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# DATA DRIVEN PREDICTIVE MAINTENANCE INFORMATION TO ENHANCE HUMAN DECISION MAKING IN GAS TURBINE OPERATION & MAINTENANCE

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## ABSTRACT

An effective way to mitigate or reduce the increasing risk of both technical and human error in gas turbine operation & maintenance is to establish a solid and reliable technical baseline for the GT installation and to support the GT operation & maintenance decision making process at all management levels with a dedicated decision support solution based on data driven predictive maintenance information.

This paper describes how a technical audit and subsequent improvement program can establish a solid technical baseline for a GT operation and it illustrates this with the outcomes of a technical audit and improvement program at a major Oil & Gas operator in Europe.

It also describes how raw GT engine operation data can be enriched through automated analysis (with the help of a tailor-made digital engine model) and can be enhanced by expert interpretation (experienced GT maintenance engineers) to transform these raw engine data into effective predictive maintenance information in a cyber secure way.

This predictive maintenance information is presented to the GT operation & maintenance staff on site in the form of practical & easy-to-understand recommendations and dashboards to enhance the quality of human decision making in gas turbine operation & maintenance.

The paper concludes with a case study how this tailormade form of decision support has contributed to improved O&M decision making and reduced unscheduled stops at a major Oil & Gas operation in the North Sea.

## INTRODUCTION

Every day gas turbine plant managers, operators, maintenance engineers & procurement officers face many decisions on how to run their plant in the best possible way. The potential profitability of a gas turbine operation depends largely on the quality of the day-to-day decision making by all these persons involved.

The heavily increased focus on cost reduction in gas turbine operation & maintenance over the past years has resulted in less specialized gas turbine plant managers, operators & maintenance engineers on site and in unnoticed negligence of routine daily maintenance. This situation has increased the risk of technical & human error in gas turbine operation & maintenance.

Many companies have tried to cope with these issues by implementing remote monitoring & diagnostic systems (solutions, services) that promise immediate improvement of GT operation & maintenance. Operators who have worked with these solutions have experienced that they do not always bring the value that they had expected. We often encounter a mismatch between the expectations and requirements of GT operators (systematic improvement of day-to-day operation & maintenance over a longer period-of-time) and the actual data & information supplied by the various remote monitoring & diagnostic systems.

## SYSTEMATIC IMPROVEMENT OF GAS TURBINE OPERATION & MAINTENANCE

Systematic improvement of day-to-day gas turbine operation & maintenance over a longer period-of-time requires systematic reduction of both technical error and human error in day-to-day operation & maintenance processes. The value that remote monitoring & diagnostic systems can deliver to operators and maintenance managers depends largely on two factors:

1. the quality of the input data into these systems (garbage in is garbage out).
2. the ability of operation & maintenance managers to translate the output data from these systems quickly into effective operation & maintenance actions.

## FACTOR 1: THE QUALITY OF DATA INPUT INTO A DIAGNOSTIC SYSTEM

Applying advanced remote monitoring & diagnostics on an engine with a below average availability, reliability & performance will only result in a huge amount of notifications with no clues to the causes and effects of the signalled issues. This kind of information will provide very limited guidance for systematic & sustainable improvement of the operation.

To provide the best quality input signals into a remote monitoring & diagnostic system the entire gas turbine operation needs to be in a good and reliable technical baseline condition. This will result in a limited amount of deviations from the optimal GT operation that can be easily monitored and followed up quickly.

An effective way to establish such a good and reliable technical baseline condition is to perform a technical audit on the entire GT operation and to execute the recommended improvement program to bring the operation up to pre-defined required levels of availability, reliability, maintainability and performance. Such an established baseline condition provides a solid foundation for the generation of reliable input data for monitoring & diagnostic systems.

### Case study: Operational results before and after a technical audit and recommended improvement program

Customer

Oil & Gas Operator in Europe with DLE LM's

Customer objective

Improve poor operational results by improving availability, reliability & maintainability and by reducing the number of trips / unscheduled stops.

Operational results before

Operational results in the year before arrival VBR on-site:

- availability in previous year: 78%
- reliability in previous year: 82%
- number of trips in previous year: 22

VBR technical audit and improvement program

VBR executed a technical audit and the proposed improvement program which included operation & maintenance training for all staff on-site over a period of approx. 1,5 years.

