

White Paper  
October 2020

# An Innovative Approach of How to Maximize the Efficiency of your Plant Assets



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## Executive Summary

With the increasing market competitiveness, the complexity of some of the plant assets, the cost of their maintenance and their direct impact on production, the need to maximize asset availability while managing their efficiency and performance is no longer an option.

Effective operations management starts by an effective asset management. Asset management is a systematic process of deploying, operating, maintaining, upgrading, and disposing of assets cost-effectively. We see it as a coordinated approach to realize value from assets. A poor performing asset such as a compressor or turbine can cause a drop in production, quality issue, and sometime all the way to creating safety related problems.

Practically, facility owners in the process industry sector are today facing several challenges in managing assets such as:

- Access to the expert who is well familiar with an asset and can quickly analyze and diagnose the behavior of the asset so immediate corrective action can be taken,
- Reduce the cycle time to diagnose any related performance issue: the longer it takes the higher unnecessary cost and loss of production end-users incur,
- Identify the optimum time to shutdown the asset for maintenance purposes,
- Get accurate diagnoses as, sometime, although the asset is poorly performing the problem is already caused by other pieces of equipment that are upstream or downstream,
- Establish proper management in order to avoid reliability issues and therefore a shorter lifecycle of the assets.

In this paper, we will be suggesting an innovative approach through the use of technology of how to address the above issues.

## Today's Asset Management Challenges

### Access to knowledge and expertise

Manufacturing process industries are dealing with several complex assets with different characteristics and operating at different conditions. Once an asset performance deviation is detected, finding the root cause relies on the plant personnel experience and requires lengthy and repetitive brainstorming meetings involving different experts and divisions to diagnose the issue. During this time, the severity of the asset performance degradation is increasing and may lead to downtimes and higher maintenance costs. This traditional process of catch-up mode for issues resolution is due to a lack of actionable knowledge online that would allow operations to proactively react, apply the required corrective actions, and shorten the problem to resolution cycle.

### Predict future performance

If operational efficiency wanes because assets are out of commission or operating below peak efficiency, companies can quickly lose traction in today's ultra-competitive markets. Thus, all asset owners are looking for ways to increase the reliability and uptime of their assets. A key factor to reach this objective is the ability to predict the future behavior of their assets and to answer questions such as the following:

- How can I predict an impending equipment failure and identify its cause?
- How do I achieve optimal equipment efficiency and availability?
- What is the life expectancy of an asset's component or part?
- How can I optimize my maintenance plan?

## Consolidate asset management

Personnel tend to find themselves depending on several applications across the organization's operational systems to manage their assets. They do not have a consolidated view of a given asset for different requirements in a single system. They need, for example, to check maintenance management applications for maintenance schedule requirements, performance management applications for KPIs reporting requirements, and alarm management applications for SOE requirements. In addition, the volume of data generated across multiple Operational Technology (OT) and Information Technology (IT) applications in the asset life cycle keeps increasing. Many facilities end up with streams of information stored in silos. This leads to a lack of visibility in asset health, uncorrelated asset data, inaccuracies in asset status and a lack of a synchronized view of asset information across enterprise and operational systems.

## Manage performance targets

Performance assessment is tied to performance targets. Inaccurate performance targets leads to erroneous decisions making based on false performance gaps alarming, higher operating costs, and missing opportunities to produce higher yields. Traditional asset management systems rely on static or manual targets that induce a lack of precision and do not consider the dynamic behavior of plants processes characterized by different products, feedstocks, operating modes, and equipment characteristics.

## Process Knowledge Out of the Box

It has never been more important than now to capture the knowledge from plant operations experts and make it readily shareable before the embedded knowledge of their experience is lost forever. Not only is it important to preserve the knowledge, but the real value is derived from applying it in decision support applications to efficiently manage the assets in the event of abnormal conditions.

Smart Equipment modules are ready-to-use software components that encapsulate years of process knowledge and expertise. They are developed on top of Emerson's Plantweb Optics Analytics decision support application, performing real-time monitoring, conducting predictive analysis, and diagnosing root causes of process issues, thus ultimately guiding operations to better resolution decisions and higher returns on capital assets.

Smart Equipment modules are available for rapid deployment with a complete standard set of:

- Performance metrics for monitoring asset status and efficiency,
- Expert rules for complex events detection and process conditions identification,
- And root cause analysis models for predicting and diagnosing equipment issues and providing advisory for corrective actions and impact evaluation.

These models can be easily customized and extended to perfectly match customers' needs. Smart Equipment modules include the main pieces of equipment used in the process manufacturing industry such as compressors, turbines, furnaces, columns, boilers, reboilers, reactors, heat exchangers, pumps, valves, and vessels.

