KEY PERFORMANCE INDICATORS (KPI) – PACKAGE

Introducing Key performance Indicators into the plant O&M management improves the plant efficiency and reliability.
We offer a comprehensive package of services that includes

- Assessment of the power plant and definition of Key Performance Indicators
- Plant or equipment inspection initiated by long term KPI monitoring, followed by necessary control or maintenance actions. Long term monitoring of KPIs, particularly its variation from set values indicates to the plant O&M team performance degradation or increased risk of equipment or system failure.
- Equipment or System Testing, Troubleshooting & Analysis of the cause of the deviation of KPI. When the KPI exceeds pre-set limit, detailed engineering analysis is recommended to understand the cause of the deviation and identify the solution to rectify

KPIs can be defined for any conventional power plant - Coal, Gas or Oil Fired, Combined Cycle, Geothermal or Biomass fired as well as for any type of plant including Solar, Wind etc.
TEAM

For every project, we put together a team of plant engineers and O&M specialist including:

- Plant Process Engineer
- Boiler Engineer
- Steam Turbine Engineers
- Plant BOP Specialists
- I&C Engineers
- Electrical Systems Engineer

BENEFITS

KPIs can be defined for single power plant unit of for the fleet of power plants operated by any power company. Implementing the KPI package allows our clients to:

- Achieve detailed understanding and control on long term performance, efficiency and reliability of the unit or units operated by the company
- Understand trends in performance degradation or O&M cost variation
- Allow for performance and O&M cost comparison between units with comparable design or technology
- Define and set benchmark KPI values applicable for the plant or units operated by the company and manage the plant O&M to maintain the KPI above the set benchmark value
- Review on Improvement of productivity and profitability
- Review of Annual Operating Plans within the Annual Budgets in accordance with safe and reliable Operation and Maintenance of the Plant.
• Review all contracted and sub-contracted maintenance, repair and testing services as shall be required to carry out scheduled inspections, overhauls and major breakdown repairs.

• Review on the stocking policies of strategic spare parts, taking into account the availability of the Plant, availability and redundancy of different components and lead times from order to delivery, with special attention paid to defining the critical spare parts stock.

• Support the management to optimize the availability, capacity and efficiency of the Plant and minimize the incidence, severity and duration of outages.

Combination of **KPI definition and its long term monitoring**, followed by **equipment inspection and testing** allows the plant O&M team to properly **plan for services intervals, allows for its extension and reduces the O&M cost related to equipment overhauls and refurbishment**

**METHODOLOGY**

The main objective of key performance indicators (KPIs) evaluation and monitoring consists in detecting low performance in power plant operation, investigating issues and setting up maintenance plans in order to minimize the operational costs.

Monitoring the operation of power generating units or groups, identifying decline in their performance and also the need to perform maintenance/repairs is the key to the profitable power plant management.
The main Operation KPI is the **Overall Equipment Effectiveness (OEE) = Availability x Performance.** KPI can further be categorized as:

**A. Operating Performance KPI**  
**B. Maintenance KPI**  
**C. Equipment KPI**  
**D. Inventory KPI**

The methodology is based on the use of industry standards to identify and list applicable performance indicators (KPI). Following criteria summarize major performance indicators

- Plant and its process systems and equipment performance  
- Reliability  
- Peak Capacity  
- Availability  
- Dispatch Response  
- Emissions  
- O&M Costs  
- Heat Rate

The methodology includes engineering & design review of the plant and key process systems and equipment, initial check and assessment of the plant performance and equipment conditions, long term monitoring of the power plant performance and O&M cost.
A. Operating Performance KPI

Improvement in thermal performance can help to achieve a competitive advantage by lowering operation cost and increasing the output. Performance degradation is often good indicator of the types of problems occurring within the equipment. Proper analysis of thermal performance degradation can lead to an early identification of the cause.

Performance monitoring activities have following purpose:

- Detect deterioration in the thermal performance by trending changes in various performance parameters
- Identify by proper data evaluation and interpretation the cause of performance degradation
- Develop cost effective solutions to correct operational and equipment problems that contribute to the degradation in thermal performance

Plant performance testing and supervision

The value of the performance testing and data analysis greatly depends on the quality of the data. The use of acceptance test procedures such as PTC 46-1996 Overall Plant Performance Test and other relevant ASME PTC testing procedures to obtain periodic performance results yields the most accurate test data for analysis and evaluation. Continuous performance monitoring doesn’t necessarily require absolute accuracy, but is useful in establishing accurate trends of various performance characteristics.
Process values alone usually give no information about the efficiency or the process quality of a plant. Performance indicators are determined by using multiple process values of various plant process systems & equipment.

**Key performance indicators for steam power plants**

A. Steam generator
   - Thermal efficiency according to DIN or ASME PTC
   - Efficiency economizer
   - Efficiency feed water preheater

B. Condenser
   - Expected condenser pressure
   - Cleanliness/heat rate

C. Feed Water System – Heaters
   - Logarithmic linear medium temperature difference
   - Heat rate impact
   - Efficiency

D. Steam turbine
   - Thermal efficiency/ heat rate impact
   - Isentropic heat power extractions
   - Shaft power

E. Unit balances
   - Heat rate of unit
   - Auxiliary power consumption
   - Auxiliary steam consumption

One of the operating KPI is the controllable losses of the plant ie values that can be controlled by the power plant operator. The controllable losses have direct impact on the plant performance if the process value deviates from the design / set values. List of key controllable losses includes:
Key performance indicators for combined cycle power plants

A. GT calculations acc. ISO2314, DIN4341, ASME-PTC22
   • Calculate actual efficiency and exhaust mass flow and enthalpy
   • Correct expected power and efficiency to ISO conditions based on correction curves for:
     o ambient air pressure, temperature, humidity
     o dp inlet and exhaust
     o grid frequency
   • Calculate expected power and efficiency from design curves

B. HRSG calculations acc. ASME-PTC4.4
   • Calculate actual thermal efficiency according to either:
     a. input / output method
     b. thermal loss method
   • Calculate actual exergetic efficiency
   • Expected efficiency based on correction curves can be calculated by using the math and core tools
The assessment of each item includes

- Actual measured value
- Design value
- Impact on plant efficiency / heat rate
- Additional plant fuel consumption

Thermal model calculates deviations between actual and expected performance and converts performance deviation to short and long-term degradation.

