Identifying poor performers while the process is running

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ABSTRACT

Plants are continuously downsizing personnel to improve their profitability. To ensure maintenance people are working where their effort will really improve performance, a process performance monitoring system identifies clearly which loops do not perform accordingly to their goal. The performance monitor software prioritizes loops based on greatest economic gain. Maintenance and actions can now be pro-active instead of scheduled. The system identifies poor performers, oscillating loops, faulty equipment, etc. Finally, the program includes tools to detect, diagnose and quantify problems.

KEY METRICS

One of the keys to making a performance monitor is to be able to quickly set up the system with metrics that are significant to your plant. There must be a template or cookie-cutter approach for setting up your system against a benchmark.

All assessment intervals and metrics are calculated, but not all metrics are important for your plant.

This is why you need to determine which metrics are the most significant for your plant. For example, paper mills may want to use variability as a key metric, since variability throughout plant loops affects variability in their final product, whereas chemical plants may consider average error or integrated absolute error more significantly.

Variability has been a buzzword for years, but performance is a lot more than variability. The performance of a flow loop in a cascade strategy is measured differently than the performance of a level loop acting as inventory control. Most plants will feel oscillation detection is an important metric. Some may want to look at the amount of time the loop is in automatic or normal mode. Loops put in manual mode are probably not working properly.

Identifying some of the key metrics is a natural habit for most plants. The plant personnel often know the important factors affecting the product quality and downtime.

After the important key metrics are identified, templates are built around these metrics. The templates are applied to a time period appropriate for benchmarks of performance. The ideal period of time would be after every loop in the plant has been checked, optimized and tuned. However, the realistic delay for

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the time period to be settled will represent a portion of time compared with future metrics. Against these benchmarks, there are thresholds to be considered for each important metric in the plant.

These thresholds combined with the benchmarks provide a comparison of this loop with other loops in the plant. They also provide a comparison of the loop, the unit operation or the plant against previous time periods. An economic weight is then applied on each value, depending on its economic significance.

HOW TO DO IT

The software is designed to help you make the biggest impacts on your plant. It pinpoints areas that will yield the greatest economic returns. This determines which controllers in a plant are not performing well, which would benefit from re-tuning and which require maintenance. The software digests data coming from the plant and generates emails, reports and lists of loops outside predetermined performance limits. Remote access capability, loop tuning, process analysis tools, equipment analysis tools and simulation tools are essential.

The loop monitoring system should provide, on demand, the control engineers and technicians a list of loops that would make the greatest increase in profits if used optimally. Managers also need to know how the plant is doing on a historical basis.

There are many possible performance indices: variability, IAE (Integral of Absolute Error), number of set-point crossings, average error, Harris index, valve travel, time in normal mode, dominant oscillation period, etc. You can choose the ones that are important for your plant.

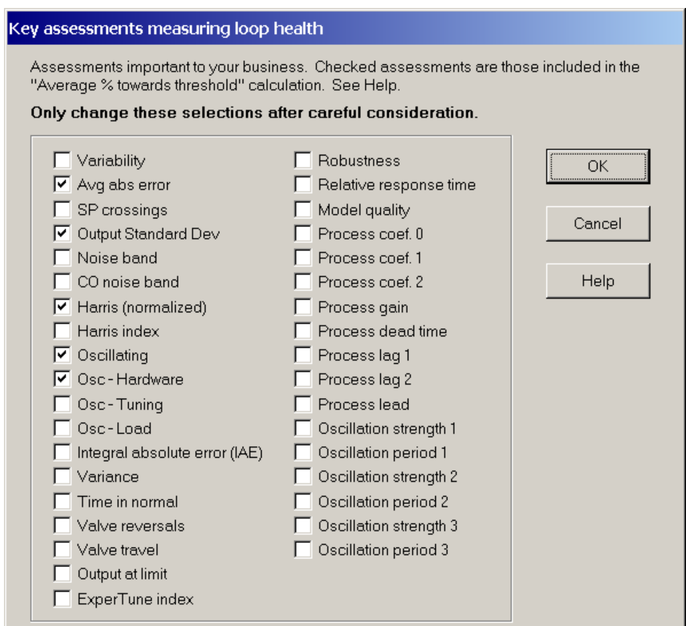

Figure. 1 Performance index

Some assessments may not be important for certain types of loops. For example, the average error on averaging level loops may not be an important indicator of their performance. The performance monitor allows specific key assessments to be removed from individual loops or categories of loops. (See figure 1.)

