Distributed Control System (DCS)

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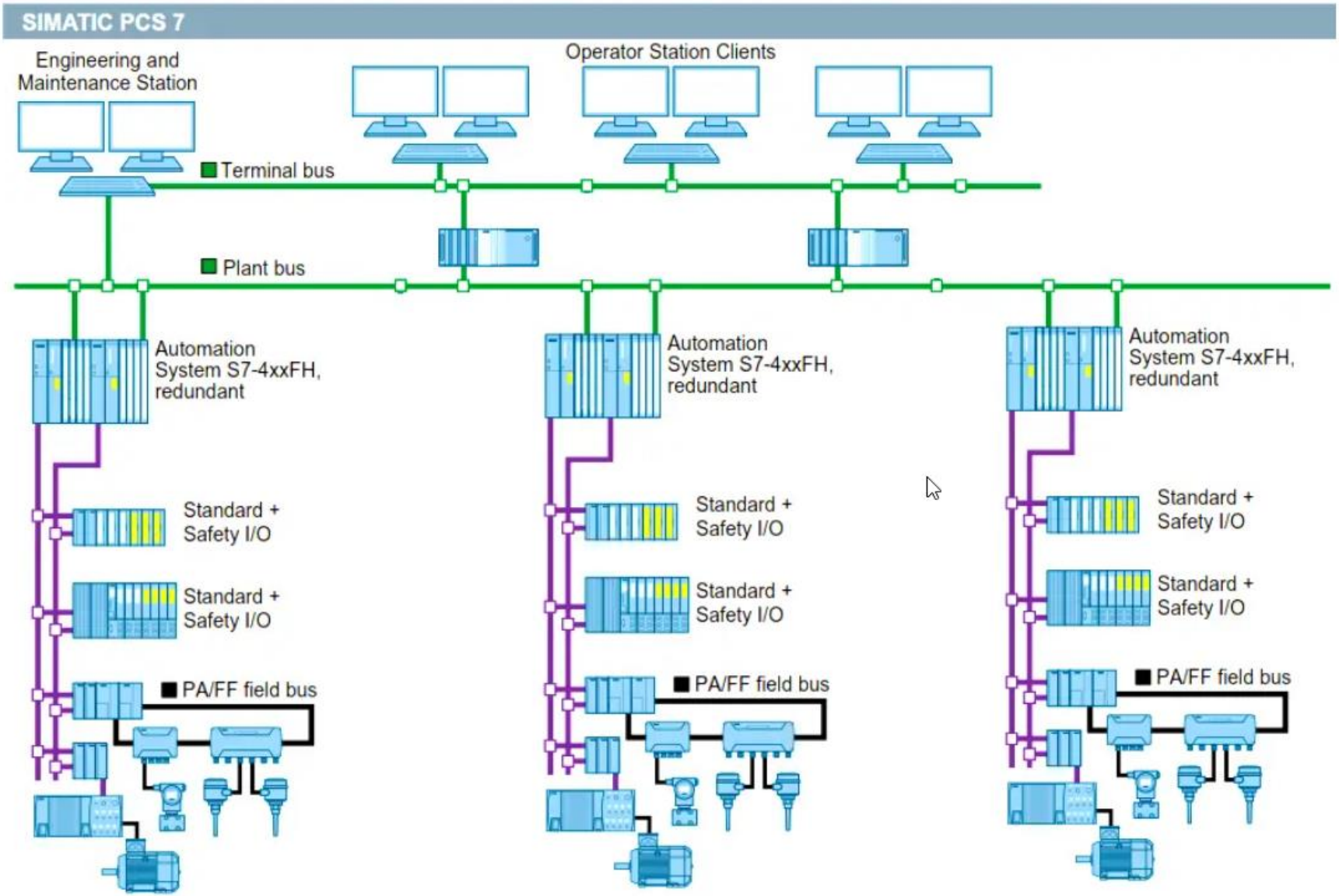
INTRODUCTION:

A distributed control system (DCS) refers to *a Control System* in which the *controller elements are not central* in a single location *but are distributed throughout the system* with each component sub-system controlled by one or more controllers.

The entire system of controllers are connected by networks for communication and monitoring.

✓Architecture



SALIENT FEATURES DCS

- ✓ **HMI :** The general control software for MMI & Operator display software.
- ✓ **Tags Information:** The data list software.
- ✓ **Graphics suite:** Graphic making software
- ✓ **Control Suite:** DPU Configuration Software.
- ✓ **Historian:** Historical Data Collection
- ✓ **Process Alarm history:** The alarm history software.
- ✓ **Trends:** The real-time and historical trend software.

SALIENT FEATURES OF DCS

- ✓ **System Monitoring :** The Self-test software
- ✓ **Annunciator Panel:** Emergency tripping systems.
- ✓ **Data Highway :** TCP/IP
- ✓ **Report Builder:** Table Data Recorder, Operator Action journal
- ✓ **Add-on systems:-** Performance Analytics and optimization package.
- ✓ **Gateways :-** Third party connectivity for OPC , Modbus, Profibus, RTU protocol.
- ✓ **LVS** – Large viewing screens

- **Essentially, We can divide DCS into two categories**

1. Hardware:

DCS Panels

Engineering and Operator Workstation

Control processor

I/O Modules

Network Switches

2. Software :

Configuration & Data Monitoring Software , Historians, etc.

Hardware :

DCS Panels :

Typical DCS panels

Typical Front Side of DCS Panel

Typical Back side of DCS Panel

Hardware :

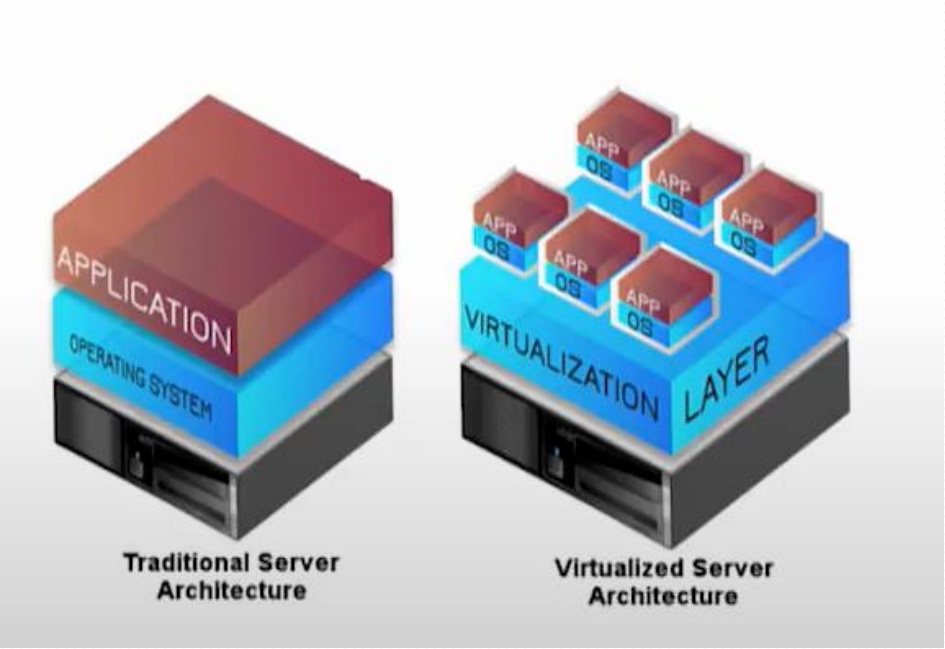
Engineering / Operator Workstation then :

Hardware :

Engineering Workstation now :

Virtualized architecture consisting all the Engineering workstation, Historian Machine, OPC Servers, Operator Workstation etc.

https://www.youtube.com/watch?v=2E09lHXkOxc



Hardware :

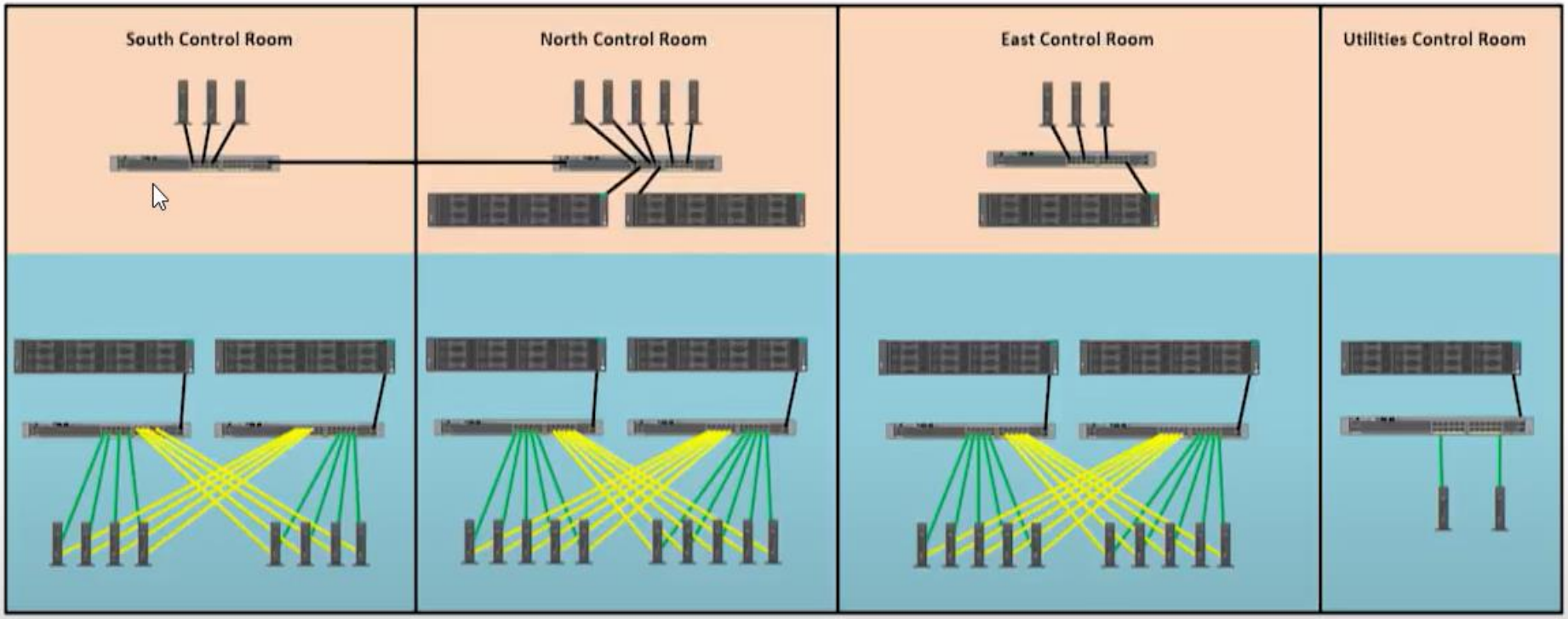
Benefits :

Redundancy

Upgradability

Backup and Restore

Scalability



Hardware :

Control Processor :

Field Control Processors are a distributed, optionally fault-tolerant, field-mounted controller modules. The processors performs regulatory, logic, timing, and sequential control together with connected Fieldbus Modules. It also performs data acquisition and alarm detection and notification.

It also serves communication interface between the IO Modules and The Mesh control network.

✓Control Processors – What do they do?

- Makes IO data available to other Software system /stations
  - Operator displays
  - Data Historian
  - Alarm Historian
  - Any other I/A station
- Performs Control functions
  - Continuous ..PID
  - Discrete
  - Calculations
  - Sequential logic
- Sends Process alarms to other stations

Hardware :

Several Players are available .

ABB

https://new.abb.com/control-systems/system-800xa/800xa-dcs/hardware-controllers-io/ac800m-controllers

Emerson

https://www.emerson.com/en-in/catalog/automation-solutions/control-safety-systems/ovation-controller-en-sg

Honeywell

https://process.honeywell.com/us/en/products/control-and-supervisory-systems/distributed-control-systems-dcs/experion-pks/controllers/experion-pks-c300-controller

Hardware :

I/O Modules :

These modules serve as an interface between the field devices and the control processor. They perform necessary data conversion, providing full support for analog measurement, discrete sensing, and analog or discrete control and digital communication.

