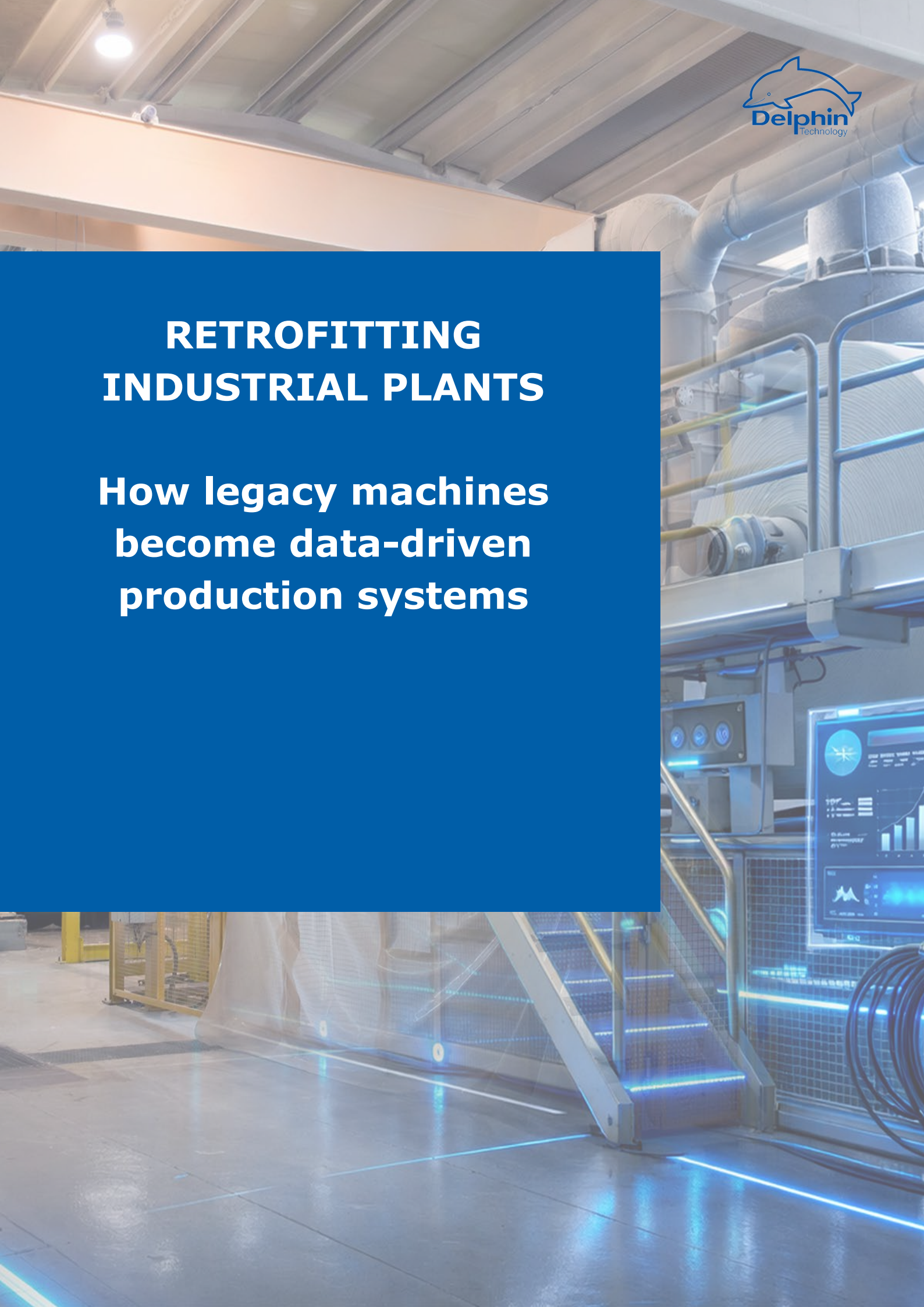


RETROFITTING INDUSTRIAL PLANTS

**How legacy machines
become data-driven
production systems**



Executive Summary

Industrial companies increasingly face the challenge of integrating machine fleets that have grown over decades into modern, data-driven production environments. While new machines usually come with digital interfaces and integrated data acquisition, many legacy assets continue to run reliably but without any transparency about their operating data.

Replacing these assets entirely is rarely economically viable. Retrofit concepts offer an alternative modernisation strategy: existing machines are digitally extended with additional sensors, modular measurement data acquisition and open communication interfaces.