LOOP MONITORING REQUIRES DATA GATHERING AND STORAGE

The first step required for loop monitoring is to get the data and save it for assessments. The primary method of connecting to the process control computer is via OPC. OPC servers are available for most process control computers.

In general, the faster is the data collection, the better it is. Sample times of about 1 second are ideal. However, although personal computers and networks are extremely fast today, it happens frequently that the process control computer is relatively slow and becomes the bottleneck for getting process data quickly. Because of this limitation, each loop can be sampled at a different sample interval. This interval should be from 1 second to 1 minute. This way, the loading time on the process control computer can be balanced.

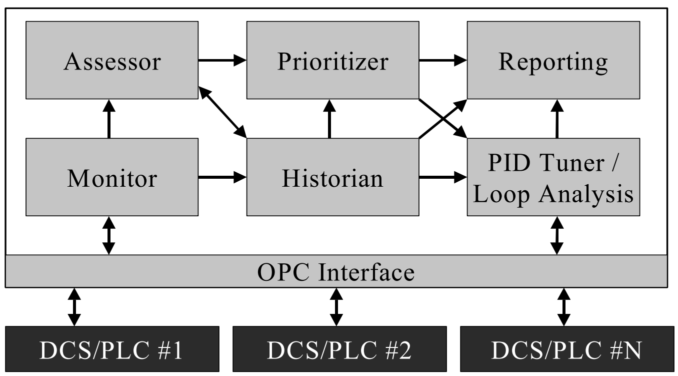

Figure. 2 System architecture

ASSESSING THE DATA

Each loop is assigned to an operation unit, the same way it is assigned to the plant. Each unit operation is assigned to an assessment interval that defines how often that unit operation performance is assessed. Assessment times can vary between 1 hour and 1 week.

It may be advantageous to set at 8 or 12 hours the assessment times in order to compare how different shift times in the day may affect the performance. One assessment every 24 hours should be appropriate.

At the assessment interval, the monitoring assessment service evaluates each loop in the unit operation. There are many evaluation points including:

- Oscillation Detection and Analysis
- Loop Robustness
- Harris index
- Settling time
- Set-point Crossings
- Normalized Integral of Absolute Error, Average Error
- Noise Band, Variability and Variance
- Valve travel, Valve reversals, Valve at limit (% time)
- Process model and quality
- Time in normal mode of operation
- Number of mode changes per shift
- Etc.

PLANT HEATH? LOOP HEALTH?

The hierarchy of performance management is:

Corporation
Site
Plant
Unit Operation
Loop
Key Performance Index (KPI) and economic significance

Against these benchmarks, there are thresholds to be considered for each important metric in the plant:

- Baselines (target or ideal value): Indicate a reference value to compare against in the future.
- Thresholds (upper or lower permissible value): Represent limits or boundaries between which the assessments would remain if the plant is running well.

These thresholds combined with the benchmarks provide a normalized index for each KPI. Since the indices are normalized, they can be aggregated to form one index for the loop. An economic weight is then applied on each value depending on its economic significance.

They also provide a comparison of the loop, the unit operation or the plant against previous time periods. For each loop, KPI are agglomerated and economic significance is determined. The result is a percentage value representing the room for improvement. The value is calculated for each assessment but averages can be obtained for any period of time.

For each KPI within each loop, values are normalized:

$$\%TowardsThreshold = 100 * \left[\frac{\text{Index} - Benchmark}{Threshold - Benchmark} \right]$$ **Equation 1**

For each loop, indices are aggregated and economically weighed:

$$\%TowardsThresholdEconomic_{Loop} = \sum_{i=1}^{n} \frac{\%TowardsThreshold_i}{n} \div EconomicSignificance$$ **Equation 2**

For each unit, an average is calculated:

$$\%TowardsThreshold_{Unit} = \sum_{j=1}^{n} \frac{\%TowardsThresholdEconomic_{Loop_j}}{n}$$ **Equation 3**

For each plant (and so on for other levels), an average is calculated:

$$\%TowardsThreshold_{Plant} = \sum_{k=1}^{n} \frac{\%TowardsThresholdEconomic_{Loop_k}}{n}$$ **Equation 4**

For each level, a number representing the performance is obtained. That number will take in account the economic weight and the KPI for that part of the process. For each number, the value represents "room for improvement". Managers, superintendents and engineers have now numbers to decide where they should use their resources.