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The Smart Compressor, one of the available assets among the Smart Equipment modules, embeds expert knowledge for centrifugal, reciprocating, and screw compressors to monitor the performance and asset conditions and preemptively alert operations about problems that could lead to costly shutdowns and slowdowns. It embeds pre-defined calculations for the key compressor’s performance metrics such as:

Performance & Health Metrics	Definition
Compressor efficiency	This performance metric measures the ratio of the compressor power to the drive motor power. Mapping to original performance curves is also considered to detect in real-time performance gaps.
Polytropic head	The polytropic head is the energy required to compress polytropically a specific quantity of a given gas from one pressure to another
Compressor power	The compressor power is the required power to compress the gas from one pressure to another. It provides an idea about the asset health and condition.

Whenever a performance gap is predicted or detected, the diagnosis engine will automatically pinpoint the reason behind the degradation before it disrupts the process. To do so, complex event expert rules are developed to monitor in real-time the asset performance. Surging is a typical example of abnormal conditions that may occur when running a compressor. Surging is an undesirable and dangerous phenomenon that affects the compressor stability and may lead to significant mechanical damage and unsafe operating conditions. Plantweb Optics Analytics helps operations predicting the surging phenomenon before affecting the equipment availability. A rule is used to detect if the anti-surge valve is open when it is not required because the operating point is far from the surge line. Within this rule, a specific model is established to take into account the surge line equation of the centrifugal compressor and calculate in real time the distance to surge. This rule replaces the standard way that mechanical and process engineers follow to identify the operating point into the compressor performance curves and check the distance to surge line. The figure below shows the rule embedded in the Smart Compressor module to predict compressor surging based on real-time process inputs and an advanced model that calculates in real-time the distance to surge based on the compressor performance curves.

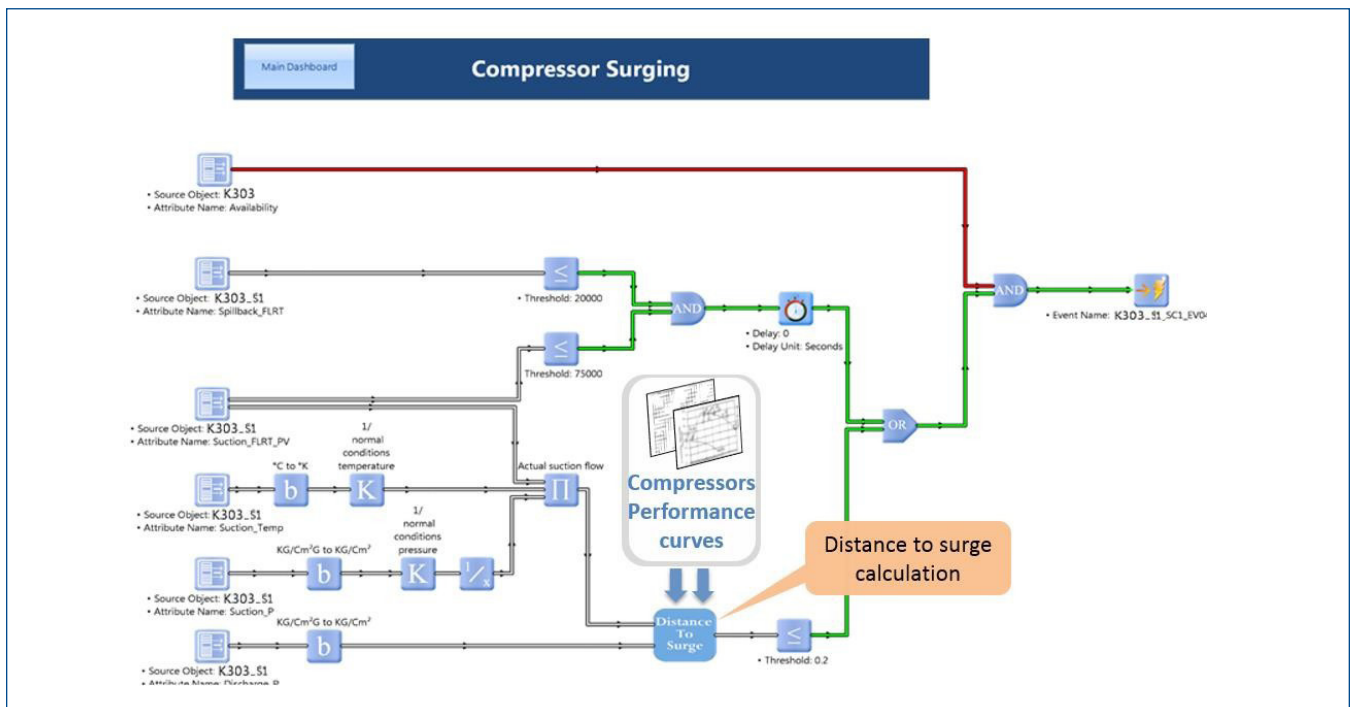


Figure 1: Complex Event Detection Model Example from Smart Compressor Module.



