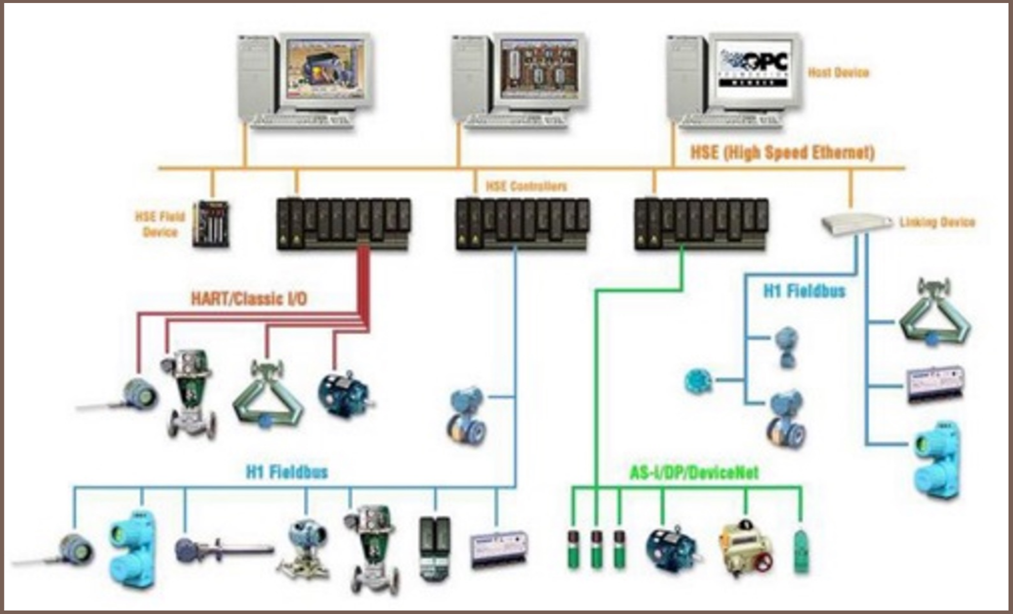
# 18ECO134T- INDUSTRIAL AUTOMATION

UNIT - 3

Distributed Control system (DCS)



# Contents

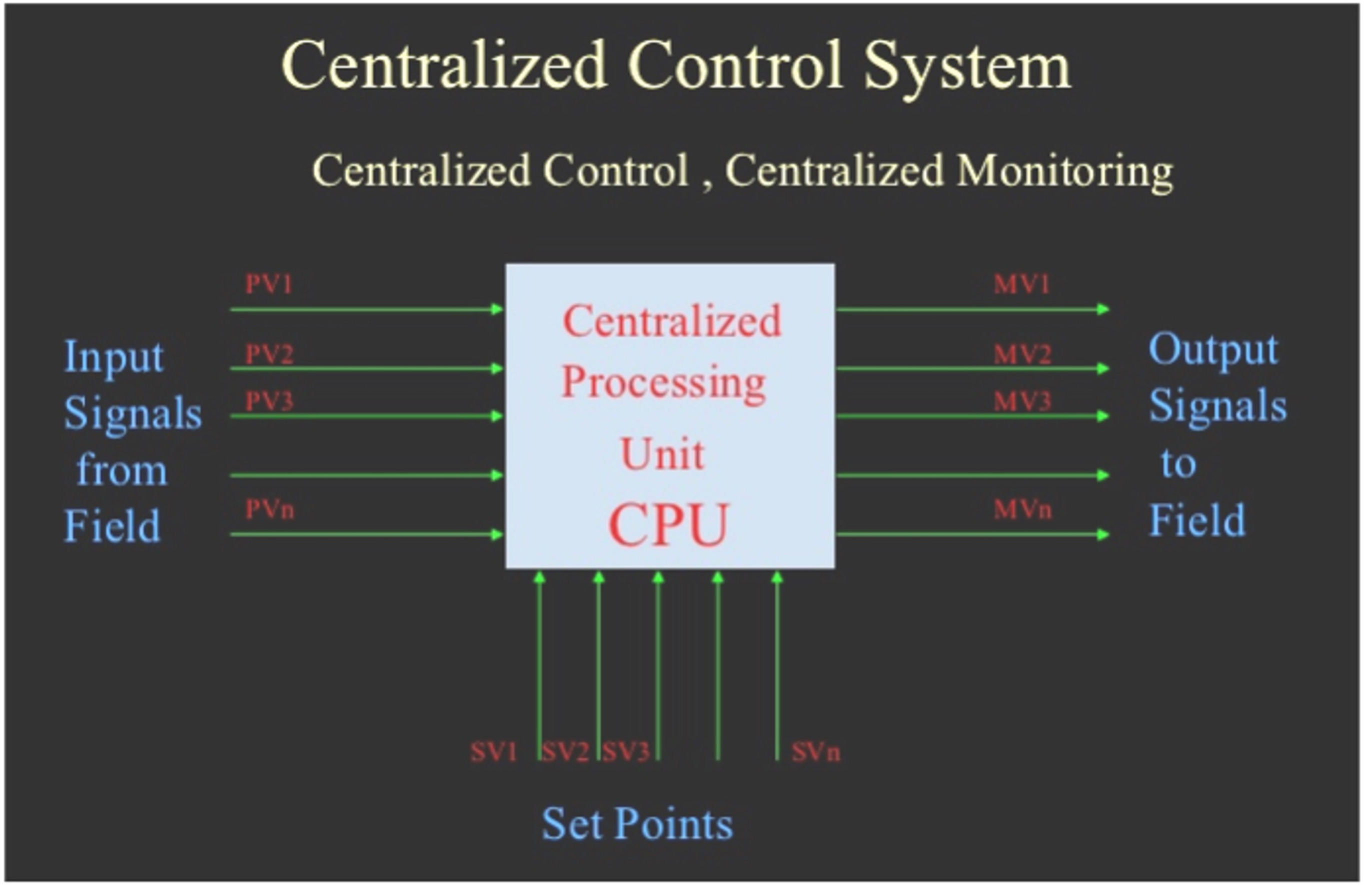
# Introduction to control techniques

Direct digital control- A single computer controls the entire process. It overcomes the interfacing problems but is vulnerable to failures and shut down

Hybrid control – An individual discrete-control hardware, typically PLCs or analog loop controllers to collect process information and generate reports

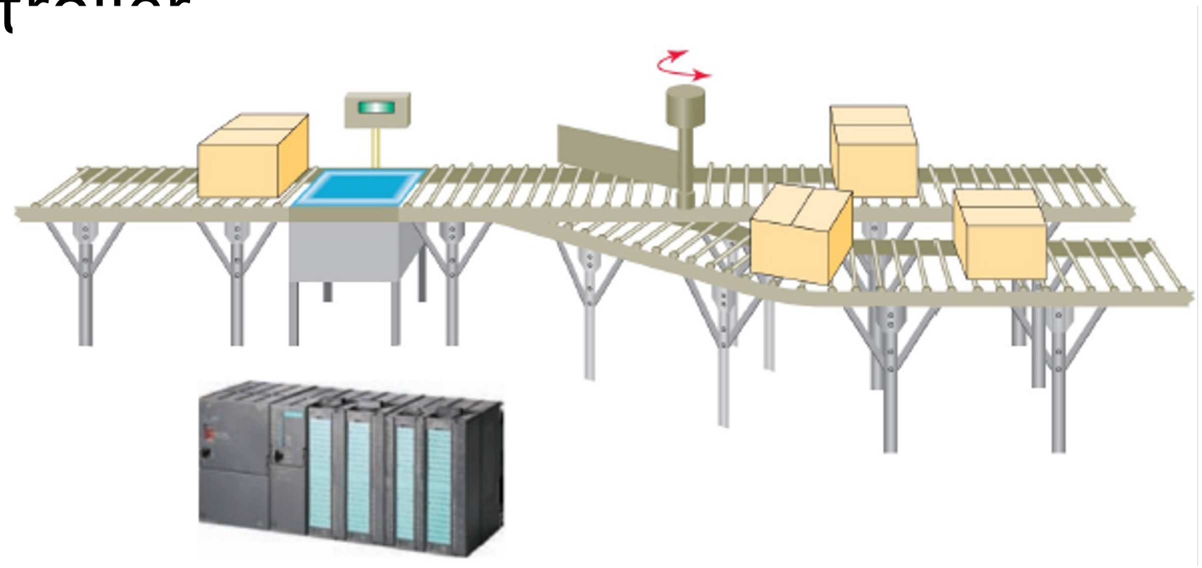
Distributed control - allows the application to be broken into subsystems that use digital, rather than analog, control techniques and that can be interfaced together easily.

