Pump ED 101

Process Control – (Part 1) Smart and Not So Smart Control

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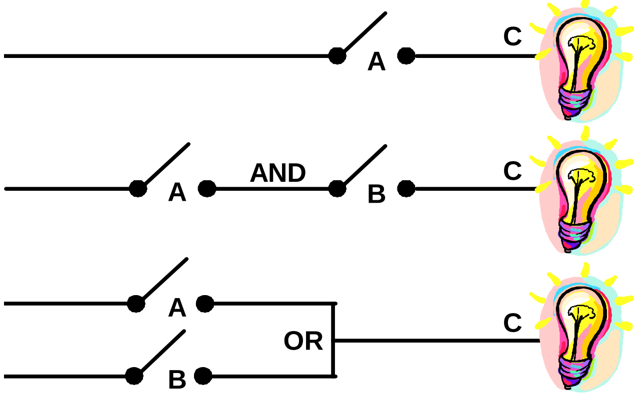
Even though control technology has become an integral part of many pumping systems, over half of our readers have not expressed much interest in pump controls. I think I know why - - today's controls are not as intuitively understandable as they used to be. Who wants to read about the advantages of PID control without a basic understanding of P, I, and D itself. This two part series will take a brief look at the hierarchy of process control technology and explain the function of those three, often confusing, letters. Remember, this column is entitled Pump Ed 101 not 301, so its purpose is to present the basics and, hopefully, make some of those more advanced control articles a little more understandable.

Before we start let's define a term, and the three words it encompasses, that may lead to some of the confusion surrounding controls. That term is "Process Control Loop". Not too long ago we referred to pump control by application - - constant pressure, pump up, pump down, circulation, etc. But today we tend lump all of these into the generic term Process Control. A "process" is a systematic series of actions that result in a desired end product. A simple process example is the removal of water from a sump. A more complex one could result in the manufacture of a 1000' reel of 20 conductor cable. But the key words, systematic and desired, apply equally to both. A process should be repeatable and provide the same result each time it is performed. "Control" is the application of direction or restraint on how that process proceeds. Basically, control supervises the actions of the process. For example, a sump pump might use simple float switch activation as a control mechanism. Or, it might go a step further and employ a level sensor and operate at different speeds in an attempt to keep the sump at some constant level. A "loop" consists of the set of instructions (digital or analog), from start to finish, that controls the process. It is called a loop because once the instructions are completed they will be repeated when the process begins again. Now, there are many different types of loops and we will discuss several in detail a little later.

A Little History

Is there any rhyme or reason to those schematics that are often found on the inside of a control panel door? Are they the result of trial and error or is there some form of logic involved? Well, back in the early 1800's an English mathematician named George Boole developed a system of logic known as Boolean algebra. It uses simple operators such as "if, and, or, & not" that can be combined to form precise and logical statements that test the "truth" of a series of events. It is the basis for the design of all control systems regardless of whether they are composed of simple switches and relays or complex microprocessors. It is also the basis for several modern day computer programming languages. The schematics that define the logic of those controllers are simply a graphic representation of Boolean algebra. Let's look at a simple example.

Suppose you want your porch light to turn on, for five minutes, each time the doorbell rings. If "A" is the input from the doorbell and "C" is a timer that controls the light the Boolean logic would be: "If A Then C". Translated into English this statement says that if A is "true" (on) then C is also "true" (on). So, every time the doorbell rings the light will turn on and remain on until the timer shuts it off. Now, if you are a tightwad you probably don't want that light to turn on during daylight hours, so you add a sensor (B) that provides an input when it is dark outside. If we add the sensor to our original logic, it becomes: "If A And B Then C". This statement says that both A and B must be true if the light is to turn on. In other words, it has to be dark outside and the doorbell must ring before the light will turn on. If you change "And" to "Or" the logic would be quite different. During the day the light will turn on each time the bell rings and, at night, it will stay on continuously. Figure 1 is a schematic representation of the different versions of this "ABC" logic. Boolean algebra is an elegantly simple method of defining the steps necessary to control some process.

