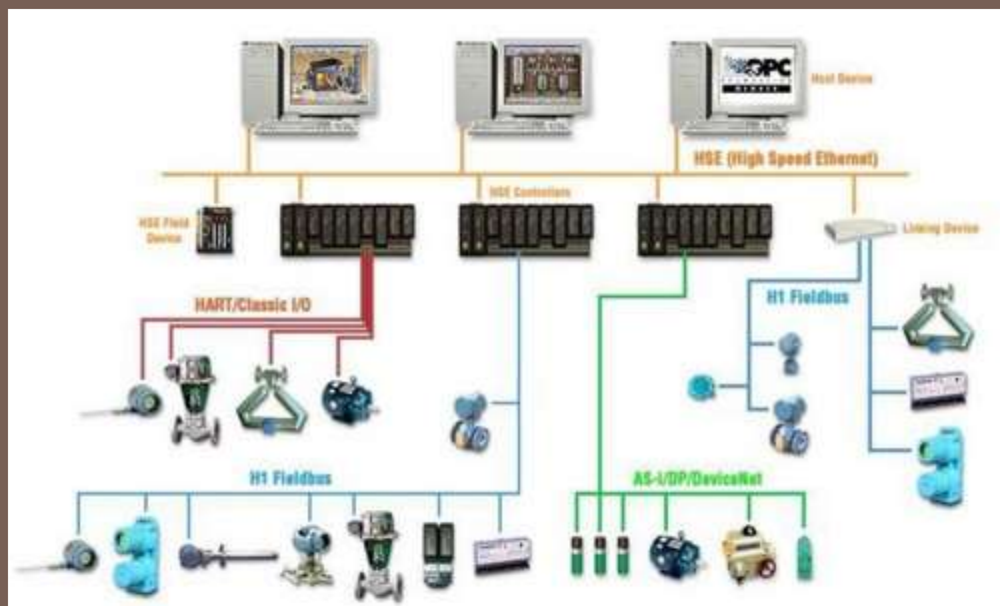
18ECO134T- INDUSTRIAL AUTOMATION

UNIT - 3

Distributed Control system (DCS)

