Tuning Anti-surge Controllers

This document discusses the tuning of anti-surge controllers on centrifugal compressors, most of which are designed around standard proportional-integral controller algorithms, possibly assisted by various vendor-specific techniques to ensure that the recycle valve opens when needed. Being a PI (or PID) controller, its tuning is actually no more difficult than any other process controller and, as long as you are confident with your normal tuning software or methodology, there is no reason why the same can't be used to tune up an anti-surge controller. Needless to say, extreme care has to be taken when testing the tuning so that the compressor is not accidentally pushed into surge, potentially with disastrous results.

There are several things I check before starting work on the controller:

- The safety features provided when the controller is in manual mode.
- The performance of the recycle valve.
- The implementation of the PI or PID algorithm.
- Any computation needed to generate the process variable.

Let's take a look at each of these items.

Safety Features in Manual

If you intend using open-loop step response techniques to tune the anti-surge controller, it is helpful to know that the controller will take over if something causes the operating point to head towards surge. For example, if the manual override parameter MOR is disabled (as is normally the case) on a CCC controller, taking the compressor too close to the configured surge line will cause the controller to switch back to automatic and to step open the recycle valve. Although this will save the compressor from surge, it is also worth bearing in mind that the sudden movement of the recycle valve may have an adverse impact on the remaining gas system! So it's a good idea to check in the user guide or chat to the vendor to make sure that any such features are available, enabled and working correctly.

Recycle Valve

As with any controller, the performance of the control valve is critical to the correct and stable operation of the loop. This is even more important for an anti-surge controller since the recycle valve plays an important role in the integrity of the compressor, so from both a control and an asset protection viewpoint it is important to check that the valve is operating as intended. The trend display in Figure 1 has been taken from one of my other articles and shows the compressor's suction flow (blue line) and the command to the valve (magenta line). As the flow drops off, the valve is commanded further and further open to keep the compressor away from the surge line. Clearly, the flow is not responding. In fact, the command has reached about 15% before the flow eventually starts increasing and it is only when the controller kicks open the valve between 8 and 9 seconds that surge conditions are eventually prevented.

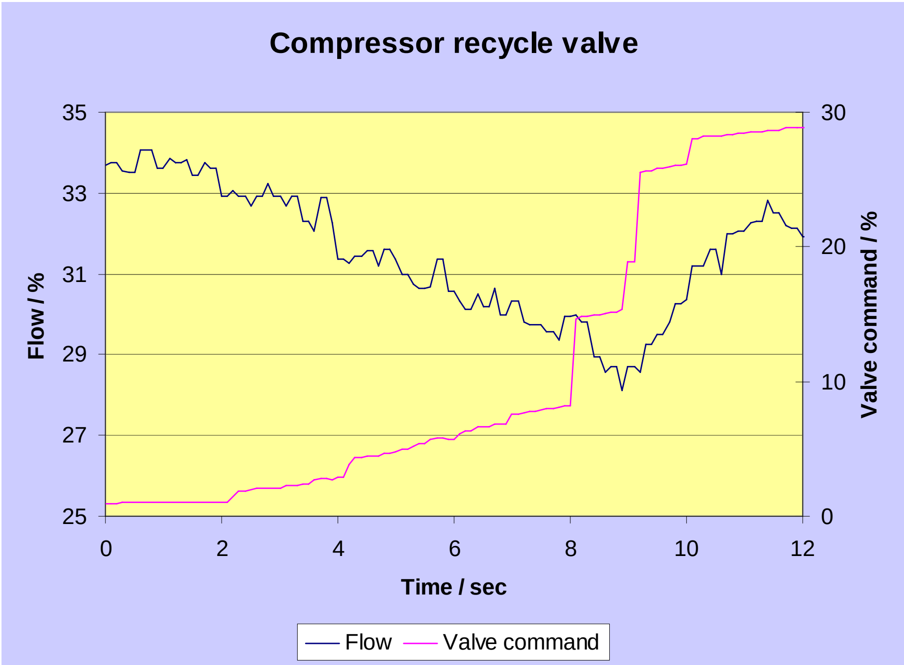

Figure 1: Valve not lifting from seat

The behavior of this valve was extreme, but by no means unusual: I also found a newly installed recycle valve actually working the wrong way around i.e. it would have closed completely during startup definitely resulting in compressor surge. So it is always worth testing the recycle valve before starting off on a tuning exercise, even if it is just a case of standing by the valve for a few minutes or carefully observing the control system trend displays for any unusual behavior. Generally, I try to find out when the valve lifts off its seat and how the valve behaves in response to small 2-3% changes in the command signal. Bad signs are hunting, stiction, hysteresis and delayed lifting, all of which will make control much more difficult and increase the risks of surging the machine. These tests are easy to do with the compressor offline, but with care can also be checked with the machine running.

