Industrial Control Systems

L-21

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a) Levels of Automation in the two industries

Typical unit operations in the process industries and discrete manufacturing industries

Typical Unit Operations in the Process Industries	*Typical Unit Operations in the Discrete Manufacturing Industries*
Chemical reactions	Casting
Comminution	Forging
Deposition (e.g., chemical vapor deposition)	Extrusion
Distillation	Machining
Heating	Mechanical assembly
Mixing and blending of ingredients	Plastic molding
Separation of ingredients	Sheet metal stamping

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TABLE 4.2 [illegible]

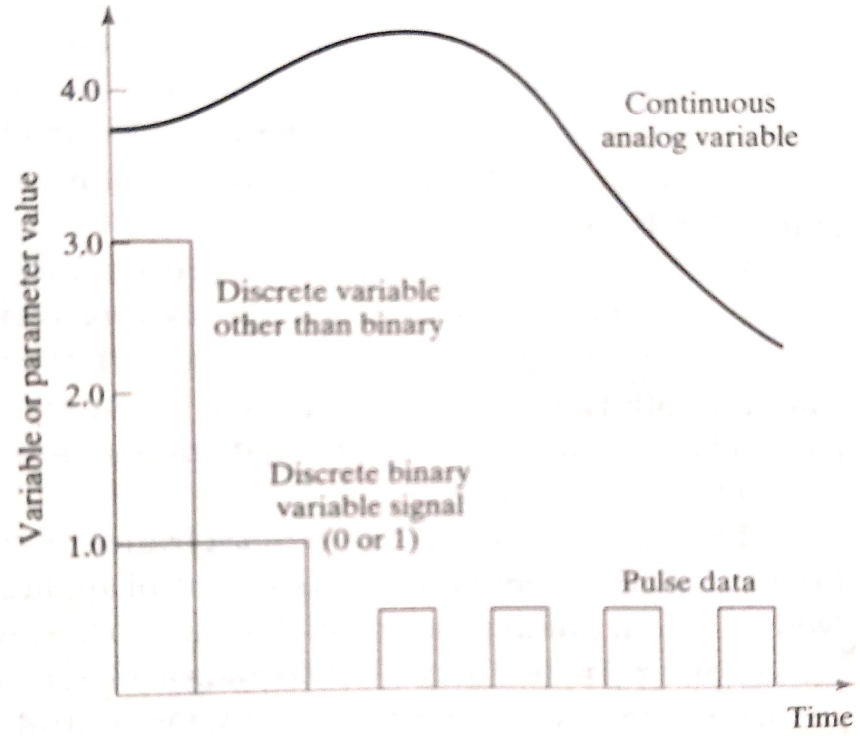
Level	Level of Automation in the Process Industries	Level of Automation in the Discrete Manufacturing Industries
5	*Corporate level*—management information system, strategic planning, high-level management of enterprise	*Corporate level*—management information system, strategic planning, high-level management of enterprise
4	*Plant level*—scheduling, tracking materials, equipment monitoring	*Plant or factory level*—scheduling, tracking work-in-process, routing parts through machines, machine utilization
3	*Supervisory control level*—control and coordination of several interconnected unit operations that make up the total process	*Manufacturing cell or system level*—control and coordination of groups of machines and supporting equipment working in coordination, including material handling equipment
2	*Regulatory control level*—control of unit operations	*Machine level*—production machines and workstations for discrete part and product manufacture
1	*Device level*—sensors and actuators comprising the basic control loops for unit operations	*Device level*—sensors and actuators to accomplish control of machine actions

b) Variable and parameters in the two industries

There are two types of parameters:

(i) Continous variable

(ii) Discrete variable



2) Continous versus Discrete control

Comparison between continuous control and discrete control:

Comparison Factor	Continuous Control in Process Industries	Discrete Control in Discrete Manufacturing Industries
Typical measures of product output	Weight measures, liquid volume measures, solid volume measures	Number of parts, number of products
Typical quality measures	Consistency, concentration of solution, absence of contaminants, conformance to specification	Dimensions, surface finish, appearance, absence of defects, product reliability
Typical variables and parameters	Temperature, volume flow rate, pressure	Position, velocity, acceleration, force
Typical sensors	Flow meters, thermocouples, pressure sensors	Limit switches, photoelectric sensors, strain gages, piezoelectric sensors
Typical actuators	Valves, heaters, pumps	Switches, motors, pistons
Typical process time constants	Seconds, minutes, hours	Less than a second

