What loops can tell us

Plant performance monitoring with the aid of loop control

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Large industrial facilities such as power plants consist of a multitude of components and sub-processes that all work together to form the overall process flawlessly and as optimally as possible. This is made possible with hundreds, sometimes thousands of control loops, which run the plant the way the owner intends it to. The plant can only run optimally if all control loops are perfectly aligned with each other. So far, this alignment has proven too time-consuming and costly in practice, because each modification and each upgrade as well as the aging of plant components require constant re-optimizing. For that reason, almost all plants operate at a sub-optimal level. Together with STEAG, ABB has now developed processes of control performance monitoring for power plants that allow continuous post-monitoring so that plants can operate at their optimum level.

When we talk about "plant performance monitoring", we refer to the performance control of a production plant. Performance control is determined by many factors. In addition to the natural aging of plant components, interruptions and faulty adjustments, such as poorly aligned valves, play a role. Process-related modifications always lead to repercussions for the entire behavior of a plant, which hadn't been originally planned. Time and cost factors would lead operators to temporarily run the plant below its capacity following such modifications. The complex task of analyzing causes can be daunting, since the positive identification of a sub-optimal function requires the interpretation of vast amounts of data.

Large facilities like power plants often have between several hundred and several thousand control loops. Only a limited number of them usually receives special attention, because their malfunctions directly impact operations. The majority of control loops, on the other hand, more or less works in the background, as malfunctions on their part don't have an immediate impact on the performance of the plant. However, they still play a significant role when it comes to the optimal performance of the plant as a whole.

Control loops are essentially the nerves of a facility, and based on their "state of being", conclusions can drawn on the condition of a plant.

The relationship between the "wellbeing", meaning the performance, of a plant and a control loop becomes evident if we keep in mind the function that a control loop has within a plant.

The control deviation – a measurement for the deviation of the process variable to be controlled (controlled variable) and of the required target objective (set point) – is the initiator of an energy or mass flow. In addition to the controlled variable and the set point, a control loop also has an output variable. That's the variable that controls the energy or mass flow based on the control specifications that are applied. These are used to manipulate a plant component so that the controlled variable is realigned with the set point. Inducing this realignment and especially maintaining it under the impact of unforeseen interruptions are the primary purposes of a control loop.

Control loop signal analysis

Control loops are essentially the nerves of a facility. Based on their "state of being", we can draw conclusions on the condition of a plant. Since the control loops are connected to each other through the plant components, a malfunction in one component will have an effect on another, possibly remote, component of the plant. Although attempts are made to minimize this mutual impact by means of process-related decoupling, such as buffer memory, it can't be eliminated entirely.

All three control loop variables (set point, controlled and output variable) together are usually enough to assess the functionality of a control loop and thus the appertaining plant component. Usually the functionality of the control loop is tested by analyzing set point disturbances during activation. Keeping in mind the multitude of controls within a plant, we can easily understand why this kind of quality control is used less and less during running operation, given the costs and lack of time.

A proven concept

The concept of applying the state of control loops as an indicator of the condition of a plant was intensively researched during the 1980s. One focus point was the paper industry. The main idea was to get way from having to analyze every single control loop, as in the classic disturbance method mentioned earlier. There had to be a way to use the signal patterns during running operation to obtain information about the quality of the control loops and to draw conclusions about the performance of the plant as a whole.

Another issue was to eliminate a problem caused by the increasing lack of qualified personnel. Whereas an engineer used to be responsible for maybe a dozen control loops, today he or she often has to deal with several hundred control loops. Time-consuming individual monitoring is therefore no longer an option.

Using terms like Control Loop Monitoring, Control Loop Performance Assessment, Loop Auditing and Control Performance Monitoring (CPM), engineers have developed methods that are similar in nature. Based on a multitude of statistical variables and their interconnections, they provide a quantitative analysis of an individual control loop [1].

At this point, these methods have been tested in practice and are functionally sound. They appeal not only to the paper industry but also increasingly to the chemical industry. This comes as no surprise if we bear in mind the amount of money the chemical industry has to invest in one control loop: Factoring in the measuring system, the actuator, the controls and the signal transfer, it can easily range from 5,000 to 100,000 EUR [2]. In this context, possible surcharges of 100 to 200 EUR per control loop for the introduction of CPM are actually less significant.

When it comes to plant performance monitoring, there's another argument for the use of CPM: The aforementioned quality problems associated with setting and dimensioning the controls. According to estimates, roughly one third of control loops works well and another third only works usefully on average. About 30 percent of controls are mostly operated manually, because their control performance is inadequate.

Factbox STEAG GmbH

STEAG GmbH, a subsidiary of RAG, is the fifth largest power producer in Germany. Its core business is electricity generation in hard-coal-fired power plants.

- Total installed electric capacity: 9,000 MW
- Revenues in 2006: € 2.73 billion
- Employees: almost 5,000

http://www.steag.de (June 2007)

… Why not use It for power plants?
The ABB-developed software tool Optimize[IT] Loop Performance Manager (LPM) includes algorithms that analyze control loop signals online and provide an up-to-date, virtual control analysis. In other words, a separate test of the individual functions based on the set point/disturbance method is now obsolete in this case: The behavior of the plant under normal operating conditions already provides enough information about the quality of the controls.

