Controller Operation

There are three basic types of controllers: on-off, proportional and PID. Depending upon the system to be controlled, the operator will be able to use one type or the other to control the process.

On/Off

An on-off controller is the simplest form of temperature control device. The output from the device is either on or off, with no middle state. An on-off controller will switch the output only when the temperature crosses the setpoint. For heating control, the output is on when the temperature is below the setpoint, and off above setpoint.

Since the temperature crosses the setpoint to change the output state, the process temperature will be cycling continually, going from below setpoint to above, and back below. In cases where this cycling occurs rapidly, and to prevent damage to contactors and valves, an on-off differential, or "hysteresis," is added to the controller operations. This differential requires that the temperature exceed setpoint by a certain amount before the output will turn off or on again. On-off differential prevents the output from "chattering" or making fast, continual switches if the cycling above and below the setpoint occurs very rapidly.

On-off control is usually used where a precise control is not necessary, in systems which cannot handle having the energy turned on and off frequently, where the mass of the system is so great that temperatures change extremely slowly, or for a temperature alarm.

One special type of on-off control used for alarm is a limit controller. This controller uses a latching relay, which must be manually reset, and is used to shut down a process when a certain temperature is reached.

Proportional

Proportional controls are designed to eliminate the cycling associated with on-off control. A proportional controller decreases the average power supplied to the heater as the temperature approaches setpoint. This has the effect of slowing down the heater so that it will not overshoot the setpoint, but will approach the setpoint and maintain a stable temperature. This proportioning action can be accomplished by turning the output on and off for short intervals. This "time proportioning" varies the ratio of "on" time to "off" time to control the temperature. The proportioning action occurs within a "proportional band" around the setpoint temperature. Outside this band, the controller functions as an on-off unit, with the output either fully on (below the band) or fully off (above the band). However, within the band, the output is turned on and off in the ratio of the measurement difference from the setpoint. At the setpoint (the midpoint of the proportional band), the output on:off ratio is 1:1; that is, the on-time and off-time are equal. if the temperature is further from the setpoint, the on- and off-times vary in proportion to the temperature difference. If the temperature is below setpoint, the output will be on longer; if the temperature is too high, the output will be off longer.

The proportional band is usually expressed as a percentage of full scale, or degrees. It may also be referred to as gain, which is the reciprocal of the band. Note that in time proportioning control, full power is applied to the heater, but cycled on and off, so the average time is varied. In most units, the cycle time and/or proportional band are adjustable, so that the controller may better match a particular process.

In addition to electromechanical and solid state relay outputs, proportional controllers are also available with proportional analog outputs, such as 4 to 20 mA or 0 to 5 Vdc. With these outputs, the actual output level is varied, rather than the on and off times, as with a relay output controller.

One of the advantages of proportional control is the simplicity of operation. It may require an operator to make a small adjustment (manual reset) to bring the temperature to setpoint on initial startup, or if the process conditions change significantly.

Systems that are subject to wide temperature cycling will also need proportional controllers. Depending upon the process and the precision required, either a simple proportional control or one with PID may be required.

Processes with long time lags and large maximum rates of rise (*e.g.*, a heat exchanger), require wide proportional bands to eliminate oscillation. The wide band can result in large offsets with changes in the load. To eliminate these offsets, automatic reset (integral) can be used. Derivative (rate) action can be used on processes with long time delays, to speed recovery after a process disturbance.

PID

The third controller type provides proportional with integral and derivative control, or PID. This controller combines proportional control with two additional adjustments, which helps the unit automatically compensate for changes in the system. These adjustments, integral and derivative, are expressed in time-based units; they are also referred to by their reciprocals, RESET and RATE, respectively.

The proportional, integral and derivative terms must be individually adjusted or "tuned" to a particular system using trial and error. It provides the most accurate and stable control of the three controller types, and is best used in systems which have a relatively small mass, those which react quickly to changes in the energy added to the process. It is recommended in systems where the load changes often and the controller is expected to compensate automatically due to frequent changes in setpoint, the amount of energy available, or the mass to be controlled.

There are also other features to consider when selecting a controller. These include auto- or self-tuning, where the instrument will automatically calculate the proper proportional band, rate and reset values for precise control; serial communications, where the unit can "talk" to a host computer for data storage, analysis, and tuning; alarms, that can be latching (manual reset) or non-latching (automatic reset), set to trigger on high or low process temperatures or if a deviation from setpoint is observed; timers/event indicators which can mark elapsed time or the end/beginning of an event. In addition, relay or triac output units can be used with external switches, such as SSR solid state relays or magnetic contactors, in order to switch large loads up to 75 A.

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