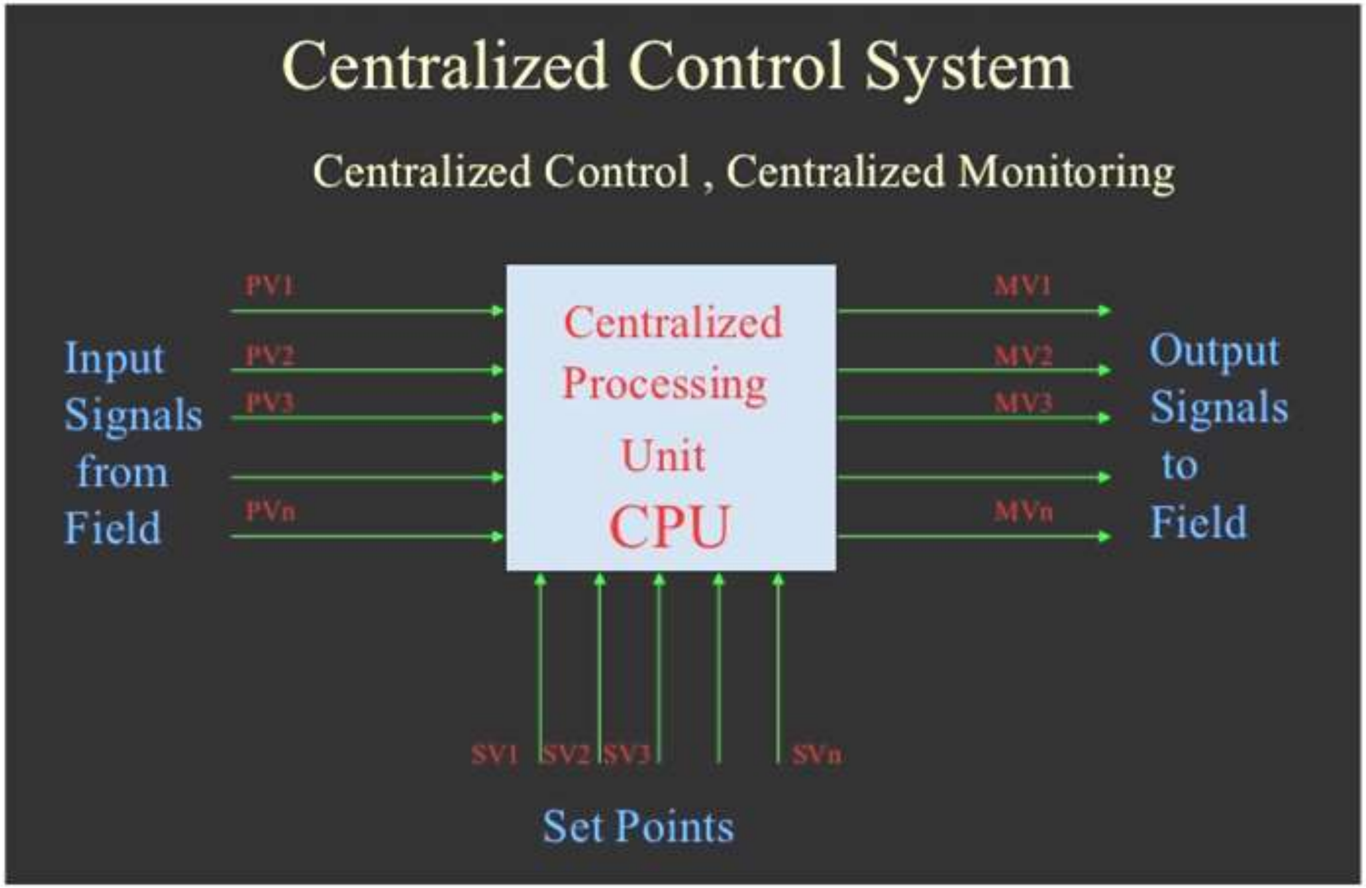


Contents

Introduction to control techniques

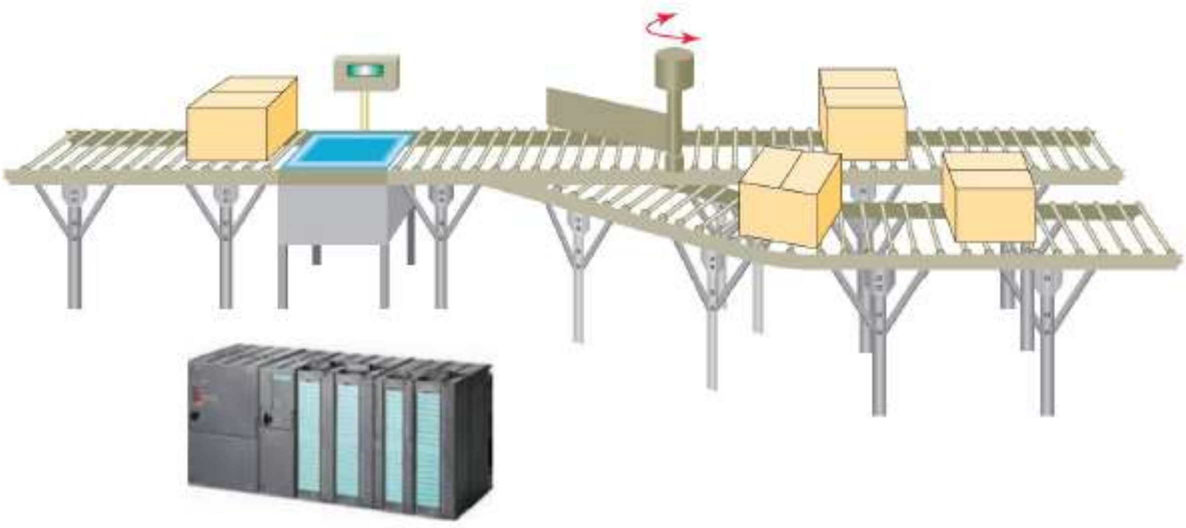
- Direct digital control- A single computer controls the entire process. It overcomes the interfacing problems but is vulnerable to failures and shut down
- Hybrid control – An individual discrete-control hardware, typically PLCs or analog loop controllers to collect process information and generate 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