In addition to providing an intelligent asset library, the proposed approach empowers decision support systems and sharing of knowledge. Users can build knowledge into the system so that Plantweb Optics Analytics can become the operations expert as it quickly identifies opportunities for assets efficiency improvements. It identifies root causes of problems when they arise and swiftly guides plant operators in making the most effective decisions.

## Innovative Predictive Approach

Giving current industry trends, asset owners started investigating in predictive analytics in an attempt to set up smart asset management system. The proposed approach goes beyond predictive analytics. It combines the following technologies in one integrated decision support application:

### Automated root cause analysis

As asset problems are identified, either by alarms or some other method, the natural approach is to make a correction to bring operations back to normal. Tests may be performed to validate the problem and link it to a fault, but these tests may not point to the actual fault causing the symptoms. Experienced human troubleshooters know that in a complex environment with multiple variables, multiple faults may have occurred that led to the symptoms that indicated the problem.

Therefore, once a problem is identified, the next step is to rely on a fault propagation model to identify possible causes. Each of the possible causes is itself another problem. Arrows are drawn between the problems to indicate the cause and effect relationship.

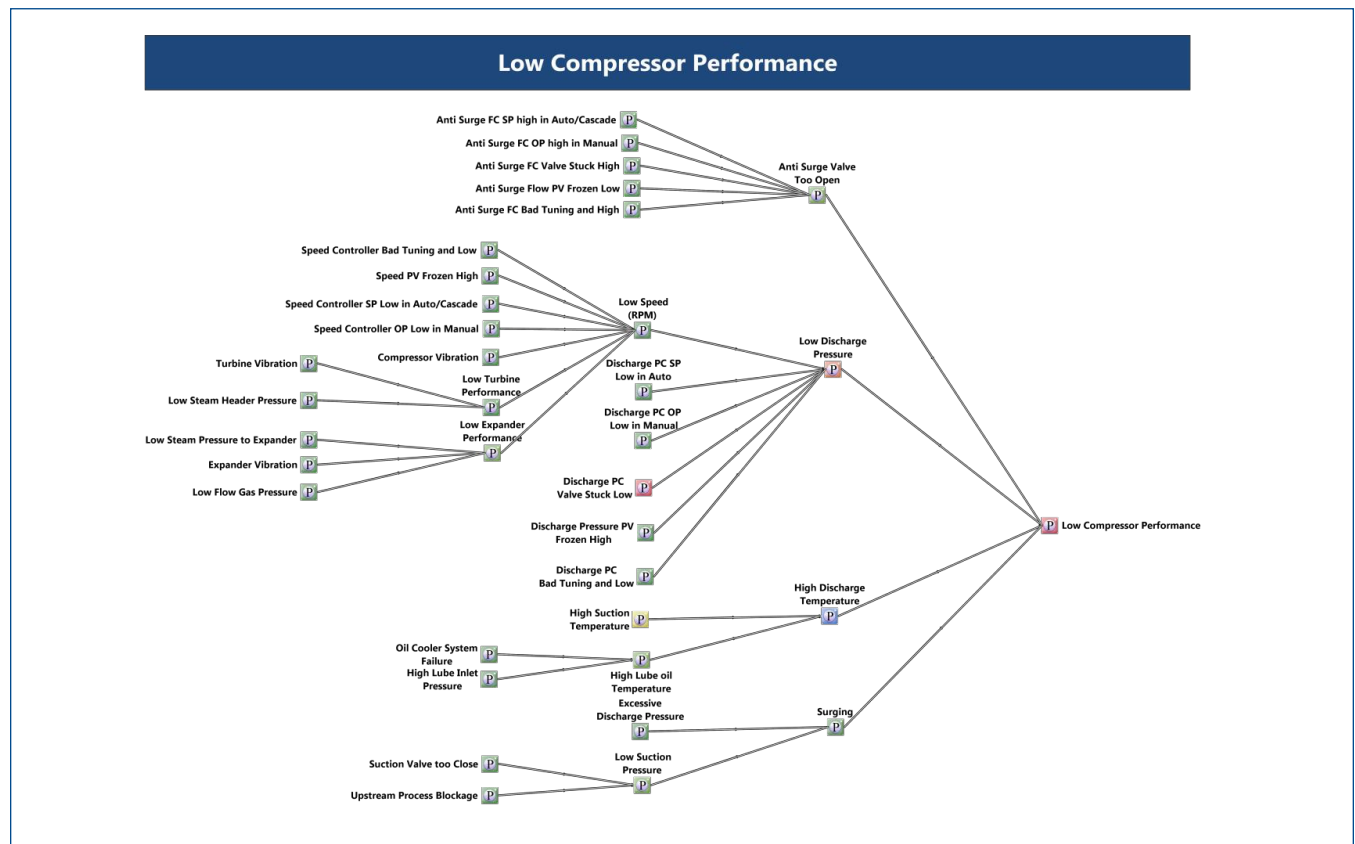


Figure 2: Low Compressor Performance Fault Model.

