2022

Distributed Control System (DCS) for Industrial Automation Solutions

PREPARED BY: REKAWT BAHADIN DARWESH
ASSOCIATION ID :9242

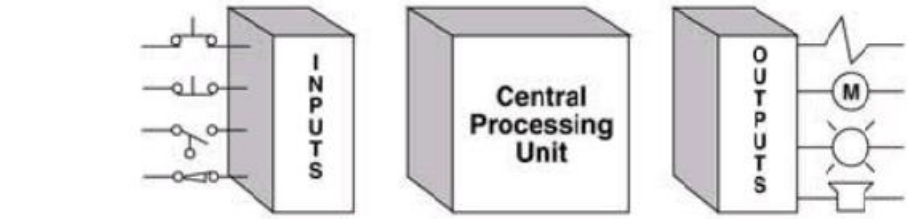
Contents

What is PLC?

A **PROGRAMMABLE LOGIC CONTROLLER** (PLC) is an industrial computer control system that continuously monitors the state of input devices and makes decisions based upon **a custom program** to control the state of output devices.

Almost any production line, machine function, or process can be greatly enhanced using this type of control system. However, the biggest benefit in using a PLC is the ability to change and replicate the operation or process while collecting and communicating vital information.

What inside PLC:



The Central Processing Unit, the CPU, contains an internal program that tells the PLC how to perform the following functions:

- Execute the Control Instructions contained in the User's Programs. This program is stored in "nonvolatile" memory, meaning that the program will not be lost if power is removed
- Communicate with other devices, which can include I/O Devices, Programming Devices, Networks, and even other PLCs

How Does A PLC Operate?

There are four basic steps in the operation of all PLCs; Input Scan, Program Scan, Output Scan, and Housekeeping. These steps continually take place in a repeating loop.

Four Steps In The PLC Operations

1.) Input Scan

- Detects the state of all input devices that are connected to the PLC

2.) Program Scan

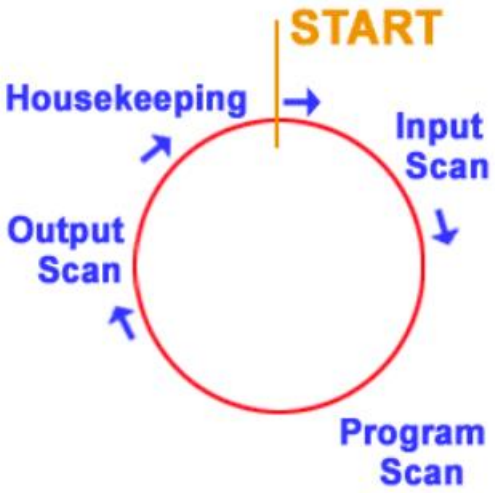
- Executes the user created program logic

3.) Output Scan

- Energizes or de-energize all output devices that are connected to the PLC.

4.) Housekeeping

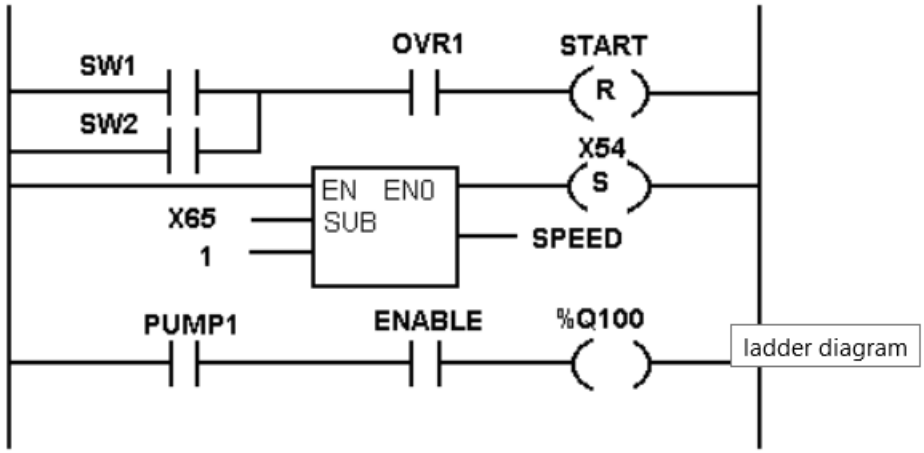
- This step includes communications with programming terminals, internal diagnostics, etc...



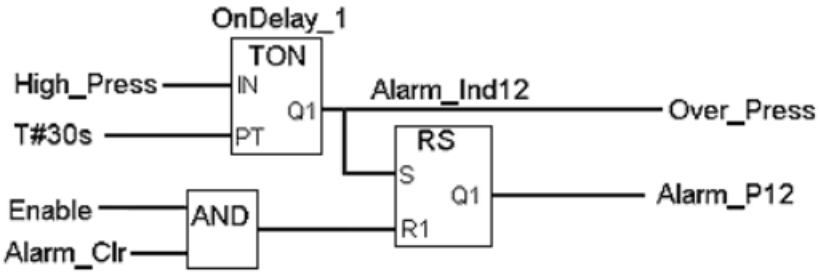
What Programming Language Is Used To Program A PLC?

