Procidia Control Solutions
Parallel Compressor Control

This application data sheet describes implementing a parallel compressor control strategy in a Siemens 353 series controller\(^1\).

Multiple compressors are operated in parallel to provide more capacity and rangeability than can normally be delivered by a single machine; see Figure 1.

The process throughput determines the number of compressors that must be operating at any given time to satisfy demand. In addition, the combination of compressors is generally designed with sufficient spare capacity to continue to operate the process even while one or more of the compressors is shut down for repairs or routine maintenance.

The primary objective of parallel compressor control is to maintain constant pressure in the header that connects the compressors to the process equipment. A change in header pressure indicates an imbalance between flow supply and demand, and the capacity of the compressors must be manipulated to hold the pressure steady at the desired operating level.

The secondary objective of parallel compressor control is to provide a convenient means for distributing the load among the machines that are operating. This is necessary even with nominally identical compressors since there is always some variation in performance from one machine to the next.

\(^1\) See Application Support at the back of this publication for a list of controllers.
When two seemingly identical machines operate in parallel at the same speed (or guide vane position or inlet valve position, depending on design), one compressor will always generate slightly more head than others. As a result, the machine generating more head will “hog” the load, while others “back out” because they cannot overcome the back pressure on the check valve in the discharge line. To avoid this problem, it is necessary to adjust the speed of one machine relative to the others to compensate for the variations in performance and to achieve a more equitable load distribution.

As process throughput varies, it will be necessary to start up or shut down compressors from time to time to provide a better match between total operating capacity and the demand for flow. Since compressors should not be carrying any load when they are started up or shut down, the control system should also provide a convenient means for loading and unloading the machines. The system should also compensate for variations in process gain that occur depending on the number of machines that are running.

The parallel compressor control strategy shown in Figure 1 consists of a header pressure controller (sometimes called the plant master), and individual auto/manual transfer stations for each compressor (sometimes called compressor masters). The pressure controller includes a position controller (ZC) to compensate for upsets and gain changes caused by starting and stopping compressors. Each compressor master includes a ratio adjustment to adjust the load distribution.

For centrifugal and axial compressors, surge protection is needed for each machine. It may also be necessary to decouple the surge and capacity control loops to minimize interaction between these variables. Control strategies for these requirements are discussed in Siemens application data sheets on capacity control (AD353-120) and surge control (AD353-121).

Design

The header pressure control configuration is shown in Figures 2 and 3 and a typical compressor master configuration is shown in Figure 4.

Header Pressure Control

In Figure 2, the PID pressure controller manipulates the setpoint of the ID position controller in Figure 3. The position controller is an integral-only (floating) controller that manipulates the total demand signal to all compressor masters.

The load summer function block (ADD1) in Figure 3 calculates the weighted sum of the loading signals to each compressor driver. These signals represent compressor speed, guide vane position, or inlet valve position, depending on the design of the machine.

Figure 3 shows a configuration for three compressors operating in parallel. For two compressors, one of the inputs to load summer ADD1 is not used, and for more than three compressors, additional summers must be configured. The input scaling of each input should be configured to match the fraction of the total flow capacity that can be supplied by the compressors. For three compressors the input scaling of each analog input is 0 – 33.333%.

Any operator action that alters the loading signal for one of the compressors will have an immediate impact on the output calculated by the summer. The position controller will then manipulate the total load demand signal to return the total load signal to setpoint. If, for example, the operator unloads compressor 1, the position controller will increase the demand signal until the increased capacity of compressors 2 and/or 3 makes up for the load that was being carried by compressor 1.

Since the position control loop contains no process lags, the ID position controller can be tuned for a fast integral time. The speed of the position loop should be able to compensate for unloading compressor 1 before it causes any significant disturbance to the header pressure.

