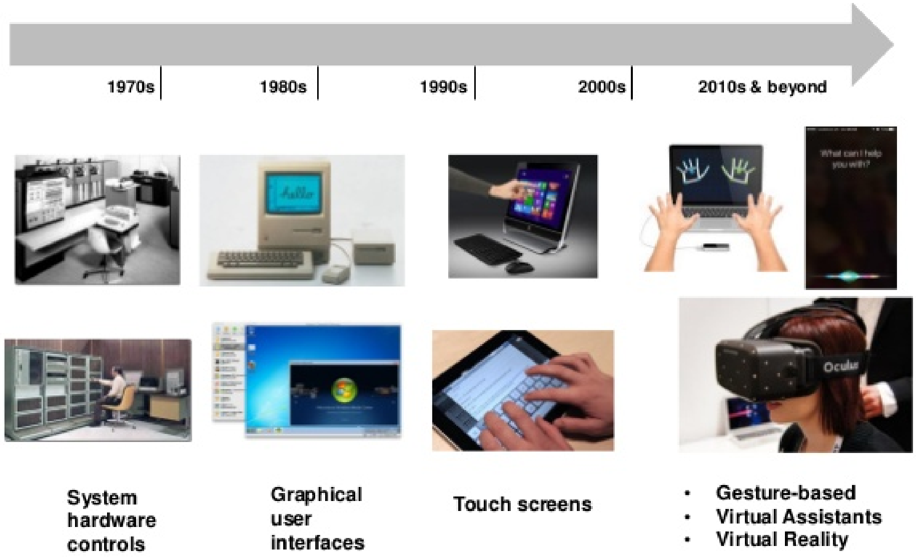

- **The 1980's: Push-Buttons:**

  In the 1980s, early HMI electronic panels extended backlight life and increased brightness for visibility, but due to the high cost, most manufacturers opted to keep push-button devices. It was when the personal computer, PCs, were introduced that HMIs started seeing a digital revolution along with the rest of the world.

- **The 1990's: Replacing CRT with LCD:** Thanks to the PC, liquid-crystal display (LCD) screens came into the picture, swiftly replacing CRTs, or cathode ray tubes. These were the less-detailed, rounded, and thicker screens used for all types of HMIs.

- **The 2000's: Touchscreens :** In recent times, old CRT based screens are replaced by fully functional touch screens.most popular types are Resistive or Capacitive screens. Advance LED touchscreens are also used in HMI which provides better color graphics and visibility but are comparatively costlier than other touchscreens.

- **Today: The Future of HMIs:**Today, HMIs allow us to have artificial intelligence (AI), virtual reality (VR), and augmented reality (AR).

  With AI, we can have virtual assistants who learn from the user's behavior, whereas previously our computer software had limited functionality. Now, we have streaming services and smart devices right at our fingertips.

Functions of an HMI:

- **Monitoring:** It is the ability to obtain and display plant data in real time. This data can be displayed as numbers, text or graphics that allow a reading easier to interpret.

- **Supervision:** This function allows, together with the monitoring, the possibility of adjusting the working conditions of the process directly from the computer.

- **Alarm:** It is the ability to recognize exceptional events within the process and report them.

- **Control:** It is the ability to apply algorithms that adjust the values of the process and thus maintain these values within certain limits.

- **Historian:** It is the ability to display and store in files, process data at a certain frequency. This storage of data is a powerful tool for the optimization and correction of processes.

4.2 Types of operator Interfaces

HMIs are classified based upon their display type as-

- **Text-Based Interfaces:** Operator interfaces may be text based, simply providing instructions or machine status to the operator. They may or may not include buttons for input. The displays are typically backlit LCD but may be vacuum fluorescent bulbs. LED arrays are also common in larger message-only-type displays with a greater viewing distance.

- **Graphical Interfaces:**

With improvements in technology, it has become standard for machines to use graphic interfaces with pictorial representations of the machine or production line for diagnostic purposes. These may be either monochrome or color and have membrane-type buttons, touch screens, or both.Two types of touchscreen displays are used in HMI such as - Resistive touch Screens and Capacitive touch screens.

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Graphical interfaces provide the ability to create a virtually unlimited number of screens and interface objects. Smaller screens can be superimposed over larger ones or minimized like the Windows operating system.

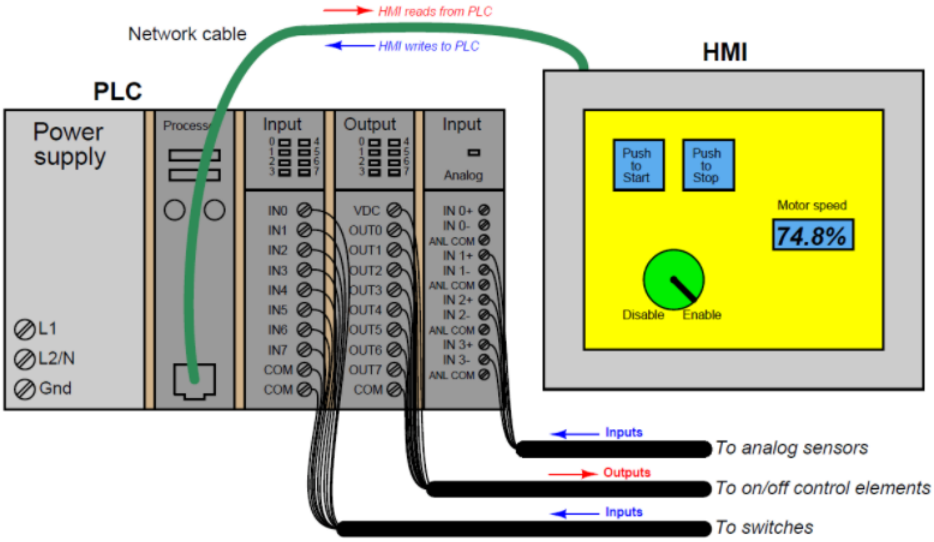
Before HMIs were introduced, they were mimicked by a hardware control panel that consisted of hundreds of LEDs and push-buttons to offer the user similar functionality. Today, the scenario is much different.

There are three types of HMIs based upon their uses -

- **Pushbutton replacer:** This type of HMI has streamlined manufacturing processes and centralized all functions that were previously handled by pushbuttons and similar hardware controls.
- **Data handler:**For systems that required constant feedback from the machinery, Data Handler HMIs were developed. Data handler allows the user to work through functions such as data trends, data logging, alarm handling, etc., putting a great deal of data at disposal.
- **Overseer:**An Overseer HMI is installed whenever SCADA or MES systems are brought in. This type of HMI runs on Windows, and has several ethernet ports for communication. These systems monitor large areas, e.g. entire sites and complex.

4.3 Connection Wiring of HMI with PLC

Wiring an HMI into a system may be an easy task if a PLC is already integrated. This connection is as simple as connecting a USB/RS-232/RS-485 cable between the HMI and PLC as shown in following figure -



Above figure shows the typical connection diagram between PLC and HMI. This connection takes place in two levels:

1. **Integration of different I/O devices to PLC:**

   In this step the different field devices such as sensors, actuators, pumps, motors, valves etc are interfaced(wired) with the appropriate I/O module of the PLC. The PLC receives the input (in the form of analog or digital signal) from different input devices connected to input module and output module change the status of a specific output device as per the processor signal. Processor of PLC uses memory and solve the user logic program and updates the status of output devices.

