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INDUSTRIAL ANALYTICS

RETROFITTING OF VIBRATION MONITORING IN A WASTEWATER TREATMENT PLANT

WHITE PAPER

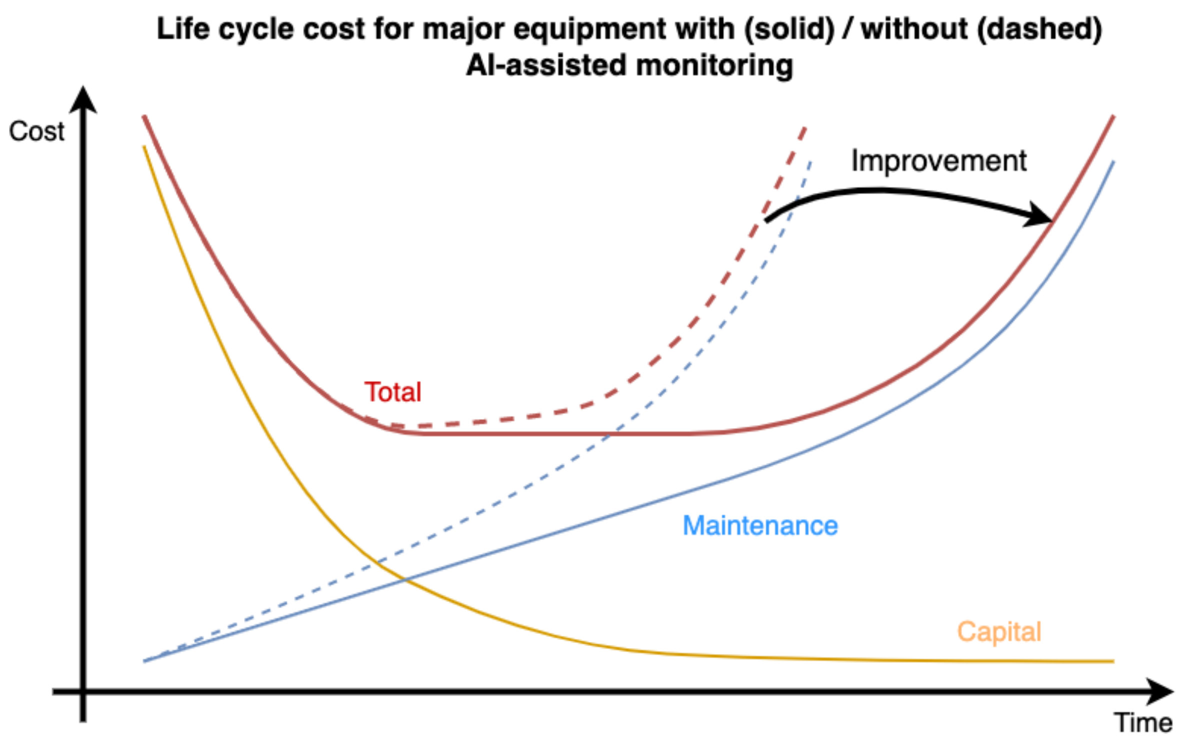
AN OVERVIEW ON IOT ENABLED VIBRATION ANALYSIS AND THE ACTUAL USAGE IN POWER PLANTS AND WASTEWATER TREATMENT PLANTS

What are the challenges when it comes to decreasing cost in reliability and maintenance for operators of rotating equipment?

Results from major equipment life cycle cost analysis[1] show a typical bath-tub curve like dependency of lifecycle cost on time. Optimization of life-cycle cost is the key strategy in capital-intensive industries such as chemicals or utilities.

The total maintenance cost not only includes the direct maintenance cost for parts and labor but also the indirect cost of redundancies, uptime, production loss and administrative costs. A challenge for optimization of the life-cycle cost is the knowledge of remaining useful life- and the considerable time periods for planning and provisioning of new equipment when it comes to major assets like custom-build rotating equipment.

The effect of AI-assisted maintenance is shown below. The total maintenance costs are reduced and the useful life of existing equipment is extended by additional information on the equipment condition. The reduction of total maintenance costs is achieved by extension of maintenance cycles and uptime increase. An important precondition for the cost reduction is that the positive effects on maintenance costs are not foiled by additional personnel costs for monitoring.



