DeltaV Predict Application

This paper provides an overview of how DeltaV Predict may be used to address a variety of multi-variable control applications within the process industry.

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Introduction

The MPC function block provided by DeltaV Predict may be used to address multi-variable control requirements. The DeltaV Predict application may be used to automatically create process models and control definitions from process data. The automated test feature of the Predict application allows the step response of controlled or constraint outputs to be determined based on changes in the manipulated inputs. This capability can be used to meet multi-variable control requirements in all process industries. In many cases, the MPC function block may be used to replace control techniques that have traditionally been used to address the control requirements of multi-variable processes.

Multi-variable control is defined as control that uses multiple process measurements to produce one or more outputs. The techniques available to an engineer for implementing multi-variable control have been limited to the conventional capability available in most commercial process control systems. The most commonly used techniques are illustrated in Table 1. Such techniques may be combined to address the control requirements of a multi-variable process. However, as the number of interacting control loops, operating constraints, and load disturbances used in the control increases, the complexity of the control system is often beyond that which can be maintained by the typical plant engineer or instrument technician. A single MPC block may be used to address the complete requirements of many multi-variable processes.

The implementation and commissioning of this block is far simpler and faster than traditional techniques as are illustrated by the following example. The difference is even more dramatic for applications involving a larger number of controlled, constraint or disturbance parameter or where throughput is to be optimized.

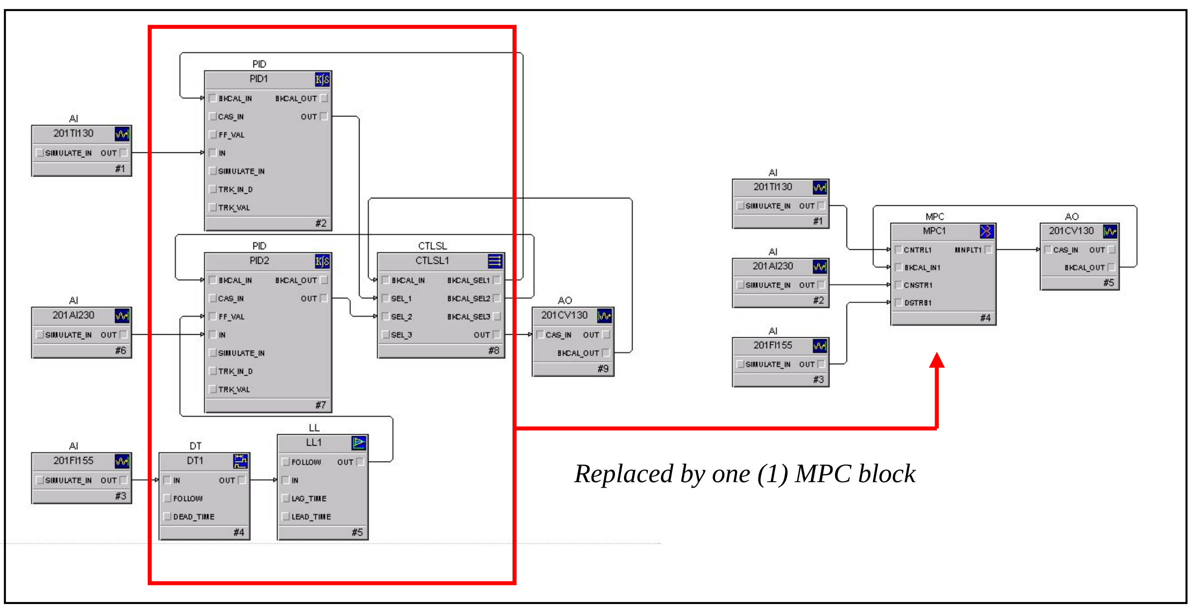
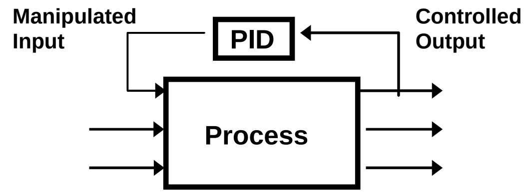
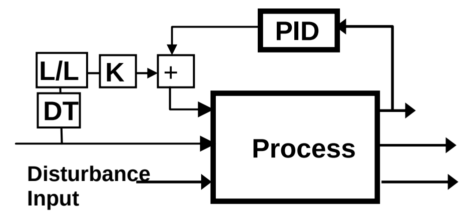