2. **PLC integration with HMI:**

   Once the above step is set then HMI can be wired to PLC using USB/RS-232/RS-485 through communication port of PLC processor. Then the PLC memory data can be fetched into HMI by configuring tag database in HMI and linking it with PLC memory. Once the data access is established between PLC and HMI, then HMI graphics can be designed.

Following figure shows how above two steps can be implemented for the controlling the speed of pump motor using VFD.

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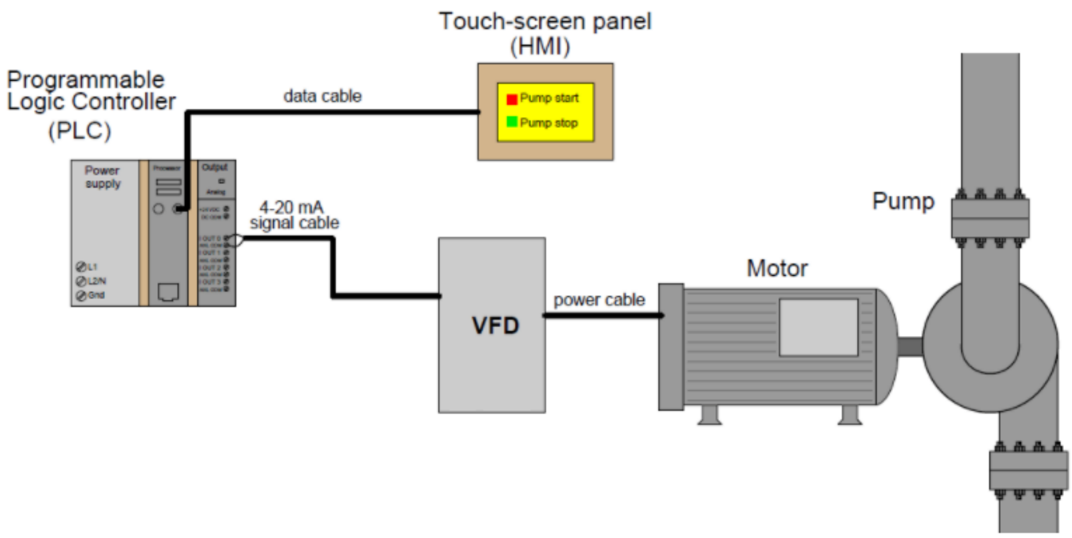
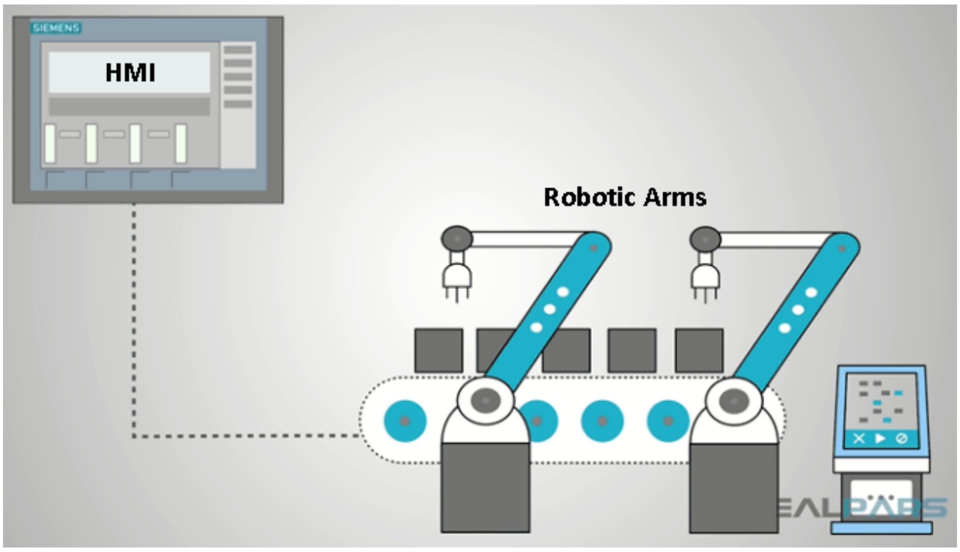


4.4 Data handling with HMI

A Human-Machine Interface (HMI) is a user interface or dashboard that connects a person to a machine, system, or device. HMIs are generally used to:

- Visually display data
- Track production time, trends, and tags,
- Monitor machine input and output



The above image shows how through HMI panel a pick and place mechanism is controlled and monitored. To display data of the process visually on the HMI screen, it requires different data to be handled or processed by HMI continuously. which may includes:

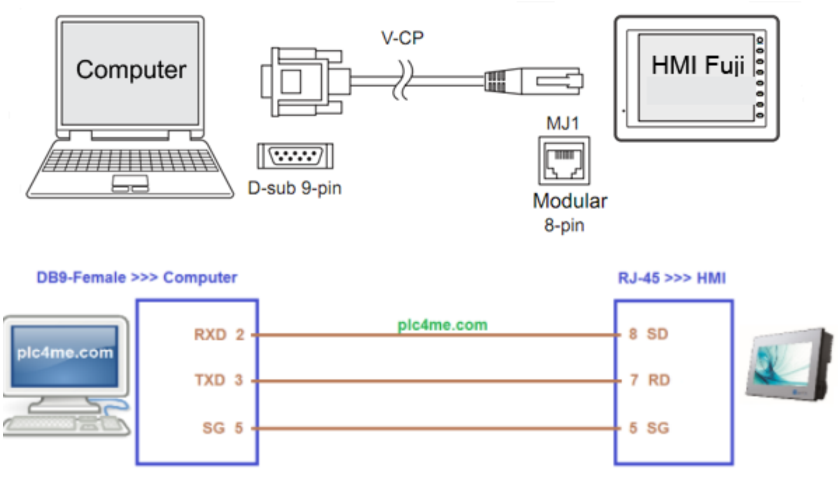
1. Information like temperature, pressure, process flow, material counts etc.,

2. Precise levels in tanks,
3. Exact positioning of control valve,
4. Speed of Motor,
5. Data required to turn the pump/motor/lamp on and off,
6. Counter and Timer values .

4.5 Configuration and Interfacing to PLC and PC

How can we connect an HMI with a PC?

The HMI terminals can be connected to the PC with the help of a USB or it can also be connected with the Ethernet port. In order to do the USB connection the panel view component must have a USB port to do the communication with the USB. In order to do the Ethernet connection we must first install the drivers.Following image shows the HMI connection with PC using RS-232 and RJ-45 connector cable.



HMI Connecting To PC

The HMI consists of a monitoring screen, operating panel, and communication ports. The HMI can be integrated into our process with the help of a PC and it is done by using HMI software and then the program will be transferred to the HMI and the HMI will run the program. The devices in the factory can be connected to the HMI like the machinery in a production line and also the input-output sensors and these sensors will give the data to the PLC.