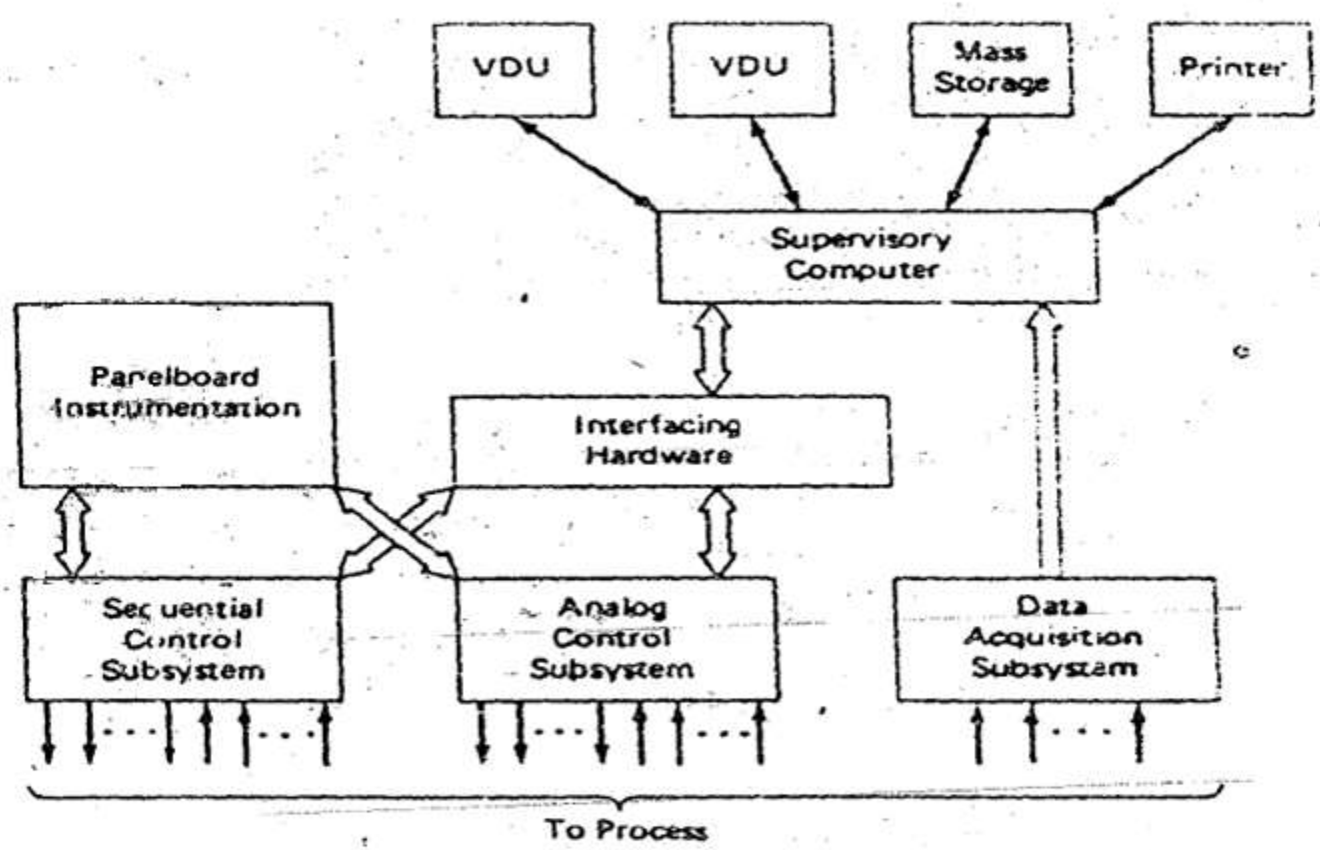
Drawbacks of centralized control

- 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

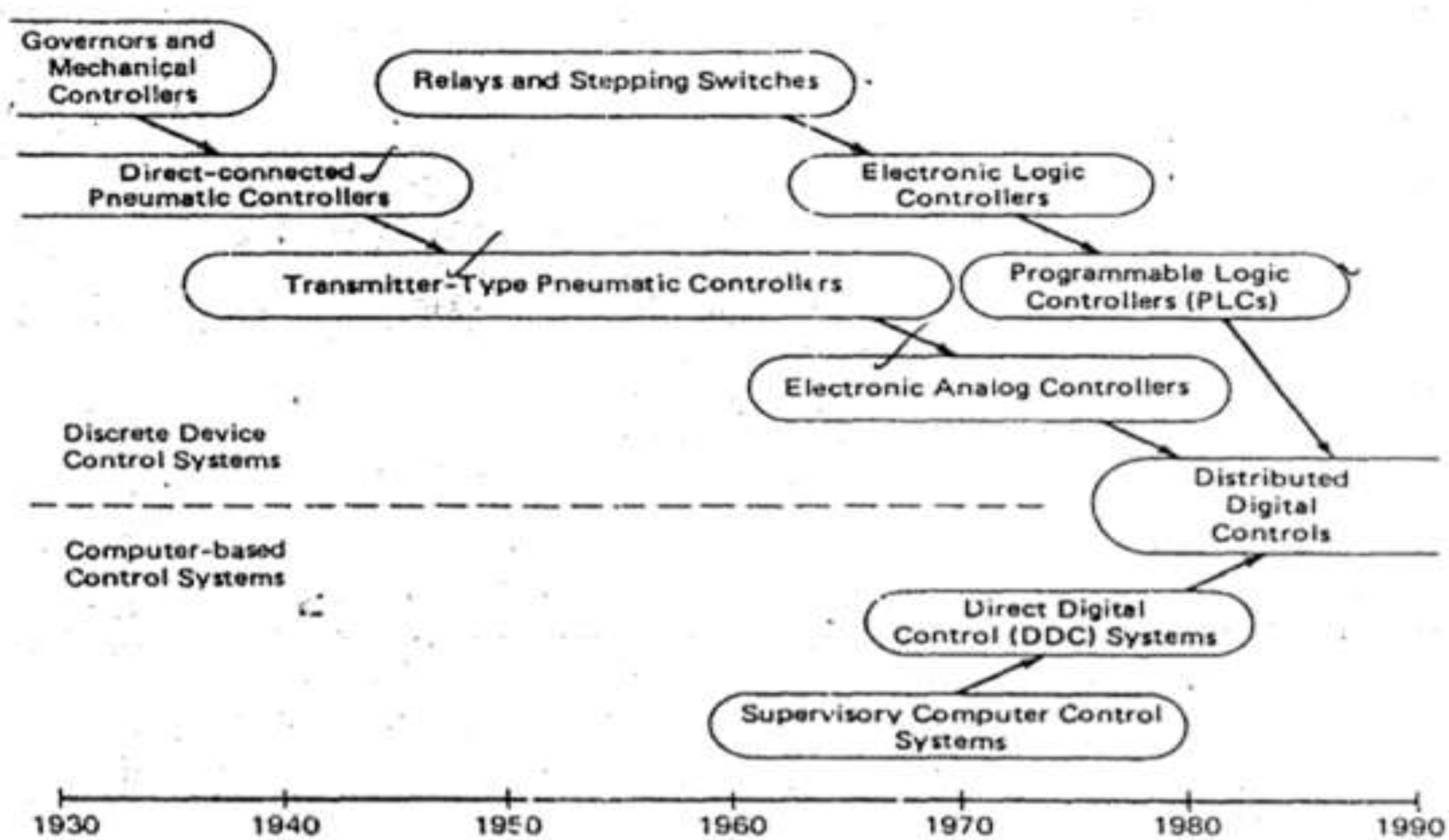
Hybrid control system

- Combination of direct digital control and a central control hardware to implement control functions
- Local control of the plant is achieieved 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

