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Performance Monitoring

Using COMPASS to optimise Plant performance

1. Introduction

COMPASS is being used on major petrochemical processing facilities throughout the world to provide safety, condition and performance monitoring. This document gives an overview of the typical benefits of performance monitoring.

Compressors, turbines and pumps performance degrades over time due to irreversible mechanical wear, and recoverable loss due to fouling and changes in operating conditions. A typical plant may lose up to 10% efficiency over several years of operation, most of which could be recovered through maintenance activities and process fine tuning if only operators and maintenance staff had access to the necessary data. These losses amount to significant amounts of money, and often go unnoticed in plants today. COMPASS performance monitoring system gives operators the necessary information to accurately assess machine performance, and schedule maintenance activities to optimize plant production.

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2. COMPASS performance monitoring

There are many performance monitoring vendors in the market today including machine manufacturers and DCS suppliers. Therefore it is important to outline the main differences offered by the COMPASS integrated performance monitoring solution.

1. Brüel & Kjær Vibro is not aligned with any machine or DCS vendor, and therefore gives the operator an ***independent*** assessment of machine performance. Due to the structure all calculations can be verified and if required in a dispute reviewed by 3rd party inspectors or company in house specialists.

2. COMPASS performance monitoring is ***integrated*** with vibration monitoring, giving operators the vibration, process and performance data necessary to accurately assess machine condition. Data stored in the powerful ORACLE based database is stored for very long periods. This enables the end-user to compare individual minor or major overhauls, even if they are 6 years apart.

3. The Performance algorithms are stored in a database, which ***automatically*** updates the results. All calculations a preprogrammed after the commissioning phase, and on fixed intervals, e.g. once per half hour, a complete calculation cycle of all machines on the plant is performed. There is no need for operator intervention or calculations/corrections based on operator methods. It has been shown that Performance monitoring has the highest benefits when the calculations and corrections are executed at the same way for a very long period.

4. The COMPASS database has a built-in real gas ***gaslibrary & steamtable*** which automatically corrects for changes in gascomposition or steam property.

5. Several machine trains can be monitored in a ***single*** COMPASS system, allowing quick comparisons between machines on different trains. Benchmarking machines or filters due to fouling is extremely simple. If for example two different filters are used, and they are assessed in a single database, they can easily be benchmarked.

6. COMPASS uses the ***internet*** to allow users to access the information when and where they need it. Through secure communication lines, SSL level 3, specialists from Brüel & Kjær Vibro, company headquarter, machine vendor and/or external consultants can review the data without the need for travelling.

7. COMPASS is an ***open*** system, allowing customers to view and edit all performance calculations. This results in traceable calculations and their input signals. The input signals required can be measured by the COMPASS system or, be transferred via a network link from the DCS. There is no need for extra hardware in this case resulting in a cost-effective solution.

8. All calculations are ***corrected*** to reference ISO or ASME operating conditions and compared to baseline data to give a true assessment of machine condition. All calculations can be performed and corrected for both ***baseload*** and ***partload***.

9. Alert alarms can be configured for all calculations to give operators an ***instantaneous*** overview of plant performance. The philosophy for alarms and alarm view/acknowledgement for performance calculations is identical to the vibrations alarms to ensure an easy to use user interface.

10. COMPASS is an ***expandable*** system, that grows with the end users needs. New machines can be added at anytime as required. End-users can extend the database

with any machine or piece of equipment (e.g. Heat Exchangers) without the need for Brüel & Kjær Vibro to be on site to make the changes.

11. The COMPASS system design ***distributes data*** in a way that operators and machine specialists have the information they need. Typically the DCS operator has all process data, which is transferred to the COMPASS database. This full database is used by machine specialists, typically Rotating Equipment Engineers, who correlate the process signals with the rotordynamics from the vibration sensors. As soon as the Performance calculations are completed, Key-Performance Indicators (KPI) are then send back to the DCS for information to the DCS operator. Typical examples of KPI are, compressor efficiency (corrected), power delivered by driver and absorbed by driven machine etc.

