Vinai Misra, Woodward, Inc., USA, outlines the role of load sharing to prevent conflict between parallel controllers.

Roughly 1500 gas compressor stations are located throughout North America, with many of these stations utilizing multiple compressor sets in parallel for capacity and redundancy reasons. The controllers for these parallel compressors are often tasked to control a common process variable such as suction or discharge pipeline pressure. However, if these controllers are not designed to work together, they will independently try to control the process variable, resulting in each controller ‘fighting’ with the other controllers. This fight causes overall unstable and poor compressor station performance.

In these types of parallel compressor applications where multiple controllers are tasked to control the same process variable, each controller acts independently and tries to control the process variable, not knowing that
Another controller is trying to do the same thing. This violates a fundamental control axiom; a process variable can only be controlled by one thing at a time. The controller may be influenced by other variables or may relinquish control to another controller, but that one-to-one correspondence between the controller and the controlled variable must be maintained. Otherwise the various controllers will ‘fight’ each other for control and chaos can ensue.

“This simple concept can easily be overlooked when trying to accommodate all the possible interactions surrounding a complex control system,” says Rich Kamphaus, Global Sales Director for steam turbine and compressor markets at Woodward. “Some means must be employed to assure that multiple controllers act in concert with each other. This is best accomplished by allowing each compressor controller to communicate with the other parallel controllers in the system and share their individual sensed process parameters.”

Woodward’s goal to develop a controller that enables this type of communication between multiple compressors culminated in the release of its new Vertex compressor controller. The Vertex controller was specifically designed to allow compressor trains to load each compressor proportionally – also commonly known as load sharing.

Figure 1 illustrates the need for proportional load sharing using the example of multiple compressors connected in parallel to a common suction header. In this example, the performance controller for each compressor controls the suction header pressure with a throttle valve. Each compressor’s controller tries to control its own throttle valve without knowing what the other controller is doing, resulting in each trying to control the header and fighting the other to maintain its set point.

If load sharing is not employed, one controller may drive its throttle valve fully open while the other controller drives its throttle valve fully closed – resulting in loading one steam turbine at maximum load and another steam turbine at minimum load. While the suction pressure might be maintained at the set point, the load is not shared between the two compressors.

The Vertex controller’s proportional, integral, derivative (PID) architecture provides a good example of how load sharing can be achieved among multiple controllers while jointly maintaining a common process variable – such as flow, suction pressure or discharge pressure. Its parallel load sharing algorithm works with the system performance controller to both maintain the common process variable and to balance the load between the compressors. Multiple process variables can be designated as the parameter to be shared between compressors. “Again, only one parameter can be in control at a time.” Kamphaus explains. For the parallel load sharing application, the load sharing core (LSC) generates a bias signal that can be applied to either the set point or the common process variable of the performance controllers.

The Vertex controller’s integrated load sharing functionality allows multiple compressor trains to work...
together to control a common suction or discharge header pressure to the desired set point, while distributing a shared parameter equally across all trains, as shown in Figure 2.

**Load sharing control logic**

The primary function of the Vertex’s parallel load sharing (LS) algorithm is to generate a bias signal for the performance controller. The LS algorithm works with the performance controller output to maintain the common process variable (suction or discharge header pressure) and to balance the load – typically Woodward surge process variable (WSPV) – between the compressors.

A block diagram of this implementation is shown in Figure 3.

In this example, a set of parallel trains (only the first train is shown) control a common discharge header pressure. The shared parameter is the flow through each compressor. The LSC using the LS algorithm compares the flow through the first train with the flow through the other trains. The difference between the first train’s flow and the average flow is used to generate the bias signal. The bias signal adds to the compressor’s set point (SP) and compares to the measured process variable (PV). The LS PID controller responds to the bias such that the flow through the first train moves toward the average flow through all trains. The bias signal is applied to the set point instead of the process variable.