Hardware :

I/O Modules (:

An Module falls into one of two major categories:

i. **Analog**

ii. **Discrete (digital)**

Various Types IO Modules
Channel Isolated 8 Input 0-20 mA
Channel Isolated 8 Input Thermocouple/mV
Channel Isolated 8 Input RTD
Channel Isolated 8 Input Pulse
Ch Isolated 16 DIN 48 Vdc Contact Sense
HART Inputs, 8 Channels
4 Modbus Channels
Channel Isolated 8 Output 0-20 mA
Channel Isolated External Source DO

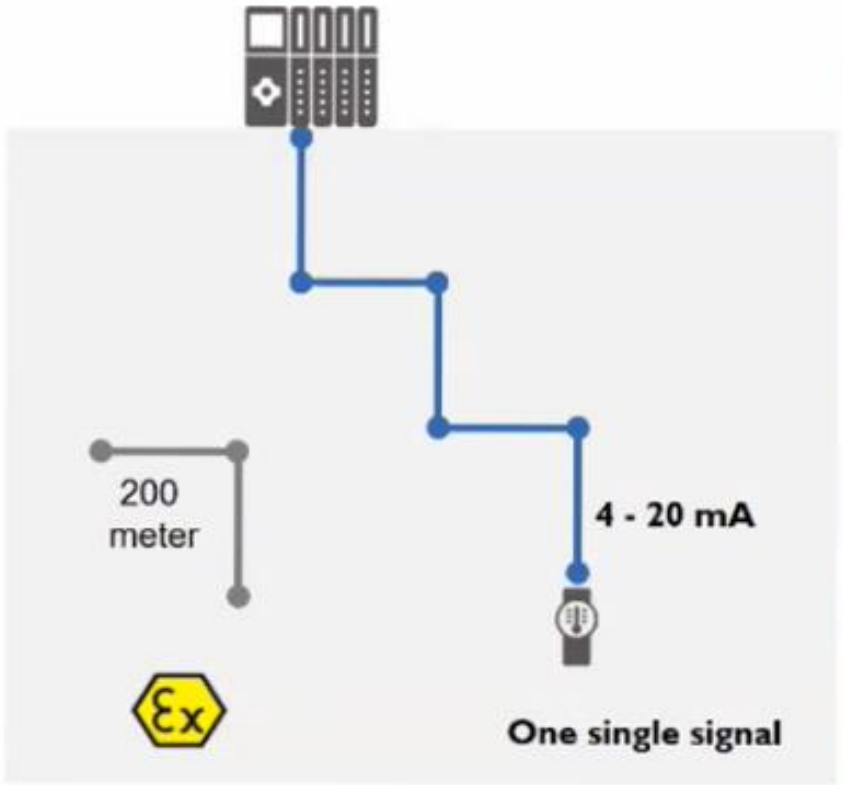
✓ Analog Signal- AI

Topology with 4 – 20 mA

The most common of methods

4 – 20 mA loop, the proven method to connect a single field instrument in an application. Here our example is connected into Zone 2.

The cable can be up to 1000 (one thousand meters) long, and supplies both power and signals across its shielded, twisted pair.



The well-established 4 – 20 mA loop

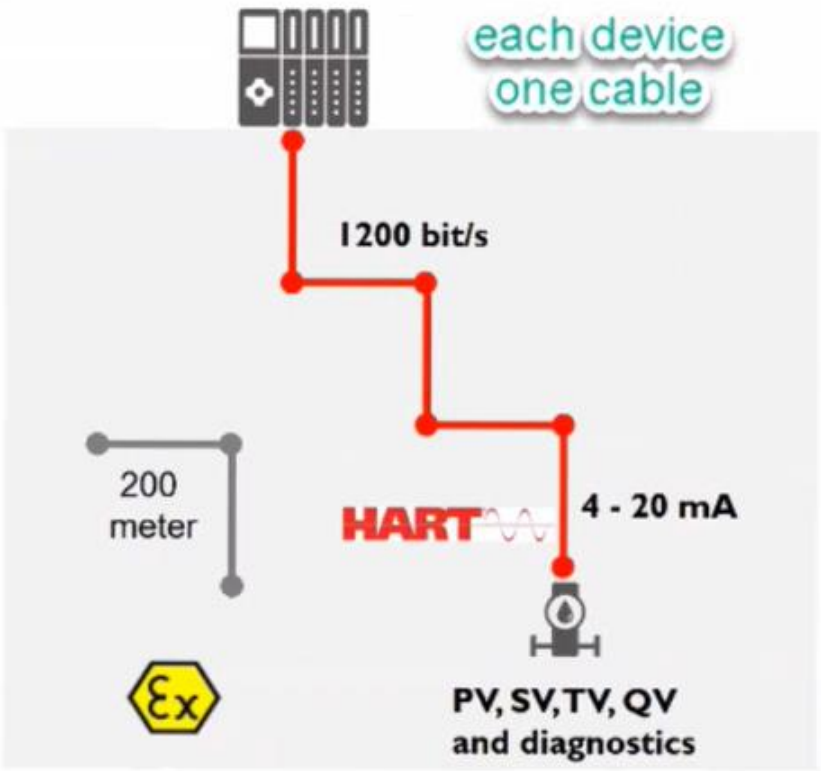
✓ FieldBus -HART

Topology of 4 – 20 mA with HART

The inclusion of additional data and diagnostics

4 – 20 mA loop with HART, a method to connect a single field instrument and allow additional access to variables inside the filed instrument.

The cable can be up to 1000 (one thousand meters) long, and supplies both power and signals across its shielded, twisted pair.



A 4 – 20 mA loop with HART

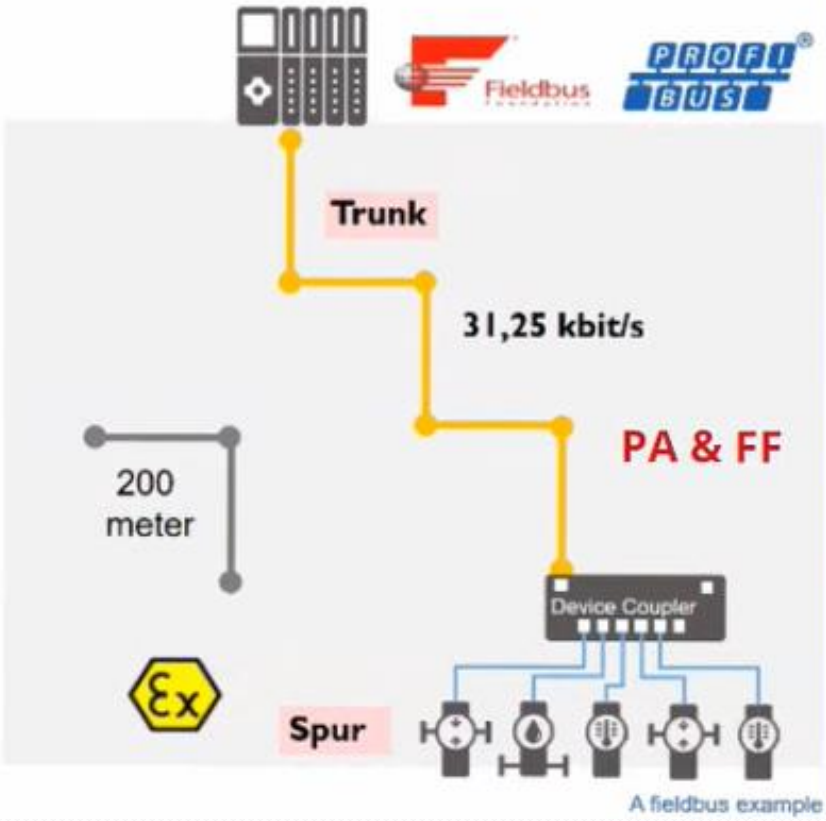
✓ FieldBus –ProfiBus & FF

Topology of Fieldbus

The streamlining of cabling to the field

Fieldbus, a method to connect multiple field instruments via a single shielded pair cable. The cable can be up over 1000 (one thousand meters) long, and while theoretically up 32 filed devices are possible, most applications are designed on average with 8 to 16 devices.

Trunk, is the long-distance cable run from controller to Device Coupler, and the **Spur** is the shorter run between device coupler and field instrument. Note that the device coupler provides isolation between all field devices.



A fieldbus example

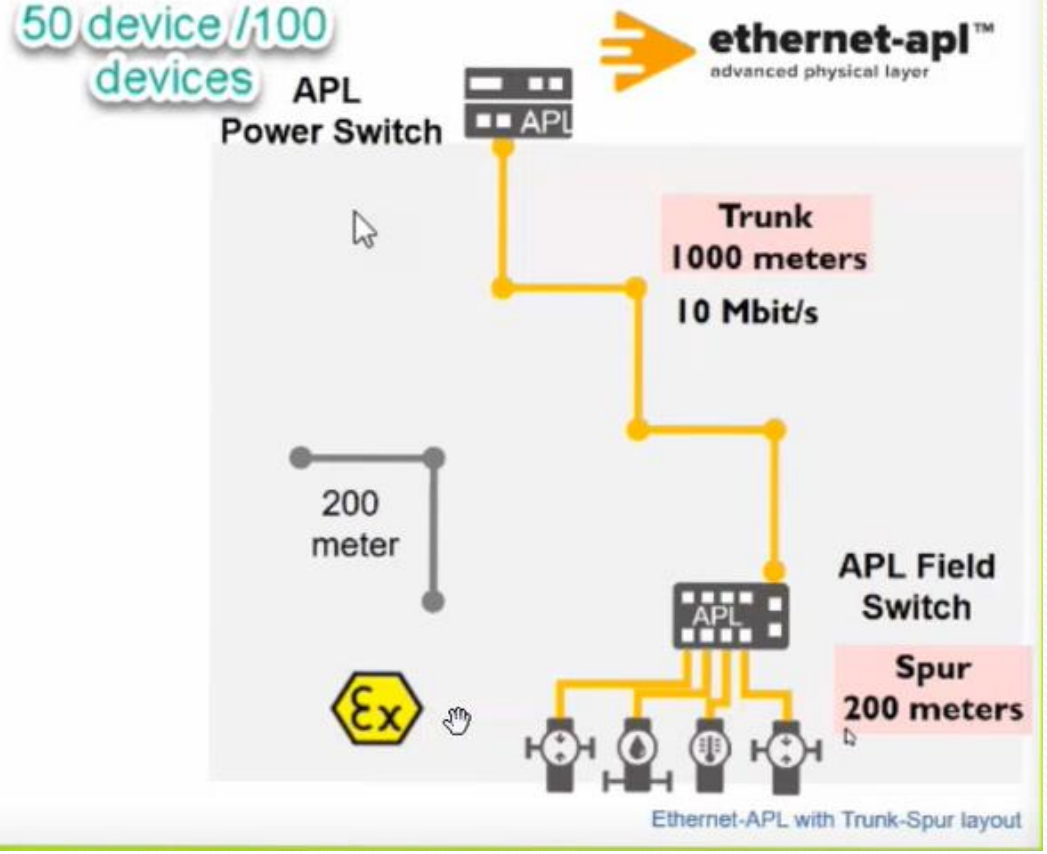
✓ FieldBus –Ethernet APL

Terminology

The important terms of Ethernet-APL

APL Power Switch, a device to power and connect multiple field instruments via a single shielded pair cable. The cable is up over 1000 meters long and can theoretically power up to XX field devices.

Trunk, is the long-distance cable run from controller to an **APL Field Switch**, and the **Spur** is the shorter run between Field Switch and field instrument.



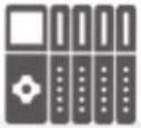
Ethernet-APL with Trunk-Spur layout

✓ FieldBus –Ethernet APL

Terminology

The important terms of Ethernet-APL

The **Star** topology, allows modular or compact combinations to be created with essentially a 200 meter radius around an **APL Field Switch**.
This compact design can be used on machine modules, skids and similar systems.
Only the **Spur** term is used in such installations.



Controller with industrial Ethernet

100 Mbit/s
100 meters copper / or further with fiber optic

EtherNet/IP HART-IP OPC UA PROFINET +Webserver

APL Field Switch

ethernet-apl™ advanced physical layer

Spur 200 meters

Ethernet-APL with Star layout

Hardware :

Network Switch:

Network switch is used to establish the communication between all control processor & workstation..

Typical plant DCS will have redundant networks .

Typically, we use third-party Switches from CISCO or Extreme Networks. etc.

https://new.siemens.com/global/en/products/automation/industrial-communication/rugged-communications.html

✓ Network Switch

What is a network Switch?

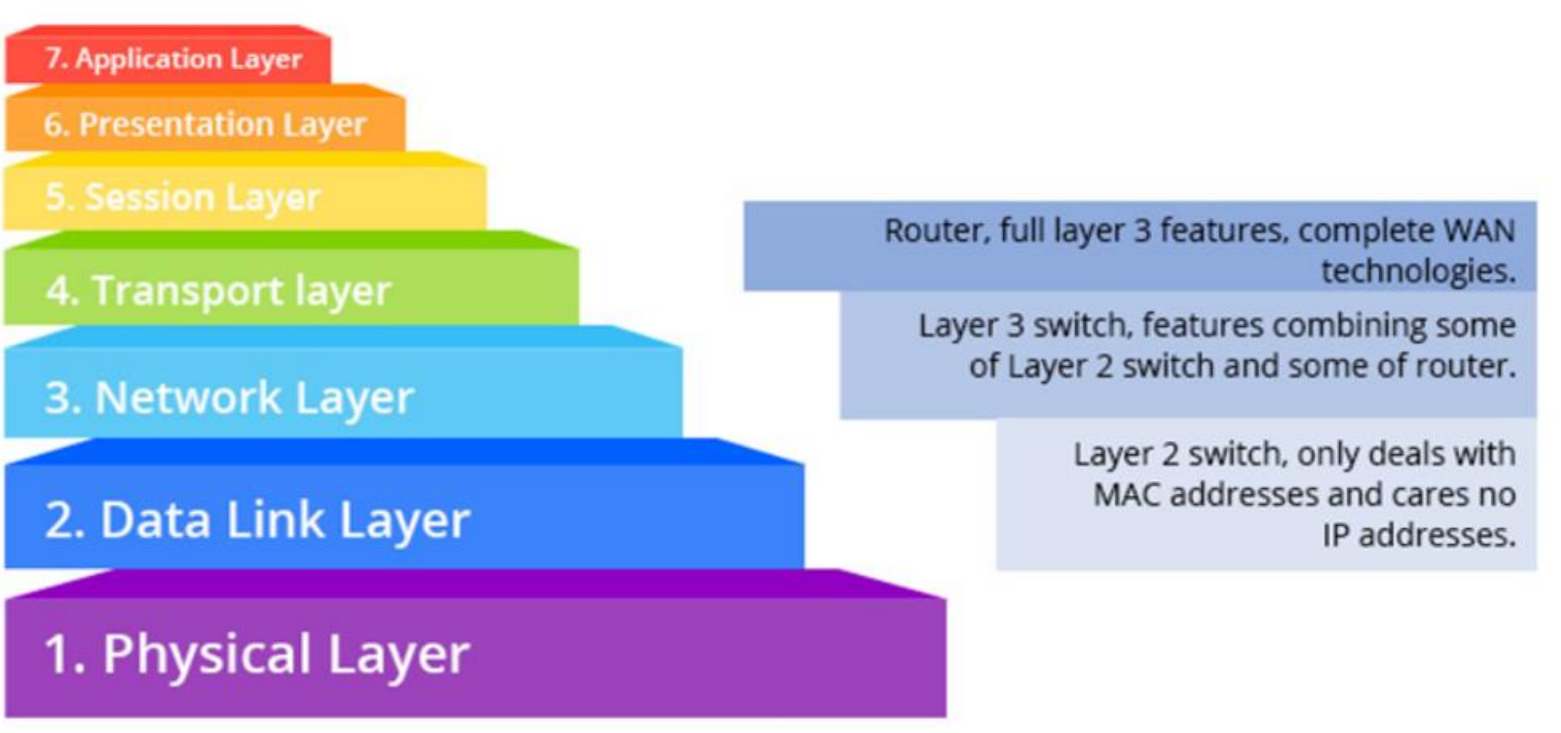
- Active multi-port network and bridge device
- Provides separate collision domain for each port
- Uses MAC (Media Access Control) layer to direct network packets
- Multiple simultaneous communications

