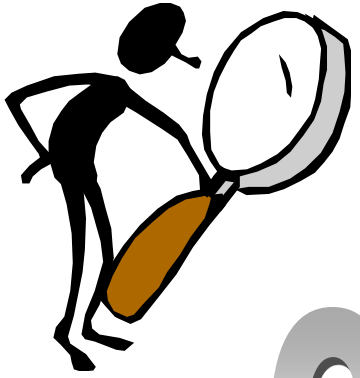
Level 1
Fundamentals Training



Control

Contents

Process Control Terminology

What is a PROCESS ?

Any operation or sequence of operations involving a change in the substance being treated.

Examples:

A change of energy state	**-**	***hot to cold, liquid to gas***
A change of composition	**-**	***a chemical reaction***
A change of dimension	**-**	***grinding coal***

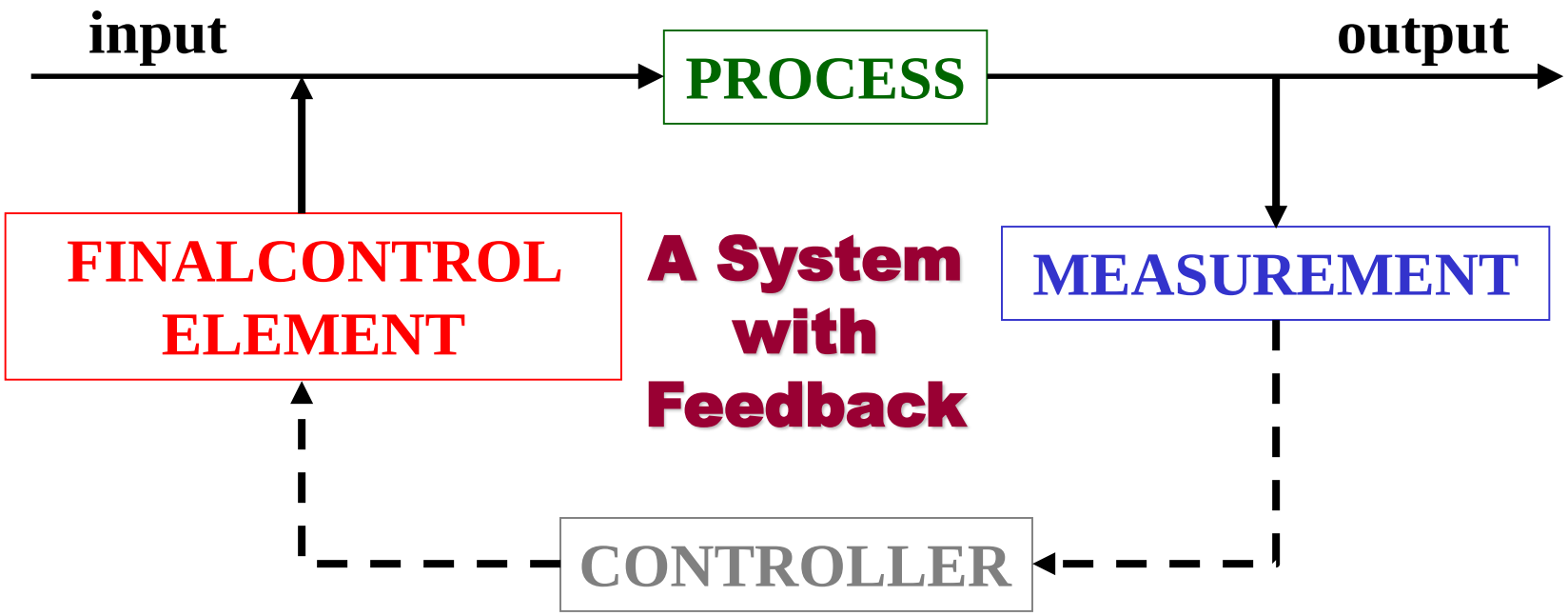
Types of PROCESS VARIABLE:

Pressure	***Specific Gravity of liquid***
Flow	***Density***
Level	***Mass***
Temperature	***Conductivity***
Liquid Interface	***Composition***
	Moles

Process Control Terminology

What is a CLOSED LOOP ?

A combination of instruments or functions that are interconnected to measure and control a process variable with feedback.



Process Control Terminology

What is a TRANSDUCER

- *A device that registers a non-electrical parameter (eg. process variable) and outputs a corresponding useable electrical signal.*
  - ***Pressure to Capacitance***
  - ***Pressure to Resistance or mV***
  - ***Temperature to Resistance***
  - ***Temperature to mV***
- *Example:*
  - ***Capacitance pressure sensor module***
  - ***Piezo-resistive pressure sensor module***
  - ***RTD***
  - ***Thermocouple***

What is a TRANSMITTER

- *A device that will translate the transducers interpretation of the measured variable into a standard transmission signal.*
  - ***3 - 15 psi pneumatic signal***
  - ***4-20 mA dc electrical signal***
  - ***1-5 V dc electrical signal***

ADVANTAGE OF 4-20mA CURRENT SIGNAL

- **Lower installation cost**
  - **simple, twisted pair wiring**
- **Better noise immunity**
  - **current vs. voltage**
- **Insensitive to wire resistance**
  - **current vs. voltage**
- **Better suited for hazardous locations**
  - **intrinsic safety**

Process Control Terminology

What is a CONTROLLER ?

- Used to keep a process variable at a desired value (set point).
  - **Closed loop vs. Open loop control**
    - Difference: Open loop control has no feedback
  - **Control Modes**
    - ON/OFF (Binary)
    - Proportional (P)
    - Proportional-plus-Integral (PI)
    - Proportional-plus-Integral-plus-Derivative (PID)

Process Control Terminology

What is a SIGNAL ?

- An event that conveys data from one point to another.

What is an INDICATOR ?

- An instrument which visually shows the value of the variable.

What is a RECORDER ?

- An instrument that makes and displays a continuous graphic, acoustic or magnetic record of a measured variable.

What is a DCS ?

- Distributed Control System consisting of functional integrated subsystems. The subsystems are connected by a communication linkage (eg) data bus,data highway.

Process Control Terminology

What is a FINAL CONTROL ELEMENT?

- The last control element in the process control loop that manipulates the process variable.
  - **Control Valves**
    - » modulates flow rate
    - » operated by actuator
  - **Louvers and Dampers**
    - » operated by pneumatic actuators
  - **Variable Speed Drives**
    - » operated by electronic control signals
      - ♦ *4 - 20 mA*

Control Principle

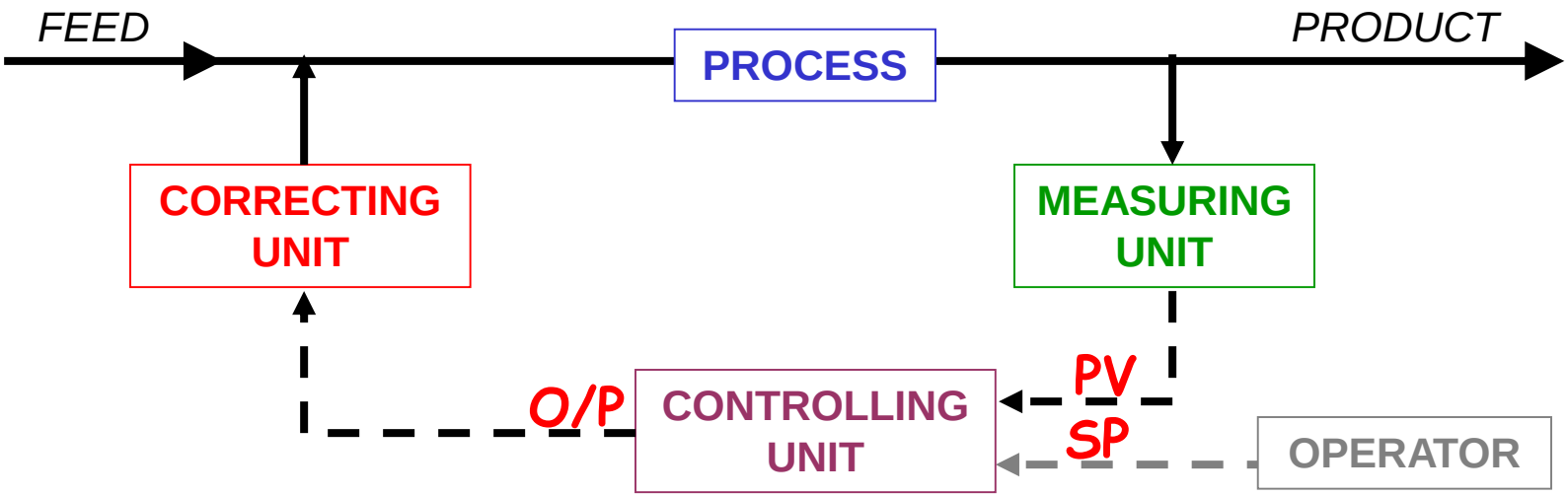
1. Measure

2. Compare

3. Adjust

Tasks

Control Principle



Control theory can be encapsulated as the matching of a measured variable (PV) to the plant requirement (SP).

A controller implements a Control Algorithm so that an output signal (O/P) activates a correcting unit. The ratio of output signal (O) to input signals (I) is Gain (K).

$$\textbf{Proportional band} \frac{1}{K}\% = \frac{100}{Gain}\% = \frac{I}{O} \times 100\%$$

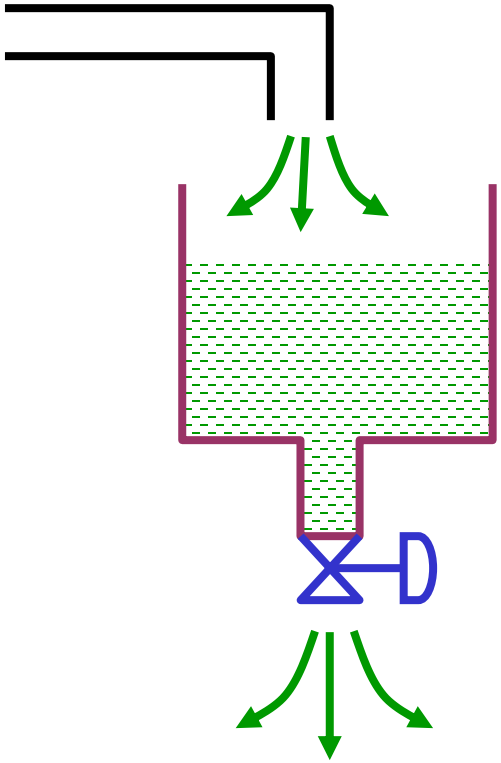
Control Principle

- **Process Variable (PV)**
  - the actual measurement of the state of the process
- **Set Point (SP)**
  - the desired state of the process variable
- **Control Algorithm**
  - the predefined response of the controller to PV-SP
- **Controller Output (O/P)**
  - a signal determined by the control algorithm
- **Offset**
  - the value of PV-SP when the system is in equilibrium
- **Direct Acting Controllers**
  - as the value of the measured variable increases, the output of the controller increases.
- **Reverse Acting Controllers**
  - as the value of the measured variable increases, the output of the controller decreases.

Control Principle

Inherent Regulation

- A plant possesses inherent regulation when, in the absence of a controller, equilibrium is re-established after a disturbance.
  - **For example, a tank with constant inflow is in equilibrium.**
  - **The outflow valve is then opened a little more.**
  - **The outflow pressure decreases as the tank level falls until inflow again equals outflow.**
  - **Manipulation of the outflow valve result in different, unique equilibrium states.**



Control Principle

Instrument Symbols

Example Instruments

Temperature Transmitter

Flow Indicating Controller

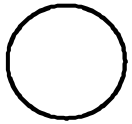
Temperature Element
(Thermocouple, RTD)

Current-to-Pressure
Transducer

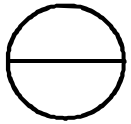
Pressure Transmitter

Pressure-to-Pressure
Transducer

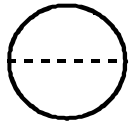
Instrument Location



Local
Mounting



Panel Front
Mounting



Panel Rear,
or Rack Mounting

Control Principle

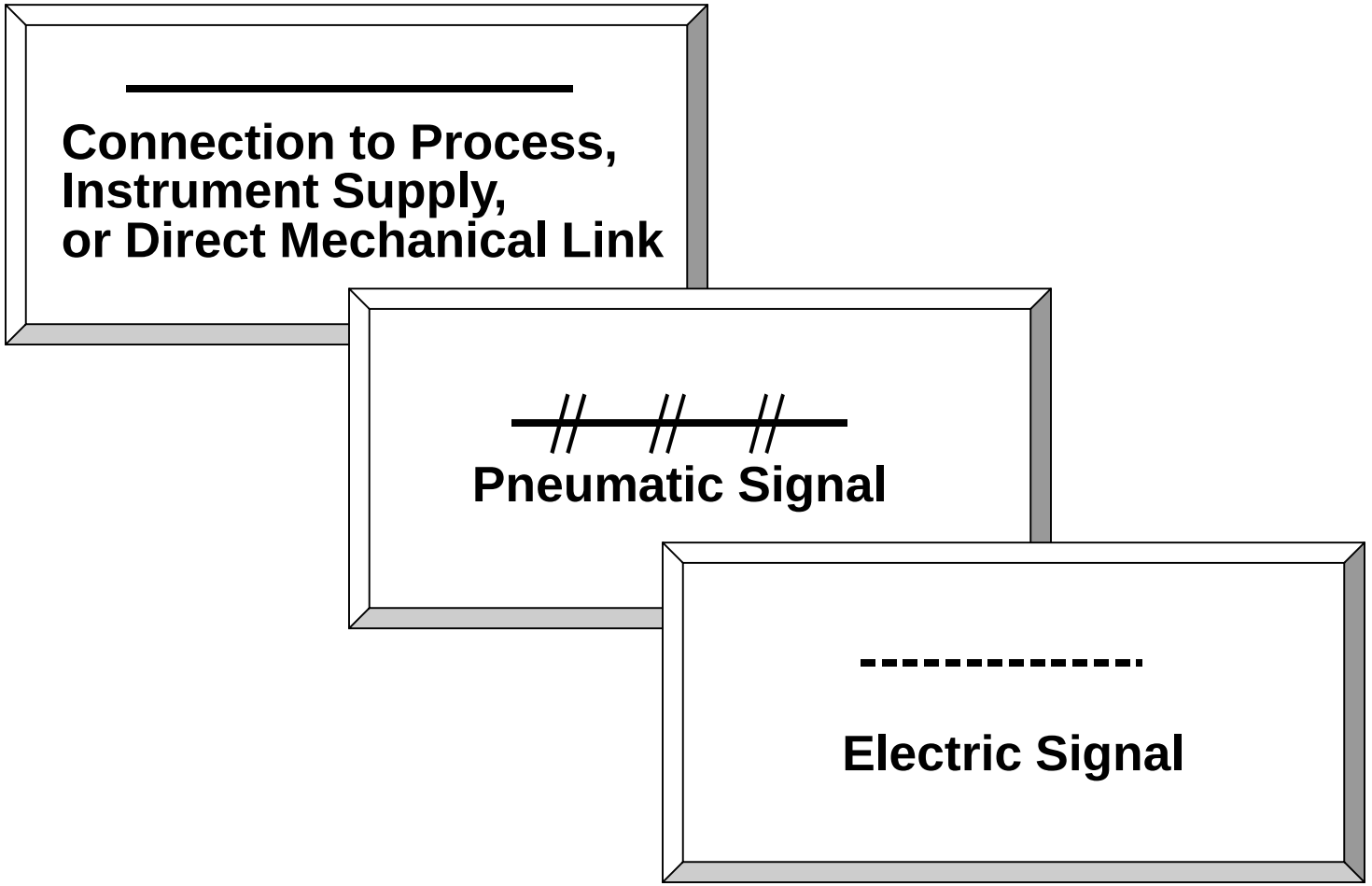
Instrument Symbols

Letter Designations

	First Letter		Succeeding Letters	
	Measured or Initiating Variable	**Modifier**	**Readout or Passive Function**	**Output Function**
A	Analysis		Alarm	
C	User's Choice			Control
D	User's Choice	Differential		
F	Flow Rate	Ratio (Fraction)		
I	Current (Electrical)		Indicate	
L	Level		Light	
P	Pressure, Vacuum		Point (Test Connection)	
Q	Quantity	Integrate, Totalize		
R	Radiation		Record	
T	Temperature			Transmit
V	Vibration		Valve, Damper, Louver	

Control Principle

Signal Types (ISA)