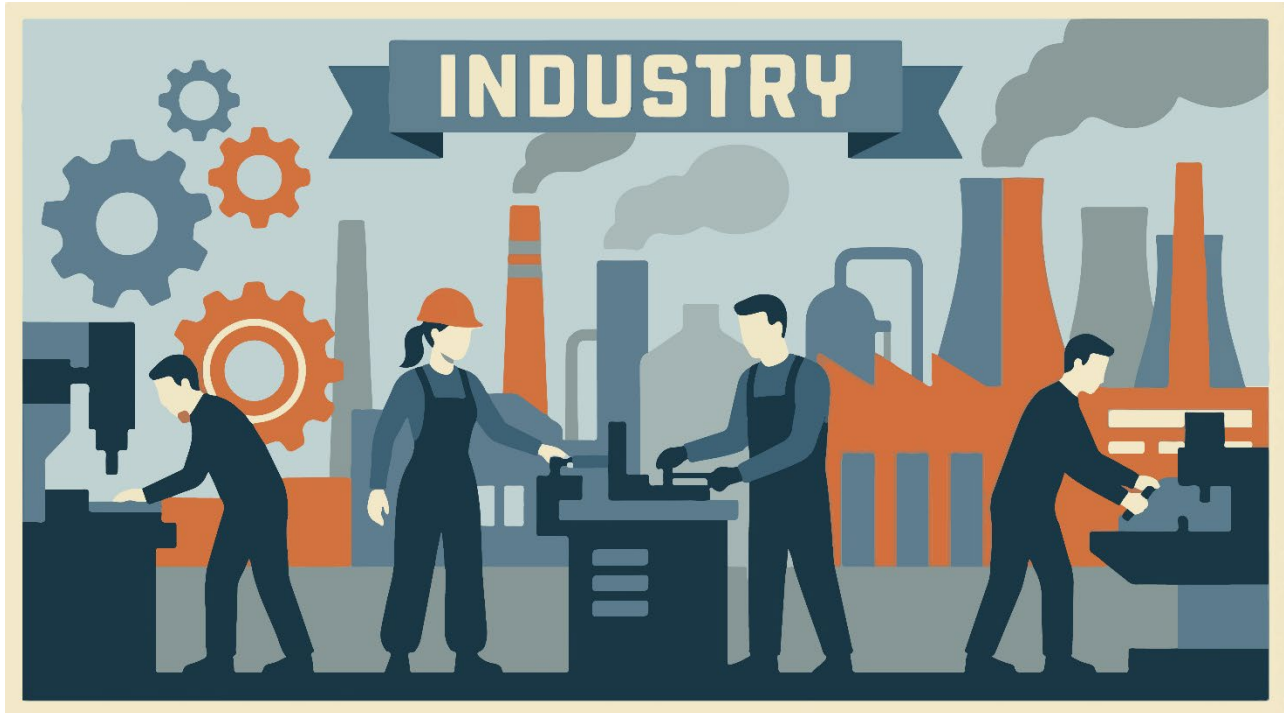
This additional layer of information delivers reliable data on machine conditions, energy consumption and process parameters for the first time. Companies thus gain the basis for condition-based maintenance, energy optimisation and data-driven production decisions.

This document describes the technical fundamentals of retrofit projects, typical challenges when modernising existing plants and a scalable architecture for industrial data acquisition. It also looks at practical examples from industrial test stand applications and modernisation projects.

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The reality of machine fleets that have grown over time



In many industrial companies, machine fleets are built up over decades. New plants are added while older machines remain in operation for as long as they work reliably.

The result is a heterogeneous production environment with different construction years, manufacturers and technical standards. Modern plants often have digital interfaces, while older machines provide only analogue signals or local displays.

Typical characteristics of such machine fleets are:

- machines from different generations
- various control platforms
- different communication protocols
- no central data acquisition
- manual documentation of operating data

Mechanically, these plants often continue to run stably and economically. The challenge lies in the lack of transparency about operating conditions. Without systematic data acquisition, important questions remain unanswered:

- **What is the actual utilisation of individual machines?**
- **Where do energy losses occur?**
- **Which components are showing the first signs of wear?**
- **Which process parameters influence quality and efficiency?**

This information gap complicates both technical decisions and economic optimisation.