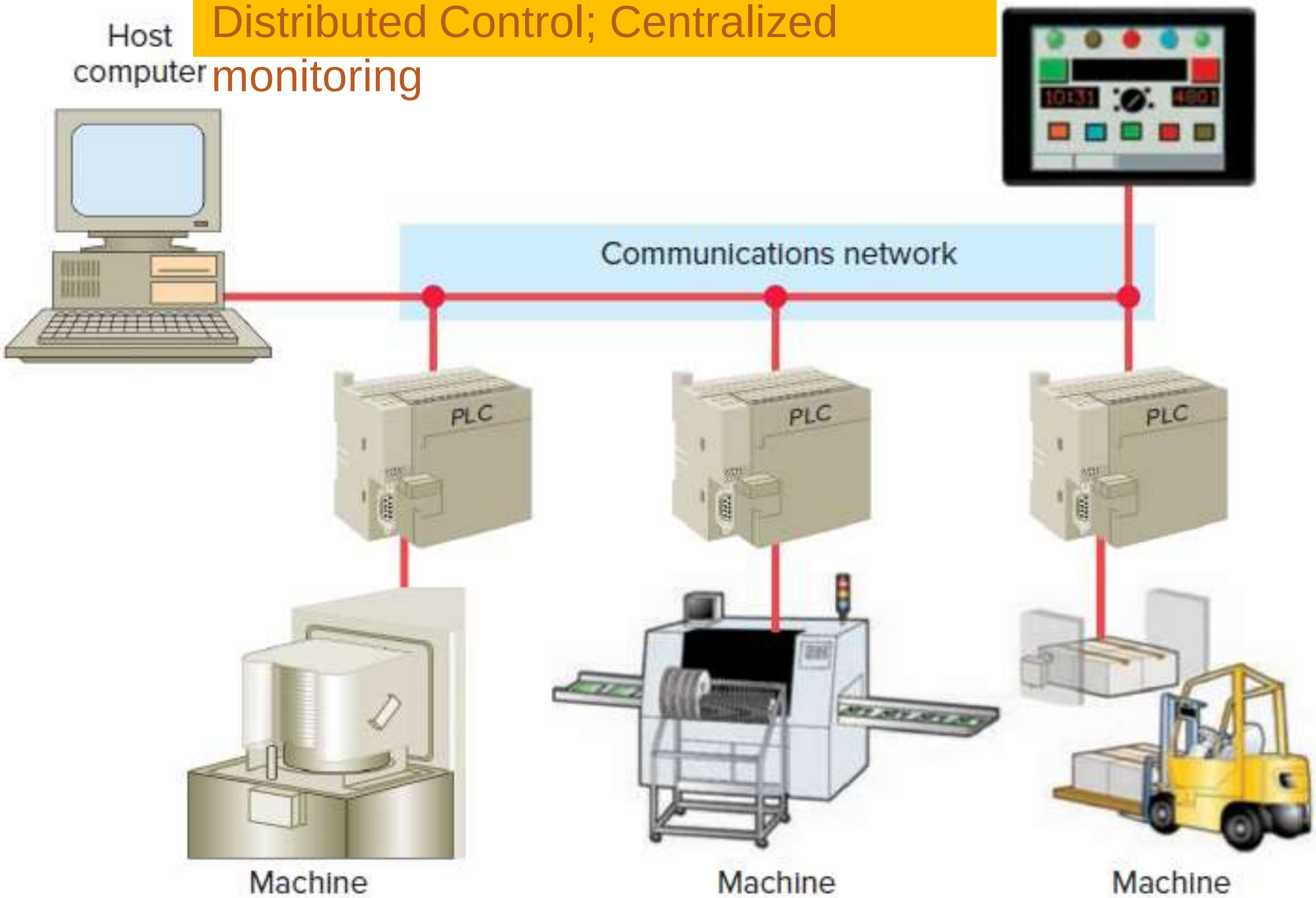


Control architecture-Time line



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

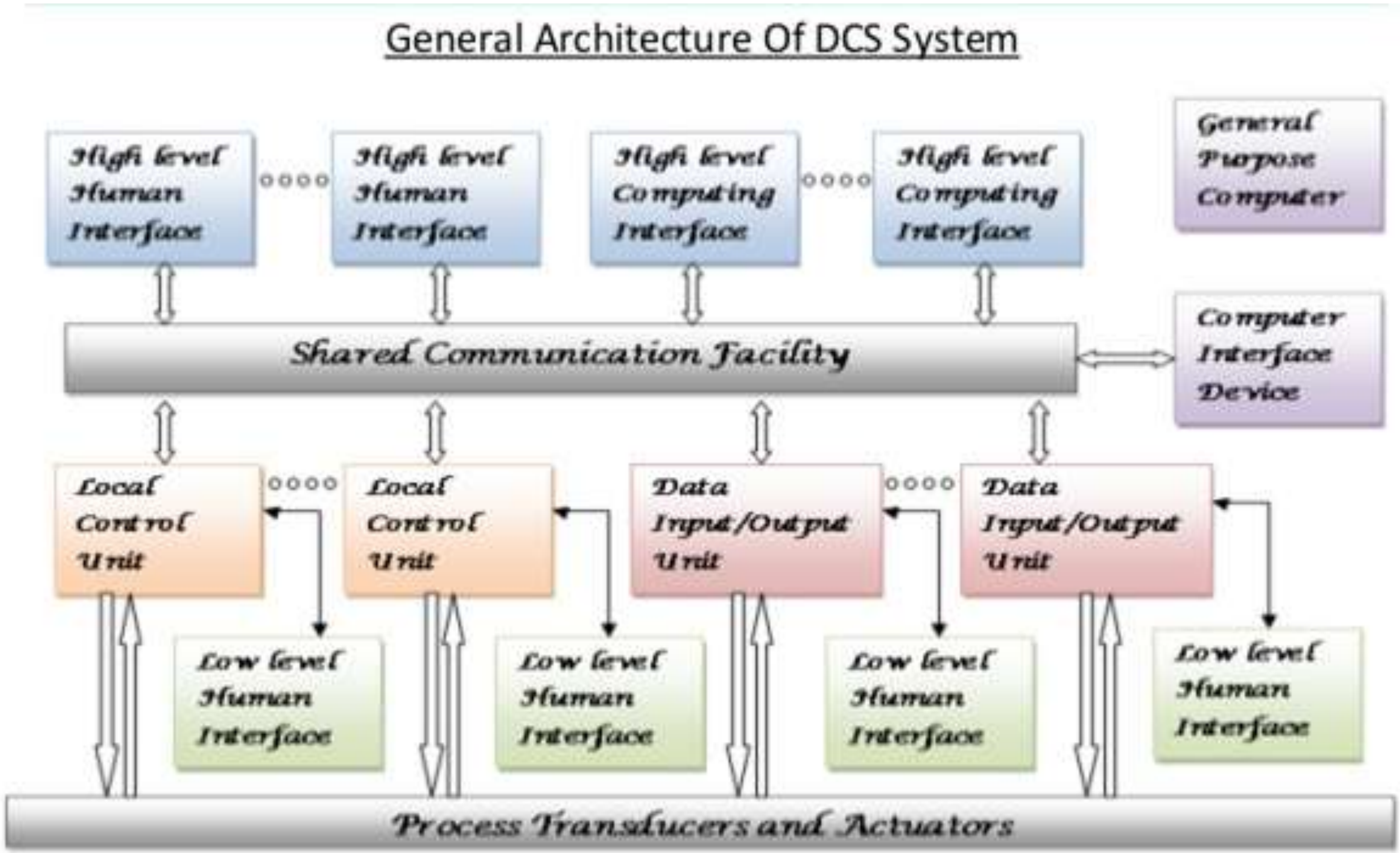
Centralized control system	Distributed control system
Centralised repository	Distributed/ local repositories
Failure of central controller leads to shut down of the entire process	Distribution of the process tasks among several controllers saves from shut down
Less reliable	Highly reliable
Complexity 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