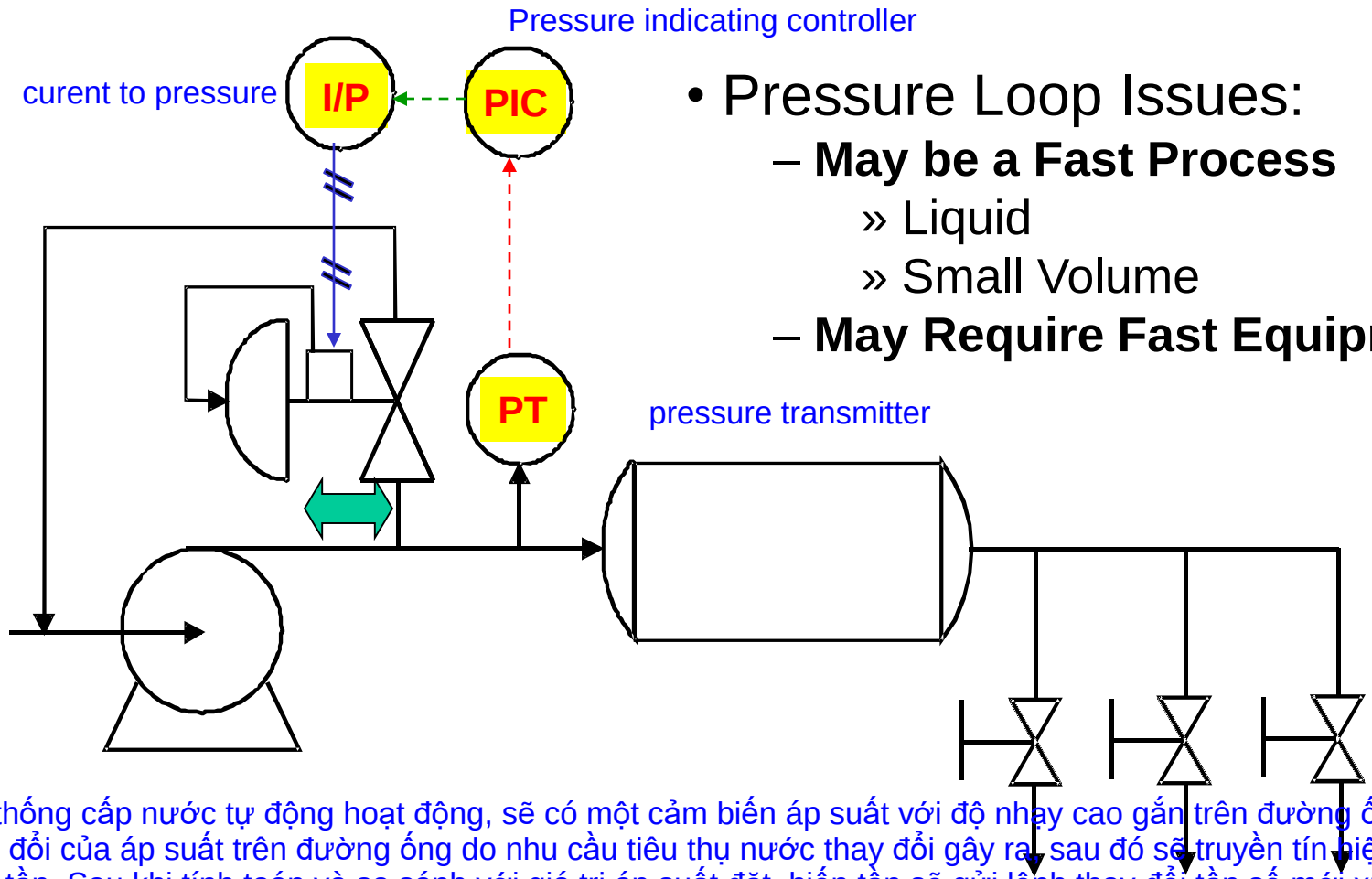
Control Principle

Controller Types

- **Pneumatic**
- **Analog**
- **Digital**
  - Single Loop Controllers
  - Distributed Control System
  - Fieldbus Control System

Basic Control Loop

Pressure Control Loop



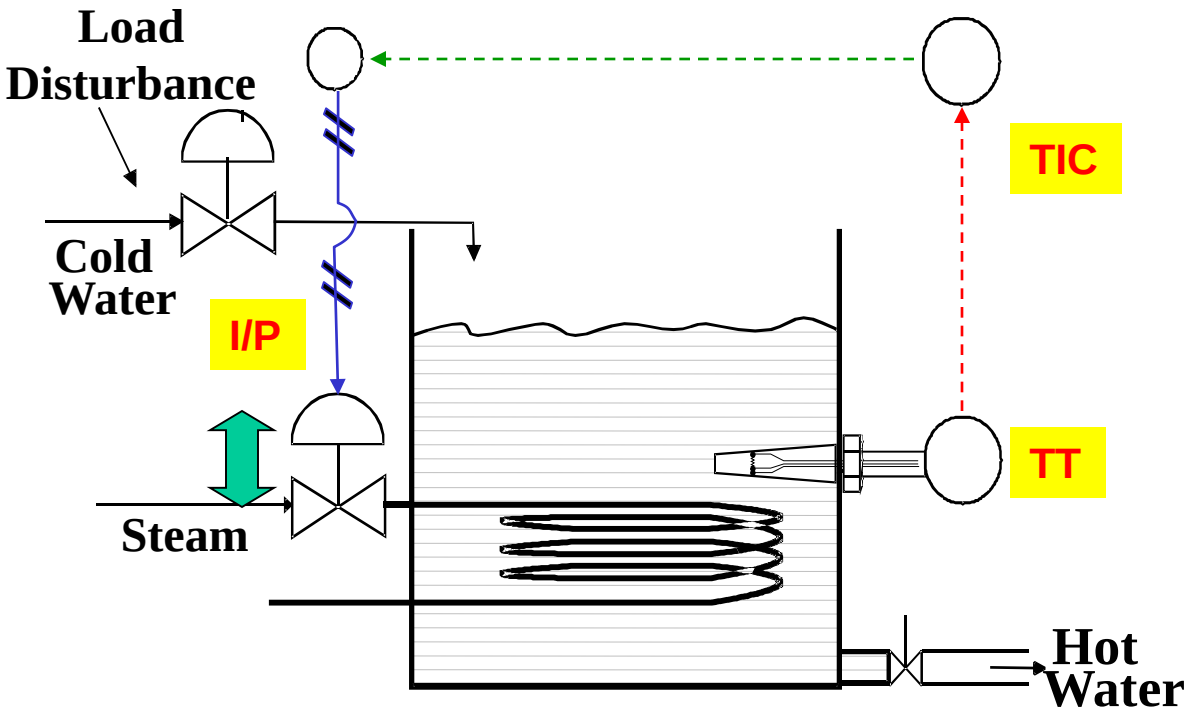
- Pressure Loop Issues:
  - **May be a Fast Process**
    - » Liquid
    - » Small Volume
  - **May Require Fast Equipment**

Khi hệ thống cấp nước tự động hoạt động, sẽ có một cảm biến áp suất với độ nhạy cao gắn trên đường ống để phát hiện sự thay đổi của áp suất trên đường ống do nhu cầu tiêu thụ nước thay đổi gây ra, sau đó sẽ truyền tín hiệu thay đổi này về biến tần. Sau khi tính toán và so sánh với giá trị áp suất đặt, biến tần sẽ gửi lệnh thay đổi tần số mới xuống bộ điều khiển tốc độ quay của động cơ cánh quạt của bơm và có thể đưa thêm hay cắt bớt các bơm trong hệ thống. Do vậy ổn định được áp suất nước trên đường ống theo yêu cầu

Basic Control Loop

Temperature Control Loop

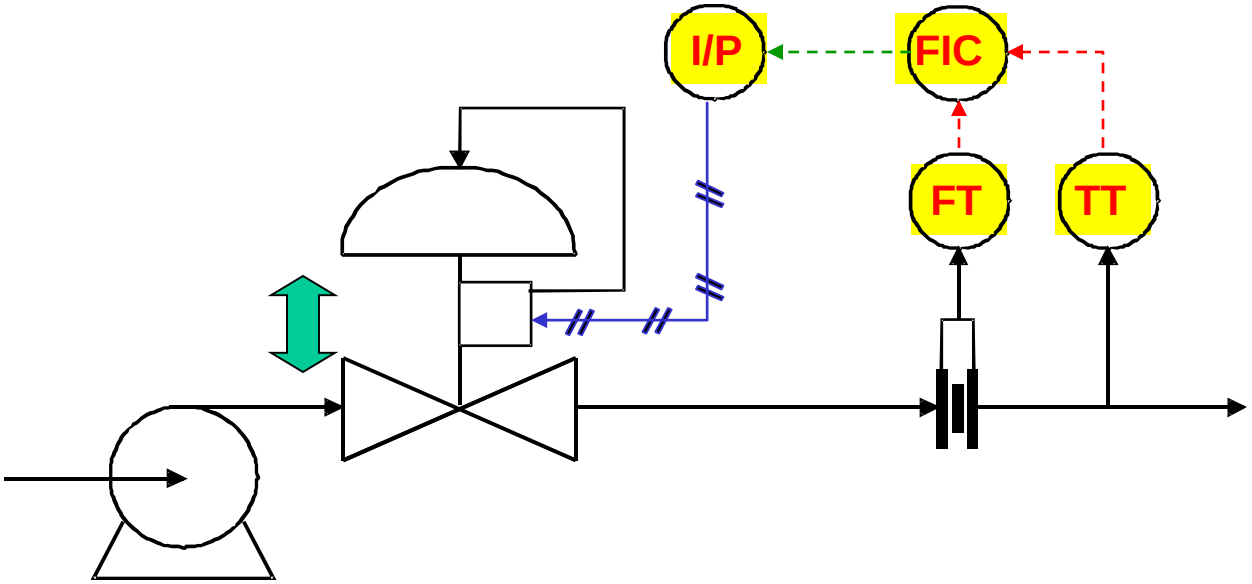
- Temperature Loop Issues:
  - **Fluid response slowly to change in input heat**
  - **Requires advanced control strategies**
    - » Feedforward Control



Basic Control Loop

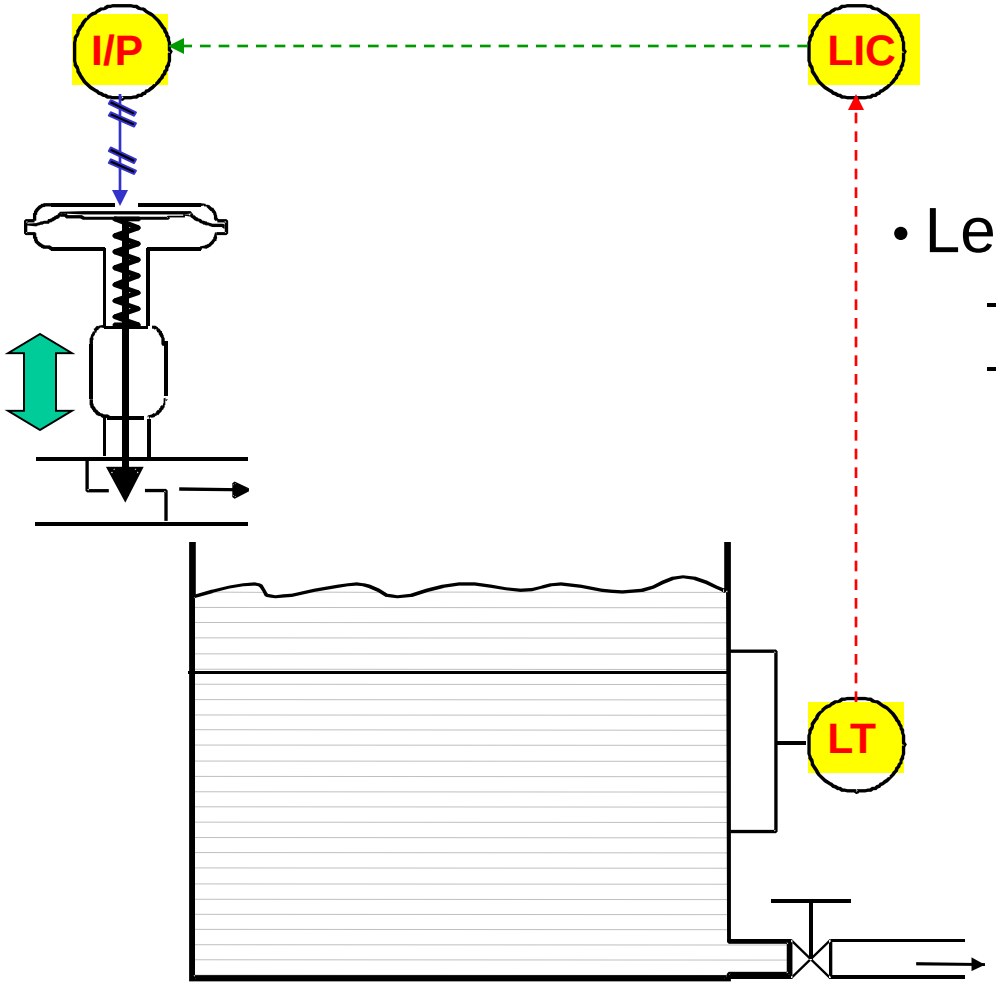
Flow Control Loop

- Flow Loop Issues:
  - **May be a Very Fast Process**
    - » “Noise” in Measurement Signal
      - May Require Filtering
    - » May Require Fast-Responding Equipment
  - **Typically Requires Temperature Compensation**



Basic Control Loop

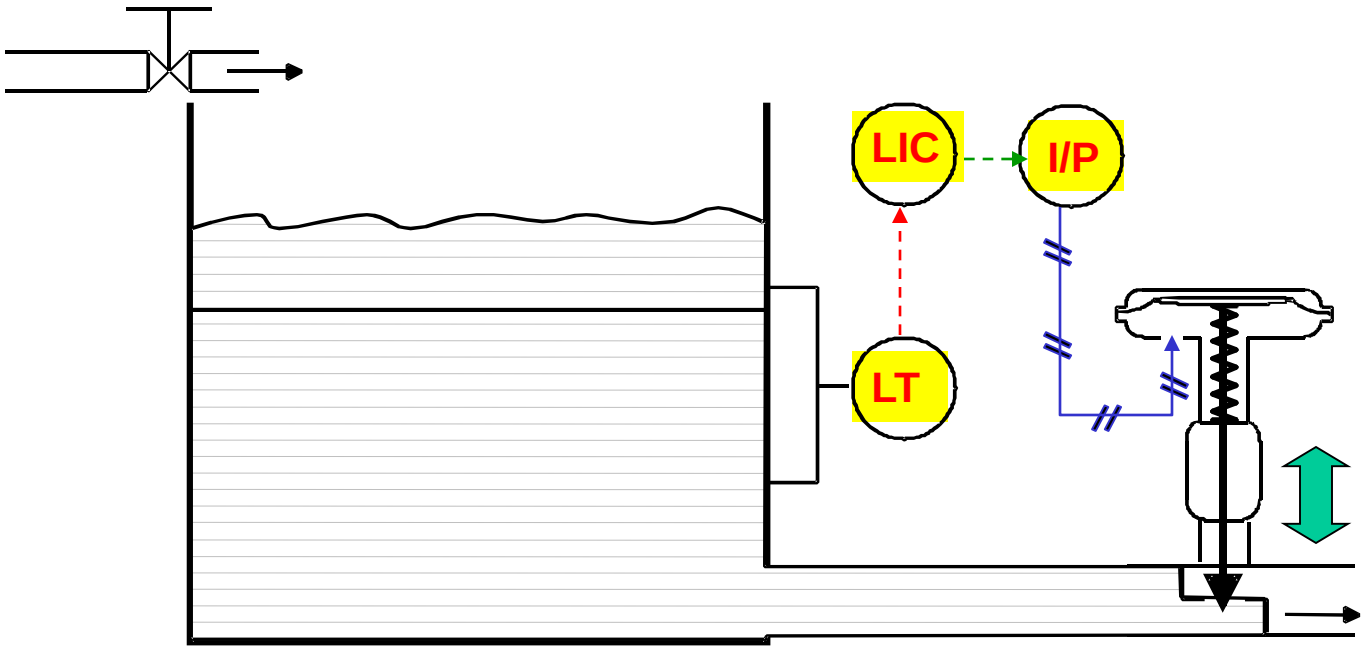
Level Control Loop (Inflow)



- Level Loop Issues:
  - **Control At Inflow or Outflow**
  - **Non-Self Regulating**

Basic Control Loop

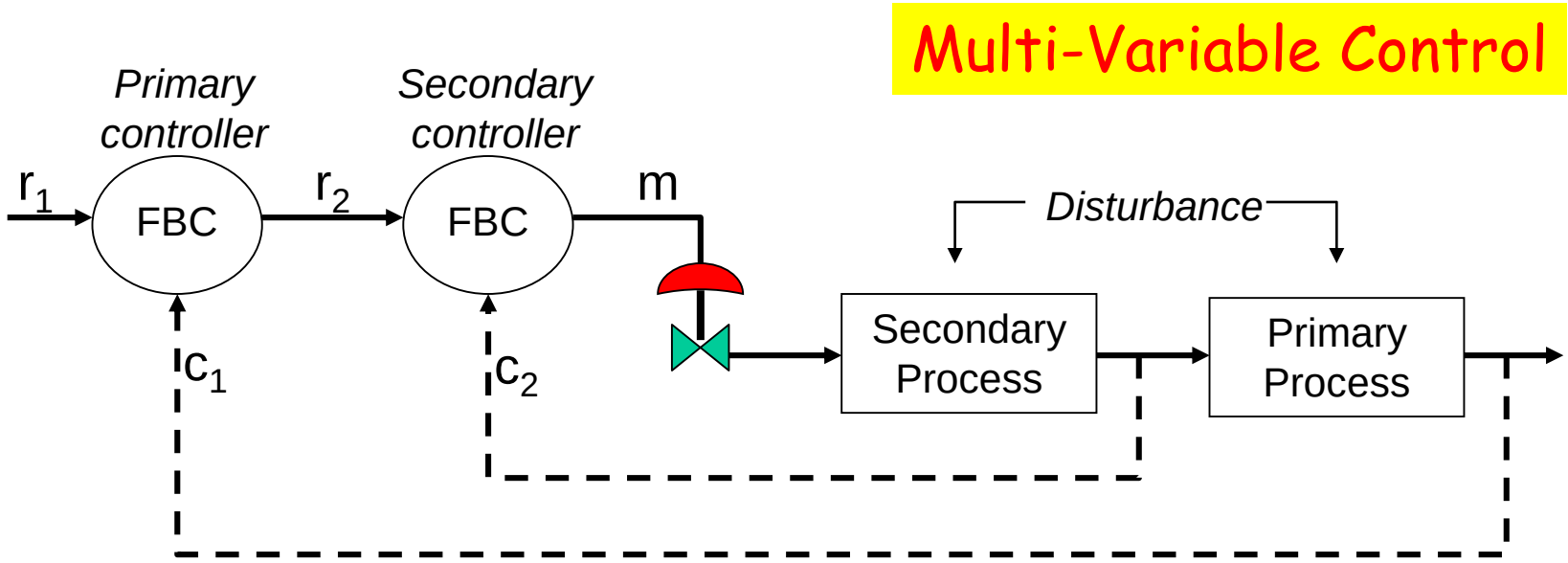
Level Control Loop (Outflow)



Advance Control Loop

What is CASCADE CONTROL ?