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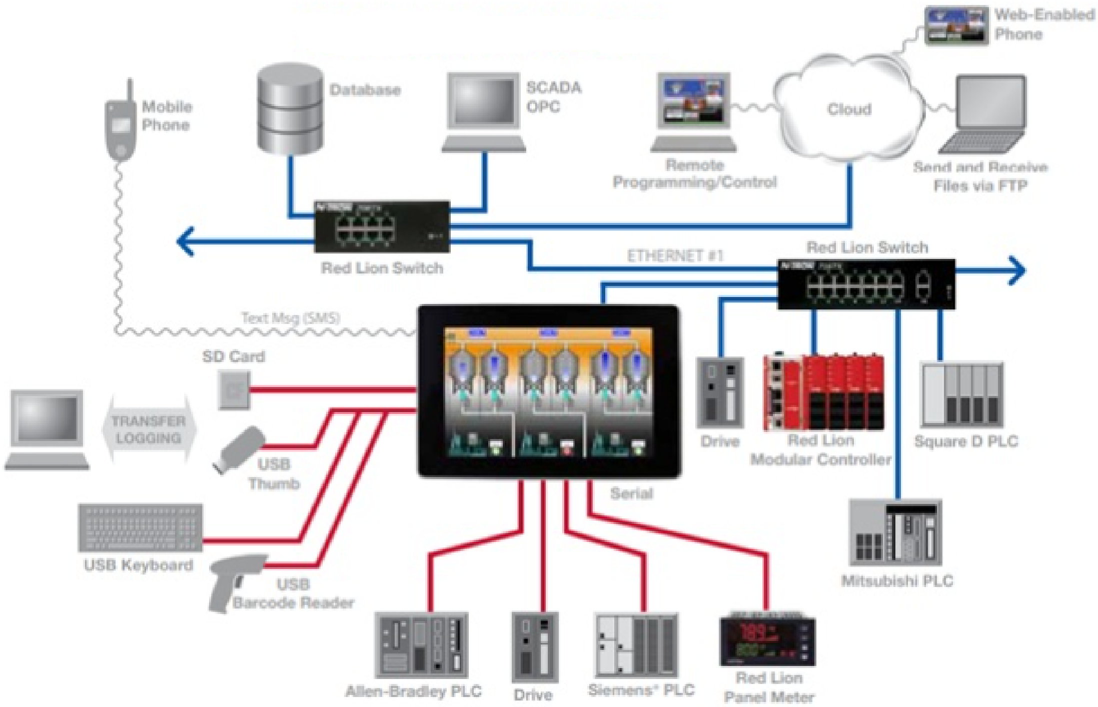

The HMI can have access to may devices such as- PLC, AC/DC drives, SCADA OPC , External USB drive, Database server etc., this idea is shown in above image.

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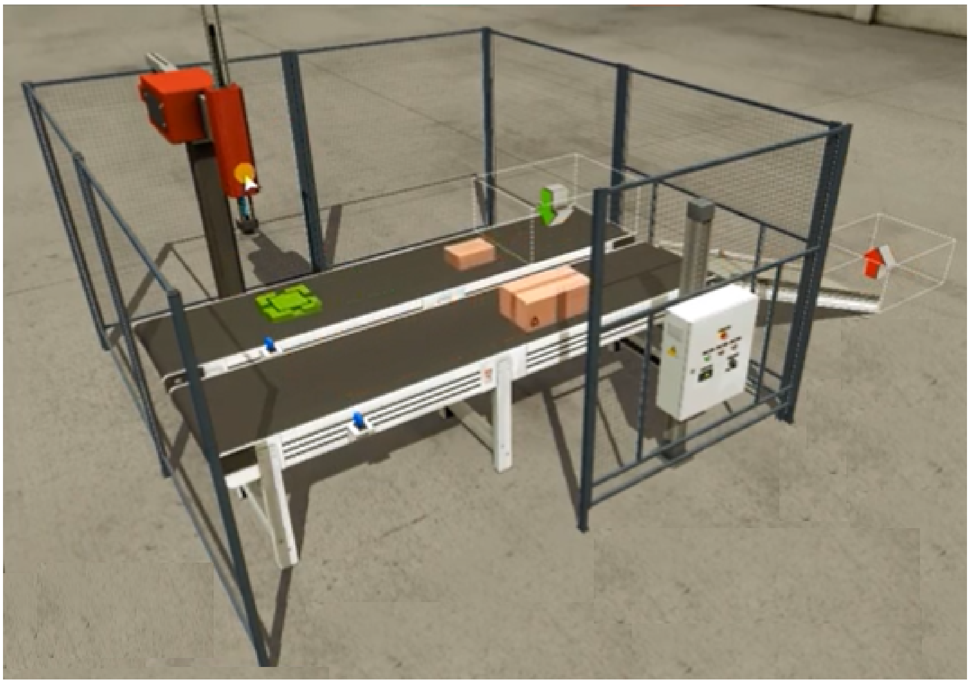
Chapter 5

SCADA Application development

5.1 Robotic pick and place mechanism

1. **Problem Statement:**



- A start and stop push buttons are used to start and stop the process in automatic mode.
- Upon starting the entry conveyor will bring a part to the item at the entry sensor.The conveyor will then stop.
- A robot arm will move down, detect the part, and then activate a grabber.
- It will then return to the up position. When it reaches the top it will extend the arm over the opposite exit conveyor.
- The exit conveyor will be stopped as the arm lowers the part to the conveyor.

- It releases the gripper and moves back up. The exit conveyor can then start.
- The arm returns to the entry conveyor. The entry conveyor will start again, to continue the same cycle.
- Upon a box being sensed from the item at the exit sensor, a counter will keep track of the number of complete cycles.
- The reset input will reset the cycle counter and the machine. All items are removed off of the conveyor belts.

2. **I/O List:**

Sr.No.	Inputs	Sr.No.	Outputs
1	Start Input – X0 (I:0/0)	1	Entry conveyor Motor -Y0 (O:0/0)
2	Stop Input – X1 (I:0/1)	2	Robotic arm Down Motor -Y1 (O:0/1)
3	Entry Sensor – X2 (I:0/2)	3	Robotic arm Up Motor - Y2 (O:0/2)
4	Exit Sensor – X3 (I:0/3)	4	Robotic arm forward motor – Y3 (O:0/3)
5	Robotic arm Up Sensor – X4 (I:0/4)	5	Robotic arm Backward Motor – Y4 (O:0/4)
6	Robotic arm Down Sensor -X5 (I:0/5)	6	Pneumatic Grabber – Y5 (O:0/5)
7	Robotic arm Forward Sensor -X6 (I:0/6)	7	Exit Conveyor Motor – Y6 (O:0/6)
8	Robotic arm Backward Sensor – X7 (I:0/7)		
9	Internal Relay -M0 (B3:0/0)		
Total Inputs: 09		**Total Outputs: 07**	
Total I/Os: 16			

