Fleetwide Monitoring – State of the Art Collaboration Meets Predictive Analytics for Optimizing the Entire Fleet

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Abstract

In this paper a fleetwide monitoring solution is presented that provides the essential information for a reliable plant operation right at the fingertips of the users. The innovative approach combines predictive analytics for early warnings with a powerful, easy to use web-based user experience.

1 Introduction

The operation of power plants is highly complex. For the utilities, managing a reliable plant operation with frequent start-up and shutdown procedures, different fuel qualities, and a high availability at maintenance costs as low as possible is both a challenge and a chance.

One reason for the changed boundary conditions is the addition of renewable energies to the market. The objective is to be able to successfully meet the volatile requirements of the energy market with a flexible and economically efficient power plant operation in future.

The expert software solutions of STEAG Energy Services ensure an assessment of plants in procedural and technical terms. By continuously evaluating available performance values, the systems provide reliable information enabling an optimized mode of operation and reliability-centered maintenance (RCM) of the plant and help to increase the plant's availability early on.

Information on the efficiency, load-independent performance factors, coal qualities, heat rates, and availabilities describes the quality of the operation and is available on site. Fouling and wear of the plant components, i.e. creeping changes of the operation, can thus be detected in a timely manner, and additional costs can be avoided. Further key figures regarding planned and unplanned shutdowns, load regime, and economic KPIs like sales and EBIT can be queried via further expert systems.

The existing systems all have one thing in common: they are designed for the responsible experts on site. A linkage of strongly condensed procedural and commercial information is required for comprehensively assessing the individual plant as well as for optimizing the entire fleet.

The fleetwide monitoring solution of STEAG Energy Services integrates state of the art software components to build a scalable solution and to match the demands of both management and operating crew on site. The use of the latest collaboration tools and methods avoids the drain of knowledge and enables a fast communication across technical and organisational borders.

2 Status quo – Demand for Real-Time Access to Essential Information

Performance monitoring in power plants has become widely used in the last ten years. This involves data archiving, thermodynamic and mechanical data analysis with first principle models on-line and off-line, neural networks for data-driven approach on data analysis, and diagnostic tools.

Meanwhile, many expert software systems like the SR solution of STEAG Energy Services are available at numerous power plant sites to assess the highly complex plant operation and to support the decision making process of plant engineers and the operating crew on site. The data administration and visualization are effected in a local data management system. Periodically, operational data are extracted from DCS systems and other source systems.

The existing systems all have one thing in common: they are designed for the responsible experts on site. The systems cover different technical topics which are mostly not linked within the software. A successful collaboration about current queries depends on the human factor.

The fundamental challenges for utilities are:

- Important management information is available in different IT systems.
- The same information is prepared new again and again in different places in the company.
- A transparent feedback of the information passed on to management is not ensured for each site.
- Usually, sites only know their own key figures.
- High investment of time for compiling the reports (diligent but routine piece of work, risk of errors due to manual transmission of data)
- No direct inference to the data origin possible
- Comparability of information not ensured due to different data conventions
- Poor availability, low proliferation of the reports (manual filing, small group of users)
- Bottom-up analysis very elaborate as different source systems with different condensation stages are used

Those issues pose a tremendous challenge to the decision making process and include some risks which are:

- Important findings may be overlooked due to the vast amount of information
- Mismanagement and communication conflicts between management and site
- Unscheduled downtime and poor maintenance practices

For executives there are plenty of reasons to demand a greater return on their enterprise assets due to rising fuel and material prices, changing industry regulations and an increasing complexity of the power plant operation. One way to ensure optimal conditions of components and efficiency of the entire fleet is to provide decision-makers with access to real-time information about the health and performance of their assets.