a) Continous Control Systems

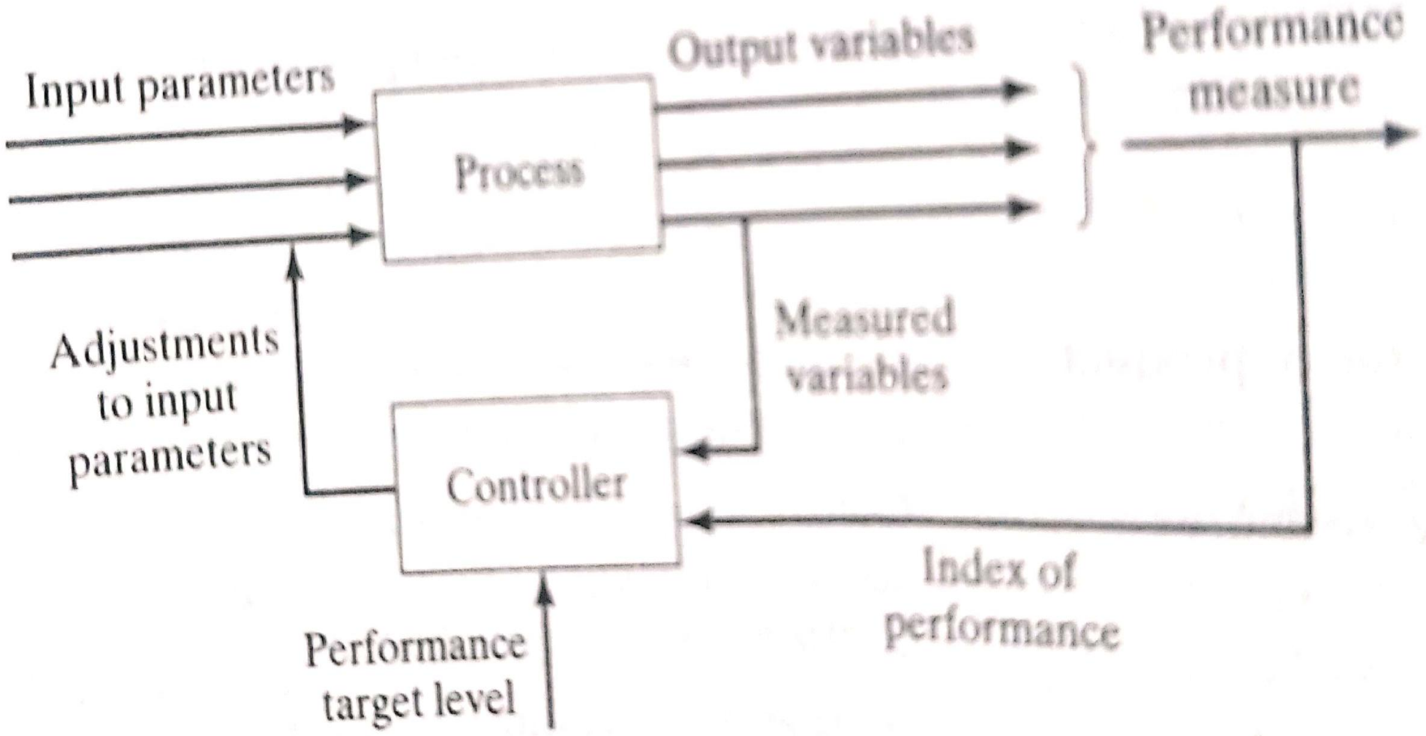
Examples of continuous processes are the following:

(i) Control of the output of a chemical reaction that depends on temperature, pressure, and input flow rates of several reactants. All of these variables and/or parameters are continuous

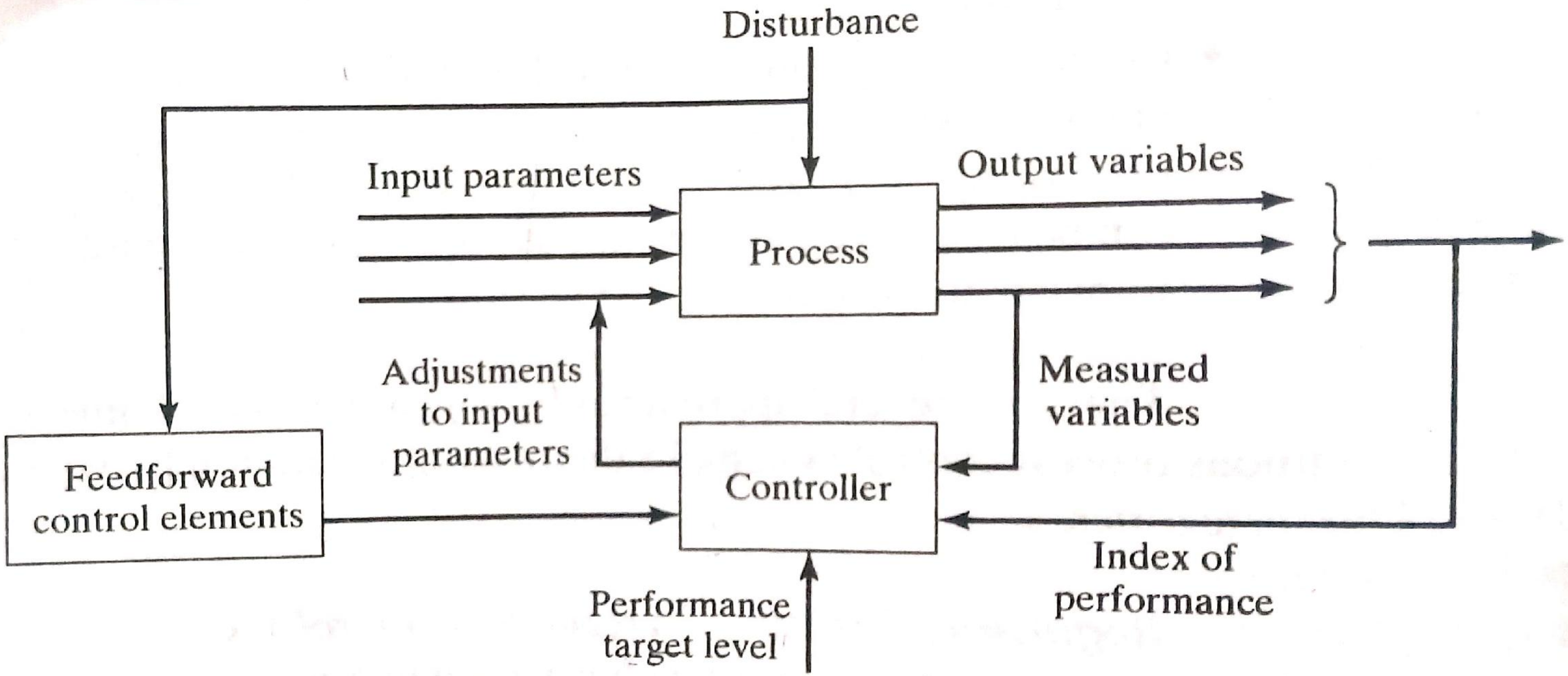
(ii) Control of the position of a workpart relative to a cutting tool in contour milling operation in which complex curved surfaces are generated. The position of the part is defined by x- , y- , and Z-coordinate values. As the part moves, the x, y, and z values can be considered as continuous variables and/or parameters that change over time to machine the part.