Compressor Master Control

In each compressor master (Figure 4), the total load demand signal is multiplied (MUL1) by a ratio-set signal. This is adjusted in the QHD1 function block using the QUICK button on the local faceplate or the iware™ detail screen using the QUICK SET parameters. The ratio range is adjustable from 0 to 2. With the ratio set for 1, the compressor is loaded in accordance with its nominal share of the total load. Increasing (or decreasing) the ratio will drive the compressor to take more (or less) of the load.

The adjusted load demand signal is clamped by adjustable limits in the LMT1 function block. These are set to keep the operation of the compressor within desirable boundaries. For example, the low limit might be set near the surge limit to minimize wasteful recycle flow. However, depending on compressor sizing, turndown, and process requirements, there may be times when some recycle
flow is unavoidable if pressure control is to be maintained. In general, if excessive recycling persists with the compressors in balance, it may be possible to shut down one of the machines to save energy.

The combination of transfer switch TSW1, rate limiter RLM1, and signal selector SEL1 provides a simple method for loading and unloading the compressor. The output of the transfer switch changes from 0% to 100% when the compressor load input DIN1 changes from “0” to “1”. The output of the rate limiter will then ramp between 0 and 100%. With the machine unloaded (“0”), a ramp begins increasing the selector output. Although the ramp continues to 100%, the output of the signal selector will ramp only until it reaches the adjusted load demand signal. When the logic is switched to unload “0”, the rate limiter will begin ramping from 100% but will not override the load demand signal until it ramps below the current value of that signal.

The signal selector also provides a third input, input C, which can be used to implement a high current override on motor driven compressors. This high current override would reduce the compressor load as required to prevent overloading the motor.

The auto/manual A/M switch gives the operator the option of adjusting the compressor driver manually.
This is particularly useful during compressor startup operations. In auto, the adjusted load demand signal is passed through the A/M function block to the compressor driver, and the manual value tracks that signal for bumpless transfer to manual. In manual, however, it is not possible to force the total demand signal to track the manual output for bumpless transfer back to auto. Therefore, the proportional-only controller PD is used to automate the alignment procedure that is necessary for bumpless transfer to auto.

The PD controller is configured with its setpoint and manual reset parameter set at 0% and its proportional gain set at 1.00. In auto, its output will track the signal at input P. In manual, the reset component of the PD controller will track the feedback signal, the manual output, at input F. This provides bumpless transfer to auto, after which the reset component will return to 0% at a rate determined by the reset time lag parameter (MR TLAG). As the reset component returns to 0, the output of the PD controller will gradually realign itself with the signal at input P. Note that the manual reset tracking feature of the PD function block must be disabled (MR TRCK set to NO) for this to occur.

The output of the compressor master goes to the compressor driver to manipulate the load and also to the pressure controller to provide load signal feedback to the total load calculation. The low limit LMT1 is used to set a threshold value for the load calculation. This recognizes the fact that some minimum loading of the compressor will be necessary to overcome the backpressure on the check valve and to begin supplying flow to the header. The low limit will prevent any change to the load calculation until the compressor load exceeds the threshold value.

Applications

The control strategy described here can also be applied to other energy supply systems that operate in parallel, such as:
- Boilers
- Pumps
- Heat exchangers
- Pulp refiners

Application Support

User manuals for controllers and transmitters, addresses of Siemens sales representatives, and more application data sheets can be found at www.usa.siemens.com/ia. To reach the process controller page, click Process Instrumentation and then Process Controllers and Recorders. To select the type of assistance desired, click Support (in the right-hand column). See AD353-138 for a list of Application Data sheets.

The configuration(s) shown in this publication were created in Siemens i|config™ Graphical Configuration Utility. Those with CF353 in parenthesis in the Figure title are available using the above navigation, then click Software Downloads > 353 Parallel Compressor Control (Reference AD353-123).

The configuration(s) can be created and run in a:
- Model 353 Process Automation Controller
- Model 353R Rack Mount Process Automation Controller

Figure 4 Compressor Master Configuration (CF353-123CM)
- i|pac™ Internet Control System*
- Model 352Plus™ Single-Loop Digital Controller*
  * Discontinued model

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