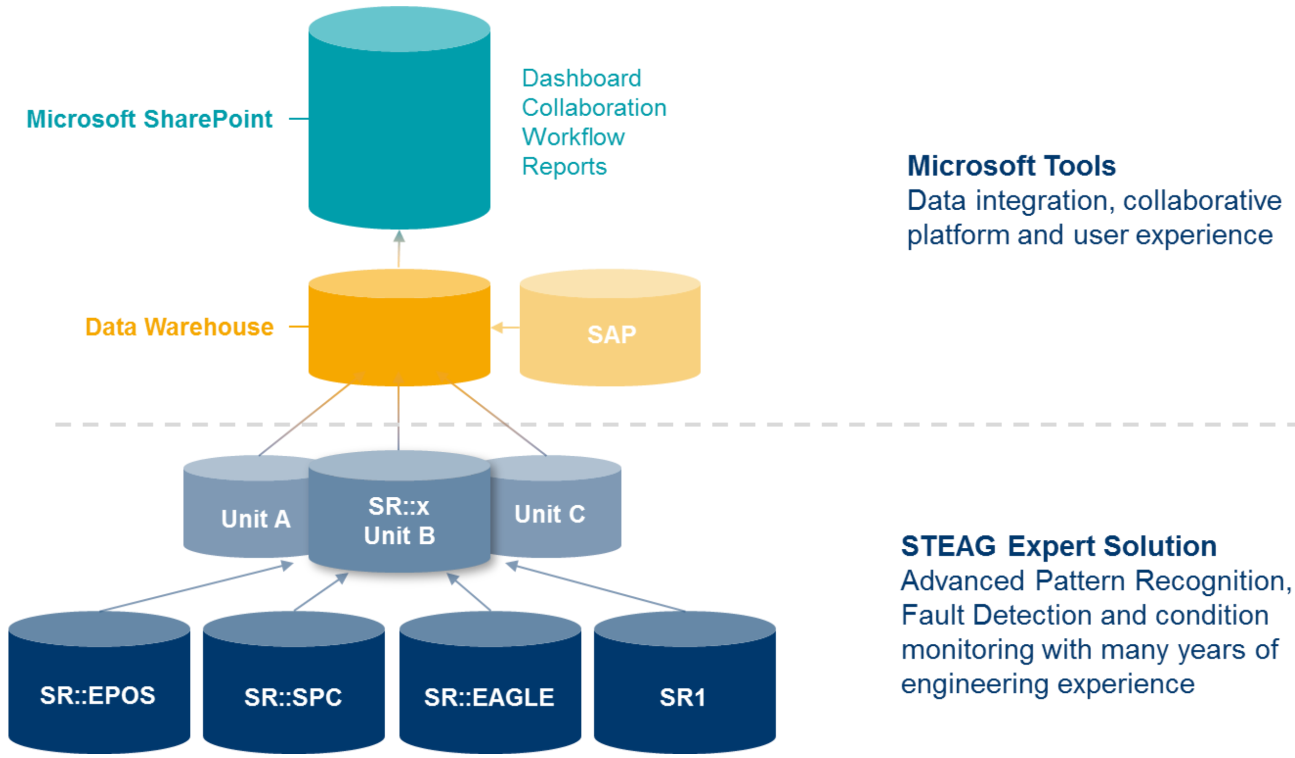

Figure 1: Data Management of the STEAG Fleetwide Monitoring Solution

3 Preconditions for a Powerful State of the Art Fleetwide Monitoring

The challenge is to automate the compression of information to the greatest extent possible in order to differentiate between important information and less relevant data. Besides methods for SPC (statistical process control) in terms of an early warning system, criteria for the weighting of information are considered for this as well.

The assessment of events regarding the plant availability, the process performance, and the operational safety enables an event ranking in order to detect essential operating potentials early on and to avoid controlling errors. In doing so, the respective current plant condition, a comparison with reference conditions, or the medium- up to long-term change of performance indicators can be assessed.

The question for all currently relevant information also depends on the range of duty of the user of the fleetwide monitoring system. Thus the system has to support different user roles and customized views. For more on this refer to Chapter 5.