3. Benefits of performance monitoring using COMPASS

Significant economical benefits can be achieved using COMPASS performance monitoring throughout the life of a plant, some of which are outlined below.

1. During plant design

To enable accurate performance calculations the machines must have adequate sensors installed. Brüel & Kjær Vibro provides customers with calculations that show the effect of missing input parameters on the quality of performance monitoring calculations. Detailed accuracy calculations are provided which indicate the expected tolerances in the calculated results.
Based on requirements from customers, the calculation in the performance software and the corresponding alarms are tailored for its function, this can be a maximum efficiency to reduce fuel costs, or in some instances the production shall be maximised even at higher fuel costs.

2. During baseline testing

COMPASS can be used to independently monitor machine performance during baseline testing at the machine vendors site. This ensures any deviations from design are detected when they can still be fixed, before site installation. Furthermore all baselines are already available in the database, so at first start-up the thermodynamic characteristics can be compared.

3. During plant startup

COMPASS performance monitoring is used to help the end user ensure that each machine is operating as it was designed. Furthermore, the detailed thermodynamic (performance) & rotordynamic (vibration & frequency analysis) information of the machine is available in the same operator display, time synchronised for cause and effect analysis.

4. During daily operation

Only by measuring actual machine degradation can maintenance and production departments coordinate activities. The scheduling of on- and off-line washing is an example where COMPASS is used to optimize plant efficiency.
The design of the Performance module focuses on achieving reliable trend signals, this is ensured by means of basic data validation techniques, a built-in real gaslibrary, and several fallback techniques where a signal is measured/calculated in more then one method. An example is the flow which can be measured by a transmitter, but also calculated based on differential pressure & orifice data or calculated based on a heat balance.
Plant operating efficiency is improved by giving operators the information they need on their desktop to run the plant. Since the COMPASS system provides a single platform and database for all rotating machines on the plant, the operators have an instant overview of the critical machines performance.

5. For maintenance planning

Maintenance personnel use COMPASS to schedule small maintenance actions such as on-line compressor washes or complete plant shutdowns while ensuring that the necessary spares are available on time.

6. Plant restart after shutdown

After machines have had a major overall, COMPASS is used to ensure that their efficiency has improved and plant output increased. All changes in the machine, e.g. change of nozzles shall reflect their influence on the Performance results. Since the COMPASS database stores data for many years, individual overhauls can easily be compared to each other.

7. Special applications

Several specialized packages are available for specific applications including:
ESD valve monitoring, continually monitors valve operation and reports on deviations from design parameters.
Transient process data capture provides the necessary high resolution data for post trip analysis.
Dedicated algorithms can be implemented to calculate remaining lifetime of components in the hot gas path in gasturbines to enable accurate planning of a major overhaul.

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4. What to do if your existing plant does not have a gas chromatograph or is missing instrumentation

Often machines on a existing plant are not foreseen of all instrumentation or of a gas chromatograph to determine the gascomposition. Many people believe that Performance Monitoring is then not possible, and this is true for a certain extent. However, several options are available to make performance calculations of your machines taking into account the lack of instrumentation or gascomposition. Brüel & Kjær Vibro can make a complete performance strategy and analysis of available calculations, fall back methods and accuracy based on existing instruments. This can result in several options such as:

- If the gascomposition is stable or almost stable the composition can be entered manually, and used as a fixed value.
- Performance Indicators that are not influenced by the gascomposition can be calculated, corrected to ISO conditions and trended at any time. Examples of these indicators are Power, CPD, compressor (e.g. of gasturbine) efficiency and exhaust temperature.
- Alternatively some very slow degrading thermodynamic performance parameters can be taken as a fixed value, and basic data validation techniques can be applied to check if the gasproperties are within specified limits. Examples of these fixed properties are swallowing capacity and efficiency of an expansion/power turbine.

Off course the results will not be as accurate as with all instrumentation available, but a perfect world does not always exist. Brüel & Kjær Vibro has designed the COMPASS System to be able to operate it in a normal plant.