*X – Mitsubishi PLC Addressing
*I:0/0 – Micrologix PLC Addressing

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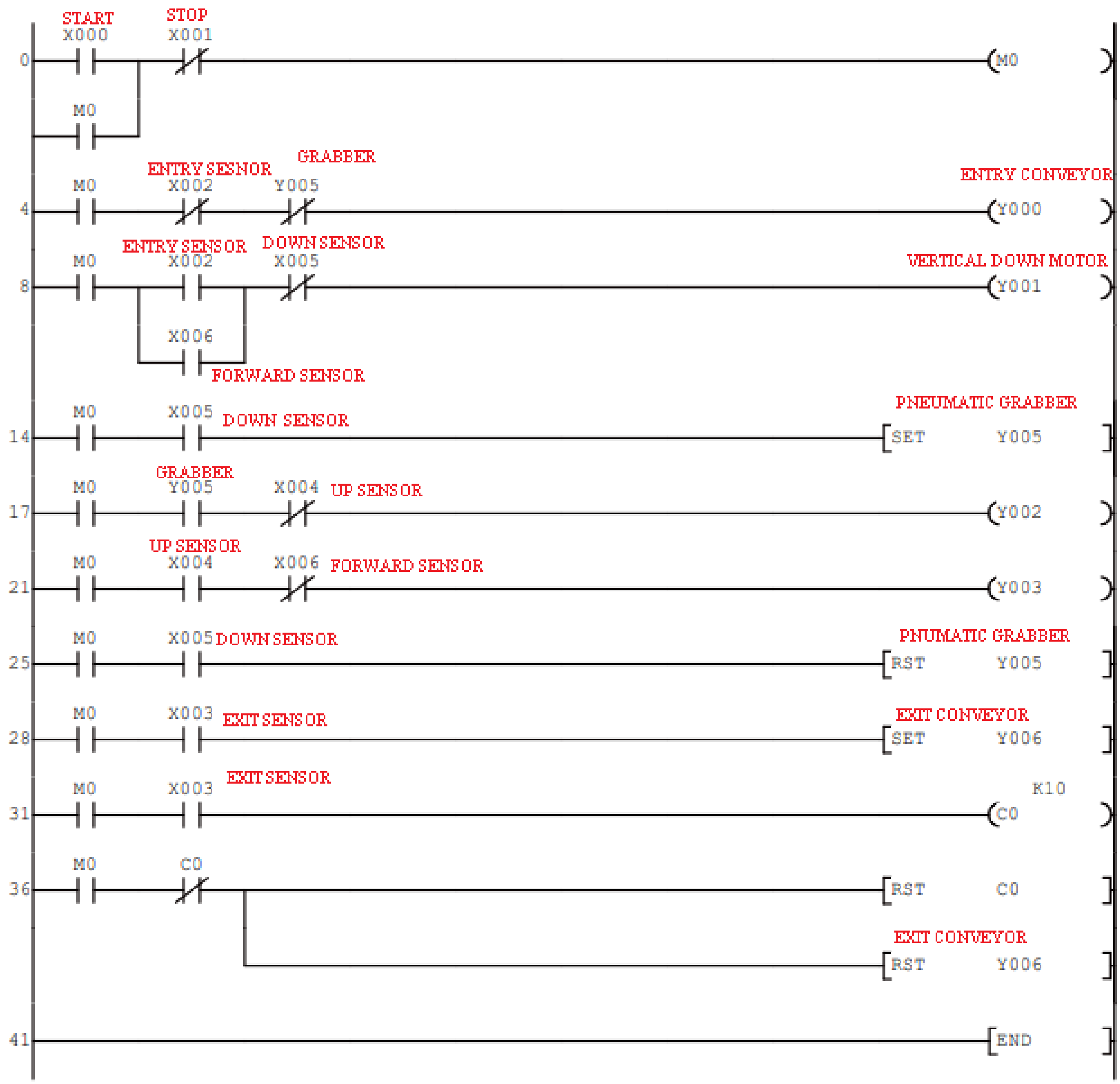
3. **PLC ladder program:**



4. OPC tag database:

Sr.No.	Tag Properties		Data Properties		
	Tag Name	Address	Data type	Client access	Scan Rate
1	Start	X0 (I:0/0)	Boolean	Read Only	100ms
2	Stop	X1 (I:0/1)	Boolean	Read Only	100ms
3	Entrysensor	X2 (I:0/2)	Boolean	Read Only	100ms
4	Exitsensor	X3 (I:0/3)	Boolean	Read Only	100ms
5	Upsensor	X4 (I:0/4)	Boolean	Read Only	100ms
6	Downsensor	X5 (I:0/5)	Boolean	Read Only	100ms
7	Forwardsensor	X6 (I:0/6)	Boolean	Read/Write	100ms
8	Backwardsensor	X7 (I:0/7)	Boolean	Read/Write	100ms
9	Entryconveyor	Y0 (O:0/0)	Boolean	Read/Write	100ms
10	Downmotor	Y1 (O:0/1)	Boolean	Read/Write	100ms
11	Upmotor	Y2 (O:0/2)	Boolean	Read/Write	100ms
12	Forwardmotor	Y3 (O:0/3)	Boolean	Read/Write	100ms
13	Backwardmotor	Y4 (O:0/4)	Boolean	Read/Write	100ms
14	Grabber	Y5 (O:0/5)	Boolean	Read/Write	100ms
15	Exitconveyor	Y6 (O:0/6)	Boolean	Read/Write	100ms
16	Counter	C0 (C5:0)	Integer	Read/Write	100ms

***X – Mitsubishi PLC Addressing**
***I:0/0 – Micrologix PLC Addressing**

5. **SCADA screen development:**

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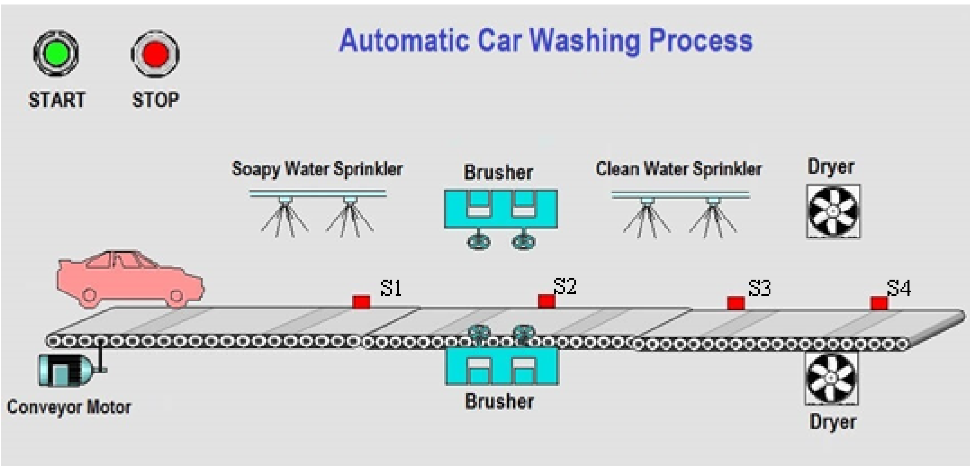
5.2 Car washing system



1. **Problem Statement:**

- When Start switch is ON, conveyor motor starts, which moves car forward.

- When limit sensor/proximity switch S1 senses the car, the conveyor stops and the soapy water sprinkler starts for 5 sec.
- After 5 sec water sprinkler stops and conveyor starts again.
- When sensor S2 senses te car, the conveyor stops again and Brusher motor starts for 5 sec.
- After 5 sec brusher motor stops and conveyor starts again.
- When sensor S3 senses the car , the conveyor stops and clean water sprinkler starts for 5 sec.
- After 5 sec clean water sprinkler stops and conveyor starts again.
- When sensor S4 senses the car the conveyor stops and dryer starts for 5 sec.
- After 5 sec dryer stops.
- Stop switch can be used as emergency stop the entire process at any time during the operation.