# Centralized Control System(CCS)



# Centralized control

- Several machines/processes controlled by a central controller
- Control configuration to control diverse manufacturing process with help of a single controller



# Drawbacks of centralized control

All individual steps in the manufacturing process are handled by a stand-alone central controller

Simple to implement, monitor and troubleshoot

No exchange of controller status

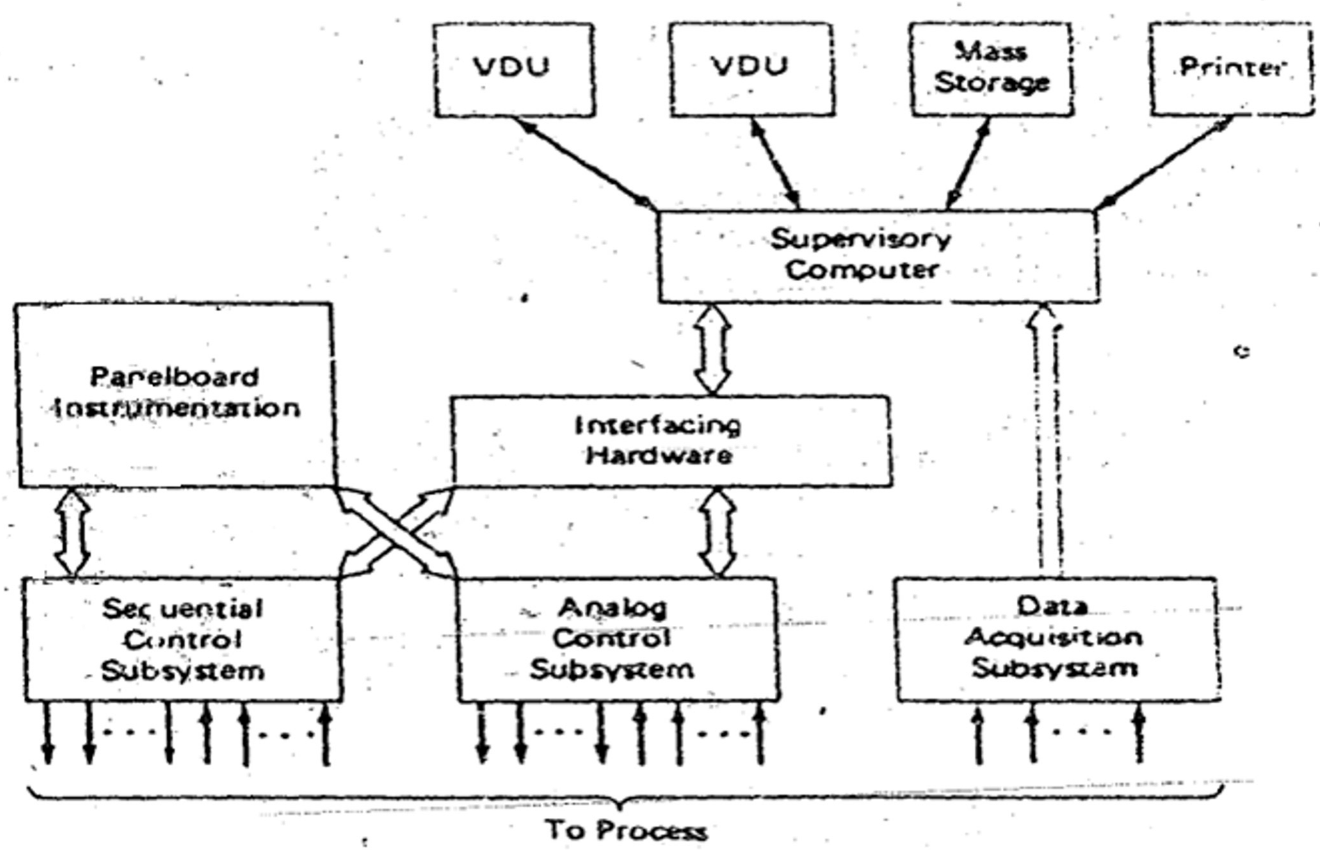
No exchange of data to other controllers