5. Monitored machines

Brüel & Kjær Vibro has extensive experience in Performance Monitoring critical machines. The machines that we have covered in previous projects that has seen benefits from performance monitoring at a plant are outlined below:

Machine Type	**Examples of machine types monitored by COMPASS**
Gas Turbines	GE Industrial F3, F5, F6, F7 and F9 GE Aero derivative LM1600, LM2500, LM6000 Solar Taurus, Centaur Siemens V64, V84, V94 Rolls Royce RB 211
Steam Turbines	Siemens
Compressors Single-stage, Multi-stage, Admission flow, Reciprocating	Dresser Rand Sulzer Nuovo Pignone Thomassen Borsig GHH Demag P. Brotherhood Atlas Copco Elliott
Turbo Expanders	Sulzer Mafi-Trench
Pumps	Ebara, David Brown
Hydraulic Turbines	Ebara
Helper Motors	ABB

Table 1: List of key machines that can benefit from performance monitoring

6. Some examples

The COMPASS performance monitoring system has been operating on several oil & gas processing plants throughout the world from Australia to the United Kingdom, since 1999. Operators at these plants have used the results from COMPASS to optimise plant maintenance schedules, increase production, lower fuel costs etc. only to have in mind a single desire: to increase economic output.

Significantly, all of these customers have expanded their initial COMPASS systems to other areas of the same plant, or to other plants within the same company, once the benefits have become clear.

7. Contacts:

For more information, please contact:

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Some plots from the COMPASS performance monitoring system are shown below.

Monitoring efficiency vs. time, with COMPASS means you know exactly when to wash the turbine.

