Anglais et Automatique
L3 Automatique

Chapter Two : Process control terminology

By Y.HIMOUR
y.himour@univ-dbkm.dz

Chapter Two: Control Systems Terminology

Second Chapter:

First tutorial: Home heating control system

A controller seeks to maintain the measured process variable (PV) at set point (SP) in spite of unmeasured disturbances (D). The major components of a control system include a sensor, a controller and a final control element (actuator).

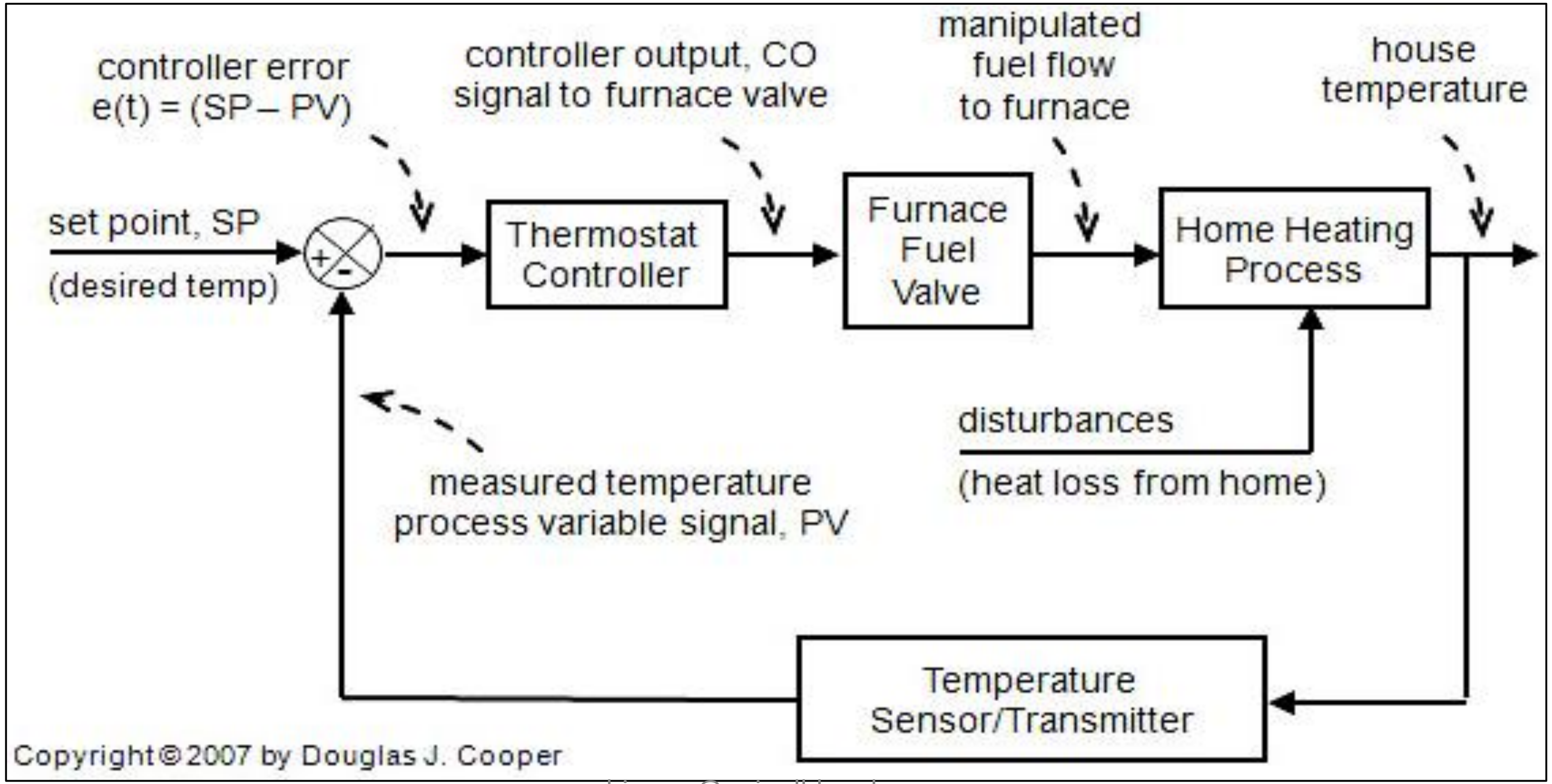


Figure 0-1 Home Heating Control Loop Block Diagram

The measured temperature PV signal is subtracted from set point to compute controller error, $e(t) = SP - PV$. The action of the controller is based on this error, $e(t)$.