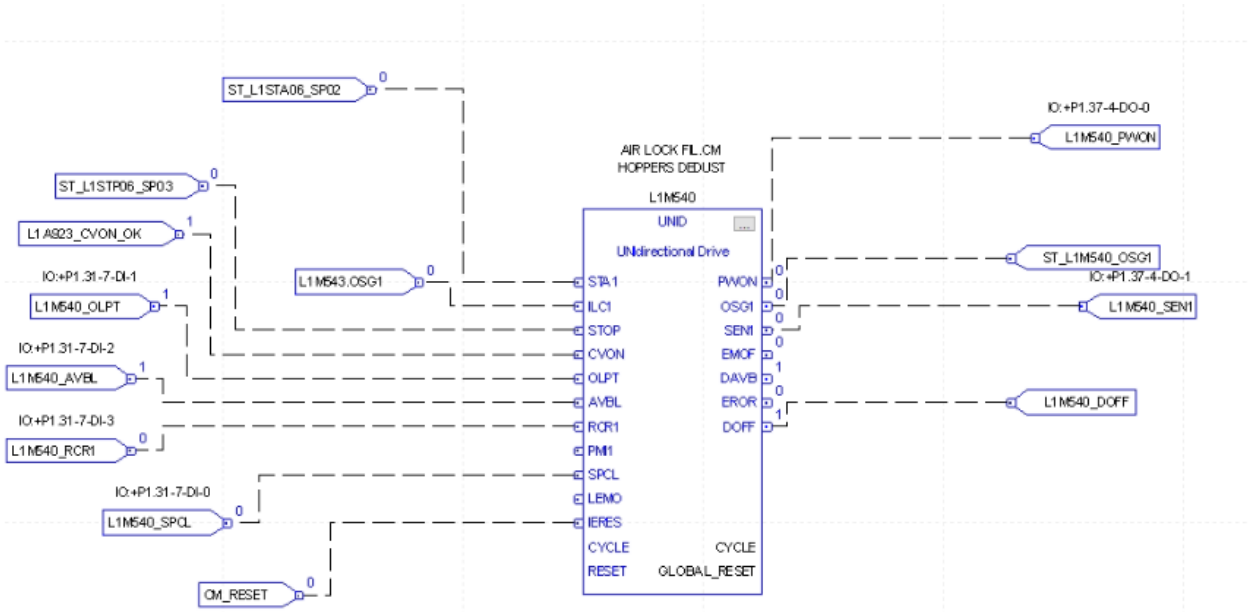
While Ladder Logic is the most commonly used PLC programming language, it is not the only one. The following table lists of some of languages that are used to program a PLC.

Ladder Diagram (LD) Traditional ladder logic is graphical programming language. Initially programmed with simple contacts that simulated the opening and closing of relays, Ladder Logic programming has been expanded to include such functions as counters, timers, shift registers, and math operations.



Function Block Diagram (FBD) - A graphical language for depicting signal and data flows through re-usable function blocks. FBD is very useful for expressing the interconnection of control system algorithms and logic.





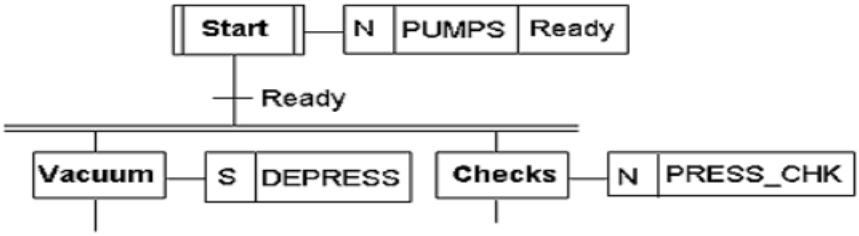
Structured Text (ST) – A high level text language that encourages structured programming. It has a language structure (syntax) that strongly resembles PASCAL and supports a wide range of standard functions and operators. For example;

```
If Speed1 > 100.0 then
   Flow_Rate: = 50.0 + Offset_A1;
Else
   Flow_Rate: = 100.0; Steam: = ON
End_If;
End_If;
```

Instruction List (IL): A low level “assembler like” language that is based on similar instructions list languages found in a wide range of today’s PLCs.

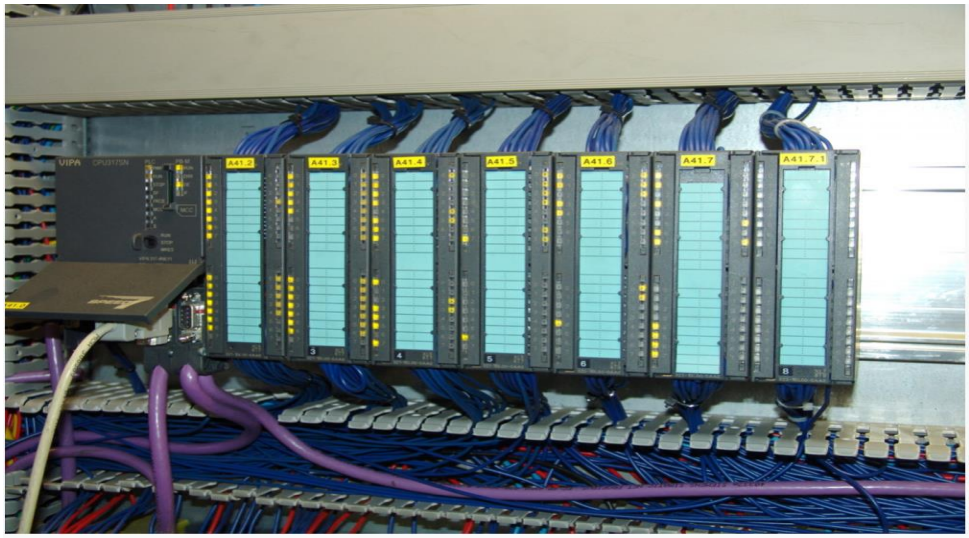
```
      LD  R1
     MPC  RESET
      LD  PRESS_1
      ST  MAX_PRESS
RESET: LD  0
      ST  A_X43
```

Sequential Function Chart (SFC) A method of programming complex control systems at a more highly structured level. A SFC program is an overview of the control system, in which the basic building blocks are entire program files. Each program file is created using one of the other types of programming languages. The SFC approach coordinates large, complicated programming tasks into smaller, more manageable tasks.



Type of I/O cards

1- Digital input card
   24VDC common use
2- Digital output card
   Switching
3- Analogue input card
   (0….5 VDC, 0….10 VDC, 0…..20mA and 4….20mA)
   Most common use is 4….20 mA, open circuit fault better than 0……20mA
4- Analogue output cards
5- RTD cards(resistance temperature detector)
   PT100, thermocouple…. Etc.
6- Weighing Card such as belt scale, weigh feeders and load cells, etc.