Figure 1. Traditional implementation vs. MPC for application with one control, disturbance and constraint parameter

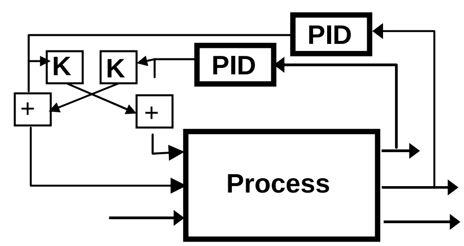
Feedback Control –regulation of a process input to maintain the process at a target operating setpoint. The common means of feedback control is the PID algorithm. Tuning of the PID is based on the dynamic response of the process to a change in the manipulated input.



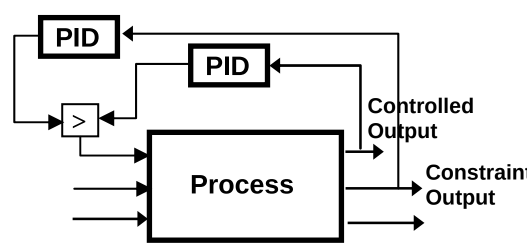
Feed-forward Control – Compensate for measured process disturbances by adjustment of process input. In general, dynamic compensation using a deadtime and lead/lag unit is required. Setup of dynamic compensation is based on the dynamic response of the process to changes in the disturbance input.



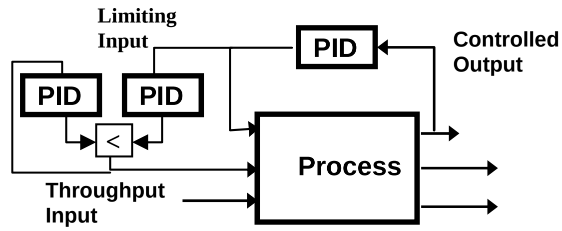
De-coupling Network – Account for process interaction in the adjustment of process inputs. Where manipulated inputs impact the process in the same timeframe, then gain compensate based on the relative gain associated with each controlled parameter may be utilized. If the dynamics are different, then a lead/lag and deadtime unit are required.



Override Control – Maintain feedback control within operating constraints. When the constraint exceeds its setpoint, the output of the override PID is selected for control. Tuning of the constraint PID is based on the dynamic response of the constraint parameter to a change in the associated manipulated input. High or low selection of the control output is used based on whether the input is to be limited high or low based on the constraint.



Throughput optimization – Throughput is maintained at its setpoint or at a limit established by a process input. When the input limit is reached, the throughput is automatically reduced to maintain the process at the input limit. Thus, the maximum throughput may be maintained.



Applications that may benefit from MPC control can be identified based on your process knowledge. The following guidelines may be used to determine when MPC should be considered.