https://www.youtube.com/watch?v=n90AdUZmytY

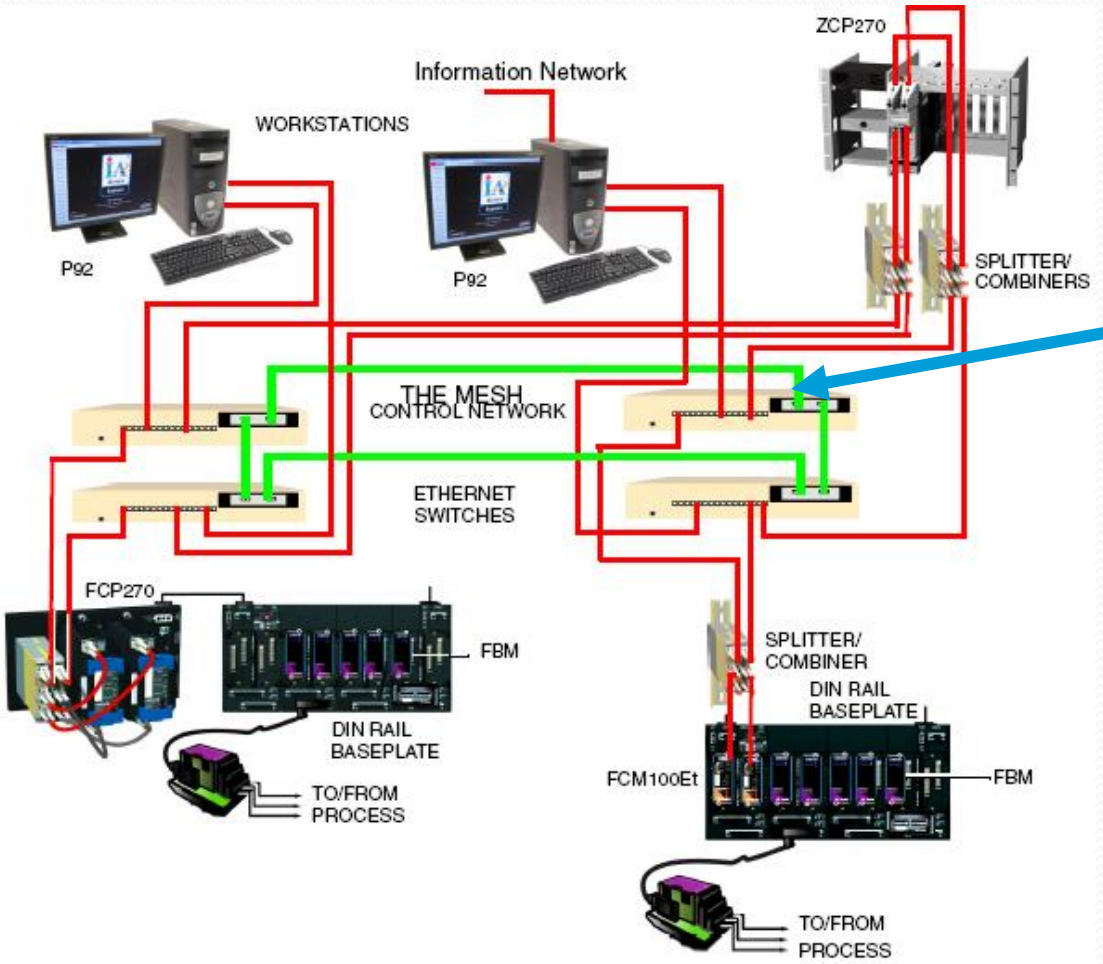
Hardware :

Network Switch:

Layer 2 and Layer 3 switches :



• The Mesh Control Network Components



Ethernet switches connected in a mesh configuration which can be configured to be a 'self healing' network.

✓ The Mesh Control Network – Features I

- Provides multiple communication paths
- Provides high availability
- Reduces network complexity, cost, maintenance
- Flexible Configurations:
  - simple as 1 workstation station connected to a Control Processor
  - Complex as a multi-switch fully meshed control network – 1gigabit /sec
- High Speed and redundancy and peer-to-peer characteristics provide high performance and superior security.
- Redundant Ethernet switches ensure secure communications between stations

✓ The Mesh Control Network – Features II

- System Scalability –Ethernet switches -8,16,24 ports or more

- Ability to connect in various network topologies
  - Linear
  - Ring
  - Star
  - Inverted Tree

- Ethernet switches connected in a mesh configuration

- Support for fast Ethernet (100Mbps) and Gigabit (1000 Mbps)

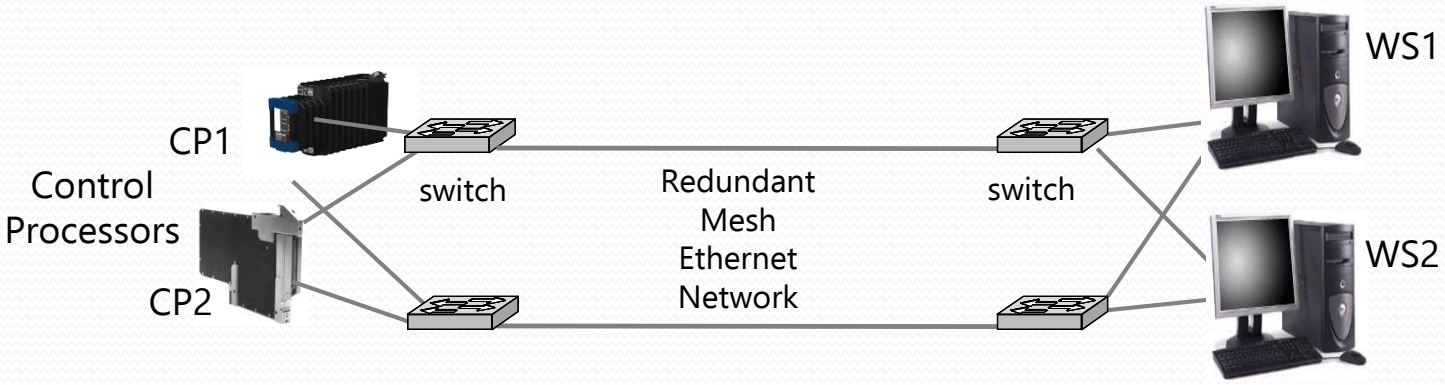
- Modular uplinks to high-speed backbones

- Full-duplex operation based on the IEEE 802.3 standards

- RSTP – which manages redundant paths, prevents loops, and provides high- speed convergence time for the network

✓The Mesh Control Network Features III

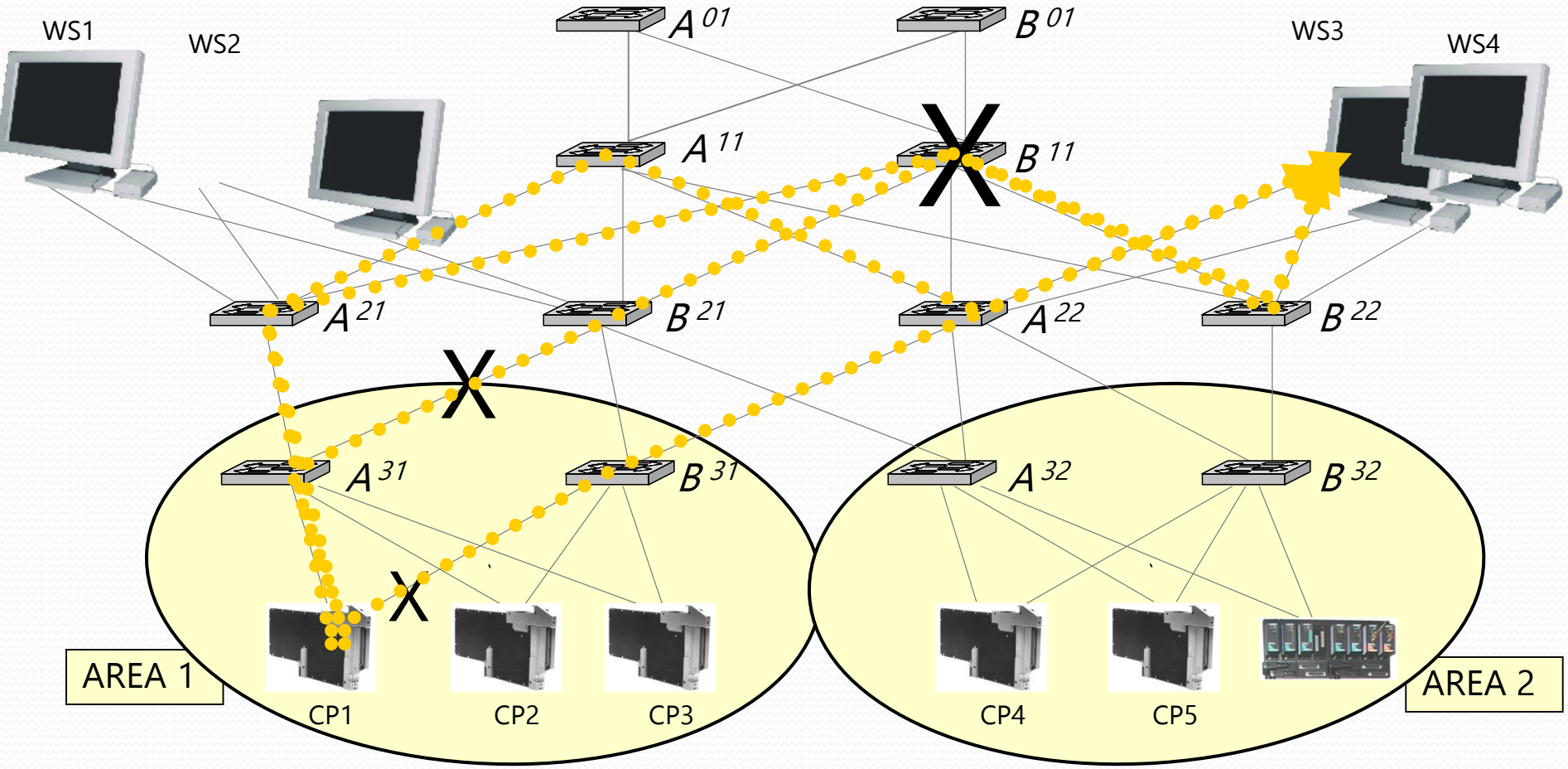
- System Management software for monitoring health of Mesh
- Software in every station that manages redundant Ethernet ports in response to network faults
- High speed response to network and station faults to provide a highly reliable fault tolerant network
- Network management and configuration via local port for managed switches



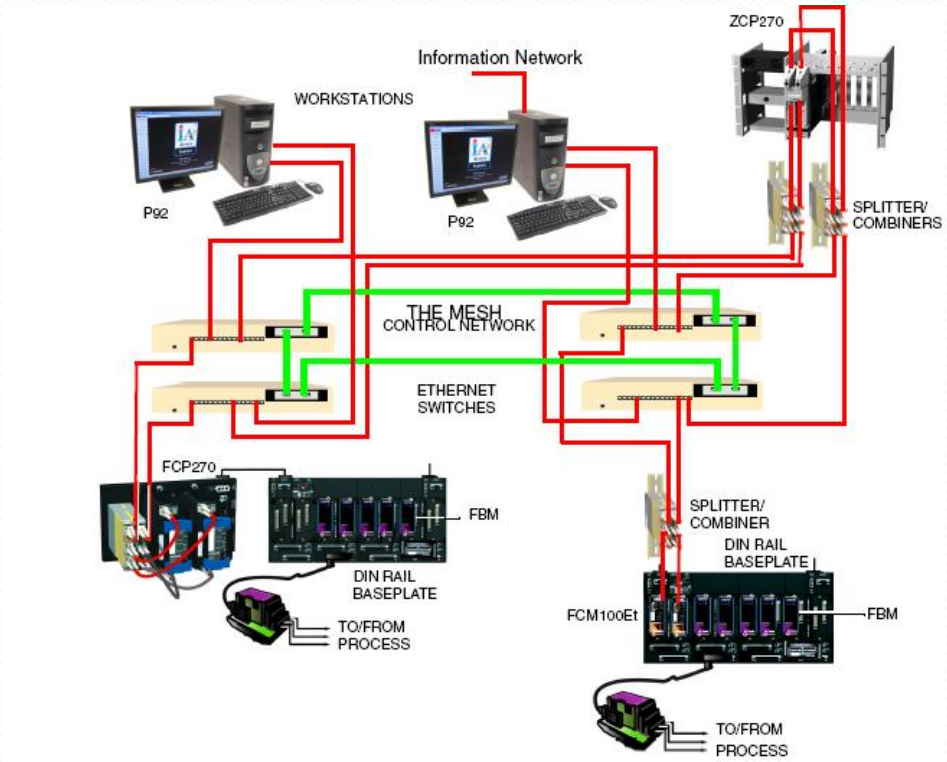
✓ The Mesh Control Network – Features IV

The mesh network tolerates multiple faults by managing alternate communication paths between devices. RSP tree topology in the switches automatically manages the connection paths to avoid unnecessary data flow.