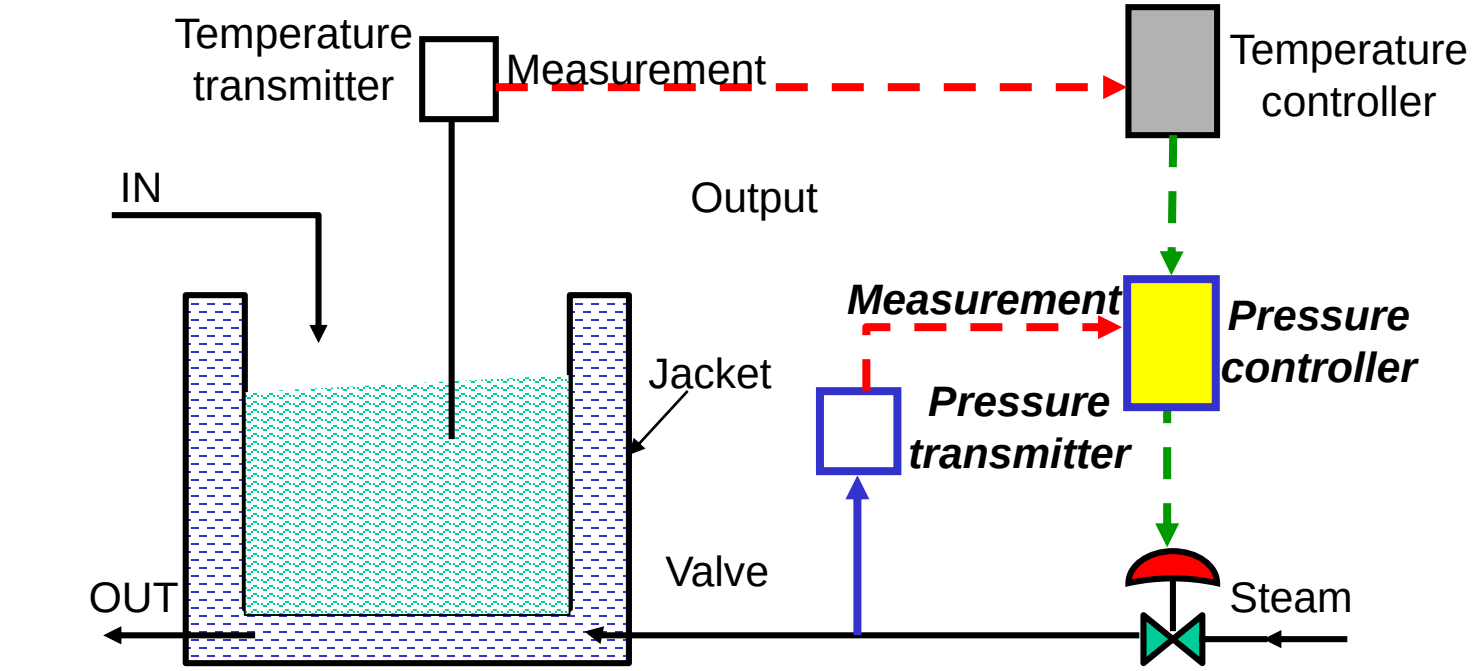
Consist of one controller (primary, or master) controlling the variable that is to be kept at a constant value, and a second controller (secondary, or slave) controlling another variable that can cause fluctuations in the first variable. The primary controller positions the set point of the secondary, and it, in turn, manipulates the control valve.



Advance Control Loop

Example of CASCADE CONTROL

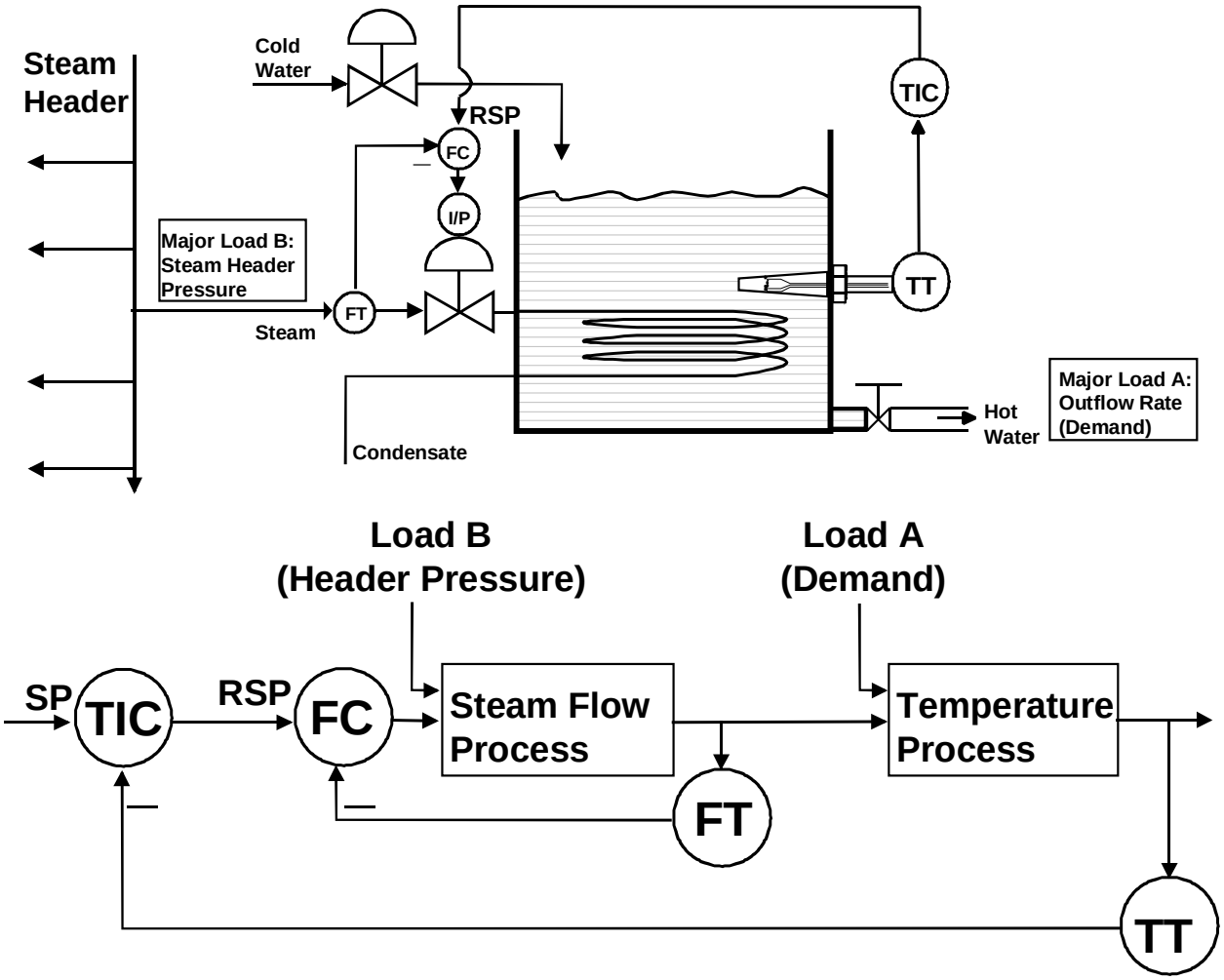
The temperature of the liquid in the vessel is controlled by regulating the steam pressure in the jacket around the vessel.



~~SINGLE-LOOP CONTROL~~ Cascade Control Loop

Advance Control Loop

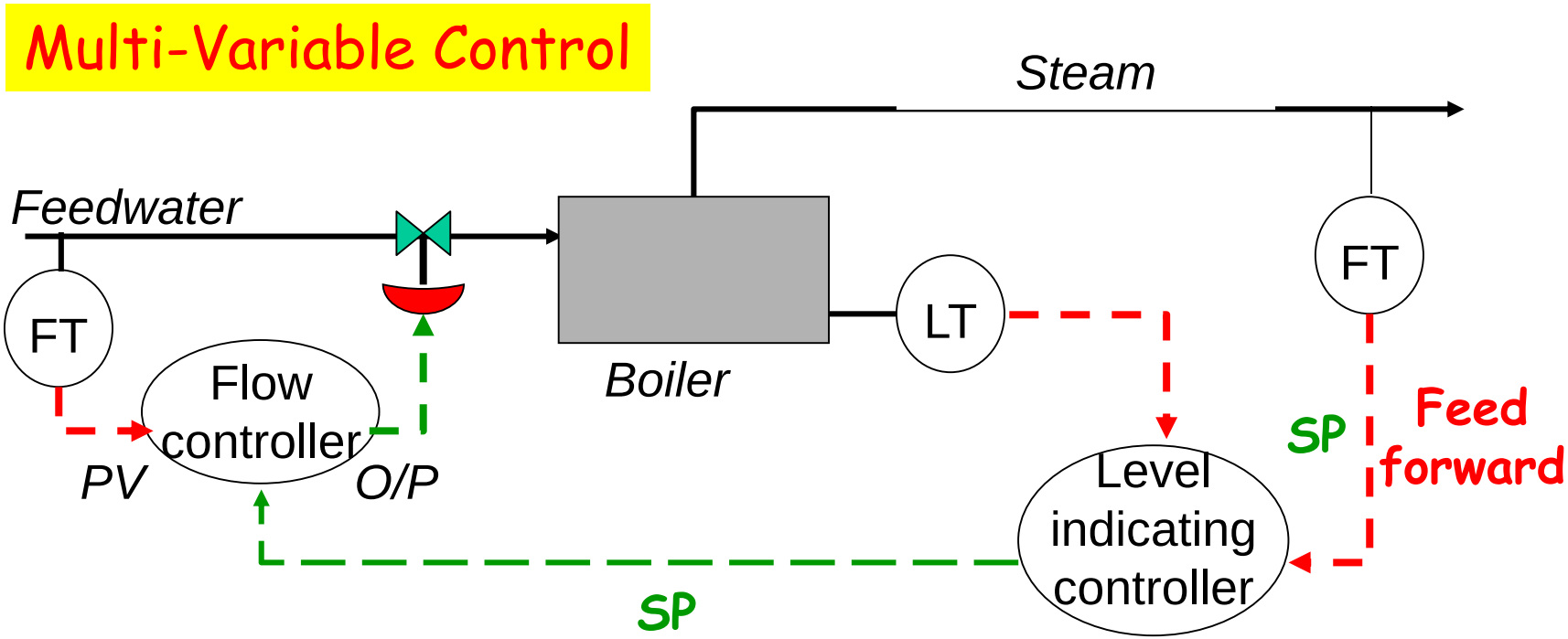
Implementing Cascade Control



Advance Control Loop

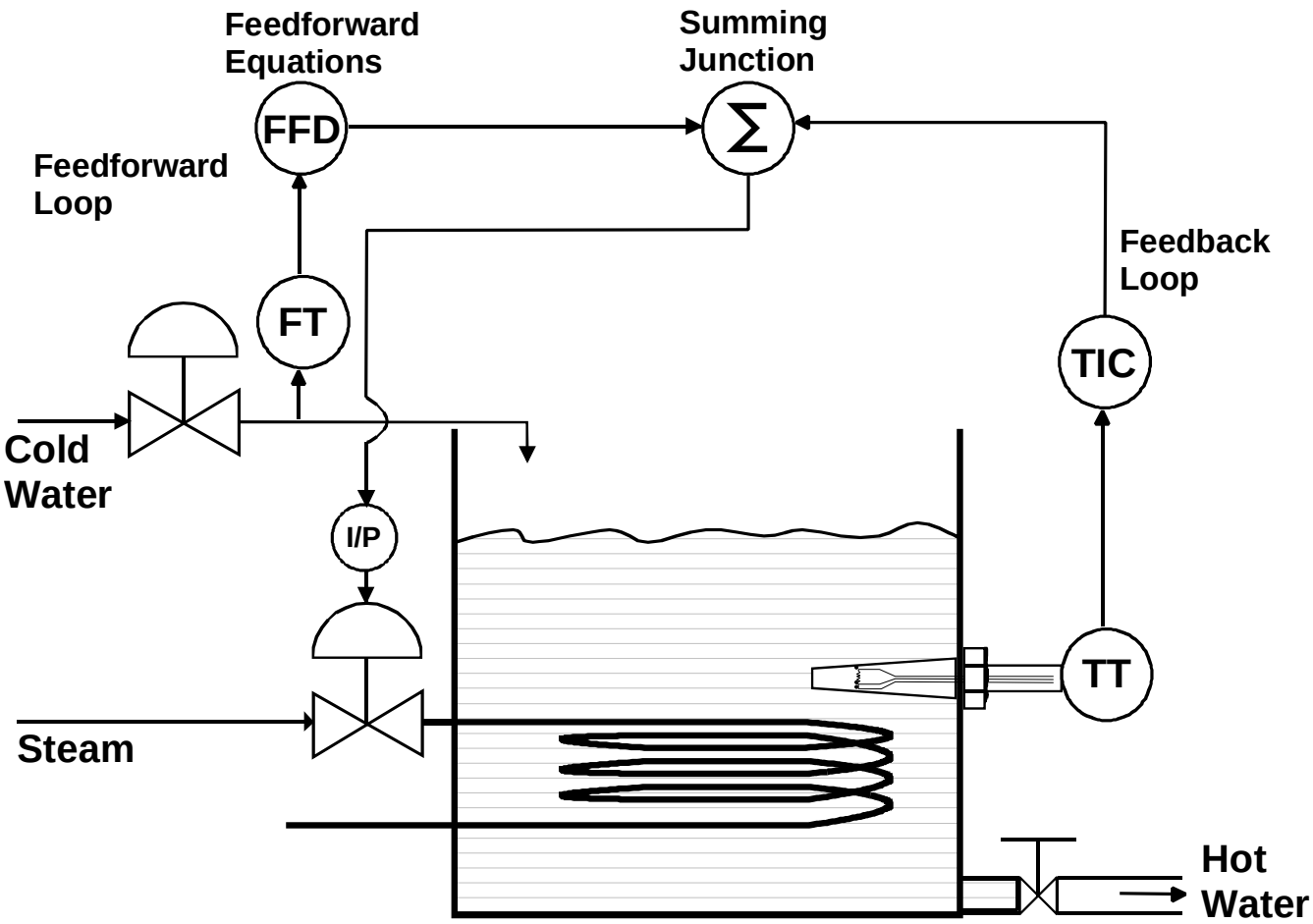
What is FEED FORWARD CONTROL ?

Applies to a system in which a balance between supply and demand is achieved by measuring both demand potential and demand load and using this data to govern supply. It gives a smoother and stable control than feedback control.



Advance Control Loop

Implementing Feedforward Control



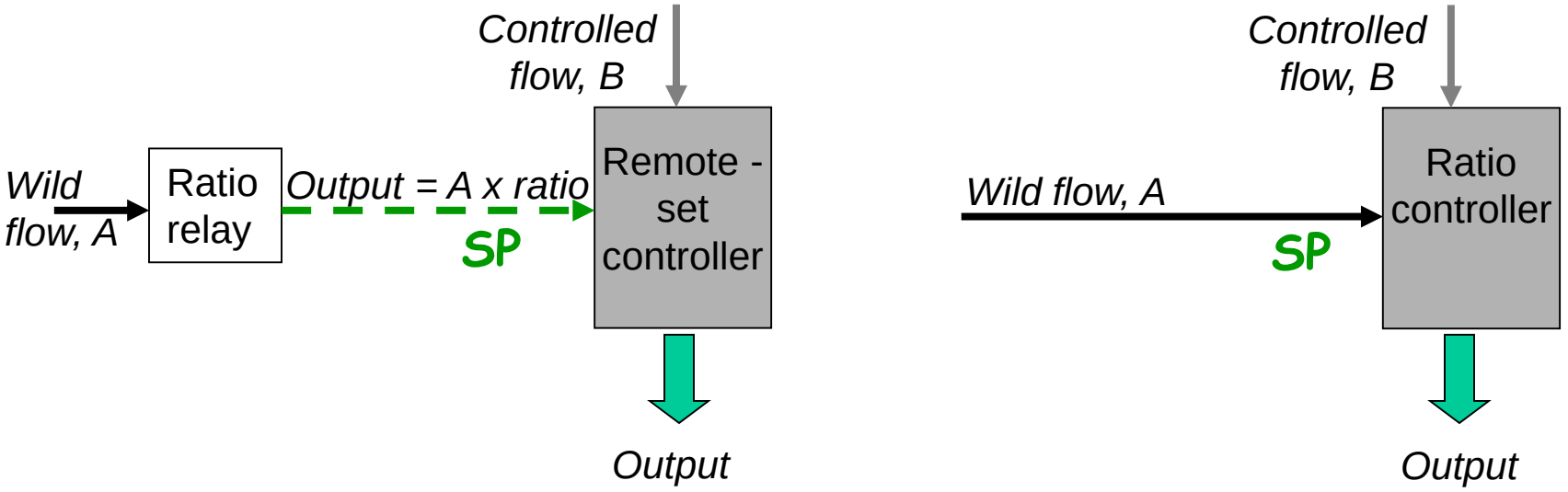
Advance Control Loop

What is RATIO CONTROL ?