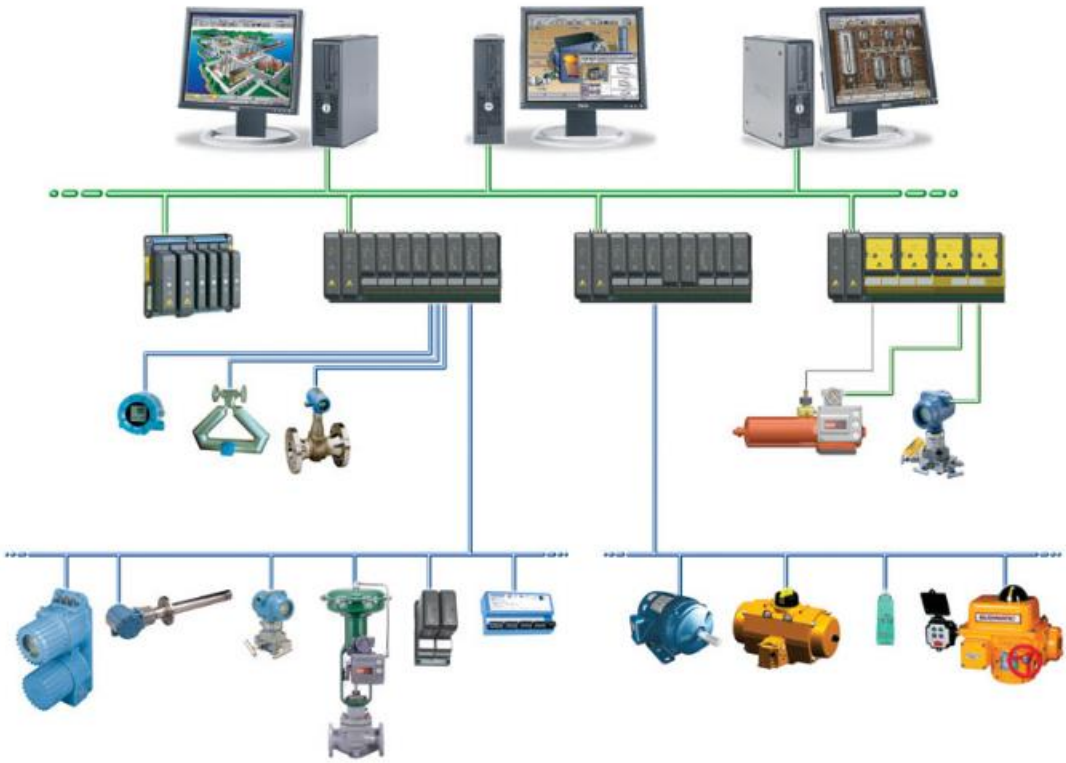
I/O cards

What is DCS?

Distributed control system (DCS):

is a specially designed automated control system that consists of geographically distributed control elements over the plant or control area.

It differs from the centralized control system wherein a single controller at central location handles the control function, but in DCS each process element or machine or group of machines is controlled by a dedicated controller. DCS consists of a large number of local controllers in various sections of plant control area and are connected via a high-speed communication network



In DCS control system, data acquisition and control functions are carried through a number of DCS controllers which are microprocessor-based units distributed functionally and geographically over the plant and are situated near area where control or data gathering functions being performed as shown in the figure above. These controllers able to communicate among themselves and with other controllers like supervisory terminals, operator terminals, historians, etc.

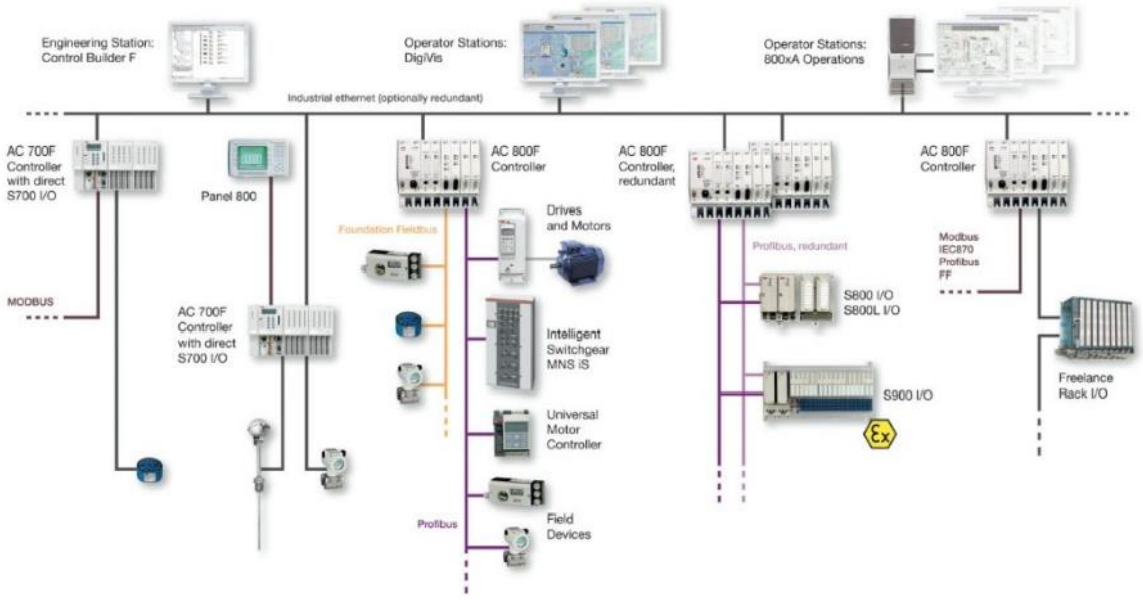
Distributed individual automatic controllers are connected to field devices such as sensors and actuators. These controllers ensure the sharing of gathered data to other hierarchal controllers via different field buses. Different field buses or standard communication protocols are used for establishing the communication between the controllers. Some of these include Profibus, HART, arc net, Modbus, etc.

DCS is most suited for large-scale processing or manufacturing plants wherein a large number of continuous control loops are to be monitored and controlled. The main advantage of dividing control tasks for distributed controllers is that if any part of DCS fails, the plant can continue to operate irrespective of failed section.

Architecture of Distributed Control System:

As the name suggests, DCS has three main qualities. The first one is the distribution of various control functions into relatively small sets of subsystems, which are of semiautonomous, and are interconnected through a high-speed communication bus. Some of these functions include data acquisition, data presentation, and process control, process supervision, reporting information, storing and retrieval of information.

The second attribute of DCS is the automation of manufacturing process by integrating advanced control strategies. And the third characteristic is the arranging the things as a system. DCS organizes the entire control structure as a single automation system where various subsystems are unified through a proper command structure and information flow.