2. **I/O List:**

Sr.No.	Inputs	Sr.No.	Outputs
1	Start Input – X0 (I:0/0)	1	Conveyor Motor- Y0 (O:0/0)
2	Stop Input – X1 (I:0/1)	2	Soapy water Sprinkler – Y1 (O:0/1)
3	Proximity Sensor S1 – X2 (I:0/2)	3	Brusher Motor – Y2 (O:0/2)
4	Proximity Sensor S2 – X3 (I:0/3)	4	Clean water Sprinkler -Y3 (O:0/3)
5	Proximity Sensor S3 – X4 (I:0/4)	5	Dryer Motor-Y4 (O:0/4)
6	Proximity Sensor S4 – X5 (I:0/5)		
7	Internal Relay – M0 (B3:0/0)		
Total Inputs: 06		**Total Outputs: 05**	
Total I/Os: 11			

*X – Mitsubishi PLC Addressing
*I:0/0 – Micrologix PLC Addressing

3. **PLC ladder program:**

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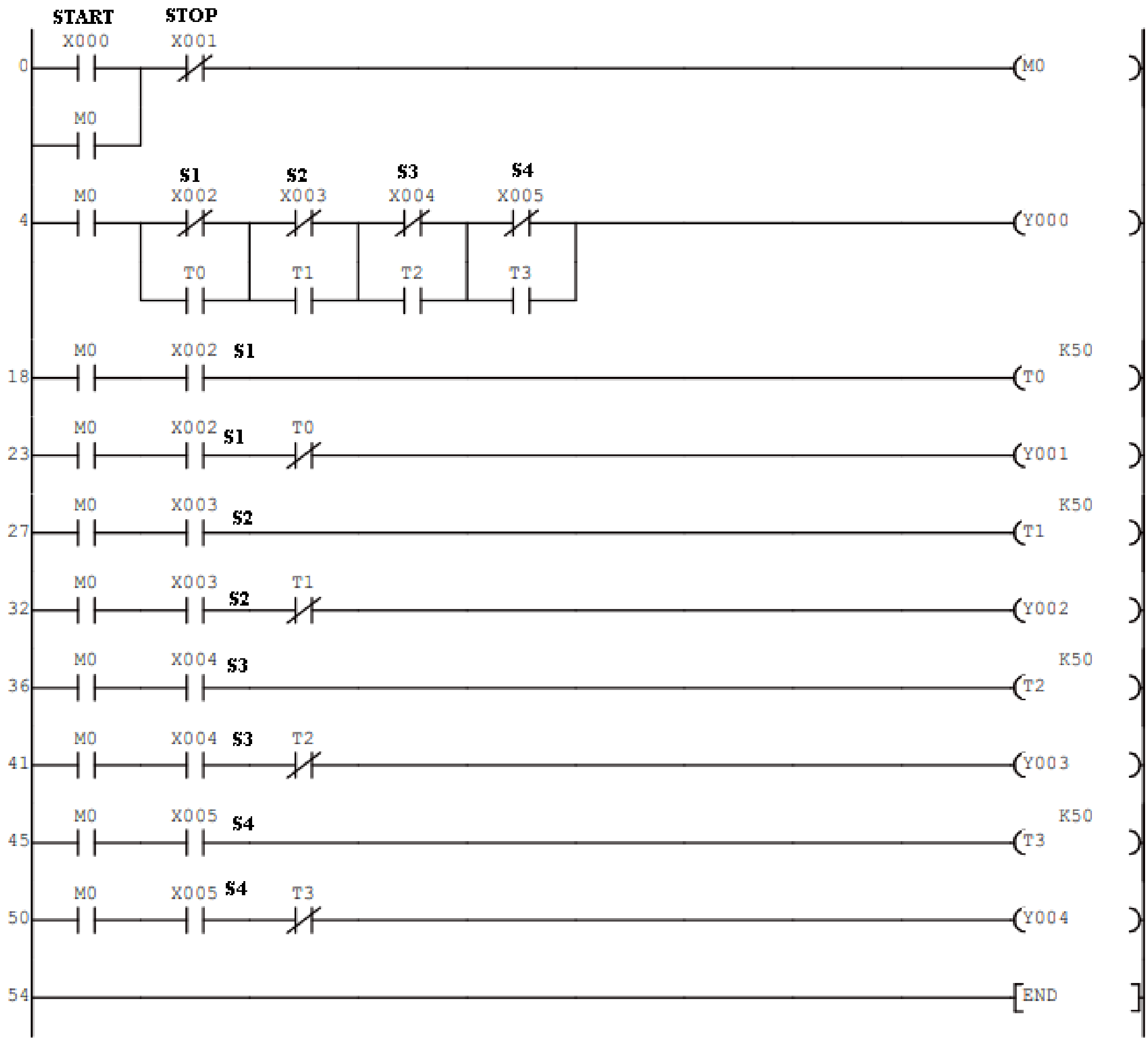


4. **OPC tag database:**

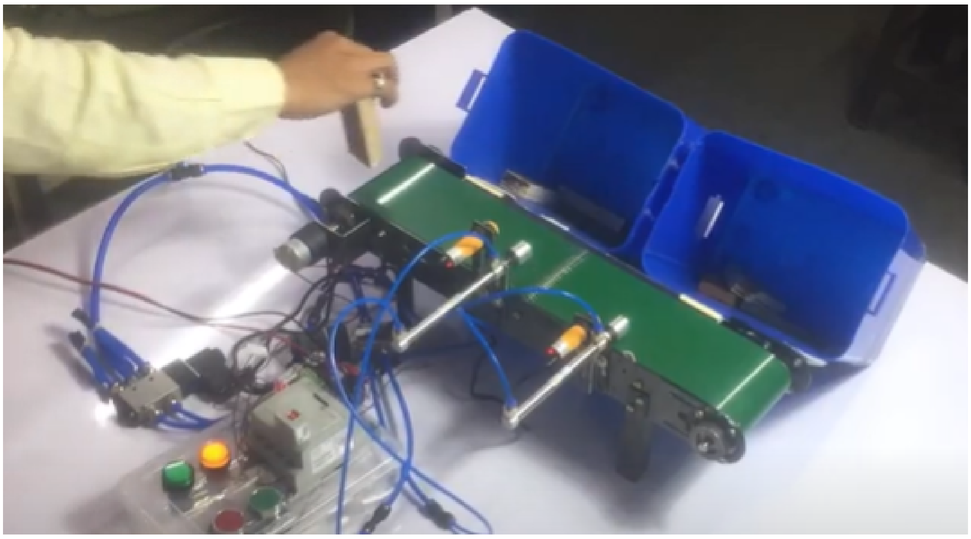
Sr.No.	Tag Properties		Data Properties		
	Tag Name	Address	Data type	Client access	Scan Rate
1	Start	X0 (I:0/0)	Boolean	Read Only	100ms
2	Stop	X1 (I:0/1)	Boolean	Read Only	100ms
3	Proxysensor1	X2 (I:0/2)	Boolean	Read Only	100ms
4	Proxysensor2	X3 (I:0/3)	Boolean	Read Only	100ms
5	Proxysensor3	X4 (I:0/4)	Boolean	Read Only	100ms
6	Proxysensor4	X5 (I:0/5)	Boolean	Read Only	100ms
7	Conveyor_motor	Y0 (O:0/0)	Boolean	Read/Write	100ms
8	Soapy_water_sprinkler	Y1 (O:0/1)	Boolean	Read/Write	100ms
9	Brush_motor	Y2 (O:0/2)	Boolean	Read/Write	100ms
10	Clean_water_sprinkler	Y3 (O:0/3)	Boolean	Read/Write	100ms
11	Dryer_motor	Y4 (O:0/4)	Boolean	Read/Write	100ms

***X – Mitsubishi PLC Addressing**
***I:0/0 – Micrologix PLC Addressing**

5. **SCADA screen development:**

5.3 Sorting and Stacking system

1. **Problem Statement:**



- A start and stop push buttons are used to start and stop the process in automatic mode. when start PB is pressed conveyor motor is ON and Green lamp is also ON indicating the start of process.

