Interaction Detection Using Oscillation Analysis

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Abstract

A method for automatic detection of cyclical variability in process plants is discussed. The method is applied to solve interactions between a Depropanizer, Debutanizer, and Boiler operation.

Summary

Interacting oscillatory loops can cause significant cost, quality, and production losses to process businesses. Being able to detect and eliminate the sources of interactions can really help process plants. This paper presents a detailed method of finding the root-cause of plant-wide or unit-wide oscillations, by using oscillation periods and harmonics of each of the participating loops in the unit or plant.

The method involves looking at the process variable data for all loops that are participating in the unit operation or plant with the oscillation interactions. The first three oscillation harmonics for each control loop must be sorted and used since sometimes the dominant harmonic may not show the common oscillation. Rather, it may be present in the secondary or tertiary oscillation harmonic. Thus sorting a list of all harmonics will naturally group all those loops that are oscillating near the common or problem oscillation harmonic. Viewing all the loops grouped near the common problem harmonic allows for systematic examination, which leads to identifying the root cause.

Further examination of oscillation diagnosis can help to quickly point to the loop that is the root cause. For example, if out of the group of loops that are oscillating, one is diagnosed with stiction or hysteresis, this is a very likely candidate for the root-cause of the problem.

Background

Using process control technology to raise profits and improve operations is hardly a new concept. Over the past 3 decades many tools have been used effectively to improve profits and operations. These include Advanced control and optimization, advanced planning and scheduling, data mining and analysis to name a few. The focus of this paper is to show how the root cause of process control interactions can be determined using a new class of diagnostic tools. These diagnostic tools are part of a larger solution for Process Supervision. The Process Supervision tool will be demonstrated on some real client data to demonstrate the power and benefits of the tool. The sample data is from a large gas processing facility.

Problem Description

In many processing industries there is a significant amount of product recycle and energy integration which forms the basis for strong process interactions. The overhead condenser on a distillation tower may be the evaporator for a refrigeration system and the tower reboiler may be the condenser for the same refrigeration system. Moreover, the same refrigeration system may be connected to several distillation towers in a similar fashion.

In cases such as these, which are not uncommon, the interaction of the control system to disturbances can be significant. A disturbance in one part of the system can result in prolonged cycling in several or all parts of the system. This cycling contributes to the variability of key product specifications.

A consequence of this variability is to keep the operation point further away from the specification limit by an amount proportional to the variability. The sources of this variability can be many. They include external upsets, poorly tuned controllers, valve problems, process equipment problems, and operational policy. This paper addresses the use of a Performance Supervisor to find process interaction sources. The presence of variability and the profit opportunity associated with removing it is summarized with Figure 1.