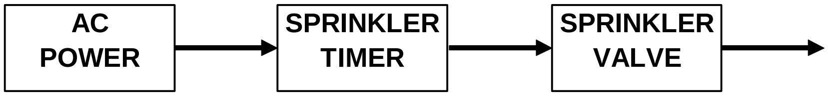


Until the 80's much of the hardware used to implement this logic consisted of electromagnetic relays. And, relays are still popular today in simpler controllers because failures are easy to diagnose and they can be replaced as an individual component. But the transistor has taken over much of this market because of price, function, and footprint. Today, a couple of chips or integrated circuits (IC) measuring just a few square inches contain hundreds of transistors and can replace dozens of relays. The reason the transistor fits in so well is that, like the relay, it is also a switch. It is part of a family known as semiconductors. Picture it as a switch with three leads. Under normal circumstances the semiconductor material will not allow current to flow between leads 1 & 2 but, if a separate current (an input from a switch or another transistor) is applied to lead 3, the semiconductor material becomes a conductor and leads 1 & 2 are connected. When these little switches are integrated into a Programmable Logic Controller (PLC) we end up with a computerized switching system that can provide a wide range of control functions. And, if the process requirements change, you can reprogram it to meet those changing conditions without rewiring the logic section.

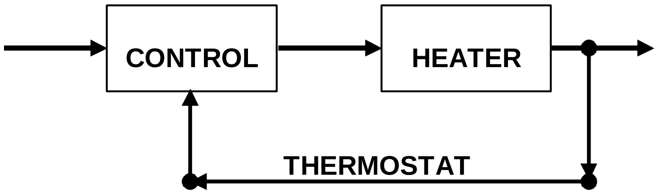
Smart and Not So Smart Control

The typical residential sprinkler system is controlled by a simple timer that turns the system on at some preset time and then turns it off at some other preset time. And, it doesn't matter if it is raining cats and dogs - - it will turn on and off based on the timer settings. In the process environment, this control scheme is known as "open loop" control. The key characteristic of open loop control is that the controller has no clue what is going on within the system. It simply follows its instructions, to the letter, regardless of its surroundings. Open loop control works well as long as the event it controls is repetitive and no damage could result from its action. If our sprinkler activates during a rainstorm, the water is wasted but no damage occurs.

Figure 2 is a graphic representation of this control loop.



It is a bit different when it comes to your home heating system. Although open loop control could be used, the results would be less than satisfactory. You would experience periods when it is too warm and others when it is too cold as the heater would start and stop based on a simple timing cycle. A better control method would provide some "feedback" to the heater based on the desired temperature and the actual measured temperature at any point in time. The system could then make its own decision as to when it should start and how long it should operate. In the typical home heating system this is accomplished with a thermostat. When the temperature drops below a certain predetermined level, the thermostat starts the heating system and runs it at its full capacity until the temperature rises to some preset, maximum. The thermostat then stops the heating system and waits to begin another cycle. This is a simple example of "closed loop" control. More specifically, it is known as "on/off, closed loop control" as the heater is either fully on or fully off and there are no intermediate settings. The key characteristic of the closed loop controller is that it receives some form of feedback as to what is going on within the system and can therefore make smarter decisions. Figure 3 is graphic representation of this closed loop example.



Smarter Control – The P in PID

Now, suppose, for a moment, that our home heating example does not use an on/off thermostat but, instead, uses one that can transmit the actual measured temperature in the room back to the heating system controller. Let's also suppose that the heating system can vary its output based upon the temperature reading it receives from the thermostat. As the temperature in the room approaches its "set point" the heater would not necessarily turn off but, instead, reduce its output and attempt to keep the room at the desired temperature. If the temperature drops, it would increase its output and if the temperature increases it would either reduce its output further or shut off completely. Furthermore, these changes in output would be in "proportion" to the change in temperature. A small change in temperature results in a small change in output while larger changes in temperature would lead to proportionally larger changes in heat output.

The example above is one of "proportional, closed loop" control and is the "P" in "PID". In the pumping environment proportional control is seen daily. Constant speed, multi-pump booster systems use pressure switches to start or stop additional pumps based upon changes in system pressure. Sewage lift stations use level switches to accomplish the same mission based on changes in the liquid level. I like to refer to these applications as "fixed, proportional control" as there is a limited number of "proportions" (pump combinations) available to the control loop. Proportional control works best in systems where the feedback measurement changes slowly. In the booster system example above, feedback (pressure) can change quickly so we will often employ a fairly large pressure differential and maybe even delay timers to keep lag pumps from cycling on or off too quickly.

But, unlike the constant speed booster, today's variable speed (dynamic) systems rely on a microprocessor or PLC to execute the Boolean logic necessary to control a pump's pressure. A computer program, or algorithm, monitors pressure and makes its own decisions about changes in pump speed. But, when conditions change quickly in a dynamic system, proportional control, alone, doesn't always do a good job.

Next month we will take a look at how the I & D of PID can help proportional control do a better job in applications where feedback changes quickly.

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