If the main controller fails, the whole process stops

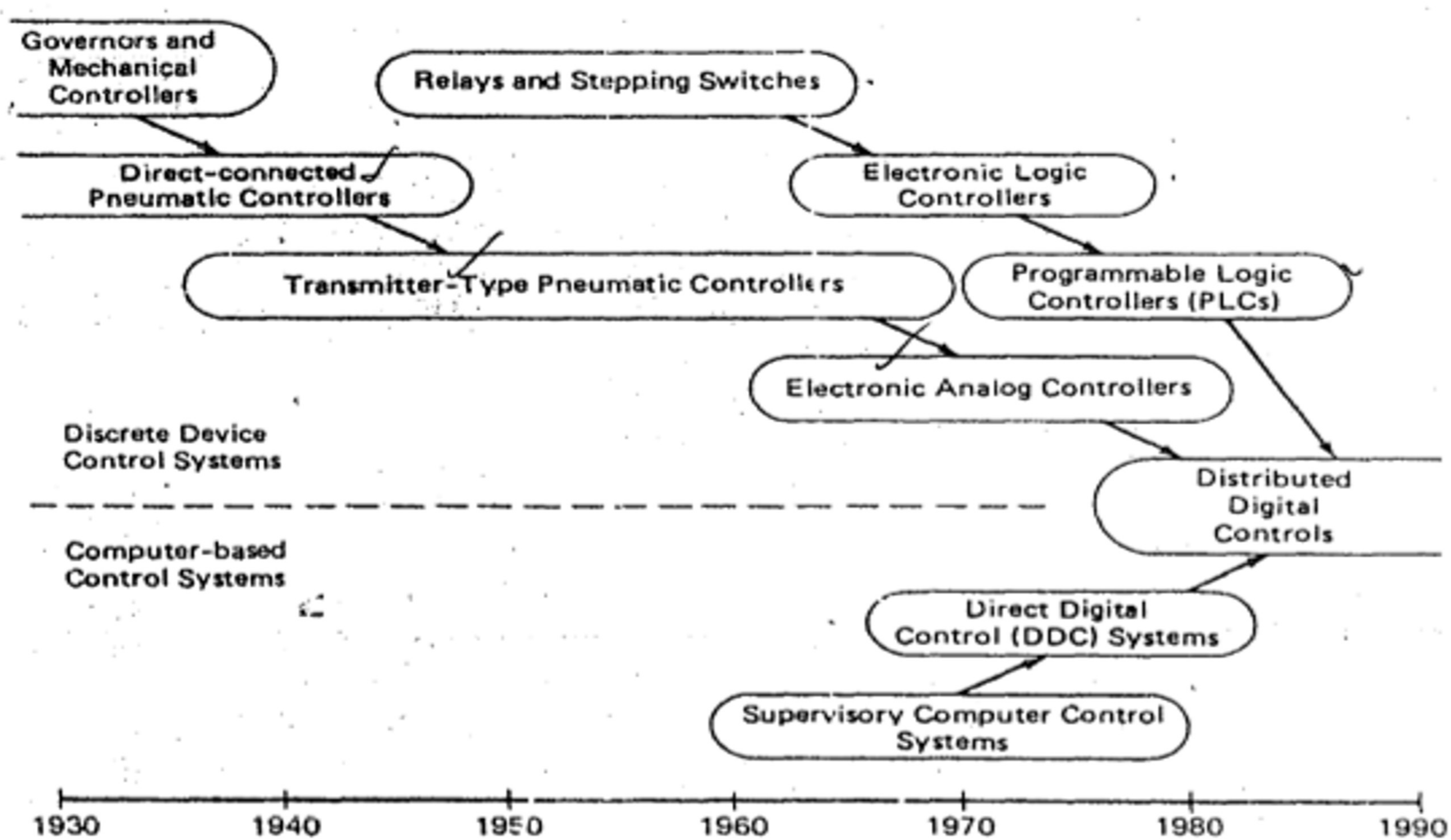
# Hybrid control system

- Combination of direct digital control and a central control hardware to implement control functions
- Local control of the plant is achieived by means of discrete analog controller
- A central monitoring system with SCADA for data logging, control, optimization & alarm management
- Dominated approach till 1970s in all industries
- Faced difficulties in maintenance of large volumes of data & centralized monitoring of complex industries

# Hybrid architecture

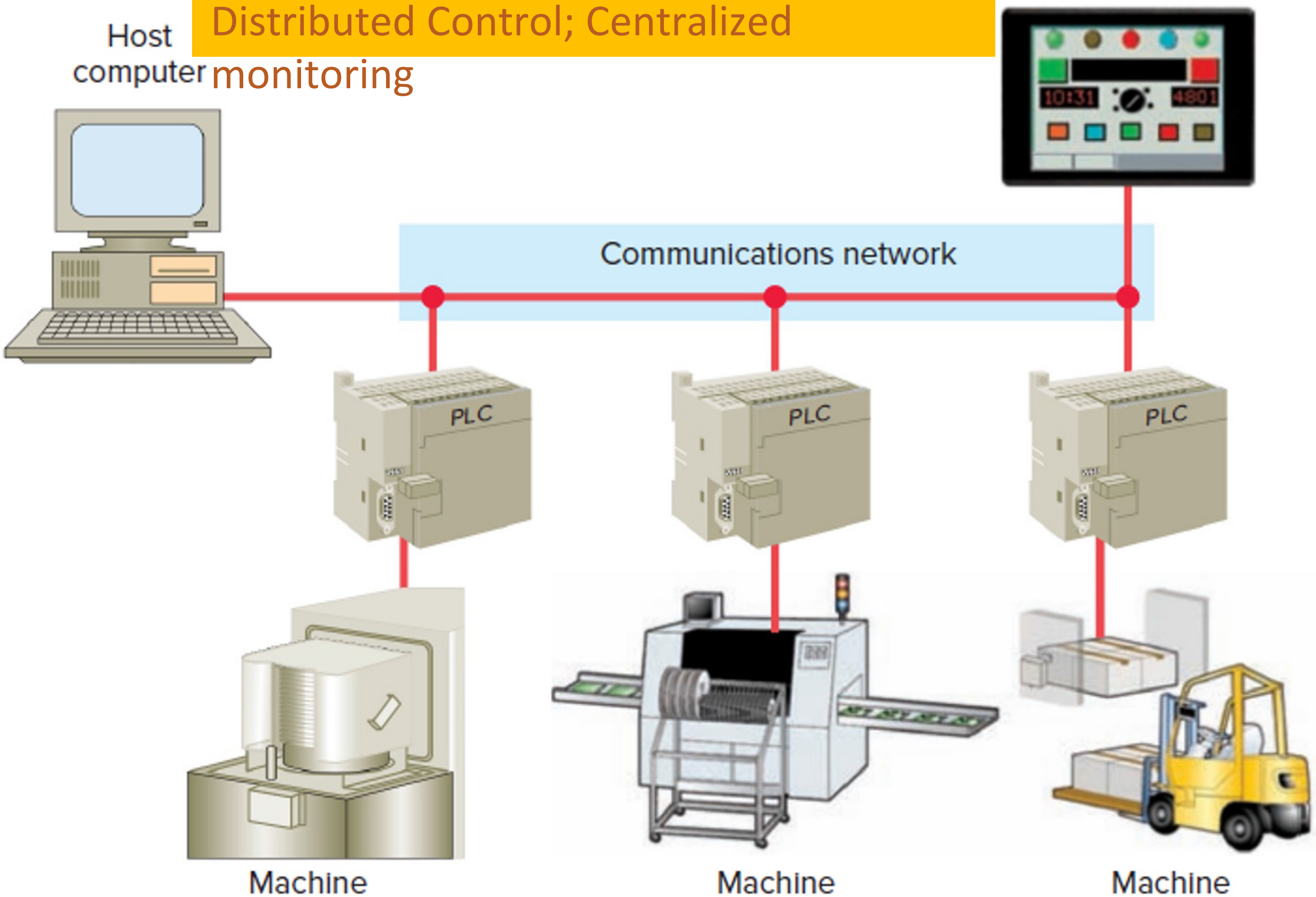


# Control architecture-Time line



# Evolution of Distributed Control System

Distributed Control; Centralized monitoring



# Need for distributed control

- Distributive control permits the distribution of the processing tasks among several controllers and is highly reliable.
- Distributive control drastically reduces field wiring and heightens performance because it places the controller and I/O close to the machine process being controlled.
- Depending on the process, one PLC failure would not necessarily halt the complete process.
- DCS is supervised by a host computer that may perform monitoring/supervising functions such as report generation and storage of data.

# Comparison between CCS and DCS

| Centralized control system | Distributed control system |
|---|---|
| Centralised repository | Distributed/ local repositories |
| Failure of central controller leads to shut down of the entire process | Distribution of the process tasks among several controllers saves from shut down |
| Less reliable | Highly reliable |
| Complexity in process dynamics and control affects the speed of operation | Improved speed of operation |
| Increased field wiring and hence difficult to troubleshoot | Reduced field wiring and so easier to troubleshoot |
| Need for dedicated communication links | Distributed communication highways |
| Low installation but high maintenance cost | High initial cost but low maintenance cost |
| No such centralised supervision of entire process | Supervision of entire process by means of SCADA software |