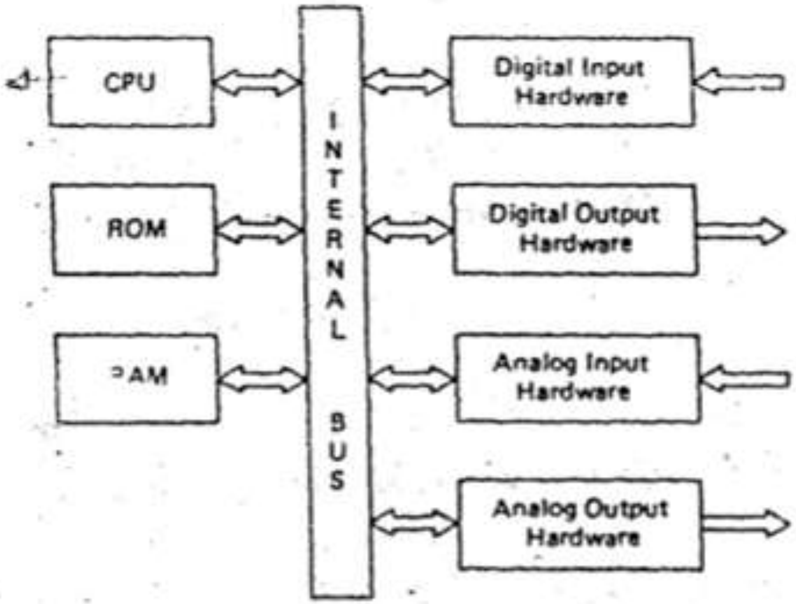
Functions of LCU

- 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.

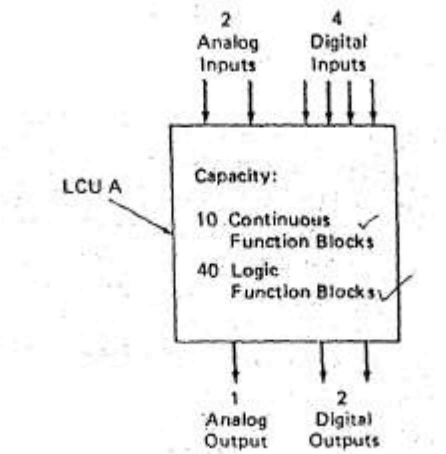
- It collects the information from discrete field devices and sends this information to operating and engineering stations.

Block diagram of LCU

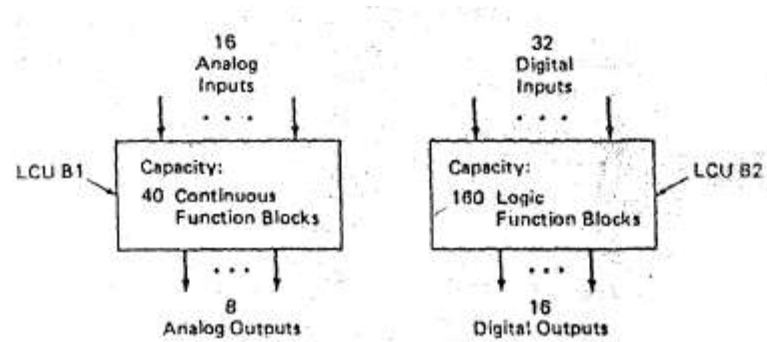


LCU configurations-A,B,C

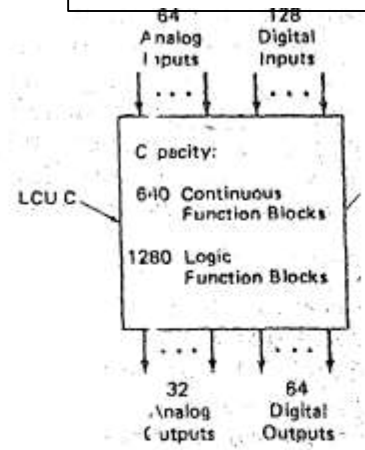
Configuration A



Configuration B



Configuration C



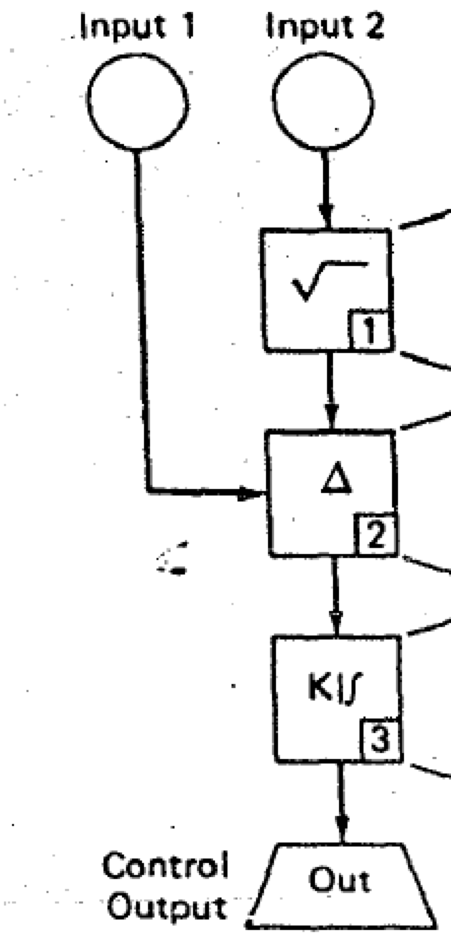
Comparison of configurations

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



NAME	SYMBOL	PARAMETERS
Square Root	√	Input Variable Name Input Gain Input Bias
Difference	Δ	Input Variable Names Input Gains
Proportional-Integral Controller	K|∫	Input Variable Name Proportional Gain Integral Gain Hi/Low Limits