Why data transparency is decisive today

The requirements placed on industrial production have changed considerably in recent years. Alongside productivity and quality, factors such as energy efficiency, sustainability and plant availability are playing an increasingly central role.



Several developments are reinforcing this trend:

Rising requirements for plant availability

Unplanned downtime causes considerable costs. Early condition monitoring can prevent failures.

Optimising overall equipment effectiveness (OEE)

Production key figures must be recorded continuously in order to identify efficiency potential.

Energy efficiency and sustainability

Energy consumption must be documented transparently, both for cost reasons and to meet regulatory requirements.

Documentation obligations and quality standards

Standards and certifications require complete traceability of production data.

Shortage of skilled personnel

Automated data acquisition reduces manual documentation effort and relieves staff.

Without consistent data acquisition across all machines, this potential remains untapped.

What retrofit means in industrial measurement technology

Retrofit describes the targeted modernisation of existing machines by adding measurement technology and data acquisition systems. The mechanical and functional structure of the machine is retained.

The retrofit principle is based on an additional information layer:

- Sensors record physical states such as temperature, pressure or vibration.
- Measurement data systems digitise and store these signals.
- Software analyses the data and visualises correlations.

In contrast to a complete machine modernisation or a control system replacement, the core function of the plant remains unchanged. Retrofit merely adds the capability for data acquisition and analysis.

This approach enables step-by-step digitalisation of existing production plants without major investment in new machinery.

Measurement technology as the basis of digital production



The basis of every data-driven production optimisation is the precise acquisition of physical measured variables.

Typical measuring points in industrial retrofit projects are:

- temperatures at bearings or motors
- vibration on rotating machines
- electrical power and energy consumption
- pressure and flow in hydraulic systems
- speed and position of moving components

High-resolution data acquisition makes it possible to detect even small changes in machine behaviour. Rising temperatures can indicate friction or overload. Vibration analyses reveal mechanical wear at an early stage. Power analyses make inefficient operating states visible.

Sensor technology therefore forms the foundation of every further digital analysis.

Technical challenges in retrofit projects

Modernising existing plants involves specific technical challenges.

Missing documentation

Older machines often have incomplete circuit diagrams or undocumented control programs.

Heterogeneous signal types

A machine fleet can involve a wide variety of signal types, including 4–20 mA, 0–10 V, Pt100, thermocouples, pulses or fieldbus data.

Limited installation space

Control cabinets in older plants often offer little room for additional hardware.

Electromagnetic interference

Production environments place high demands on EMC protection and industrial robustness.

Different communication systems

Some machines use proprietary or outdated protocols.

A retrofit solution must therefore be flexible, modular and robust.

Architecture of modern retrofit systems

A typical retrofit architecture consists of several levels.

- **Sensors**
Sensors record physical process variables.
- **Local data acquisition**
Modular measurement systems digitise and synchronise the signals.
- **Edge processing**
Calculations, limit value monitoring and event detection take place directly at the machine.
- **Communication**
The data is transmitted via industrial networks.
- **Central data platform**
Long-term archiving, visualisation and analysis take place centrally.

This architecture enables scalable digitalisation – from individual machines through to the entire production site.



Case study:

Retrofit of an industrial pump test stand

Initial situation

A manufacturer of wastewater pumps operates several test stands for the acceptance testing of pumps in different performance classes. The systems are used to measure and document the hydraulic and electrical characteristics of the pumps under defined operating conditions.

One central test stand was based on an automation and measurement technology platform from an earlier generation. Although the plant continued to work reliably in mechanical terms, data acquisition, documentation and integration into the existing IT infrastructure were only possible to a limited extent.

The existing control architecture dated from an older system generation, which made extensions or adaptations increasingly complex. At the same time, the technical documentation was partly incomplete, so important information on signal processing and communication had to be reconstructed.

In addition, part of the data evaluation and test logging was still carried out manually, which caused additional effort in the testing process.

The aim of the project was therefore to modernise the measurement technology and data acquisition without fundamentally changing the mechanical structure of the test stand or the hydraulic infrastructure.