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As an example, an arrow may be drawn from “Low Discharge Pressure” to “Low Compressor Performance”. This arrow indicates that “Low Discharge Pressure” can be the cause of “Low Compressor Performance”. Another example of a cause may be “Surging”. Progression continues “upstream” for possible causes until the “root causes” are identified and corrective actions can be taken.

Similarly, a downstream execution of this fault propagation model predicts equipment failure issues and efficiency drops. “Compressor Vibration” may lead to another problem such as “Low Speed (RPM).” Again, arrows are drawn to indicate the cause and effect links. The result of the process to look upstream for possible causes and downstream for effects is a fault propagation model.

Automating the execution of fault propagation models online with real-time data inputs provides a powerful mechanism to predict and diagnose equipment failures, performance drops and their root causes, to take past studies and to incorporate the modeled knowledge for real-time use.

As you can also see in the provided example, the root cause analysis model will allow you to tie the dots together between assets, production units or even plants and consequently provide operations with accurate prediction and diagnosis results in general and especially in cases pertained to assets poorly performing because of other equipment that are upstream or downstream.

## Predictive models

Predictive analytics are the process of using statistical and data mining techniques, such as analysis, modeling, clustering and classification algorithms, to analyze historical and current data sets in order to create models to predict future events.

A predictive model (or a baseline model) describes the relationship between a key parameter, typically a KPI such as the equipment efficiency, and its primary drivers. The process of building models, as illustrated in the figure below, involves selecting a baseline dataset, creating and testing a baseline model, and generating one or more target models to track performance.

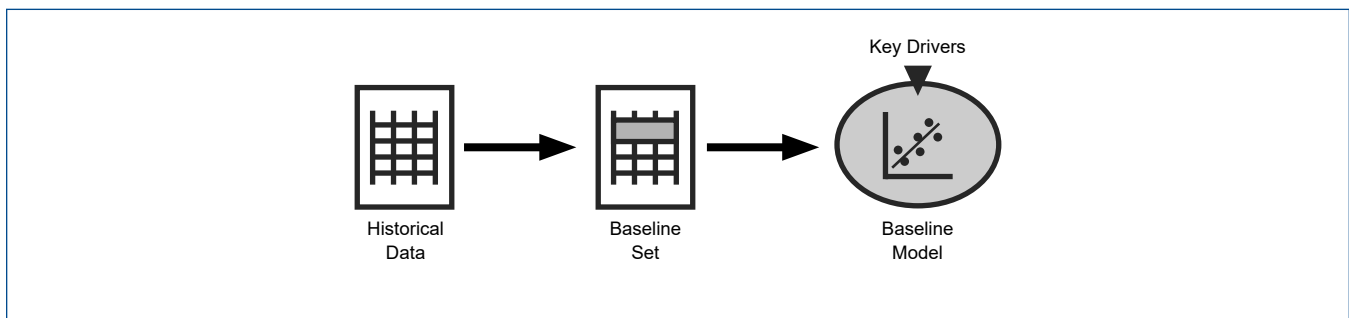


Figure 3: Steps in Building Baseline Model.

## The Baseline Dataset

The baseline dataset is created by selecting a dataset over a defined length of time to capture the behavior of the KPI. To be accurate, the dataset used to build the baseline model should reflect the “normal” behavior of the KPI: shutdown/unavailability periods should be discarded, points corresponding to outliers and abnormal conditions should be removed. The dataset period should encompass the time needed for the process to cycle through its entire operating range.

## The baseline model

The baseline model is built using a correlation table or a correlation graph highlighting often strong relationships between the KPI and the primary drivers. In some cases, there may be a strong linear relationship between the KPI and its primary drivers. Figure 4 shows an example where the KPI, in this case the energy consumption, is plotted against one primary driver, which is the production volume. The trend shows the “best fit” baseline model.