In our home heating system, the controller output (CO) signal is limited to open/close for the fuel flow solenoid valve (our FCE). So in this example, if $e(t) = SP - PV > 0$, the controller signals to open the valve. If $e(t) = SP - PV < 0$, it signals to close the valve.

As an aside, note that there also must be a safety interlock to ensure that the furnace burner switches on and off as the fuel flow valve opens and closes.

As the energy, output of the furnace rises or falls, the temperature of our house increases or decreases and a feedback loop is complete.

The important elements of a home heating control system can be organized like any commercial application:

- **Control Objective:** maintain house temperature at SP in spite of disturbances.
- **Process Variable:** house temperature.
- **Measurement Sensor:** thermistor; or bimetallic strip coil.
- **Measured Process Variable (PV) Signal**: signal transmitted from the thermistor.
- **Set Point (SP):** desired house temperature.
- **Controller Output (CO)**: signal to fuel valve actuator and furnace burner. **Final Control Element (FCE):** solenoid valve for fuel flow to furnace. **Manipulated Variable:** fuel flow rate to furnace.
- **Disturbances (D):** heat loss from doors, walls and windows; changing outdoor temperature; sunrise and sunset; rain…

- **<u>Control systems (Systèmes de commande)</u>**

The study of those systems in which one or more outputs are forced to change in a desired manner as time progresses.

- **<u>Process (Processus)</u>**

In manufacturing, the physical or chemical change of matter or the conversion of energy, for example, change in pressure, temperature, speed, electric potential, and so on.

- **<u>Process variables PV (Variables du processus)</u>**

Any variable property of a process.

- **<u>Process output (Controlled process variable) (Sortie du système)</u>**
- **<u>Process Value – PV or Measurement (Mesure)</u>**

The actual value in the control loop, temperature, pressure, flow, composition, pH, etc

- **<u>Manipulated variable (MV) (Grandeur réglante)</u>**

In a process that is intended to regulate some condition, a quantity or a condition that the control alters in order to initiate a change in the value of the regulated condition.

- **Set Point (Consigne)**

The set point is the desired value of the process variable.

- **Error (erreur)**

In the control loop the error = set point - process value.

- **Load Upset/ Disturbance (Perturbation)**

An upset to the process not from changing the set-point.

- **Sensor (Capteur)**

The generic name for a device that senses either the absolute value or a change of physical quantity. Meanwhile, a transducer (Transducteur) is a device that receives a signal and retransmits it in a different form. If the sensor element does not produce a signal suitable for transmission through the plant, an additional transducer element is needed. This combined sensor/transducer device is typically called a transmitter (Transmetteur).

- **Controller (Régulateur, Contrôleur)**

A device or program that operates automatically to regulate a controlled variable.

- **Comparator (Comparateur)**
- **Final control Element/ Actuator : Actionneur**
- **Interlock safety (Verrouillage de sécurité)**
- **Feedback control system or closed loop control system**

(système de contrôle à rétroaction ou système de contrôle en boucle fermée) An error-driven control system in which the control signal to the actuators is proportional to the difference between a command signal and a feedback signal from the process variable being controlled.

- **Bang-bang controller, on-off controller (régulateur tout ou rien)**

A two-position controller in which one of the two discrete values is zero.

- **Block diagram (Shéma fonctionnel)**

Diagrammatic representation of the mathematical relationships defining the flow of information and energy through the automatic control system.

- **Distributed Control System – DCS (Système numérique de contrôle-commande SNCC)**

A control system where the controller elements are not central in location but distributed throughout the system with each component sub-system controlled by one or more controllers.