Several approaches by which control objective is achieved in a continuous process control system

(i) Regulatory control



(ii) Feedforward Control



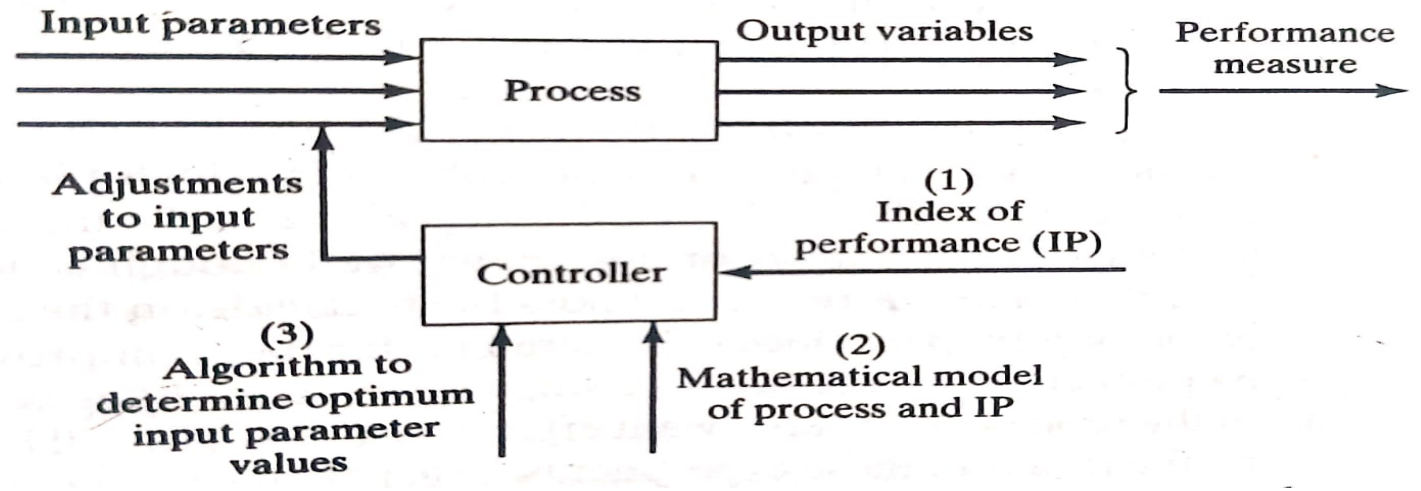
(iii) Steady State Optimization

This refers to a class of optimization techniques in which the process exhibits the following characteristics

(1) There is a well defined index of performance, such as product cost, production rate, or process yield.

(2) The relationship between the process variables and the index of performance is known.

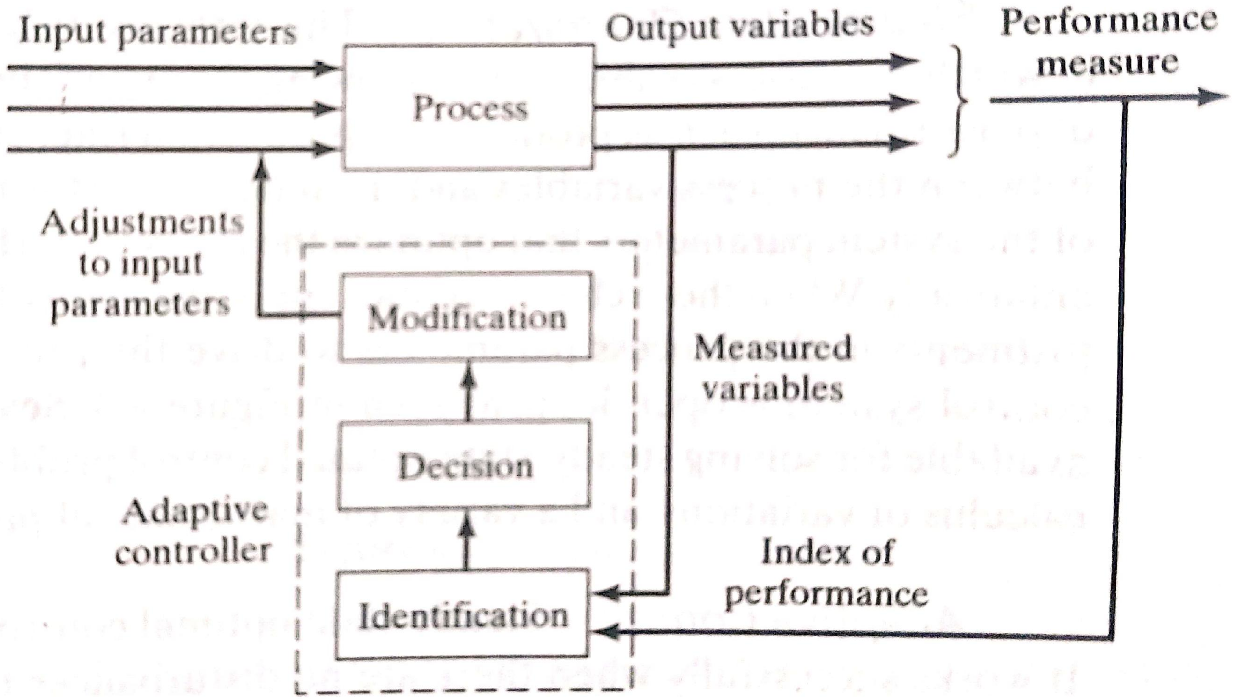
(3) The values of the system parameters that optimize the index of performance can be determined mathematically.



iv) Adaptive Control

Adaptive control system performs three functions:

1) Identification function
2) Decision function
3) Modification function



v) Online search strategies

- On-line search strategies can be used to address a special class of adaptive control problem in which the decision function cannot be sufficiently defined; that is the relationship between the input parameters and the index of performance is not known, or not known well enough to use adaptive control.