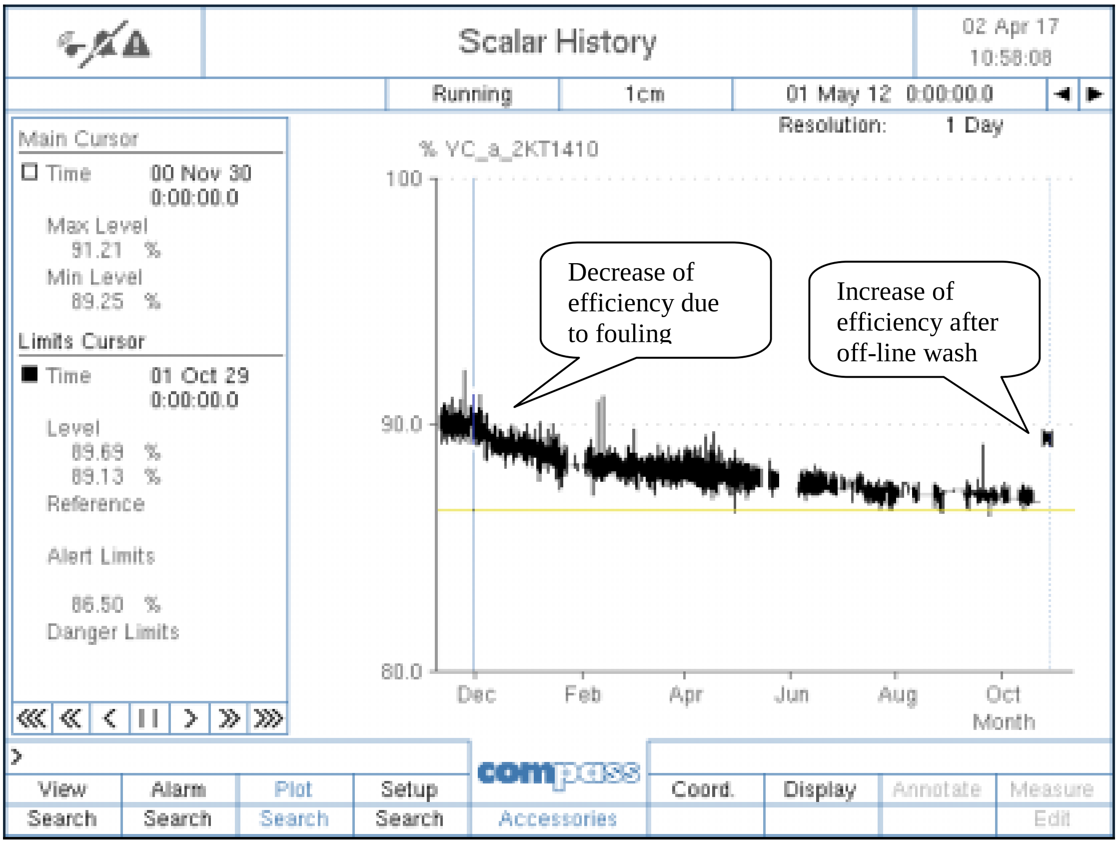

Figure 1**: Machine performance degrades overtime due to mechanical degradation and fouling. Loss due to fouling is recovered after off-line washing.**

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Monitoring efficiency vs. time, efficiency increase due to Off-Line wash of axial compressor

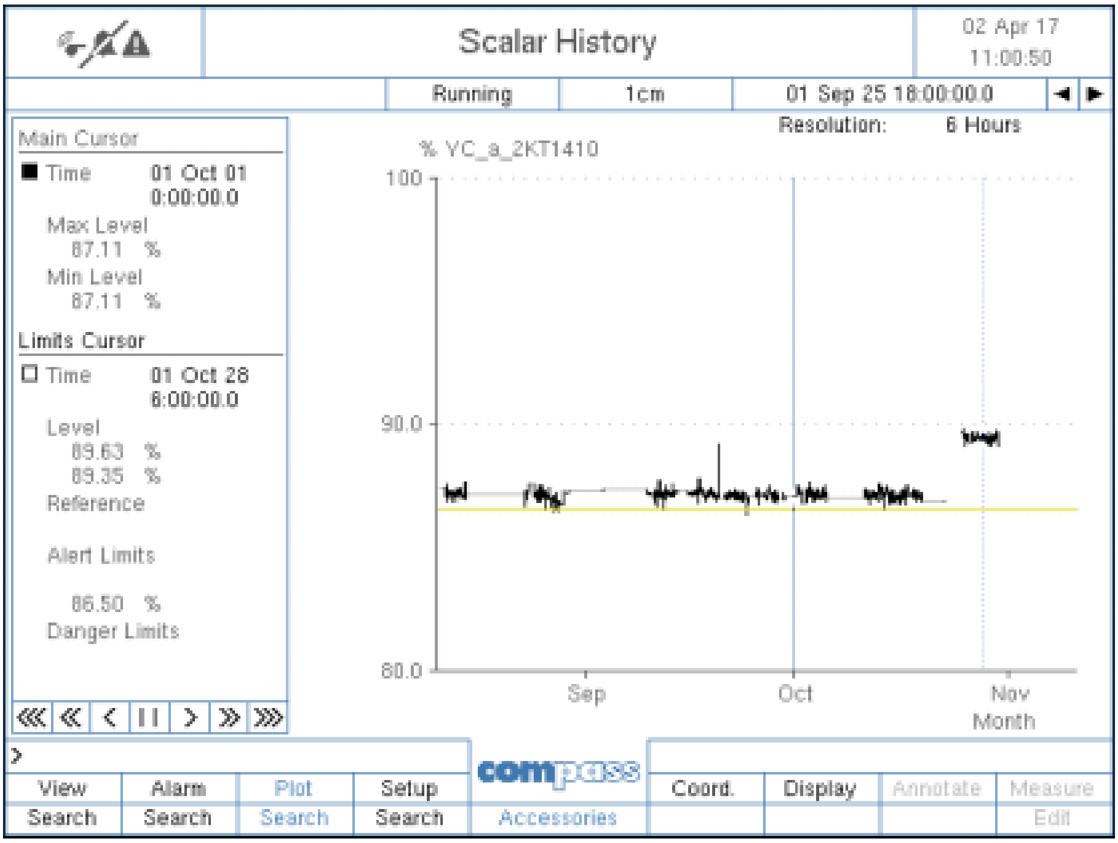

Figure 2**: Detailed picture of effect of Off-Line wash.**

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Effect of Off-Line wash on Power Output, relative loss (corrected for ISO condition) in %.

