Room for improvement

Identifying limiting factors in process industries

Andreas Kroll, Frank Simon, Gordon Cheever, Tomi Pilbacka, David Stanier

Processing plant operators are under constant pressure to increase profitability. An important first step to securing competitiveness is to understand how an individual plant compares with that run by the most efficient operating authorities. Despite the variation between different plants, this can be done using industrially accepted performance indicators.

When plant improvement projects are initiated, an important challenge is to identify opportunities likely to yield the highest improvement impact. A possible selection criterion is to choose an area based on the assessor's personal experience, and carry out an initial survey. Typically this would be followed by a focused techno-economic analysis to estimate the improvement potential. Often, a performance baseline is established in order to measure the effect of the improvement projects.

The principle of this top-down procedure is to search for improvements across disciplines, functions and components.

This article presents an alternative approach that broadly screens automation systems and working practices in the process industry for improvement potential[1)]. The screening is functionally limited to the assessment of:

- on-line process automation and information systems
- instrumentation and analytical devices, motors and drives
- motors and drives which will be referred to as „I&C" in the following

The newly developed, computer supported, systematic procedure enables the assessor to screen a plant in just a few days. Firstly, a complete technical evaluation of installed systems and equipment as well as working procedures is made. Secondly, the economic improvement potential of increased throughput and cost savings is estimated by comparison with the performance of world-class plants.

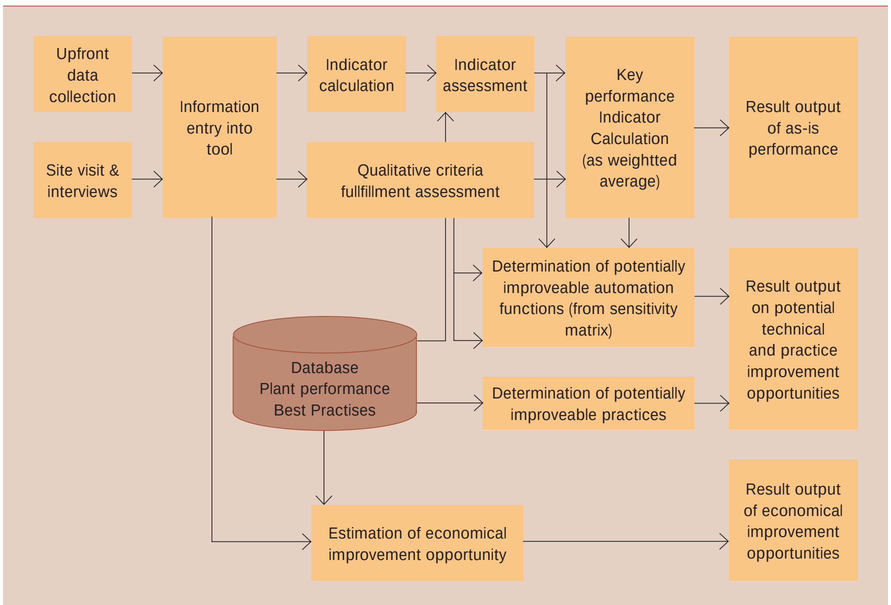
The principle of this top-down procedure is to search for improvements across disciplines, functions and components. Typical questions include: "Do reduced maintenance costs have a higher impact than the implementation of advanced process control (APC), or would better support of operating-point and product changes have a higher economic impact?"

An interdisciplinary team has developed a process for rapidly screening I&C systems and components and related working procedures by combining assessment and benchmarking methods. The new method, which requires a site visit of only two to three days, has been tested in pilot applications in the chemical- and pulp and paper industries.

Methodology

An overview of the individual steps and the required data processing of the developed methodology is provided in 1.

1 Steps in information collecting and processing



Assessment and benchmarking

Assessment denotes the act of determining whether items, processes, or services meet specified requirements. In this article, the term assessment refers to the evaluation of plant performance using predefined measures. An important, though difficult, task is the identification of the maximum achievable performance value, ie, when exactly 100 percent performance is achieved.

Ahmad and Benson [2] defined benchmarking as a structured process to compare the performance of a plant with the best similar plants worldwide. The underlying objective is to learn from the best in the class. Some assessments even make comparisons between different industries. In this article, benchmarking refers to the comparison of a plant with other plants in order to rank its performance. This ranking procedure will identify whether a plant performs better than average and whether it falls within the top 25 percent best performers of the chosen comparison set. Comparisons can be conducted on a global or regional basis, cross-industry or within an industrial sector, or they can be based on other criteria.