Other specialized techniques:

- Other specialized techniques include strategies that are currently evolving in control theory and computer science. Examples include learning systems, expert systems, neural networks and other artificial intelligence methods for process control.

b) Discrete Control Systems

- The discrete control, the parameters and variables of the system are changed at discrete moments in time. The changes involve variables and parameters that are also discrete, typically binary (ON/OFF).
- The changes are executed either because the state of the system has changed or because a certain amount of time has elapsed. The two cases can be distinguished as

1) event-driven changes
2) Time-driven changes

Event-driven change

The event-driven change is executed by the controller in response to some event that has caused the state of the system to be altered. The change can be to initiate an operation or terminate an operation, start a motor or stop it, open a valve or close it and so forth. Examples of event-driven changes are:

- A robot loads a workpart into the fixture, and the part is sensed by a limit switch. Sensing the part’s presence is the event that alters the system state. The event-driven change is that the automatic machining cycle can now commence.
- The diminishing level of plastic molding compound in the hopper of an injection molding machine triggers a low-level switch, which in turn triggers a valve to open that starts the flow of new plastic into the hopper. When the level of plastic reaches the high-level switch, this triggers the valve to close, thus stopping the flow of pellets into the hopper
- Counting parts moving along a conveyor past an optical sensor is an event-driven system. Each part moving past the sensor is an event that drives the counter.

Time-driven change

The time-driven change is executed by the control system either at a specific point in time or after a certain time elapse has occurred. As before, the change usually consists of starting something or stopping something, and the time when the change occurs is important. Examples of time-driven changes are:

- In factories with specific starting times and ending times for the shift and uniform breaks periods for all workers, the ‘’shop clock’’ is set to sound a bell at specific moments during the day to indicate these start and stop times
- Heat treating operations must be carried out for certain length of time. An automated heat treating cycle consists of automatic loading of parts into the furnance (perhaps by a robot) and then unloading after the parts have been heated for the specified length of time.
- In the operation of washing machine, once the laundary tub has been filled to the preset level, the agitation cycle continues for a length of time set on the controls. When this time is up, the timer stops the agitation and initiates draining of the tub.(By comparison with the agitation cycle, filling the laundry tub with water is event-driven. Filling continues until the proper level has been sensed, which causes the inlet valve to close)

3) Computer Process Control

a) Control Requirements:

A real time controller is there to communicate and interact with the process on a real-time basis. A real-time controller is able to respond to the process within a short enough time period that process performance is not degraded.

Factors that determine whether a computer controller can operate in real-time include:

(1) The speed of the controller's central processing unit (CPU) and its interfaces (2) the controller's operating system (3) the design of the application software (4) the number of different input/output events to which the controller is designed to respond.

Contd.

There are two basic requirements that must be managed by the controller to achieve real-time control.

1) Process-initiated interrupts
2) Timer-initiated actions
3) Computer commands to process
4) System and program-initiated events
5) Operator-initiated events

b) Capabilities of Computer Control

1) Polling(Data Sampling): In computer process control, polling refers to the period sampling of data that indicates the status of the process.

Issues related to polling include:

(i) Polling frequency

(ii) Polling order

(iii) Polling format

Contd.

2) Interlocks: An interlock is a safeguard mechanism for coordinating the activities of two or more devices and preventing one device from interfering with the other.

There are two types of interlocks, input interlocks and output interlocks, where input and output are defined relative to the controller.

Input interlock:

An input interlock is a signal that originates from an external device(e.g a limit switch, sensor, or production machine) and is sent to the controller. Input interlocks can be used for either of the following functions:

(i) To proceed

(ii) To interrupt

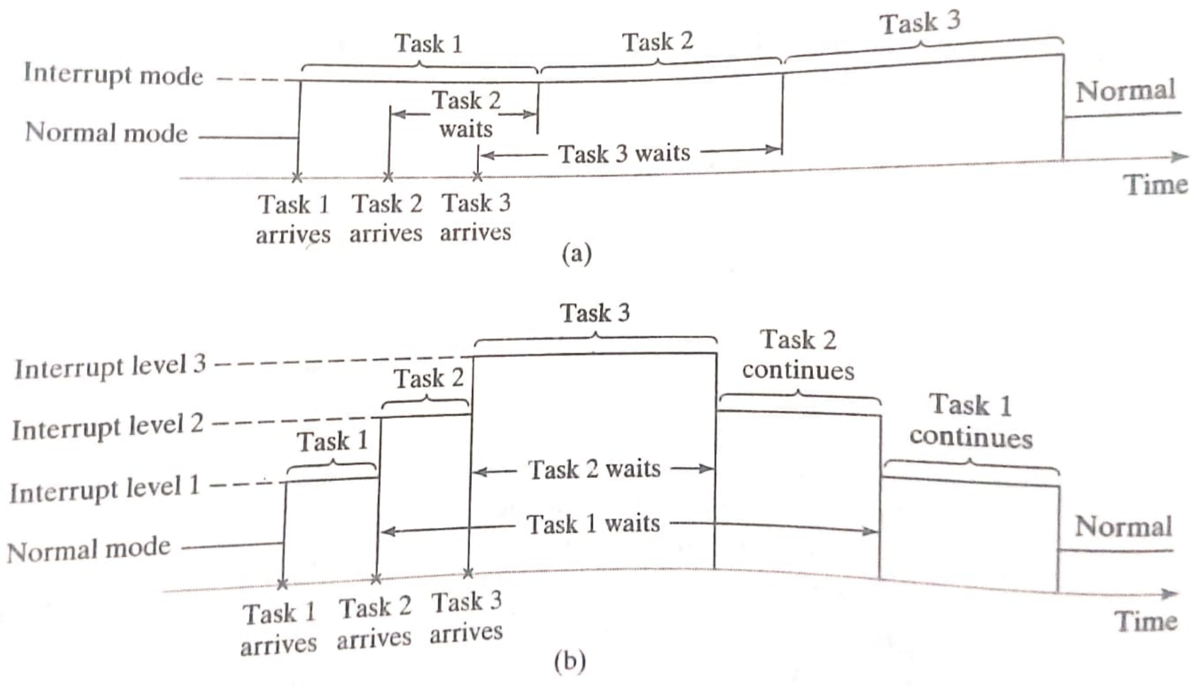
Contd.

Output Interlock: It is a signal sent from the controller to some external device. It is used to control the activities of each external device and to coordinate its operation with that of the other equipment in the cell. For example, an output interlock can be used to send a control signal to a production machine to begin its automatic cycle after the workpart has been loaded into it.