Table 1—Traditional Multi-variable Control Techniques
1. Single or multi-loop control that is characterized by long delay or inverse process response. Since the control action taken by the MPC blocks is based on a process response model, better control may be achieved than is possible with PID feedback control or deadtime compensation techniques such as the Smith Predictor. The response model used by MPC is determined automatically during commissioning using the Predict application.
2. The interaction of two or more control loops impacts process operation i.e. a change in the output of one control loop impacts the control parameter of the other control loops in a significant manner. Such interaction is automatically accounted for when the MPC block takes control action. Thus, control may be improved since any correction that is taken to adjust one control parameter will only impact that parameter.
3. One or more disturbances to a controlled parameter(s) are measured. By including these measurements in the control, the impact of disturbances will automatically be compensated by the MPC block. Thus, changes in the disturbance input will have little or no impact on the control.
4. One or more measurable constraints must be observed in control of the process. The MPC block constantly calculates the impact of a disturbance or control action on constraint parameters. If the future value of a constraint output violates its limit, then MPC will automatically take the appropriate action to prevent the constraint limit from being violated.
5. One or more measurable constraints must be observed in control of the process. The MPC block constantly calculates the impact of a disturbance or control action on constraint parameters. If the future value of a constraint output violates its limit, then MPC will automatically take the appropriate action to prevent the constraint limit from being violated.
6. Production is limited by one or more inputs to a process. Control of the throughput may be included in the MPC along with the control associated with the inputs that limit production. Throughput is automatically adjusted to maintain the process at its input limit and thus achieve maximum production.

The execution rate of the MPC block is limited to 1 second or slower. Therefore, MPC should be applied to processes where their control requirements may be satisfied at these execution speeds.

Difficult Process Dynamics

When the process response to a change in the manipulate input is dominated by delay or exhibits an inverse response, then regulation provided by PID control may be too sluggish to meet your control requirements. In such cases, the MPC block may be utilized for this control application. Since the control provided using MPC is based on an accurate model of the process, you may achieve tighter control than can be achieved with PID. An example implementation of MPC for single loop control is shown below.

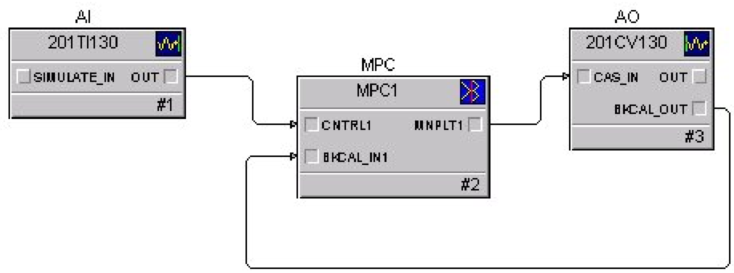


Figure 2. MPC for single-loop control

Interacting control loops

The model that is developed for MPC control captures the impact of a change in manipulated and disturbance inputs on all the process outputs. Thus, it is possible for the MPC block to correct for a deviation in one controlled parameter without impacting other controlled parameters associated with the MPC block. The implementation and commissioning of such control may be done quicker and easier than using traditional techniques, such as decoupling networks, to compensate for loop interaction. An example of the control of two interacting control loops using MPC is shown below.

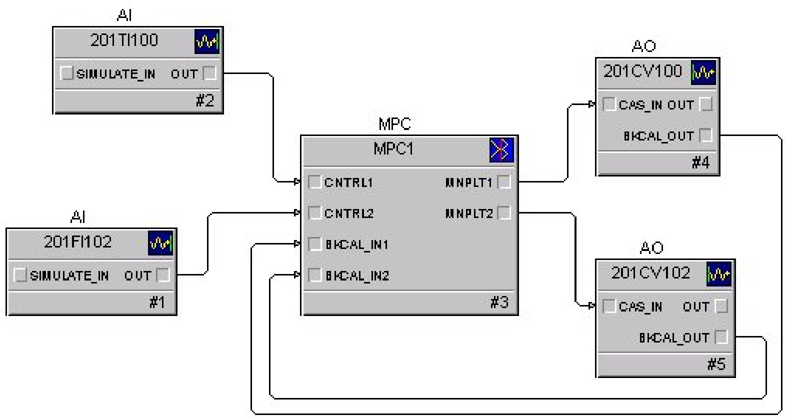


Figure 3. The control of two interacting control loops using MPC

Measured Disturbances

The MPC process model identifies the dynamics associated with a measured process disturbance. This model is the basis for MPC control and allows the control to automatically compensate for disturbances. No additional dynamic compensation elements are required (as with traditional techniques) to compensate for process disturbances. An example of a single control loop with two measured disturbances is shown below.