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

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

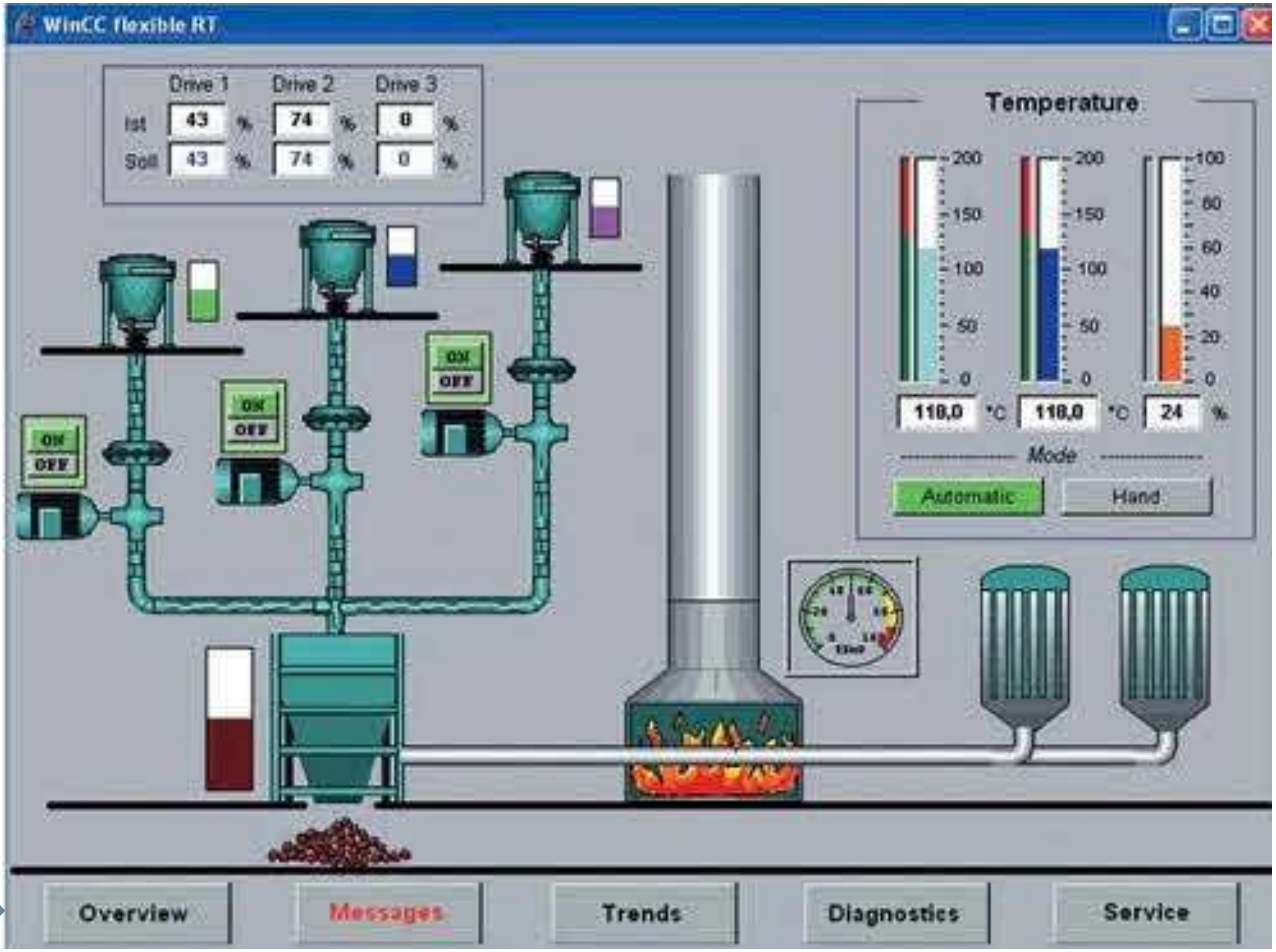
Interfacing requirements

- 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

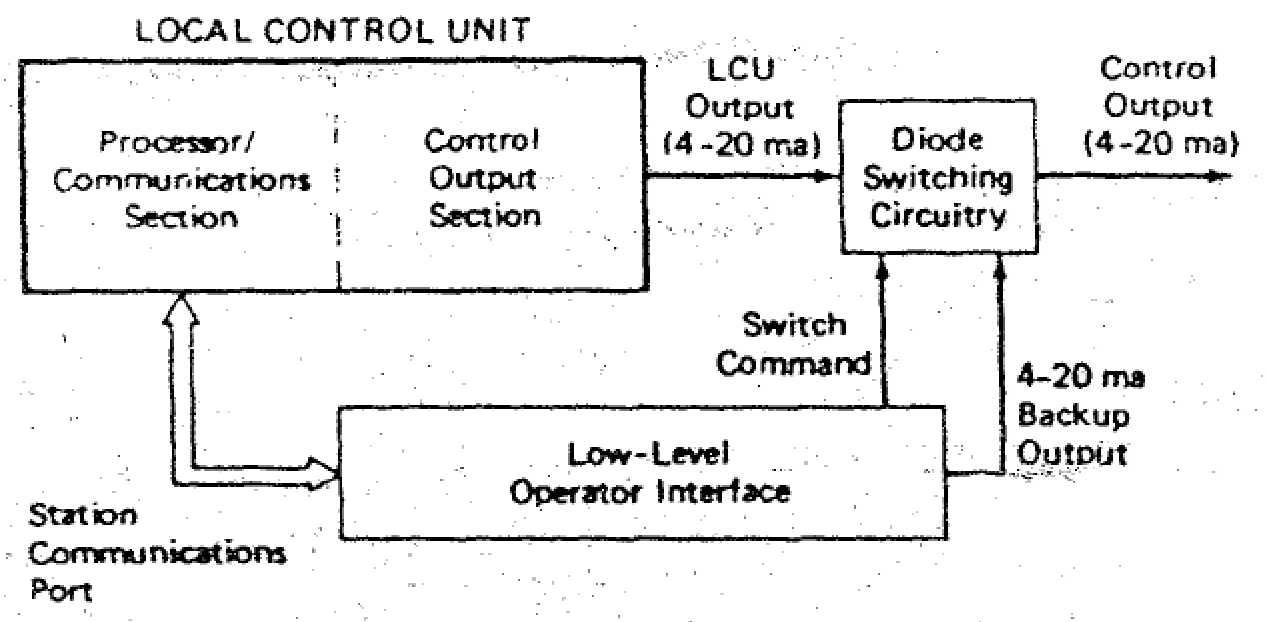


High Level User Interface

- 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

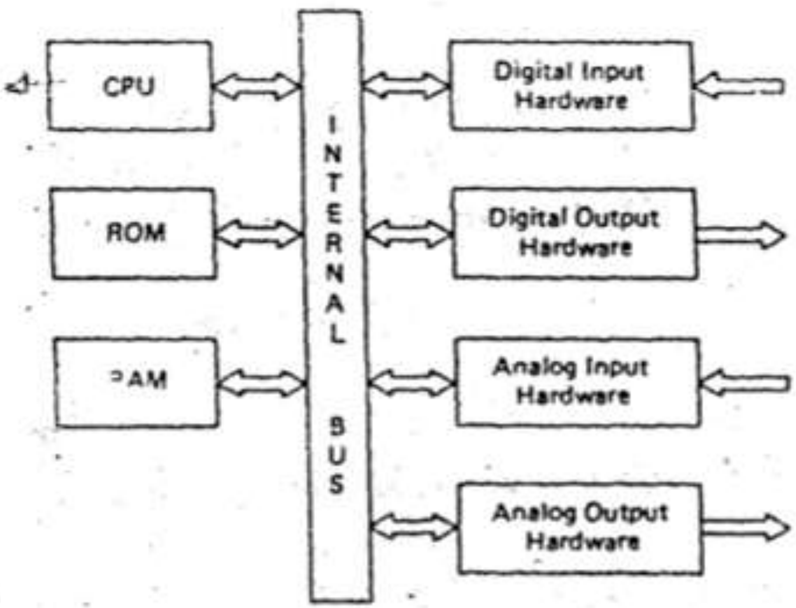
- Field devices communication
- Directly communicates with LCU
- Plant operator can directly configure controller, switch control operation and override (Auto/Manual) control



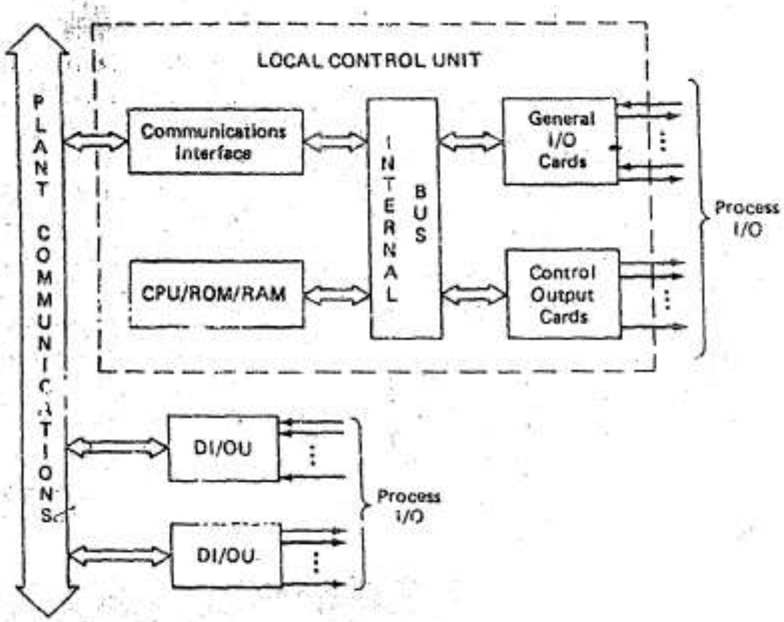
DI/OU modules