Inverted Tree - Utilizing Rapid Spanning Tree (RSP)

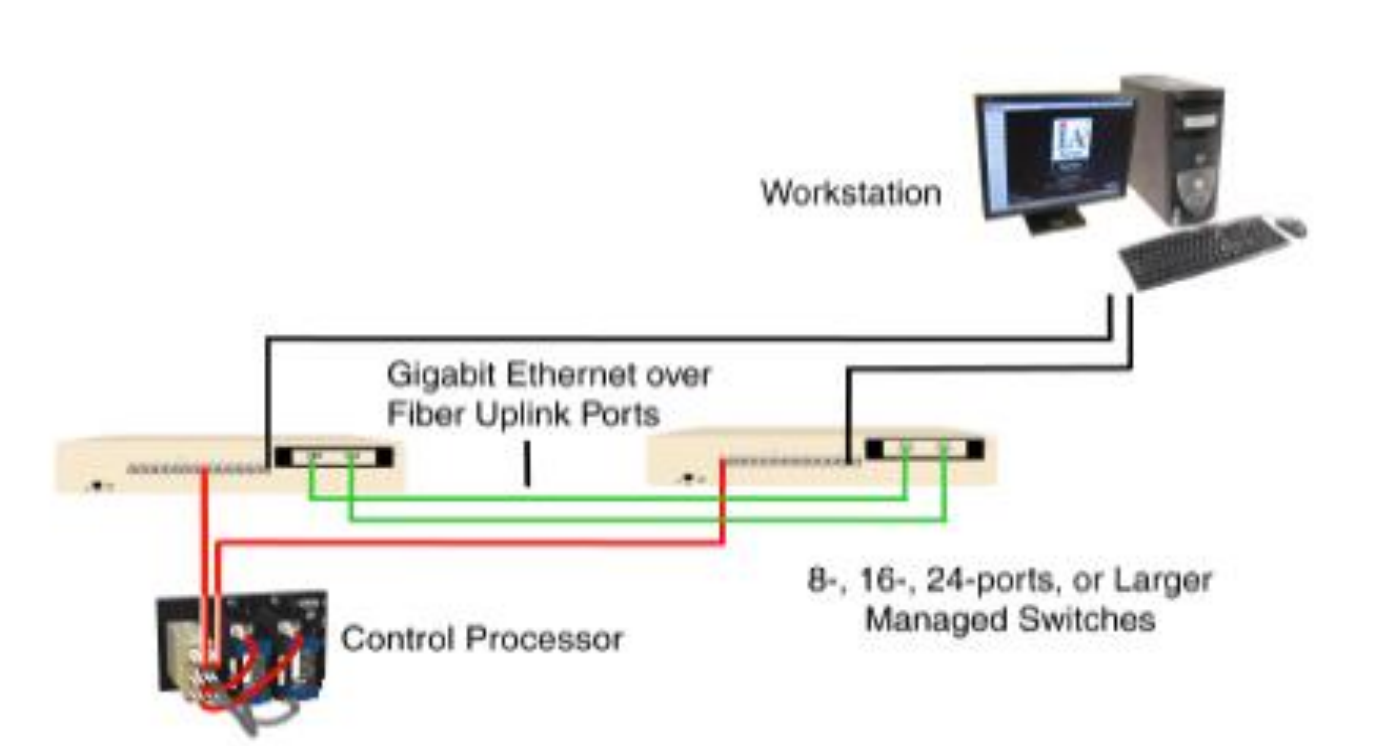


✓The Mesh Control Network - Topologies

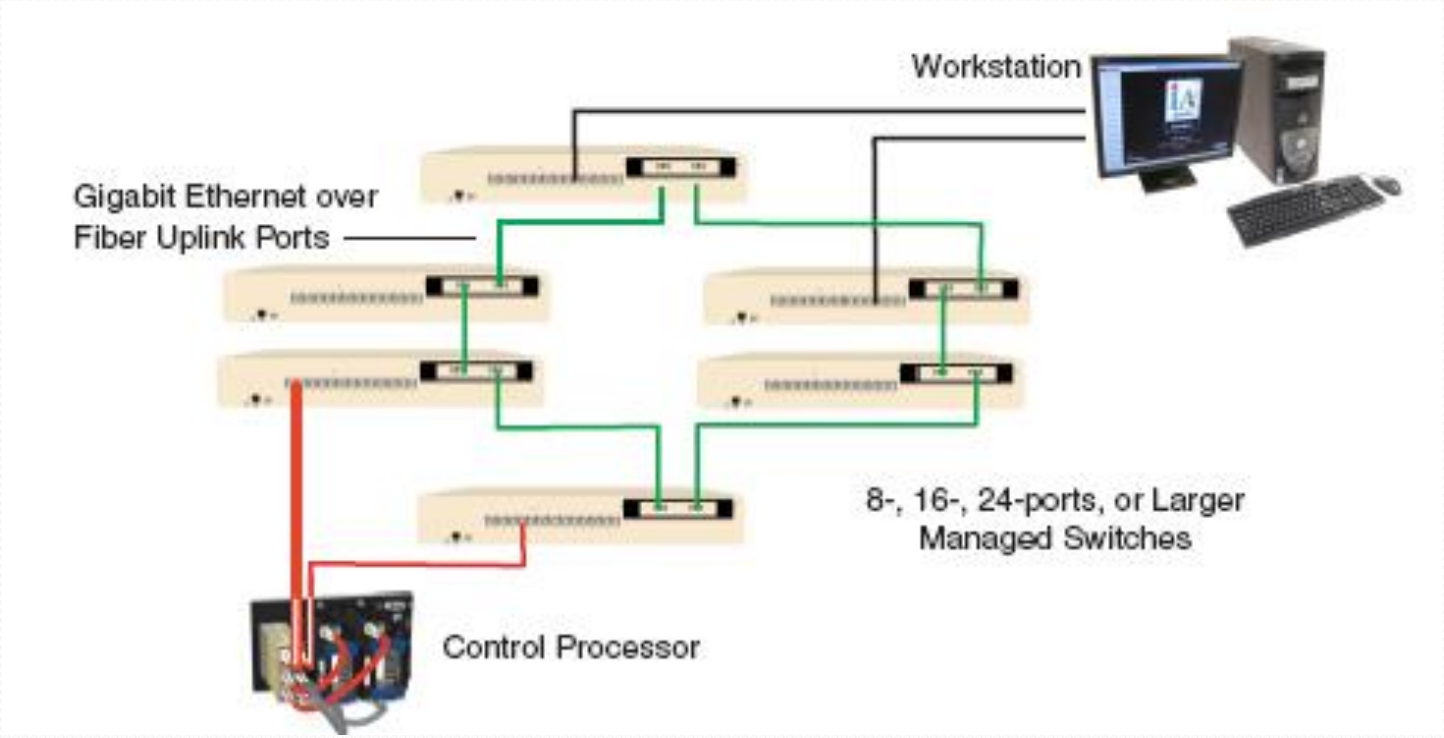


- Linear Topology
- Ring Topology
- Star Topology
- Inverted Tree Topology

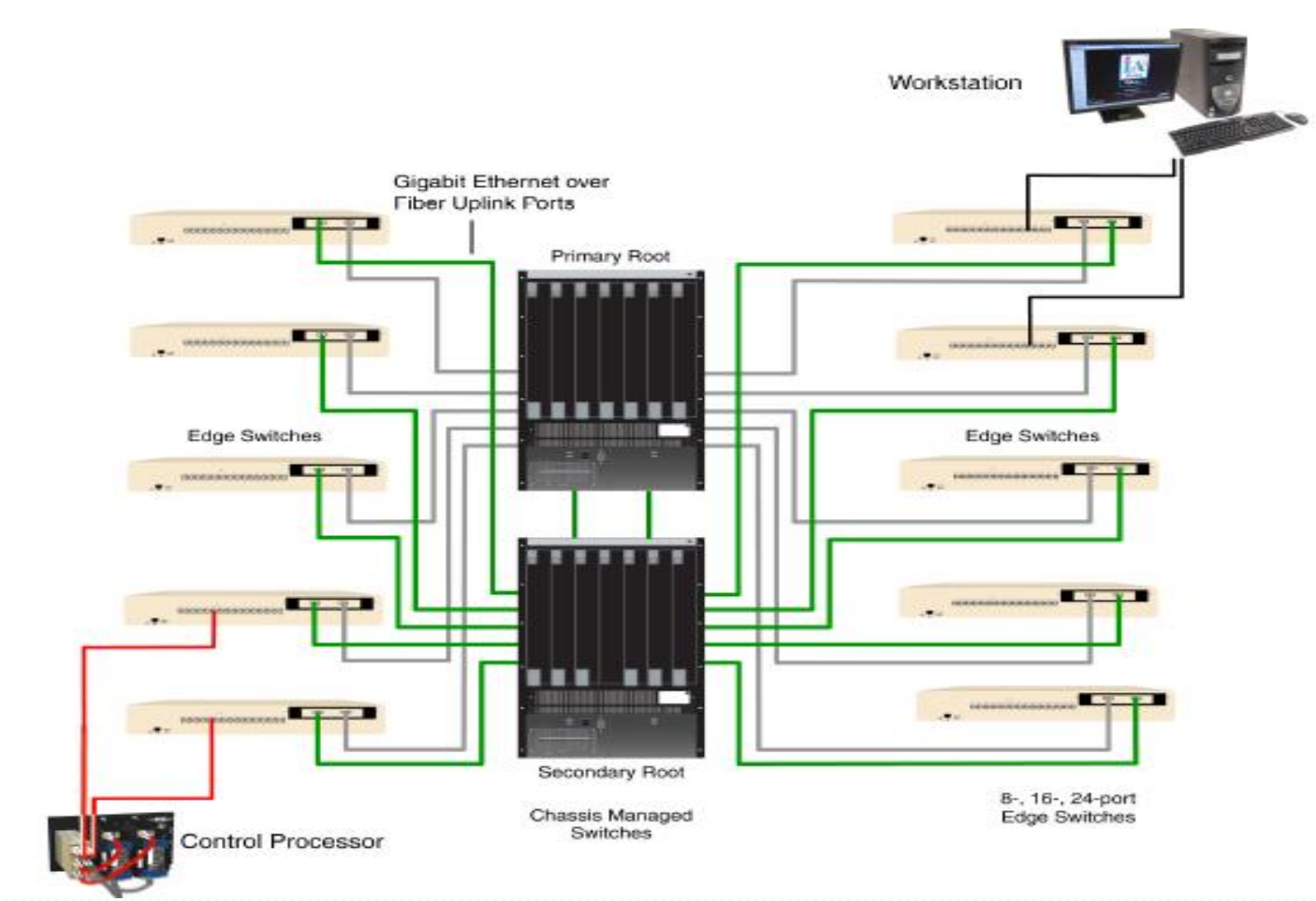
✓ Mesh Topologies - Linear Topology



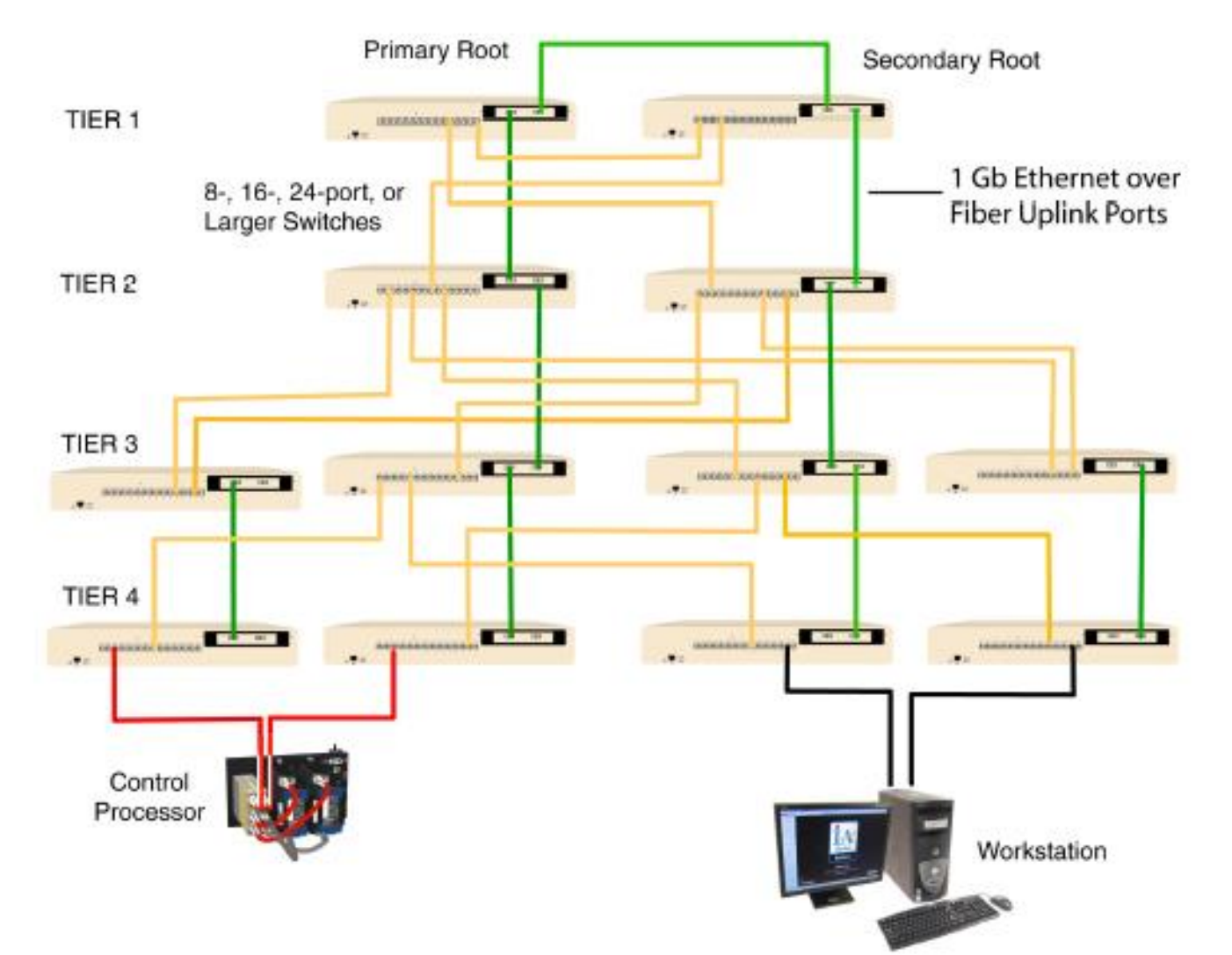
✓ Mesh Topologies - Ring Topology



✓ Mesh Topologies - Star Topology



✓Mesh Topologies - Inverted Tree Topology



Software system:

The software for the DCS is for optimum process control and management capability for a wide range of applications.

Software systems comes in a variety, we can divide it to following group for our references.

i. **Workstation Software.**
ii. **Application Software.**

Software system:

Workstation Software :

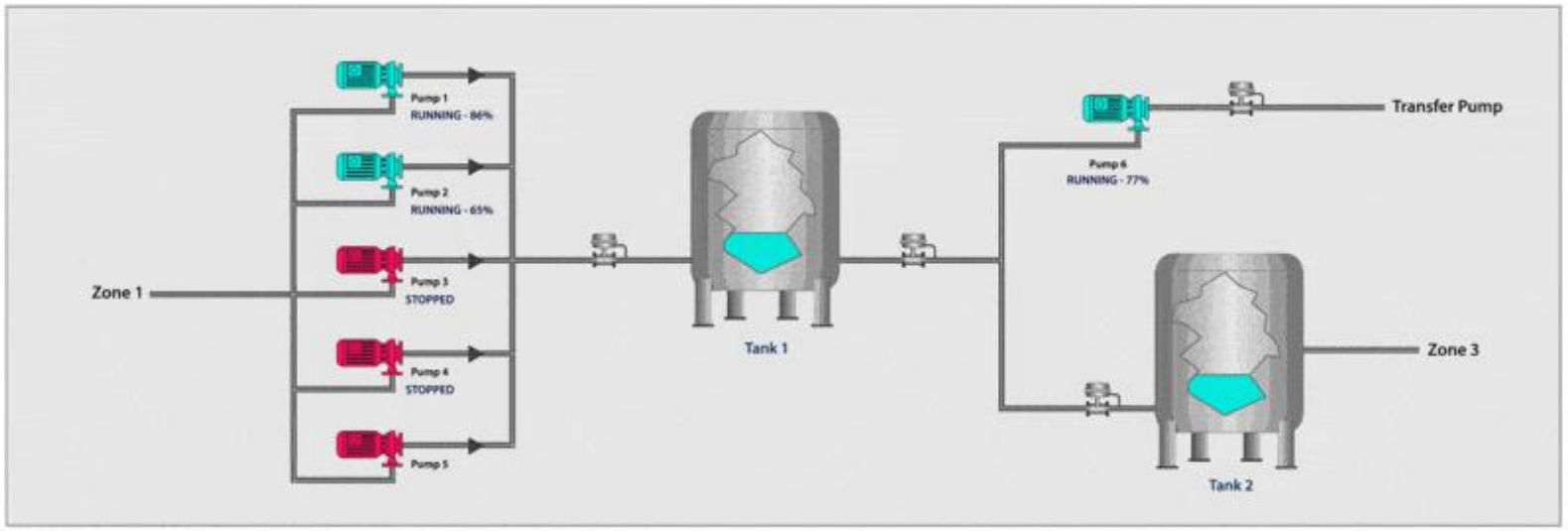
i. Windowing capability allows for various applications to be accessed simultaneously