An uncontrolled flow determines a second flow so that a desired ratio is maintained between them.

The ratio factor is set by a ratio relay or multiplying unit which would be located between the wild flow transmitter and the flow controller set point. Flow B is controlled in a preset ratio to flow A.

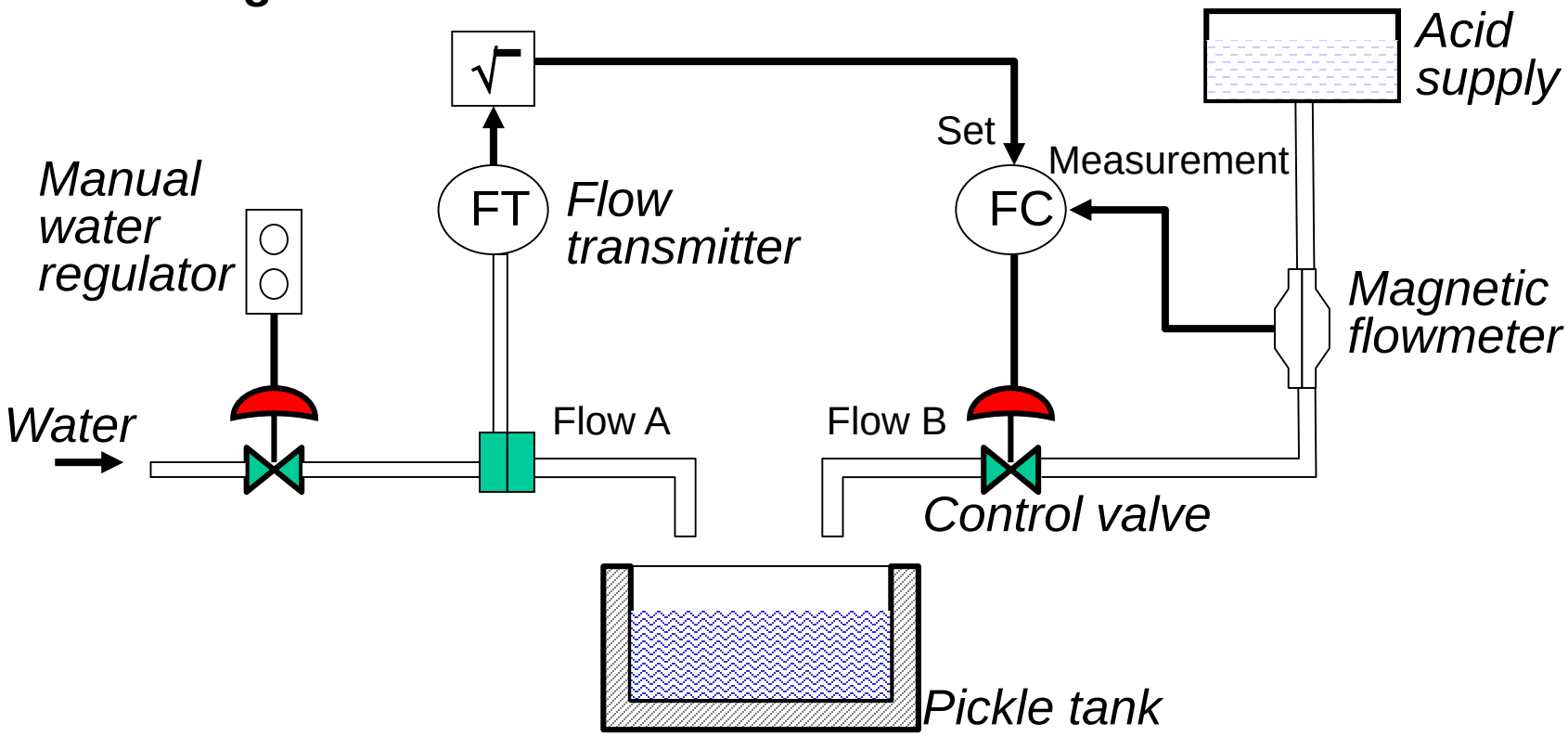
Multi-Variable Control



Advance Control Loop

Example of RATIO CONTROL

Pickling Process



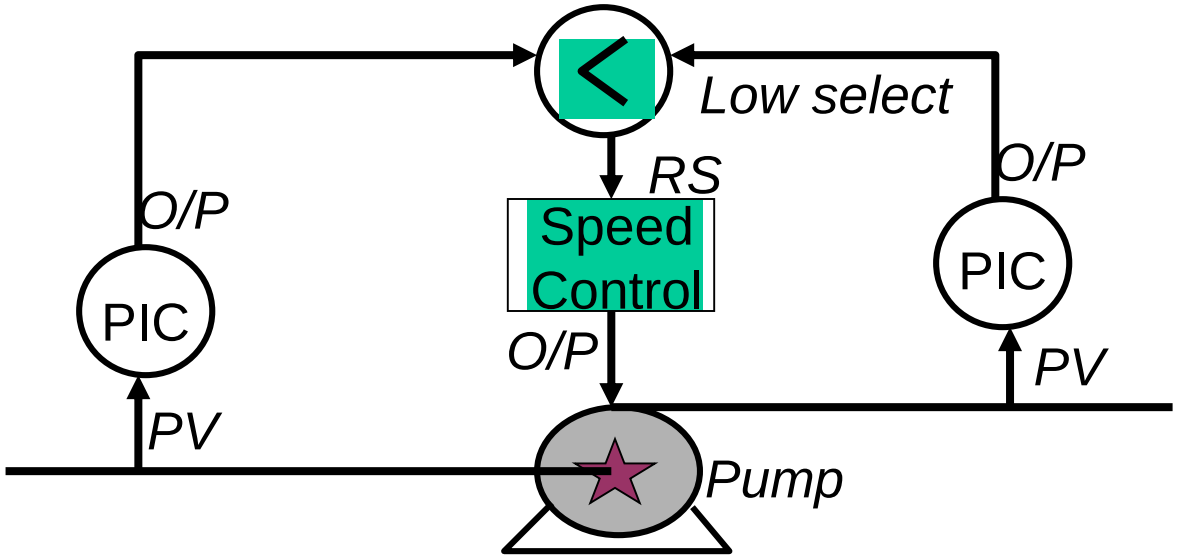
Other Application : *Fuel/air ratio control system on combustion equipment, e.g. boilers.*

Advance Control Loop

What is SELECTIVE CONTROL ?

The more important condition between two or more candidates is selected. They are used mainly to provide protection to a piece of equipment which could suffer damage as a result of abnormal operating conditions.

Multi-Variable Control



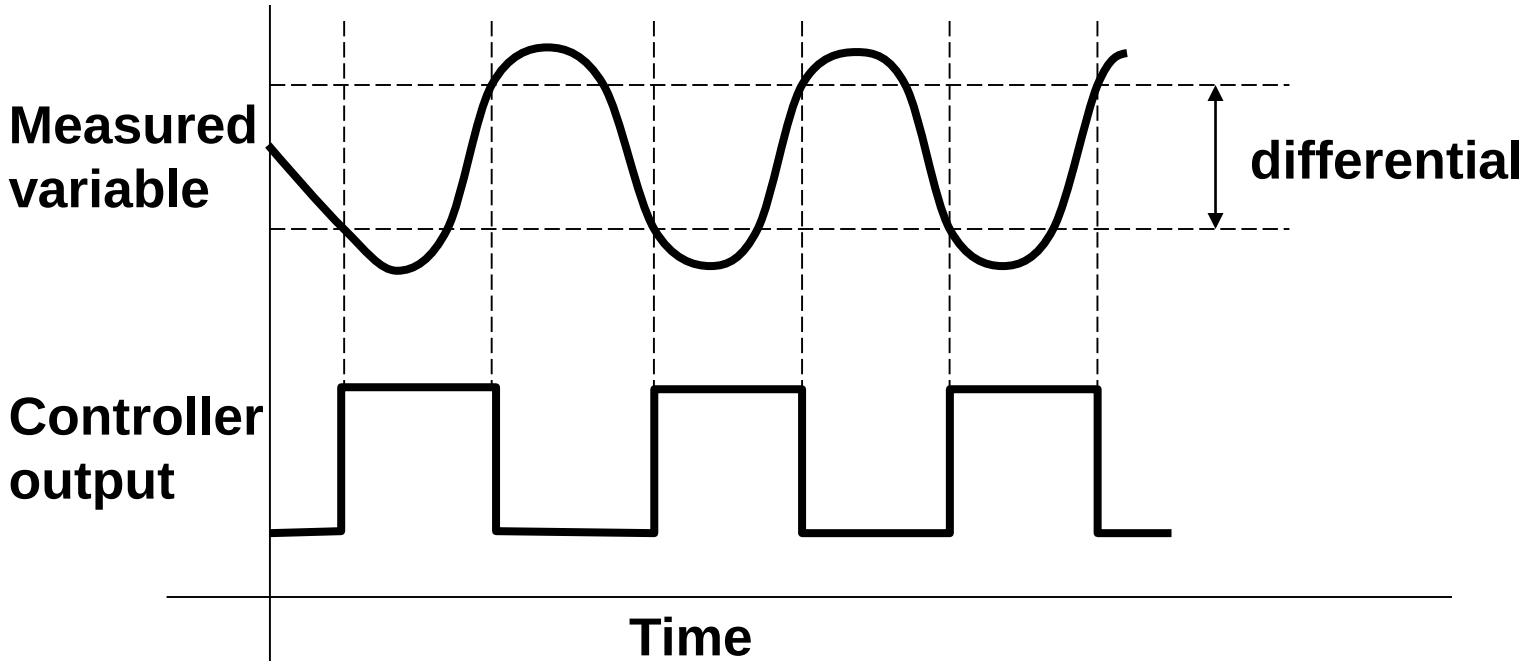
Control Algorithm

- On/Off
- Multi-step
- Proportional
- Integral
- Derivative

Control Algorithm

On-Off Control

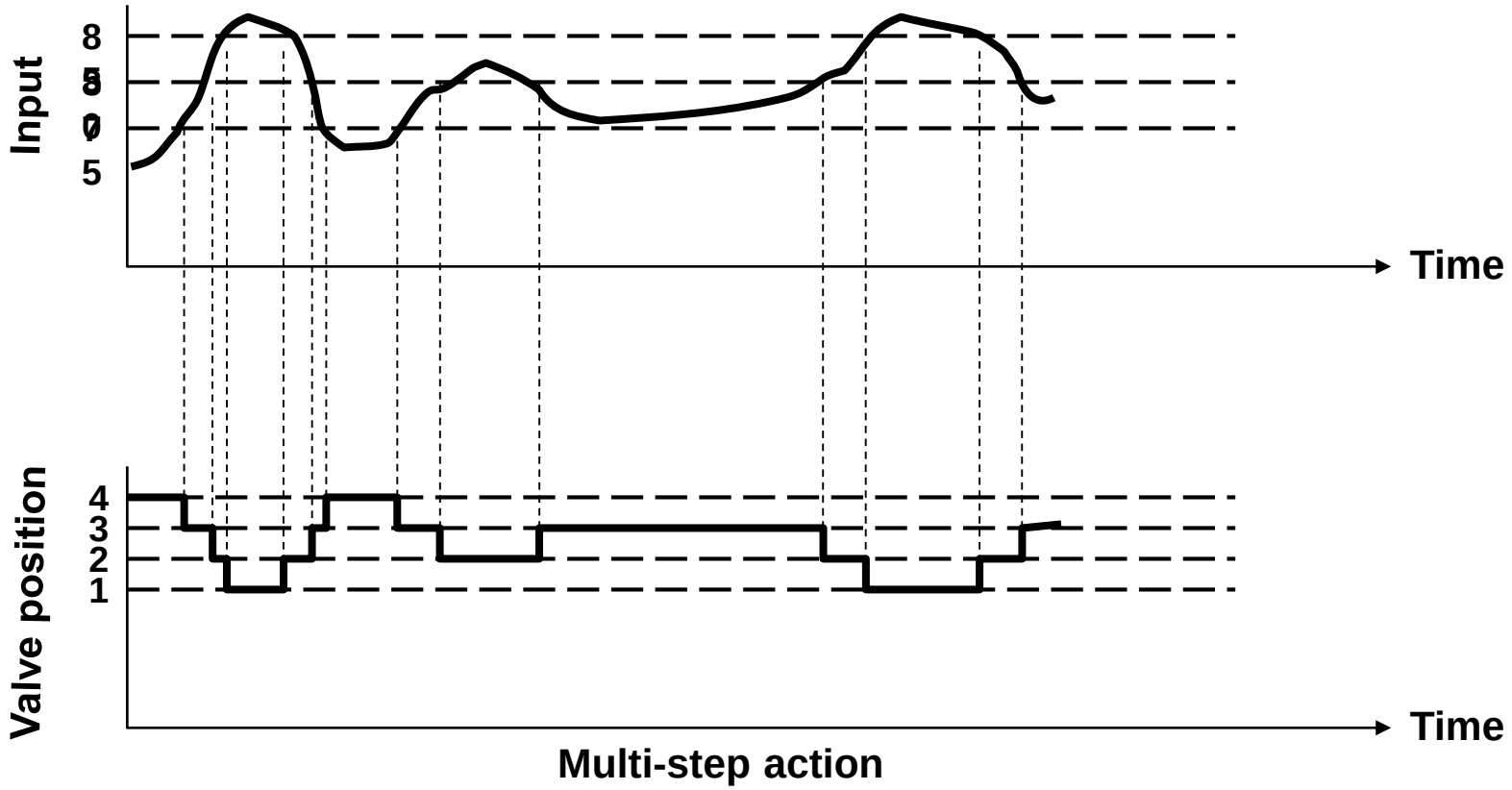
It is a two-position control, merely a *switch* arranged to be **off** (or on as required) when the error is positive and **on** (or off as required) when the error is negative. *Ex.. Oven & Alarm control.*



Control Algorithm

Multi-Step Action

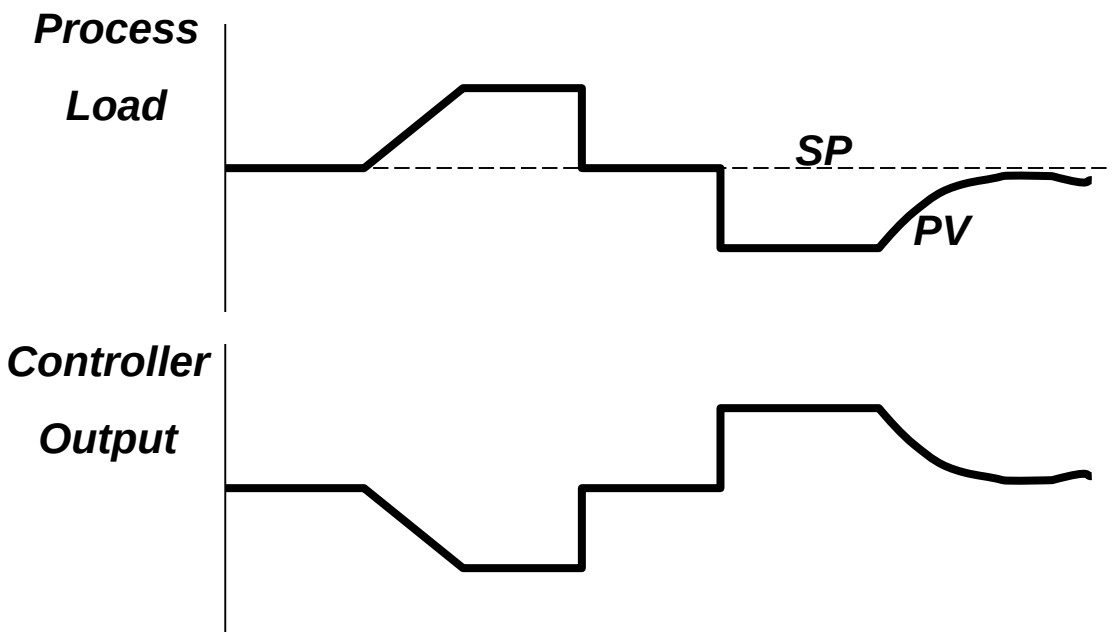
A controller action that may initiate more than two positioning of the control valve with respect to the respective predetermined input values.



Control Algorithm

Proportional Action (P)

It is the basis for the 3-mode controller. The controller output (O/P) is proportional to the difference between Process Variable (PV) and the Set Point (SP).