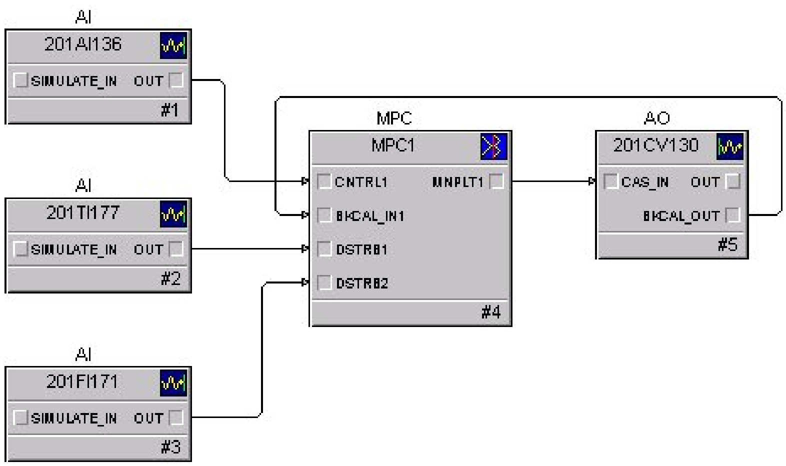


Figure 4. A single control loop with two measured disturbances

Measured Constraint

Constraint handling is an integral part of the MPC block. Based on the predictions done by MPC, the impact of disturbances and changes in manipulated inputs on the constraint may be predicted. When the value of the constraint is predicted to exceed the constraint limit defined by its setpoint, then the internal target of the associated controlled parameter will automatically be reduced so that the resulting changes in manipulated inputs prevent the constraint from exceeding its limit. As part of the constraint configuration, you must identify the associated controlled parameter and whether the constraint setpoint represents a minimum or maximum limit. An example of a single control loop with one constraint is shown below.

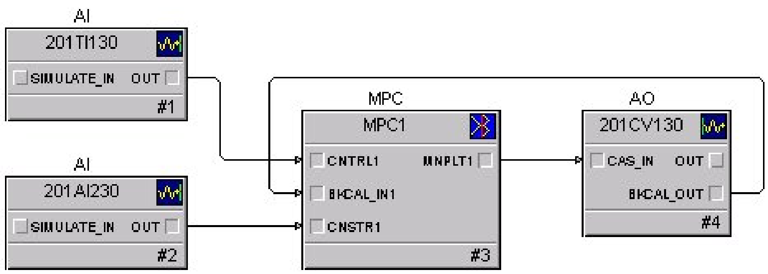


Figure 5. A single control loop with one constraint

Process Input Limits Production

One manipulated input defined for the MPC block may be identified as an optimizing input i.e. an input that is to be maintained at target or at a value which keeps one of the other manipulated inputs at a defined maximum or minimum limit. When a manipulated input is selected for optimization, then a minimum or maximum limit must be configured for the other manipulated inputs. Also, no connection is required for the control input associated with the manipulated output used to set throughput. When the throughput setpoint is changed, the manipulated output for throughput adjustment will be changed until the setpoint. If another manipulated parameter is at or exceeds its configured high or low limit on a change in throughput target or during normal operations, then the throughput will automatically be adjusted to maintain the manipulated output at its limit. An example of an MPC block used to control two parameters and optimized throughput is shown below.