The LSC will change the sign of the bias signal based on application to the PV or the SP. In addition to the shared parameter, the position of the anti-surge valve can also affect the bias calculation in compressor applications. As shown in Figure 5, if distance from surge (WSPV) is the shared parameter, all trains will reach the surge control line at the same time. Distance from surge will be fixed at the surge control line and will no longer be a valid shared parameter. The anti-surge valve position of each train then affects the bias calculation so that all trains open their anti-surge valves in a balanced manner.

The primary function of the parallel LS algorithm within each controller is to generate a bias signal for the LS PID that works to move the load share parameter towards the average of all trains in the load sharing group, represented by the equation: \( \text{Bias} = (\text{average WSPV} - \text{my WSPV}) \times \text{gain} \).

### Enabling load sharing

To enable load sharing, all parallel compressor controllers must comply with minimum requirements, such as the performance controller of each unit must be active and not have any faults. Figure 6 shows a list of permissives that allow the load sharing control to be enabled.

Once enabled, if the respective compressor train is the first to be enabled in the load sharing group, it immediately transitions to an active state. If the compressor train is not the first one to be activated, it will remain in a ‘joining’ state until the load share parameter (i.e. WSPV) deviation is within the ‘joining window’. While in this joining state, the load share parameter deviation ‘kick out’ function is disabled and the load share bias attempts to bring the joining Vertex into the joining window. This action assures that an added compressor will transition smoothly into load sharing with the other units.

### Disabling load sharing

Once in the load sharing mode, ‘kick out’ conditions will cause the unit to leave the load sharing mode and go back to performance control of the local variable. If auto re-join is enabled in the service menu, load sharing control is automatically re-enabled after the kick out condition has
been resolved and the permissives to enable are met within
the auto re-join delay time.

If a sensor failure is detected (flow, pressure,
temperature) at any point and backup strategies are
unreliable (last good value, default value, calculated from
other parameters, etc.), the affected compressor must
be removed from the load sharing scheme. It may remain
active for other process control such as compressor
suction or discharge pressure. However, its WSPV cannot
be accurately determined if a critical process signal is
unavailable. Similarly, disabling or inhibiting individual units
in this manner is allowed if the operator determines that
unit operation could be dangerous or unstable, or simply
unnecessary.

“If the required flow drops below the compression
capability of the compressor set, one or more of
the compressors can be taken off line,” Kamphaus adds. “You
want to be able to bring on compressors as demand
increases and take compressors offline as demand drops.”

While maximising load sharing efficiency is preferred,
traditional anti-surge protection and control along with
start-up/shutdown sequencing are always active on each
individual compressor’s recycle valves. When it is enabled,
the traditional performance control remains active and acts
as a cascaded control to influence the unit’s speed control
of the individual compressor motor/turbine drives.

**Communication setup among load sharing devices**

It is crucial for participating load sharing controllers to
exchange control state information between each other in
order for them to function smoothly. Figure 8 shows the
Vertex’s communication lines that allow load sharing to
occur with easy plug and play setup.

“Essentially, Vertex controllers communicate between
each other so they know what portion of the load each
compressor needs to carry,” Kamphaus says. “If one
compressor set is half the size of the other, you don’t split
the load in half. Instead, one has to carry more than the
other to compensate for the size inequality.”

Designed to function as a plant DCS node or as a
standalone compressor controller, the Vertex controller is
a cost-effective compressor control and protection device.
Used as a replacement for old or obsolete anti-surge
controllers, it can be configured to function like those
controllers, but with faster scan rates and improved surge
anticipation logic. It comes in one integrated package for
all control functions (anti-surge control loop 1, anti-surge
control loop 2 and performance control). Also, for load
sharing function, there is no need for additional master
controller hardware.

The communication information shared between each
controller for load sharing purpose is selectable, and is
performed via a simplex communication network.

Packaged in an industrially hardened enclosure, the
Vertex control is designed to be mounted within a system
control panel located in a plant control room or next to
the compressor. The control’s user-friendly front panel
serves as both a programming station and operator control
panel. It allows plant engineers with password authority
to access and program the unit to the specific plant’s
requirements. It allows operators to easily start/stop
the compressor and enable/disable any control mode.
The Vertex’s 8 in. graphical display allows operators to
view actual and set point values from the same screen,
simplifying compressor operation.