- Different size objects are passed on the conveyor belt. similar height objects are sensed by sensor 1 and sorted by pneumatic cylinder piston 1 into the box 1.
- Larger height objects are detected by sensor 2 and sorted by pneumatic cylinder piston into box 2.
- When any box is full with the 10 objects then conveyor stops and alarm indication is given to operator.(RED light flashing)
- Once the alarm is settled by the operator then conveyor belt starts with sorting operation.
- Stop switch can be used as a emergency stop the entire process at any time during the operation.

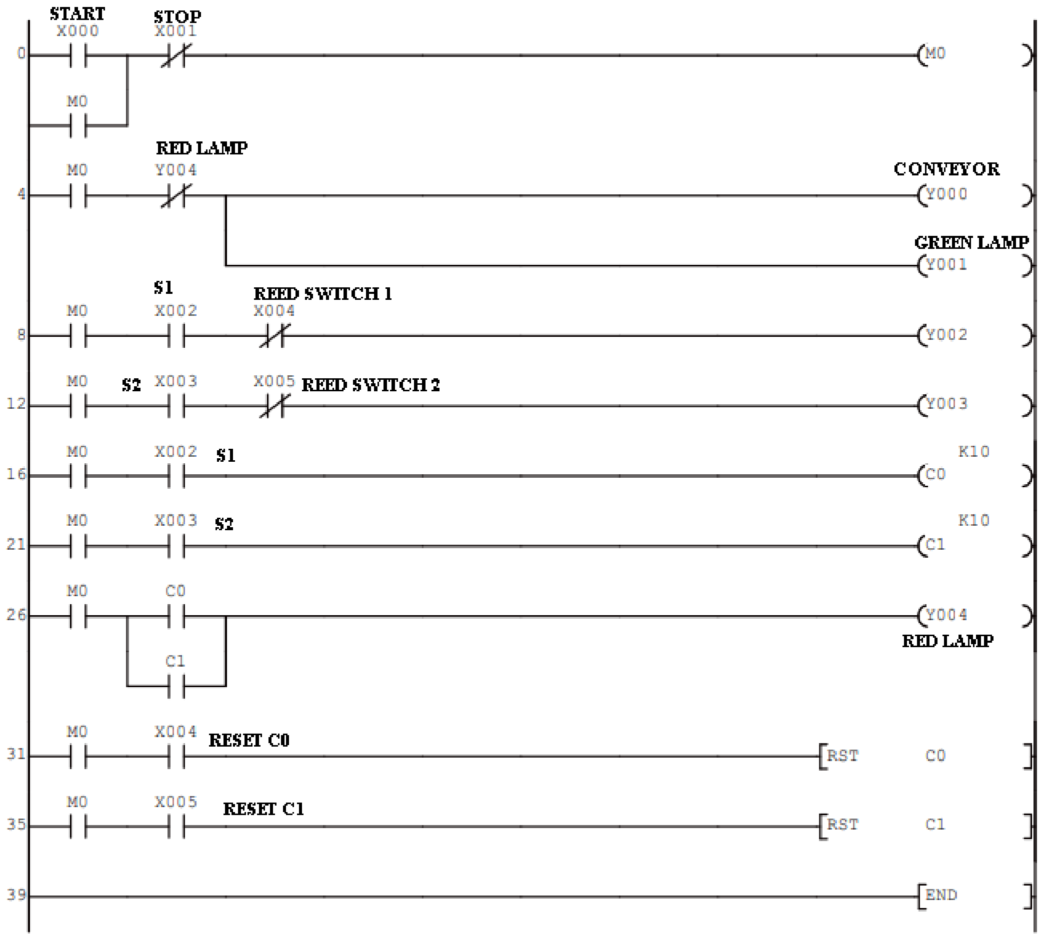
2. **I/O List:**

Sr.No.	Inputs	Sr.No.	Outputs
1	Start Input – X0 (I:0/0)	1	Conveyor Motor- Y0 (O:0/0)
2	Stop Input – X1 (I:0/1)	2	Green Lamp – Y1 (O:0/1)
3	Proximity sensor – X2(I:0/2)	3	Piston1 Solenoid -Y2 (O:0/2)
4	Proximity Sensor- X3 (I:0/3)	4	Piston2 Solenoid -Y3 (O:0/3)
5	Reed switch 1- X4 (I:0/4)	5	Red Lamp – Y4 (O:0/4)
6	Reed switch 2 – X5(I:0/5)		
Total Inputs: 06		**Total Outputs: 05**	
Total I/Os: 11			

*X – Mitsubishi PLC Addressing
*I:0/0 – Micrologix PLC Addressing

3. **PLC ladder program:**

Notes By - Kalpesh Bagal



4. **OPC tag database:**

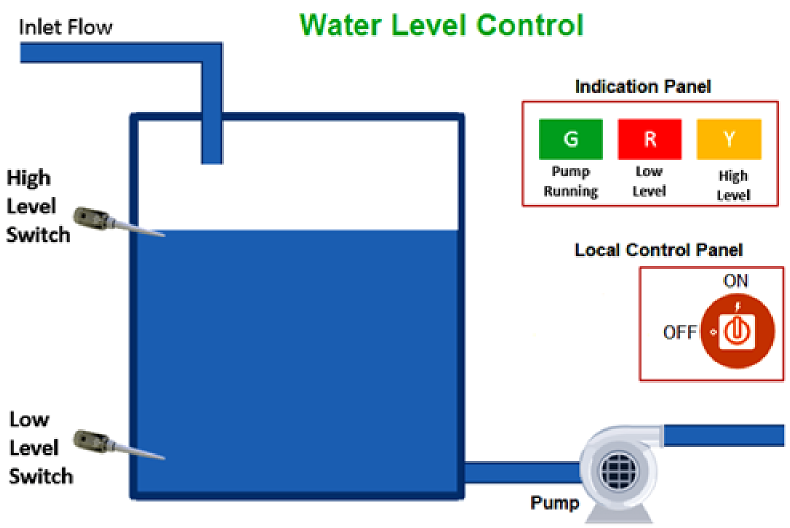
Sr.No.	Tag Properties		Data Properties		
	Tag Name	Address	Data type	Client access	Scan Rate
1	Start	X0 (I:0/0)	Boolean	Read Only	100ms
2	Stop	X1 (I:0/1)	Boolean	Read Only	100ms
3	Proxysensor1	X2 (I:0/2)	Boolean	Read Only	100ms
4	Proxysensor2	X3 (I:0/3)	Boolean	Read Only	100ms
5	Reed_switch1	X4 (I:0/4)	Boolean	Read Only	100ms
6	Reed_switch2	X5 (I:0/5)	Boolean	Read Only	100ms
7	Conveyor_motor	Y0 (O:0/0)	Boolean	Read/Write	100ms
8	Green_lamp	Y1 (O:0/1)	Boolean	Read/Write	100ms
9	Solenoid1	Y2 (O:0/2)	Boolean	Read/Write	100ms
10	Solenoid2	Y3 (O:0/3)	Boolean	Read/Write	100ms
11	Red_lamp	Y4 (O:0/4)	Boolean	Read/Write	100ms