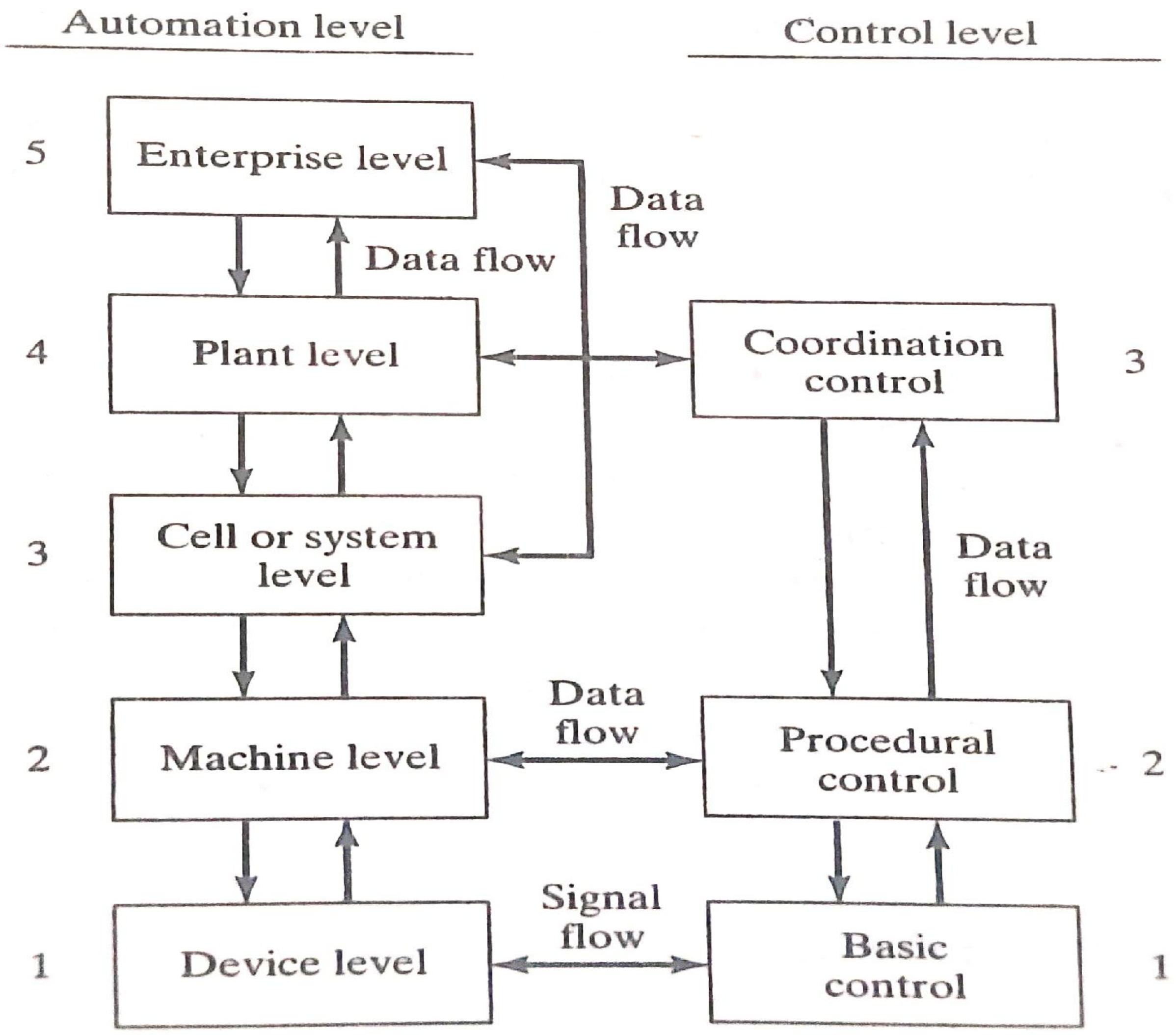
3) Interrupt system: An interrupt system is a computer control feature that permits the execution of the current program to be suspended to execute another program or subroutine in response to an incoming signal indicating a higher priority event.

Interrupt system

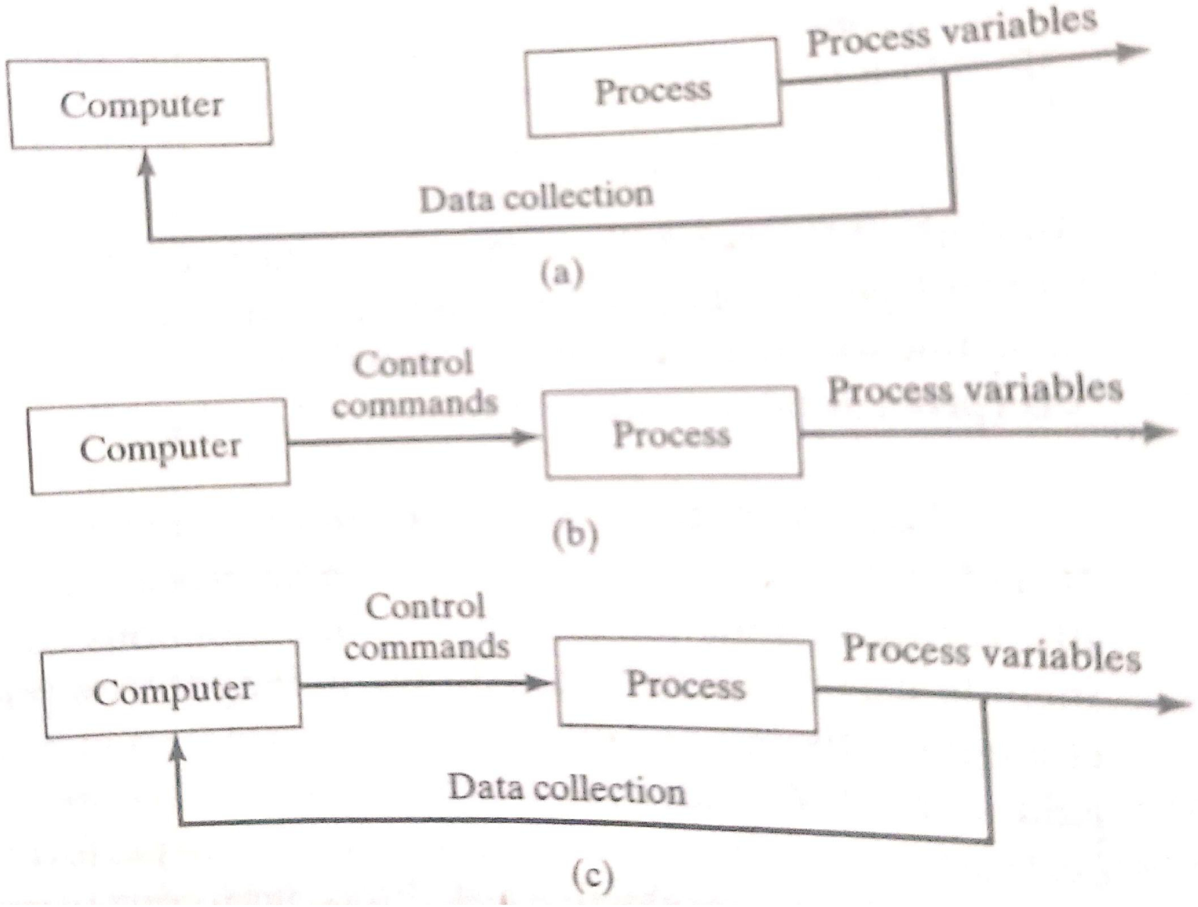
Priority Level	Computer Function
1 (lowest priority)	Most operator inputs
2	System and program interrupts
3	Timer interrupts
4	Commands to process
5	Process interrupts
6 (highest priority)	Emergency stop (operator input)