The essential precondition for the representation of so-called meta-KPIs that describe the current overall condition of a plant consists in reliable findings on process quality, component conditions, and external influences. The following modules are vital elements of the comprehensive fleetwide monitoring solution of STEAG Energy Services GmbH.

3.1 Performance Quality Monitoring – SR::EPOS

Continuous monitoring of process quality is an essential way of discovering optimization potentials in power plant operation. Deviations from optimum operation develop slowly and are often concealed by the effects of external boundary conditions, such as environmental parameters. The result is a considerable deviation from maximum efficiency.

SR::EPOS continuously monitors the power plant process under technical and economic aspects. Important plant components are assessed cyclically. Within the scope of online diagnostics, additional operating costs are shown to reflect deviations from the optimum conditions that are possible at that time. This allows to weigh the individual deviations and to take the required measures.

Depending on the plant's design and on the possible modes of operation, SR::EPOS can suggest an optimum mode of operation from both economic and ecological aspects. Typical applications for optimizing operation with SR::EPOS are setting the optimum cooling water volume, especially in partial load operation, optimizing the use of soot blowers, and optimizing grinder operation.

SR::EPOS fully automatically conducts what-if calculations in order to determine the influence of individual process parameters or components of the plant on the overall efficiency. The results calculated here clearly show how large the contribution of a specific process parameter or of a certain component to the increased heat rate is. On the basis of this information, the operator can assess the individual influences and design the countermeasures in such a way that the greatest effect is achieved as quickly as possible.

3.2 Statistical Process Control – SR::SPC

Power plants and their components are subject to continuous changes in their operational behaviour, which, for instance, can be traced back to wear-and-tear or fouling. Every now and then, these changes lead to failures of components.

In order to get early indications of developing faults through the continuous evaluation of relevant measured values, the use of statistical methods is recommended here. By this means, non-disposable non-availabilities can be converted into disposable ones. Then necessary repairs can be prepared foresightedly and they can e.g. be purposefully scheduled in periods of weak load or during weekend shutdowns.

SR::SPC imitates the engineer's work of analyzing time series and – just like the experienced engineer who looks at a recording strip or history of measured values, but automatically – detects significant trends and patterns or sudden leaps in the monitored characteristic. By applying various procedures and suitable rules for evaluating the results, the reliability of the statements can be further enhanced.

This module is able to deduce indications for an optimized mode of operation of the plant on the basis of simulation in the context of thermodynamic modeling or also by means of heuristic approaches like fuzzy logic. Prominent examples of such applications are the optimization of the cold end of a power plant regarding the amount of cooling water / the mode of operation of the cooling tower or intelligent sootblowing.