Technical challenge

The test stand is used to test various pump types with different performance and delivery ranges. Several physical variables have to be recorded and evaluated simultaneously, including:

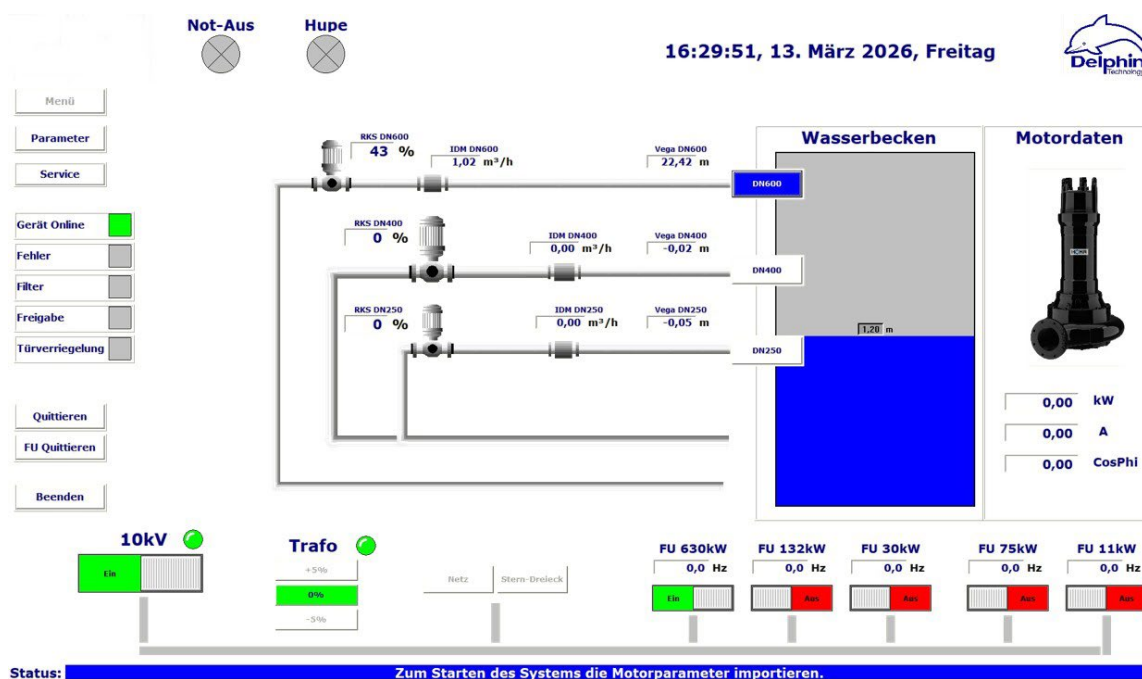
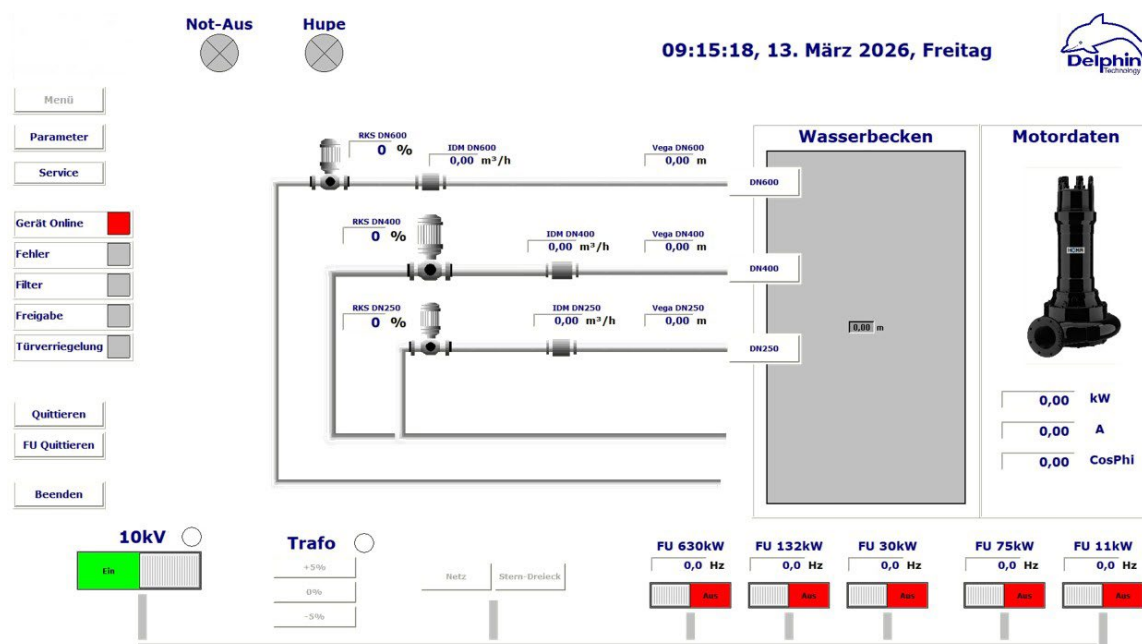
- delivery head (differential pressure)
- flow rate
- electrical power consumption of the drives
- speed and operating states
- temperature values of various components

The measurement data must be recorded synchronously, analysed and made available for test logging.

