An On-line Self-tuning Algorithm of PI Controller for Heating and Cooling Coils

M. Liu and Q. Zhou

The feedback loop control is often used for the heating and cooling coils in air handling units. The controller receives the coil discharge air temperature and compares it with the preset-value. When a bias is identified, a correction control signal is sent to the control valve. Consequently, the water flow rate to the coil is changed to maintain suitable discharge air temperature. Since HVAC systems have relatively large inertia, the controller only use P and I portions to generate the control signal.

The output of the controller depends on the proportional and integral gain. The supply air temperature either oscillates around the preset-value or drifts away from it (if incorrect values of P and I gain are used). Figure 1 shows that the discharge air temperature fluctuates up to 10°F when the P and I gain are set 3-times larger than the correct values. When the correct P gain and I gain are used, the discharge air temperature reaches the preset-value within five minutes (shown in Figure 2).

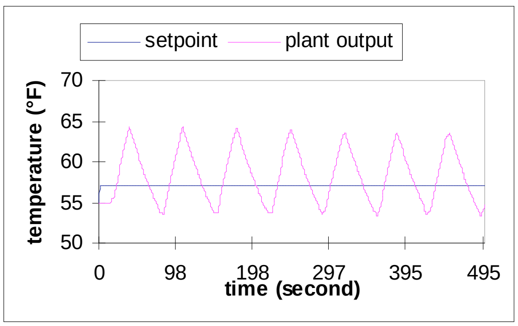

Figure 1 The step response of the system when high P and I gain are used

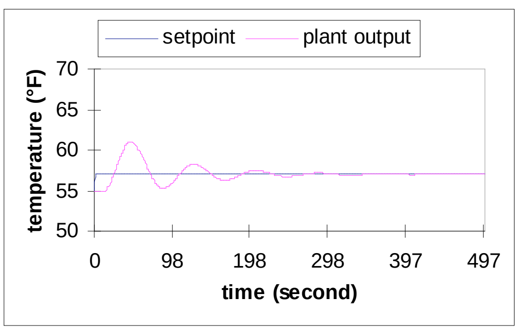

Figure 2 The step response of the system when the correct P and I gain are applied.

A number of auto-tuning programs have been developed, based on the model identification method. First, a step change is imposed to the preset-value. The response of the discharge air temperature is recorded and the system model is identified. Finally, the P and I gain are calculated by using the measured data based on the empirical or theoretical equations. This method can only be used periodically since an artificial step change must be introduced. Therefore, normal operation and auto tuning are separated in HVAC control systems. Auto tuning must be manually turned on when the operator finds the controller needs to be tuned. Current auto tuning is done off-line.

To improve the control performance, NN controllers can be introduced. These controllers require extensive training, in order to achieve acceptable performance. Moreover, NN controllers are still in the research stage. Recently, FFPI control was proposed. This method produces the primary control signal based on pre-defined modes of the control subject. The PI control provides a correction to the primary control signal. Since it is often hard to develop the model of the control subject, significant research has to be performed to implement it in real systems.

An on-line self-tuning algorithm with satisfactory results has been developed for PI controllers. The algorithm was tested using a cooling coil in existing AHUs. This new algorithm has the following advantages over the existing methods. The algorithm uses 'iteration' to search for the optimal P and I gain and no model identification is needed. Therefore, it does not interrupt the normal coil operation and it can be realized on line.

The algorithm evaluates the controller performance by the integral square error (ISE) of the control target. The system performance is directly assured. For the AHUs, indoor comfort and energy efficiency is maintained as long as this criterion is under the allowed range.