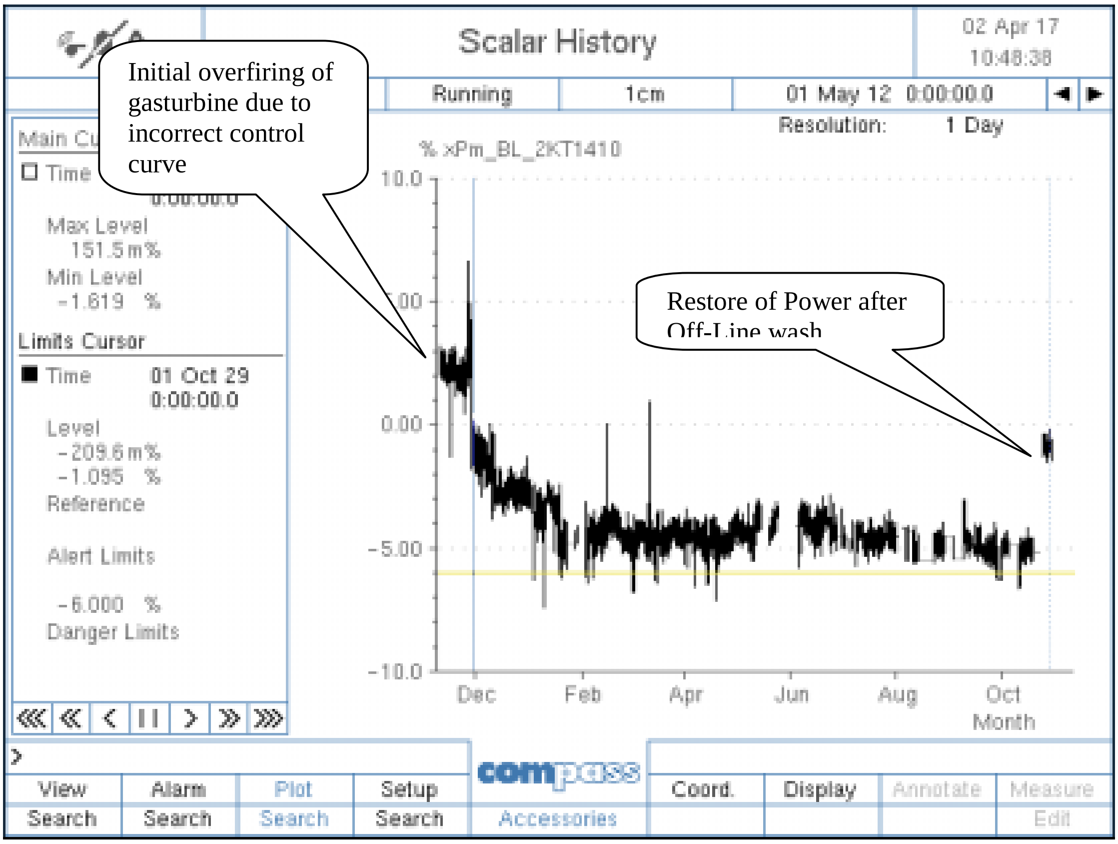

Figure 3**: Power Output of the gasturbine is influenced by fouling and Off-Line wash.**

Faulty On-Line wash installation is identified by overlay of Compressor Discharge Pressure & thermocouples after axial compressor.