# DCS-Manufacturers

***Company***

*Centum (first DCS unit in the year1975)*

*ABB*

*Honeywell*

*Rockwell*

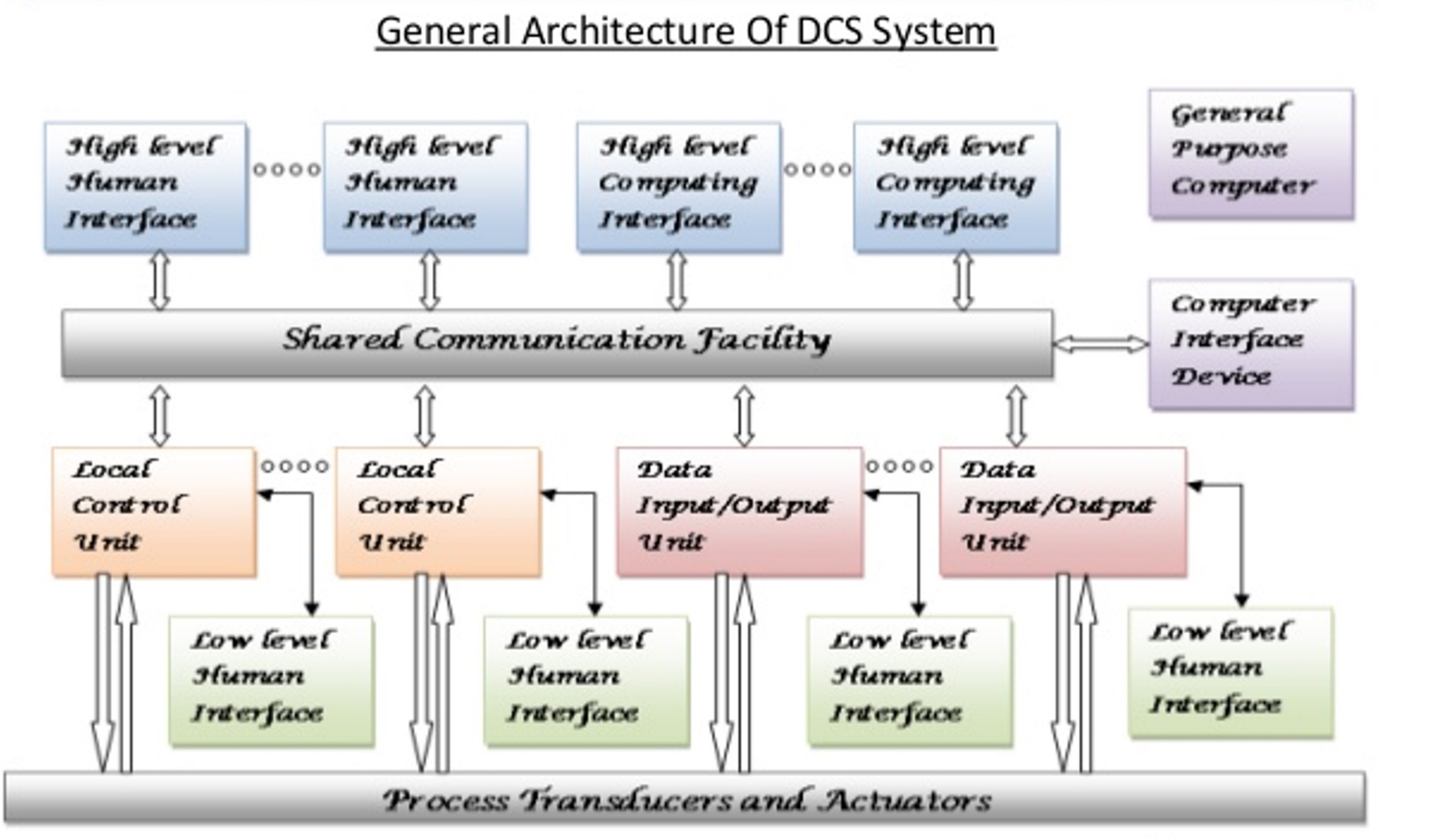
*Invensys*

*Siemens*

*Emerson*

*Yokogawa*

# DCS architecture



# DCS hardware

- Local control unit (LCU)
- Data I/O (DIO) modules
- Human Machine Interface (HMI)- low and high level
- Process interfacing
- Shared data communication
- Field level communication

# Local control Unit (LCU)

- Represents a smallest collection of hardware in the DCS setup that performs the closed loop control
- Takes inputs from field devices and sensors
- Processes commands given by the operator
- Controls the output to actuators-motors, solenoids etc.,
- Communication between other LCUs
- Stand alone operation during changeovers
- Changeover from Auto to manual and vice versa

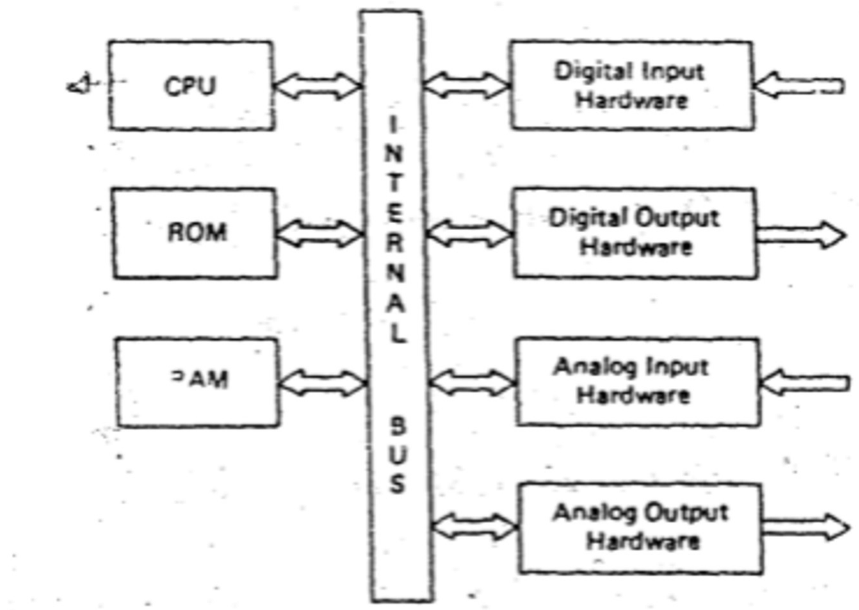
# Functions of LCU

It receives the instructions from the engineering station like set point and other parameters and directly controls field devices.

It can sense and control both analog and digital inputs/outputs by analog and digital I/O modules.

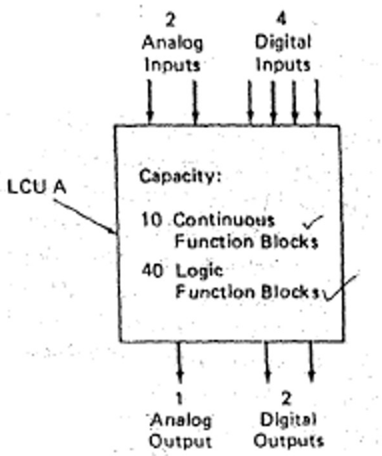
It collects the information from discrete field devices and sends this information to operating and engineering stations.

