Xiera
Intelligence in Decision Making

CASE STUDY: A COAL FIRED ELECTRIC POWER GENERATION STATION

This simulation example is intended to illustrate the power of Xiera's technology.

Pulverized Coal Mill

In pulverized coal mills, such as those used in coal-fired power generation stations, a highly-volatile mixture of pulverized coal dust entrained by a carrier gas is delivered into the burning chamber. Such fuel mixtures are produced in roller mills which receive "raw" coal and pressurized air. The automatic regulation of the amount of coal fed into the mill is a function of the steam generator load. Control for achieving such coal feed regulation, while at the same time insuring safe mill operation, is typically achieved by controlling the volume of carrier gas in accordance with pre-calculated ratios of coal to primary-feed air. In addition to maintaining the appropriate coal/air ratio, the temperature of the fuel stream exiting the roller mill is required to be maintained within safe limits. This requisite temperature control is accomplished by mixing cold air with the "hot" or primary air delivered to the mill.

One particular disadvantage of coal mill control resides in the problem of large delayed reaction. Existing conventional control systems are unable to provide the mill with the ability to respond quickly when the rate of change of the steam generator load is high. The conventional method of overcoming this disadvantage is to override the mill control. However, this solution presents the possibility of local overheating in the steam generator to which the pulverized coal/air mixture is being delivered.

To eliminate the problem of delay in plant response, a feedforward method which suitably adjusts the proportional gain of a conventional PID controller and the time constant of the integrator is generally employed, but the method is not satisfactory, as feedforward control may lead to instability. In addition, various operations such as number change control, manual operation, and bias control must be made. Furthermore, a feedforward control signal cannot assume an arbitrary value. An ideal value for the feedforward control signal would be one that minimizes the necessity of correction by feedback control. This is a tough problem to resolve.

Another problem arises in the control of a pulverized coal mill: the two loops are highly interactive. As a result, existing control systems are only capable of manipulating the dampers within a specific narrow range. To provide a fundamental solution to this problem, a multivariable controller is required. Such a controller does not exist at present.

To summarize, two loops are controlled in a pulverized coal mill (see Figure 1): the Mill Discharge Temperature and the Mill Mass Air Flow. The two loops have:

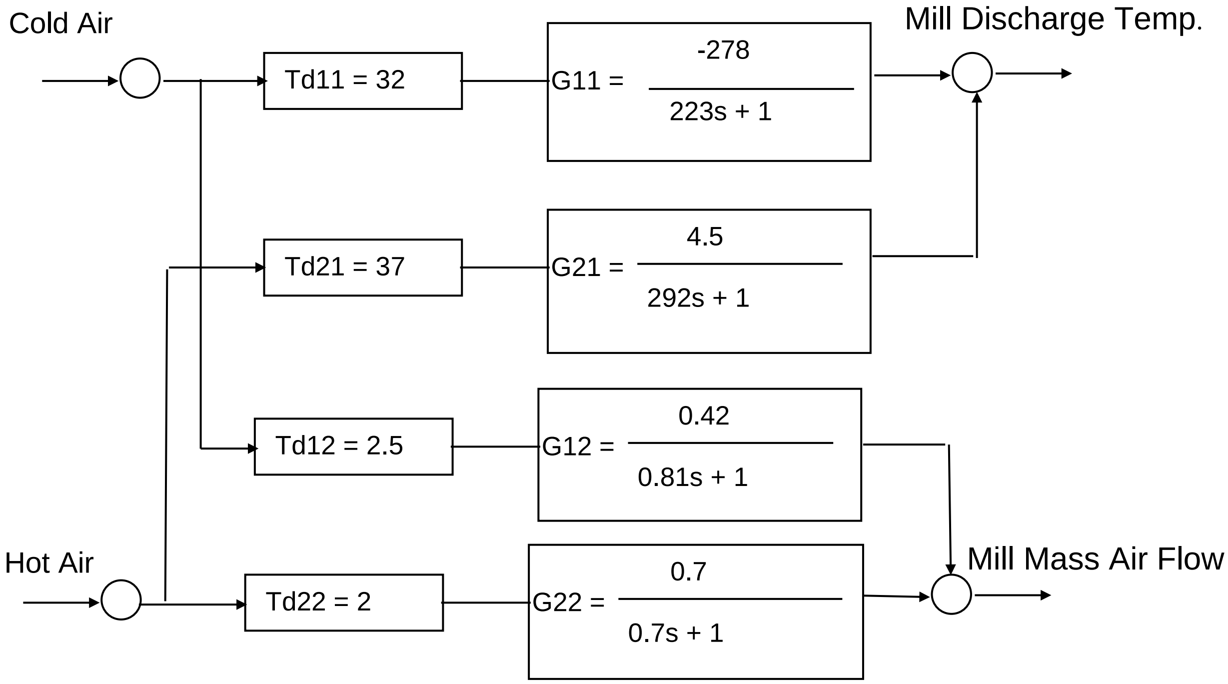
- Large time delays
- High interactions

In addition, due to the limited range that the dampers should be opened, excessive opening of the cold-air inlet damper lowers the discharge temperature upon demand instead of increasing it which results in positive-like feedback leading to instability.

These problems make the control of the pulverized coal mill a nontrivial problem.

The Process Model

The figure below shows a block diagram of the transfer function model of an actual pulverized coal mill obtained from real data. The data was obtained from an electric-power generation station using coal as fuel.



Notes:

TD = Time Delay

Figure 1: Block Diagram of the Pulverized Coal Mill Open Loop Model

G11(s) represents the main loop for the mill discharge temperature. Td11 represents the time delay for this loop. This time delay is high, as can be seen from Figure 1, which translates into overall nonlinear response behavior. Also, this loop has a negative response, which can easily give rise to instability. When the station requires higher load, necessitating more demand on air, the cold air influx (required for increasing the rate of coal burning) lowers the discharge temperature causing cooling of the burning chamber instead of heating it. The result is a negative nonlinear behavior response of the mill discharge temperature loop.

G22(s) represents the main loop for the mass air flow. TD22 represents the time delay for this loop. As can be seen, this is a fast-acting flow loop with very small-time delay.

G12(s) represents the interaction (effect) of the cold air input on the mass air flow. Td12 represents the time delay for this interaction. As can be seen from Figure 1, this effect is substantial and has a very small-time delay, which translates into a high and very fast interaction effect of the first loop onto the second loop.

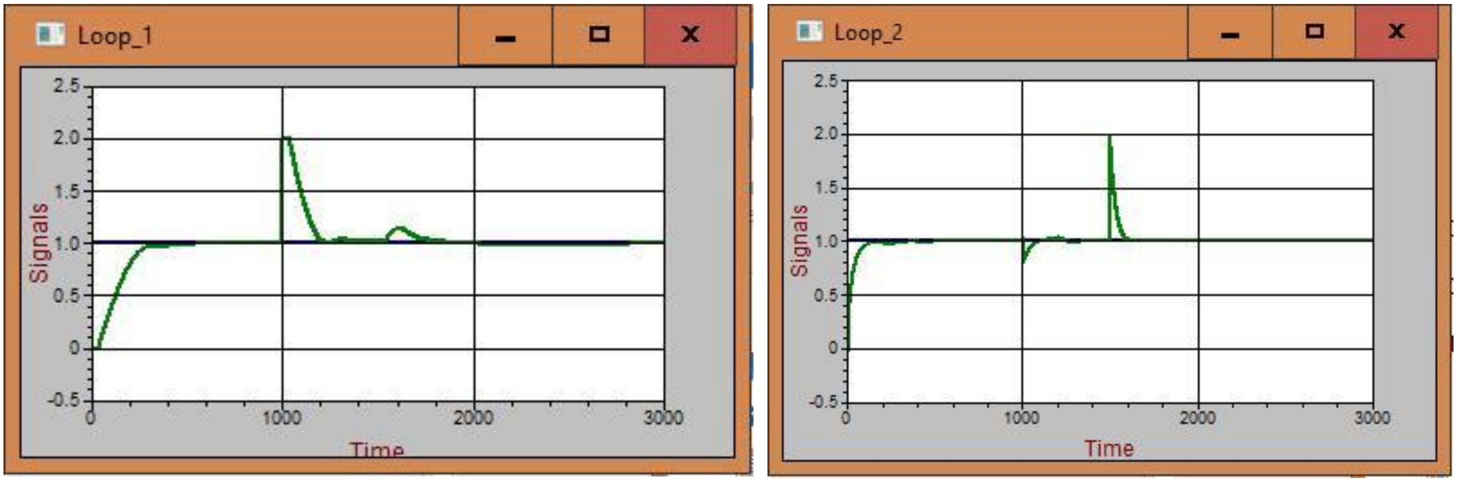
G21(s) represents the interaction (effect) of the hot air input on the temperature. Td21 represents the time delay for this interaction. As can be seen from Figure 1, this is a large time delay, which translates into nonlinear interaction behavior of the loop

The above diagram shows two highly interacting loops: a temperature loop with very large time delay (slow response), and a very fast acting flow loop, with high influence from the first loop. This makes the pulverized coal mill a non-homogeneous system which is difficult to control using conventional control methods.