Control Algorithm

I was fault-finding on a poorly performing gas compressor and noticed the tuning parameters displayed on the operator console showed a gain of 1.95, an integral of 3 repeats per minute and a derivative of 6 seconds. Digging into the code, the parameters were actually scaled as a gain of 0.195, an integral of 0.3 repeats per seconds (18 repeats per minute) and a derivative of 0.6 seconds. Without having checked the code, I might have calculated new tuning parameters and typed them in at the operator console not realizing that the parameters would then be rescaled to something completely different and totally unsuitable.

Similarly, when commissioning a new gas compressor, the flow signal to the anti-surge controller was scaled 0-150 psi rather than the expected 0-100%. Tuning parameters are supposed to be based on normalized input and output signals i.e. the input to a flow controller should not be scaled 0-150 psi but 0-100% of range, so that the controller gain is in units of % output per % input rather than % output per psi input. Similarly, the output should also be 0-100% (but then this is normally the case). This fact is occasionally misunderstood by the software programmer. If the controller has not been implemented correctly and cannot be corrected onsite, it is actually a simple matter to adjust the gain to compensate for the extra gain term inadvertently included in the controller, but it helps not to have to!

So the moral is to check the implementation of the controller before changing the parameters.

Process Variable

There are several methods of tuning a controller, but many are based on analyzing the response of the process variable to a step change of the valve while in open loop, manual control. The process variable of an anti-surge controller may be as simple as the input from an orifice plate or may be a more complicated algorithm utilizing several variables e.g. the flow, the suction and discharge pressures and the suction and discharge temperatures. Find out exactly what the controller is using as the process variable. This is usually defined in the user manual.

If the process variable is generated as a function of several process measurements, all these measurements must be collected during the step test and the values used to generate the process variable. I use an eight channel Dataq data acquisition unit to gather process data, so I've got sufficient channels for even the more complicated algorithms. I then export the data to Microsoft Excel to convert into the process variable and then imported into U-Tune for response analysis and parameter identification.

The Step Tests

First of all, keep a careful record of the existing tuning parameters and any other values which are likely to be changed.

If possible, increase the safety margin of the controller before starting the tests as this will reduce the likelihood of inadvertently pushing the compressor into surge. Since the controller will be running under manual control, this of course is referring to the safety features mentioned in the 'Safety Features in Manual' section e.g. the location of the CCC Recycle Trip line. It is usually possible to monitor the proximity to surge during the test: CCC controllers have a DEV display which should be kept positive throughout.

The step test must be performed with the controller in manual and with the valve off its seat, preferably somewhere between 15-85% open. Bear in mind that the compressor will be on recycle throughout the test, so make sure that the remaining process is able to cope. The first valve step will probably be in the open direction so as to move the compressor further from surge. If the response is unknown, start with small valve movements, even down to 1-2% and then increase them if possible for the real tests.

One important consideration when operating in recycle is that the gas may thin out due to loss of the heavier components. The surge line of the lower molecular weight gas may be rather different to the normal gas and can risk inadvertent surges. Therefore, it is best to ensure that some amount of new gas is always being fed through the compressor.

Figure 2 shows a typical series of step tests where the lower trend is the command to the recycle valve and the upper trend is the process variable in this case calculated from the flow, suction and discharge pressures and temperatures. The occasional 'blips' on the valve command is noise due to radio interference: one of the operators was communicating with the control room following each step test. The response of the process variable is quite typical of most anti-surge controller step tests with a short time delay and a lag in the order of 5-10 seconds.

When finished with the tests, don't forget to put the controller back to automatic and to set the safety margin back to normal while analyzing the results.

To test the new tuning parameters, I usually operate the compressor with some recycle and as much safety margin as I can reasonably get away with. I check first that the parameters allow the controller to remain on the setpoint without obviously increasing oscillations or the like. If something looks wrong, change the values back and think again.

The ultimate test is to introduce a disturbance to the compressor such as cutting back the suction throttle valve slightly or changing the turbine speed if it's a variable speed machine. Check that the recycle valve opens without any significant undershoot of the setpoint.

Some anti-surge controllers have a non-volatile memory into which the tuning parameters have to be stored in case of power failure. Check the user manual to see if this is the case and if so make sure the new parameters are saved away.