ii. User-friendly human interface that uses menus, displays and dialog boxes
iii. Graphics suite gives the ability to generate sophisticated, interactive process control and management displays
iv. Security software to allow access to only authorized personnel

Software system:

Application Software :

i. Additional configurators (e.g., Operator Action Journal) provide easy-to-use programs
ii. for monitoring local and remotely distributed systems
iii. Production control and plant information management applications packages such as Microsoft Excel, spreadsheets, Historian and Statistical Process Control (SPC)
iv. Expandability to add additional hardware

✓HMI Normal Vs High Performance



REALPARS

Reference c

✓ OT Security

Security Applications

✓Alarms

Alarm Summary

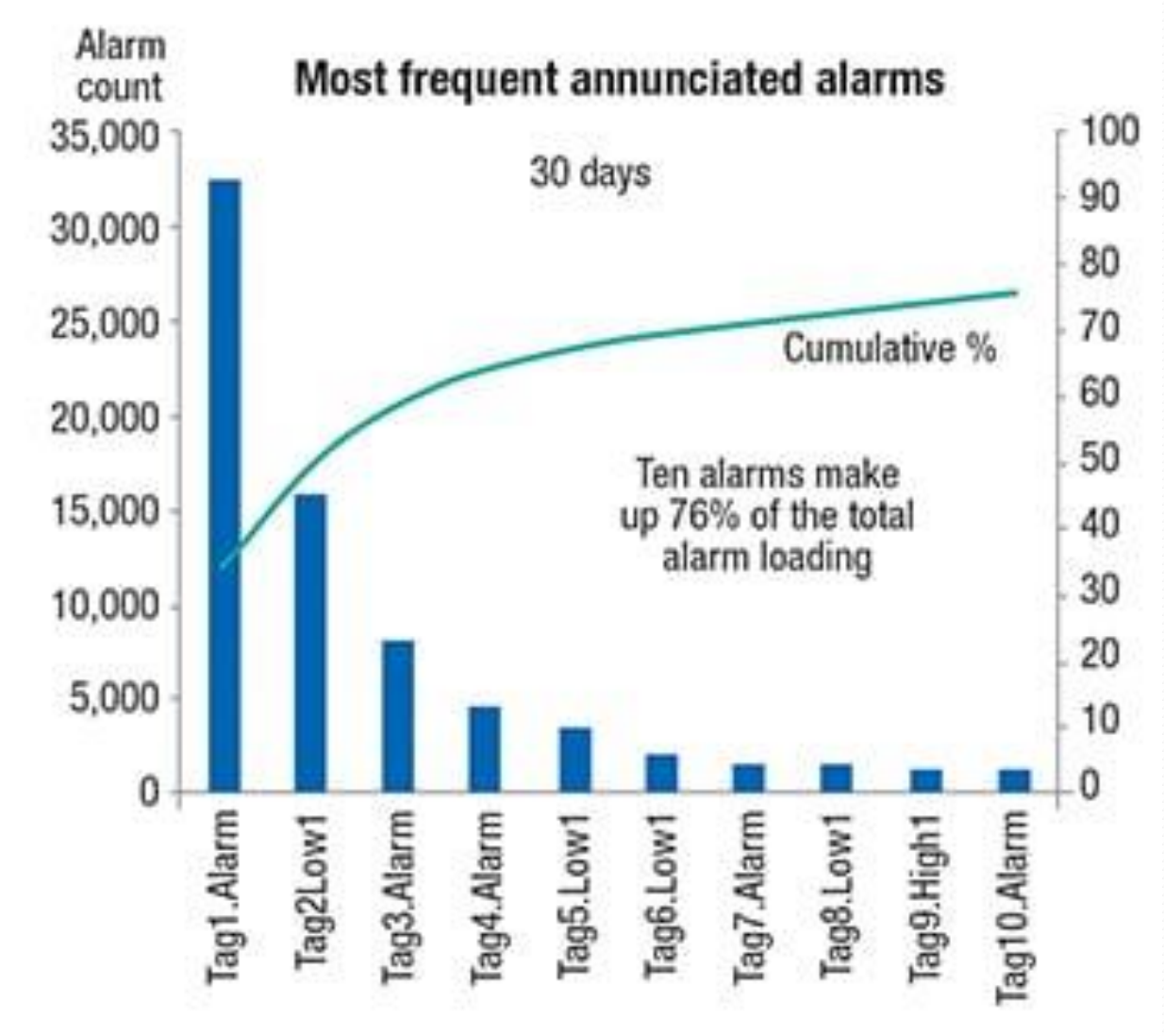
ACK All | SILENCE | UNIT A | UNIT C | SysA16 Con M5 | 10:04:45 02/12/16