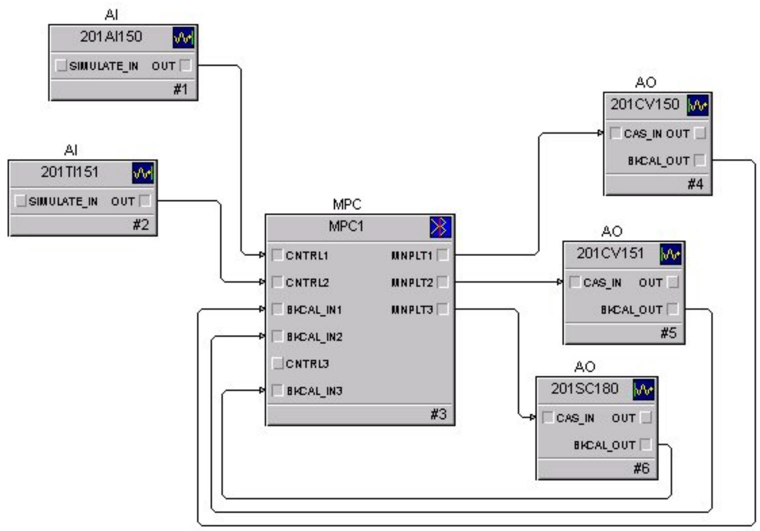


Figure 6. An MPC block controlling two parameters and optimized throughput

Large Multi-variable Applications

The design of many processes requires that the control strategy address multiple controlled, constraint, disturbance outputs through the adjustment of multiple manipulated process inputs. The MPC block may be used to control processes of size 8x8 i.e. 4 controlled, 4 constraint, 4 disturbances, and 4 manipulated parameters maximum. The lime kiln example in this section demonstrates how the techniques utilized in the previous examples may be combined to meet the control requirement of this more complex process.

A typical limekiln process and instrumentation for the recausticizing area of a pulp mill are shown in the following diagram. This process is 3x4 in size, where gas and ID fan speed are to be manipulated to control the material and exit gas temperature at the hot and cold end of the kiln. Constraints on gas and ID fan speed adjustment are set by limits on O2 and hood draft respectively. The lime mudflow throughput is to be maximized within the constraints of the ID fan speed limits.