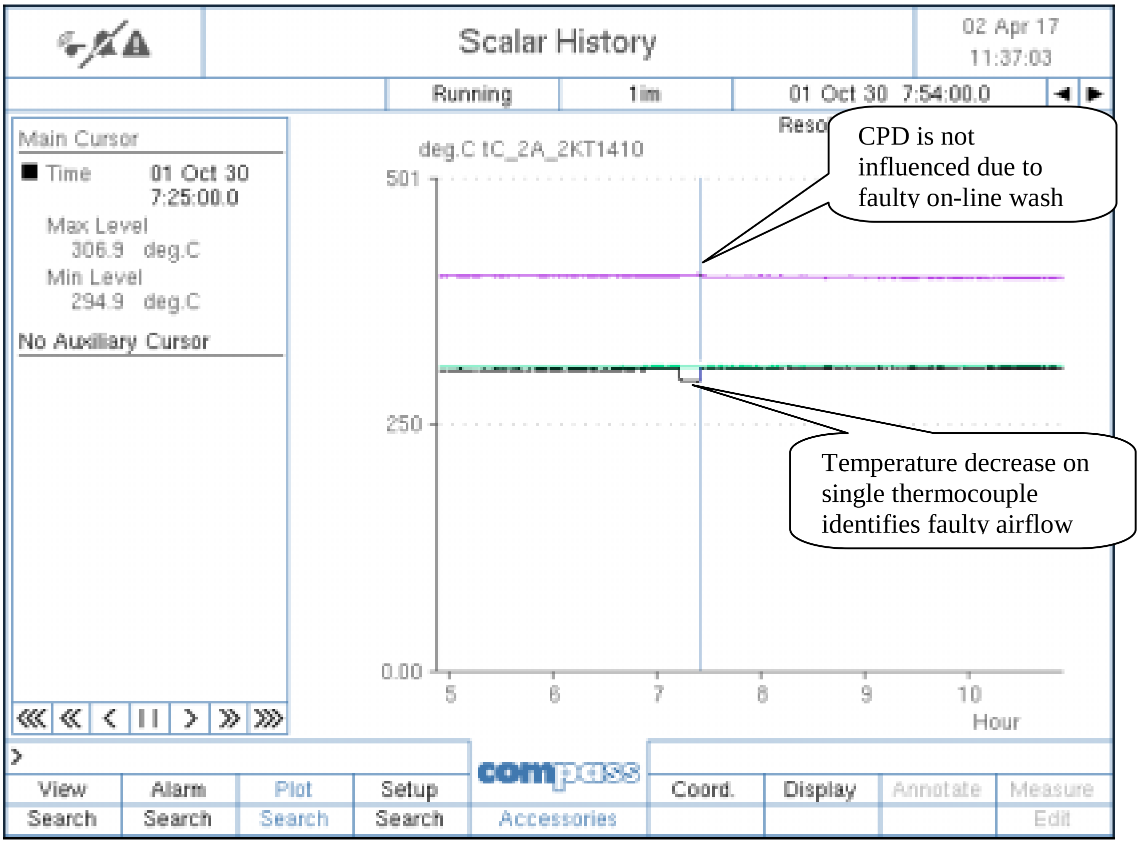

Figure 4**: Overlay of CPD and thermocouples after axial compressor.**

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Independent Control Curve check will identify overfiring of gasturbines, which results in reduced lifetime.