An important, though difficult, task is the identification of the maximum achievable performance value, which does not necessarily equal the theoretical 100 percent performance.

Hierarchy of performance and key performance indicators

Process automation is broadly scrutinized during the technical evaluation. This identifies the most significant issues for further detailed analysis in the follow up engineering study.

The spectrum of assessments ranges from instrumentation, through control systems and APC, to production scheduling and maintenance management systems. The assessment considers the technology, its utilization,

Ease of use

working procedures, and operational and maintenance costs.

Approximately 100 criteria, some qualitative, others quantitative, have been identified. Quantitative criteria are defined as *performance indicators*. Some examples are shown in the Factbox.

Qualitative criteria are defined for different performance levels and provide a means by which to carry out consistent, reproducible and comparable assessments. All these criteria are aggregated into ten key performance indicators (KPIs), highlighting subgroups of areas that may require improvement.

1. Instrumentation and control (I&C) asset condition
2. I&C life cycle (obsolescence)
3. Throughput
4. Quality and yield
5. Flexibility / agility
6. Environment, safety and compliance
7. Maintenance
8. Operational costs
9. Personnel
10. Operator support

Assessing the performance indicators

Once the performance indicator values have been computed, they must be assessed. Each is evaluated to determine whether the process performance is already at a good level or whether there is a significant opportunity for improvement.

The scale of each performance indicator can be different, but a common scale makes the interpretation and correlation of KPIs easier. For this reason, four performance indicator reference levels were defined:

- World-class performance (Score = 4)
- Good performance (Score = 3)
- Intermediate performance (Score = 2)
- Significant improvement potential (Score = 1)

2 The result example shows the 10 KPIs with the achieved score percent and score points, respectively, and the lowest score (in points) of the supporting performance indicators

Assessment Aspect	Score percent (0–100%)	Score points (1–4)	Min score (1–4)
I&C Asset Condition	33%	2.0	1.5
I&C Life Cycle (Obsolescence)	42%	2.3	1.5
Throughput	32%	2.0	1.0
Quality and Yield	59%	2.8	1,5
Flexibility / Agility	35%	2.0	1.0
Environment, Safety and Compliance	40%	2.2	1.0
Maintenance / Sustainability	51%	2.5	1.0
Cost of Operation	24%	1.7	1.0
People / Sustainability	63%	2.9	1.8
Operator Support	46%	2.4	1.0

Factbox Quantitative criteria are defined as performance indicators. Examples include:

ACUI = Automatic Control Utilization Index

$$:= 1 - \frac{\text{Number of control loops designed for automatic but operated in manual mode}}{\text{Number of control loops designed for automatic mode}}$$

QCDI = Quality Control Degree Index

$$:= \frac{\text{Number of on-line measured and controlled product quality parameters}}{\text{Number of product quality parameters}}$$

ARSI = Average Alarm Rate in Steady Operation Index

:= Number of alarms received in 10 minutes

AMCI = Automation Maintenance Cost Index

$$:= \frac{\text{Maintenance cost for Automation}}{\text{Estimated replacement value of Automation}}$$

In order to determine the boundaries between these four levels, an ABB database with more than 300 performance assessments, together with results from industry councils and publicly accessible literature, were evaluated. The experiences of ABB experts were also taken into account. This expertise comes from a variety of sources, including ABB's large portfolio of automation products, many grassroots and modernization projects, and full service contracts for many plants.

To simplify processing, a non-linear scale was introduced to score each performance indicator. This harmonizes the different scales used to assess each performance indicator, mapping the result to a common scale (1 to 4) for all performance indicators.

The critical success factors that make up each of the ten KPIs are computed as a weighted average, so that the proportional relevance of each component is taken into account. This results in a score on a scale of 1 to 4 and a percentage performance rating. An example calculation in tabular form is given in **2**. The first KPI (I&C asset condition) has a percentage score of 33, or a score of 2.0.

> Combined performance indicators can be superimposed on the matrix elements to indicate which automation applications, components and systems are most relevant to improve operations.

Applying a weighted average score to calculate KPIs can, however, mask individual components that are underperforming. To draw attention to such cases, the component with the lowest score is displayed as the Min Score. For example, the KPI throughput in **2**, has an intermediate perform-ance score of 2.0 with a min score of 1. This suggests that at least one component of the KPI has significant improvement potential.