- 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



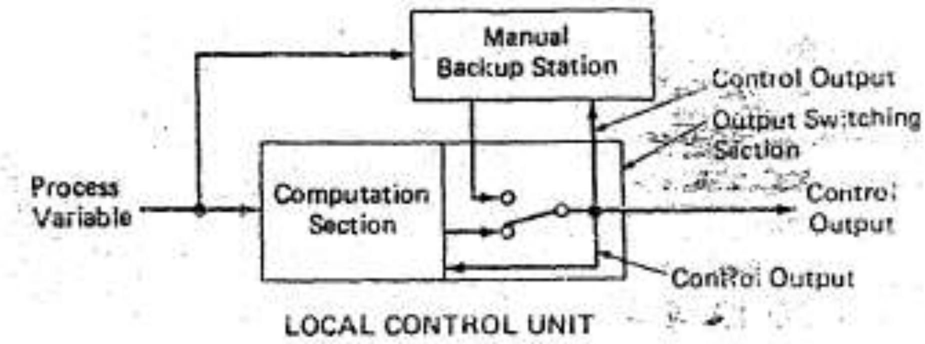
Multi loop controller

Security features

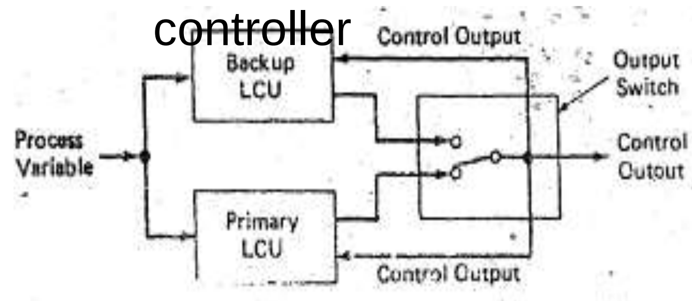
- Objectives- safe transmission, Auto/manual switch over during shutdown and fail-safe operations
- Three security design approaches:
  - Manual backup only- Operator can take manual control and link inactive LCU with active ones
  - Standby redundant controller – One LCU acts as master, remaining are redundant -bumpless transfer
  - Multiple active controllers- Multiple LCUs active at a time for control operation-decision by polling