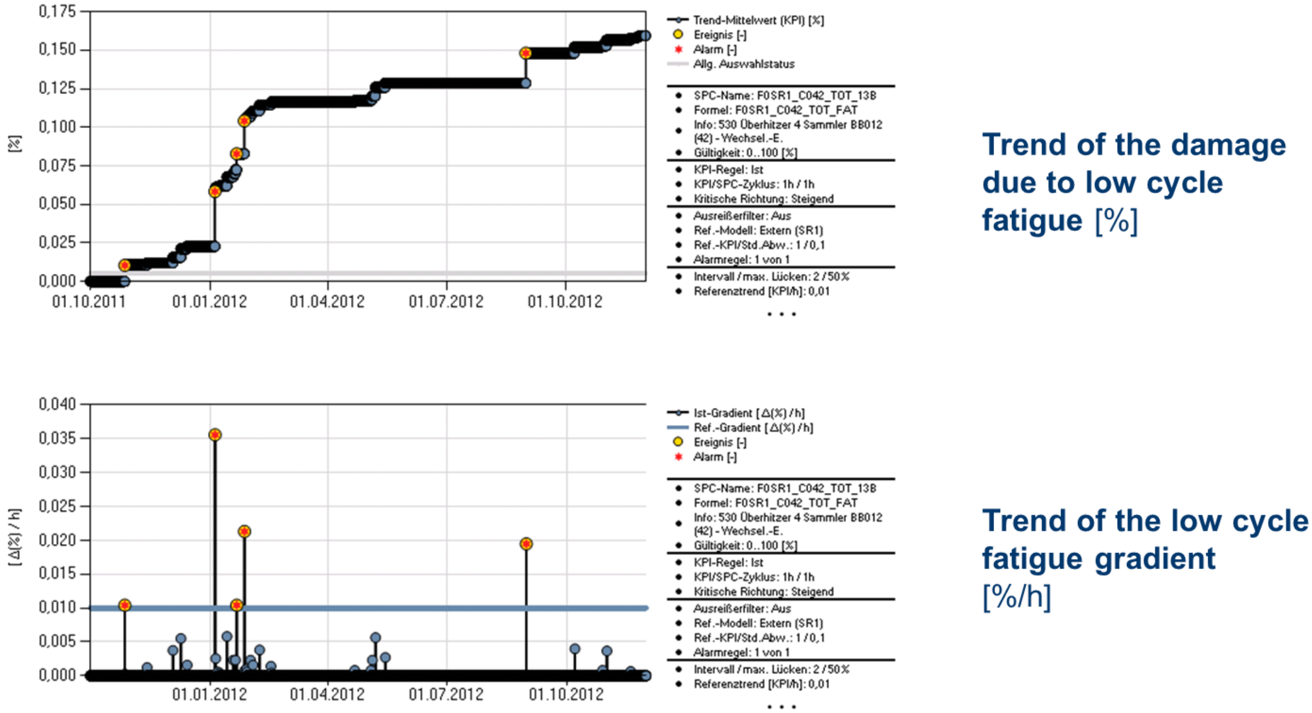

Figure 2: Event Detection of Low Cycle Fatigue

3.3 Decision Tree Based Fault Detection – SR::EAGLE

Fault Tree Analysis (FTA) is a technique by which the possible causes which can lead to undesirable top event are identified and organized in a logical manner. The 'Top Event' is the major failure to be analyzed in the fault tree .The primitive or basic failure events that ultimately cause the TOP event are connected through logical AND-gates and OR-gates. The gate symbol denotes the type of relationship of the input events to the output event.

The attractive nature of fault tree stems from the fact that it can isolate multiple fault conditions simultaneously. In many cases there are multiple causes for an undesirable event.

SR::EAGLE performs real time evaluation of the fault tree. The active causes of the problem are isolated when the system is in on-line or operating mode by evaluating the basic events. The evaluation of fault tree is triggered only if expression at top event returns a true value. The on-line fault tree has the advantage that is possible to define personalized trees for plant-specific phenomena; one is not limited to predefined trees.

3.4 Condition Monitoring for thick-walled boiler components and steam pipes – SR1, SR::SPM

In a scenario of increasing use of renewable energy the conventional power plants will be more and more forced to compensate for the volatility of the natural resources. Even huge coal fired units which have been designed for base load operation will face an increased