c) Levels of Industrial Process Control



4) Forms of computer process control



a) Computer Process Monitoring

The data collected by the computer in computer process monitoring can generally be classified into three categories.

1) Process data
2) Equipment data
3) Product data

b) Direct Digital control

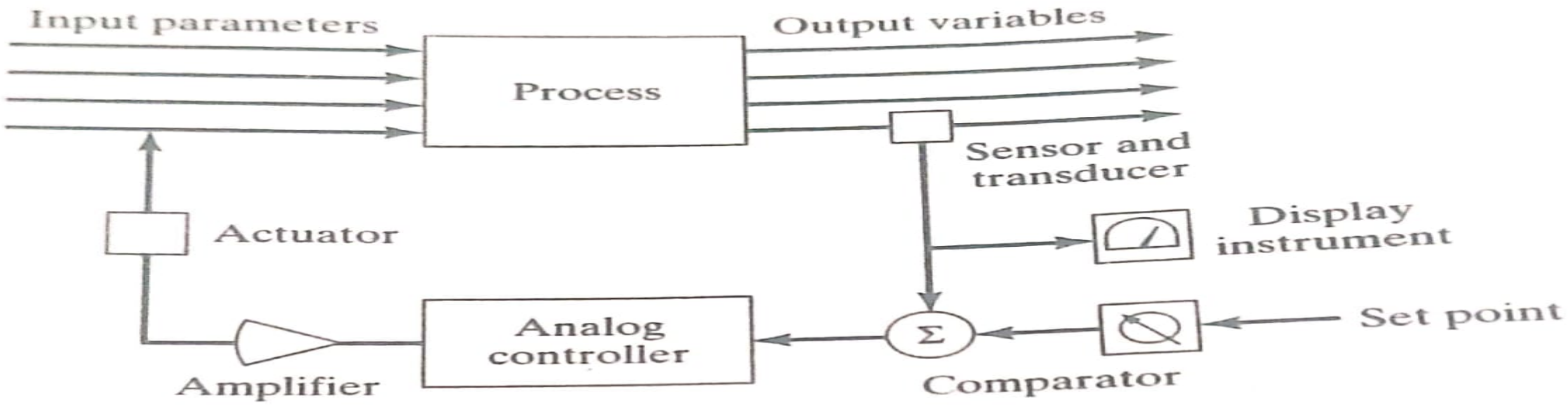


Figure 4.9 A typical analog control loop.