Identifying targets for improvement

The technical assessment recognizes the strengths and weaknesses of a plant and identifies areas with potential for improvement. Depending on which automation-related system, application or practice is changed, the different performance categories are improved to different extents. For example, analyzers tend to affect yield and product quality. The reliability of systems can be improved by condition monitoring, while energy management systems have a particular influence on energy costs.

The sensitivity of (automation) drivers and (performance) results can be summarized as a generic sensitivity matrix 3 that can be read in two directions:

- The key automation areas for improving selected performance measures can be determined in a focused manner.
  (Effect area → Systems / components / applications)
- Where automation is missing, or working sub-optimally, the most affected areas can be identified and studied in more detail. (Systems / components / applications → Effect areas)

Combined performance indicators can be superimposed on the matrix elements to indicate which automation applications, components and systems are most relevant to improve operations. This highlights a subset of factors that can be studied in more detail. An example is shown in 3: The red cells contain large numerical values, indicating that the associated automation issue is highly relevant to the linked improvement issue. The numbers in the cells represent the *relevance* or the *strength* of the *association* and not the performance itself (as in the case of performance indicators).

Economic improvement potential

Technical improvements are a means to an end: improved safety, sustainability and profitability of plant operations. Two typical economic objectives are increased throughput and reduced costs. The potential for improvement by increasing throughput can be estimated from an OEE (overall equipment effectiveness) loss analysis. OEE is expressed as a percentage and is defined as:

OEE = availability × production rate × quality rate

This measure is acknowledged as a best practice performance indicator. It compares current production with maximum possible production. The latter is achieved when a plant runs constantly at maximum capacity with no reduction in product quality. 4 shows an example of an OEE loss graph for a paper machine.

ABB holds databases with assessment results for different industries, including chemical, metal and mineral, and pulp and paper. The data sets can be classified by region, industry, type of operations, etc. This allows a selected plant to be assessed against a suitable sample.

The data provide demonstrated examples of excellent industrial performance and an indication of how performance can vary 6. This can be used to assess the potential for economic improvement and to rank a target plant within the sample set.

3 Excerpt of the sensitivity matrix of (automation) drivers and (performance) effects for an example assessment: Red cells (circled) indicate areas with improvement potential

	Product / Application	Improvement Area / Driver				
		Process Yield / Efficiency improvement	Throughput / Capacity / Production rate improvement	Process Quality improvement	Energy & utility cost reduction	Plant agility improvement
Instrumentation & Control	Instrumentation – sensors & transmitters	1.6	1.8	1.9	2.1	1.6
	Instrumentation – control valves and positioners	1.6	1.8	1.9	2.1	1.6
Motors & Drives	Motors, Drives, Motor Control Center	1.3	1.3	1.3	2.9	1.3
	Analyzers of software property estimators / inferential measurements	2.8	1.8	2.8	1.8	2.0
	DCS – kernel i.e. Information and control (system type & size suitable for plant)	2.2	2.0	2.2	2.1	2.0
	SCADA & RTUs	1.0	1.5	1.3	1.4	1.6
	MES integration with DCS	1.2	2.0	1.3	1.4	2.3
	LIMS integration with DCS, QCS and PIMS	2.2	2.0	2.2	1.4	2.3

Ease of use

The potential for cost savings (both fixed and variable) is of particular interest when a plant's operations are limited by the market rather than by production efficiency. The cost factors to consider include energy consumption, maintenance, and personnel. Improvement opportunities can be estimated by comparison with world-class benchmarks.

Software support tools

A software tool was developed for process plant assessment. The application guides data entry and conducts most of the analysis automatically. Computer support for assessing and benchmarking provides easy access to the integrated know-how and experience of many specialists. Furthermore, it ensures that assessments are carried out in a systematic man-ner. This improves consistency and reproducibility of results. The probability of making errors during data processing is reduced, allowing the assessor to focus on the primary tasks.

Without computer support it would also be difficult to conduct a broad assessment of a plant's performance within such a short time with a staff of only one or two people.