***X – Mitsubishi PLC Addressing**
***I:0/0 – Micrologix PLC Addressing**

5. **SCADA screen development:**

5.4 Water level control system

1. **Problem Statement:**



Assumption: Tank is Full and Inlet is continuously ON

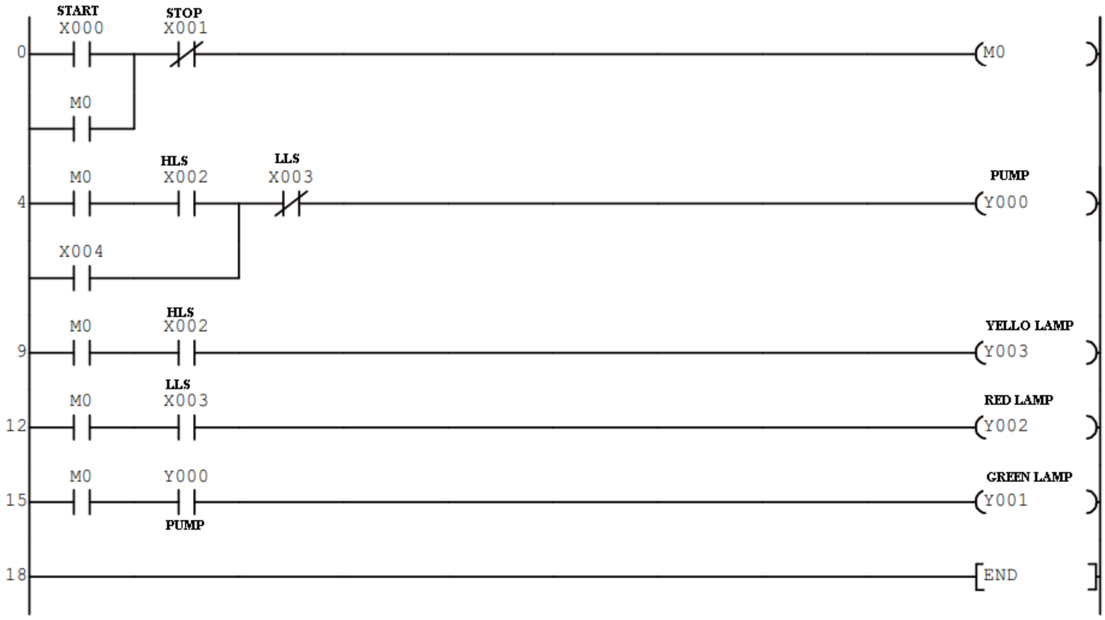
- When start switch is pressed and if Tank is full (*i.e.* HLS is reached) then Pump is ON.
- When level of liquid goes below HLS then HLS is activated and pump is OFF.
- Since the inlet is continously ON, tank fills again. if the level goes above HLS then the Pump is ON again.
- To empty the tank, Tank Empty button can be pressed which will on the pump forcefully.
- In this case if LLS is reached pump will be off and protected from dry RUN.

2. **I/O List:**

Sr.No.	Inputs	Sr.No.	Outputs
1	Start (ON) Input – X0 (I:0/0)	1	Pump -Y0 (O:0/0)
2	Stop (OFF) Input – X1 (I:0/1)	2	Green Lamp -Y1 (O:0/1)
3	High level limit switch -X2 (I:0/2)	3	RED Lamp - Y2 (O:0/2)
4	Low level limit switch– X3 (I:0/3)	4	Yellow Lamp – Y3 (O:0/3)
Total Inputs: 04		**Total Outputs: 04**	
Total I/Os: 08			

*X– Mitsubishi PLC Addressing
*I:0/0 – Micrologix PLC Addressing

3. **PLC ladder program:**



4. **OPC tag database:**

Sr.No.	Tag Properties		Data Properties		
	Tag Name	Address	Data type	Client access	Scan Rate
1	Start	X0 (I:0/0)	Boolean	Read Only	100ms
2	Stop	X1 (I:0/1)	Boolean	Read Only	100ms
3	HLS	X2 (I:0/2)	Boolean	Read Only	100ms
4	LLS	X3 (I:0/3)	Boolean	Read Only	100ms
5	Pump	Y0 (O:0/0)	Boolean	Read/Write	100ms
6	Green_lamp	Y1 (O:0/1)	Boolean	Read/Write	100ms
7	Red_lamp	Y2 (O:0/2)	Boolean	Read/Write	100ms
8	Yellow_lamp	Y3 (O:0/3)	Boolean	Read/Write	100ms

***X – Mitsubishi PLC Addressing**
***I:0/0 – Micrologix PLC Addressing**

Notes By - Kalpesh Bagal

5. **SCADA screen development:**

5.5 Integrating Pneumatic components with SCADA

Pneumatic Cylinders: Pneumatic cylinders, also called air cylinders, pneumatic actuators, or pneumatic drives, are relatively simple mechanical devices that use the energy of compressed air and turn it into linear or rotary motion. Pneumatic cylinders are a clean and cost-effective option for reliable linear motion in many industrial environments.

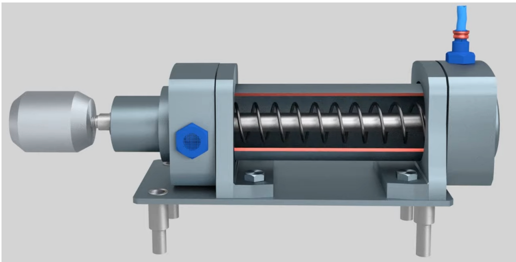
The most common design consists of a cylinder or tube that is sealed on both ends, with a cap at one end and head at the other end. The cylinder contains a piston, which is attached to a rod. The rod moves in and out of one end of the tube, actuated by compressed air.

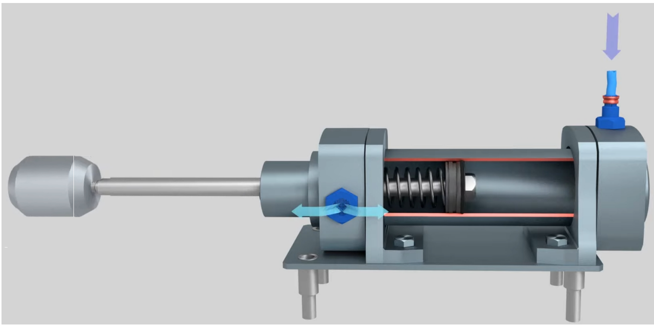
Two main types of Pneumatic cylinders are:

- Single - acting
- Double - acting

The main design difference between both cylinders is the number of ports. Single acting cylinders has one port where pressurized air enters, while double acting cylinders use two ports to operate. This simple design difference distinguishes both cylinders in terms of movement and speed. When choosing a design, it is important to know the application of each device, their differences, advantages and disadvantages.