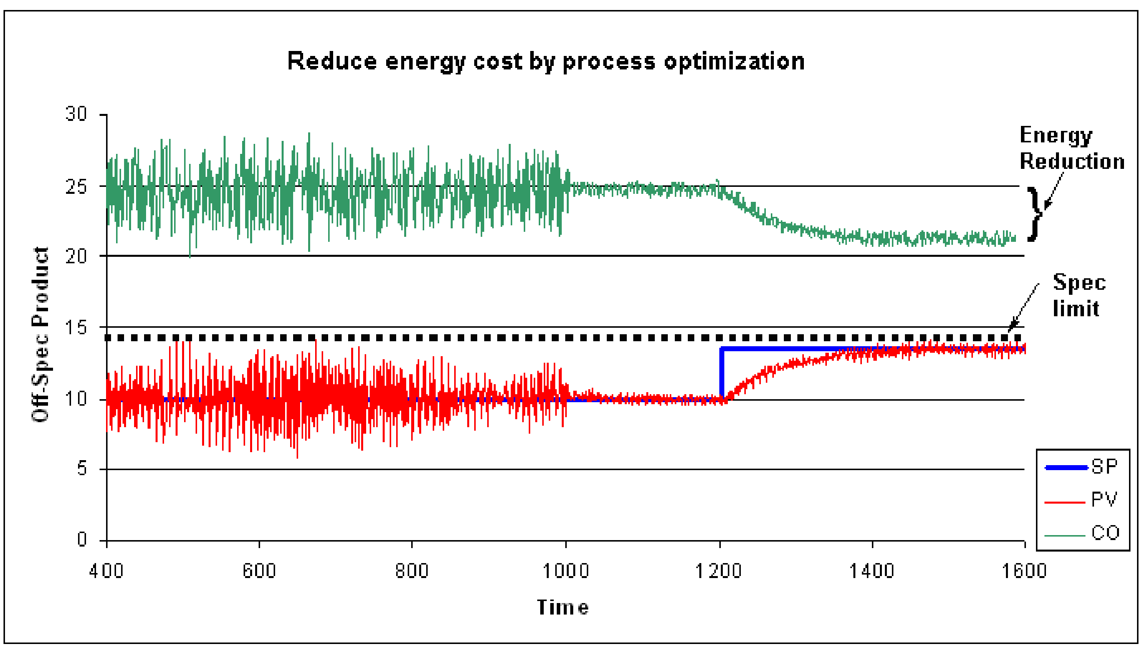

Figure 1

In Figure1 the red line represents the levels of off-spec(off-specification) product being re-blended into one of the key product streams. On the left side of the graph the variability of the red line is high. In about the middle section of the red line, at time 1000, the variability is reduced due to removal of interactions in the process. Once this is done the blue line for the setpoint can be moved closer to the specification by an amount proportional to the reduction in the variability.

On the left side of the plot the setpoint must be kept away from the spec limit so that the spec is not violated. After the interactions are removed the setpoint is raised closer to the spec limit due to a reduction in the variability. The green line in figure 1 is the flow of steam to the reboiler of the distillation tower. As soon as the setpoint is raised a measurable reduction in energy is observed. This reduction in energy is a direct contribution to profit improvement.

Performance Supervisor Software

Several suppliers have released software packages over the past 4-5 years which are aimed at performing control loop analysis based on normal operating data. These packages reside in a server class PC (personal computer). They read normal operating data to perform diagnostics about the health and performance of the control system. In addition to calculating controller health and diagnostics calculations a few of these applications also make determinations about the dominant frequency components found in the operating data. These techniques employ spectral analysis, relational databases and proprietary algorithms to present a clear and concise picture of interactions present in a process.

One of the leading suppliers of PC based control loop monitoring software is ExperTune with their PlantTriage® Performance Supervision product. The package resides in a PC server class machine and connects to a variety of DCS (Distributed Control System) and PLC (Programmable Logic Controller) systems via OPC (OLE for Process Control). OPCHDA (OPC Historical data Access) is supported as well. OPCHDA is a relatively new spec permitting connectivity to historians such as PI, IP21, and others. OPC is a good choice since it is supported by a wide variety of suppliers. Once connected, the package reads data from the underlying system and performs a variety of performance and diagnostic assessments. Many other indices are calculated but the focus of this paper is to show how the use of the spectral analysis can be used to solve very subtle interaction problems.

The control loop supervision software utilizes normal operating data to develop control loop diagnostics. No special step tests or stroking of control valves is necessary to develop diagnostics. With the use of OPC technology, any device can be monitored including traditional 4-20 ma devices. As long as the underlying system has OPC connectivity then data can be obtained and the diagnostic calculations can be performed.

Figure 2 shows the generic connection structure from the DCS or PLC system to the performance monitor.