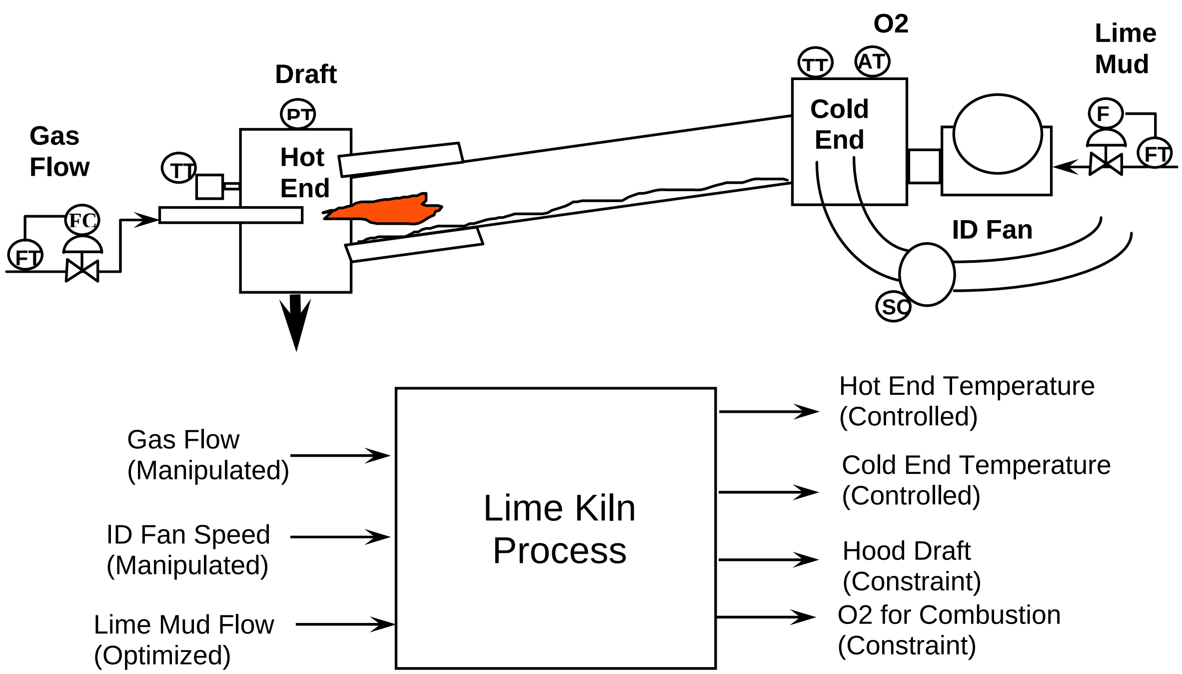


Figure 7. Lime kiln process and instrumentation—typical

A traditional control strategy for the limekiln is shown below. For simplicity, the PID controller associated with the mud flow and gas flow are not shown but are required in the final implementation. A total of six (6) PID controller (plus the gas and lime mud flow PID controllers), three control selectors, and nine math and dynamic elements would be required for the kiln control. A decoupling network addresses interactions between the hot and cold end temperature control. Constraints on O2 and draft are provided as overrides on gas flow and ID fan speed adjustment. Throughput is maximized based on the ID fan being the limiting factor on production.

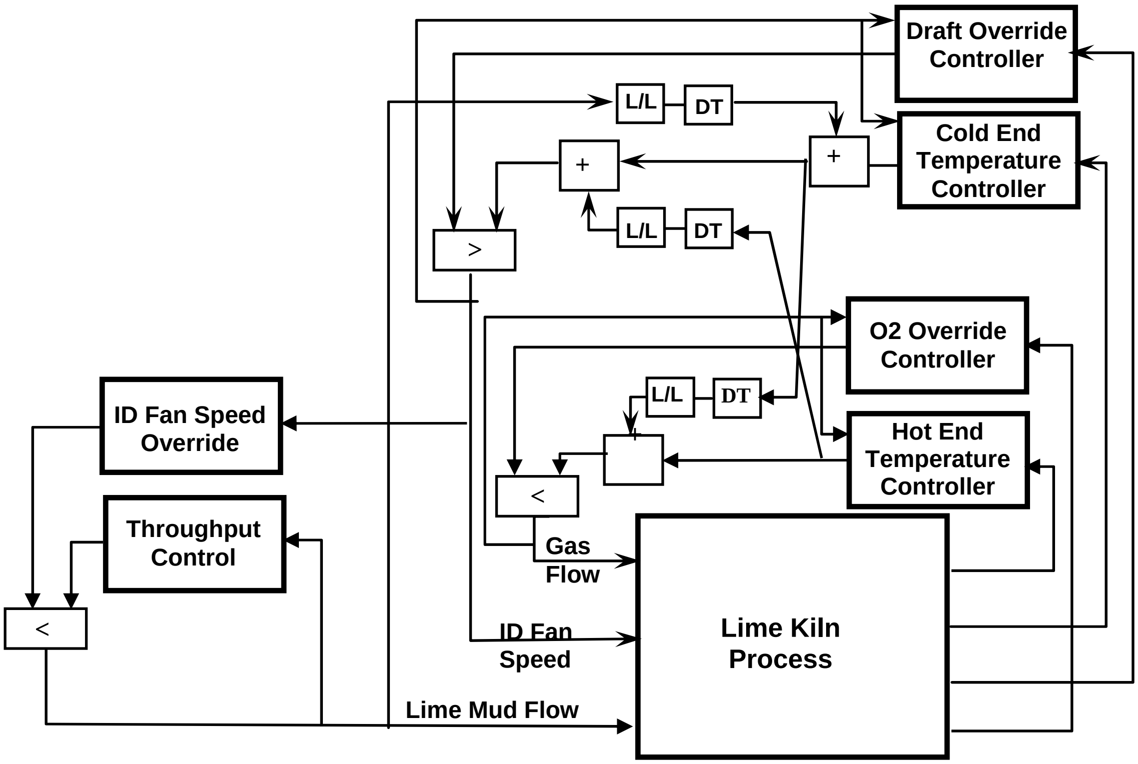


Figure 8. A traditional control strategy for the limekiln

The equivalent control is provided by one(1) MPC block. The complete control strategy (including the lime and mud flow control) using the MPC block is shown in the following figure.