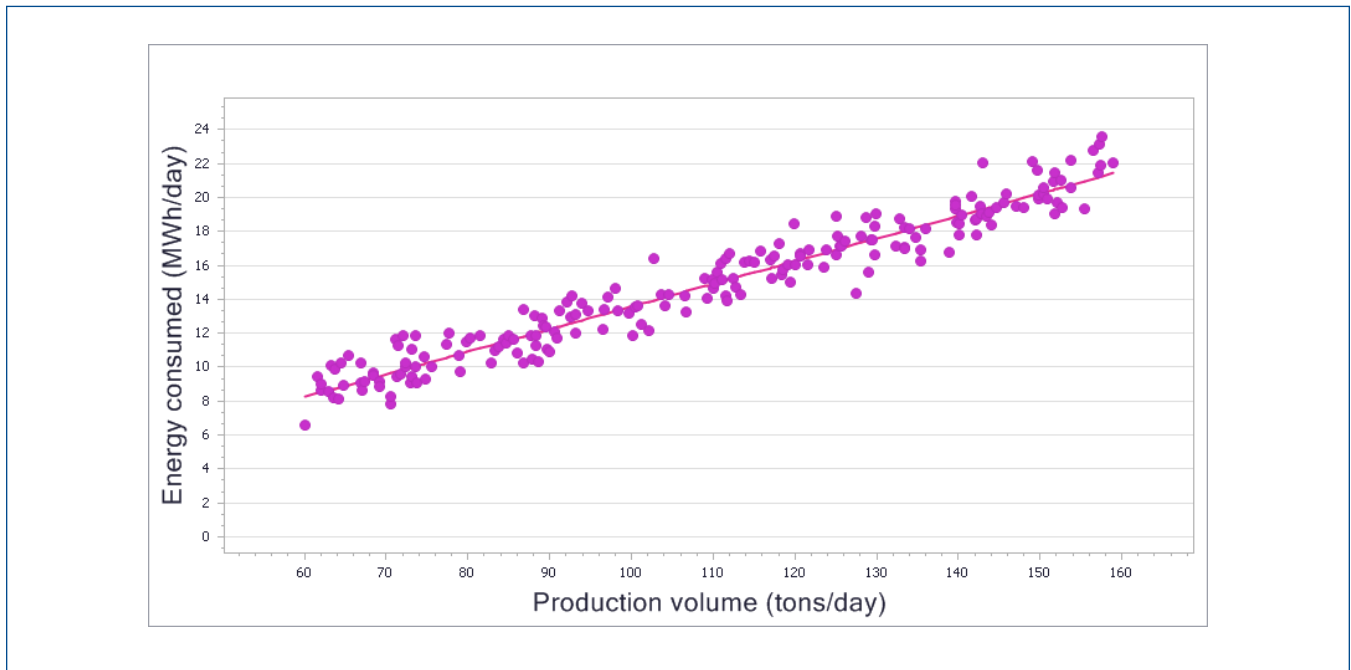


Figure 4: Scatter Plot of Energy Consumption vs. Production Volume.

When the relationship between the KPI and the primary drivers is not linear, technical tools are available to help interpret results and develop appropriate baselines. An interesting case of non-linearity arises when the scatter plot consists of several clusters corresponding to different behaviors of the process. This happens when the process switches between two or more operating modes and process scenarios. Clustering algorithms and identification techniques should be used accordingly to create separate datasets and generate different baseline models, one for each cluster. An example of clustered scatter plot is shown in the figure below.



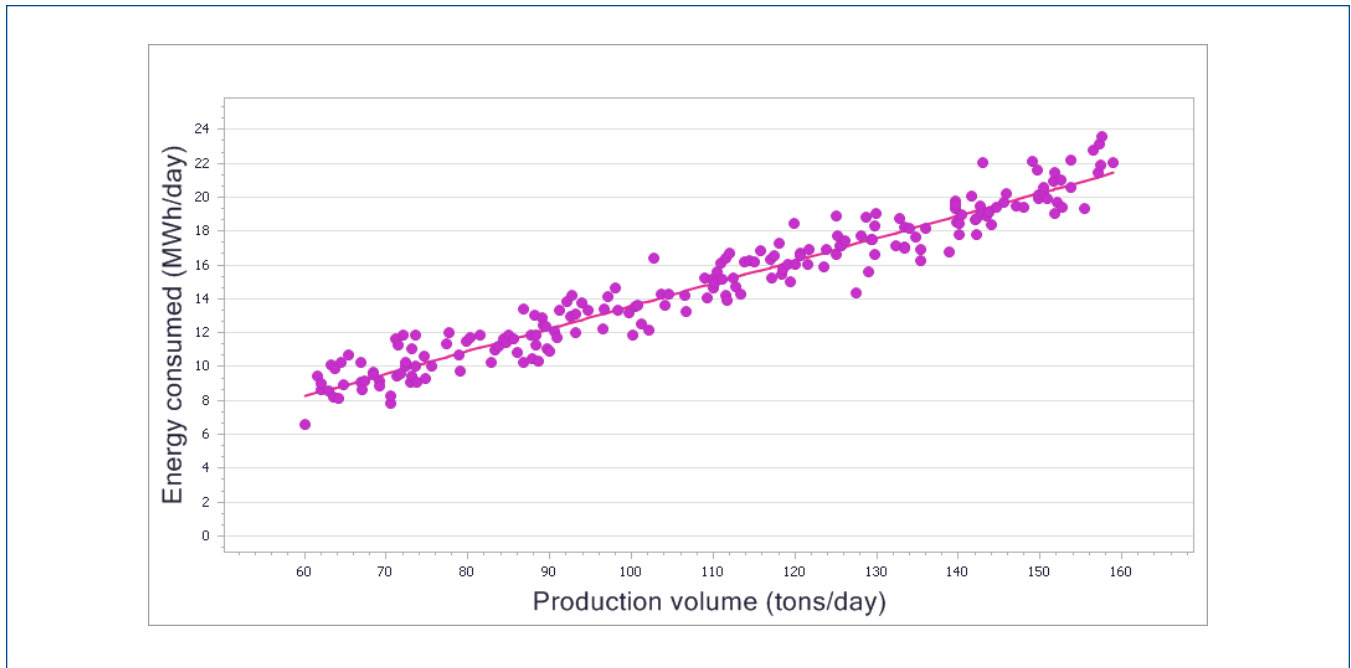


Figure 5: Example of Clustered Scatter Plot with a Best-fit Line per Cluster.