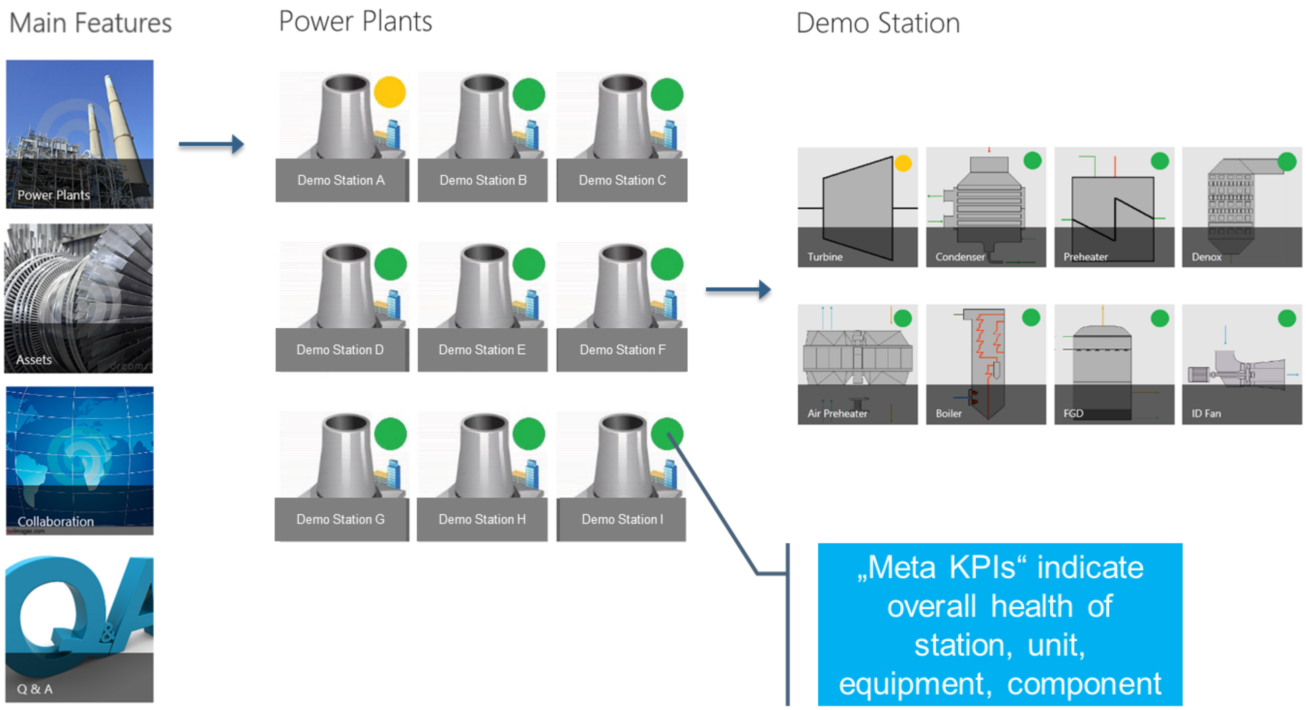

Figure 3: Visualization of "Meta KPIs"

number of start-up/shut down cycle and the requirement for faster load changes.

Particularly regarding thick-walled boiler components (e.g. drum, separator vessel, headers, moldings), the high cyclic loading by internal pressure and temperature leads to an increased alternating stress.

The calculatory stress is determined by means of online monitoring systems in order to allow for a realistic projection for optimizing the mode of operation. Thus the systems significantly contribute to ensuring a safe and economical plant operation.

A continuous monitoring of the component stress using statistical methods is particularly helpful in this context. The increase of creep damage and alternating fatigue is monitored by means of the online system SR::SPC. When an admissible warning limit is transgressed, the user is immediately informed about the status (Figure 2).

In addition, the trend analysis can be used for an extrapolation of creep damage and alternating fatigue into the future. For this, the projection period and a fatigue admissible in this period are defined. Planned shutdowns of the plant (no increase in fatigue) can be taken into account. If the expected fatigue is transgressed during the projection period due to the current mode of operation, one can react with a more moderate mode of operation, or the additional consumption can be economically assessed and tolerated if applicable.

3.5 Data Management and Visualization – Microsoft SharePoint

In order to allow all users direct access to the information relevant to them, the data

visualization is effected in the web browser. With SharePoint, Microsoft has developed a powerful enterprise platform for the company-wide collaboration. Besides views for different user groups, individual reports can be configured as well.
SharePoint supports a workflow management for forwarding, editing, and commenting. The activities are saved per KPI. In the case of recurring events, it is possible to quickly assess which findings and measures were chosen and carried out in the past.

The central data management of the fleetwide monitoring solution is preferably effected with an SQL server technology as data warehouse in combination with SQL Analysis Services for the configuration of different query and filter requests. By means of SQL Integration Services (SSIS), the integration of numerous data sources can be implemented without any problems.