Footnote

As with all my control engineering articles, this article is not aimed at complete beginners. If you don't understand the relevance of the above guidelines, it's best to pay someone to do the job for you. If possible, watch how they approach the task and learn from their experience.

Contek Systems Ltd

Contek is located in Aberdeen, UK and was formed in 2002 to provide my specialist process control services to the offshore and onshore oil & gas industries.

Based on a broad practical and theoretical control engineering background, Contek is also the developer of control and mathematical applications for use on Microsoft® Windows. Please see my other control engineering articles.

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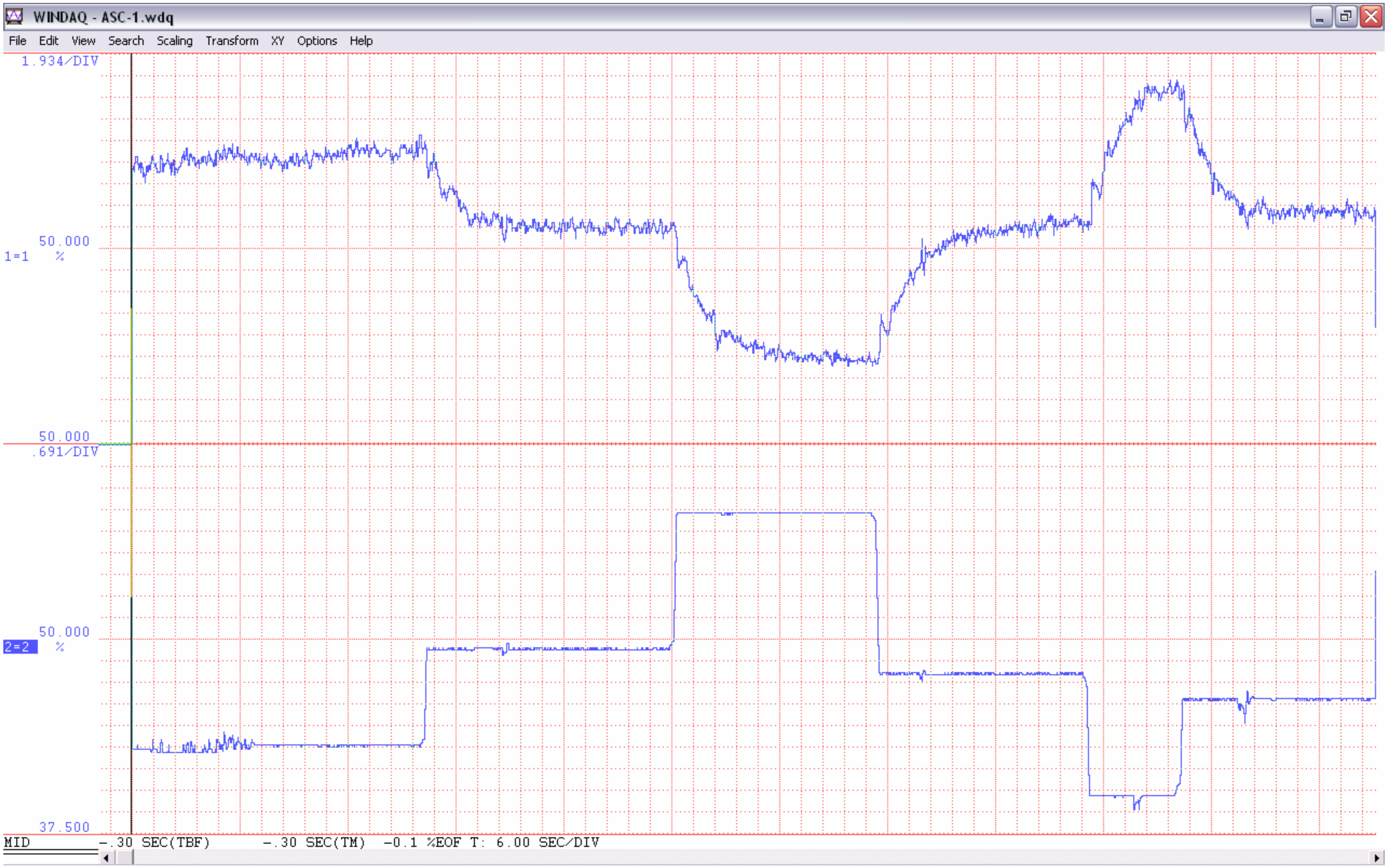

Figure 2. Step test result of a CCC controller (mode 65)