Introduction

CSE 425 Process Control

Lecture 1

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About the course

Grading Scheme

Semester work	**45**
Final	80
Total	**125**

References

1. R. Rengaswamy, B. Srinivasan,and N. P. Bhatt, ***Process Control Fundamentals-Analysis, Design, Assessment, and Diagnosis,*** CRC Press, 2020.
2. H. Wade, ***Basic and Advanced Regulatory Control: System Design and*** **Application**, 2nd edition, 2004.
3. T. Blevins and M. Nixon, ***Control Loop Foundation Batch and Continuous Processes,*** **ISA, 2011.**

Topics to be covered:

1) Introduction
2) The feedback loop
3) Common dynamic systems
4) System structures
5) PID control
6) PID modifications
7) PID Tuning
8) Cascade control
9) Feedforward control and Ratio control
10) Multi-loop interaction

Blevins 2.4

Process

- Operation (chemical or physical) used to convert feed materials into products.
  - Examples: mixing - separation - heating - cooling - filtering – compression - etc.
  - The term process is used for both the processing operation and the processing equipment.
- Nearly every product we use today is the output of some **process industry** (Food – Pharmaceuticals – Paper – Rubber – Oil and Gas - Cosmetics – Fertilizers – Textiles – Glass - Steel)
- The design of such processes are part of process engineering (under chemical engineering)

Process Control

- Methods used to control Process Variables (PV) when manufacturing a product.
- **PV examples:** Temperature – Pressure - Flow - Concentration of chemicals - Liquid levels
- Process control maintains a PV at the desired operating conditions despite any disturbance. This is achieved by comparing measurements with their desired values and then adjust Manipulated Variables (MV), which are mainly flow rates, accordingly.
- Process control ensures stable process operation, smooth transitions, and rapid recovery from disturbances.
- Process control is the largest application area for control engineering.

Process Control Objectives

- Although the objective of a control system is to keep PVs at their desired values, we can consider this as a **low-level objective**.
- This low-level objective is necessary to achieve one or more of the following higher-level objectives:

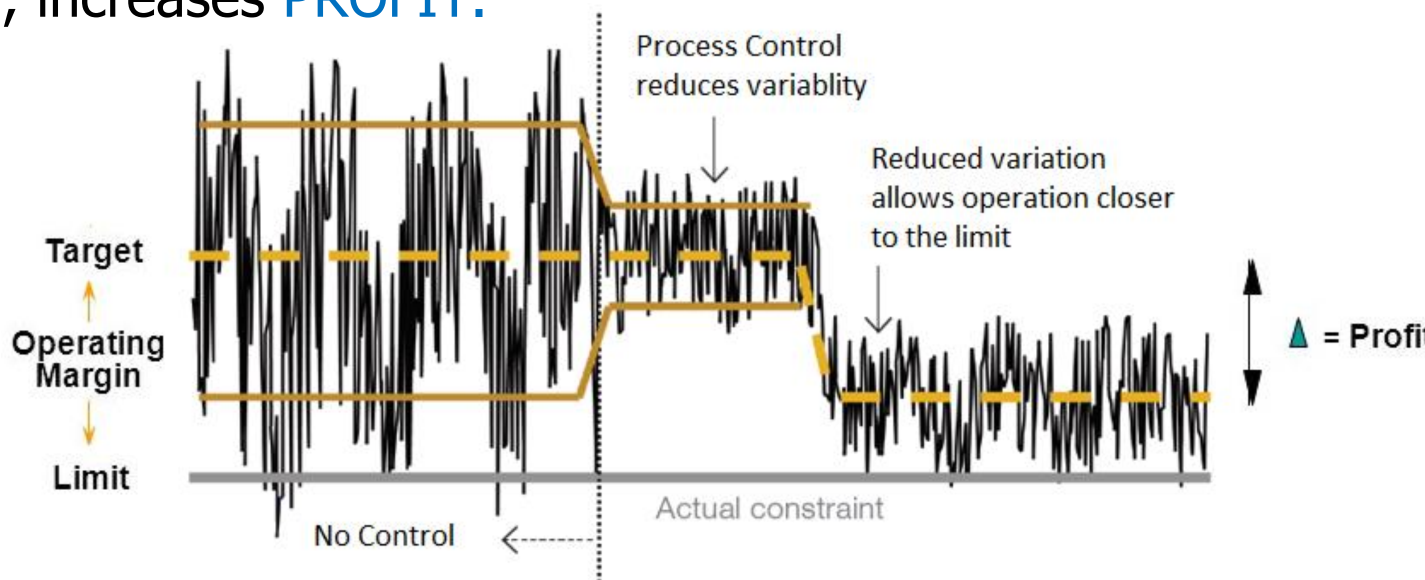
1. **Safety**
2. **Environmental Protection**
3. **Equipment protection**
4. **Product quality**
5. **Profit**

Why Process Control?

- When we run Process plants, we want to:
  - Operate them profitably – Fuel economy
  - Ensure required quality of the product
  - Ensure safety of each equipment of plant
  - Meet regulations of government
- Process control is the answer
  - Automate the process of maintaining PVs at their desired set points by manipulating MVs to reject the disturbances in a safe and economical manner while respecting the regulations of government – all of this within the constraints of process dynamics.

Benefits of Process Control

- Automatic control aims to reduce **variability** in PVs.
- Without control, PV will show high variability and, hence, the process has to run at a level higher than the target to guarantee the quality of the product. This leads to loss of raw material and so less profit is gained.
- With control, the process can run close to the limit specified by quality, government regulations, or safety requirements. This, in turn, increases PROFIT.



Automation Vendors

General Electric

Honeywell

Rockwell Automation

SIEMENS

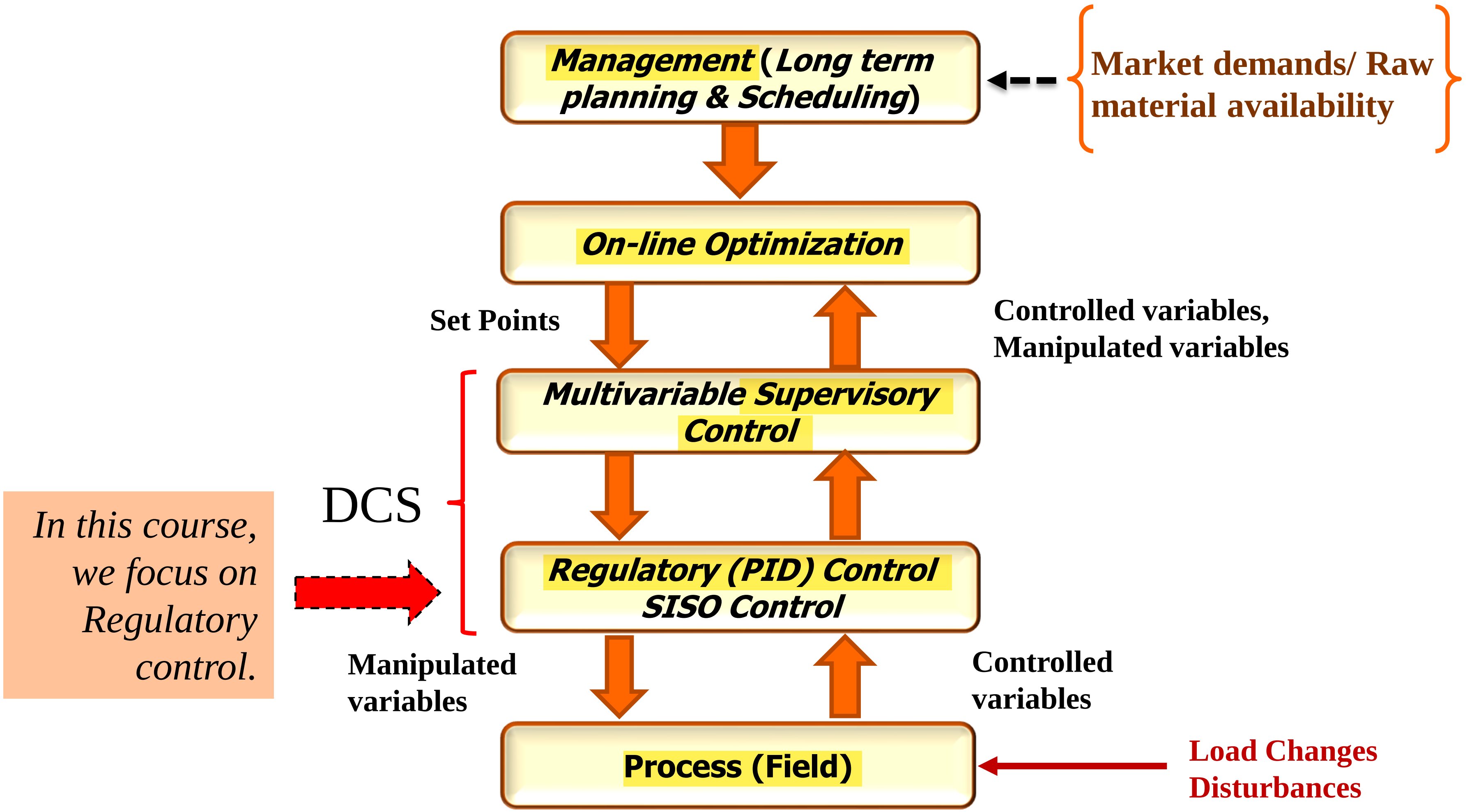
Schneider Electric

ABB

YOKOGAWA

Plant Wide Control Hierarchy

- Control of large plants can be divided into the following layers.



Adapted from https://nptel.ac.in/downloads/103101003

Types of Control

- Regulatory (continuous) control
- Logic control (PLC)
- Interlock control (safety-oriented logic control)
  - stop a pump if the liquid level it pumps is below certain level.
  - open a relief valve if the gas pressure in the tank is above a certain level
- Sequence control
  - washing machine program
  - bottle filling machine

Common Industrial Controllers

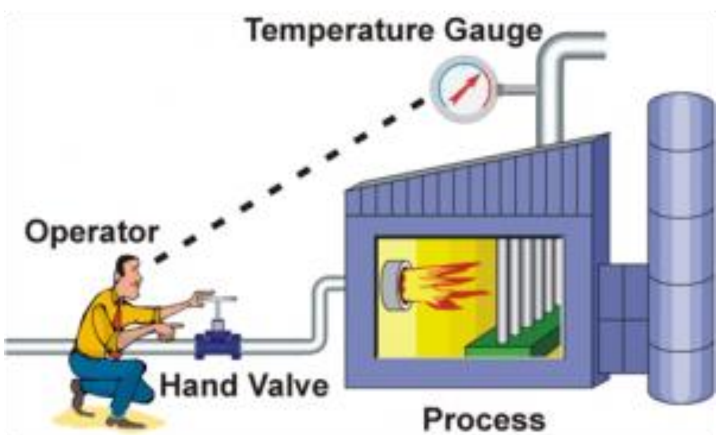
- Single station/loop stand-alone controller
- Distributed Control Systems (DCS)
- Programmable Logic Controllers (PLC)

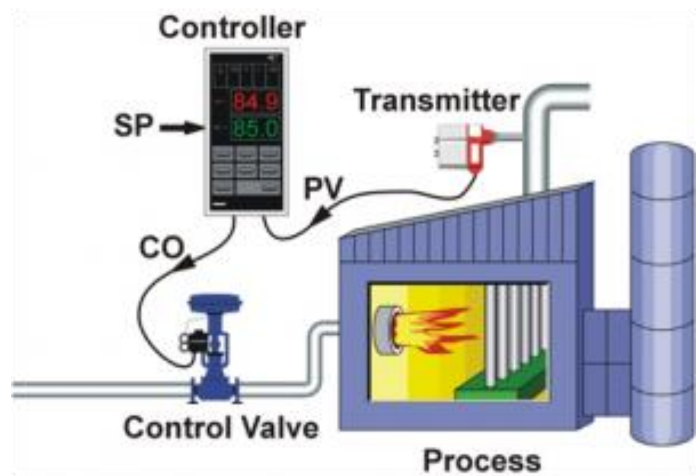
Stand-alone Controller

- Single PID controller (sometimes, 2 or 4 PID on the same device).
- The unit has a display to show the value of process variable and set point.
- It also allows the operator to tune the gains of the controller.

Manual vs. Automatic Control

- There are two modes for the controller: auto (automatic) or manual. Auto means that the PID controller is ON, i.e., it reads PV and SP, finds the error, calculates the control signal CO, and apply it to the process.
- Sometimes, the operator has to intervene and override the controller action. For example, if the tuning is not correct, the operator must have the ability to control the process manually.

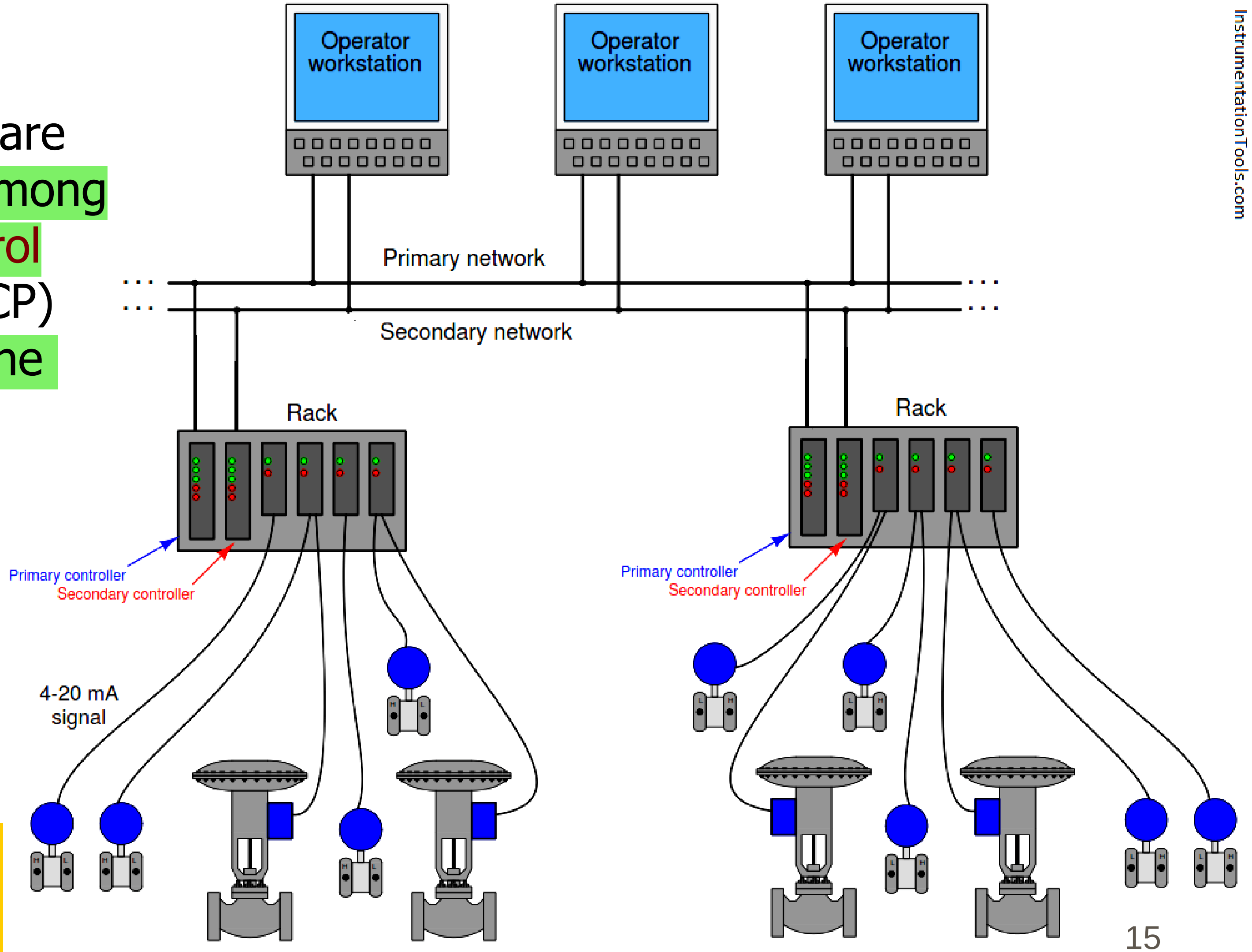




https://blog.opticontrols.com/archives/344

DCS

- In DCS, the control functionality are distributed among several Control Processors (CP) throughout the entire site



(Blevins and Nixon, pp. 22-30)

DCS

- Each CP is put in a rack and can handle 1000s loops.
- Thanks to the distributed functionality, the amount of cabling needed if all devices had to connect to a central CP is avoided.
- Each rack has two CPs for redundancy; if the primary fails the secondary will take over.
- DCS also contains:
  - Operator workstation
  - Engineering workstation (for maintenance)
  - Server (called historian) to store data
- CPs and stations are connected using network Ethernet switches.
- DCS is integrated with Emergency Shut Down (ESD) System for Safety purposes

DCS

- Each rack has I/O modules to interface to field devices.
  - DI & DO points: for logic, interlock or sequence control
  - AI & AO points: for regulatory control
  - IO count determine the size of the project (a project which contains say 400 IO points is considered a small project).
- The most important feature of a DCS is the **Scan time** or processing cycle (200-500ms) which is suitable for most loops
- DCS is programmed using function blocks similar to the way we build a model in SIMULINK
  - blocks for PID controller, input and output modules

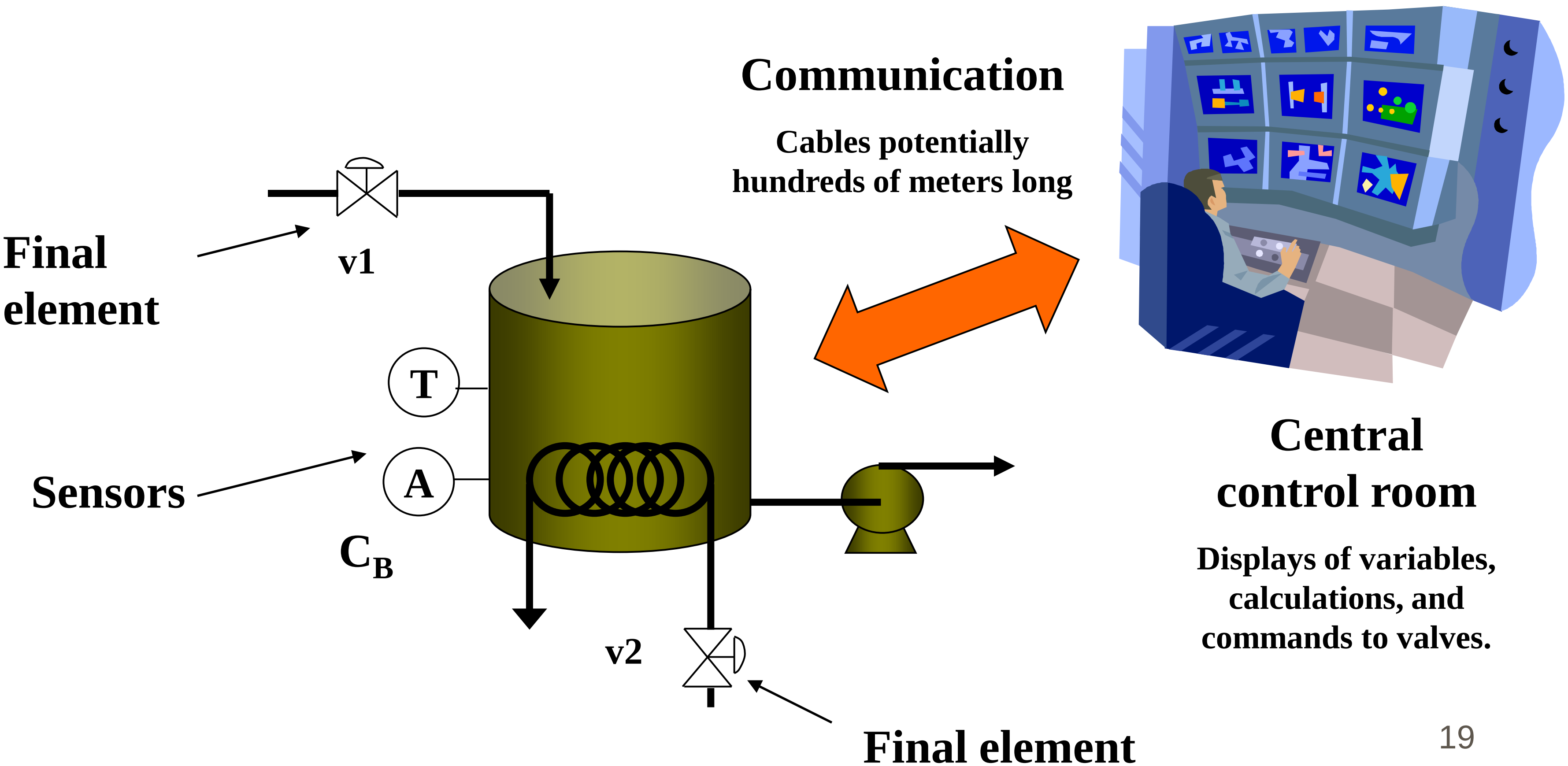
PLC

- While DCS focuses more on analog inputs and is suitable for processes with advanced control loops, PLC focuses mainly on digital and logic operations
- Of course, there is some overlap between PLC and DCS. Vendors try to take a share of the market of the others. For example, you can find analog PID in a PLC.
- ESD safety systems is implemented using a PLC because of its short Scan cycle which is only 20 ms.
- DCS needs a network while PLC does not.

PLC

Human-Machine Interface (HMI)

- A **HMI** is a user interface or screen that presents process data to human operators, in the control room, and through which the operator can control the process.



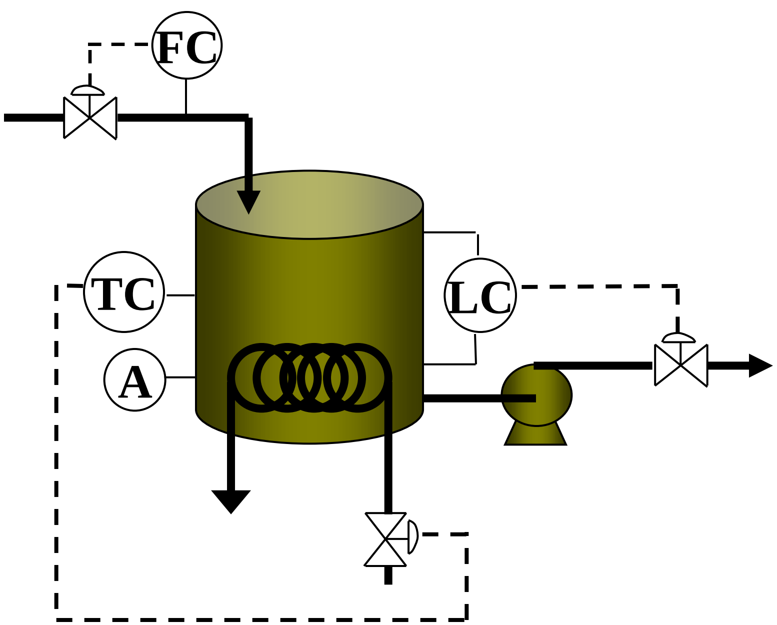
HMI

- HMI mimics plant units (reactor, pipes, …) in front of the operator
- The control engineer design displays for each specific plant:
  - process display
  - trend display of variables; i.e. shows signals changing with time. This is important for controller tuning
  - alarm display: to inform the operator if a certain variable hits a given threshold

    (three alarm levels: High – High High – High High High)
- Colors are used to inform the operator about the state of valves and other devices
- If we click on a certain block, an overlay of faceplate pops up (looks like stand-alone controller)

Control system documentation

- Piping and Instrumentation Diagram (P&ID) provides documentation for plant design.
- Standard symbols are used.



F = **flow sensor**

L = **level sensor**

P = **pressure sensor**

T = **temperature sensor**

A = **Analyzer (Concentration sensor)**

FC = **flow controller**

LC = **level controller**

TC = **temperature controller**

- - - - Electric (Usually 4 - 20 mA)

Standards for Signals in Industry

- In process industry, there is a standard for control signals (MV) and sensor readings (PV). No matter what is the nature of PV and MV variables, they are converted into electric current signal in the range of 4-20 mA.
- A current signal is more immune to noise compared to a voltage signals. In addition, due to voltage drop across the line, the voltage sent will not the same as the voltage received at the other end of the line, specially over long transmission lines.
- It is interesting to realize that the range starts from 4 and not 0 mA. The reason is that if 0 mA was a valid reading, it would be confused with open circuit fault when the line between sensor and controller is broken.
- In industry, pneumatic signals are also used. Their range is 3-15 psi.

YouTube Resources

- Process Control Course by Dr. Ahmed Ismail, Cairo University, 4th year - 2nd term, EECE 2019

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

- ABB Process Automation

  https://www.youtube.com/playlist?list=PLOgEb39vsYlu2WFdWSe5kvOtmJyC-ew2e