Procedure

For increased efficiency, the assessment procedures were standardized. The process is summarized from a project per-spective below (see 1 for an outline of the methodology):

1. The scope of the assessment is agreed upon with the customer.
2. The plant receives a data collection form upfront.
3. The assessor conducts a short on-site visit, following a preagreed schedule that includes a plant tour and staff interviews.
4. The collected information is analyzed and benchmarking conducted.
5. The analyses result in the performance assessment and an overview of improvement opportunities.
6. Optionally, technical and economical improvement opportunities can be investigated in a more detailed study.
7. As an option, a follow up project can be initiated to ensure that the specified improvement opportunities become a reality.

Pilot applications

Pilot studies using the methodology and the supporting computer software described in this article have been conducted in several industries: a continuously operated chemical plant, a plant for recycling wastepaper and some paper machines.

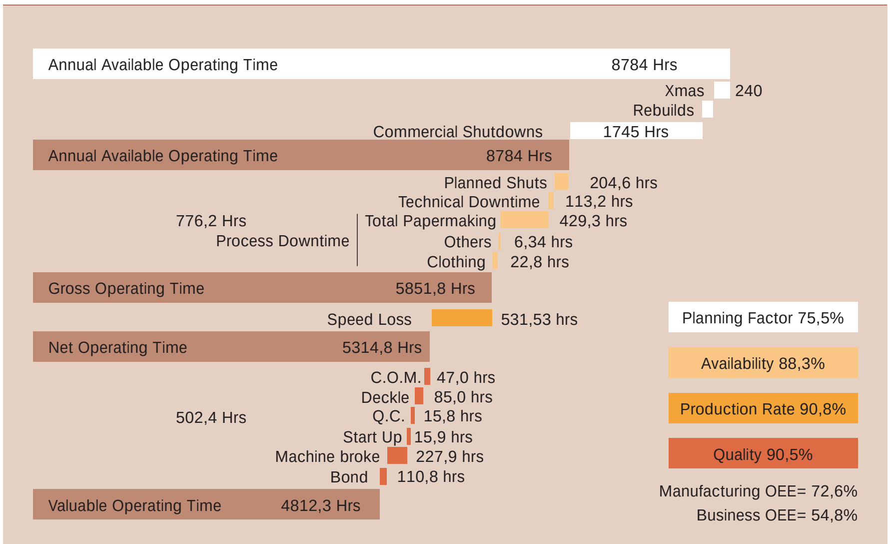
The plant operators provided the relevant production and financial data, and site visits of two to three days followed. In order to get a comprehensive view of the plant, interviews were carried out with panel operators, automation engineers, maintenance personnel, production planners, controllers, and the plant manager. With the help of the I&C assessment method and software tool, it was possible to assess the plant, rapidly, systematically and structurally, to obtain a full picture of the automation performance. Different functional areas were integrated in the assessment and a full view of the plant's performance was gained, showing its strengths and weaknesses.

Computer support for assessing and benchmarking provides easy access to the integrated know-how and experience of many specialists.

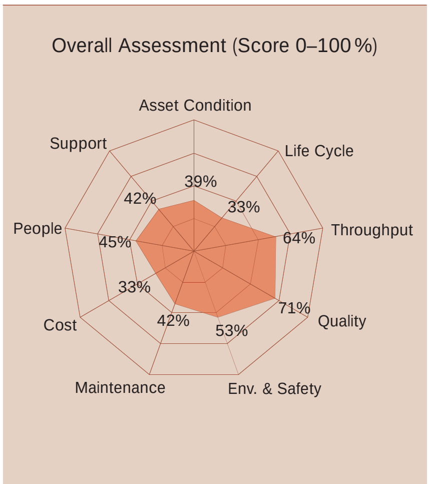
Wastepaper recycling plant

Results from the I&C assessment of the paper recycling plant are presented in 5. The assessment highlighted short falls related to the lifecycle of the control system and identified that the current control system would have been unable to cope with the planned expansion of capacity. The low cost score is also linked to the age of the control system, since more than 50 percent of maintenance time is spent on reactive maintenance. A preventive maintenance strategy should reduce this time and allow more time to be spent on improving the performance of the control system.