Single - Acting Pneumatic Cylinder:

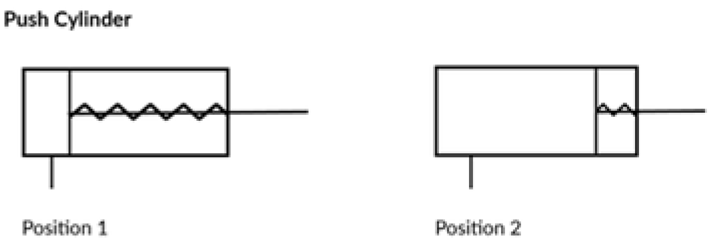




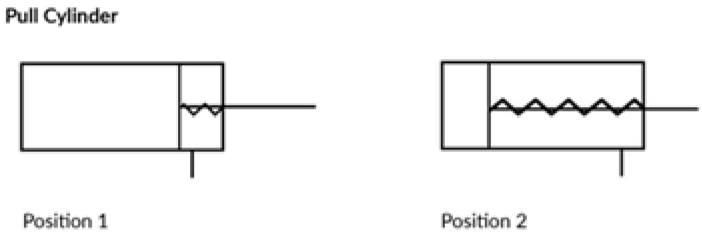
Single acting cylinders have one port where pressurized air enters in one direction. A spring, or a load, is usually fitted to the piston. Once air is cleaned and compressed it enters through the single port forcing the piston to extend in one direction compressing the spring. The spring (or another external force) will retract the piston back to its original position after releasing air through the same port where it originally entered. Simply put, the compressed air will force a forward stroke inside the cylinder and the spring will return the stroke.

There are two different types of single acting cylinders, push and pull.

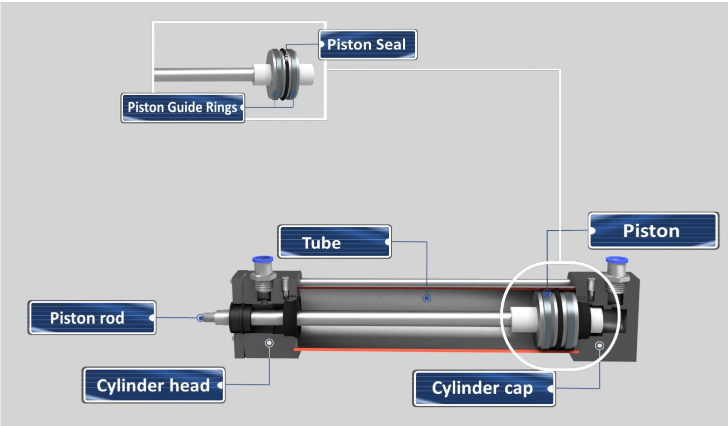
- **Push Type Cylinder:** Air enters to push the piston out of the cylinder

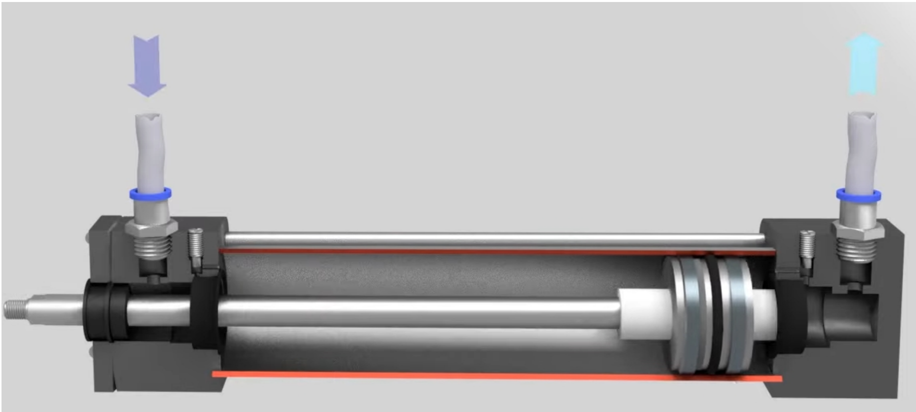


- **Pull Type Cylinder:** Air enters to pull the piston inside of the cylinder

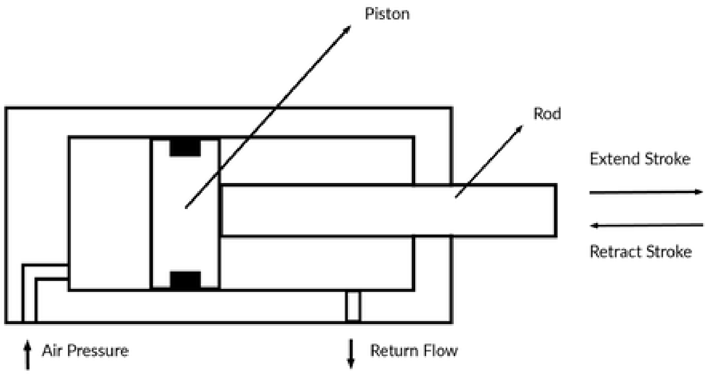


Double - Acting Pneumatic Cylinder:





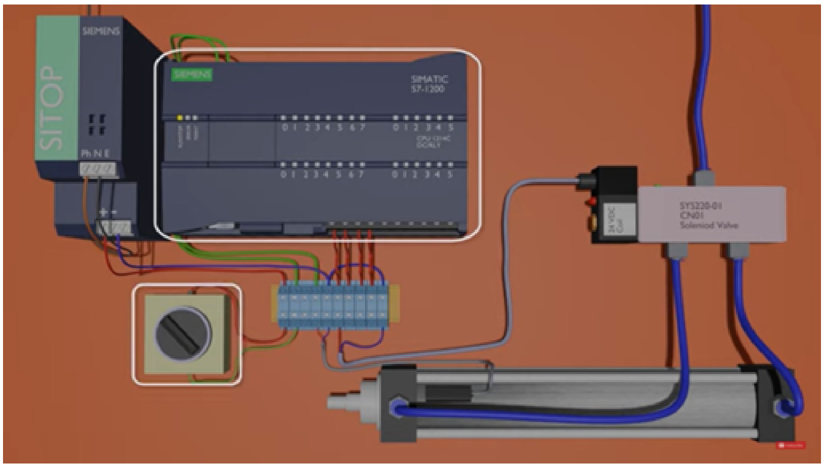
When looking for a device to move load in both directions, double acting cylinders are a useful application when your machine requires more than one movement. Unlike single acting air cylinders, double acting cylinders can extend and retract without the need of a spring. Instead of applying pressurized air into one port, double acting cylinders have two ports where air can enter in and out.



Air enters through one port moving the piston forward and then applies pressurized air into the other port retracting the piston back into the cylinder. Double acting cylinders are the most widely used pneumatic actuators compared to single acting cylinders given their ability to extend and retract within a shorter time period, thus, becoming more efficient and precise.

Operating Pneumatic cylinder through PLC:

In this section, PLC ladder program is developed to operate single acting pneumatic cylinder. The practical setup is shown in following image:



As per above setup, PLC operates the back-and-forth movement of single acting pneumatic cylinder piston through three-way solenoid valve and On-Off rotary switch. Here, On -Off Rotary switch is connected to the input side of the PLC and from output side of PLC a connecting wire is taken out to connect three-way solenoid vale to the PLC. Solenoid valve control the flow of pressurized air to the piston of pneumatic cylinder and exhaust air flow from cylinder. Reed switch attached to the piston gives signal to PLC about the forward movement of the cylinder piston.

When rotary switch is Off then PLC send the signal to solenoid valve to remove the air from piston which in turn make backward motion of piston and it comes to the original position.

Notes By - Kalpesh Bagal

To operate single acting pneumatic cylinder, following logic diagram is used: