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Introduction to Industrial Control Systems

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Introduction to Industrial Control Systems
Course No. IC-1001

Course Outline

1. Definition of a process
2. Batch vs Continuous Process
3. Process Control
4. The Process Control Loop
5. Going Further…
6. Discrete Controls

1. Definition of a Process

A process is any means by which work is done on material or energy to change its physical properties. For example, in an automotive plant, multiple raw materials enter the plant, and new automobiles exit the plant. The plant is a process, but it is a very complicated one, and it would be a daunting task to try to explain it in this context. We also know that the automotive plant process is broken down into many sub-processes, sub-sub-processes, and so on.

A more elementary example of a typical process is the means of heating a room. There is a heat source, and that source needs to be controlled to provide a reasonable amount of comfort. If the heating process is controlled manually, and we assume the heat source is hot water, then we can conclude that an occupant can control the room temperature within reasonable limits by simply adjusting the hot water valve to allow more or less hot water into the radiator. It appears that a point could be reached where no further adjustments were necessary to maintain a particular temperature. That is, assuming no other people enter the room, the temperature outside the room does not change significantly, the sun does not rise or set, etc. Clearly, we do not want to have an operator spend a significant amount of his or her time adjusting the temperature controls in various rooms, so we make these types of processes automatically controlled.

We will re-visit this example later to discuss the automatic control functions.

2. Batch vs Continuous Processes

There are two basic types of processes; Continuous processes and Batch processes. Continuous processes are those that operate without interruption for an extended period of time. Examples are sewage treatment plants, which must operate continuously in order to meet municipal wastewater flows; heating and ventilation processes in buildings; electric power generation, etc.

Batch processes, on the other hand, are processes that are best done in a manner to produce a known quantity of product in a scheduled period of time. Examples are brewing various brands of beer; food production, production of bags of fertilizer, blending barrels or vats of liquids or solids for plastics, etc.

You can probably identify many processes or sub-processes that fall into either category. The basic distinction is whether a set amount of product is made before the process is modified to produce a similar but different product; for example, various brands of a particular product necessitating different “recipes” of raw materials.

3. Process Control

Let’s go back to our heating example, to see what we need in order to automatically control the process. When the operator manually controlled the room temperature, he or she performed three distinct functions:

a) they measured the room temperature (with their body comfort),
b) they decided whether more or less heat was required, and
c) they took action to change the amount of heat (if necessary).

These same three functions need to be done by any process control system. Henceforth, we shall consider process control to mean automatic control of the process by an electronic device. Although manual control by an operator is a very important consideration that must never be overlooked, we shall concentrate on automatic control systems.

a) Process measurement

In order to control the room temperature, we need a means to measure the average temperature in the room. This can be done by a number of devices, and we shall review each of them in a later course. Suffice it to say that a thermostat can be mounted in a “reasonable” location to provide an “average” of the room temperature, and that device can provide an electrical or electronic signal to another device.

b) Controller

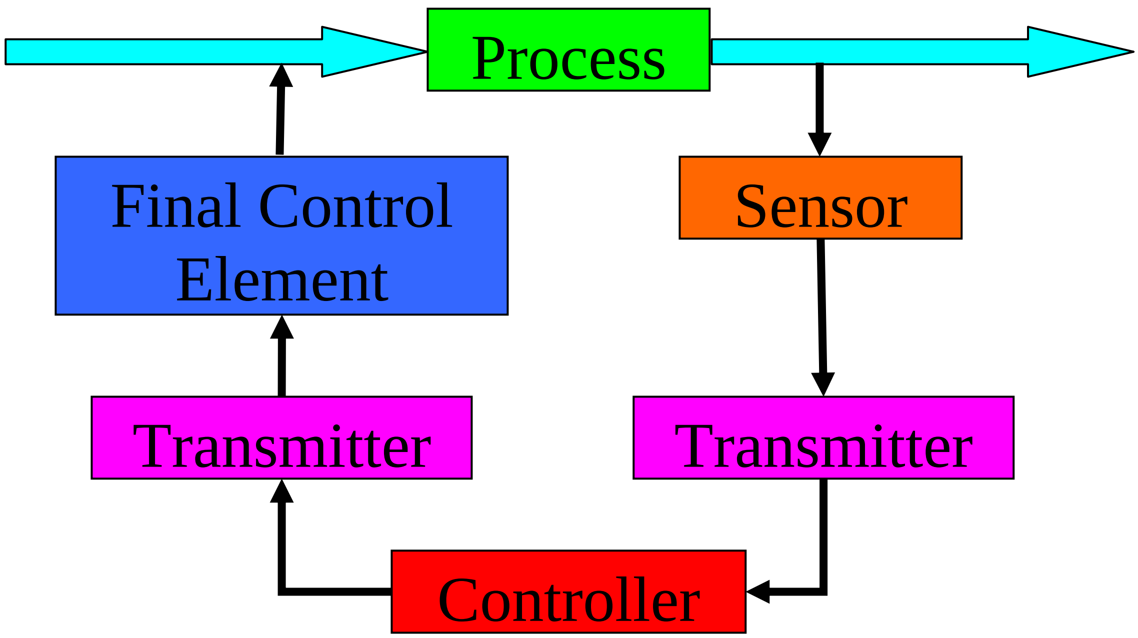
Now that we have measured the temperature, converted that information into an electrical signal, and transmitted it to another device, we must compare that temperature to the desired temperature to see if more or less heat is required. That function is done by a controller. The controller has an operator set point feature that allows the operator to determine the desired temperature. The operator will select the proper value in engineering units (in this case, degrees Fahrenheit), rather than electrical units (such as millivolts). The controller compares the set point to the actual temperature, and transmits the difference to a device to modify the temperature.

c) Final Control Element

This device receives the signal from the controller, and modifies the volume of hot water to the radiator, to raise or lower the heat from the room radiator. In this case a final control element would likely be a control valve. The control valve would respond by opening or closing depending upon the size of the signal that is received from the controller.

4. The Process Control Loop

The following diagram illustrates the functions of each of the devices in a typical feedback control loop. It is referred to as a "feedback" control loop because it takes a sample of the process output, and feeds back control changes to manipulate the process input. There are also feedforward control loops, but they are beyond the scope of this course.



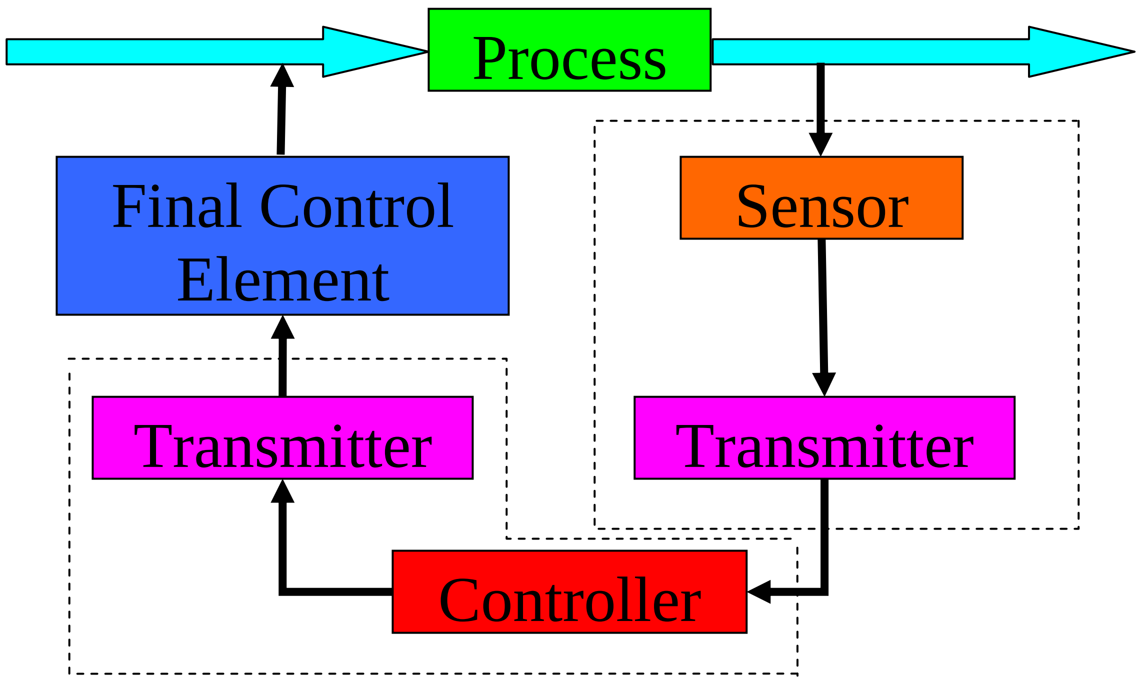
You will see that the three functional devices; measurement, comparison, and action device are present, along with two other devices called transmitters.

Transmitters

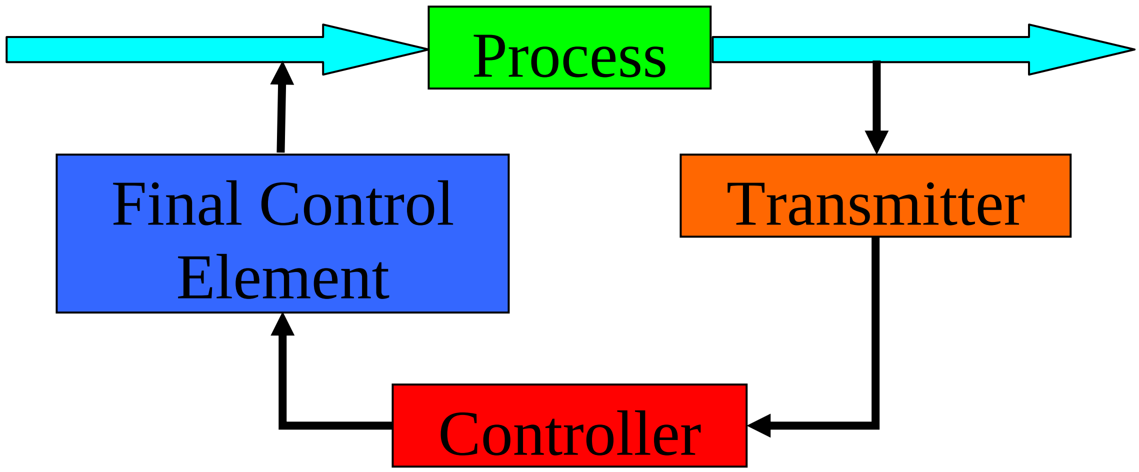
The signal from the measurement device, or sensor may need to be send several hundreds or thousands of feet from the measurement point to a control room where the controller resides. Since most sensors provide a very small electrical signal, that signal would be reduced or attenuated by the length of control wires to the controller, therefore there is a need to boost the signal to levels that will allow for their successful transmission to the controller. That is one of the primary purposes of the transmitter.

A second and equally important feature of the transmitter is the ability to take a myriad of sensor signals, and a myriad of ranges of signals, and convert them to a standard signal that can be interpreted by any manufacturer's controller. This standardization of the signal means that various manufacturers' equipment can be interfaced to do the job, and the facility owner is not restricted to only using one manufacturer's equipment. Clearly this leads to competition in the market, but it also helps the manufacturers by providing a standard to which they can focus their designs.

The transmitter between the controller and the final control element provides the same features.



Presently, most sensors and transmitters are provided in a single housing, and frequently are called transmitters; whereas the controllers also contain the transmitter functions, and they are housed in the same unit.



Therefore we can reduce our feedback control loop to four devices; the measurement device, the controller, the final control element, and the process itself.

Succeeding courses in this series shall address each of these devices in detail to allow you to select the best transmitters, controllers, and final control elements for the process.

5. Going Further…

Now that we have a basic understanding of how a single control loop operates, we need to expand that understanding to include all of the control loops and control devices in a typical plant.

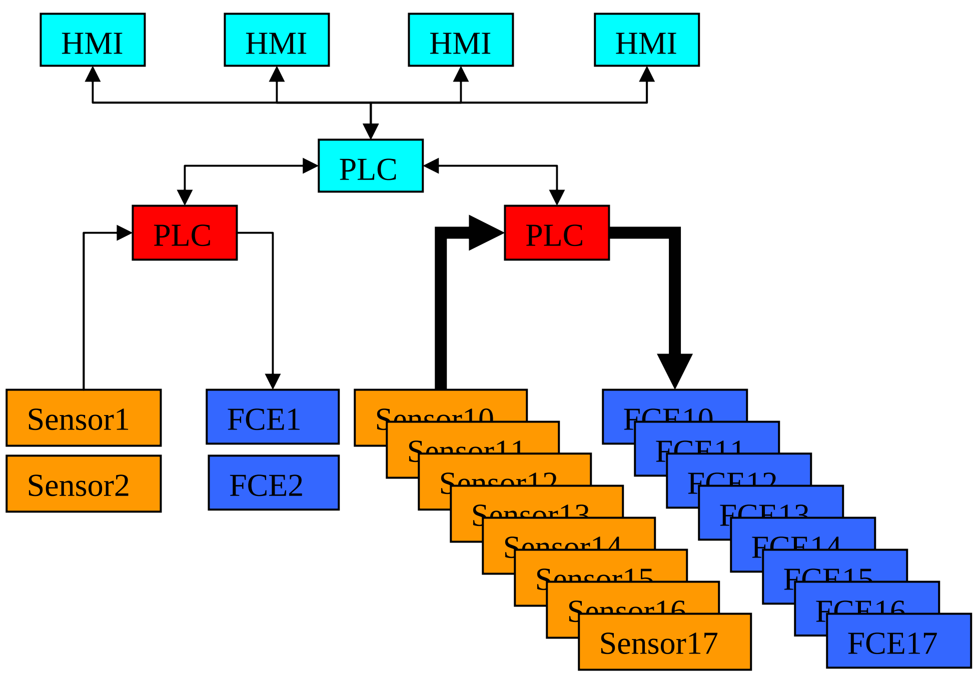
Let's say, for example, that we had a small plant that had 100 control loops. That would mean that there were 100 processes or sub-processes that required automatic control. They could be heating, ventilating, and air conditioning (HVAC) processes; pressure control, process temperature control, flow control, level control, etc. In any case, there could be 100 sensors, 100 individual controllers, and 100 final control elements (control valves, pumps, etc). The sensors and final control elements would be on the plant floor, and the controllers could also be on the plant floor, housed in various control panels. It would be likely, however, to find the controllers in a climate controlled control room. The reasons for this may be obvious, but let's review them:

1. The plant floor may be a hostile environment, which is washed down with high pressure water, or contains excess heat, explosive gases, excessive dust and dirt, etc. Any of these conditions would require the controller housing to be rated for the environment, and therefore would be expensive.
2. The controllers need to be manipulated by the process operator to change set points, manually adjust outputs to the final control element, etc. Having a multitude of controllers spread over the plant floor might require multiple operators and a form of constant communication between them to coordinate actions.
3. Instrument technicians need to perform preventive and corrective maintenance on the controllers, and these actions can take lengthy time periods. During

these efforts it is important that the plant operator appreciates how that work will impact the process, and what sub-processes need to be operated in manual mode during this work. Close coordination is required between the two functions to complete the work without disrupting the plant process, so it would best be done in close proximity.