# Block diagram of LCU

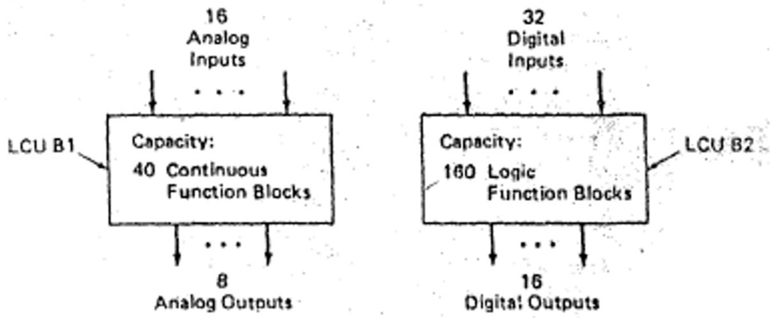


# LCU configurations-A,B,C

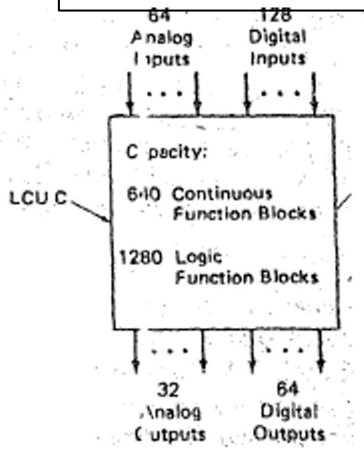
Configuration A




Configuration B




Configuration C



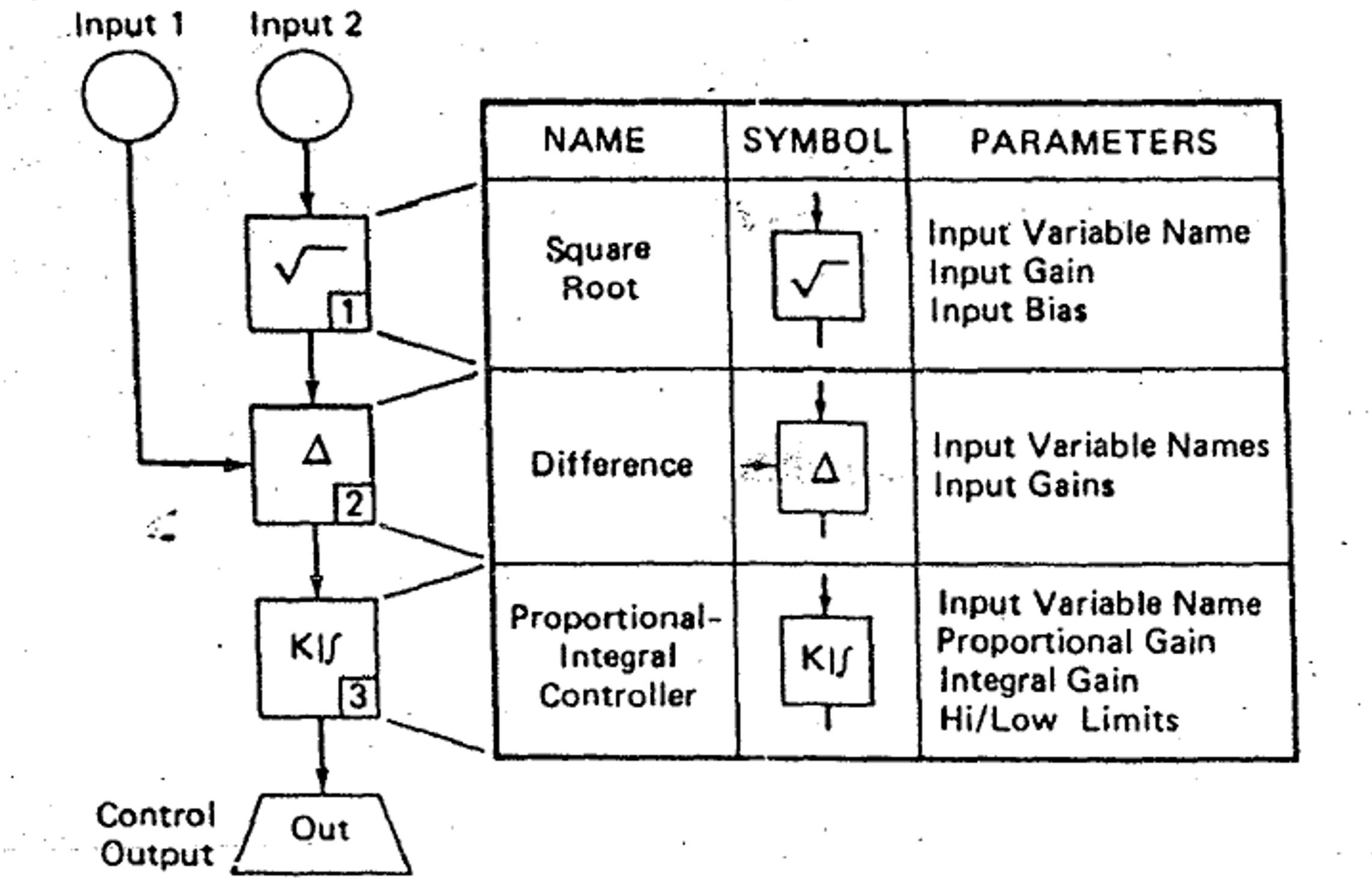
# Comparison of configurations

| Parameter | Configuration A | Configuration B | Configuration C |
|---|---|---|---|
| Controller size | Number of functions needed for single PID loop or motor controller. | Includes functions and I/O needed for eight control loops and a small logic controller. | System size is equivalent to small DDC system. |
| Controller functionality | Uses both continuous and logic function blocks. | Continuous and logic function blocks split between controllers. | Uses both continuous and logic function blocks; can support high-level languages. |
| Controller scalability | High degree of scalability from small to large systems | Requires both controller types even in small systems. | Not scalable to very small systems. |
| Controller performance | Requirements can be met with inexpensive hardware. | Because of functional split, performance requirements are not excessive. | Hardware must be high performance to execute large number of functions. |
| Communication channels | Need intermodule communications for control; only minimum needed for human interface. | Functional separation requires close interface between controller types. | Large communication requirement to human interface; minimal between controllers. |
| Controller output security | Controller has single-loop integrity; usually only manual backup is needed. | Lack of single-loop integrity requires redundancy in critical applications. | Size of controller requires redundancy in all applications. |

# Functional Blocks (FB)

- To enter the  control program and control system configuration in the processor memory of LCU
- High level (FORTRAN or BASIC) / block oriented
- Blocks with set of parameters can be sequentially connected to implement a particular process
- It overcomes the need to learn computer programming
- It also helps to avoid manual hardwiring as in the case of relay logic
- It helps in easy implementation of the changes to be made in configuration and troubleshooting
- Number of FBs used influences the size of the LCU

# Typical Functional blocks



# Functional Block Libraries

2 types of FB libraries:

- Complex FB library- for PID controller, sqrt etc.,
- Simple FB library- for single arithmetic/logic function
- Important factors to be considered- LCU utilization, Flexibility of modification, scalability and difficulty level of implementing algorithms
- Important functionalities in High level languages- Text editor, debugger and file manager

# Typical FB libraries

**COMPUTATIONAL FUNCTIONS**

Sum—2 input/4 input
Multiply
Divide
Square root
$y^x$, $e^x$
log x, ln x
Trigonometric
Generalized polynomial
Function generator
Two-dimensional interpolation
Matrix addition
Matrix multiplication

**CONTROL FUNCTIONS**

PID control
Pulse positioner
Adapt block
Smith predictor
General digital controller

**INTERMODULE COMMUNICATIONS**

Analog input (local/plant level)
Analog input list
Analog output (local/plant level)
Digital input (local/plant level)
Digital input list
Digital output (local/plant level)

**SIGNAL PROCESSING FUNCTIONS**

Integrator
Lead/lag
Moving average
Analog time delay
High/low limit
Rate limit

**SIGNAL STATUS FUNCTIONS**

High/low alarm
High/low select
Analog transfer
Digital transfer

**LOGIC FUNCTIONS**

AND
OR
Qualified OR
NOT
Latch
Digital timer
Up/down counter
Remote control latch
Pulse rate counter

**OPERATOR COMMUNICATIONS**

Control station
Indicator station
Cascade station
Ratio station

# LCU Architecture parameters

Size of the controller- Number of I/Os, processes and functional blocks that can be processed

Functionality- Analog/ Digital, Continuous/ Discrete

Performance – Speed of performance, accuracy, scanning rate etc.,

Communication channels- PC-PC communication, Interface devices, field level communication etc.,

Output security- Fail safe operation, manual or auto backup, frequency of backup and routine checks

# Human Machine Interface

Effective Control and visualization of the process

Electronic interfacing between human and the process to control monitor and diagnose processes

Graphical user interface to check:

- Operation summary- routine monitoring of process
- Configuration/setup- Control configuration and parametric values
- Event history-Time stamped list of all significant events
- Auto/manual changeover – Bypass control during shutdown/maintenance
- Trend values – Flow, pressure, temperatures as a function of time
- Diagnostics –cause and occurrence of failures

# Interfacing requirements

Communication Interfaces are needed in order to:

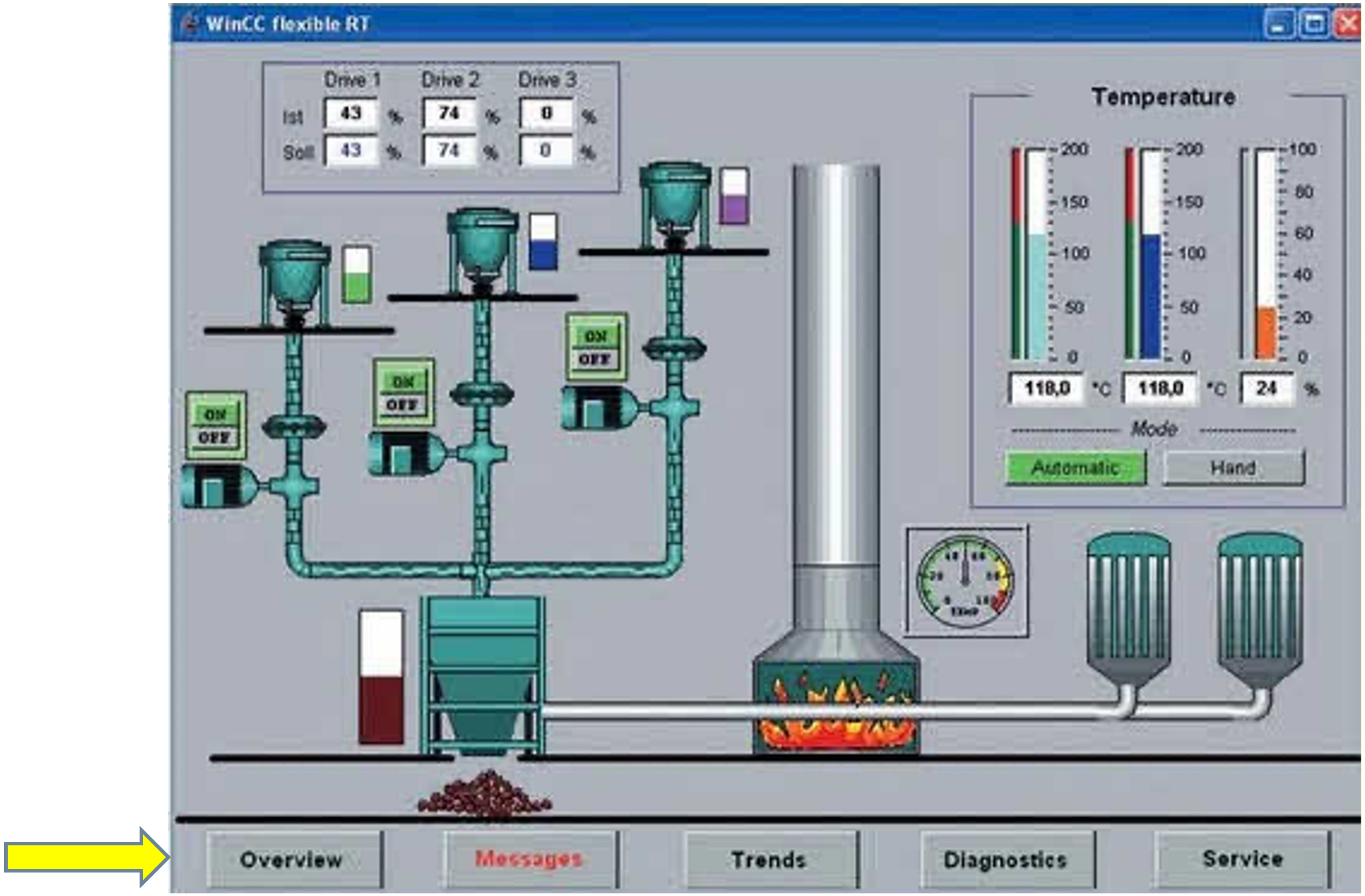
- Establish communication between LCUs
- Allow transmission of process data to higher level elements
- Transmit information command and requests to LCUs
- Augment I/O capacity of LCU to DI/Ous
- Implement redundancy operation of one or more LCUs

# Reliable interfacing

For maximum reliability,

- Minimise the number of components and electrical connections
- Current value of output should be indicated to the LCUs
- Powering the output circuitry from an independent supply to avoid loss of data
- Analog output device should be able to indicate “last minimum output” “last maximum output” “ go to last output”

# Sophisticated HMI

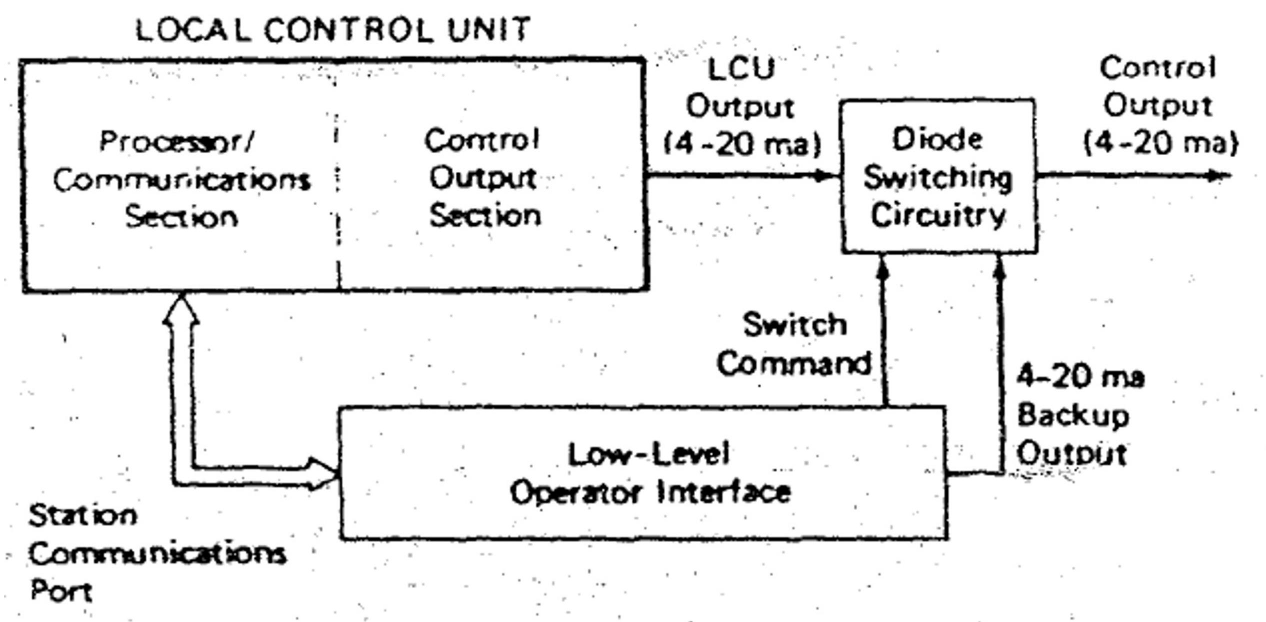


# High Level User Interface

- Interfacing with the process
- Real time control
- Interfacing with other elements in DCS
- Security features required for process application
- Supporting utilities
- Modifying the program

# Low level User Interface

- Field devices communication
- Directly communicates with LCU
- Plant operator can directly configure controller, switch control operation and override (Auto/Manual) control



# DI/OU modules

A Microprocessor based data acquisition unit meant for receiving and generating inputs and outputs

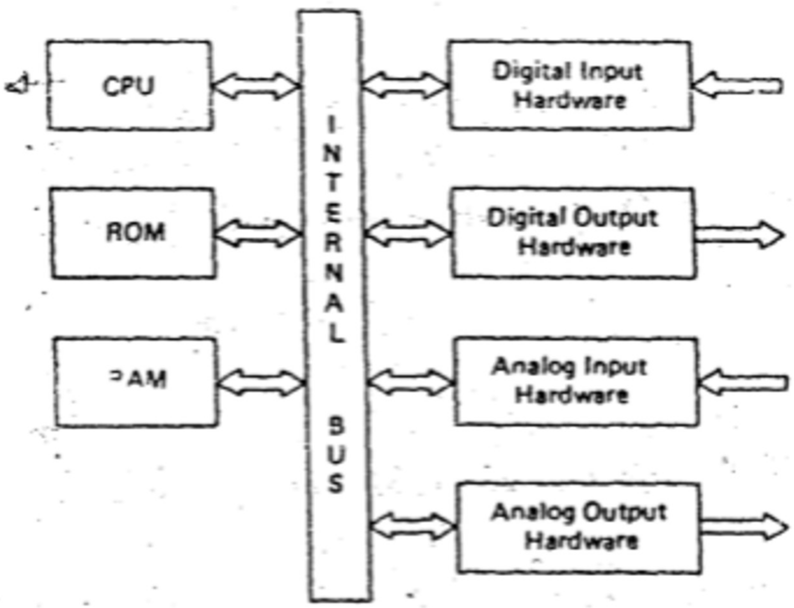
It can be used as an auxilliary unit capable of handling multiple I/Os (not possible with LCUs)