4 Example of an OEE loss graph for a paper machine



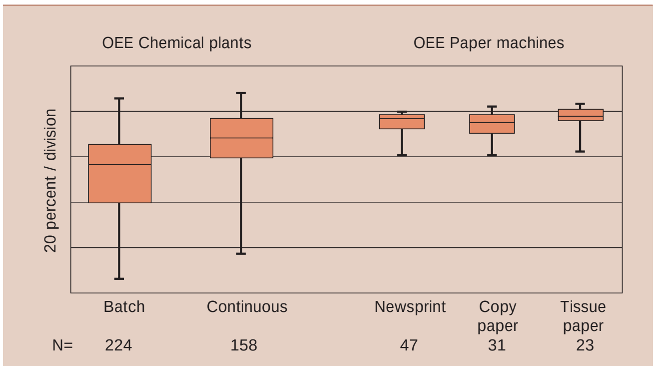
5 Result of the technical assessment of a recycled fibre plant for waste paper



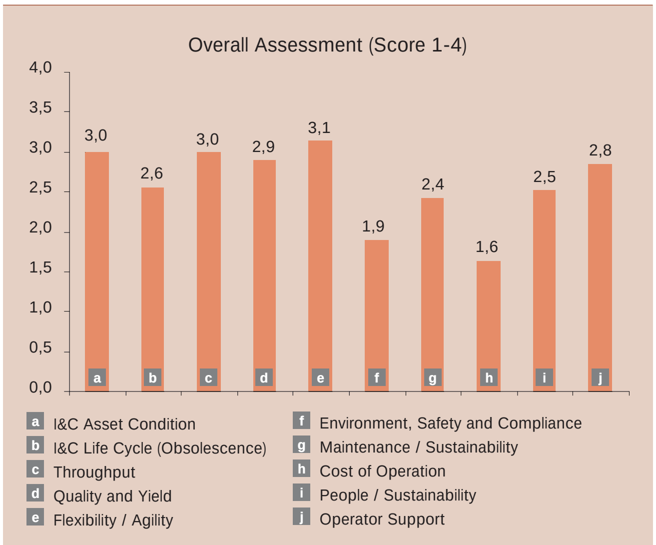
Even though production was already at a high level, significant variations in the production rate were observed, resulting from different operator practices. By using common setpoint management and corresponding operational procedures, it should be possible to stabilize the production rate at its maximum.

Without computer support it would be difficult to conduct a broad assessment of a plant's performance within such a short time with a staff of only one or two people.

6 OEE distribution of a sample of chemical plants (left; error bars indicate minimum and maximum; lower and top box boundaries indicate first quartile, median, and third quartile) and of a sample of paper machines (right; error bars indicate minimum and maximum; lower and top box boundaries indicate median, top 25 percent, and top 10 percent)



7 Result of the technical assessment of a paper machine



Paper manufacturing

In the case of the paper machine, the PAS assessment provided the results shown in 7. After extensive modernization of the control system, the customer consistently obtained good results for the KPIs Asset Condition and Support. Low cost performance was highlighted by the assessment and attributed to suboptimally coordinated support from the plant's own maintenance and engineering departments, as well as from suppliers and other third parties. A better clarification of responsibilities was suggested to help improve efficiency and lower costs.

Chemical processing

After assessing and benchmarking the continuously operated chemical plant yield, energy efficiency, and capacity were identified as major areas for improvement. Measures to improve plant operations were implemented after conducting a detailed engineering study. More precisely, measures to reduce yield losses by 10 percent were identified. No investments were required to realize this potential, just some adjustments to the control system and operational procedures. Energy savings of up to 15 percent could be made by modifying the plant's operation. The customer remarked that relevant issues were rapidly identified using this systematic approach and more objective results were obtained using external assessors.

Summary and outlook

The method and computer-aided tool described in this article can be used for the rapid assessment and benchmarking of automation systems, their performance and related working procedures. Potential for improvement can be identified and its economic impact estimated. This new method has helped customers to identify the most relevant issues in several pilot studies.

Andreas Kroll
Measurement & Control
University of Kassel, Germany
andreas.kroll@mrt.uni-kassel.de
(previously with ABB Corporate Research, Germany)

Frank Simon
ABB Automation GmbH
Mannheim, Germany
frank.j.simon@de.abb.com

Gordon Cheever
ABB Process Automation
Service Business Development
Wickliffe, USA
gordon.r.cheever@us.abb.com

Tomi Pilbacka
ABB Full Service
Helsinki, Finland
tomi.pilbacka@fi.abb.com

David Stanier
ABB Engineering Service
Billingham, Great Britain
david.stanier@gb.abb.com

Footnote

[1] A similar version of this article was published in German in 2006 [1].

References

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