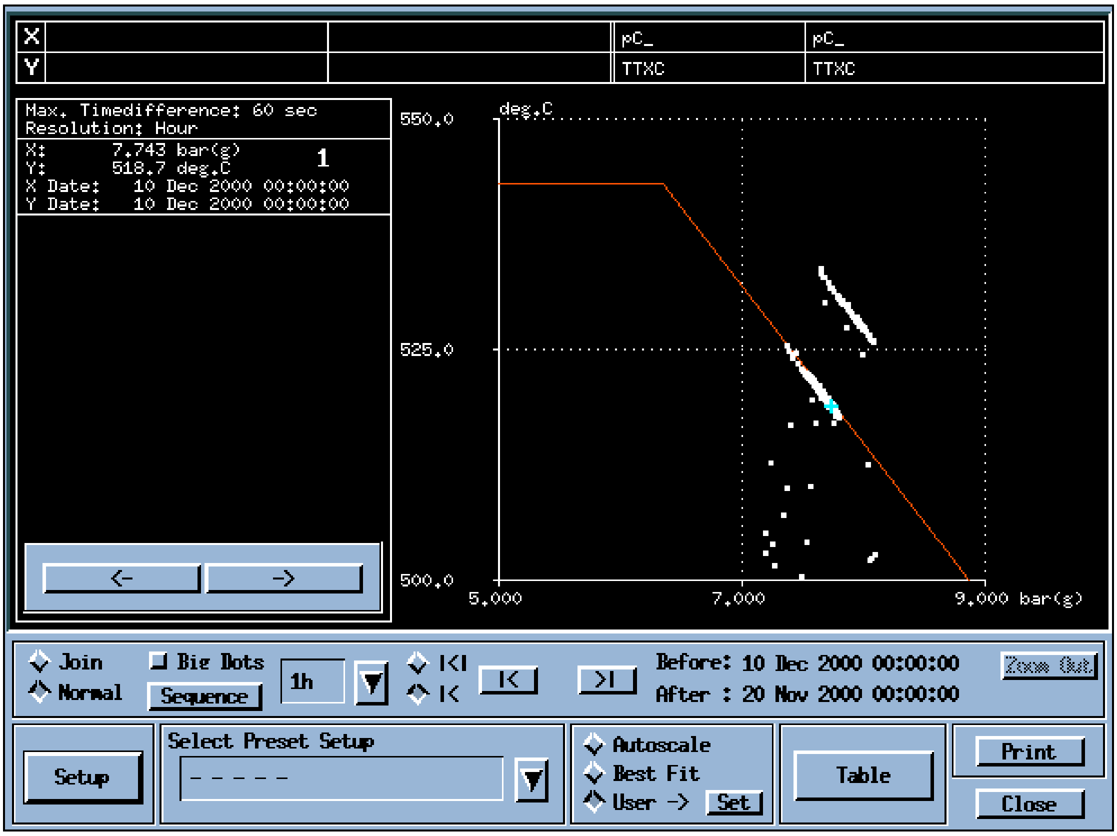

Figure 5**: overfiring of gasturbine is checked with control curve display.**

Compressor maps identify thermodynamic problems in your machines, this example identifies a centrifugal compressor running in Stonewall condition.