Multivariable Fuzzy Controller Design

The Auto-tuner technology developed by Xiera, which is embedded in the edeX design tool, makes it possible to design multivariable fuzzy controllers capable of eliminating the high interaction between the two loops of the pulverized coal mill, and overcoming the problem of large delays in the plant response.

A multivariable fuzzy controller was designed and tuned for this system using edeX. The simulated control system response is shown in figure below.



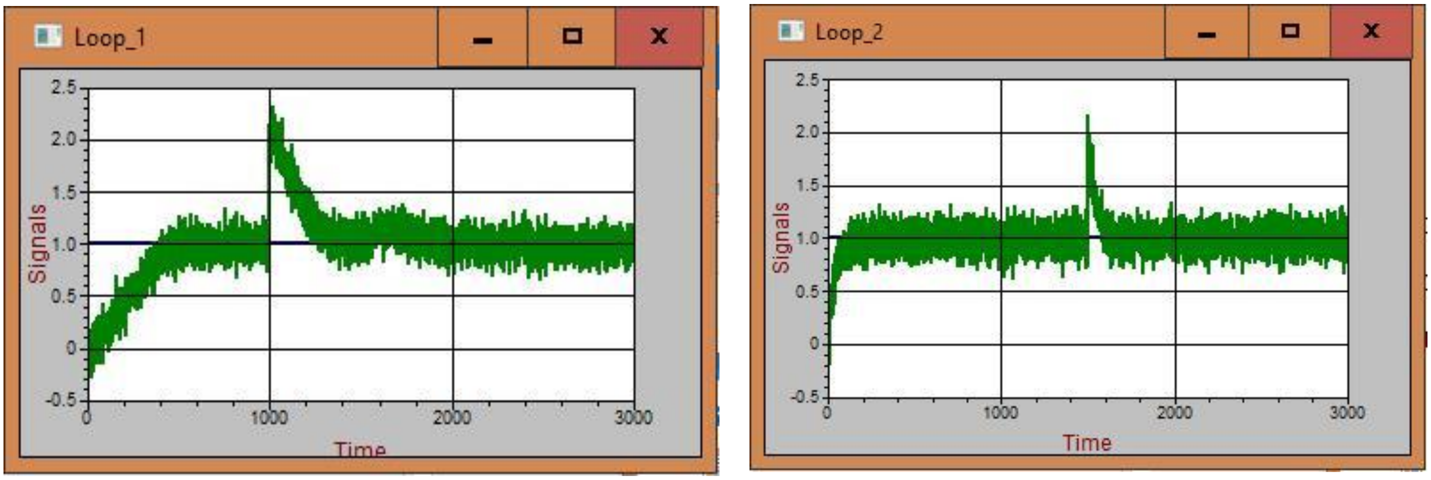
a) Mill Discharge Temperature Loop Response

b) Mill Mass Air-Flow Loop Response

Figure 2

To highlight the power and robustness of the fuzzy controller for this highly-interactive multivariable system, the response is shown for a maximum step change which is equal to the full range of operation for both loops. Furthermore, disturbances of 100% magnitude (equal to the set-point) were applied at each output to simulate process disturbances (i.e. a worst-case scenario), one disturbance on the second loop at 200 seconds, and the other on the first loop at 500 seconds. The simulated loop responses demonstrate the following:

- Smooth, highly robust, and stable control.
- Fast-acting response with low rise time, which means more efficient burning and less wastage, resulting in lower operating cost and less gas emission.
- The fast-acting response overcomes the disturbance, which means higher stability allowing operation for a wider mill range.
- Elimination of interactions between the two loops. This allows the control of each loop individually, providing more efficient control and savings in raw materials.



a) Mill Discharge Temperature Loop Response with high process noise

b) Mill Mass Air-Flow Loop Response with high process noise

Figure 3

In summary, applying fuzzy logic to the pulverized coal mill control yields several advantages:

- Overcomes the problem of large time delays, making the pulverizer system more stable.
- Nonlinear control which allows control over a wider operating range.
- More robust control which provides a stability in the presence of noise and disturbances which occurs when the coal dust is not uniform.
- More efficient control which results in:
  - More efficient burning of coal.

- Less emission of gases to atmosphere.
- Raw material saving.
- Operational cost saving.