Also, for each performance index, it is possible to calculate an average for a group of loops, a unit, a plant or any other group (for example, for all flow loops).

$$\%TowardsThreshold_{SpecificPerformanceIndex} = \sum_{k=1}^{n} \frac{\%TowardsThreshold_{SpecificPerformanceIndex\,Loop_k}}{n}$$ **Equation 5**

For example, a manager could have, as part of an automatic weekly report, the percentage of time when the valves (within a group) reach their limit.

WHICH LOOPS ARE THE BIGGEST PAYBACK IN YOUR PLANT?

Take the “Flow1” loop as an example in figure 3 (top left-end of the diagram). It has an average economic assessment of nearly 52%; it is the largest average economic assessment for all the loops shown.

The higher the average economic assessment is, the greater the negative economic impact the loop has on the bottom line of the plant.

Biggest payback loops

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Loop name	Description	Average economic assessment
Flow1	Water Tank Out Flow	51.8%
Temperature	Water Temperature	22.8%
Level	Water Tank Level	12.4%
Flow2	Cooling Water Flow	12.1%
Pressure	Water Tank Pressure	0.5%

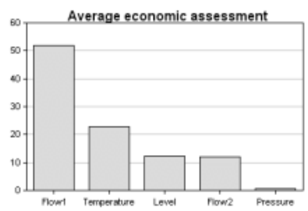

Figure. 3 Greatest economic impact on the operation

However, this represents an opportunity to engage this loop, find out why it is ill and fix the problem. It will allow you to create the greatest economic impact for the plant. The Biggest payback loops report automatically set up the triage order of loops to focus attention on.

The system then determines where the problems are coming from; diagnostics are made and possible causes are presented. Figure 4 shows a custom loop list including all the possible causes of oscillation and a suggestion of diagnosis. This list has been customized to show all the potential suggested causes of oscillation: hardware, load upsets or tuning. The first row shows our Flow1 loop, confirming that oscillation is caused by the valve: 100% of the time, it will suggest that the cause of oscillation is tuning.

My Loop List

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Loop name	Avg % to threshold	Average error	Oscillating	Osc - Hardware	Osc - Tuning	Osc - Load
Sort	Sort	Sort	Sort	Sort	Sort	Sort
Flow1	103.6	1.583	100	100	0	0
Flow2	24.4	0.9352	0	0	0	0
Level	24.78	6.762	0	0	0	0
Pressure	1.809	0.6616	0	0	0	0
Temperature	6.258	0.2215	0	0	0	0

Figure. 4 Loop List including possible diagnosis of oscillation.

PERFORM FURTHER TESTING

Once the loop has been identified as having a cycling problem that is probably caused by the valve, you can perform additional tests on the valve to pinpoint and verify the problems. By using the tools and equipment, control strategies and tuning parameters can be analyzed.

Two of the suggested tests to perform are the stiction test and the hysteresis test. Both stiction and hysteresis are problems that often affect valves, and both will cause the loop to cycle. The tests are made while the process is running and calculated values are presented. Figure 5 shows that two actions were taken based on the examination result of the Biggest payback loops report: valve was repaired, bringing the hysteresis to 1% and stiction to 0.2%.

	Found	Acceptable values	
Hysteresis	1.55 %	less than 1% from 1 % to 2% more than 3%	ideal acceptable to be checked
Gain	1.04	less than 0.5 from 0.5 to 2 more than 3	too small ideal too high
Noise	2.71 %	less than 3%	acceptable
Stiction	Stiction is less than 1.2%	less than .1% more than .1%	ideal to be checked

Figure. 5 Report of the hysteresis and stiction

Using the optimization software integrated in the process monitor, the Flow1 loop was re-tuned and so were two other loops in the unit: a level loop and a pressure loop. Flow1 was the inner loop of a cascade. The results can be seen after letting the plant rest for a day following the repair and re-tuning of the unit operation.

RESULTS OF REPAIRING BIGGEST PAYBACK LOOPS

Figure 6 now shows that the Flow1 loop is performing better the day after the repair.