The picture show an example of the plant thermal model that shall be developed and used to review operating performance of the cycle and equipment and identify deviations between actual and expected performance values.
B. Maintenance KPI

Preventive maintenance activity has a direct impact on the reliability of the equipment or components by improving their technical condition and prolonging their life. All maintenance procedures involve both costs and benefits. Maintenance operations are profitable when the costs are lower than associated potential cost of a failure, which these operations are trying to prevent.

Most of the maintenance plans on short and medium term do not take into account the operation conditions in which the components operated throughout their runtime but rather are scheduled based on the occurrence of defects and previous repairs.

But, in recent years, several applications for continuous monitoring of current operation led to the development of a variety of diagnostic techniques. These techniques verify certain parameters and then analyze whether certain components are defective at the moment and can make an estimate of their evolution.

The main purpose of the maintenance plan is to minimize production costs per unit of energy generated.

Too little maintenance causes an excessive number of unplanned stops resulting in lost production and emergency maintenance. Too much maintenance causes large maintenance costs and lost production during each planned maintenance.
KPIs include:

- Total maintenance cost per equipment / system
- Maintenance costs / Produced output over a time period.
- Maintenance time /Produced output over a time period.
- Number of alarms over a time period.
- Ratio of planned maintenance costs vs actual maintenance costs
- Mean time to Repair
- Mean time between failures
- % Availability of equipment

The objective is to set the timeframe for periodic inspection, maintenance of the plant systems and equipment and identify methods to evaluate costs and effectiveness of the plant maintenance.

C. Equipment KPI

These KPIs can be used to follow the condition of equipment and in some cases also predict when maintenance will be required. Following can be basic indicators signaling maintenance action

- Different types of efficiencies e.g. heat transfer rate of heat exchangers, pump/fan efficiency, drying efficiency, etc.
- Equipment wear (based on e.g. operating hours, speed, load, startups)

The objective is identification of process signals or combinations of process signals that are strongly correlated with the KPI of interest. The KPI is then improved by changing the correlated process signals in the direction that improves the KPI.
As an example the calculation and monitoring of condenser heat transfer coefficient can be applied (for condenser, heat exchangers or HRSG sections etc).

Heat Duty

\[ Q_{th} = F \text{ Cooling Water} \times c_p \times (T_2 - T_1) \]

Log Temperature Difference

\[ \Delta T_{\text{log}} = \frac{T_2 - T_1}{\ln\left(\frac{T_{\text{condensate}} - T_1}{T_{\text{condensate}} - T_2}\right)} \]

Heat Transfer Coeff

\[ K = \frac{Q_{th}}{S \Delta T_{\text{log}}} \]

Another example for coal fired boiler can be monitoring of S2 content in fuel, calculation of flue gas dew point and monitoring of flue gas exit temperature.

Many power plants experience issues with limited lifetime of air heater, caused by increased level of corrosion. This is typically caused when the boiler operates at partial load or at any mode when the combination of flue gas temperature, inlet air temperature and flue gas dew point results in condensation of water and sulphuric acid on air heater tube surface. Long term monitoring of flue gas exit temperature, flue gas dew point and S2 content in fuel may help to the operator to protect and extend air heater lifetime.
Typical list of plant equipment or process systems that can be monitored using KPIs includes:

- Steam Generators (SG)
- Heat Recovery Steam Generators (HRSG)
- Combustion stoichiometry (for SG or HRSG)
- Gas turbines
- Steam turbines
- Feed water heaters
- Evaporators
- Super heaters
- Heat exchangers
- Desuperheaters
- Air preheaters
- Condensers
- Pumps, fans
- Generators
- Overall plant balance
- Auxiliary power and steam
- District heat
- Process steam
- Mathematical and statistical calculations
- Water/steam properties
- Gas properties
D. Inventory KPI

Large inventories are expensive, too small inventories may cause production disturbances. The plant maintenance may use parts available permanently on the site, part available for delivery on long / short notice as well as list selected suppliers of parts or services required for plant O&M.

The objective is to set efficient spare part management system.

SCOPE OF SERVICES

The scope of works includes identification of applicable KPIs to monitor the plant performance. The scope of works includes and is limited to:

A. Engineering & design review

- Thermal calculation and heat balance of the plant and main equipment
- Equipment inspection and assessment of mechanical conditions and process performance
- Boiler/Turbine/BOP Performance Test Assessment
- Boiler Performance Analysis
- Steam Turbine Cycle Performance Analysis
- Other plant systems performance analysis
B. Initial check and site assessment

The purpose of the initial check is to analyse the existing status and condition of the plant and to collect all necessary data and to set up the basis for more detailed analysis.

C. Long term operation check / monitoring (the long term by the plant operating personnel)

Based on the result of the initial check, the scope of services will include identification of plant systems that will be monitored on long term basis to understand and optimize the performance. The target will be to continuously analyse selected plant systems to identify various options to control and manage O&M activities.

D. Identification of applicable KPIs

The result of the engineering & design review, assessment of the plant conditions and performance, review of maintenance records and history, assessment of the plant, process systems and equipment conditions will set the basis for identification of applicable KPI.