SMALL BATCH CONTROL PROJECTS

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INTRODUCTION

Controlling small batch control processes has been a difficult problem for the control engineer. If the process has a large analog component then distributed control systems have been ideal, but they tend to be costly. Therefore, their usage has been limited to large jobs. If the process has little analog control and limited operator interface requirements, then programmable logic controllers (PLCs) can be good choices. However, small batch jobs often have several analog loops and the need for good operator interface. Thus, the engineer using the PLC usually ends up installing conventional analog controllers, switches, indicator lights, etc. Costs and complexity increase as the engineer puts together the various components. The result is often a very unsatisfying control system.

As a means of getting around these problems, vendors are now developing small, panel mounted controllers. These controllers incorporate the analog and sequential control capability of distributed control systems with process oriented operator interface. In addition, the controllers can communicate with each other. This eliminates the cost and difficulty of hardwiring signals between units. To distinguish these controllers from conventional panel mounted controllers (which bear a superficial likeness for these programmable panel controllers) the new controllers are often called smart controllers.

CONTROLLER DESCRIPTIONS

Two basic functions must be carried out by the control system in a batch control application. The first is the analog control and operator interface. The second is the digital, sequential control.

From the faceplates, the smart analog controllers appear to be single loop controllers (see Figure 1). However, internally the controllers are microprocessor driven and must be capable of a wide range of functions. These functions must include alarming, analog conditioning and scaling, advanced control algorithms, process interlocking, and full communication with other controllers.
The smart digital controller is, however, a new breed of controller. It must perform complex digital control, communicate with the analog controllers (i.e. change setpoints, provide tracking signals, etc.), and a reasonable amount of operator interface. In addition, the digital controllers must be capable of being linked together to provide the I/O and logic power for complex applications. Figure 2 shows such a controller.

The faceplate of the smart digital controller links directly to several specialized control blocks. The operator can change sequence modes, step numbers, and device modes from the faceplate.

In addition, each output of the smart digital controller is interfaced to the faceplate through a device driver function block (DDRIVE). This block can be controlled from the faceplate or the automatic sequence and does all of the base level interlocking (such as feedback checking, and waiting for device stroke time).

**CONTROLLER CONFIGURATION**

One of the banes of small batch control applications is that there has never been a standard batch control terminology as there has been in analog control. PLCs are configured via ladder logic. This works well with interlock control, but provides some difficulty with analog control. Process control vendors have often used either computer like languages or function blocks that are linked together. Each have their advantages depending upon the background of the engineer configuring the system and the maintenance staff providing support. Generally, as the application becomes more process oriented (i.e., more analog control and logic using analog signals), ladder logic is less advantageous and function blocks are better. To get a better appreciation of this, a few applications need to be considered.

**Simple batch logic**

A simple need in batch control is to open valves, check devices, and set timers. For the purposes of this discussion, consider the application where a valve is to be opened, a timer started. At the end of the timed period, control proceeds to the next step called for by the sequence. Figure 3 shows a typical ladder logic approach. Figure 4 shows the same logic in a function block format. Note that the logic is very similar. The only difference is that in the PLC the user had to install a timer in to delay the alarm from being set until the valve feedback had time to confirm the valve's position. This logic is built into the DDRIVE function block. In addition, the function block contains the alarm and interface capability since it directly ties to the faceplate of the smart controller. In the PLC, additional hardware and software would have to be constructed to allow the user to have this type of interface.
Integration of flow

In most applications, the batch control sequence has to scale and integrate analog values. Normally the integrated flow is compared to a target or recipe value. Figure 5 shows a typical ladder logic configuration for analog scaling and Figure 6 shows the integration logic.

In Figure 5, the analog value comes into the PLC logic as an 0 4095 value that is unscaled. The multiply block converts the range to the correct range in engineering units and the ADD block adds any necessary offset. Figure 6 simply performs a trapezoid integration algorithm on the incoming scaled analog signal.

Figure 7 shows similar logic in a smart controller. Note that the function block algorithms of the smart controller are process oriented. In defense of the PLCs, newer PLCs are developing ladder logic components that are similar to the process oriented function blocks. The evolution of both products seems to be paralleling.