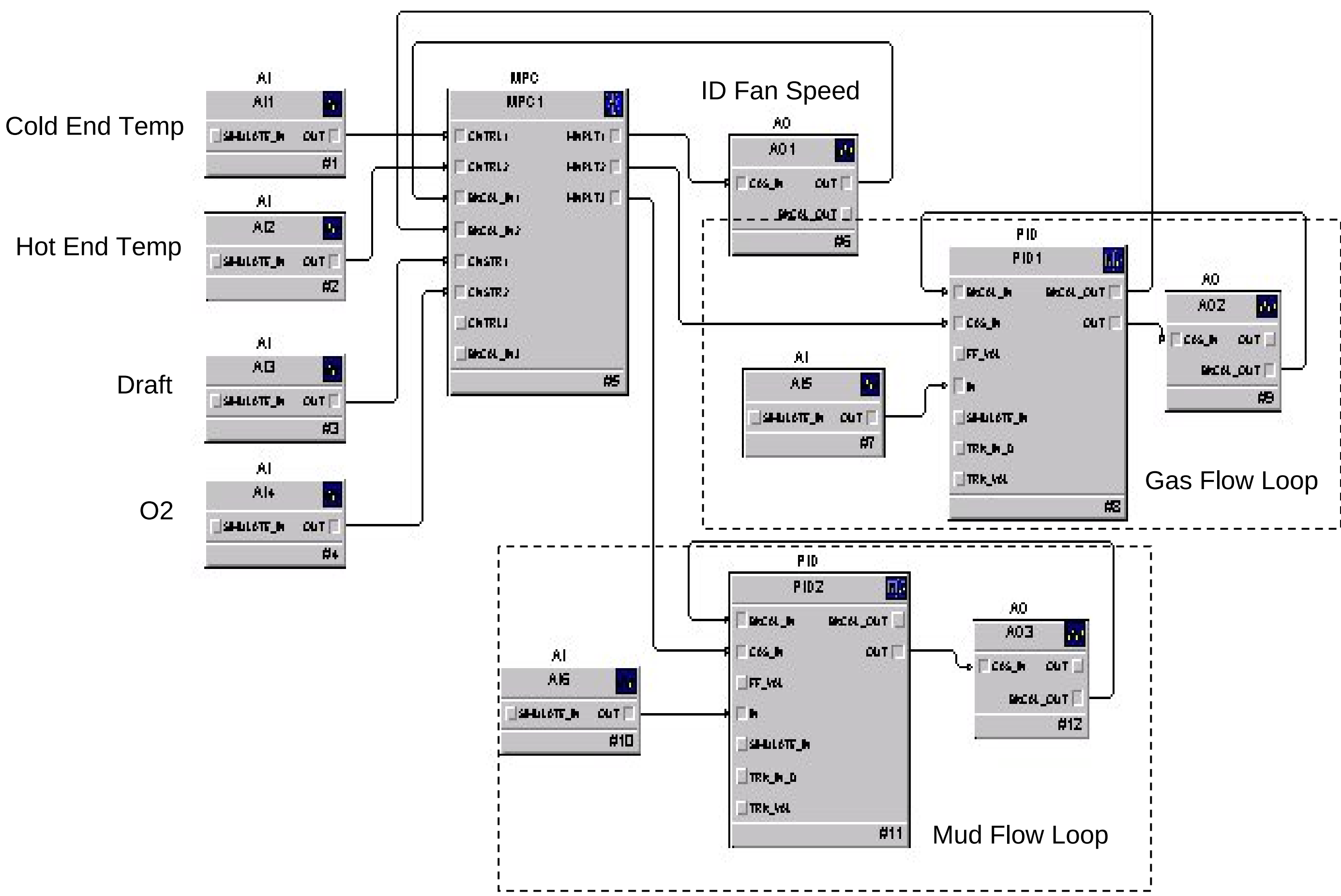


Figure 9. The complete control strategy (including the lime and mudflow using the MPC block)