Engineering Workstation:

It is the supervisory controller over the entire distributed control system. It can be a PC or any other computer that has dedicated engineering software (for example, control builder F engineering station in case of ABB freelance distributed control system).

This engineering station offers powerful configuration tools that allow the user to perform engineering functions such as creating new loops, creating various input and output points, modifying sequential and continuous control logic, configuring various distributed devices, preparing documentation for each input/output device, etc.

You may also read: What is P&ID Controller & How it Works?

Operating Station or HMI:

This is used to operate, monitor, and control plant parameters. It can be a PC or any other monitoring device that has a separate software tool on which operator can view process parameter values and accordingly to take control action. For instance, it is a DigiVis software tool that can run on a simple PC-environment in case ABB DCS.

Operating stations can be a single unit or multiple units where a single unit performs functions like parameter value display, trend display, alarming, etc. while multiple units or PCs performs individual functions such as some PCs display parameters, some for trend archives, some for data logging and acquiring, etc.

Process Control Unit of DCS:

It is also called as a local control unit, distribution controller, or process station. A distributed control system can consist of one or more process stations that can be extended with different types of I/O units. These controllers consist of a powerful CPU module, field bus or communication module with extended field bus capability and either direct or remote connected I/Os.

The field devices like sensors and actuators are connected to I/O modules of this unit. Some field devices can be directly connected to field bus (such as Profibus) without any I/O module, which can be termed as smart field devices.

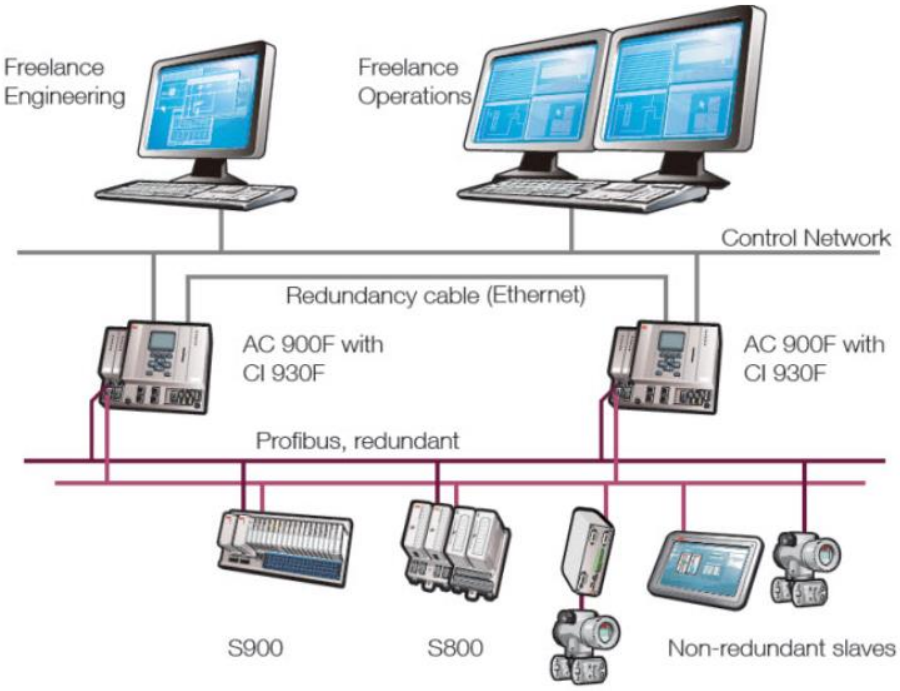
AC900f, CPU: PM902F-ABB

1756-L74, Allen Bradley

Communication System:

The communication medium plays a major role in the entire distributed control system. It interconnects the engineering station, operating station, process station and smart devices with one another. It carries the information from one station to another. The common communication protocols used in DCS include Ethernet, Profibus, Foundation Field Bus, DeviceNet, Modbus, etc.

It is not mandatory to use one protocol for entire DCS, some levels can use one network whereas some levels use different network. For instance, consider that field devices, distributed I/Os and process station are interconnected with Profibus while the communication among engineering station, HMI and process station carried though Ethernet as shown in the figure below.



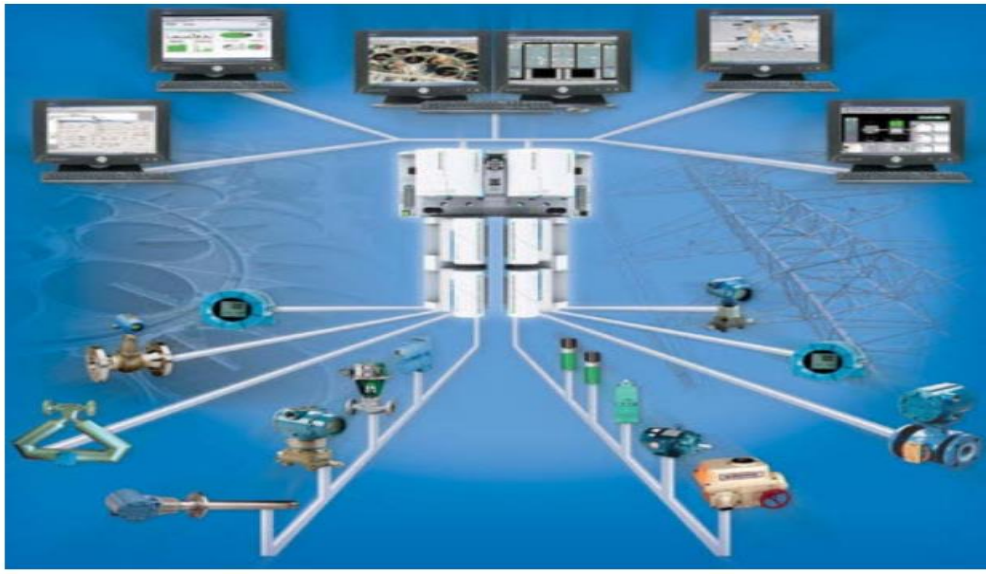
Smart or Intelligent Devices:

The intelligent field devices and field bus technology are advanced features of DCS technology that replaces traditional I/O subsystems (I/O modules). These smart devices embed the intelligence required for simple sensing and control techniques into the primary sensing and actuating devices. Hence, it replaces the need for a DCS controller to perform routine sensing and control process.