PROCESS APPLICATION

A major food processor in the midwest needed to install a pasteurizer for their product. A pasteurizer is basically no more then a series of automated conveyors traveling within a stainless steel shell. Within the shell there are multiple zones, each one of which must be controlled within prescribed temperature limits.

The control engineer is faced with the following problems:

1. To maximize production and reduce manpower, a fully automated startup and shutdown is necessary.

2. To manage the process, full interlocking (with systems upstream and downstream) is necessary. The conveyors are all speed controlled and, therefore, each loop is under analog control. The speed of the conveyors is directly under the influence of the speed of product removal.

3. To minimize manpower costs, the equipment has to be capable of a fully automated Clean In-Place (CIP) sequence.

In the past, such an application would have been satisfied with the combination of a PLC, analog controllers, and a custom switch panel (see Figure 8). With a set of smart controllers a system can be designed with fewer components, far less wiring, and less communication problems. Figure 9 shows the same application using smart controllers.

APPLICATION CONFIGURATION

The smart controller is designed to allow the engineer to solve control problems via a set of 'step logics' and via a matrix output for each step. This means that the user can divide the batch process into
a series of discrete steps, each of which are fairly simple to solve. For illustration, the pasteurizer startup and normal run mode will be examined.

Step Matrix outputs are assigned to a matrix and given an output condition based upon the step number. Table 1 shows the output matrix for the first six steps.

The individual step logics follow. Below is a written description of each step.

Step 1 — This step simply checks to make sure that all of the analog controllers are in automatic and the start input is on. Figure 10 details this logic. Note that the smart digital controller need not be hardwired to the analog controller since the information is passed via the communication system.

Step 2 — This step fills the levels of the pasteurizer pans. When the levels are full, control advances to the next step. Figure 11 shows this logic.

Step 3 — This step starts to heat up the pans. It does this by opening up auxiliary steam valves. When the temperature is above 190°F, control advances to the next step. Figure 12 shows this logic.

Step 4 — This step shuts down the steam valves and loads set points into the heat exchanger controllers. When the temperatures of all zones of the pasteurizer are above 195°F, then the conveyors are started. Figure 13 shows this logic.

Step 5 — This is the normal run phase of the pasteurization. Here the system monitors the feed inlet conveyor and discharge crowd switch. If the feed inlet crowd switch goes on, then not enough product is being fed to the conveyor. In this case, a signal is sent to the conveyor control logic of the analog controller to reduce speed. If the discharge crowd switch is on, then the product is not being removed fast enough from the conveyor. In this case, the conveyors will all come to a stop. However, the heating control elements are kept on. If the stop pushbutton is energized, control goes to step 6. Figure 14 shows this logic.

Step 6 — This step is shutdown 1. Its purpose is to stop feeding product to the pasteurizer. Consequently, the feed conveyor is shutdown. When the restart pushbutton is energized control returns to step 5. If the start pushbutton goes off, control goes to step 8. Figure 15 shows this logic.

Step 7 — This step is Shutdown 2. All conveyors are stopped, but the control loops are unaffected. This leaves the pasteurizer warm for a restart. Figure 16 shows this logic.

Step 8 — This is the normal shutdown. All conveyors, pumps, etc. are shutdown by the matrix. All control loop setpoints are ramped to zero. Figure 17 shows this logic.
CONCLUSIONS

Smart controllers offer several advantages in controlling small batch applications:

1. Entry costs are low.
2. Controllers can communicate with each other without hardwiring costs.
3. Smart controllers have function block algorithms that are process oriented.

**FIGURE 1** Smart Analog Controller

**FIGURE 2** Smart Digital Controller
FIGURE 3  Simple Batch Logic Via PLC

FIGURE 4  Timed Step Logic
FIGURE 5  Scaling Analog Signal
FIGURE 6  Simple Integration Via PLC

FIGURE 7  Integrate Flow
FIGURE 8  PLC with Analog Controllers

FIGURE 9  "Smart" Controllers
STEP 1  BEGIN STARTUP

FIGURE 10  Step 1 Logic

FIGURE 11  Step 2 Logic

FIGURE 12  Step 3 Logic
FIGURE 16  Step 7 Logic

FIGURE 17  Step 8 Logic

TABLE 1  Step Matrix for Process