Biggest payback loops

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Loop name	Description	Average economic assessment
Level	Water Tank Level	11.3%
Flow2	Cooling Water Flow	11.3%
Pressure	Water Tank Pressure	7.5%
Flow1	Water Tank Out Flow	5.7%
Temperature	Water Temperature	2.4%

Figure. 6 Biggest Payback Loops after intervention

When we look at the loop history graph as shown on figure 7, we can see how the loop has improved since the corrections were made. This graph shows the Flow1 loop previous assessments. The shading represents the overall or average percentage towards threshold for all the important assessments. This is made up of 4 assessments, as indicated by the additional lines on the graph. The oldest assessment (25 hours ago) is on the far-left end and the latest is on the far right end of the graph.

At assessments 22 and 21, the loop was tested and the assessments all increased. After this time, the valve was repaired and the loop was re-tuned. In consequence, the assessments after 21 steadily decreased. The two other lines show the oscillation measure and oscillation diagnosis. Together, they are an average of the 10 previous assessments; it takes 10 assessments to reach 0. The average error and normalized Harris index dropped immediately after repair.

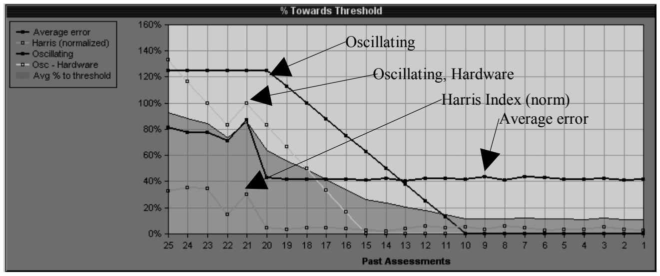

Figure. 7 Loop history graph for Flow1.

- Testing and improvements made during assessment 22 and 21. Improvements starting to show in assessment 20.

PLANT PERFORMANCE MONITORING

Finally, it is interesting to examine the plant monitoring results over a year, as shown in figure 8.

Economic Average Percent Towards Threshold

(☑ Use Economic Weighting)

Divided Up Into 1 month Windows Over the Last 12 months

Location	1 Month	2 Months Ago	3 Months Ago	4 Months Ago	5 Months Ago	6 Months Ago	7 Months Ago	8 Months Ago	9 Months Ago
Entire Plant	24.9%	35.6%	32.8%	38.9%	46.2%	52.8%	68.9%	56.2%	65.6%
TMP	22%	20%	12%	25%	10%	29.8%	28.4%	32.2%	29.5%
PM3	40%	50%	52.8%	63.9%	56.2%	35.8%	74%	58.2%	70.6%
PM8	38%	44%	42.8%	30.9%	36.2%	42.8%	55.9%	66.2%	68.6%

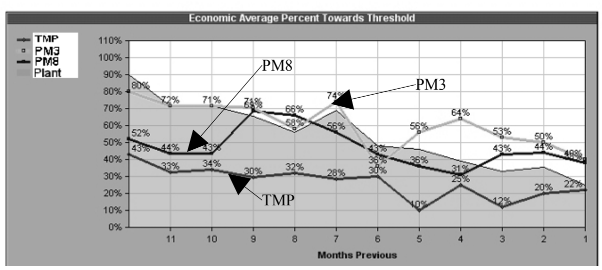

Figure. 8 Plant monitoring over a year

CONCLUSION

Very quickly, it is possible to establish a benchmark of metrics or assessments for an entire plant or a group of loops. Once established, these benchmarks and threshold settings are used as a comparison with other loops in the plant. This will direct the efforts of the plant personnel and mostly affect the operation. It also allows a comparison with time that shows, from an economic point of view, how the plant operation benefits from the work and money spent on the process monitoring system.

The process monitoring system should allow plants to prioritize their time to make the biggest economic impacts on the company bottom line.

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Michel Ruel is a registered professional engineer, university lecturer and author of several publications and books on instrumentation and control. Michel has 28 years of plant experience in several companies such as Monsanto Chemicals, Domtar Paper, Dow Corning, Shell Oil, Abitibi-Consolidated, Petro-Canada, Noranda, Degussa, Alcan, Smurfit Stone, Kruger, Pratt & Whitney and International Paper. He is experienced in solving unusual process control problems. Michel has presented process control lectures to over 4,000 engineers and technicians in many countries. He translates his experience in a very user-friendly presentation and teaching style, in French and English. Michel is president of TOP Control Inc. He is an ISA Fellow member.