## Rules

Rules are often used to conclude on the asset status and to detect abnormal conditions. The proposed predictive approach takes advantage of the rules functionality to drive any predictive analytics implementation. They will be used to:

- Validate the data inputs to the predictive models in order to eliminate bad data and filter noise,
- Determine when and what predictive models can be applied based on current operating modes, process conditions, maintenance schedule, current equipment status, etc.

Over time, new operating modes will occur, for which there was previously no data. When this happens, there should be rules in place to detect and manage such cases and trigger notifications.

- Validate the prediction results based on sanity checks and logic.

## Integrated Asset Management System

An integrated asset management starts by data management to integrate multiple data silos as companies use multiple systems such as SCADA, DCS, PLC, data historians, online monitoring, Excel spreadsheets, manual data from visual inspections, etc., which often do not easily communicate with one another.

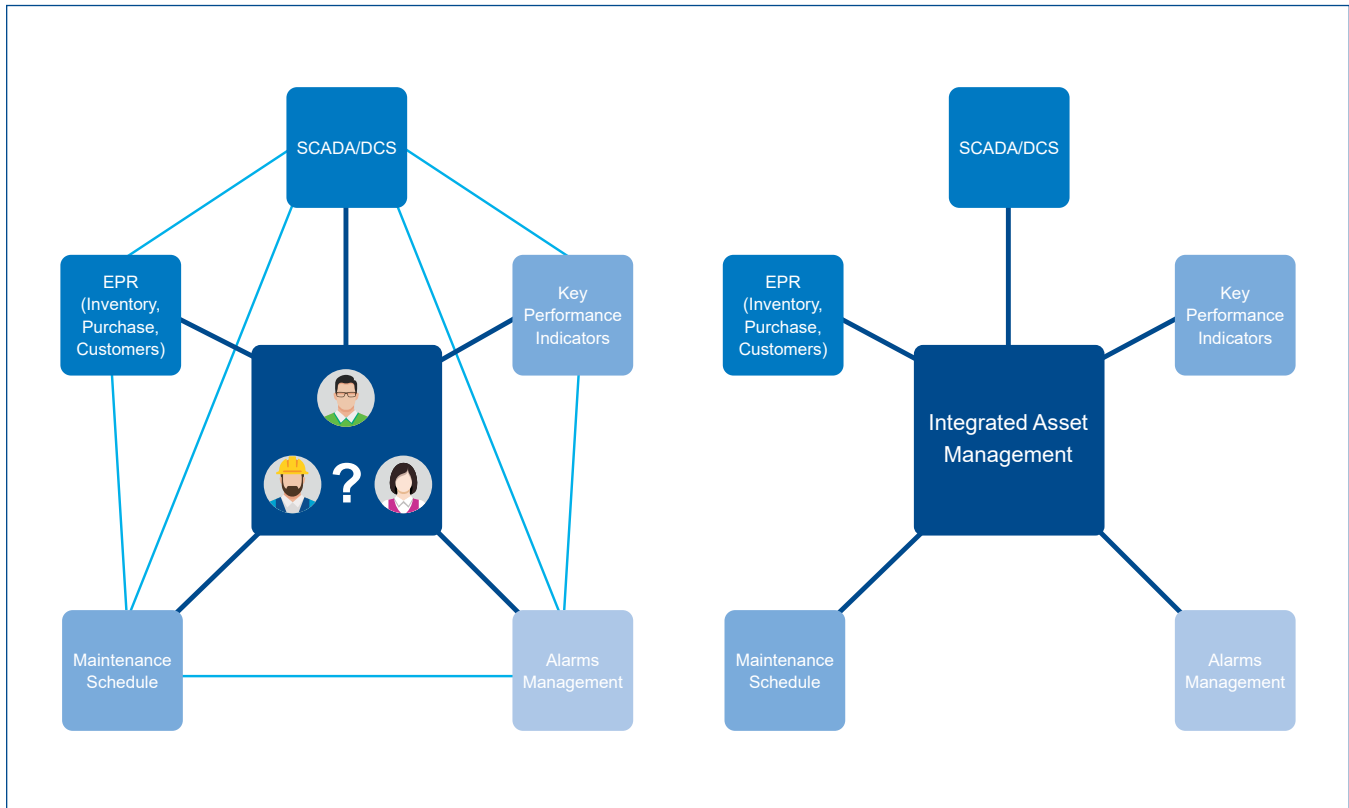


Figure 6: Scattered Silos of Information vs. Integrated Asset Management.