Open-loop response of proportional mode

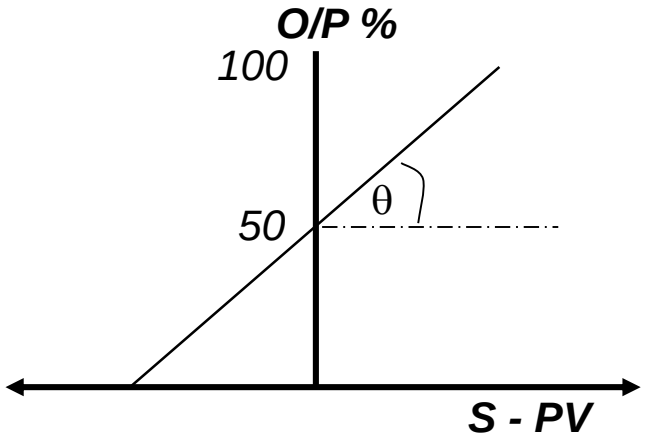
Control Algorithm

Proportional Action (P)

The Algorithm is :

$$O/P = \frac{-(PV - SP)}{\text{Proportional Band}} + \text{Constant}$$

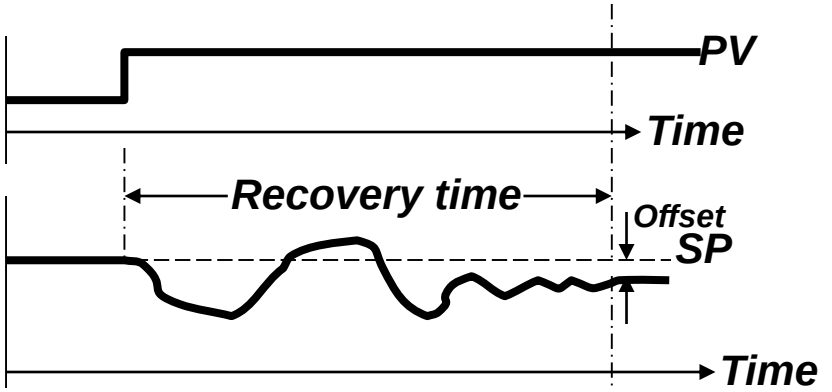
(Constant is normally 50%)



Tan θ = Gain = 100 / Proportional Band

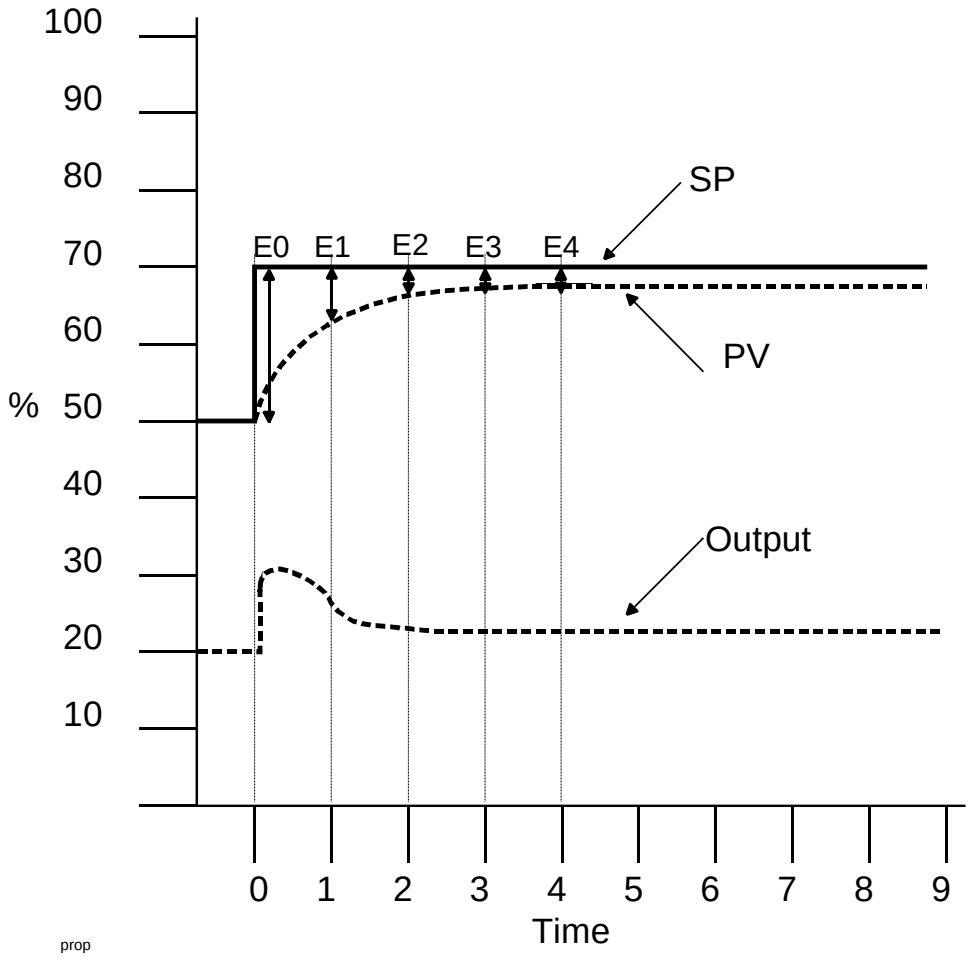
When a disturbance alters the process away from the set-point, the controller acts to restore initial conditions. In equilibrium, **offset** (PV-SP = constant) results.

Many controllers have a 'manual reset'. This enables the operators to manipulate the 'constant' term of the algorithm to eliminate offset.



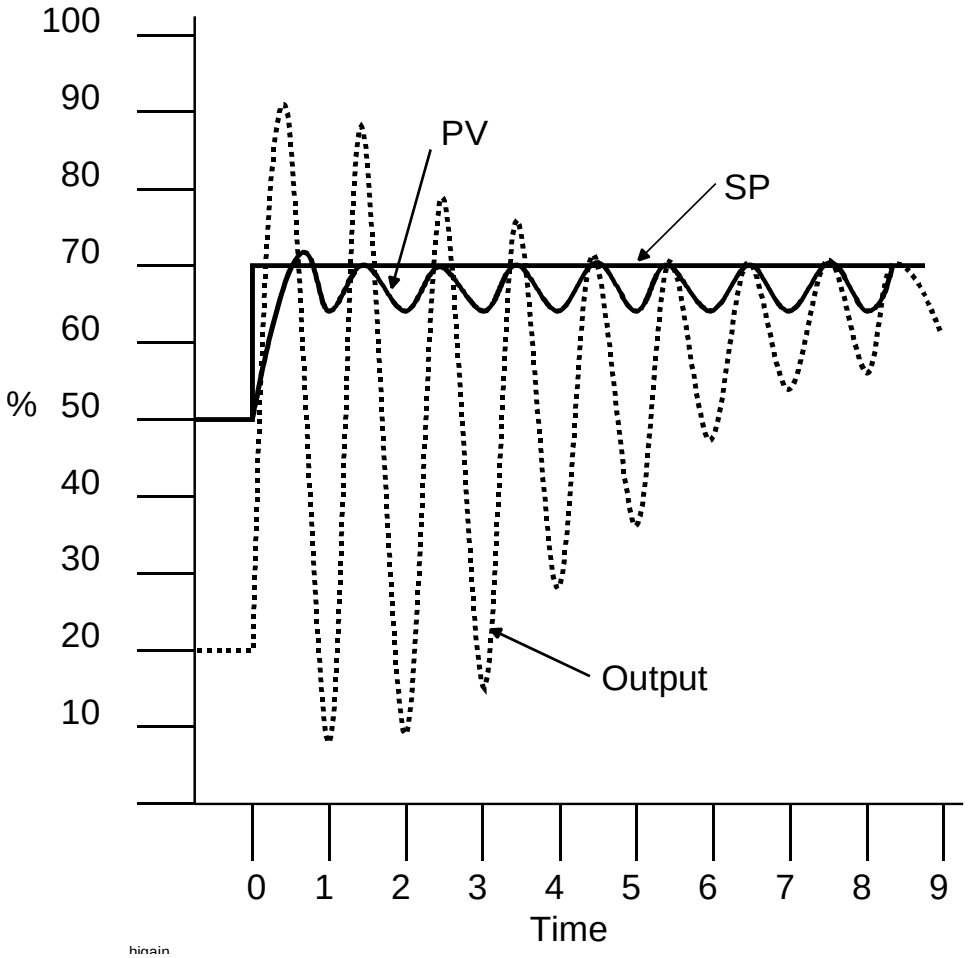
Control Algorithm

Low Proportional Gain: (Closed Loop)



Control Algorithm

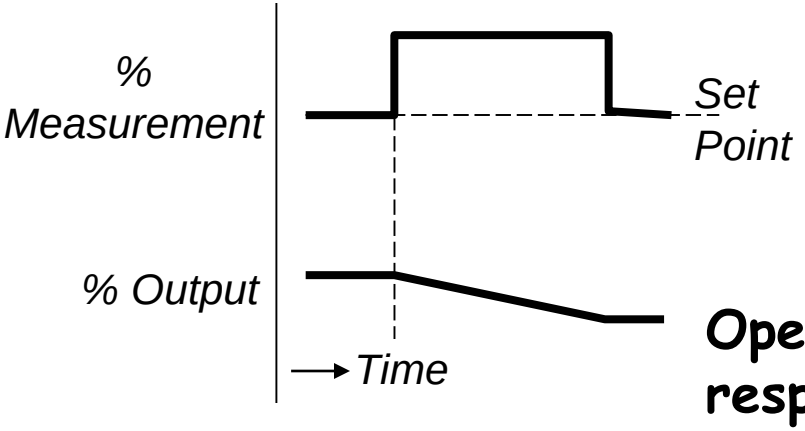
High Proportional Gain: (Closed Loop)



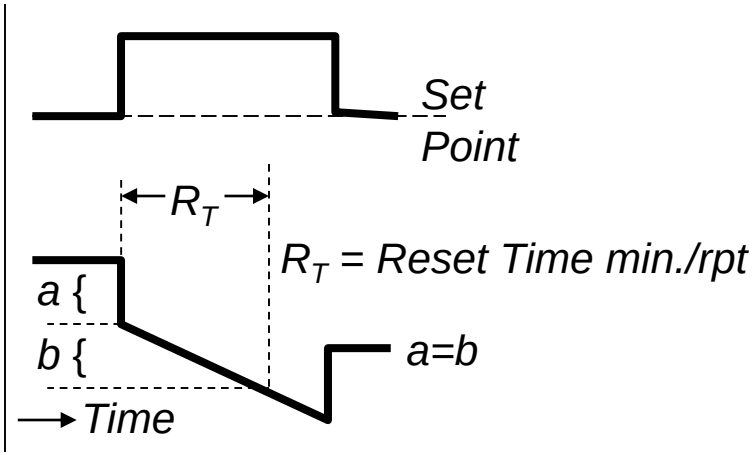
Control Algorithm

Integral Action (I)

Whilst PV ≠ SP, the controller operates to restore equality.
As long as the measurement remains at the set point, there is no change in the output due to the integral mode in the controller.
The output of the controller changes at a rate proportional to the offset.
The integral time gives indication of the strength of this action. It is the time taken for integral action to counter the 'offset' induced by Proportional Action alone.



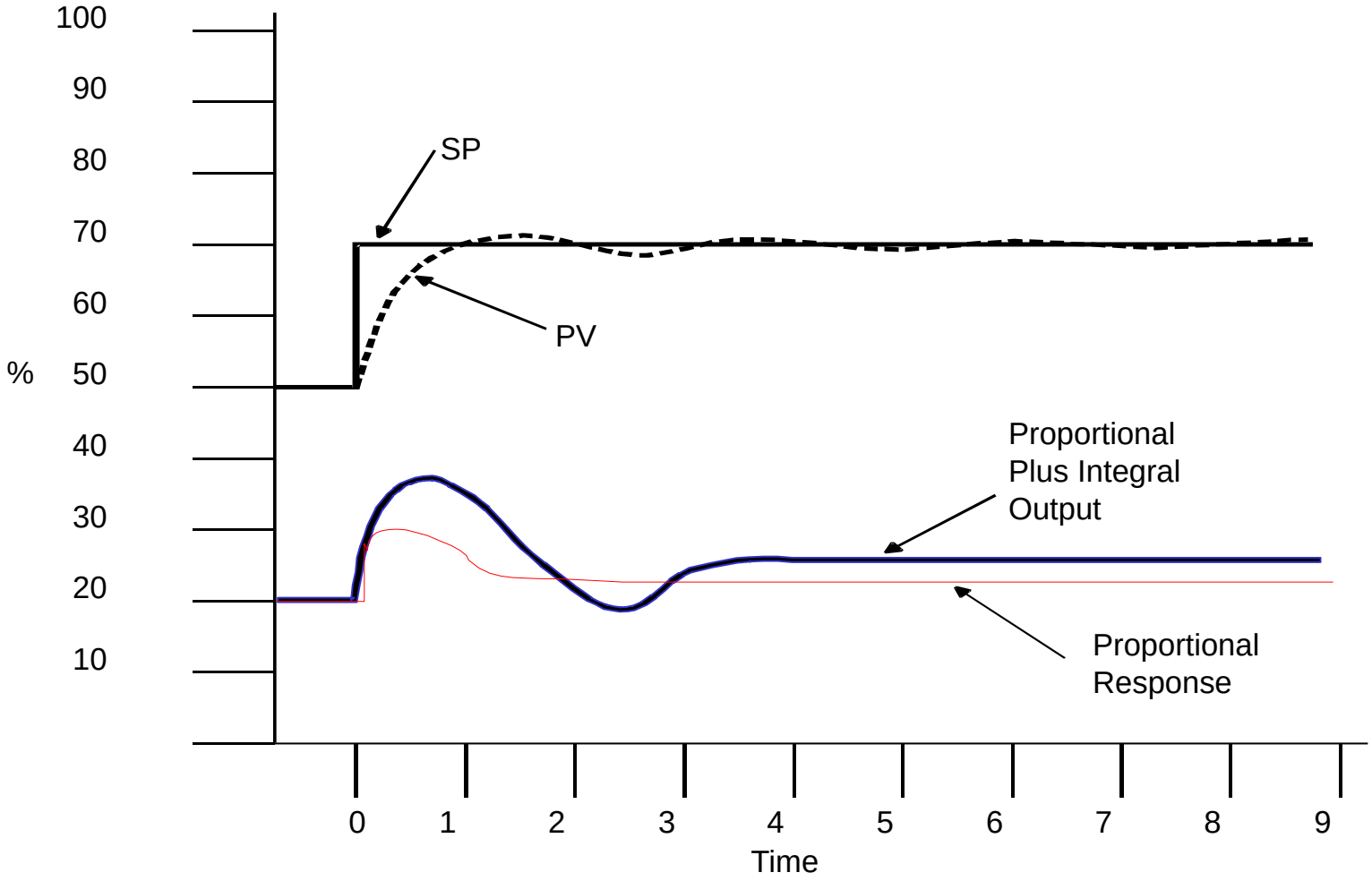
Integral mode



Proportional plus Integral mode

Control Algorithm

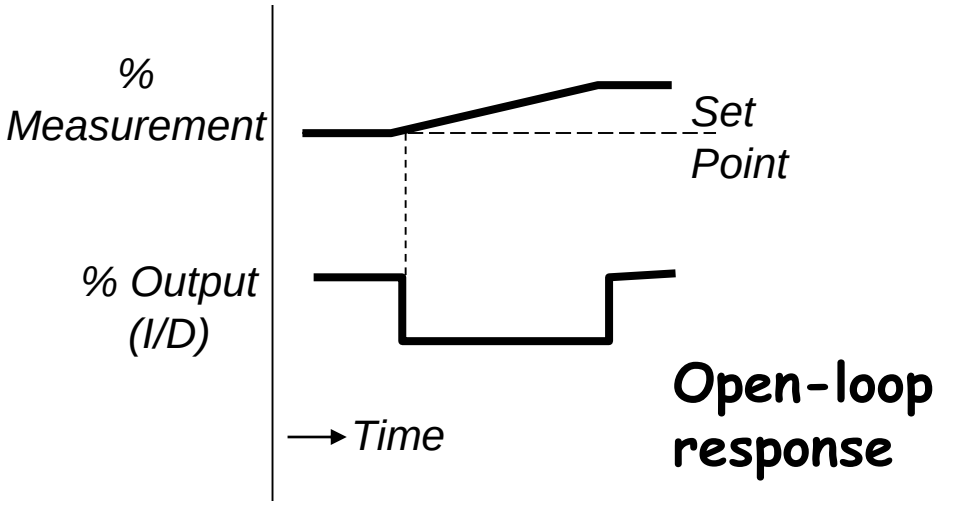
Integral Action: (Closed Loop)



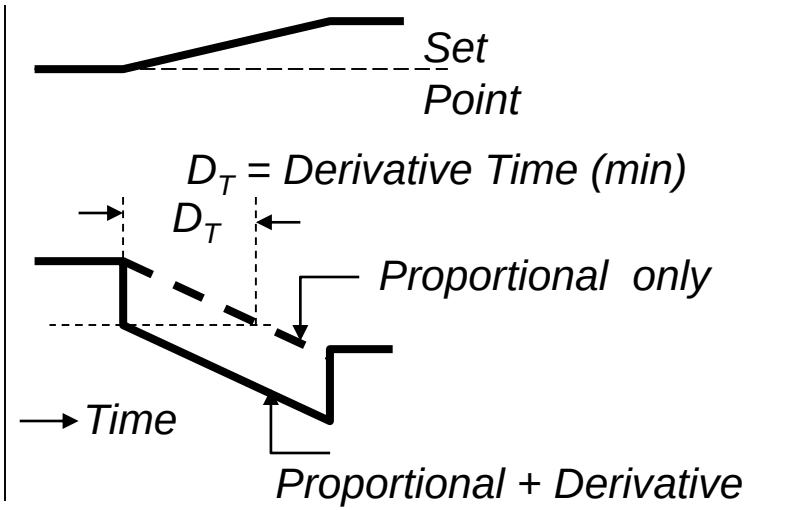
Control Algorithm

Derivative Action (D)

As the PV changes, the controller resists the change.
The controllers output is proportional to the rate at which the difference between the measured and desired value changes.
The derivative time is an indication of this action. It is the time that the open-loop **P+D** response is ahead of the response due to **P** only.