Adds up to the installation and maintenance cost

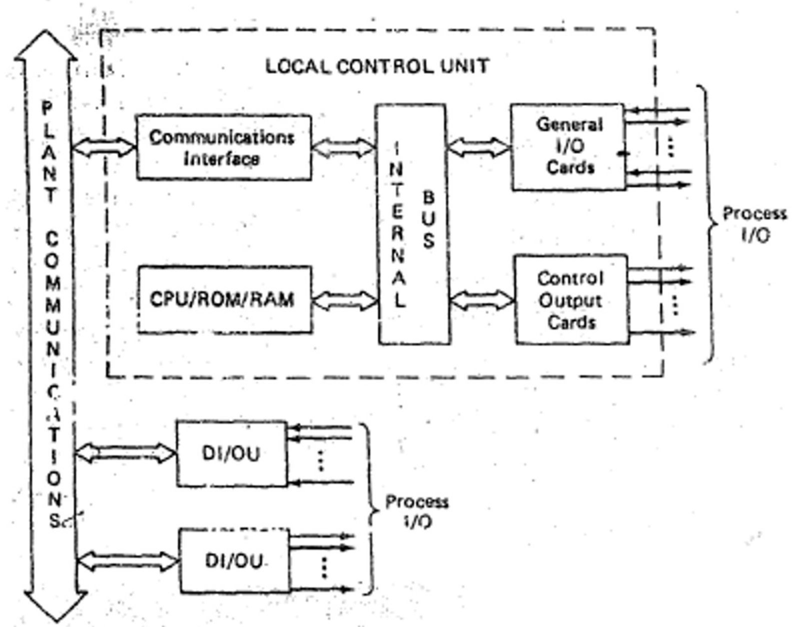
Similar to LCU but differs in two ways:

- Lack of security features
- No control but only data acquisition

# DI/OU Block diagram




Single loop controller




Multi loop controller

# Security features

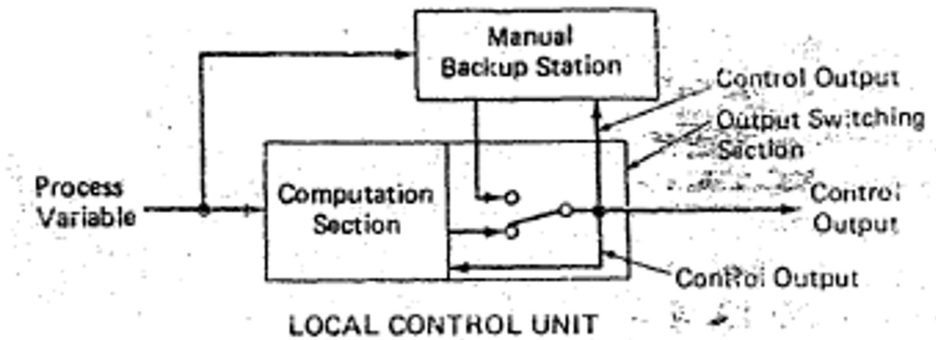
Objectives- safe transmission, Auto/manual switch over during shutdown and fail-safe operations

Three security design approaches:

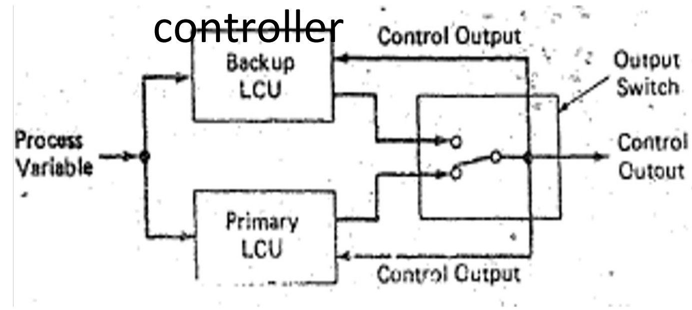
- Manual backup only- Operator can take manual control and link inactive LCU with active ones
- Standby redundant controller – One LCU acts as master, remaining are redundant -bumpless transfer
- Multiple active controllers- Multiple LCUs active at a time for control operation-decision by polling

# Security design approaches

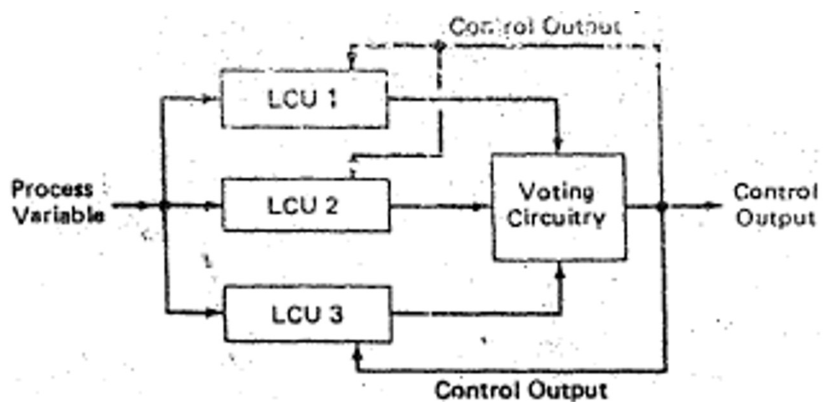
(i) Manual backup




(ii) Redundant controller




(iii) Multiple active LCUs



# Online diagnostics

Frequency of diagnostics- during start up, at regular intervals and upon occurrence of failure

Onset of failure/shutdown, the LCU

- should communicate the failure to LL and HL interfaces
- should initiate hardware failure indicator/alarm
- should be able to trigger internal process fail safe sequence and isolate the process
- Safety precaution operations to shut down in orderly way

# Types of online diagnostics

| DIAGNOSTIC TYPE | NAME | DESCRIPTION | WHEN PERFORMED | ACTION ON FAILURE |
|---|---|---|---|---|
| Input diagnostics | A/D converter check | Processor applies known zero and span voltages to converter and uses measurements to correct for input errors. | Periodically during operation | If correction becomes too great, sets alarm and shuts converter down. |
| | Sensor out of range check | Processor checks that input from sensor is in acceptable range. | Every input scan | Declares sensor input to have bad quality. |
| | Excessive rate of change check | Processor checks that time rate of change of input from sensor is in acceptable range. | During operation | Declares sensor input to have bad quality. |
| | Open T/C detection | Processor checks thermocouple for open circuit using standard methods. | During operation | Declares T/C input to have bad quality. |
| Configuration diagnostics | I/O hardware check | Processor checks that selected I/O hardware options are present. | At startup | Alarms and shuts LCU down. |
| | Memory check | Processor checks that selected memory options are present. | At startup | Alarms and shuts LCU down. |
| Memory diagnostics | ROM/EAROM sumcheck | Processor compares the computed sum of the contents of memory with the prestored correct value. | Periodically during Operation | Alarms a ROM failure and shuts LCU down. |
| | RAM test | Processor writes a known pattern into RAM, then reads back and checks the results. | At startup | Alarms a RAM failure and shuts LCU down. |

# Types of online diagnostics

| | | | | |
|---|---|---|---|---|
| Output diagnostics | D/A converter check | Processor writes a known value to the D/A converter, reads it back through analog channel, and compares results. | Periodically during operation | If error becomes too great, sets alarm and shuts converter down. |
| | Output register check | Processor writes a known number to the D/A converter and reads digital value back to verify number. | During operation | Sets alarm and shuts converter down. |
| End-to-end processor/ memory diagnostic | Test problem | Processor executes a test control or arithmetic algorithm, then compares results with prestored answer. | At startup | Sets alarm and shuts LCU down. |
| External hardware check | Watchdog timer | Processor sets an external timer periodically to confirm proper operation. | Periodically during operation | Timer hardware shuts LCU down. |
| Power system diagnostics | Voltage monitor | Processor uses external hardware to monitor the voltages generated by the LCU power supply. | Continuously during operation | Alarms power supply failure and shuts LCU down. |