The process control team at the thermal power plant STEAG in Lünen, Germany (see title picture), was very keen on trying out the ABB process for performance analysis at his power plant. “We have enormously wide-ranging data material about our controls that can be used for testing the power plant compatibility of the CPM process”, was their challenging statement.

In this respect, an important asset was the long-standing, positive cooperation of STEAG with ABB: On the one hand, the power plant already had an ABB process control system, on the other hand, the ABB Service had been maintaining the power plant for years – basic conditions that came in handy for the pilot test. What was particularly promising was the synergy between the personnel of the power plant, the longstanding service experience of ABB and the know-how of the ABB scientists for developing a new approach to condition performance monitoring in the sector of power plants.

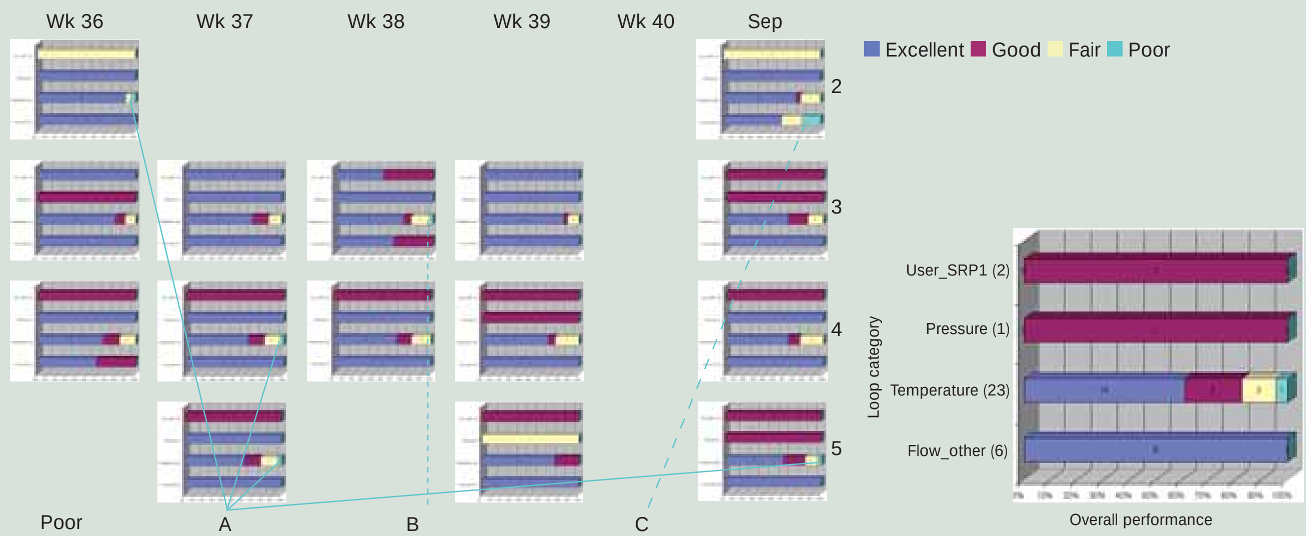
The test scenario chosen for the power plant was the induction of air into the combustion chamber. This is an area known as a possible source for malfunctions because of the large quantities of air, the long air ways and scattered mills. The engineers deliberately chose a restricted area of the plant. That way, they were able to concentrate on peculiarities unique to power plants and to make sure that the outcome could be verified using traditional methods as well. To be able to analyze archived data too, the algorithms, partly developed at the ABB research center, were packed into a software frame that made it possible to access exported archive data and to display the results of the analysis in EXCEL®. This approach rendered a solution that was independent of process control systems 1.

CPM readily allows both sporadic and cyclical control loop analyses at large intervals thereby eliminating the need to install a special analysis PC.

Initial applications on site quickly revealed the differences between power plants and paper factories. Whereas today’s thermal power plants, including those designated for basic operations, can certainly operate at full load one time and at light load the next on any given day, the production of paper takes place under relatively consistent basic conditions. So the working conditions of a control differ accordingly in a power plant.

It soon became evident that not all required data was available in one archive. That’s because data analyzes