In addition, the test stand was required to support several operating modes:

- manual test sequences for development purposes
- automated test sequences for series testing
- reproducible measuring points for generating pump characteristic curves

A further requirement was to transfer the test data automatically into the existing ERP system so that test reports could be created without additional manual data entry.



Retrofit solution

As part of the project, a new modular measurement technology platform was integrated into the existing test stand.

The solution comprised several components:

Integration of existing sensor signals

Existing sensors for pressure, flow and electrical power values were integrated into the new data acquisition system. Additional measuring points were also added to enable a more detailed analysis of the test sequences.

Modular data acquisition

Analog and digital signals are recorded synchronously via modular measurement data acquisition systems and processed centrally. The architecture allows flexible extension of the measurement channels, so that future adaptations to the test stand are possible without fundamental system changes.

Control of the test sequences

The test stand can be operated both manually and automatically. During automated tests, defined operating points are approached, for example by controlling the opening of control valves so that the required delivery heads or flow values are reached. As soon as stable operating conditions are achieved, the measured values are stored automatically.

Integration of drive technology and communication

Frequency converters, sensors and other components are connected to the controller via industrial communication interfaces and integrated into the test sequences.

Integration into the IT infrastructure

An important element of the retrofit project was the integration of the test stand into the existing corporate IT.

The test data is transferred automatically to the company's ERP system. Data is exchanged via defined file interfaces, so that test reports can be generated and archived automatically.

The test process begins with the import of the test data from the ERP system. The test parameters are transferred automatically to the test stand, which is pre-configured accordingly.

Once testing is complete, the recorded measured values are exported and assigned to the corresponding test object in the ERP system. This creates end-to-end digital documentation of the test process.

Results of the modernisation

After implementation and commissioning of the modernised test stand, initial tests could be carried out with various pump types.

The very first measurements already showed a high level of agreement with previous reference measurements, confirming the accuracy of the new measurement technology.

The modernisation led to several improvements in the testing process:

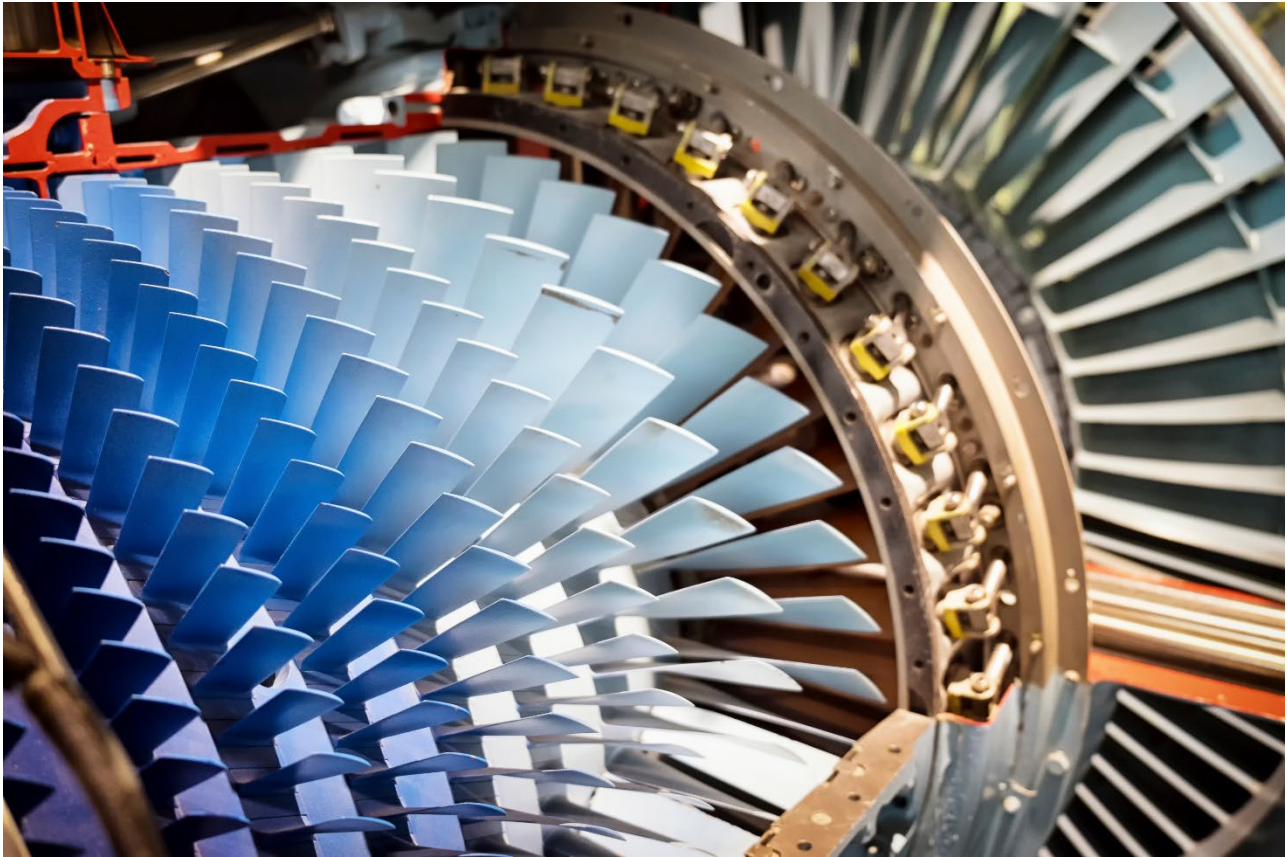
- automated execution of test sequences
- reproducible measuring points for pump characteristic curves
- central storage of all test and measurement data
- automatic generation of test reports
- significantly reduced manual documentation effort