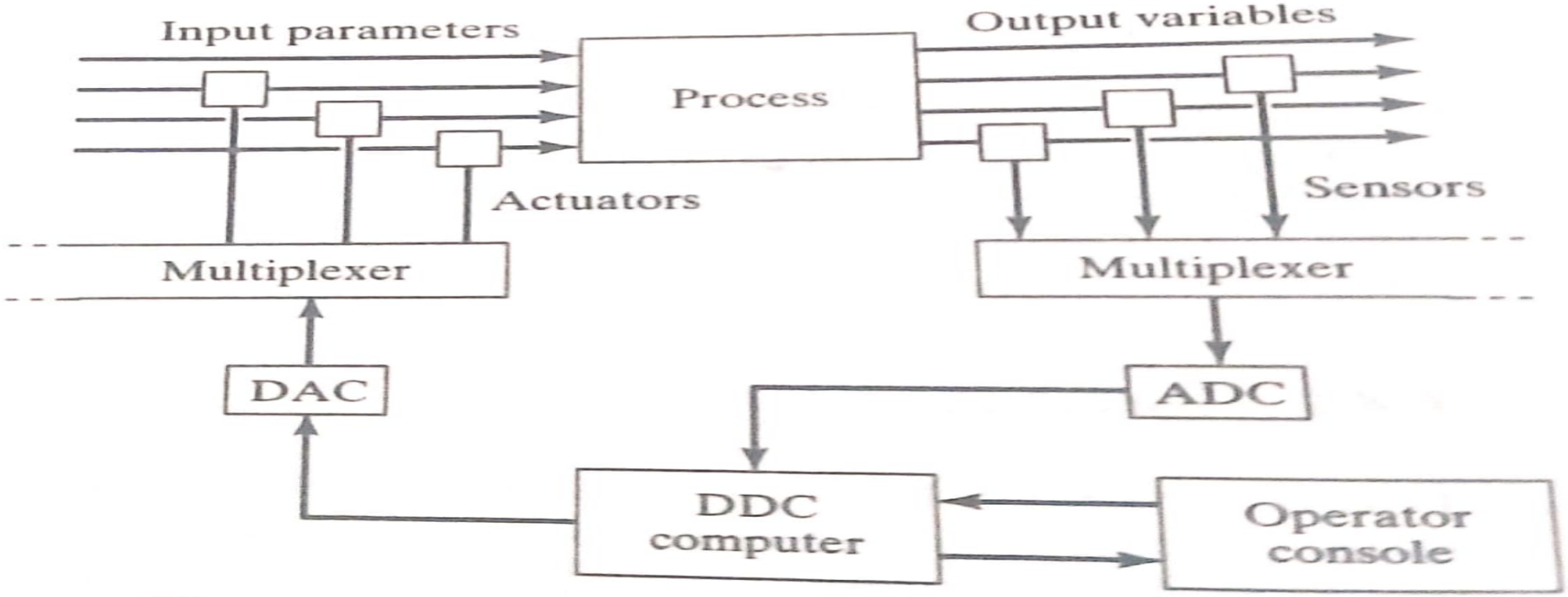


Figure 4.10 Components of a DDC system.

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- Additional opportunities for the control computer were soon recognized, including.

(i) More control options than traditional analog

(ii) Integration and optimization of multiple loops

(iii) Editing the control programs

C) Numerical Control and Robotics

(i) Numerical control (NC) is another form of industrial computer control. It involves the use of computer to direct a machine tool through a sequence of processing steps defined by a program instructions that specifies the details of each step and their sequence

(ii) The distinctive feature of NC is control of the relative position of a tool with respect to the object being processed.

(iii) Computations must be made to determine the trajectory that must be followed by the cutting tool to shape the part geometry.

d) Programmable Logic Controllers

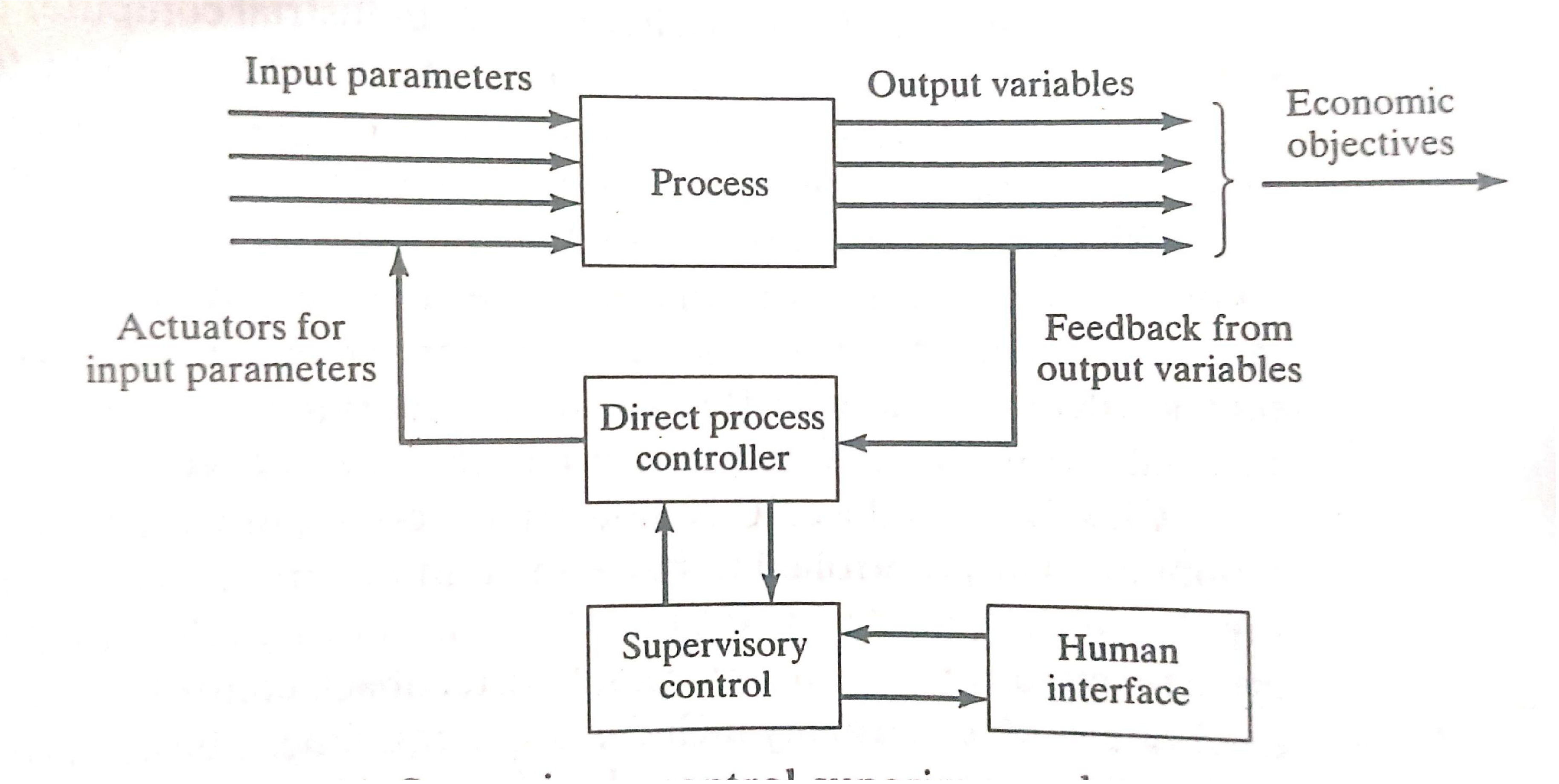
(i) Programmable logic controllers(PLCs) were introduced around 1970 as an improvement on the electromechanical relay controllers used at the time to implement discrete control in the discrete manufacturing industries

(ii) The evolution of PLCs has been facilitated by the advances in computer technology and present day PLC are capable of much more than the 1970s-era controllers

(iii) Programmable logic controller as a micro-processor based controller that uses stored instructions in programmable memory to implement logic, sequencing, timimg, counting and arithmetic control functions for controlling machines and processes

(iv) Today’s PLCs are used for both continuous control and discrete control applications in both the process industries and discrete manufacturing.

e) Supervisory Control



f)Distributed Control Systems and Personal Computers

1)Distributed Control Systems: With the development of the microprocessor, it became feasible to connect multiple microcomputers together to share and distribute the process control workload. The term distributed control system (DCS) is used to describe such a configuration, which consists of the following components and features.