ACK SELECTED | RE-SORT | UNIT B | UNIT D | System Alarms | SUPPRESSION

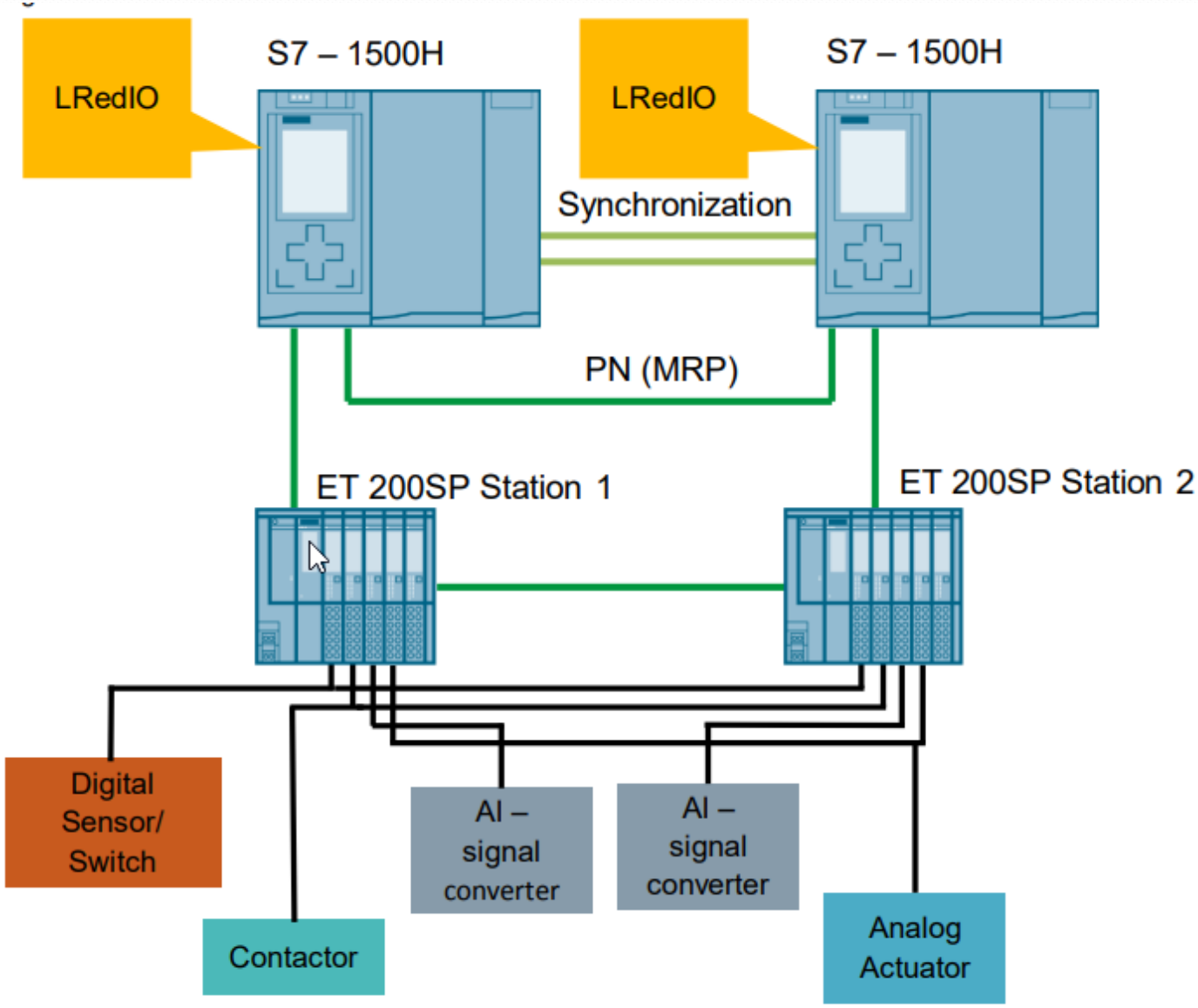
TIME	EVENT	POINT	DESCRIPTION	TYPE	PRI	AREA	UNITS	TIA	STATE	INDEX
02/10/16 15:44:12	ALM	47TG01CO2F	CO2 DO TG - BATERIA 1	OFFNRM	2	M5	STATE	0:00:00		
02/10/16 15:44:11	ALM	142DI103	DENSIDADE SODA DILUIDA	PVLO	3	M8	PSI	0:00:01		
02/10/16 15:44:10	ALM	DMDINTA	DEMAND INTERVAL FLAG A	OFFNRM	4	N11	DEGC	0:00:02		
02/10/16 15:44:09	ALM	TLCPLOT	TLC ENERGY PLOT POINT	LOGIC-A	3	K14	AMPS	0:00:03		
02/10/16 15:44:08	ALM	142DI103	DENSIDADE SODA DILUIDA	PVHI	3	L27	PSI	0:00:04		
02/10/16 15:44:07	ALM	170FI18	GN PARA COP599	BADPV	3	TT78		0:00:05		
02/10/16 15:44:06	ALM	42PHI02	PH AGUA SERVICO P/ CEMAP	PVLO	2	ED77	PPH	0:00:06		
02/10/16 15:44:05	ALM	148LAH20	148T801A SEM ESCORVA	OFFNRM	1	BH71	STATE	0:00:07		
02/10/16 15:44:04	RTN	AL5_SSUMMER	SOMA ALIMENTADOR 5 E 9	PVHI	1	Y77	GPH	0:00:08		
02/10/16 15:44:03	ALM	42PAL04	AGUA CLARIFICADA	OFFNRM	5	B7N	STATE	0:00:09		
02/10/16 15:44:02	ALM	148LAH24	148B01E SEM ESCORVA	OFFNRM	2	CC34	STATE	0:00:10		
02/10/16 15:44:01	ALM	42PHI02	PH AGUA SERVICO P/ CEMAP	PVHI	3	N11	GPM	0:00:11		
02/10/16 15:44:00	ALM	42AI104	PH AGUA DESCARBONATADA	PVLO	3	K14	MMHG	0:00:12		
02/10/16 15:43:59	ALM	42PHI03	PH AGUA CLARIFICADA	PVLO	3	L27	FT3/S	0:00:13		
02/10/16 15:43:58	ALM	42PHI01	PH AGUA POTAVEL	PVHI	3	TT78	MKS	0:00:14		
02/10/16 15:43:57	RTN	148LIC11	NIVEL DO 148V03A	PVLO	2	ED77	PSI	0:00:15		
02/10/16 15:43:56	ALM	42PHI06	PH 42-TQ-148	PVHI	2	BH71	PSI	0:00:16		
02/10/16 15:43:55	ALM	74PAL11	FECHA MINIFLUX 74PV20/21	OFFNRM	2	Y77	STATE	0:00:17		
02/10/16 15:42:55	ALM	170FX22	CONDUTIV 42V05AA	BADPV	5	B7N		0:01:17		
02/10/16 15:41:55	ALM	42PI101	ENTRADA O.R.	PVLO	4	CC34	FT3/S	0:02:17		
02/10/16 15:40:55	ALM	42PDAH112	PRES DIF ALTA SEG ESTAG	OFFNRM	4	N11	STATE	0:03:17		
02/10/16 15:39:55	ALM	42PHI06	PH 42-TQ-148	PVLO	4	K14	DEGC	0:04:17		
02/10/16 15:38:55	ALM	42PHI01	PH AGUA POTAVEL	PVLO	4	L27	PSI	0:05:17		
02/10/16 15:37:55	ALM	42PHI03	PH AGUA CLARIFICADA	PVHI	1	TT78	DEGC	0:06:17		
02/10/16 15:36:55	ALM	42CIT02C	CONDUTIV 42V05C	PVHI	5	L27	GPH	0:07:17		
02/10/16 15:35:55	RTN	148LAH27	TANQUE 148V04	OFFNRM	1	TT78	STATE	0:08:17		
02/10/16 15:34:55	ALM	148ZALL06	DOSANDO CLORO	OFFNRM	2	ED77	STATE	0:09:17		
02/10/16 15:33:55	ALM	74PAL01	PRESSAO BAIXA AF RAMAL 1	OFFNRM	4	BH71	STATE	0:10:17		
02/10/16 15:32:55	ALM	47PAL18	PRESS M BAIXA EXTRACAO	OFFNRM	4	Y77	STATE	0:11:17		
02/10/16 15:31:55	ALM	180FI400	GN P/ DA SULGAS	PVHI	4	B7N	GPH	0:12:17		
02/10/16 15:30:55	ALM	42PDAH103	PRES DIF ALTA SEG ESTAG	OFFNRM	1	TT78	STATE	0:13:17		
02/10/16 15:29:55	ALM	42CIT02D	CONDUTIV 42V05D	PVHI	2	ED77	FT3/S	0:14:17		
02/10/16 15:28:55	ALM	174PALO02	PARTIDA AUTO BBA DIESEL	OFFNRM	3	BH71	STATE	0:15:17		