- **Analog Signal (Signal analogique)**

Analog signals are like voltage or electric current signal, representing temperature, pressure, level etc. Usually the electrical current signal is of magnitude 4-20 mA where 4 mA is the minimum point of span and 20 mA is the maximum point of span.

- **Digital Signal (Signal numérique)**

A discrete value at which an action is performed. A digital signal is a binary signal with two distinct states - 1 or 0, often used as an on - off indication.

- **Analog to Digital Converting, A-D Converting (Conversion analogique numérique)**

Electronic hardware converts analog signal like voltage, electric current, temperature, or pressure into digital data a computer can process and interpret.

- **Auto Mode (Mode automatique ≠ mode manuel)**

In auto mode, the output is calculated by the controller using the error signal, the difference between set point and the process variable.

- **Thermostat (Thermostat)**

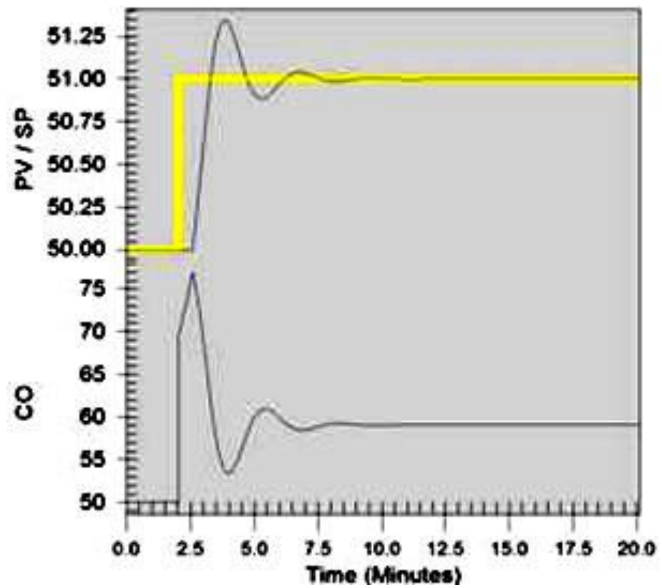
An instrument, which measures, changes in temperature and directly or indirectly controls sources of heating and cooling to maintain a desired temperature. Also known as thermorelay..

Second Chapter

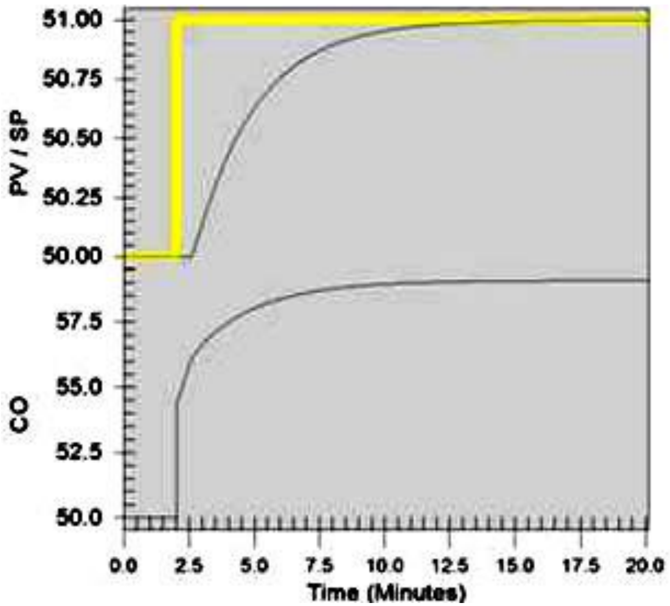
Second tutorial: Designing PID response

"The primary difference between a load (disturbance/upset) response and a set point response lies in the objective the end-user is typically trying to achieve. In most cases, users trying to get a good set point response are looking for a fast but smooth response which usually comes from the use of less aggressive tuning parameters. If the user is trying to reject a disturbance, then they are after a much faster response using more aggressive tunings. Therefore, they are at best conflicting control objectives. You cannot be both quick and responsive, while being smooth with little to no overshoot. There is always a trade-off when trying to tune for both set point tracking and load rejection using a typical PID-type controller. There is an‘I-PD' type controller, which is a ‘proportional on measurement' approach vs. ‘proportional on error,' which can improve the set-point tracking response under aggressive PI-control.“