While the data integration challenge can be resolved by using an enterprise service bus technology and is important to provide consistent data models for the assets, integrated asset management should provide an integrated framework allowing organizations to correlate and analyze asset information to ensure plant and assets are running at peak efficiency.

This framework should combine several functionalities in order to achieve this goal:

- Online monitoring that provides operations with a consolidated view of their assets in real-time, automatically correlates equipment status, performance and maintenance information; thus allowing operations to focus on key issues,
- Performance reporting that brings KPIs, statistics and data at users fingertips without having them refer to multiple dashboards, current or past Excel spreadsheets and thus providing tools to drill down into the details of past performance,

- Predictive analytics that are used to predict future performance behavior of the assets in order to increase their reliability and uptime,
- Abnormal conditions management that enables operations to proactively detect equipment issues, identify their root causes and benefit from online advisory about corrective actions,
- Integrated workflow management capability that augments collaboration among organizations' systems and furthers automating business processes such as work orders, equipment failure analysis and predictive maintenance.

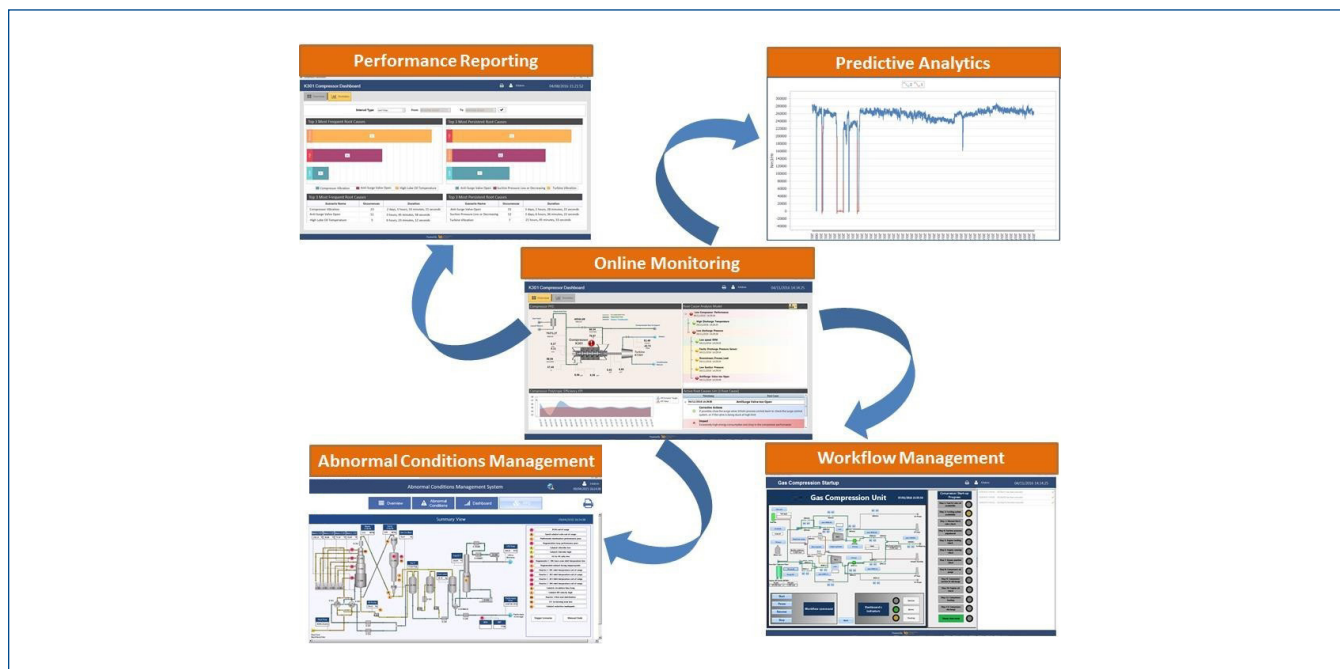


Figure 7: Integrated Asset Management.

## Dynamic Performance Targets

Assessing an equipment performance implies comparing the current equipment performance to a target value. Targets are defined in order to quantify the desired level of performance. Setting the right targets is essential to truly assess the current performance and avoid false warnings of performance gaps.

In this context, equipment operating envelopes are defined as the boundaries that take into account the tightest of the overlapping limits set by safety, environment, quality, reliability, maximum yield and minimum operating costs. Performance targets are also critical to define, for equipment requested to operate under varying values of variables affecting their performance.

To address these challenges, asset performance targets should be developed based on advanced models to dynamically adjust the target to the current process conditions. This is performed using Plantweb Optics Analytics that offers advanced algorithms and tools. It allows defining baseline models that are used to adjust targets dynamically as the process is running and changing based on the automatically detected operating mode, the process scenario, and the processed feed.

This new paradigm of dynamic targets is key in moving operations into a proactive mode by greatly improving equipment reliability and truly assessing assets performance.