These field devices can be directly connected to field bus so that sourcing of multiple measurements to the next higher level control station is possible via digital transmission line by eliminating extraneous hardware such as local I/O modules and controllers.

Working & Operation of DCS System:

The operation of DCS goes like this; Sensors senses the process information and send it to the local I/O modules, to which actuators are also connected so as to control the process parameters. The information or data from these remote modules is gathered to the process control unit via field bus. If smart field devices are used, the sensed information directly transferred to process control unit via field bus.



Advantages of Distributed Control Systems:

A distributed control system (DCS) centralizes plant operations to provide flexibility and simplicity by allowing central control, monitoring, and reporting of individual components and processes. A DCS is designed to control complex processes that can be geographically disseminated using networked control elements that are distributed throughout the system. These features, along with redundancy that is designed into the overall structure to facilitate high system availability and reliability, drive operators of large, complex facilities and processes, such as those used in nuclear power plants, to choose DCS

Unlike programmable logic controllers, DCS use a suite of configuration tools to set up the database, control logic, graphics and system security. Control applications are distributed to system controllers that are dedicated to specific plant processes utilizing field devices. Control logic can be created and dispersed across the system controllers. This allows changes that must be made to meet new requirements and/or the addition of new controllers or field devices, to be made efficiently and accurately, easing, and simplifying updates and new equipment integration.

The controllers and associated inputs/outputs are connected through a redundant communications network to operating and engineering stations. The stations have graphical, easy-to-use displays for data monitoring, data logging, alarming and control. Field devices, such as actuators and sensors, are directly connected to input/output modules that communicate with assigned controllers while reading and reporting real world information, such as pressure and temperature.

DCS are scalable. A DCS can be deployed in an initial installation as a large, integrated system, or as a standalone system that can be added to as planned or needed. New controllers and inputs/outputs can be added throughout a plant. When new systems are added, they become part of the integrated DCS and are automatically updated by the controlling database.

The Westinghouse DCS of choice is the Ovation® DCS platform. The Ovation DCS has the ability to integrate system security models and cybersecurity, advanced alarm capabilities, system-wide diagnostics and multiple simulation solutions that are extended to every new system added. There is redundancy at all levels, from the inputs/outputs to the controllers, at the network level and to the user interface workstations. Operating experience from more than 3,000 power generation installations worldwide has demonstrated system reliabilities in excess of 99.9 percent. The system is also favored for its forward design. It uses many commercially available, off-the-shelf technologies. This facilitates a secure, powerful architecture that avoids obsolescence by enabling system progression to adjust to rapidly advancing computer technologies. Deployment to operating and new nuclear units solidifies a 25-year working forward compatibility.

DCS allocates flexibility and simplicity by allowing central control monitoring and reporting of individual components and processes

DCS is scalable and possible to control through dynamic graphics Eliminating human error by Logging data

Disadvantages of DCS system

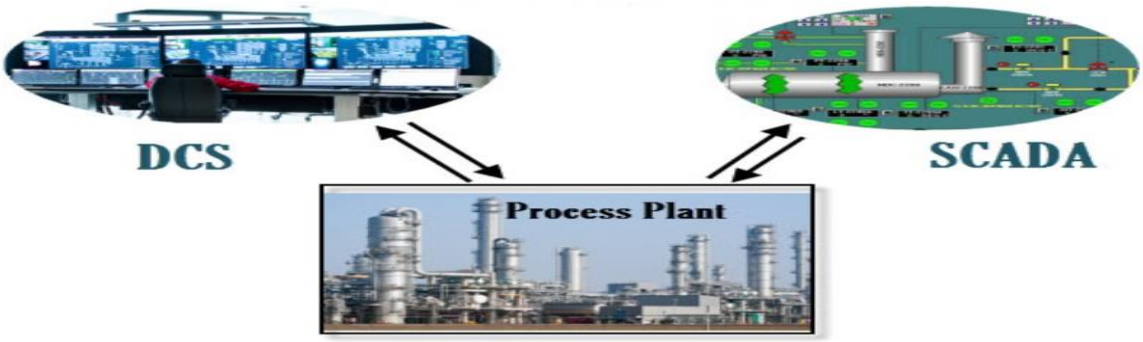
Failure of one controller effects more than one loop

DCS required skilled operator because all information hidden behind CRT

Difference between SCADA and DCS (DCS vs SCADA):

Although both DCS and SCADA are monitoring and control mechanisms in industrial installations, they have different goals. There exists some commonality between DCS and SCADA in terms of hardware and its components; however, there are certain requirements by the end applications that separates a robust and cost-effective DCS from the viable SCADA system. Some of the differences between DCS and SCADA are listed below.

1. DCS is process oriented, whereas SCADA is data gathering oriented. DCS emphasizes more on control of the process, and it also consists of supervisory control level. And as a part of doing so, it presents the information to the operator. On the other hand, SCADA concentrates more on acquisition process data and presenting it to the operators and control center.
2. In DCS, data acquisition and control modules or controllers are usually located within a more confined area and the communication between various distributed control units carried via a local area network. SCADA generally covers larger geographical areas that use different communication systems, which are generally less reliable than a local area network.
3. DCS employs a closed loop control at process control station and at remote terminal units. But in case of SCADA there is no such closed loop control.
4. DCS is process state driven where it scans the process in regular basis and displays the results to the operator, even on demand. On the other hand, SCADA is event driven where it does not scan the process sequentially, but it waits for an event that cause process parameter to trigger certain actions. Hence, DCS does not keep a database of process parameter values as it always in connection with its data source, whereas SCADA maintains a database to log the parameter values which can be further retrieved for operator display and this makes the SCADA to present the last recorded values if the base station unable to get the new values from a remote location.
5. In terms of applications, DCS is used for installations within a confined area, like a single plant or factory and for a complex control process. Some of the application areas of DCS include chemical plants, power generating stations, pharmaceutical manufacturing, oil and gas industries, etc. On the other hand, SCADA is used for much larger geographical locations such as water management systems, power transmission and distribution control, transport applications and small manufacturing and process industries.



What is PROFIBUS DP?