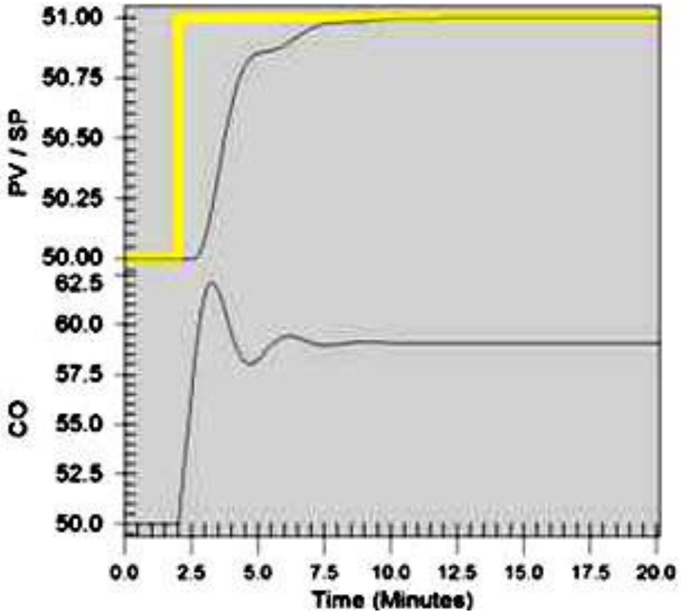
Source: Control Engineering Process & Advanced Control Monthly eNewsletter. http://www.controleng.com/ (11/2016)



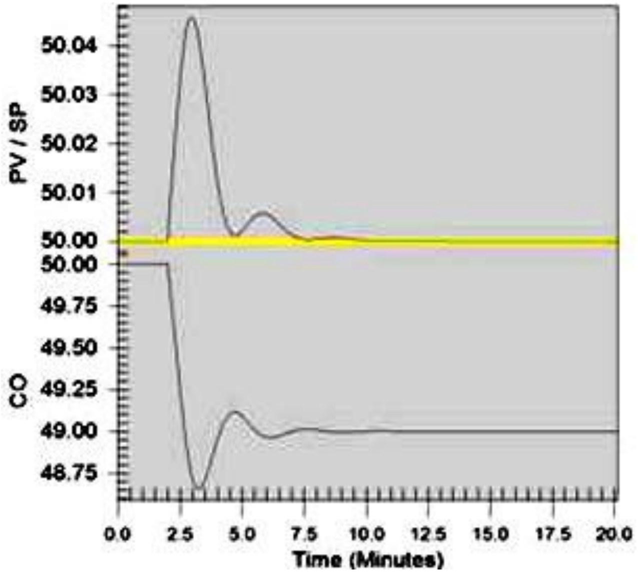
Aggressive PI control, set point tracking