[1] *Bengtsson, Marcus & Kurdve, Martin. (2016). Machining Equipment Life Cycle Costing Model with Dynamic Maintenance Cost. Procedia CIRP. 48. 102-107. 10.1016/j.procir.2016.03.110.*

Vibration Monitoring

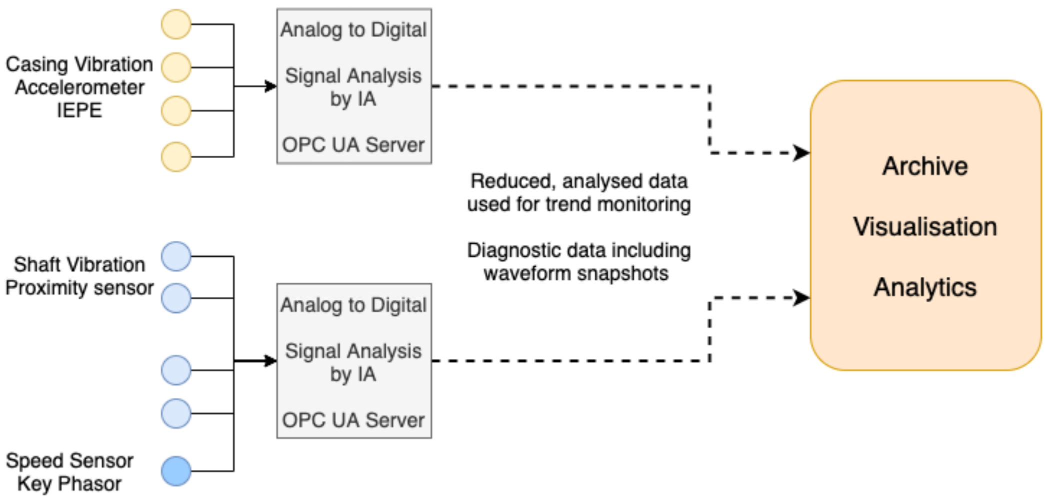
Major rotating equipment is typically not fatigue critical and can be operated for 40+ years. The enhancements in efficiency of new machinery are usually not sufficient enough to justify a replacement. This makes a lifetime extension of this machinery specifically interesting. Machinery vibration reacts highly sensitive to changes in the machine and provides early warning on the machinery condition. However, the extended vibration monitoring of existing equipment comes with several challenges:

1. The machinery is sometimes not equipped with sensors or with a modern data acquisition.
2. Systems consisting of vibration data acquisition hardware and software are typically closed and do not integrate into existing industrial IoT infrastructure.
3. The software provides functionality for visualisation of vibration spectra, trends and also special rotordynamic analysis like orbits, but is meant to be used by vibration diagnosis experts.

How do the plant operators solve this issue?

The first important step is to identify the right partner in the digital transformation journey. Offerings from established vendors often fall behind in respect of innovation like open architecture, IoT interfaces and application of latest AI technologies. Very important is an intimate understanding of the machinery and industry, since otherwise the plant operator has a considerable specification effort in order to make the solution applicable.

Data Flow IoT Vibration Analysis



Retrofitting of sensors and / or data acquisition hardware in the machine has to be industrially approved with a high cost effectiveness. Industrial Analytics is using hardware from well-established vendors like ifm or Gebhardt Automation. The specialized vibration signal analytics is deployed on the device to ensure a seamless integration in the existing environment. An interesting alternative is to leverage the full functionality of the widely used Bently Nevada 3500 Monitoring System (BN 3500) and to extract analytics values like amplitude and phase at specific orders from the system via Modbus protocol without the need of any additional hardware.

The transfer of analysis values from the edge device is done using open standards like OPC UA that provide a secure way of accessing data[2].

Signal Analytics

The following list shows the analytics values used for monitoring.

Casing Vibration	
Vibration velocity v_rms according to ISO 10816-3 (1kHz)	The ISO defines absolute acceptance limits that are useful additional to a relative trend analysis.
Vibration velocity peak-to-peak	Useful frequency range with max 10-30 kHz is used for monitoring
Vibration velocity crest factor	Changes of the crest factor indicate to problems like rub, looseness
Frequency / order band power	Frequency bands relative to the machine rotational speed are defined to extract vibration signatures. For example an increase of sideband amplitudes are an indicator before changes in the overall values are found. The values are defined after an initial review of raw waveform snapshots.
Octave	An octave analysis gives a good overview on the vibration spectrum while using limited amount of data points

The shaft vibration displacement allows additional diagnostic rotor-dynamic analysis. The order analysis is possible to visualize shaft centerline, filtered orbit, Bode plot.