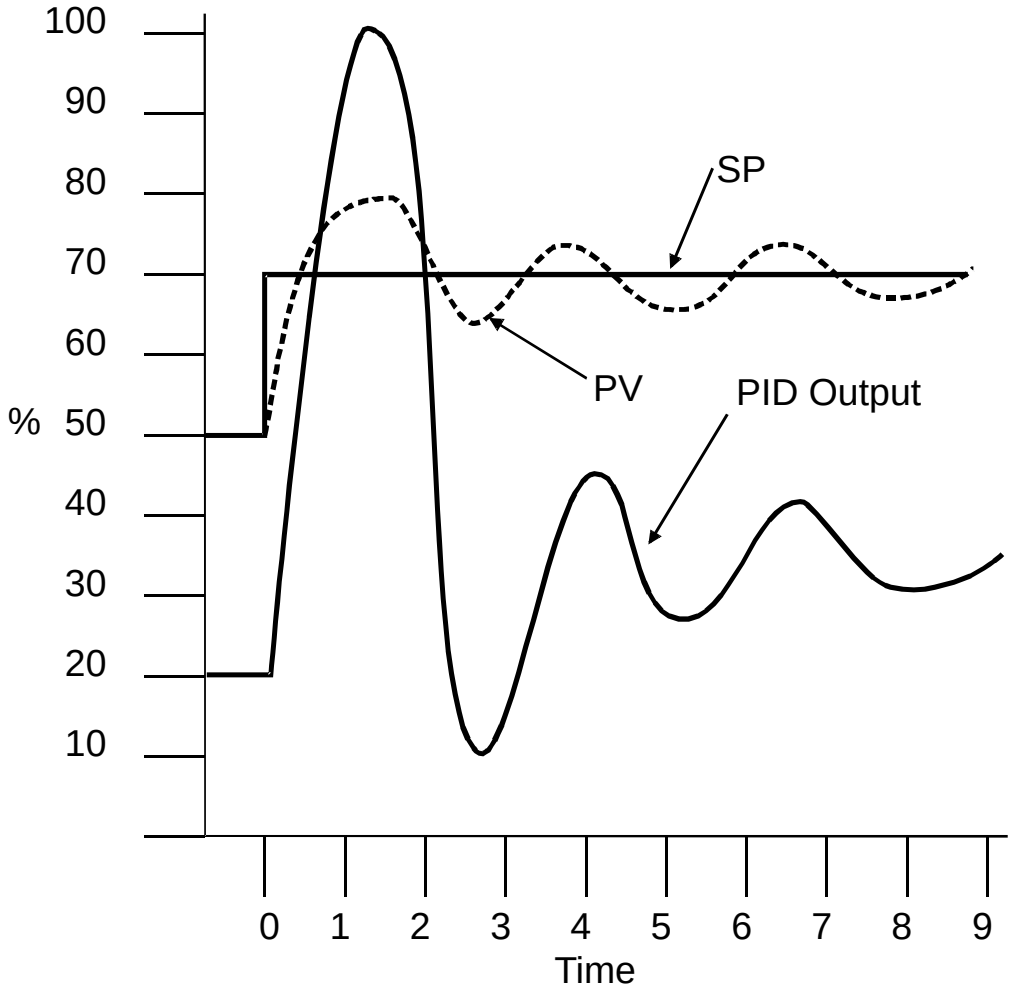
Derivative mode



Proportional plus Derivative mode

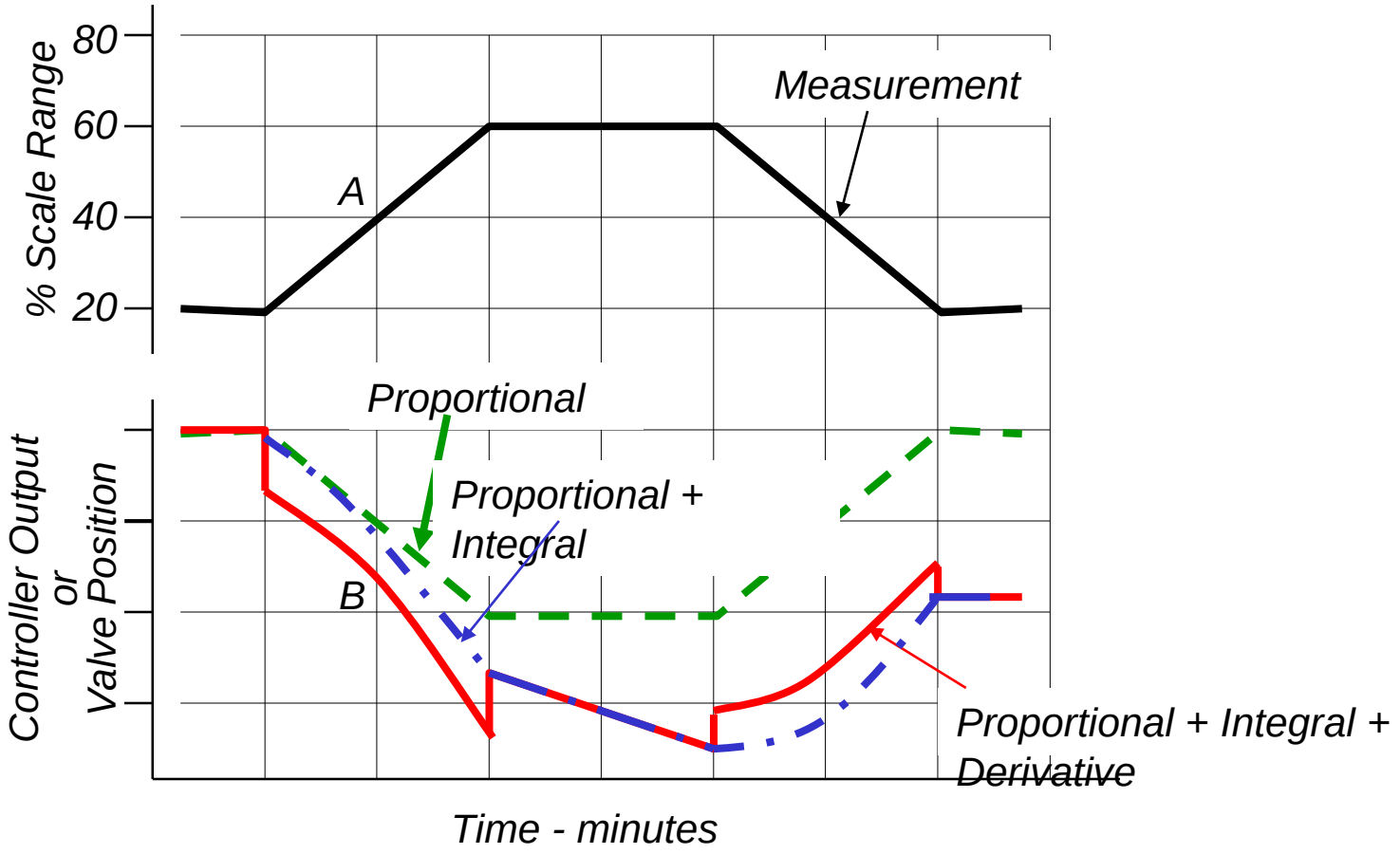
Control Algorithm

PID Action: (Closed Loop)