4 IT-Based, Partly Automated Workflow for Plant Optimization

STEAG Energy Services has long years of experience in the field of online diagnostic systems for condition assessment and process optimization. In the context of the continuous development of the SR::Suite, modules have been developed to support the analysis and decision process as well as automate it depending on the progress of the solution, as part of a fleetwide monitoring solution.

The workflow is divided into the following five steps:

1. Detecting the event
2. Analyzing the cause
3. Assessing the effects of the cause
4. Carrying out measures
5. Building up the knowledge pool

4.1 Detecting the Event

Various IT tools are available for detecting events. The performance quality monitoring provides findings on the current process quality. SR::SPC allows to detect changes of process parameters and component conditions long before DCS warning limits are reached. SR::Query enables the systematic evaluation of processes limited in time (like e.g. fuel consumption during start-up, load change velocities as well as start-up times).

4.2 Analyzing the Cause

Basically it can be assumed that a cause in the operation leads to a large number of events that are identified by means of the tools which are described in Chapter 3. The root cause analysis can be effected manually involving a sometimes significant expenditure of time, or IT-supported.

Manual Root Cause Analysis:

Initially, the analysis of the events is carried out isolatedly. Detailed procedural knowledge of the plant as well as operational experience are required to be able to draw inferences about possible causes. The manual root cause analysis is often time-consuming and requires to involve various departments as the necessary knowledge is often not available from one and the same person.

Automated Root Cause Analysis:

STEAG Energy Services has developed the module SR::EAGLE for supporting the fast and systematic root cause analysis. The logic heat rate trees for coal-fired power plants of the EPRI (Electric Power Research Institute) are already preconfigured in the system. Further plant-specific coherences are put into effect in the context of the implementation phase of the

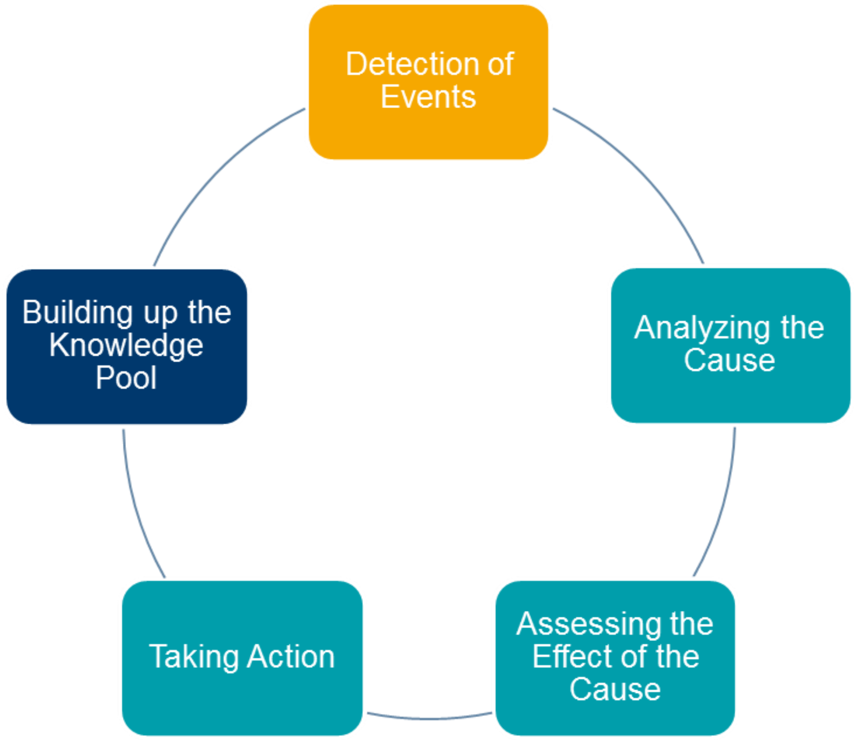

Figure 4: IT-Based Workflow for Plant Optimization

fleetwide monitoring system. The visualization of the automatic fault analysis is directly integrated into the web display of the fleetwide monitoring.