SCROLL ▲ ▼

✓Alarms Analysis

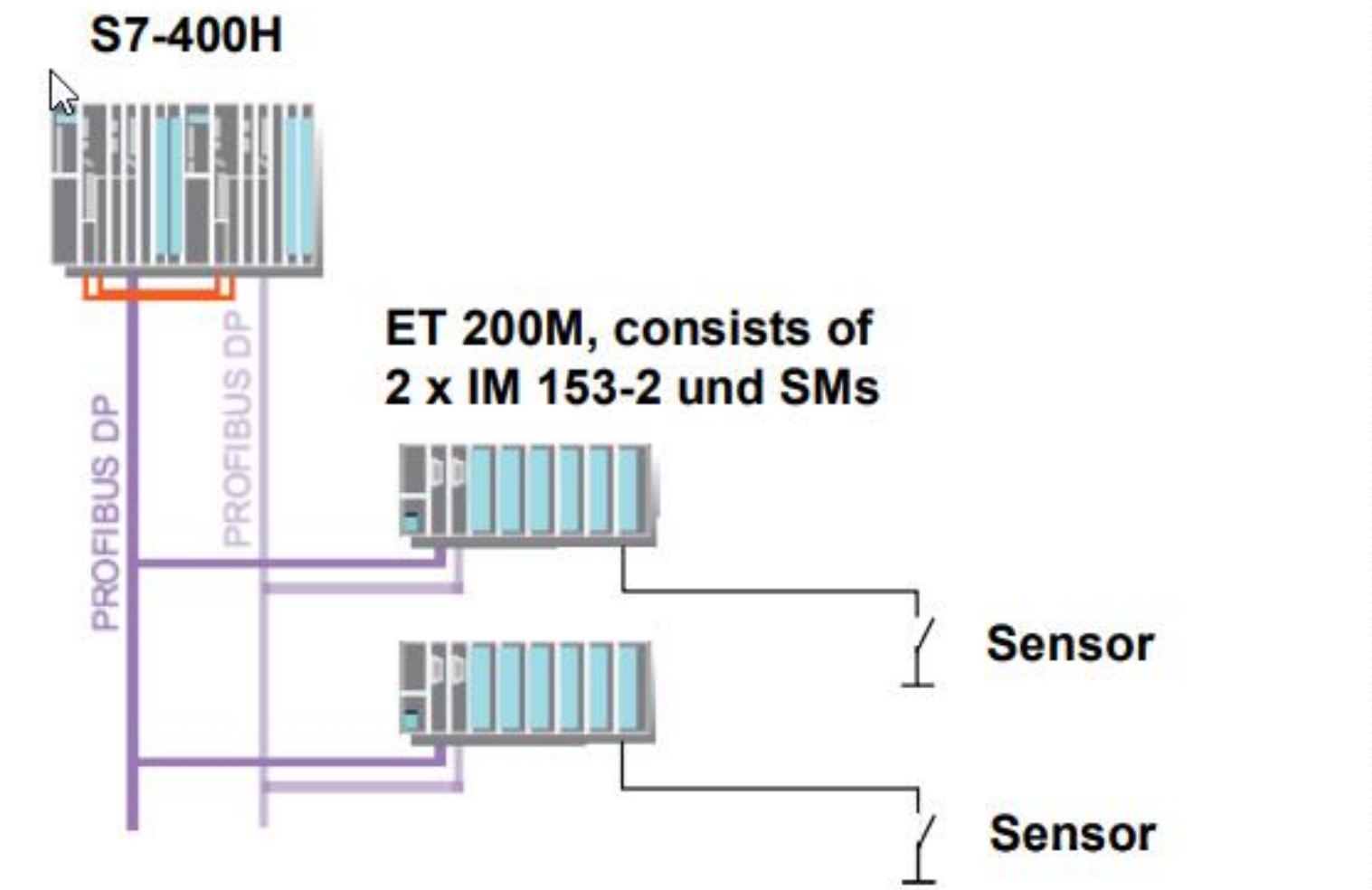


✓Redundancy Techniques at Controller level



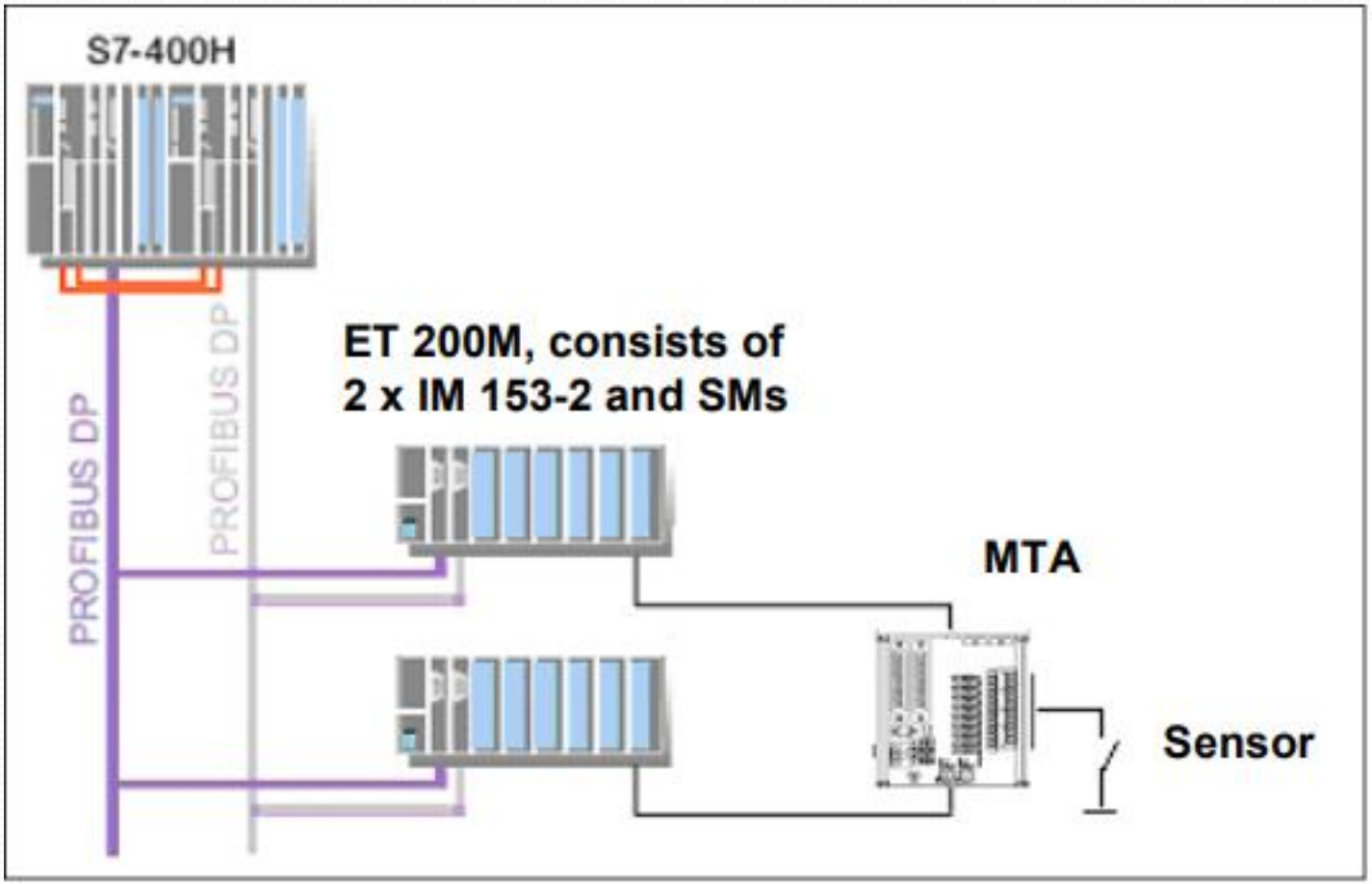
✓ Redundant IO

Redundant System with IO redundancy

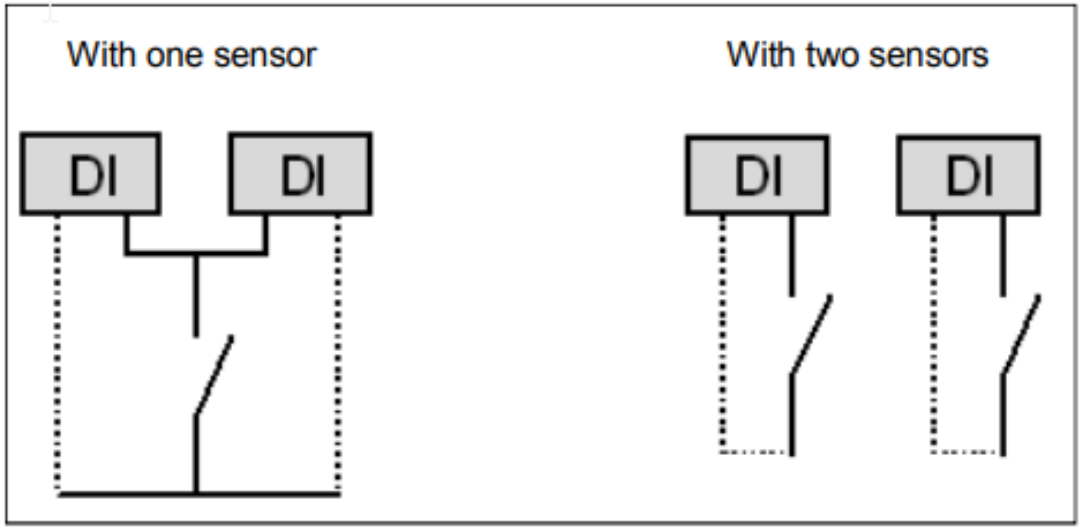


✓ Display Objects

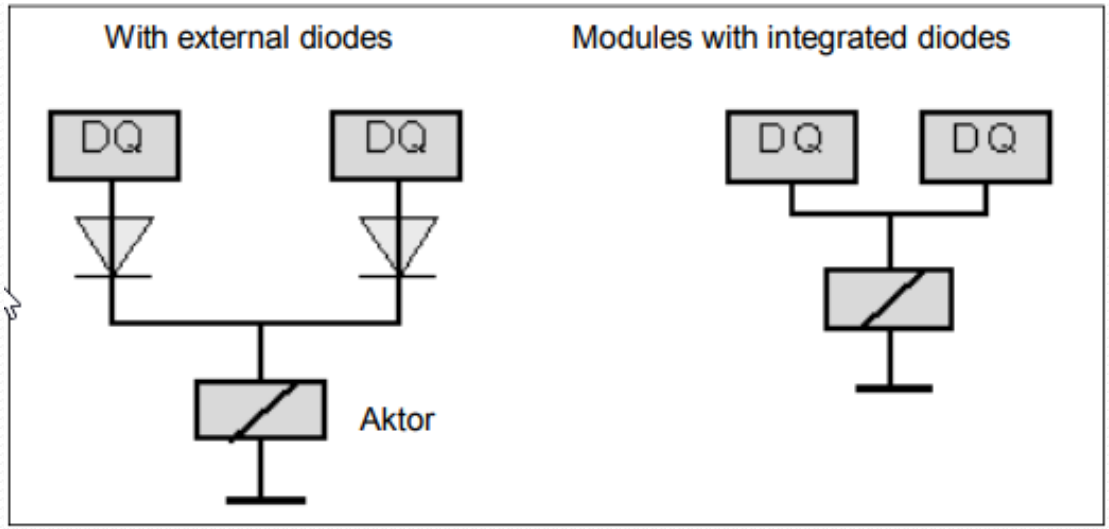
Redundant system with till IO module redundancy



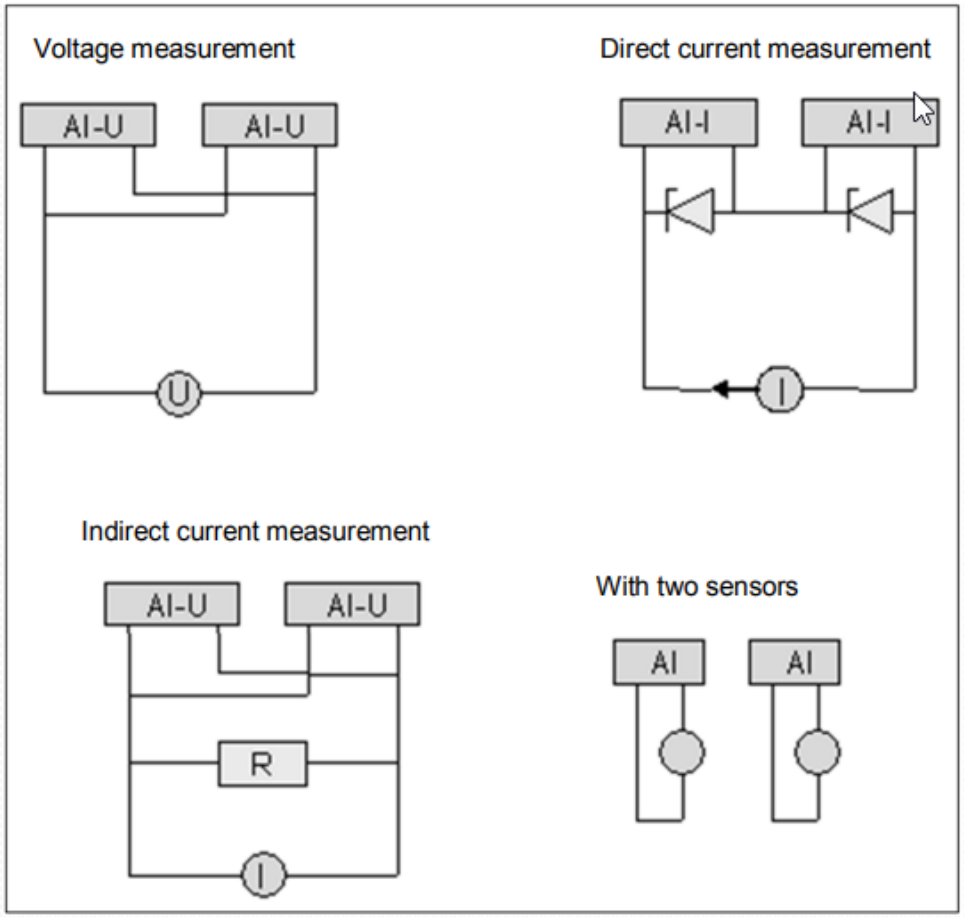
✓ Redundant IO configurations

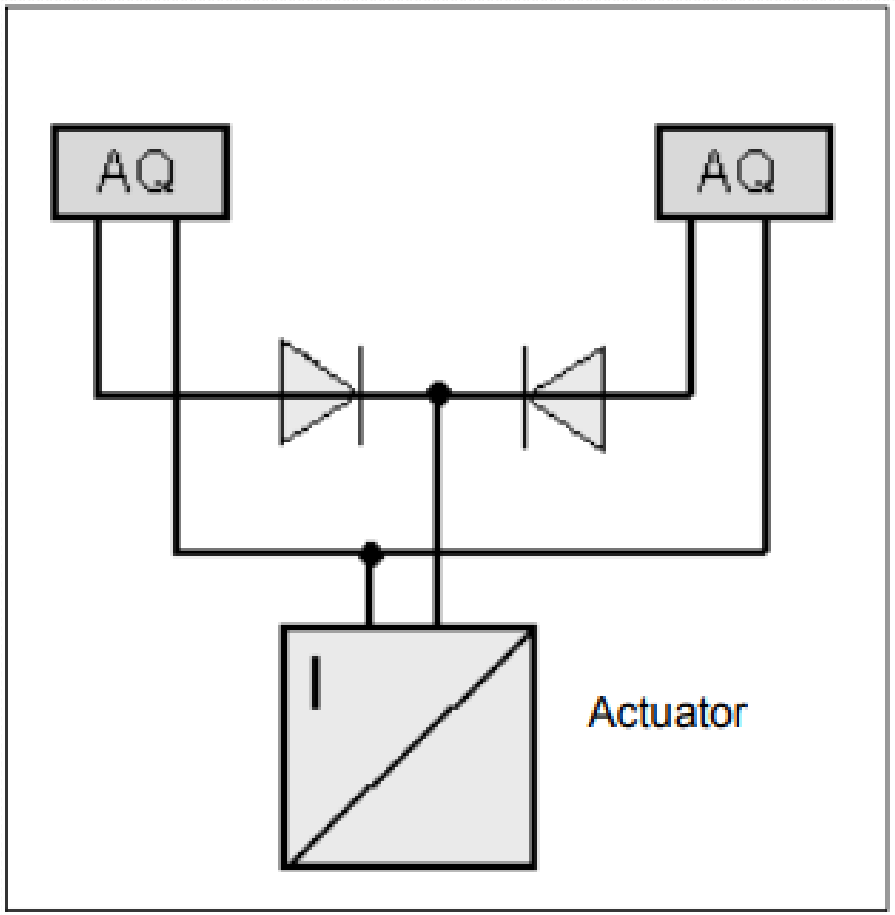


In order to reach a maximum availability it is recommended to use two encoders.



✓ Redundant IO configurations





✓ Trend Configuration Objectives

Module Objective:

Make on line modifications to trend displays and create Scratchpad trends

Enabling Objectives:

Perform trend modifications:

Scan rate and duration

Graph, Off Normal, and Grid line colors

Merged and Banded

Pen color and scale

Add data points to a trend through FoxView

Assign historian to a trend pen and trend historical data

Create Scratchpad trends

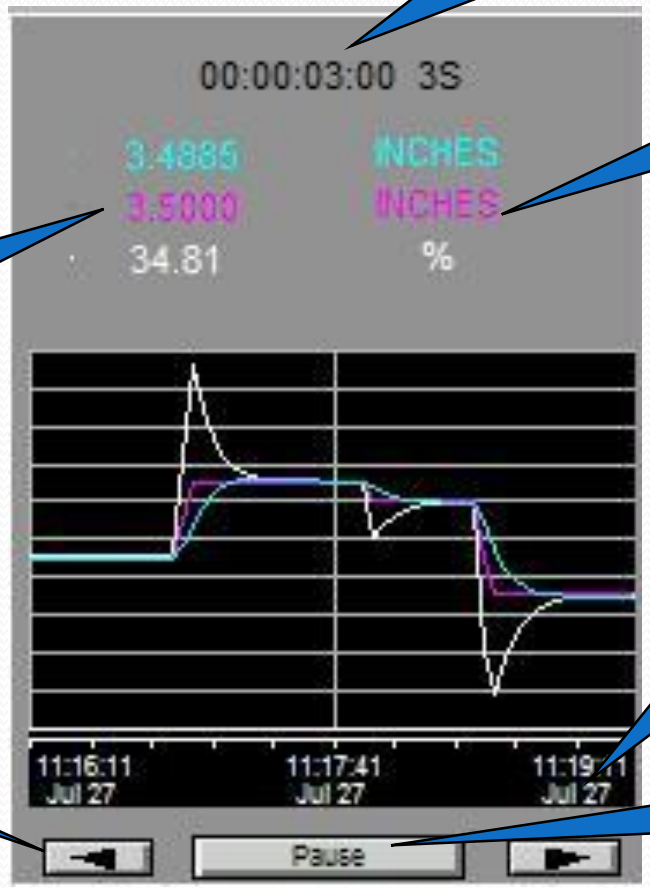
✓ Trends Functions

- View process data
- Monitor and control process variables
- Real time and historical data
- Continuous, Boolean parameters