Operational results afterwards

Operational results in the first year after executing the technical audit and the recommended improvement program:

- availability in following year: 88%
- reliability in following year: 94%
- number of trips in following year: 2

## FACTOR 2: THE TRANSLATION OF DATA OUTPUT FROM A DIAGNOSTIC SYSTEM

Most monitoring & diagnostic systems provide a wide choice of possible data views, analytics, zoom-in possibilities etc. In the past years we have observed that the amount of available options and choices in most systems is so overwhelming that the effective use of these systems requires a long learning curve and working with it every day to get sufficiently acquainted, educated and experienced to retrieve the right information for day-to-day operation & maintenance decision making. For most operators and maintenance managers this is not the preferred way of working. They like to have 24-7 overviews of the overall status of their operation, to receive timely and correct signals when something is about to happen and to receive easy-to-understand practical recommendations how to act on these signals in the most effective way. This enables them to take the right operation & maintenance decisions at the right time every time again.

## FROM REMOTE DIAGNOSTICS TO DATA DRIVEN DECISION SUPPORT

To support GT managers in their ambition to realize systematic improvement of day-to-day GT operation & maintenance over a longer period-of-time VBR Turbine Partners has developed a cyber secure decision support service which is enabled by data driven predictive maintenance information. This service provides predictive maintenance information in 4 clearly defined steps:

1. cyber secure 100% one-way acquisition of all relevant engine data.
2. automated analysis and intelligent diagnostics to transform raw engine data into useful information and smart alarm management. Acquired engine data are compared with the outcomes of a tailormade digital engine model (digital twin) to detect early deviations from the ideal operation modus.

3. professional interpretation of the information and insights gained. Specialized & experienced maintenance engineers draw conclusions from the enriched engine data, automated analysis and smart alarm management info.
4. feedback to GT operation & maintenance management in the form of recommendations, easy-to-understand dashboards and periodic reports to enable quick and effective O&M decision making.

## BENEFITS OF ENHANCED DECISION MAKING ENABLED BY DATA DRIVEN DECISION SUPPORT

- sustainable higher GT revenues.
- sustainable lower GT O&M costs.
- improvement plant safety & employee wellbeing.
- sustainable reduction of environmental impact.

## THE VALUE OF ENHANCED DECISION MAKING ENABLED BY DATA DRIVEN DECISION SUPPORT

- realize better results in a more professional way.
- be more in control (relevant decision information & support available 24/7).
- reduced risk of management liability for safety, health or environmental issues.
- feel more confident about the entire GT operation.

## TWO CASES OF ENHANCED DECISION MAKING ENABLED BY DATA DRIVEN DECISION SUPPORT

Customer
Oil & Gas Operator in the North Sea.

Customer objective
Improve operational results by reducing the number of trips / unscheduled stops by at least one per year (for quick ROI).

Issues not visible on the HMI

Not long after implementation of the remote decision support service this operator detected two issues for which the HMI of the control system did not provide any indications about upcoming failures:

### Case 1: Temperature deviations in two thermocouples

The running data of the engine showed temperature deviations in two thermocouples that were not visible for the operators on the HMI of the control system.

After analyzing and interpreting the enriched engine data VBR recommended to assign dedicated time and attention to inspect the thermocouples, the complete fuel lines and the fuel nozzles at the next scheduled engine stop. We also recommended to bring sufficient replacement parts on-site in case the parts to be inspected would appear to be defective. During this additional inspection the fuel nozzles were found defective and some fuel lines appeared to be clogged. All required repairs could be performed immediately and within the time window reserved for the scheduled engine stop because all required spare parts were already brought on-site. This timely decision for an additional maintenance intervention has prevented hot component thermal stress and has prevented the engine from tripping in the foreseeable future due to unnoticed temperature spread.

### Case 2: Deviations in actuator positions

The running data of the engine showed small but increasing deviations in some actuator positions. These deviations were not visible for the operators on the HMI of the control system.

After analyzing and interpreting the enriched engine data VBR recommended to bring sufficient new actuators on-site and to replace all deviating actuators at the next scheduled engine stop.

This additional intervention has prevented the engine from not starting up in the foreseeable future due to unnoticed actuator problems.

## SUMMARY

Human decision making in GT operation & maintenance can be effectively enhanced by implementing a user-friendly decision support solution based on data driven predictive maintenance information.

Important prerequisite for the effective implementation of any management decision support system: the entire GT operation needs to be in a good and reliable technical baseline condition to provide reliable input data for the initial engine health condition monitoring.