Security design approaches

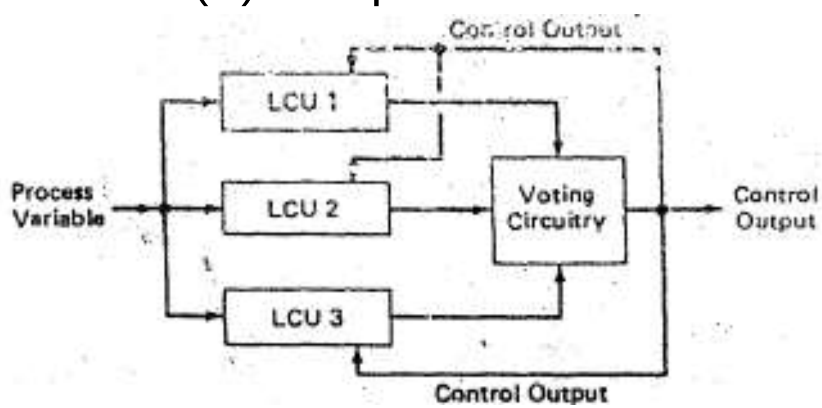
(i) Manual backup



(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

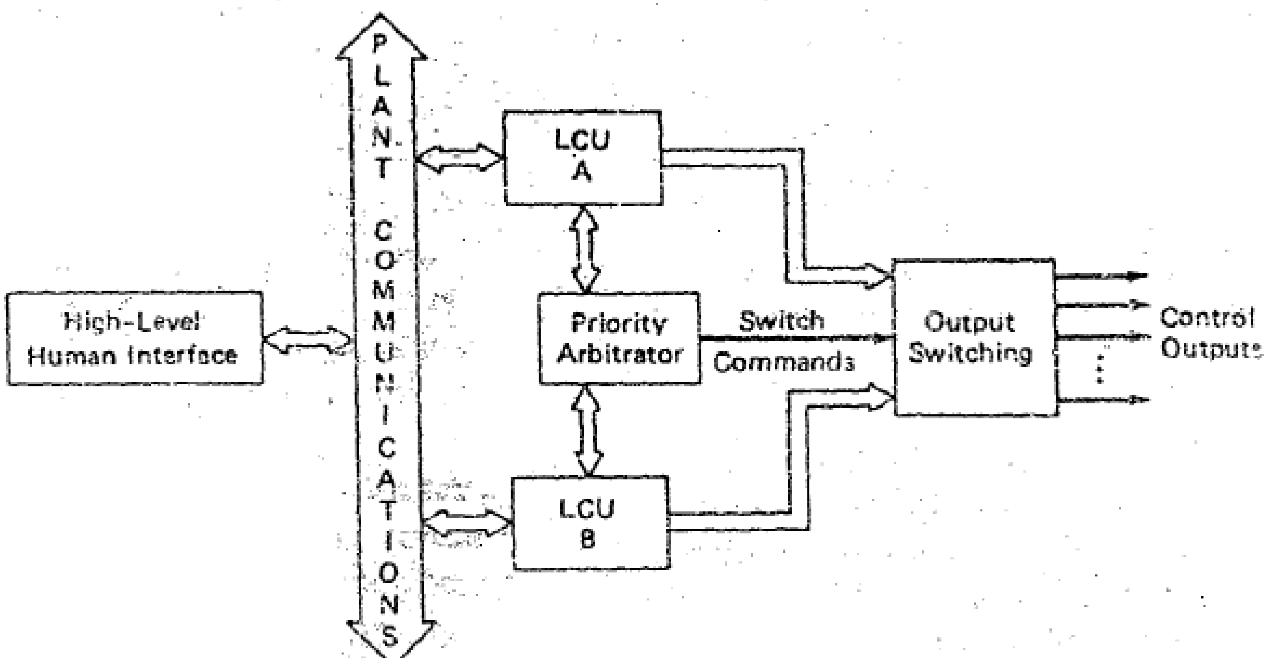
Output diagnostics	D/A converter check	Processor writes a known value to the D/A converter, reads it back through analog channel, and compares results.	Periodically during operation	If error becomes too great, sets alarm and shuts converter down.
	Output register check	Processor writes a known number 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

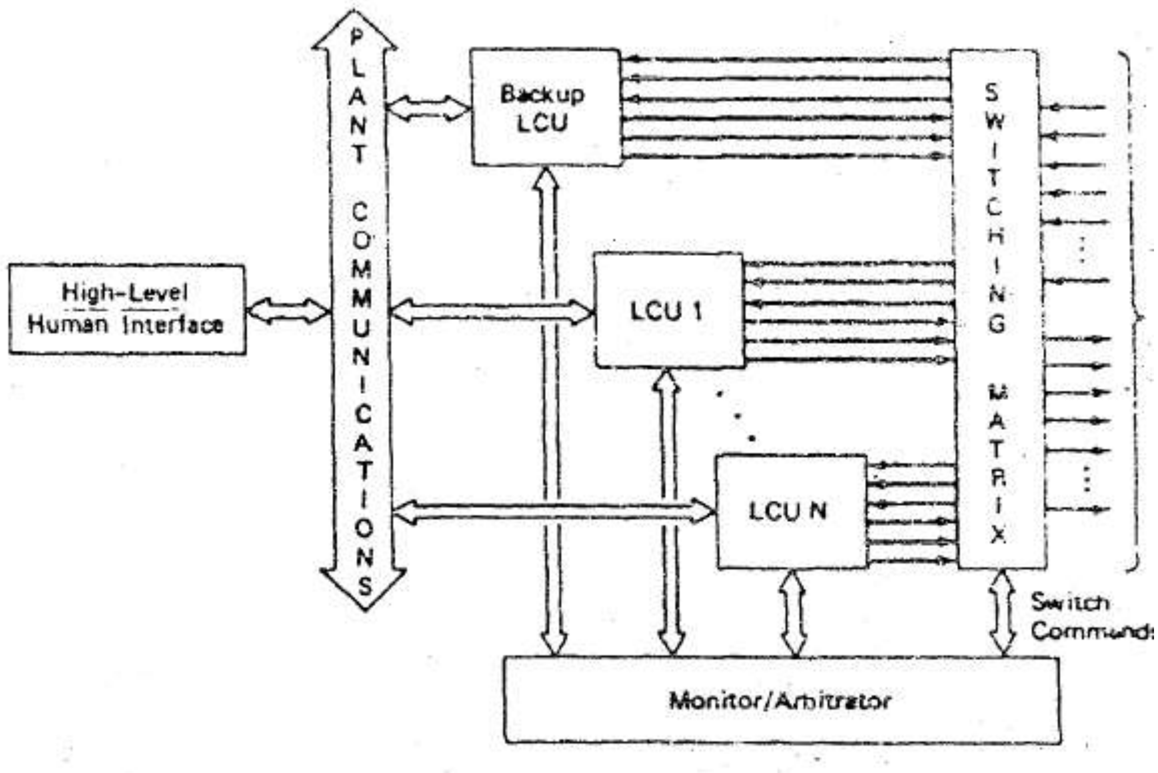
One on one redundancy

- 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

- <u>Book references:</u>

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

- <u>Video references:</u>

Introduction to DCS

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

Difference Between PLC and DCS

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