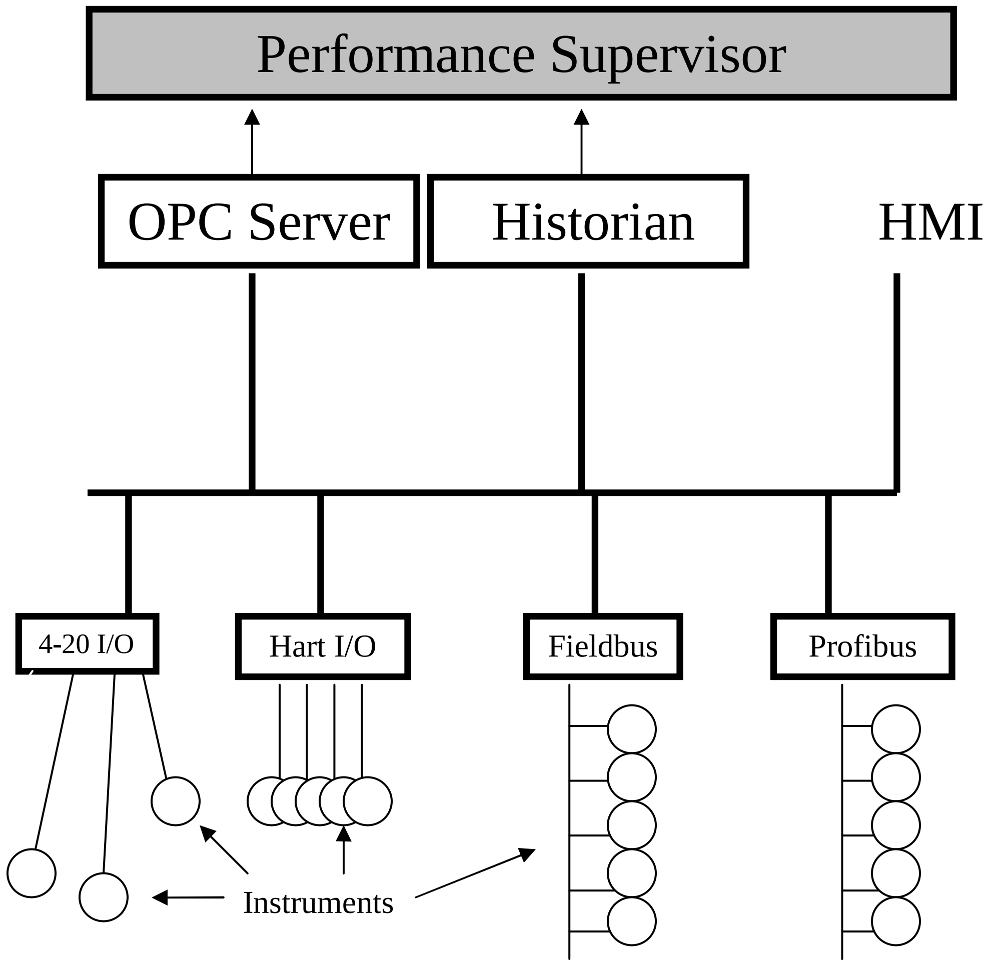

Figure 2

Performance Supervisor Applied to Distillation Towers

One week of data was taken from a set of distillation towers which were part of a large gas plant. The unit operations were a Depropanizer and a Debutanizer with associated utilities including a gas fired boiler. The Performance Supervisor analyzed the data and several important control loops were found to be oscillating but the cause was not tuning or field actuator problems according to the advanced diagnostics from the Process Supervisor system.

All the inventory controls (Level Control) were oscillating at a period of 2hr 45 min peak to peak. This was pointed out by the Performance Supervisor. The Performance Supervisor system first performs a spectral analysis on all the data. It then applies proprietary algorithms to remove the insignificant frequency components and lastly it arranges this information in a relational database so that sorting can be performed to show all the similar frequencies.

Figure 3 shows a trend of all the level controls highlighted by the performance monitor. The four level control representing the overhead and bottoms of the Depropanizer and

Debutanizer respectively are shown. The fifth line on this trend is the O_2 control for the gas fired boiler feeding steam to both distillation towers. The Performance Supervisor System showed that the O_2 stack control system was experiencing a significant upset every 2 hrs and 45 minutes as well. Further investigation showed that the sequence of process interaction as follows.

Fuel Gas composition Upset → Upset Combustion Stack Gas Composition→In Turn manipulated Firing Control→In Turn upset the steam pressure to the reboilers of the towers→ In Turn upset the Inventory and quality control of the Towers.

Further investigation of the source of the disturbance to the stack O2 controls revealed that a vessel elsewhere in the process was pressuring up and relieving into the fuel gas system!!