In addition, the new measurement technology platform enables the test stand to be extended step by step, for example with additional test sections or further measurement channels.

The project shows how retrofitting can technically modernise existing test and production facilities without having to replace functioning infrastructure entirely. At the same time, it creates a digital data basis that can be used for quality assurance as well as for development and production optimisation.

Case study:

Retrofit of an overhaul line for gas turbine blades



Application description

In addition to several production lines for the various gas turbine components, a gas turbine manufacturer also operates an overhaul line for one essential part of the turbines: the gas turbine blades.

These blades are mounted radially on turbine wheels inside the turbine and are one of the central components of a gas turbine. They are largely responsible for making the basic operating principle possible in the first place – the combustion of fossil fuels to generate rotational energy and, ultimately, electrical energy by means of a generator. This illustrates their high relevance and the correspondingly high quality requirements.

To meet these requirements, a general overhaul is carried out every 40,000 to 60,000 operating hours (equivalent to approximately 5 to 7 years of operation). During this process, known as a major overhaul, the turbine is opened completely and all blades are removed and cleaned. They then pass through the overhaul line and undergo numerous inspections. These include examination for cracks and determination of the current wall thicknesses, which are reduced by material removal during operation. A particularly important part of such a general overhaul is the thorough inspection of the internal cooling capillaries in the turbine blades. Because the blades are exposed to extreme temperatures of up to 1500 °C in operation – far above the melting point of the special alloys used – they must be actively cooled. The capillaries and

fine channels in gas turbine blades serve this internal cooling. Since a failure of the cooling system destroys the blade within seconds and causes major turbine damage, inspecting the internal geometry is one of the most critical steps in overhauling the component.

In addition to the actual inspection results, a large number of process parameters are recorded on the overhaul line. These are essential for assessing process quality and for continuously optimising it.

Initial situation

Before the retrofit, one central challenge was that the process parameters were available in very heterogeneous formats and were not linked with one another. As a result, it was barely possible to identify correlations between individual parameters and process quality, or to optimise the process in a targeted way.

The aim was therefore to link and synchronise the process parameters from different sources and to consolidate the data format for uniform visualisation and analysis.

This would also make it possible to create a *digital twin* – a kind of “patient record” for each individual turbine blade, containing all quality and process parameters and how they develop over time.

Retrofit solution

To solve these challenges, a central measurement data management system was implemented on the existing overhaul line – without any intervention in the plant inventory. This system collects the incoming measurement data, consolidates it and makes it available to a visualisation and analysis system.