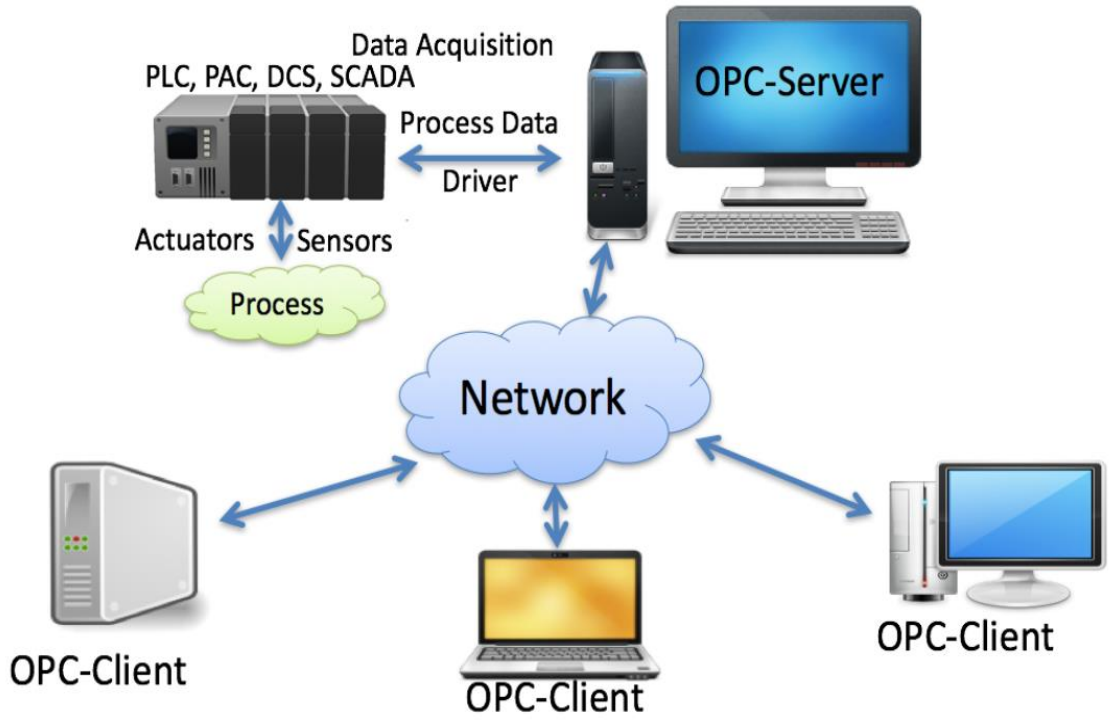
PROFIBUS is a 2-wire industrial data communication standard (fieldbus) that allows components such as sensors, actuators, and controllers to exchange process values and achieve the automation of a complete process. It is the most used fieldbus

PROFIBUS DP delivers high speed data transfer and low installation costs. It is designated as the standard PROFIBUS for the automation of production. PROFIBUS PA is designed for process automation to replace 4-20 mA and HART applications. Data and power are modulated on both wires, and it offers an option for intrinsic safe applications.

OPC (Open Platform Communication) server:

OPC is the interoperability standard for the secure and reliable exchange of data in the industrial automation space and in other industries. It is platform independent and ensures the seamless flow of information among devices from multiple vendors. The OPC Foundation is responsible for the development and maintenance of this standard.

The OPC standard is a series of specifications developed by industry vendors, end-users, and software developers. These specifications define the interface between Clients and Servers, as well as Servers and Servers, including access to real-time data, monitoring of alarms and events, access to historical data and other applications.

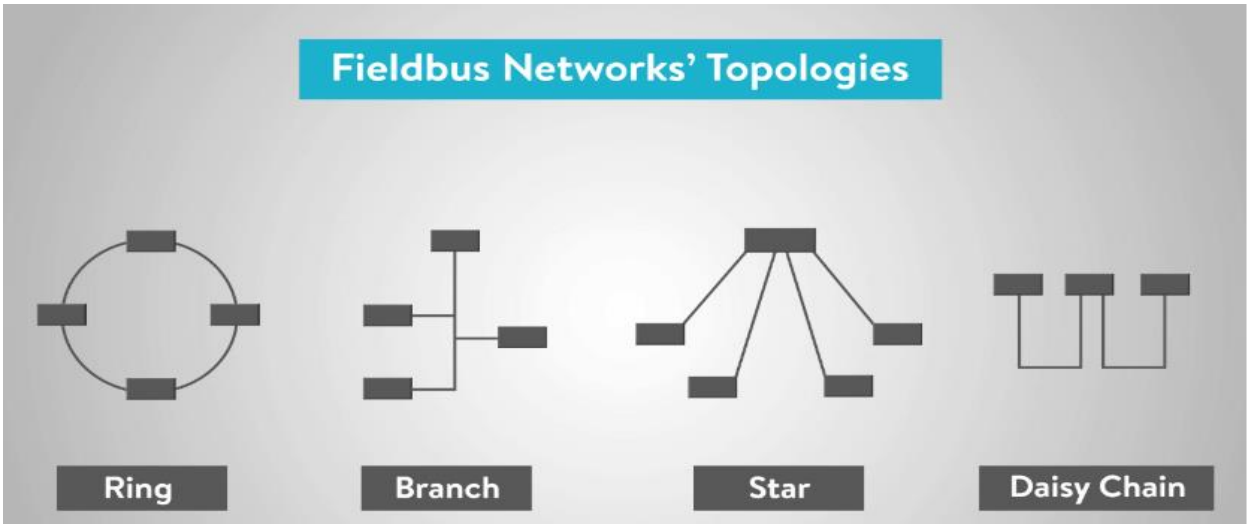


Fieldbus protocol:

Fieldbus isn't really one thing but more of a collection of things. Fieldbus is a group of protocols that are used in the industrial arena.

The Fieldbus protocols have been standardized as IEC61158

Basically, Fieldbus works on a network that permits various topologies such as the ring, branch, star, and daisy chain.



Prior to Fieldbus protocols, industrial controller systems were connected using RS232 serial communications.

As you know, serial communications allowed only two devices to communicate.