# Redundancy concept

One-on-one

One-on-many

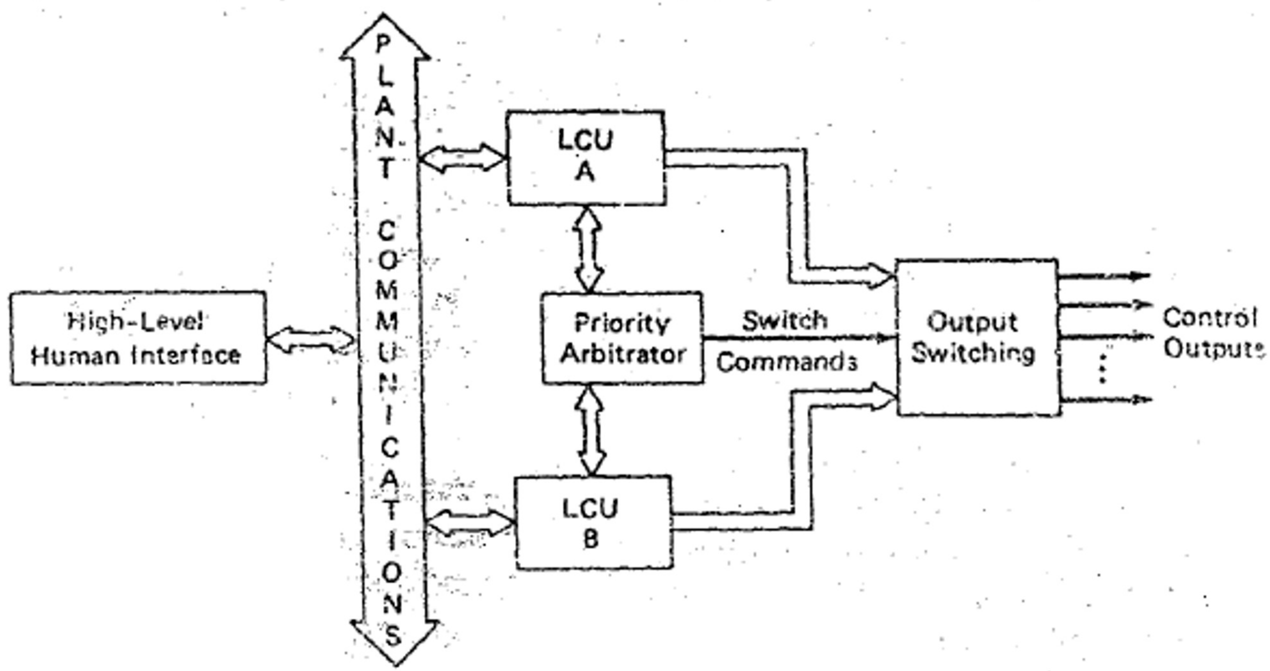
Multiple active

# One on one redundancy

Total backup of LCU configurations to primary LCU

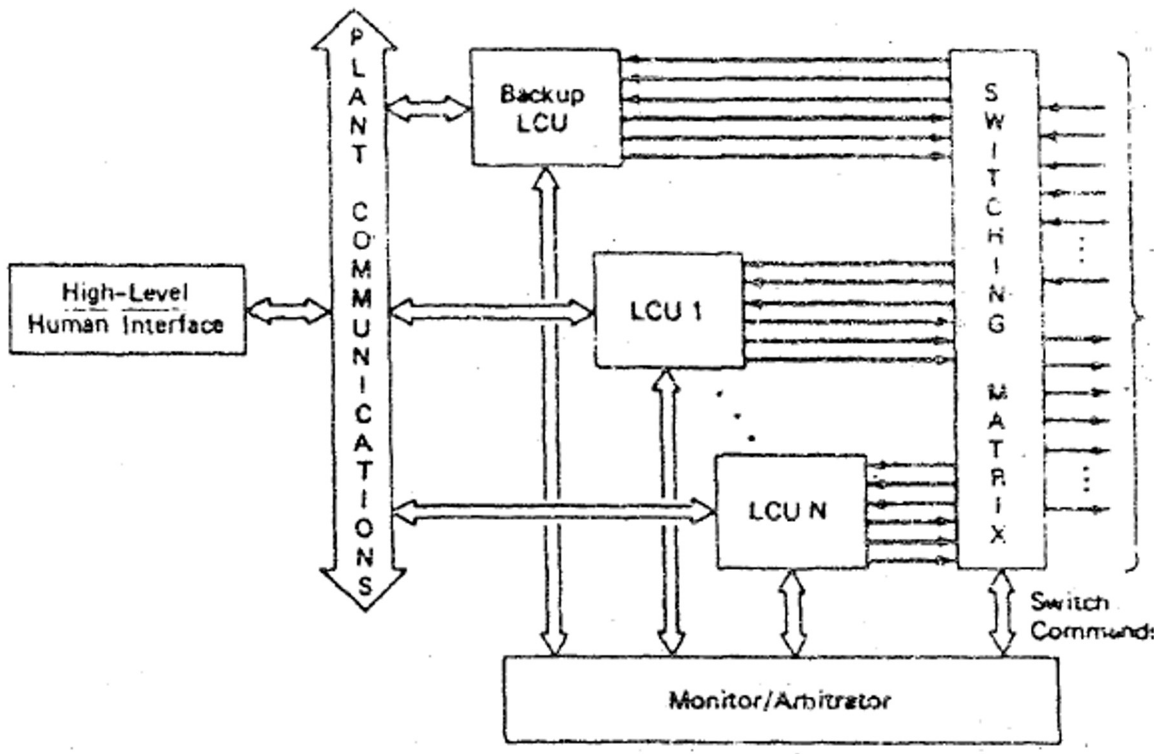
No manual back up needed

But expensive approach as all of the LCU elements needs to be duplicated and the redundant one has be safeguarded and has potential single point failure problems



# One on many redundancy

- Cost effective approach – single LCU is used as standby to backup any one of the several LCUs
- Switching matrix essential, complex and so careful design needed
- An arbitrator should carry the information regarding the LCU



# Comparison of architectures

| Feature | Hybrid control | Centralized control | Distributed control |
|---|---|---|---|
| 1. Scalability and expandability | Good due to modularity | Poor—very limited range of system size | Good due to modularity |
| 2. Control capability | Limited by analog and sequential control hardware | Full digital control capability | Full digital control capability |
| 3. Operator interfacing capability | Limited by panelboard instrumentation | Digital hardware provides significant improvement for large systems | Digital hardware provides improvement for full range of system sizes |
| 4. Integration of system functions | Poor due to variety of products | All functions performed by central computer | Functions integrated in a family of products |
| 5. Significance of single-point failure | Low due to modularity | High | Low due to modularity |
| 6. Installation costs | High due to discrete wiring and large volume of equipment | Medium—saves control room and equipment room space but uses discrete wiring | Low—savings in both wiring costs and equipment space |
| 7. Maintainability | Poor—many module types, few diagnostics | Medium—requires highly trained computer maintenance personnel | Excellent—automatic diagnostics and module replacement |

# References

## Book references:


*Krishna Kant, Computer Based Industrial Control, Second edition, Prentice Hall of India, New Delhi,2015*

*Michael P Lukas, Distributed Control Sytems- their evaluation and design, Van Nostrand Reinhold company, USA, 1986*


## Video references:

Introduction to DCS

https://www.youtube.com/watch?v=jXRksET5vNo

Difference Between PLC and DCS

https://www.youtube.com/watch?v=iF99iKlDpxA