Control Algorithm

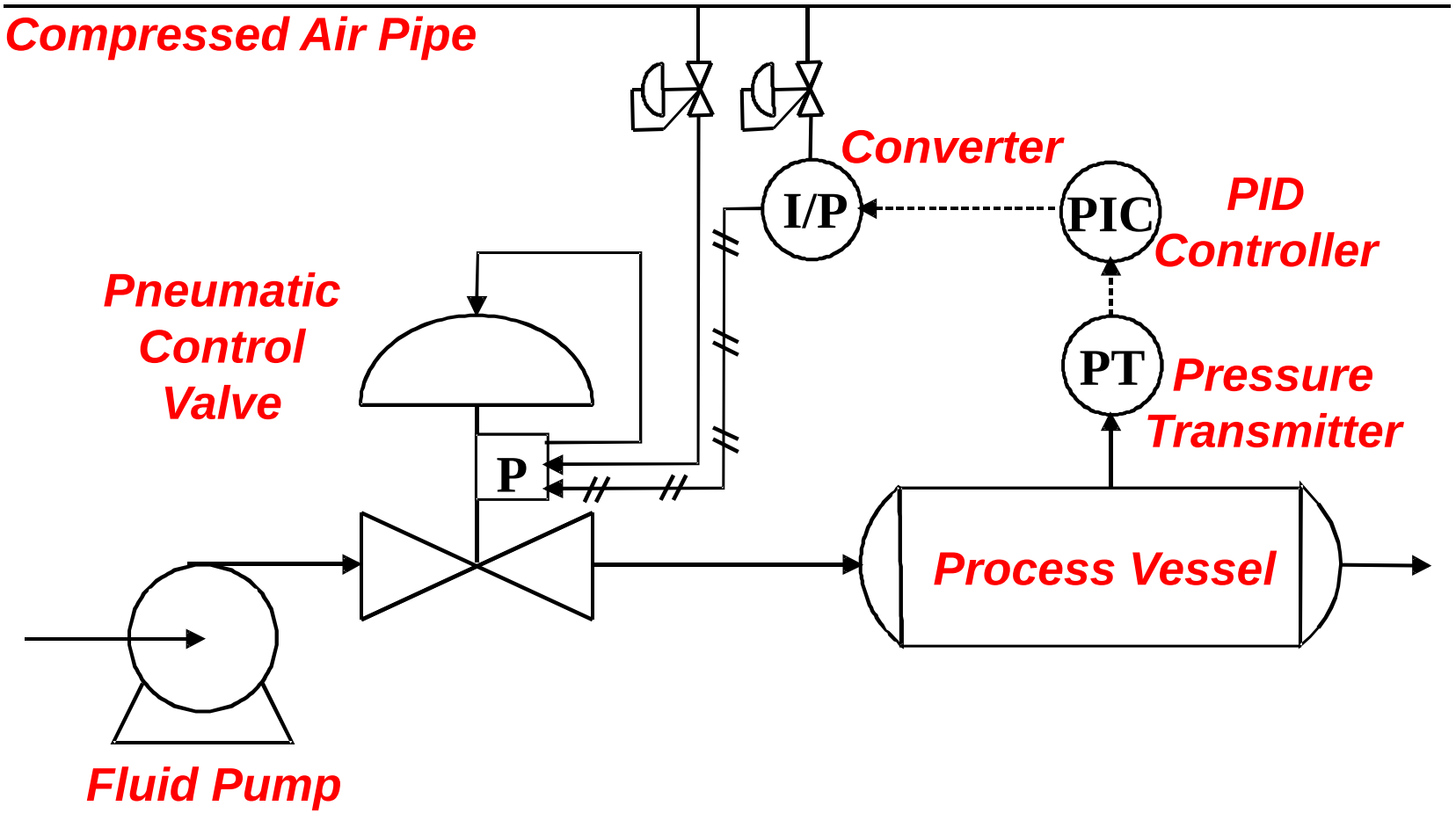
PID Control



Open-loop response of three-mode controller

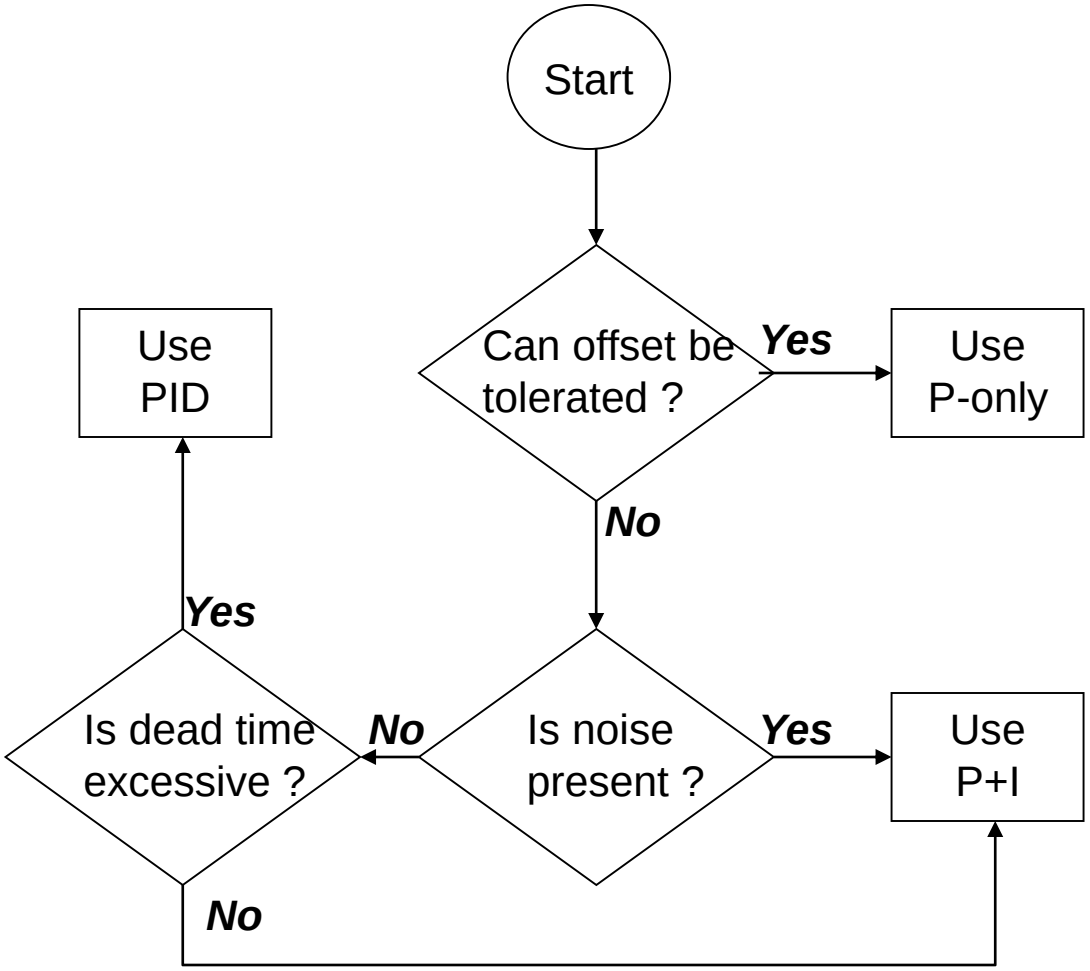
Control Algorithm

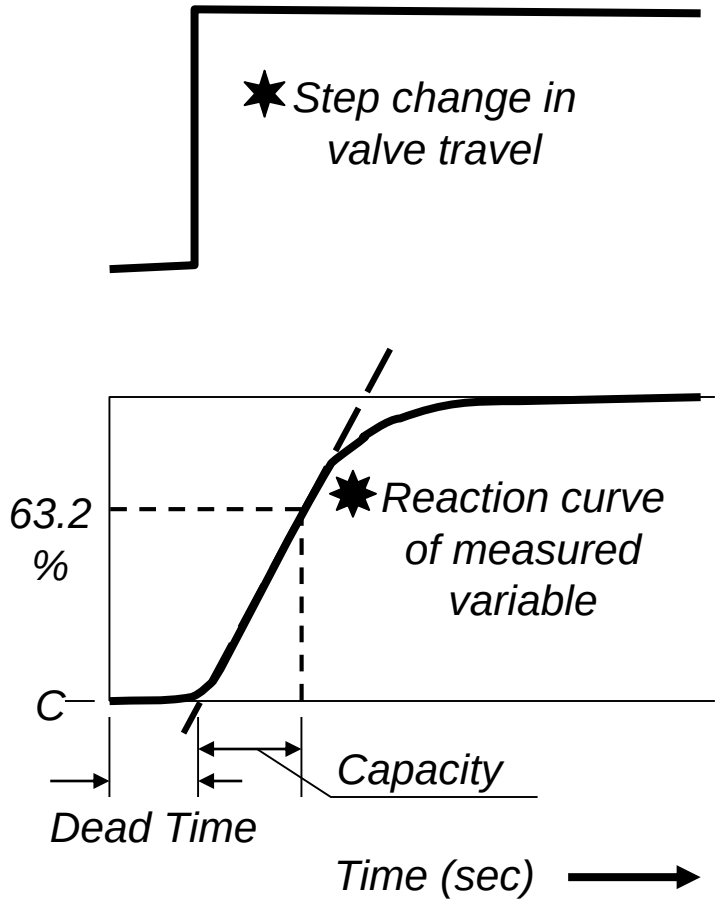
P & ID Piping & Instrumentation Drawing



Control Algorithm

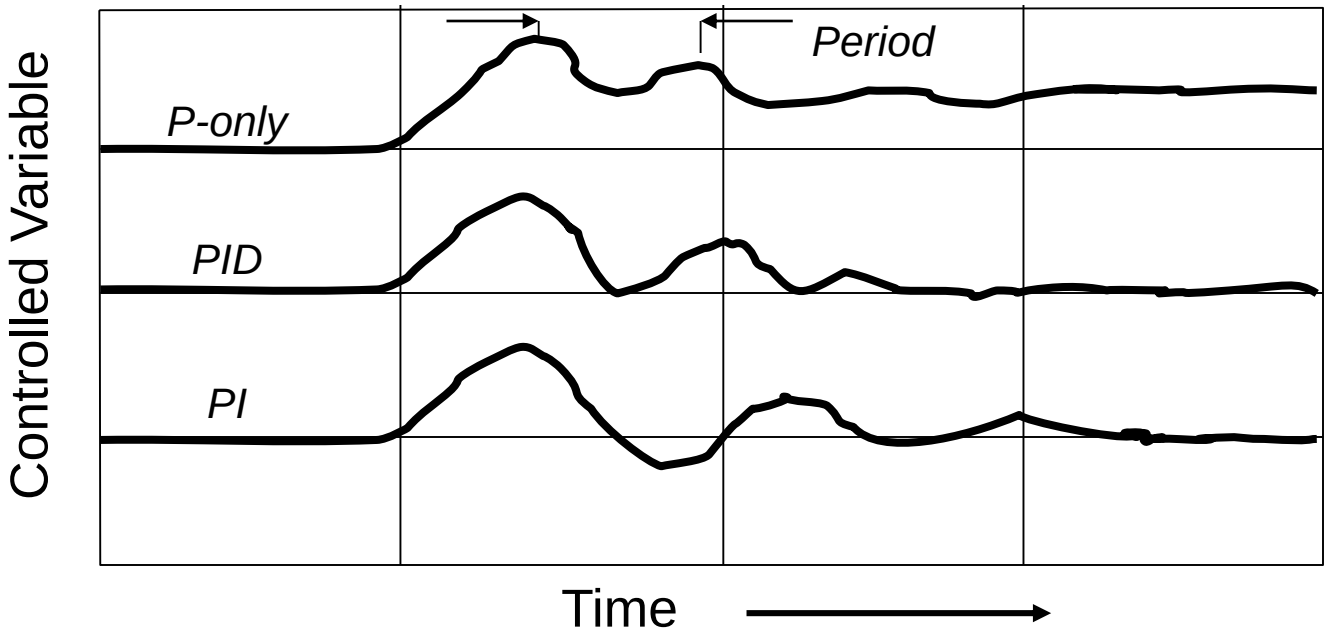
Controller Selection





Control Algorithm

Controller Adjustment



Control loop	*Proportional band*	*Time constant*	*Derivative*
Flow	High (250%)	Fast (1 to 15 sec)	Never
Level	Low	Capacity dependent	Rarely
Temperature	Low	Capacity dependent	Usually
Analytical	High	Usually slow	Sometimes
Pressure	Low	Usually fast	Sometimes

Adaptive Control

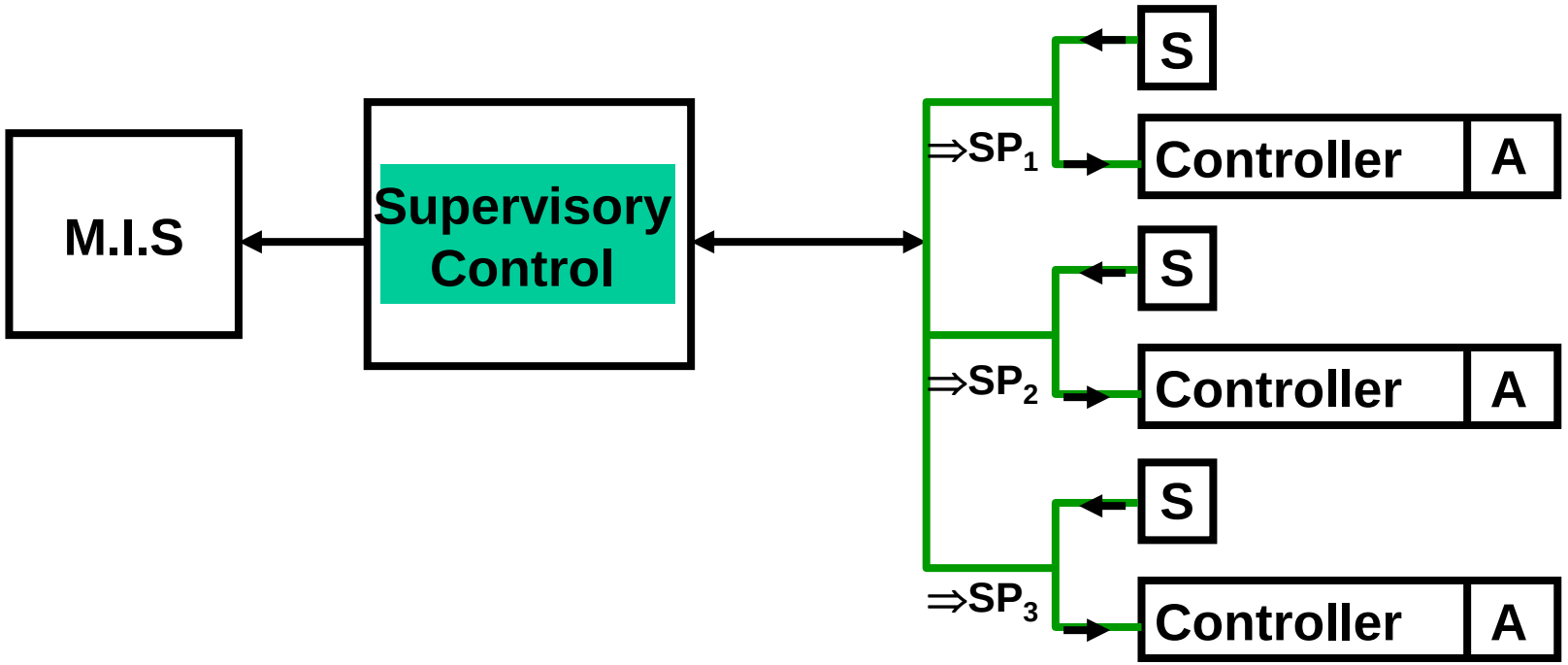
An automatic control scheme in which the controller is programmed to evaluate its own effectiveness and modify its own control parameters to respond to dynamic conditions occurring in or to the process which affect the controlled variables.

Ex) **Digital Controller**

- *Sensors are run to the computer's input.*
- *Servomechanisms are connected to the computer's output.*
- *Future changes don't require re-wiring.*
- *Changing control functions (P,I, and D) and configurations (between cascade mode and feedforward mode) will be made on the computer's program and not necessarily to any hardware.*

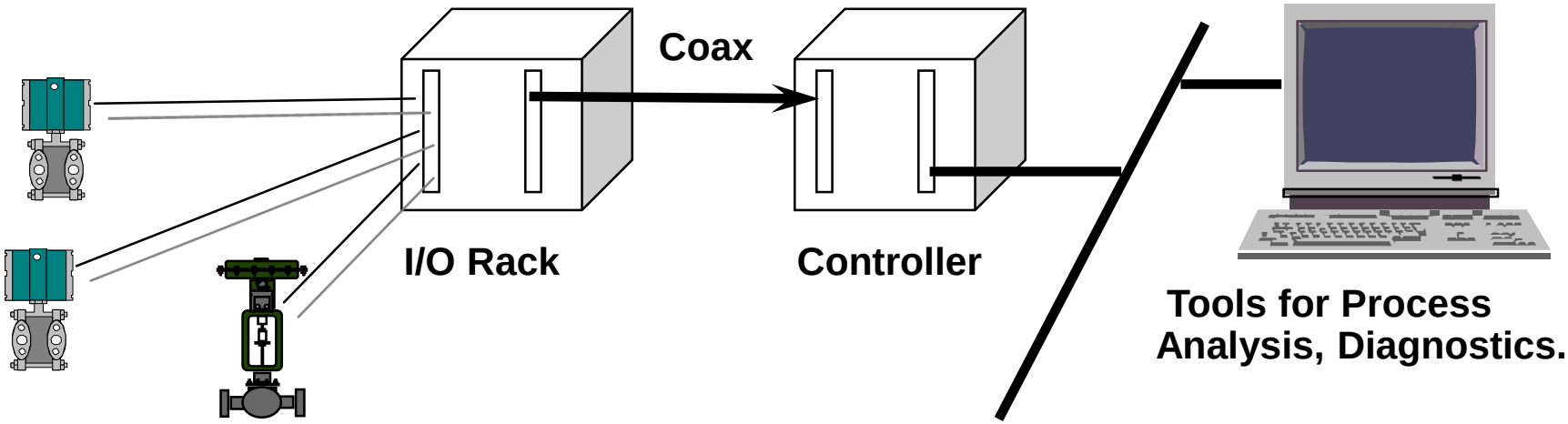
Supervisory Control

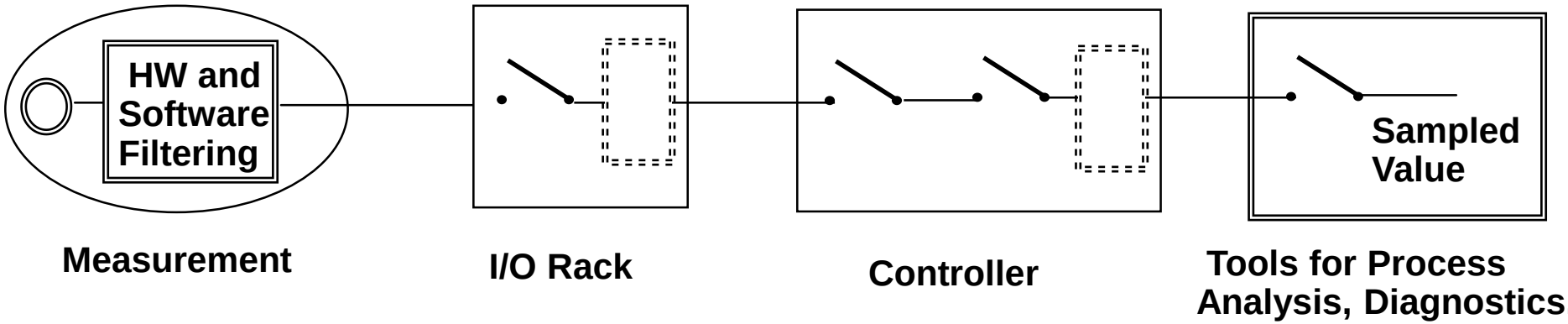
A control strategy where the process control computer performs system control calculations and provides its output to the setpoints inputs of conventional analog controllers. These analog controllers actually control the process actuators, not the main-control computer.



Control System

Today's DCS System

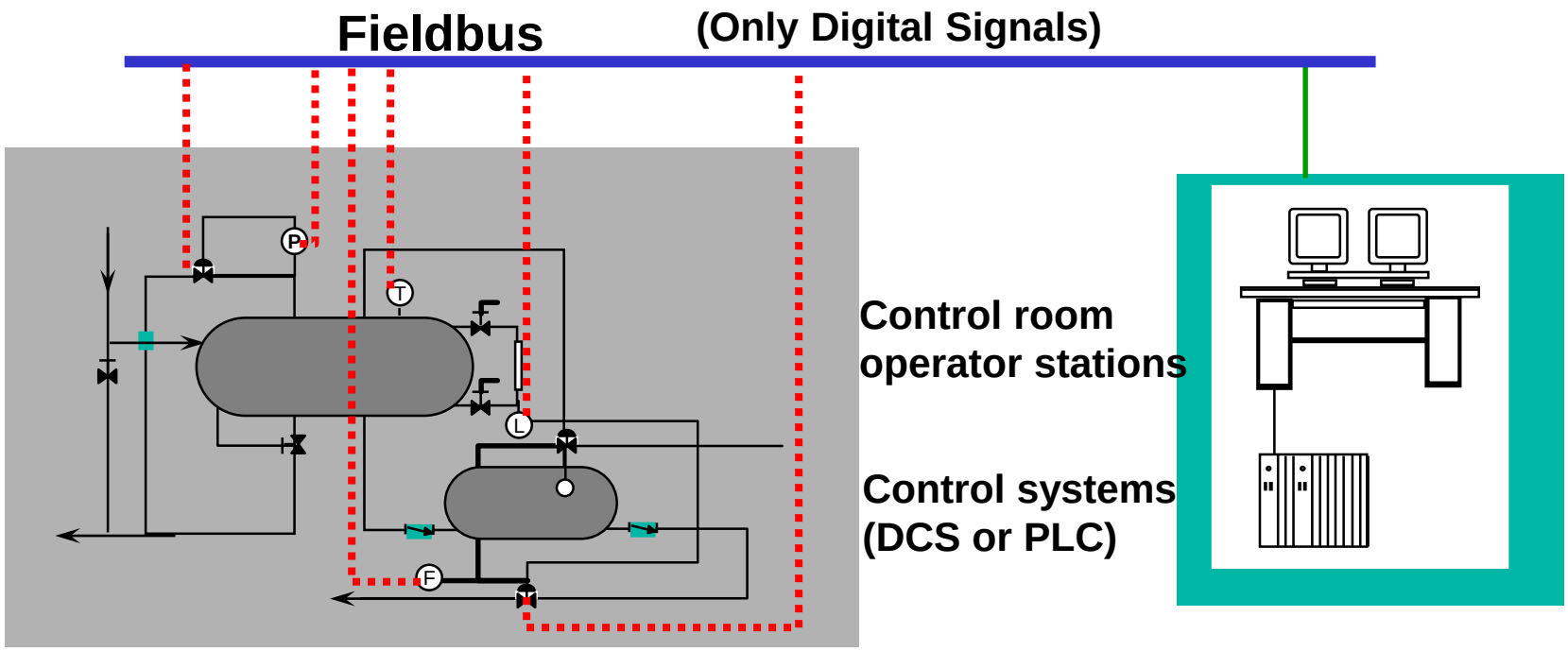




What is a FIELDBUS ?

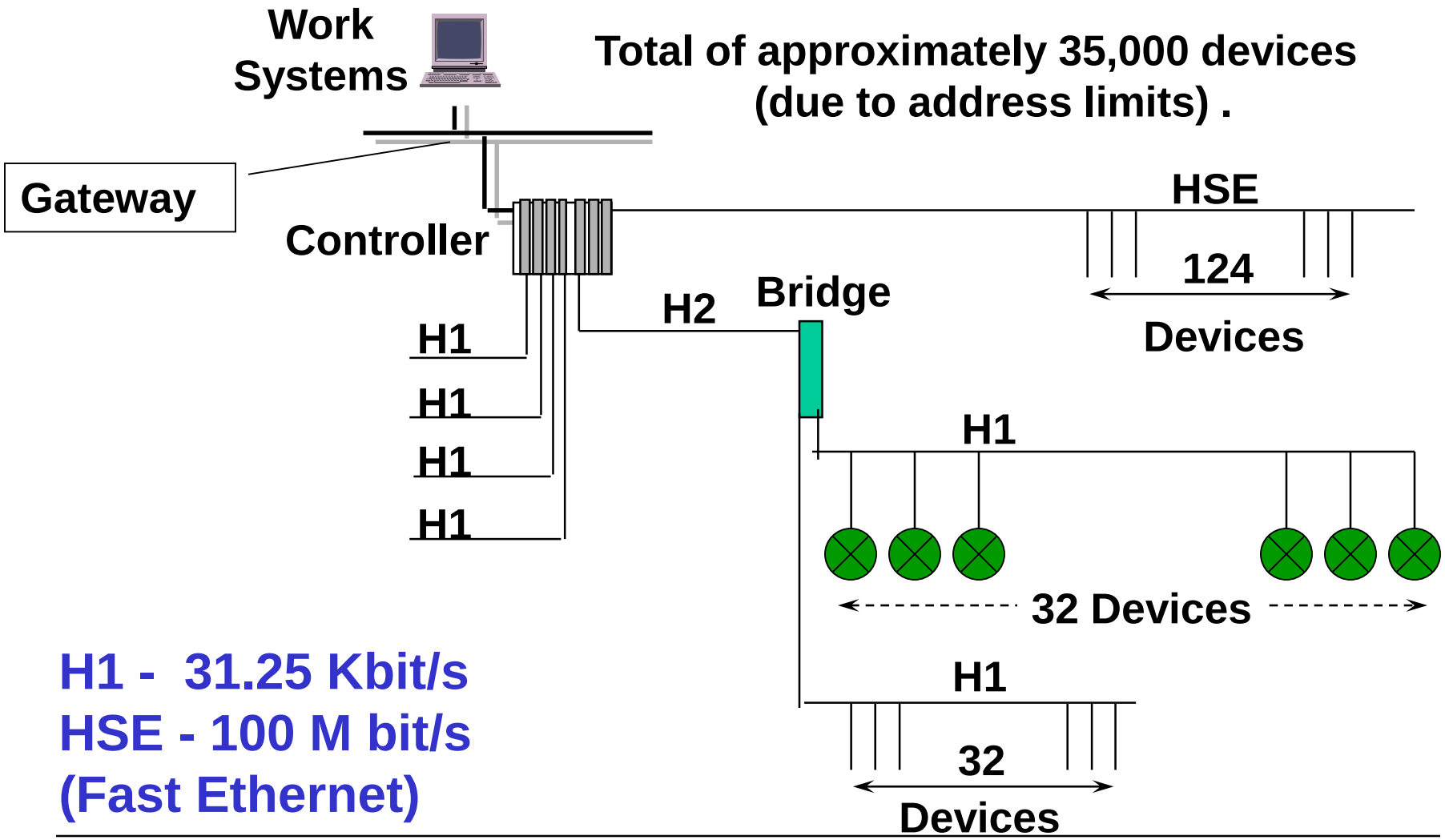
Definition...