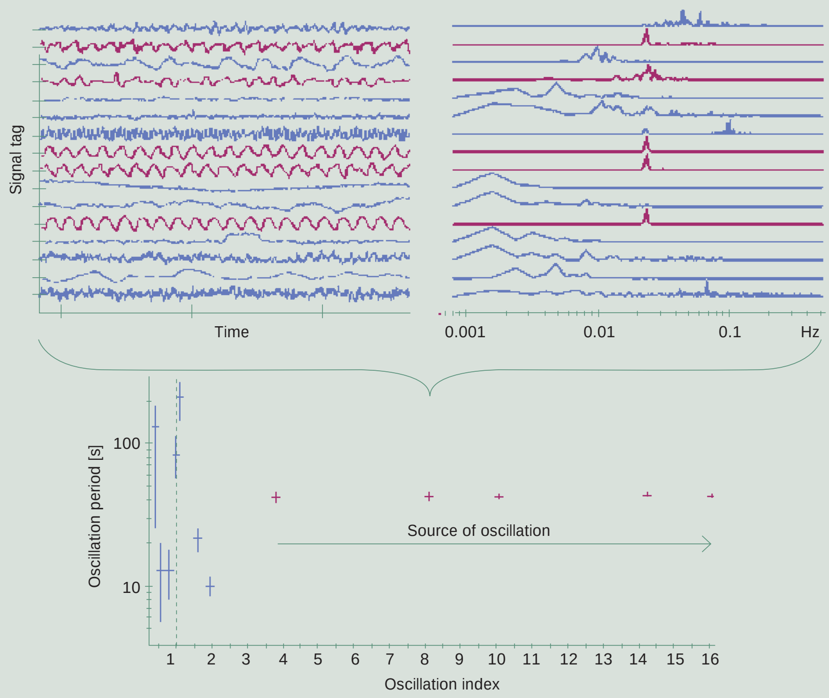
1 Result of a control loop signal analysis spanning several weeks.



The grey part is the summary of a loop performance analysis over week 36 to 39 in September of 2005. The blocks of bar graph below the week numbers and the month inform about qualitative loop performances (Excellent, Good, Fair, Poor) in that week / month, represented by special colors. There are up to four bar graph blocks in a date column as there were different load cases (eg, low load, middle load), represented by number 2,…, 5 at the right side of the picture, in September – the assessment is not an over all assessment, each load case is assessed separately.

The letters A, B and C represents coal-mill loops which are of poor quality. That is a strong indication for a real problem with that loops and an indication to have a look at the coal-mill control.
The loop assessments are clustered. All loops of a loop category (e.g. temperature control loops) are collected together. Such an assessment overview is zoomed below to show this more accurate. The numbers in the bars correspond to the count of (Excellent-, Good-, Fair-, Poor-) loops of a category. For example, 14 of all (24) temperature control loops are of excellent quality and only one is of poor quality.

2 Procedure of a PDA



Signals of suspicious control loops are collected and sent to the PDA tool via an EXCEL file. An oscillation analysis show which signals have similar oscillations. These signals are clustered. All signals of such a cluster are highlighted in red (upper left: Time series of investigated signals, upper right: Signal spectra – the impulse at the same frequency point is an indication for similar oscillations).

The calculation of the oscillation index versus the oscillation period of a signal (below) informs about the main source of an oscillation. The higher the oscillation index the higher is the probability that the signal is the source of the oscillation of a cluster of signals. The vertical line of the cross of an oscillation index is a measure of the variance of the oscillation period and therefore a value of oscillation symmetry.

based on mathematics also require variables that are often neglected in purely empirical analyzes based on curves.

However, the close cooperation between the highly motivated staff of the power plant, the ABB Service and ABB Research made it very easy to come up with solutions. While the staff of the power plant went about completing the archive data, the ABB Service paved the way to the most efficient data export. This involved vast quantities of data that were analyzed in the laboratories of the ABB Research Center at Ladenburg. That was also the site where the necessary supplements to the analytical algorithms were developed.

Accessing vast amounts of control loop data from a power plant made it desirable to apply a process that hitherto had not been planned for use in power plants. Known by the term Plant-wide Disturbance Analysis (PDA), it involves a method for the analysis of signal data that differs from traditional CPM methods [3]. PDA allows for better analyses of the coupling between plant components. It's also a more reliable way of tracing back the cause of an interruption **2**.

The evaluation and discussion of the analysis results of about three dozens of control loops – in addition to the distribution of air, the steam-overheating control was later added to the monitoring process – across a period of about one month gave captivating new insights into the analyzed plant components. Based on the control loop data, engineers were able to present the client with links that were not apparent otherwise. Some of the client's open questions were answered that way. As a result of the success of the on-line analysis, the process is now being expanded across the entire block of the power plant.

CPM for broad application

The question whether CPM can be applied to plant performance monitoring in power plants has now been answered – it can! The ABB Service portfolio has now grown to include this service as well. Not only does this additional service make work easier for the qualified staff of the power plant, it also forms the foundation for establishing a universal knowledge base for the behavior of control loops in power plants.

Furthermore, there's no need to install a special analysis PC and to incorporate it in the plant network. CPM readily allows both sporadic and cyclical control loop analyzes at large intervals. The discussion concerning the results of the analysis between the power plant staff and ABB Service substantiates the measures that have to be taken. In any case the analysis is based on well-founded data material. The joint development project with STEAG has shown once again that the combination of experts from different scientific fields can be a very successful one.

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[2] Dittmar, R., Bebar, M., Reinig, G., 2003, Control Loop Performance Monitoring – Motivation, Methoden, Anwenderwünsche, Automatisierungstechnische Praxis 45 No. 4, pp. 94–103.

[3] Horch, A., Cox, J., Bonavita, N., Peak performance – Root cause analysis of plant-wide disturbances, *ABB Review* 1/2007, pp. 24–29.