4.3 Assessing the Effect of the Cause

To be able to assess when and if a measure for problem solution is required, the effect is assessed with reference to performance, availability, component condition, and operational safety. For this, information from commercial systems (like e.g. SAP), tools for the planning of maintenance and overhauls, systems for condition monitoring as well as the performance quality monitoring are incorporated. For instance, the influence of the cause on the additional heat consumption and the efficiency loss respectively is assessed this way.

4.4 Taking Action

When it is certain that a measure makes sense and is necessary, workflows can be initiated. In the simplest case, these comprise a forwarding of the previously gained experiences to colleagues for further processing. This includes:

- Further analyses
- Optimization of the plant operation
- Initiating repair orders
- Planning of shutdowns for repair

Linkages with existing operation management systems and systems for maintenance management are possible.

4.5 Building up the Knowledge Pool

In the context of the event analysis, findings are gained that may be of great interest when events occur repeatedly. Which causes were identified lately? Which measures were successful / necessary? Who was involved in the workflow and might have more information? With its collaboration methods, SharePoint supports the user in setting up a knowledge pool. Besides a wiki and a Q&A report, one comment history per KPI is available as well.

5 Different User Roles for an Efficient Workflow

Not all information is of equal importance to all users. In order to optimally support the users in their daily tasks, different user roles are defined first of all in the context of the implementation phase of the fleetwide monitoring system. Later, individual views and favourites can be created per user.

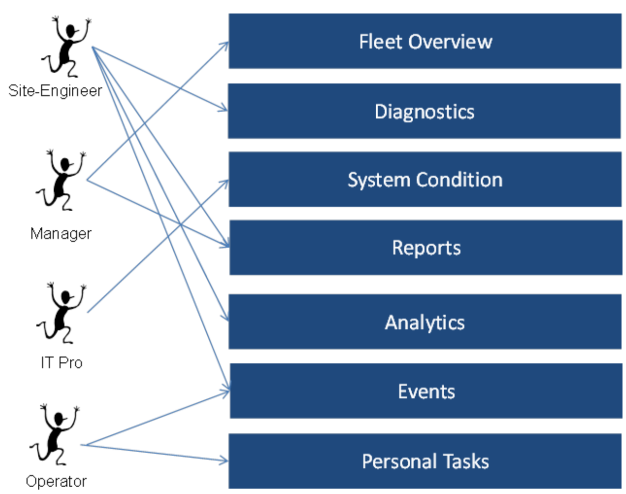

Figure 5: Different User Demand

By way of example, four user roles (site engineer, manager, IT expert, operator) are briefly described in what follows: while the operator is responsible for the current operation of the plant (measured value quality, compliance with DCS system limits and operating procedures for process control), the site or performance engineer, for instance, concentrates on medium- and long-term changes of the process quality in particular and analyzes conspicuous events.

In the overview of the entire fleet, the manager is interested in strongly compressed meta-KPIs like e.g. availability, maintenance costs, fuel consumption, and start-up costs.

The IT expert checks the system availability and the condition of the server hardware.

According to requirements, the access to reporting and analysis tools, to the event ranking and to the workflow manager can be set up for the different user roles in order to support an efficient workflow within the own scope of duties.

6 Summary

The combination of procedural, physical, and statistical methods of analysis with promising tools for pattern recognition is an essential feature of the fleetwide monitoring solution of STEAG Energy Services GmbH.

This makes events detectable earlier, causes can be analyzed and assessed, and measures can be initiated. Overviews of all plants enable a benchmarking in the positive sense in order to detect similarities and differences in the operation of the plants and learn from each other. The company-wide collaboration ensures that all departments for process optimization can be involved. A modern data management and an open system architecture allow for a flexible scalability of the intended solution and for the integration of different data origins.