## Achieving the Proposed Approach using Plantweb Optics Analytics

Emerson's Plantweb Optics Analytics decision support application includes primarily:

- Data server that collects data from many sources such as DCS, SCADA, data historians, LIMS and ERP.
- Rule engine used to detect complex events by combining logic, events, models, statistics, temporal reasoning, Fourier transforms, etc.
- Root cause analysis engine to build cause and effect fault models that is event driven and can identify the root cause of any predicted issue.
- There are several major differences between Plantweb Optics Analytics Root Cause Analysis (RCA) and other variations of fault propagation models. The first is that RCA is used online and responding in real-time. The other techniques are typically manual efforts and focused on past problems.
- Workflow engine that is event driven and can execute procedural and sequence of actions. Workflows are used to enforce and automate best practices for corrective actions.
- Advanced analytics that help end-users understand the depth of their manufacturing processes, identify different operating modes including abnormal conditions, clean and transform data into useful information, build predictive models and extract knowledge by loading big data and alarm databases.
- Smart Equipment library that encapsulates domain expertise in terms of KPIs, complex event detection models, fault propagation models, workflows and predictive models templates.

Plantweb Optics Analytics also provides tools to facilitate the organization of knowledge and the transformation of data into graphical rules, fault models and workflows, thus simplifying and improving visibility at every level of the plant assets hierarchy. It also provides a graphical object framework that makes applications such as asset management and operational performance reporting easy to deploy.

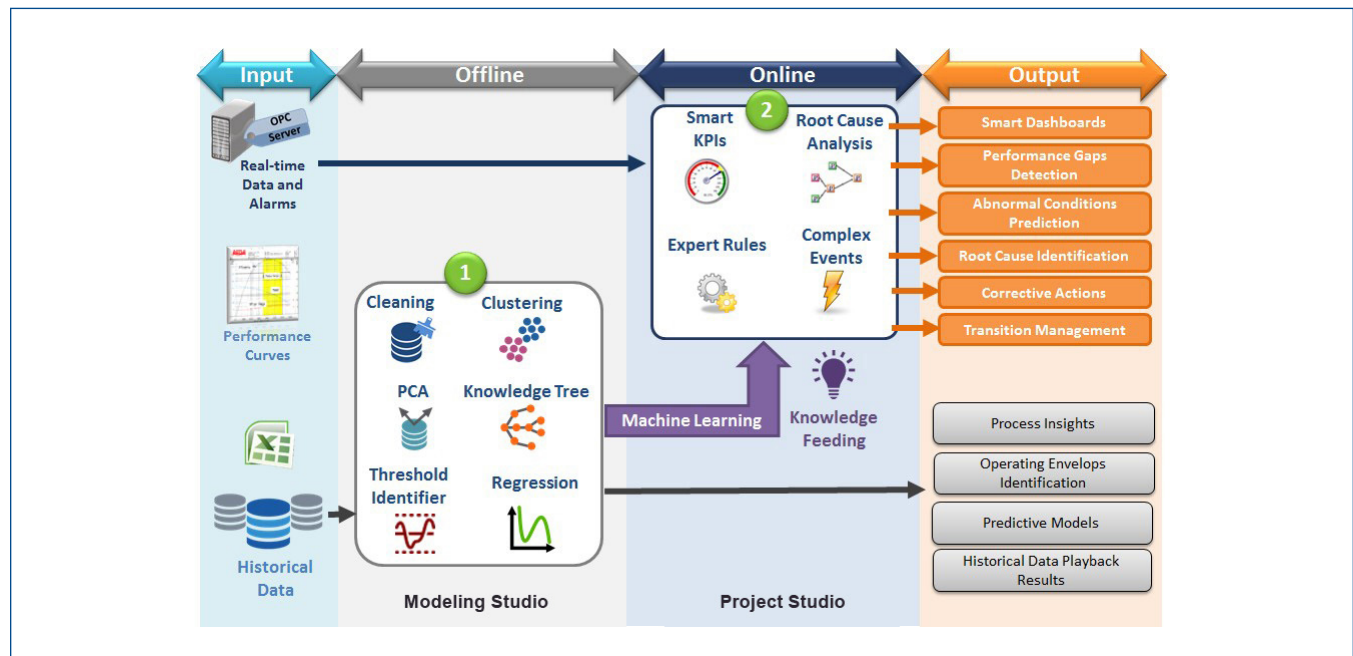


Figure 8: Plantweb Optics Analytics Approach.

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The expected benefits and advantages for the proposed approach and technology are:

- Increased operations performance insights, asset availability and safety.
- Significant reduction of the issue detection, diagnostic, to the corrective action cycle time.
- Reducing the burden of manually analyzing data, collecting information from different sources and manually diagnosing abnormal scenarios.
- Reduced learning curves for the operators and increased reactivity with actionable knowledge online.
- Consistency and best practices in addressing abnormal conditions.
- Retained and shared operational knowledge as needed.

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