Event Management

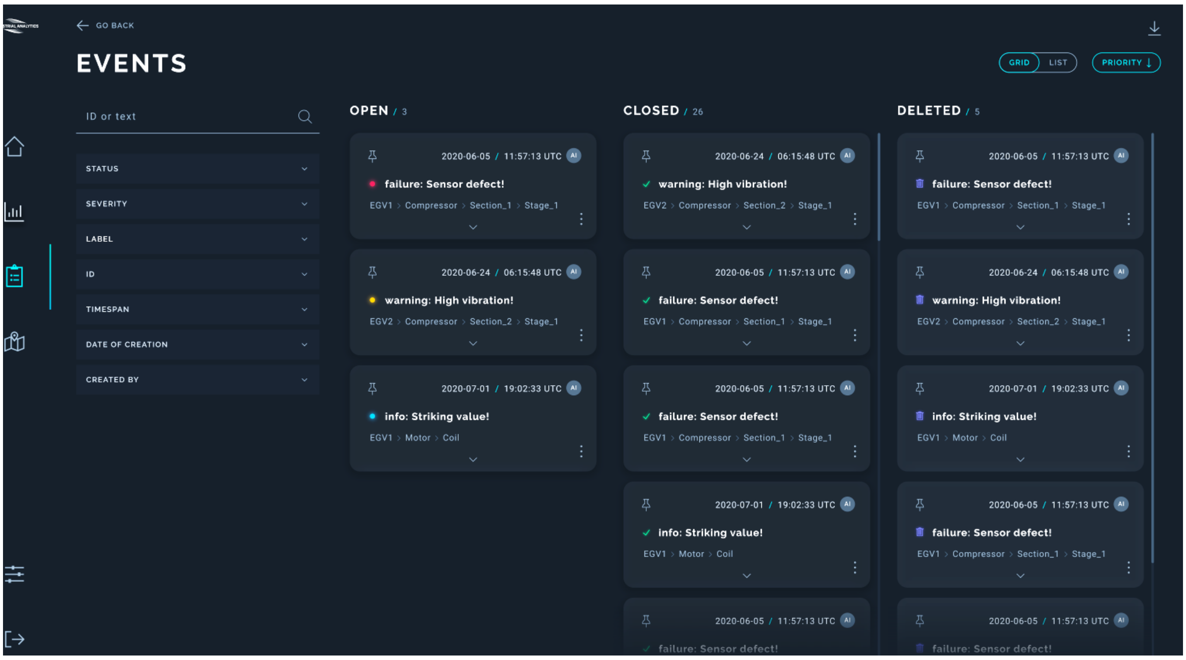
A very decisive step in any monitoring is the combination of available signals sometimes referred to as sensor fusion. The vibration signature of a rotating machine will change

[2] *Bundesamt für Sicherheit in der Informationstechnik; OPC UA Security Analysis; 02/03/2017* *https://www.bsi.bund.de/SharedDocs/Downloads/EN/BSI/Publications/Studies/OPCUA/OPCUA.pdf?__blob=publicationFile&v=2*

when it comes to changes of its operating point. For a turbomachine it is necessary to have information on pressure, temperatures, flows available, rotor speeds, position valves and guide vanes available to monitor the operation point. The data streams are typically available in the control system or other centralized data infrastructure like OSIsoft's PI System.

Industrial Analytics merges the different data streams within the analytics AI-service and therefore generates a holistic picture of the machinery and/or plant. The AI-services calculates expected values of the monitored data streams and sends events only in case of changes within the machine. The event information gives already indication on severity and recommended actions.

The result is an open solution which provides vibration signal analysis together with diagnosis.



Blower Monitoring

Compared to turbomachinery in a power plant, the blowers in wastewater treatment do not require a demanding investment. However, a wastewater plant is considered as critical infrastructure and the operation depends on the blowers that provide the air in order to feed the bacteria.
The cost for renewal of aging equipment depends on efforts for planning and execution in a cost-sensitive environment.
Additional to optimizing the maintenance works, advanced vibration monitoring provides the opportunity to extend the equipment lifetime. A continued operation of the ageing machinery without additional monitoring would not allow to choose the right moment for a machinery renewal.
The existing machinery is not equipped with any vibration monitoring. A trial with a well-known supplier of vibration measurement systems lead to acceptance problems due to complex integration in existing infrastructure and to additional vibration diagnosis efforts by the wastewater treatment plant operator which would in consequence lead to an increase of monitoring personnel capacity.

Retrofitting

The solution is to retrofit the machinery with accelerometers and an edge computing device which is connected to an AI-service in the cloud. With this solution, it is possible to realize a ISO conform vibration monitoring and to provide a long term monitoring that will indicate a very early progressing deterioration of the equipment and therefore ideal timing for maintenance and renewal.
The solution is especially cost effective since there is no additional infrastructure needed than an - existing - power supply. The network connection is realized wirelessly in a secure manner. The security of the setup is guaranteed since there is no physical network connection between the vibration monitoring system and the plant network.
The read-only interface to the operator central PI AF server from OSIsoft is done in a secure manner using a VPN connection together with latest security measures.
Due to the simplicity of the approach using standard cost-effective hardware and minimal infrastructure effort, a running service was **operational only 9 days** after receiving the order.

Outlook

The vibration analysis will be further improved by a research project in order to include rotordynamic models in the interpretation. This means that by using a rotordynamic Finite Element Model expected vibrational amplitudes are simulated and compared with the measured data.

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