A digital, two-way, multi-drop communication link among intelligent field devices and automation systems.



Control System

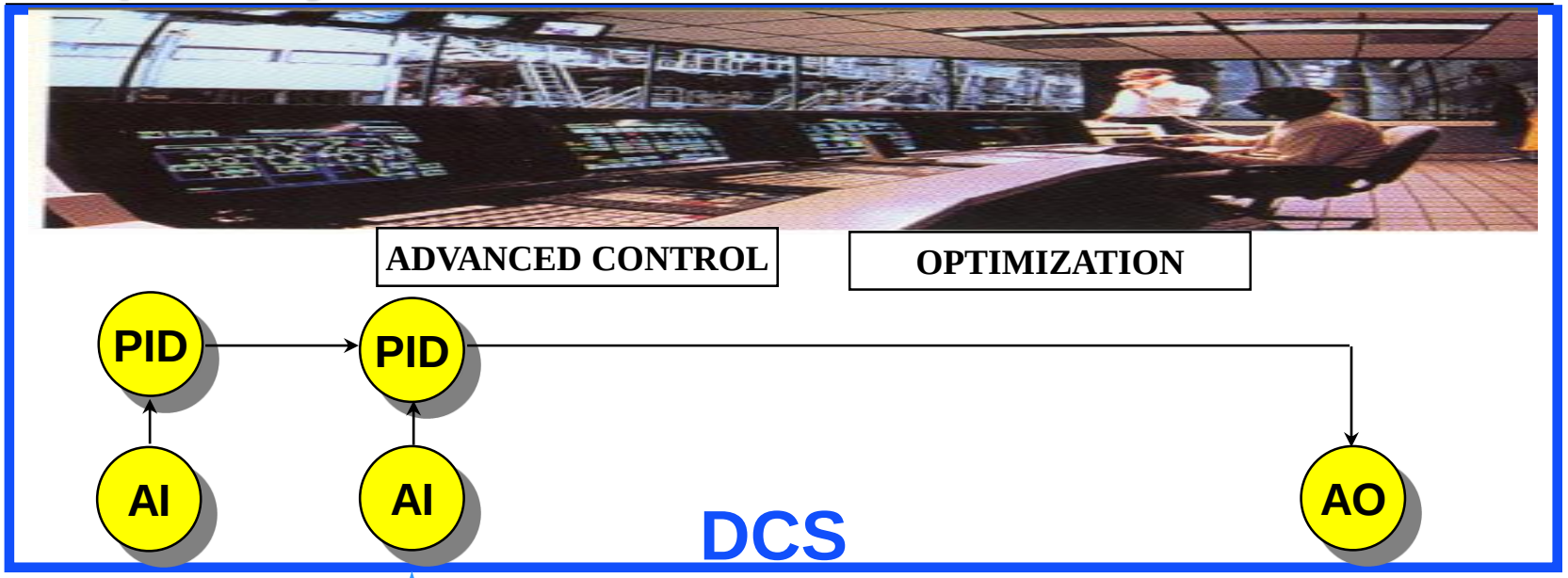
Fieldbus Control System



H1 - 31.25 Kbit/s
HSE - 100 M bit/s
(Fast Ethernet)

Control System

Proprietary Bus

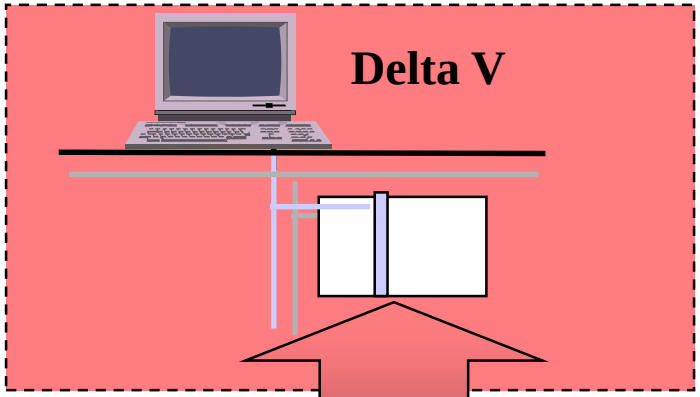


- **Control in the control room**

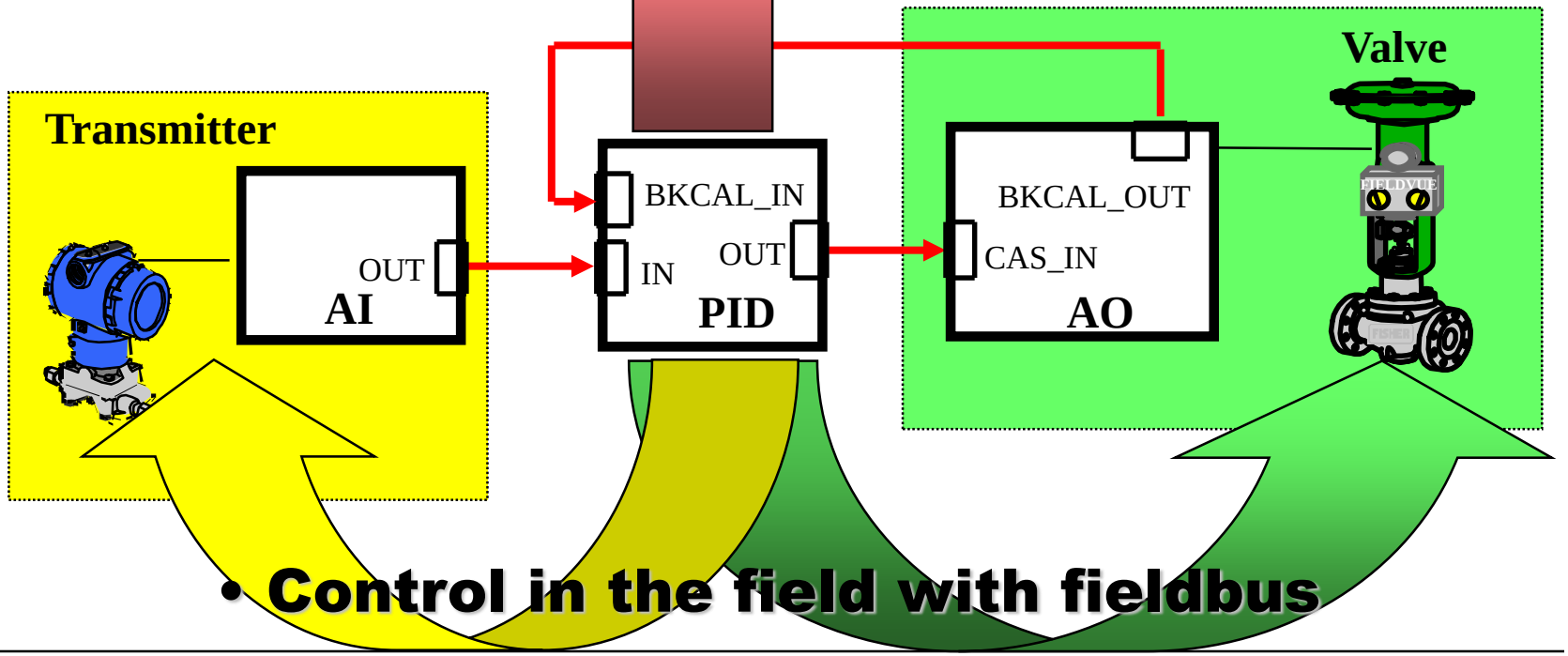
Control System

Foundation Fieldbus Devices

Built-In
Function
Blocks

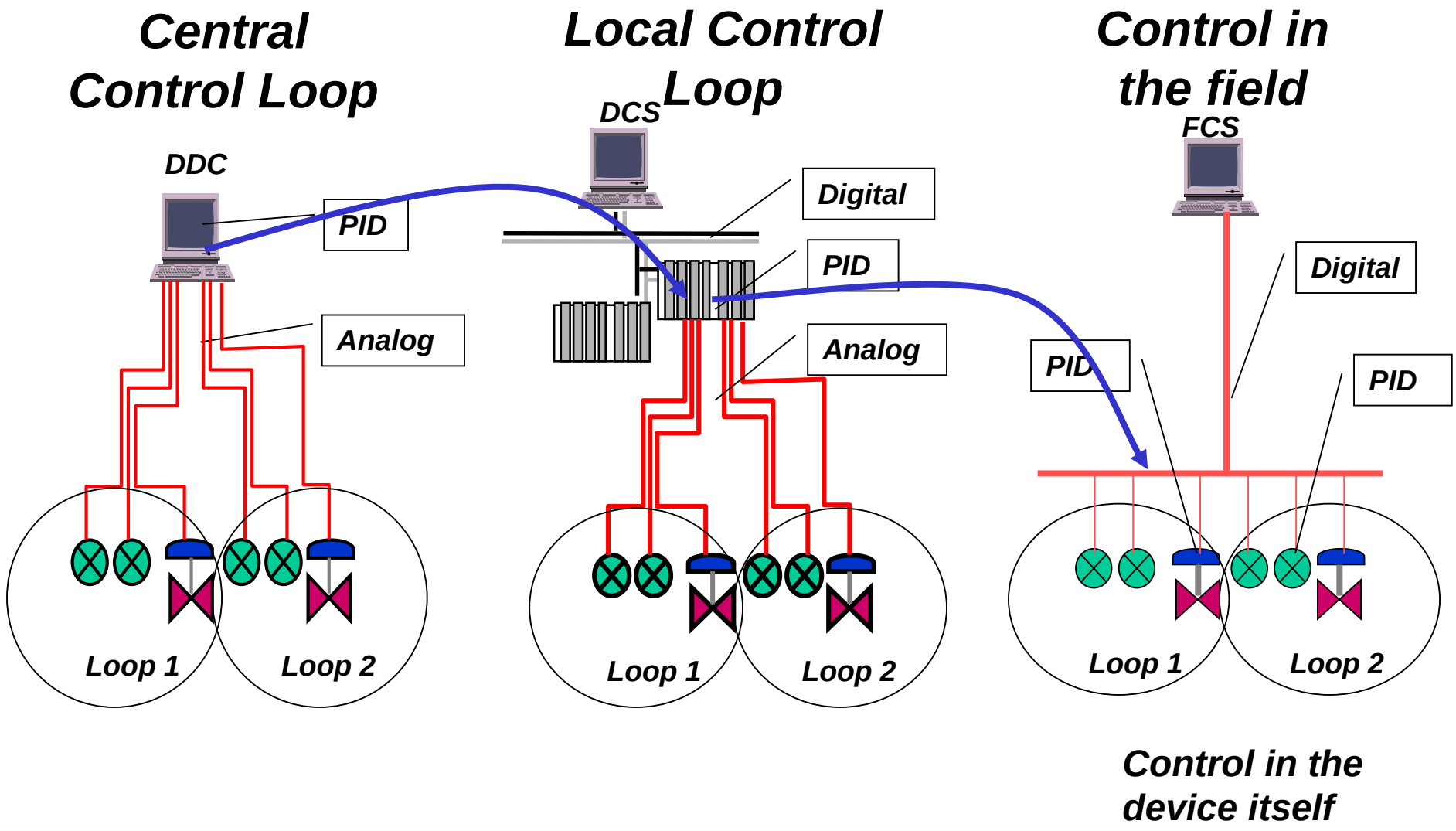


Control
Anywhere



- **Control in the field with fieldbus**

Look at how the CONTROL migrate



Exercise

Which defined term is closest to the description or encompasses the example given?

A.	*Controller*	*F.*	*Primary element*
B.	*Converter*	*G.*	*Signal*
C.	*Instrument*	*H.*	*Transducer*
D.	*Point of measurement*	*I.*	*Transmitter*
E.	*Process*		

1. Process temperature increases the measurable resistance in a monitored electrical circuit. [ ]

2. Pulsed output from a turbine meter. [ ]

3. Heat-injected plastic molding. [ ]

Exercise

4. Temperature transmitter. [ ]

5. Device which adjusts the measured value of the process to the requirements of the operator. [ ]

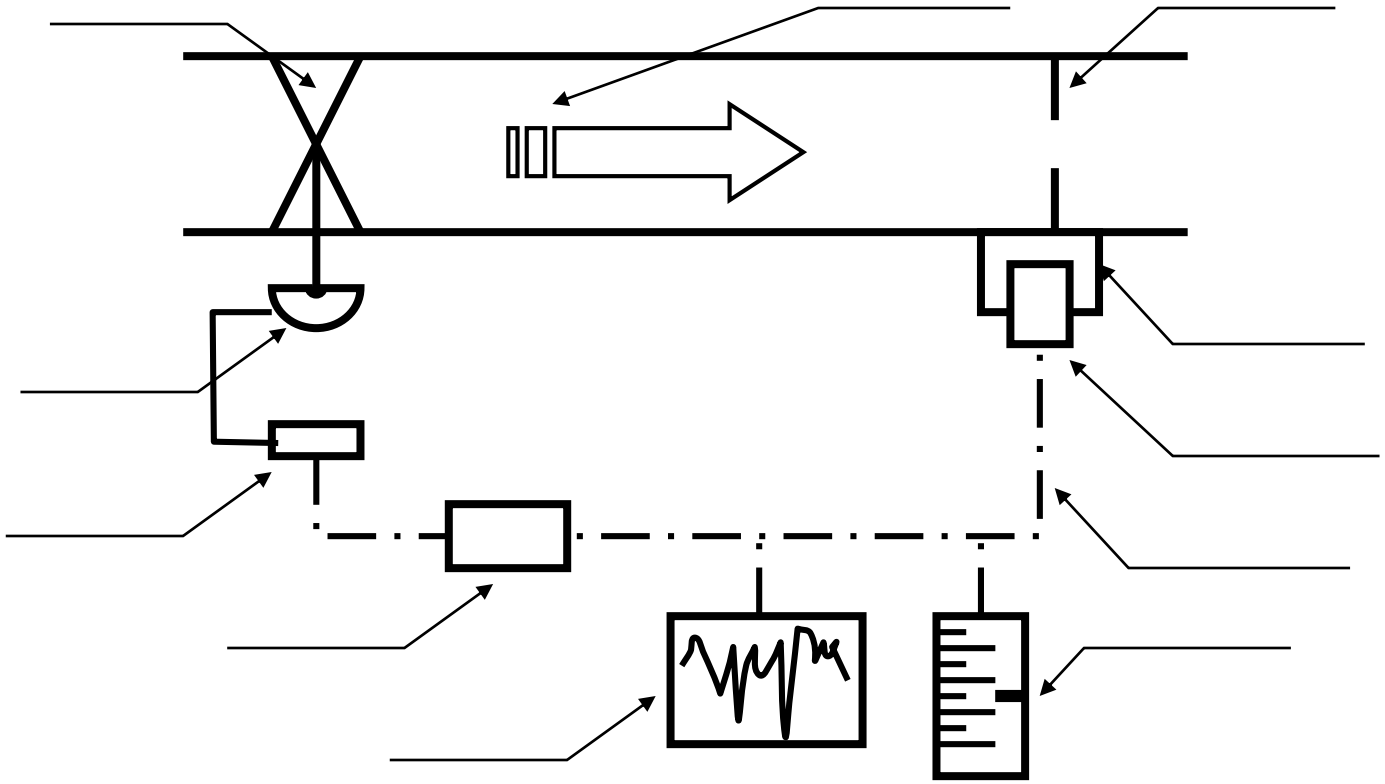
6. Element, flow transmitter, controller and correcting unit. [ ]

7. A pipe piece is tapped for a sample fluid. [ ]

8. A device changes an industry standard pneumatic signal to an industry standard hydraulic signal. [ ]

Exercise

9. Identify the components indicated by the Arrows.



Exercise

Which defined term is closest to the description or encompasses the example given.

A.	*Cascade control*	*F.*	*Gain*
B.	*Control algorithm*	*G.*	*Offset*
C.	*Control valve*	*H.*	*Proprietary Bus*
D.	*Feed-forward control*	*I.*	*Smart Device*
E.	*Foundation Fieldbus*		

10. The predefined response of the controller to PV-SP. [ ]

11. The value of PV-SP when the system is in equilibrium. [ ]

12. The ratio of controller's output to input. [ ]

13. It is a final control element operated by an actuator. [ ]

Exercise

14. Involves master & slave controllers. [ ]

15. The output of the loop drives the input. [ ]

16. A digital communication based control network with control action in the controller only. [ ]

17. A digital communication based control network that allow control in the field. [ ]

18. A device that provide both analog & communication signal in its loop wire pair. [ ]