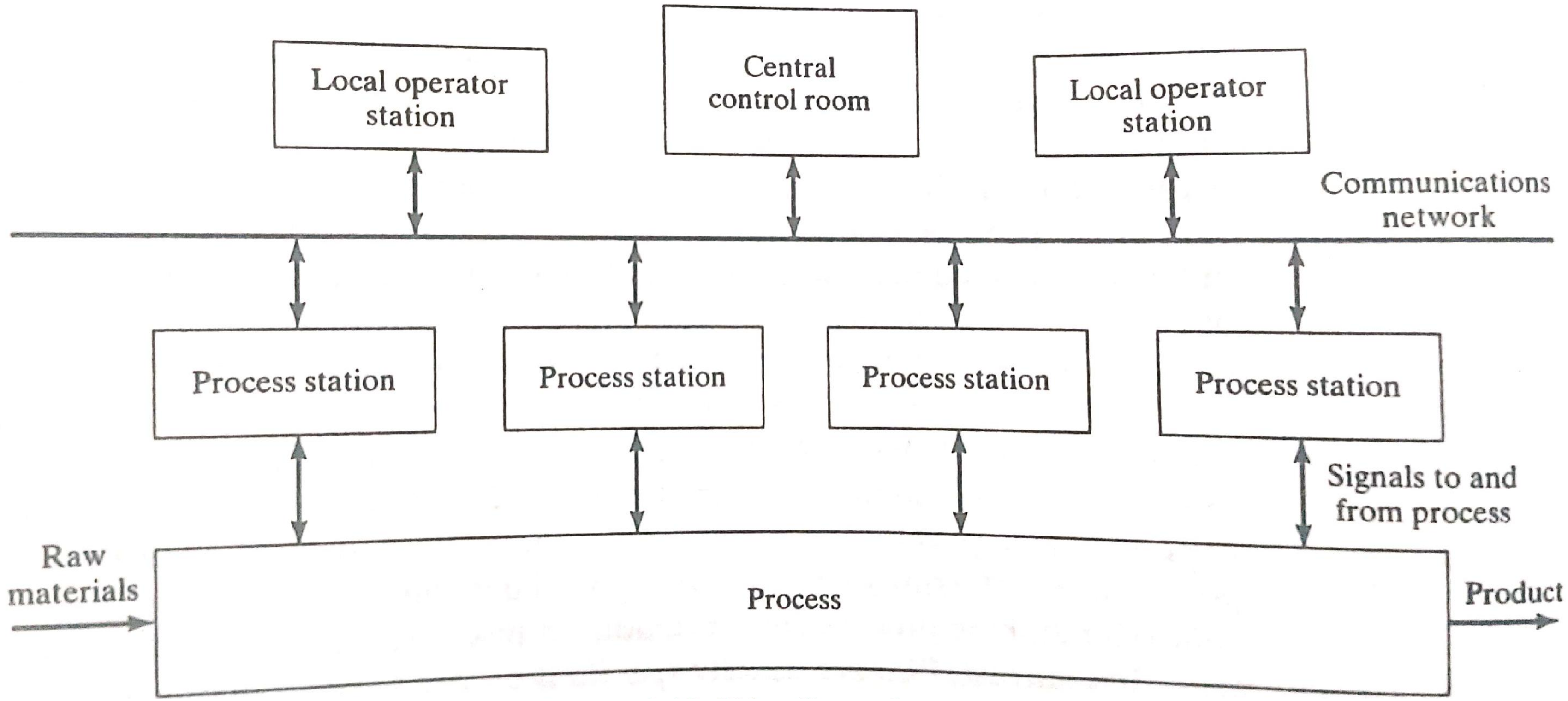
(i) Multiple process stations

(ii) A central control room

(iii) Local operator stations

(iv) All process and operator stations interact with each other by means of a communications network, or data highway, as it is often called.

Diagram-distributed control system



PCs in Process Control

There are two basic categories of PC applications in process control can be distinguished (i) Operator interface (ii) direct control

Advantages of using a PC as the only operator interface include:

(i) The PC provides a user friendly interface for the operator

(ii) The PC can be used for all of the conventional computing and data processing functions that PCs traditionally perform

(iii) The PLC or other device that is directly controlling the process is isolated from the PC, so a PC failure will not disrupt control of the process

(iv) The computer can be easily upgraded as PC technology advances and capabilities improve, while the PLC control software and connections with the process can remain in place

PCs have been installed at an accelerating pace for direct control of industrial processes. Several factors can be identified that have enabled this trend:

(i) Widespread familiarity with PCs

(ii) Availability of high performance PCs

(iii) Trend toward open architecture philosophy in control systems design

(iv) Microsoft’s windows NT (the latest version is windows 2000) as the operating system of choice.

Enterprise-wide Integration of factory data

Following are capabilities that are been possible by PC –based enterprise wide integration of factory data that provides process data available

(i) Managers can have more direct access to factory floor operations

(ii) Production planners can use the most current data on times and production rates in scheduling future orders

(iii) Sales personnel can provide realistic estimates on delivery dates to customers, based on current shop loading

(iv) Order trackers are able to provide inquiring customers with current status information on their orders

(v) Quality control personnel are made aware of real or potential quality problems on current orders, based on access to quality performance histories from previous orders.

(vi) Cost accounting has access to the most recent production cost data

(vii) Production personnel can access part and product design details to clarify ambiguities and do their job more effectively.

Diagram- Enterprise-wide PC-based DCS