✓ Analog Trends

Continuous Values

Up to 4 points



Duration & Scan Rate

Engineering Units

Current Values

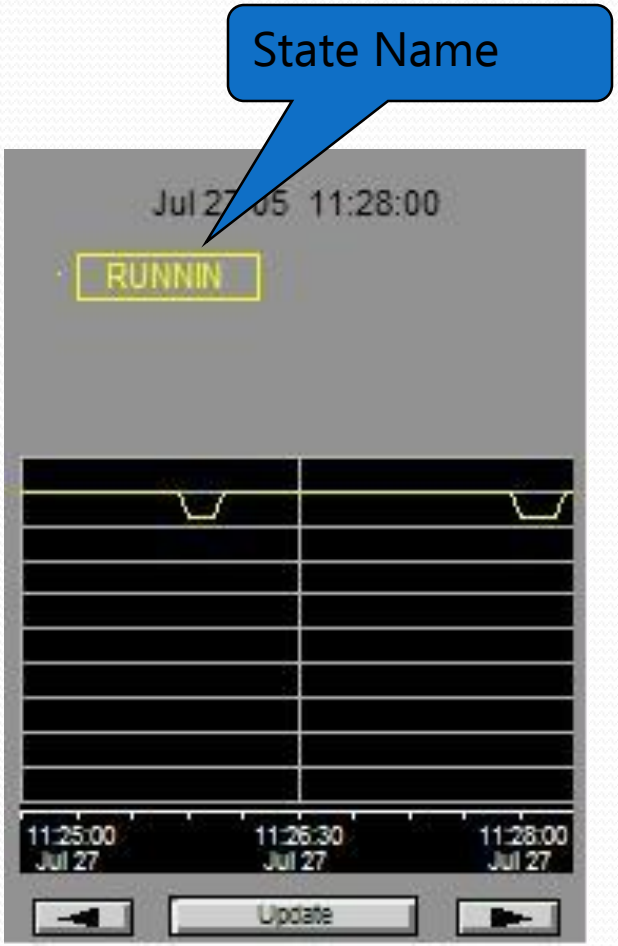
Current Time & Date

Scrolling Keys

Pause & Update Modes

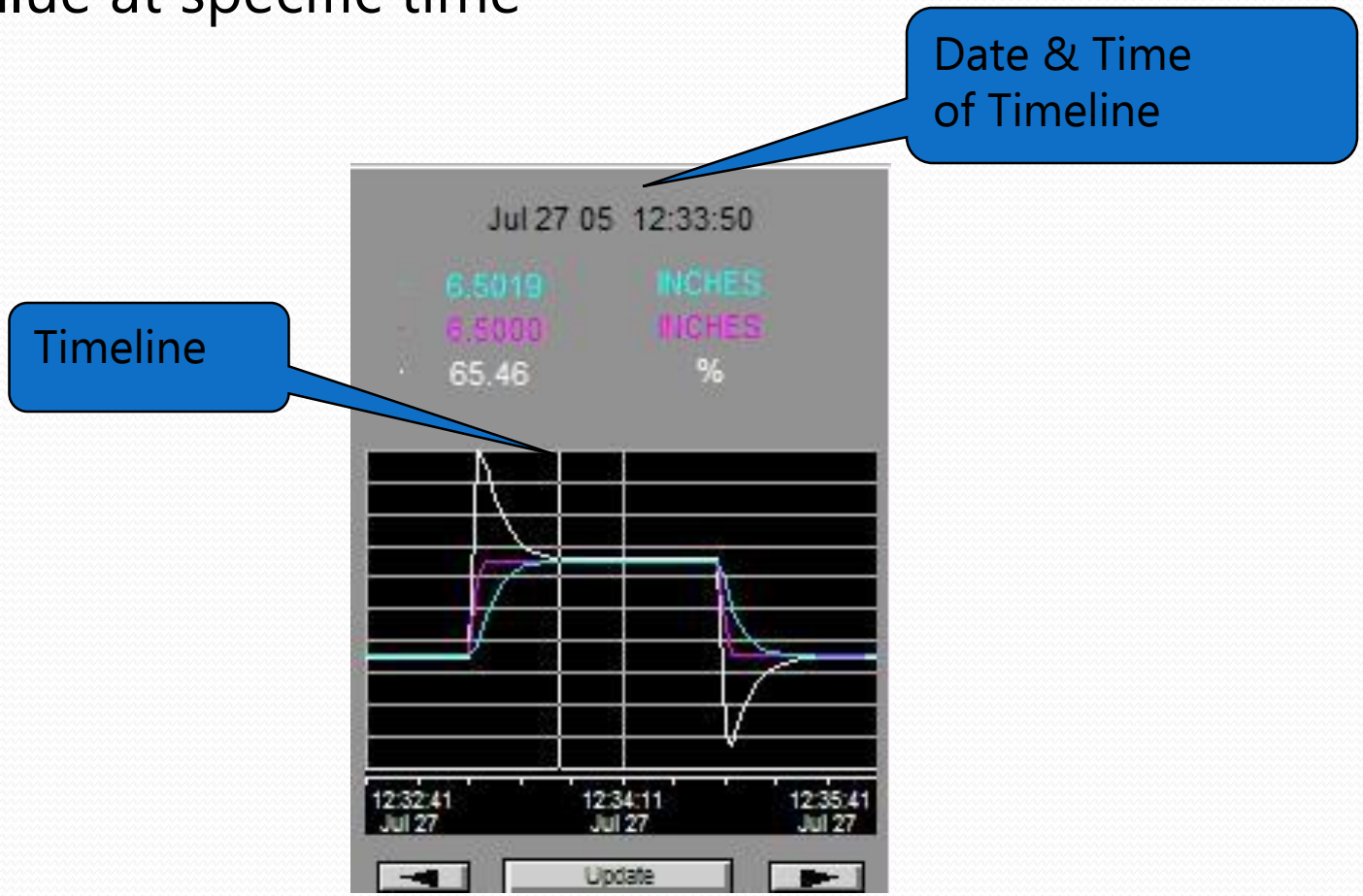
✓ Boolean Trends

Monitor contact status

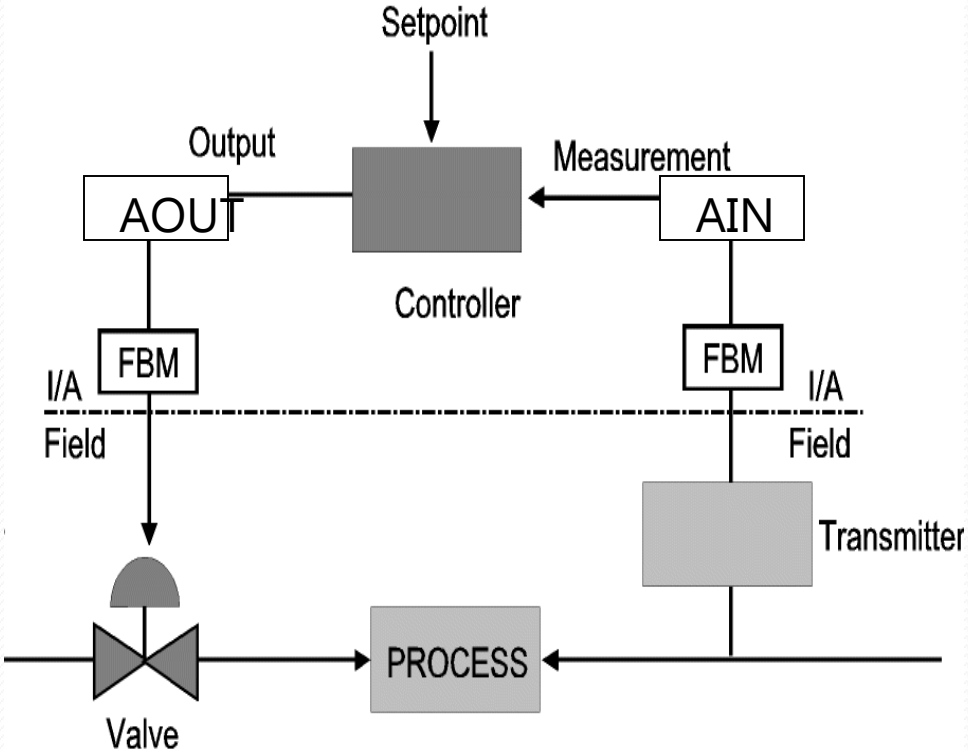


✓ Pausing a Trend

- Can Pause trend
- Value at specific time



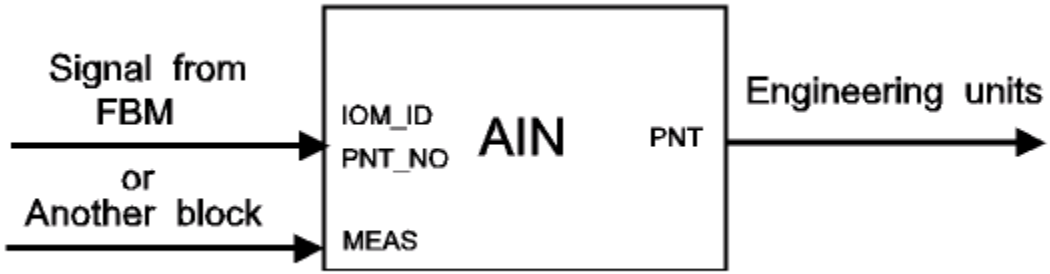
✓ Feedback Loop



Functions provided by:

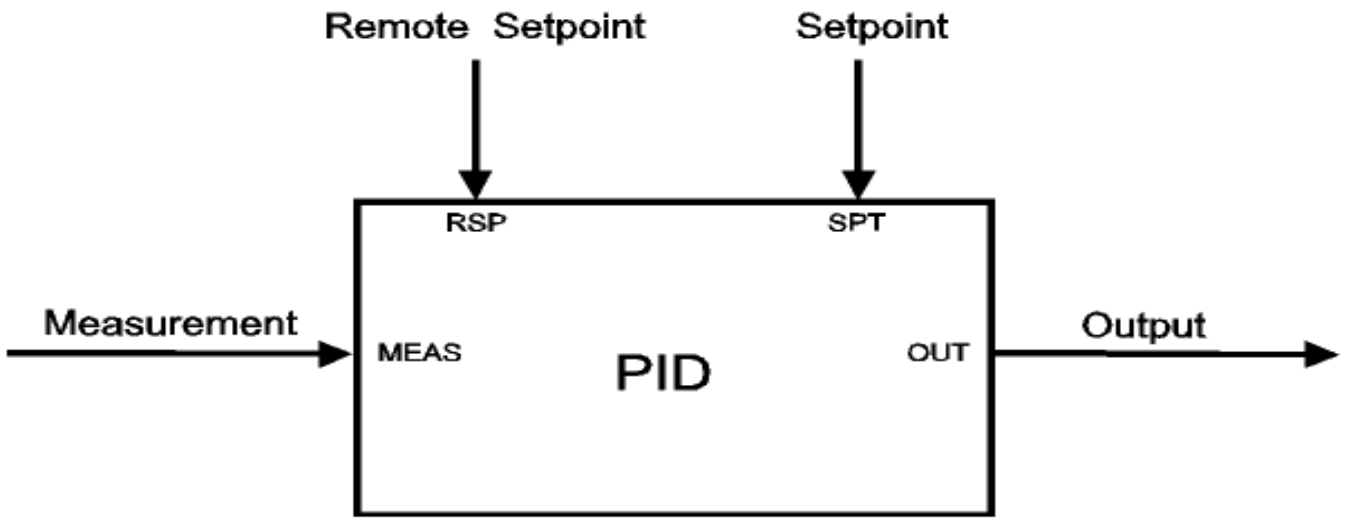
- Analog Input block
- Controller block
- Analog Output block

✓ Analog Input Block Functions



- Input from FBM point or another block
- Signal conditioning
- Filtering
- Scaling
- Alarming
  - Absolute
  - Bad FBM or FBM channel
  - Out-of-Range

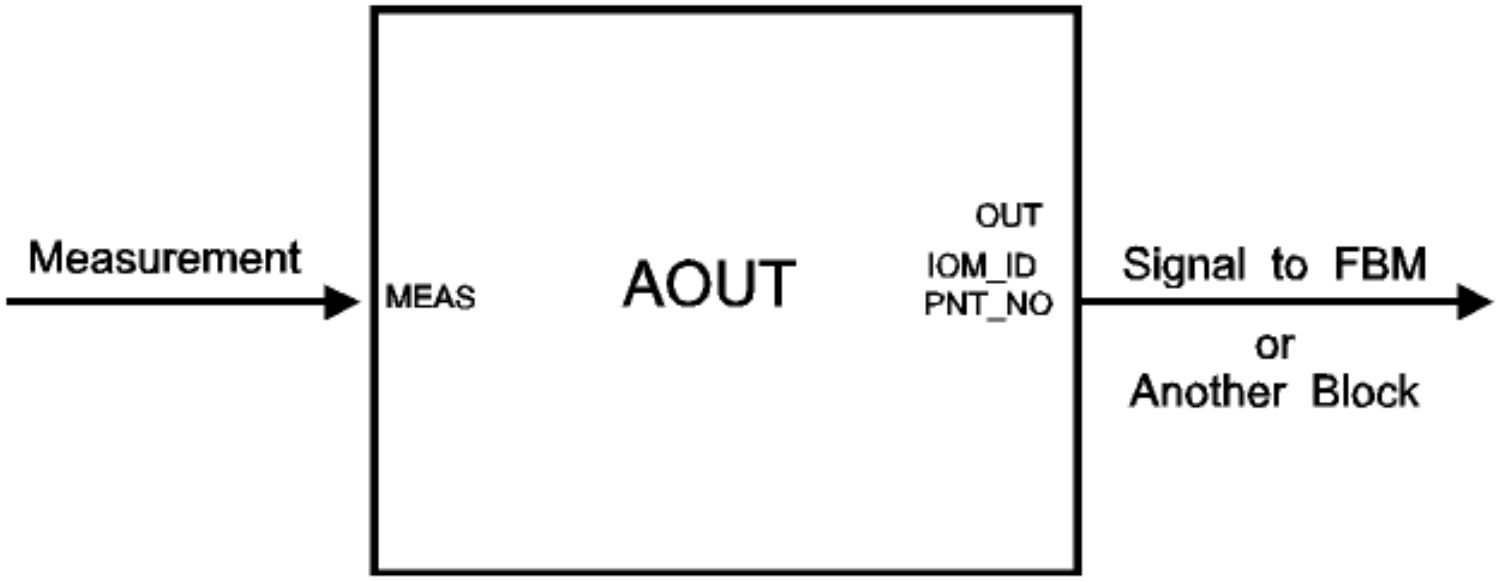
✓ Controller Block



Major Functions

1. Control of process variable
2. Alarming
   a. Measurement (input)
      Absolute
      Deviation
   b. Absolute alarming on output

✓ Analog Output Block

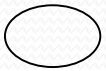


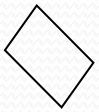
Major Functions

1. Send output signal to an analog FBM or another block
2. Alarm if FBM or FBM channel (point) goes bad

✓ SAMA DRAWING OVERVIEW

- SAMA : Scientific Apparatus Makers Association
- SAMA Symbols : Measuring , Manual signal processing , Automatic Signal Processing Etc .


: Measuring


: Manual signal processing


: Automatic Signal Processing


: Final Controlling

Logical AND 

Logical OR 

Logical NOT 

Set, Reset