4. Since onboard transmitters allow the sensor and controller signals to be sent several thousand feet, it is possible to locate the controllers in a control room, and thereby resolve the concerns of having the controllers spread over the plant floor.

In plants built up until about 1985, you would have seen such control rooms with walls of controllers, indicators, recorders, piping graphics, and various other devices. Now however, the same control rooms have computers, and similar devices. Rest assured that the same functions that we have discussed are being performed by these computer systems. Instead of having 100 individual controllers, we can now have a Programmable Logic Controller (PLC), a Distributed Control System (DCS), a Supervisory Control and Data Acquisition (SCADA) system, a Human-Machine Interface (HMI), or similar systems doing the same functions. We still need the 100 sensors on the plant floor, and the 100 final control elements, but the controllers have been amalgamated into a single device, or several similar devices communicating with each other. Now, most of the functions that were done by hardware controllers are being done in software by the computer systems. In many critical applications you will still find individual controllers, as a back up to the computer system, or in cases where the computer system is too slow to perform the necessary control function. The graphic below will help you appreciate the interconnections of the various control devices in a modern plant.



The Sensors and Final Control Elements (FCE) serve the same function as before, and the two red PLCs serve as the loop controllers. The sensors, and their integral transmitters, send analog signals to the PLC which performs the necessary logic and outputs an analog signal to the respective final control element. The blue PLC acts as a communication device between the two controllers and the HMIs. The operator uses the graphics and control functions on the HMI to view the process and input set point changes to the PLCs. Once a change is made on the HMI, it is communicated to the PLC, and it will reside in the PLC until another change is made. The PLC does all the controlling functions and does not need the HMI to continue operations, because no process logic should be in the HMI. Theoretically, the HMI is only a “window” on the process for the operator, and it has no controlling functions. Unfortunately, this distinction is lost in some cases and some of the process logic may be placed on the HMI system, because it is easier to implement. This should be avoided whenever possible, because it puts the process logic in two separate systems, and troubleshooting and documentation can be made very difficult. Typically the technician that works on the HMI system is not the same as the one doing the PLC programming, so two people may be required to troubleshoot logic problems. As well, the industrial computers are not as robust as PLCs, so the process logic should reside on the more robust system. The functions of the HMI are:

a) to display process data, such as flows, pressures, temperatures, levels, equipment status (ON, OFF, ALARM, etc.);
b) to record data for later review by trending charts, etc.; and
c) to provide a means for the operator to modify control set points, and to manually control devices.

This sample plant control system is simplified for illustration. Any real system would appear more complex with additional interfacing equipment, and a network of PLCs serving different process areas. Typically a PLC would serve one process area, but be connected to one or more control rooms, so that all process information was available to the operator at one location. As well, the HMIs could be distributed around the plant at the various PLC locations to give the operator an ability to view any plant process from anywhere in the plant. This feature is most important if the plant has a public address system that broadcasts alarm conditions, and the operator can respond to an alarm from any HMI location in the plant.
PLCs, HMIs, and their communication requirements will be addressed in more detail in subsequent courses.

6. Discrete Controls

In this course we have concentrated upon control loops which monitor and control process values, but there is another form of control, and that is discrete control. Control loops deal with analog signals that can have any value within a range, such as 0 to 100%, whereas discrete signals are binary and are Open or Closed, On or Off, Start or Stop, etc. Discrete signals typically represent the majority of status signals in a plant, such as whether all the motors are on or off, whether all two-position valves are open or closed, whether product is present on a conveyor, and they also represent the command signals from the operator or control systems to turn motors on, close valves, etc. Although discrete signals can be used with control loops, we shall consider them to be an ancillary function.

To receive credit for this course, you will be required to take the quiz, which can be accessed by clicking on “Take Quiz” at the bottom of the course web page. It is suggested that you print the test, answer each question, and then come back online to fill in the answers.