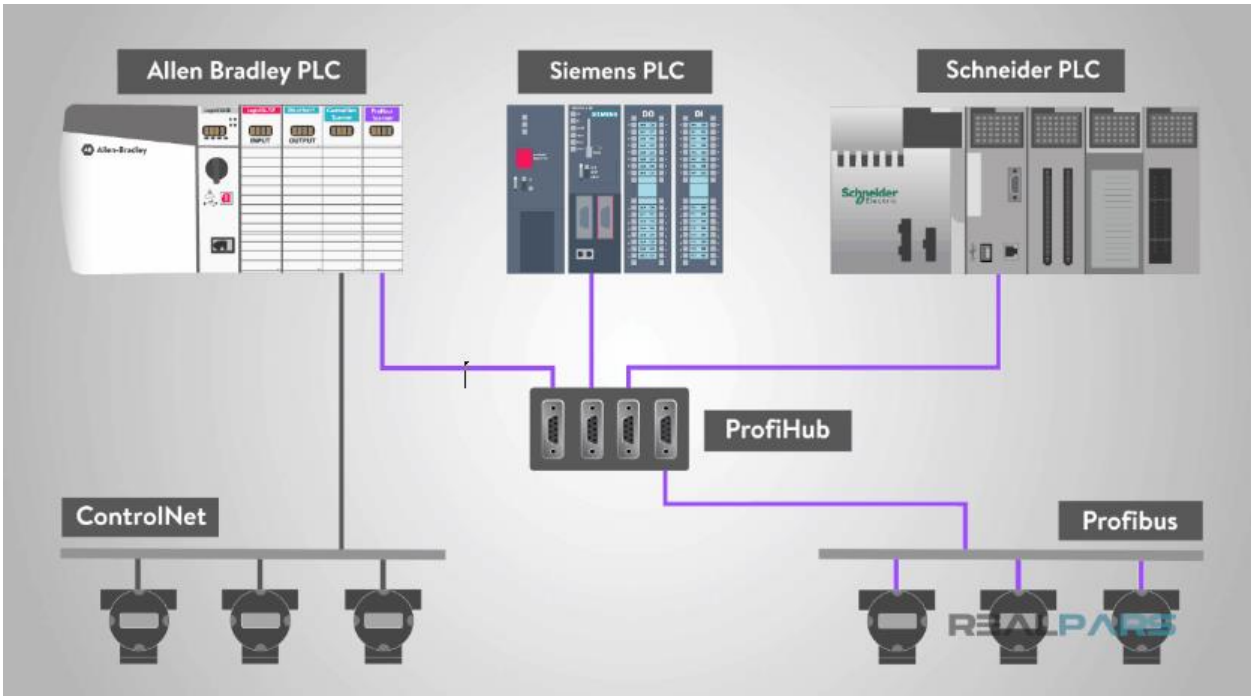
Whereas today, the Fieldbus connections are more closely compared to the typical Ethernet connections where you can connect multiple field devices to a single connection point that would then connect to the controller.

Fieldbus protocol:

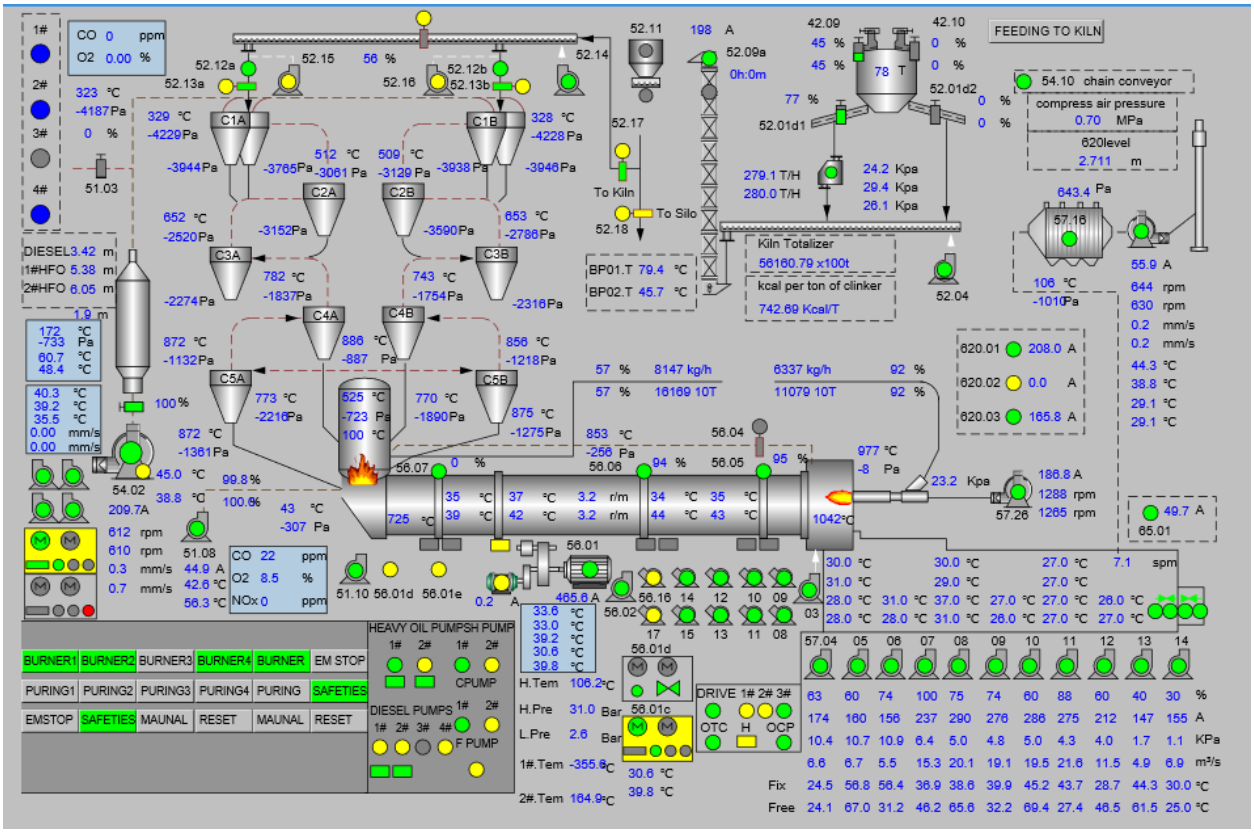
However, Fieldbus is not a connection type, per se, but instead, a description used to indicate a group of protocols.