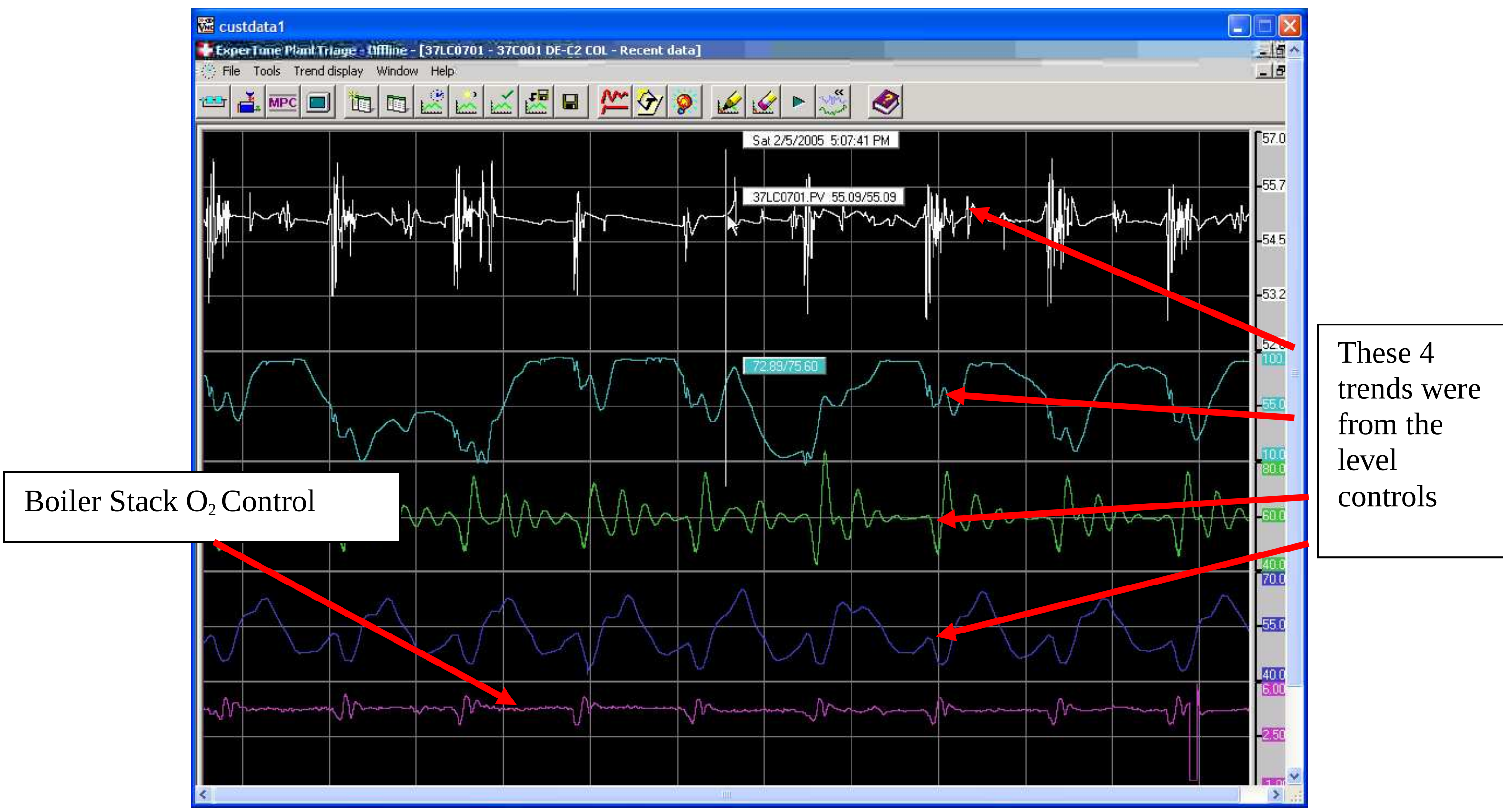

Figure 3

Results

By removing the source of disturbance of the fuel gas composition the entire process ran much more stable. This includes both the inventory control and the quality control. For those readers familiar with hydrocarbon processing and distillation in particular the inventory control and the quality control are a source of interaction which prevents moving the setpoints closer to the specification limits. For each 1 % closer to the specification limit an increase in profit of 1-3% is possible.

Conclusions

Interaction in process plant is a significant source of lost profit. Finding the root cause of the interaction is a very time consuming process which often fails to produce results since the proper tools are not available. A modern Process Supervision system which has the algorithms and presentation layer can quickly trap the most subtle problems. The sources of interaction are often found in unlikely places as the cited example pointed out. By using the Process Supervision system key process interactions can be quickly understood and root causes pinpointed for fast resolution.

References

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