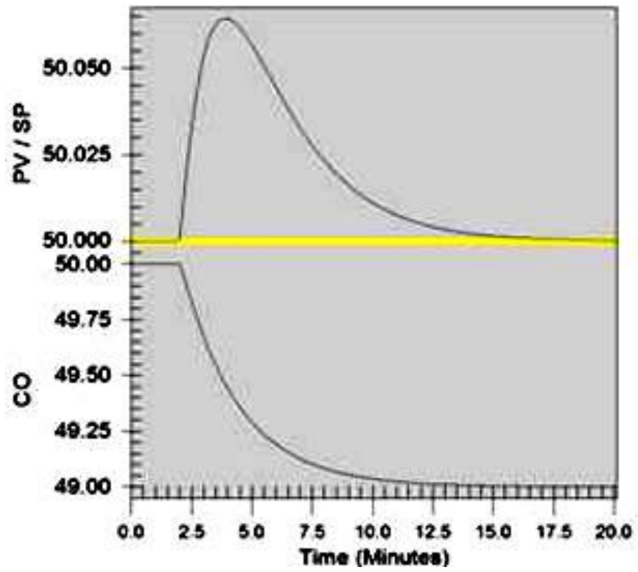
Moderate PI control, set point tracking



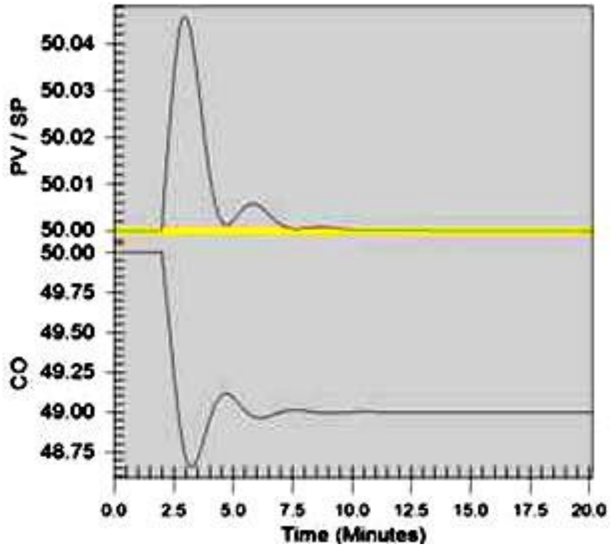
Aggressive I-PD control, set point tracking



Aggressive PI control, load response



Moderate PI control, load response



Aggressive I-PD control, load response

- Bounded Input Bounded Output Stability (BIBO)(Stabilité au sens BIBO) A system is stable if the output remains bounded for all bounded (finite) inputs.
- Steady state (Régime permanent/ stationnaire) System response as time approaches infinity.
- Settling time/Response (Temps de réponse) The time interval between the step change of an input signal and the instant when the resulting variation of the output signal does not deviate more than a specified tolerance from its steady-state value.
- Rise time (temps de montée) The time required for the output of a system (other than first-order) to change from a small specified percentage (often 5 to 10 percent) of the steady-state increment to a large specified percentage (often 90 to 95).
- Overshoot (Dépassement) The amount a process exceed the set point during a change in the system load or change in the set point.
- Dead Time /Delay (Temps mort) The interval of time between the initiation of an input change or stimulus and the start of the resulting response.

- Damping factor (Coefficient d’amortissement) -for second order systems- It determines how much the system oscillates as the response decays toward steady state:
    - Overdamped (sur amorti) → Damping factor > 1.
    - Underdamped (sous-amorti)→ Damping factor <1.
    - Critically damped (Amortissement critique)→ Damping factor =1.
- Undamped frequency(Pulsation propre non amortie)-for second order systems- It determines how fast the system oscillates during any transient response.
- Time constant (Constante de temps) -for first order systems- The time it takes for the system to reach 63% of the steady-state value for a step response or to decrease to 37% of the initial value for an impulse response.
- Step response (Réponse indicielle) The output of the system when the input is a step.
- Impulse response (Réponse impulsionnelle) The output of the system when the input is an impulse.

- Gain (Gain) “Change in process output" divided by "change in process input". A process with high process gain reacts more to a change in the process input than a process with low process gain. More gain in a controller gives a faster loop response - and a more oscillatory (unstable) process.
- PID Controller (Régulateur PID) Proportional-plus-integral-plus-derivative controller.
- Proportional Band – P (Bande propostionnelle) With proportional band the controller output is proportional to the error or a change in process variable. Proportional Band = 100/Gain
- Integral Action – I/Reset (action integrale) The integral part of the PID controller. With integral action, the controller output is proportional to the amount and duration of the error signal. If there is more integral action, the controller output will change more when error is present.
- Derivative – D/ Rate (Action dérivée) The derivative - D - part of a PID controller. With derivative action, the controller output is proportional to the rate of change of the process variable or process error.

Practice

In the figure, where the input used is a unit step, illustrate and/or give the value of the following:

- The steady state,
- The settling time (at 95%),
- The first overshoot,
- The dead time,
- The rise Time (10%-90%),
- the damped period (pseudo period).