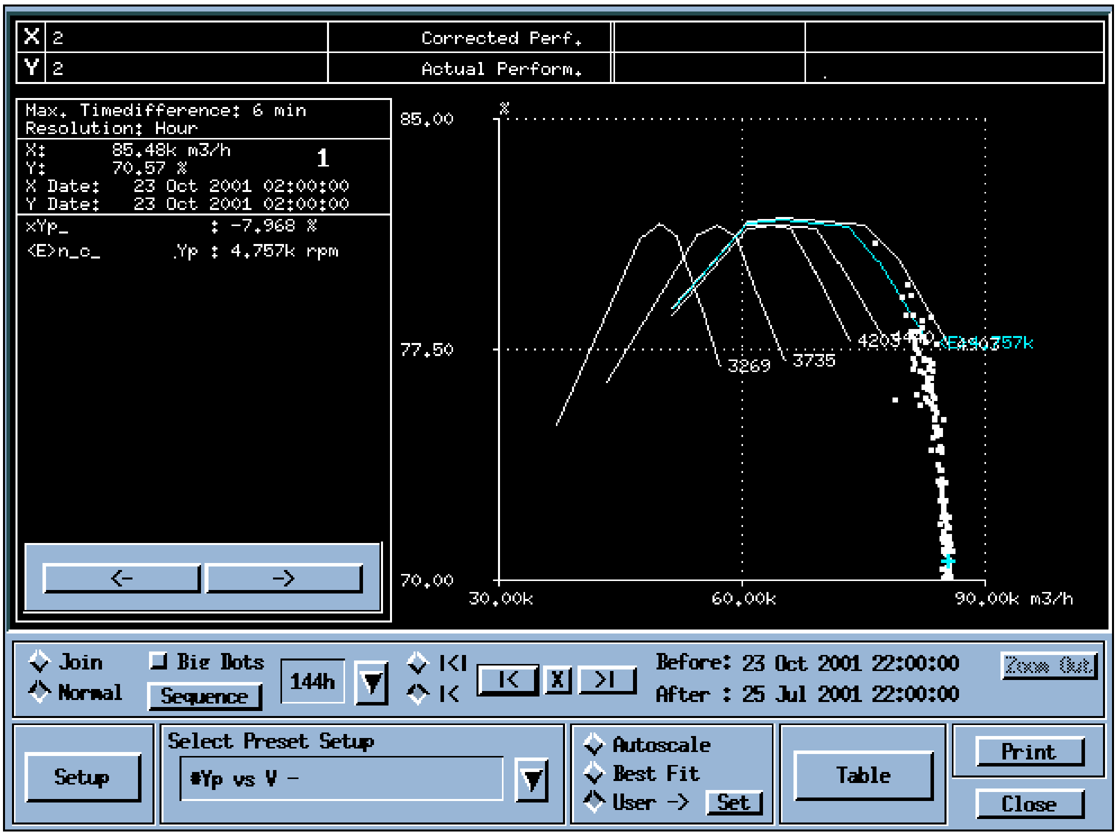

Figure 6**: Machine performance of a compressor in Stonewall.**

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Why integrate Rotordynamic (Vibration) information with Thermodynamic (Performance) information

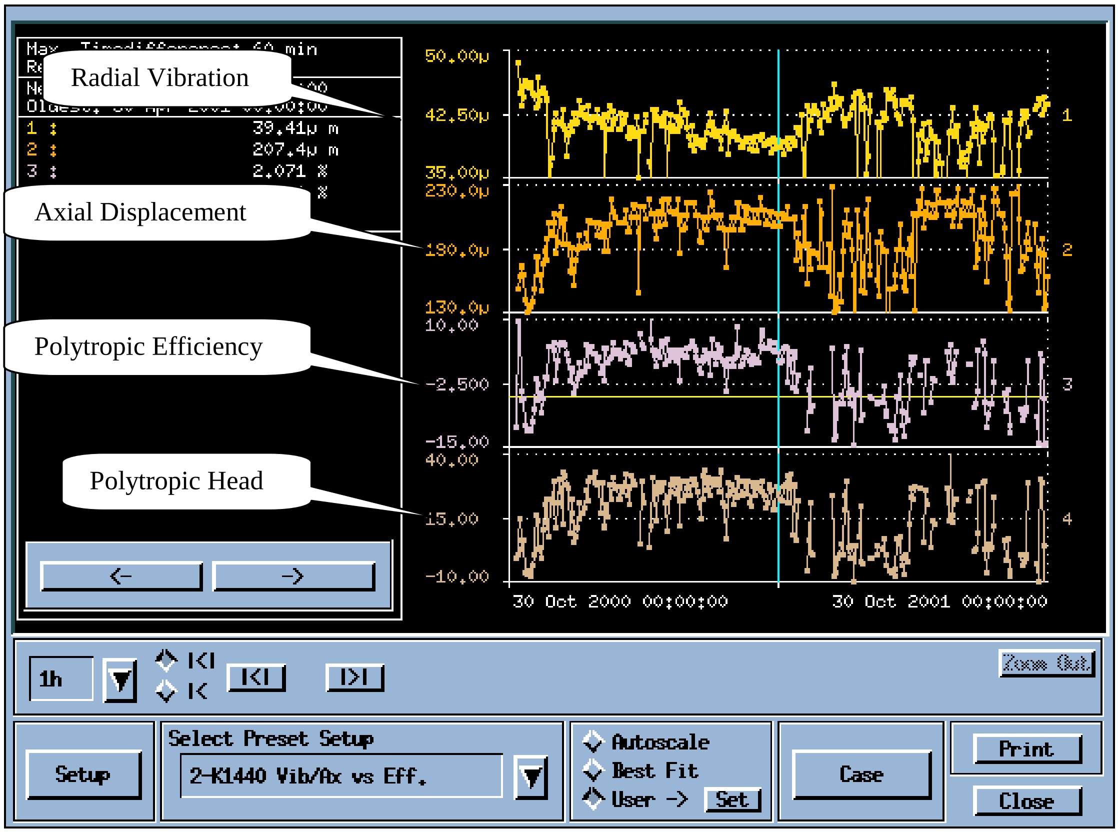

Figure 7: **Multitrend display identifying increased vibration and axial displacement at low efficiency and head, caused by unstable process in the compressor.**