The measurement data is extremely heterogeneous: it comprises physical variables such as voltages, currents, temperatures and pressures as well as information transmitted via high-level protocols such as OPC UA. Thanks to the wide range of interfaces offered by the measurement data management system, these different data sources can now be integrated and evaluated together.

Results of the modernisation

The retrofit means that the process parameters of the overhaul line can now be evaluated and analysed together with considerably less effort. This has made complete traceability of every single test process possible, along with seamless documentation of plant and process parameters. It has also created the basis for generating digital twins of the turbine blades.

As a result, operating costs were reduced, plant availability was increased significantly and unplanned downtime was minimised.

Economic benefits of retrofitting



Retrofit projects offer considerable economic advantages over the complete purchase of new machinery.

- **Investment protection**
Existing plants can continue to be used.
- **Reduced downtime**
Early condition monitoring prevents unplanned failures.
- **Optimised maintenance**
Maintenance intervals can be planned on a condition-based basis.
- **Energy savings**
The energy consumption of individual machines becomes transparent.
- **Scalability**
Retrofit can be implemented step by step.

These factors often lead to a rapid return on investment.

Beyond the direct economic effects, retrofitting offers concrete benefits for different groups of people within the company:

Executive management

- well-founded investment decisions based on transparent operating and energy data
 - better predictability of maintenance and servicing costs
 - demonstrable efficiency gains (e.g. OEE, energy key figures)
 - a basis for strategic digitalisation initiatives without high CAPEX
- **Added value:** Greater cost-effectiveness, lower risk and better control of the production system

Maintenance / engineering

- early detection of wear and critical conditions
 - fewer unplanned stoppages thanks to condition-based maintenance
 - better root cause analysis using historical data
 - prioritisation of maintenance measures based on actual conditions
- **Added value:** Fewer faults, more efficient maintenance and targeted use of resources

Operating personnel / machine operators

- transparency about current machine states and process parameters
 - operating support through clear data visualisation
 - reduced manual documentation effort
 - faster response to process deviations
- **Added value:** Relief in day-to-day work, greater process reliability and fewer sources of error

Quality assurance

- seamless documentation of process and test data
 - reproducibility of production conditions
 - faster traceability in the event of deviations
- **Added value:** Higher product quality and better audit readiness

IT / digitalisation

- integration of existing plants into higher-level systems (ERP, MES)
 - a standardised data basis for further applications (analytics, AI)
 - reduced integration effort thanks to a modular architecture
- **Added value:** Scalable digitalisation without a complete system replacement

Conclusion

Retrofitting is an economically and technically sound strategy for integrating existing machine fleets into digital industry.

Combining modern sensors, modular data acquisition and intelligent data analysis creates a new level of transparency about machine states and production processes.

Companies can unlock efficiency potential, reduce downtime and modernise their production systems for the long term – without having to replace machines that still work.

Self-assessment: Is your machine fleet ready for a retrofit?

Many companies operate a machine fleet that has grown over years or decades. In such environments, modern plants with digital interfaces sit alongside older machines that continue to work reliably but provide hardly any transparent operating data.

A retrofit project often begins with a simple question:

Which machines already supply usable data today – and which do not?

The following questions help you to quickly assess the level of digitalisation of your existing plants.



Answer the following points spontaneously with yes or no:

- Do some of your machines **have no digital data interfaces**?
- Are **operating or production data** still recorded manually, e.g. using forms or Excel?
- Is there no **central platform for collecting and evaluating machine data**?
- Does your machine fleet contain **different signal types** (e.g. 4–20 mA, 0–10 V, pulse signals or fieldbus data) that are currently not evaluated together?

- Are **stoppages or efficiency losses hard to trace** because there is no continuous data acquisition?
- Are there machines whose **actual utilisation or energy consumption is not transparently documented**?

Evaluation

If you answer **at least three of these questions with "yes"**, your machine fleet probably holds considerable potential for retrofit measures.

In such cases, additional sensors, modular measurement data acquisition and a central data platform can help to integrate existing plants step by step into a data-driven production environment. Even manageable measures can create transparency about machine states, energy consumption and process parameters.

Retrofit allows you to continue using functioning machines economically while creating the basis for data-driven optimisation, condition-based maintenance and higher plant availability – an approach that is becoming increasingly important in modern industrial production.

"Free retrofit potential analysis"

If you would like to know how ready your machine fleet really is for a retrofit, we will be glad to support you with an initial technical assessment of your plants.



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