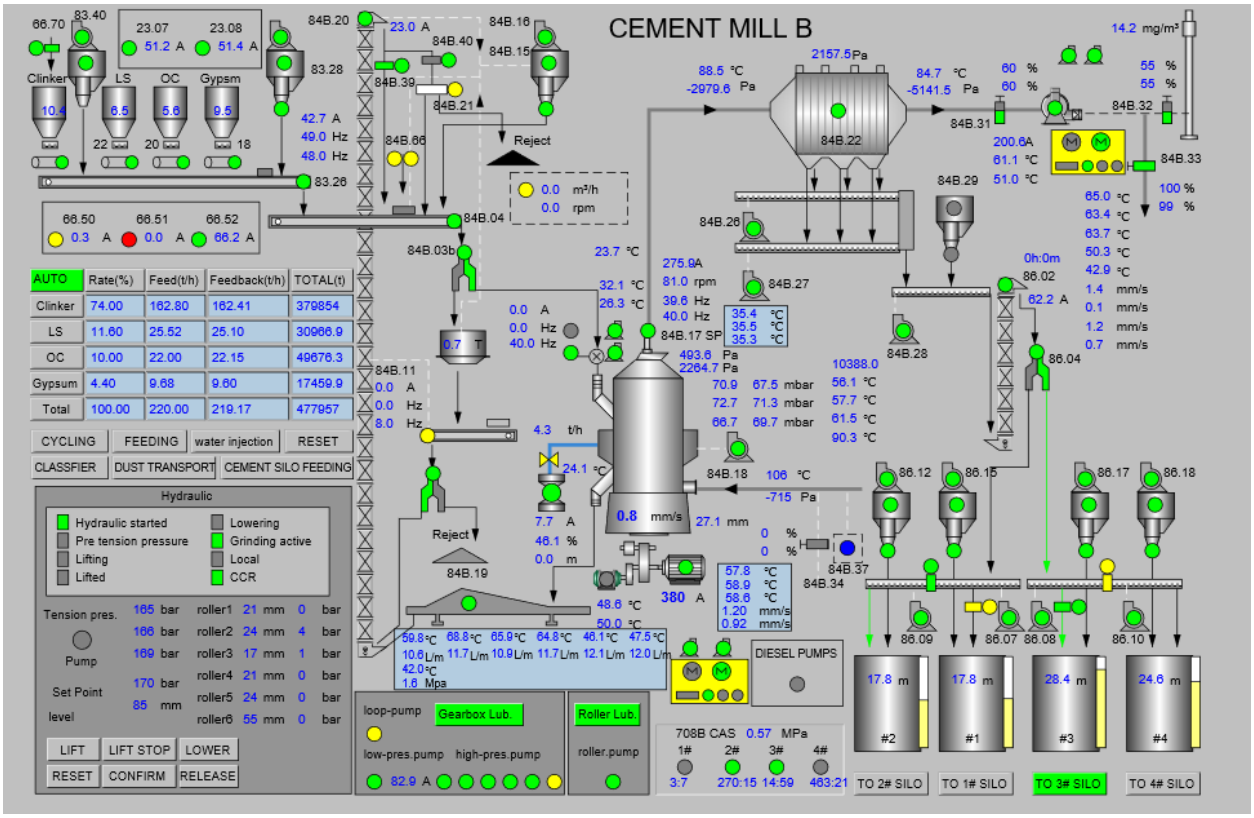
There are several protocols in the group such as ControlNet in the Allen Bradley family, Modbus, Profibus, Ether CAT, HART, CIP, and many more

A primary benefit of Fieldbus is for field connected devices. For instance, consider you have several field devices that are quite a distance from your controller. With Fieldbus devices such as sensors, motors, lamps, switches, these devices are connected to an “I/O data block”, which is then connected to a “field distribution device”, which is connected to a Fieldbus power supply, then finally connected back to the Programmable Logic controller. The connections to the Fieldbus components, except for the field devices themselves, are single cable connections. This connection scheme may vary depending on the Fieldbus protocol that you are using. This type of field device connection saves on wiring runs that would have to go all the way back to the controller. As you can see, this type of device wiring would have many benefits when the distance is an issue.


Allen Bradley PLC
Siemens PLC
Schneider PLC
ProfiHub
ControlNet
Profibus

HMI Samples


FEEDING TO KILN
Kiln Totalizer
kcal per ton of clinker
To Kiln
To Silo
HEAVY OIL PUMPS
H PUMP
DIESEL PUMPS
F PUMP
BURNER1
BURNER2
BURNER3
BURNER4
BURNER
EM STOP
PURING1
PURING2
PURING3
PURING4
PURING
SAFETIES
EMSTOP
MAUNAL
RESET


CEMENT MILL B
AUTO
Rate(%)
Feed(t/h)
Feedback(t/h)
TOTAL(t)
Clinker 74.00 162.80 162.41 379854
LS 11.60 25.52 25.10 30966.9
OC 10.00 22.00 22.15 49676.3
Gypsum 4.40 9.68 9.60 17459.9
Total 100.00 220.00 219.17 477957
CYCLING
FEEDING
water injection
RESET
CLASSIFIER
DUST TRANSPORT
CEMENT SILO FEEDING
Hydraulic
Hydraulic started
Pre tension pressure
Lifting
Lifted
Lowering
Grinding active
Local
CCR
Tension pres.
Pump
Set Point
level
LIFT
LIFT STOP
LOWER
RESET
CONFIRM
RELEASE
Reject
DIESEL PUMPS
loop-pump
Gearbox Lub.
Roller Lub.
low-pres.pump
high-pres.pump
roller.pump
708B CAS
TO 2# SILO
TO 1# SILO
TO 3# SILO
TO 4# SILO


SIEMENS
SIMATIC PANEL
TOUCH
Start
F11
F12
F13
F14
F15
F16
Select the
with F11 until F16

DCS Systems from Different Vendors:

Some of the available DCS systems include

- ABB- Freelance 800F and 800 xA
- Yokogawa- Centum CS 3000 and 1000
- Honeywell-TDC 3000
- Emerson- Delta V Digital Automation
- Siemens- Simatic PCS 7
- Rockwell automation Allen-Bradley RSLogix 5000