PRÜFTECHNIK

DIGITALISATION OF VIBRATION BASED CONDITION MONITORING

Enhancing human proficiency in machine health monitoring

Summary

Condition monitoring with non-destructive vibration analysis is experiencing an accelerated development due to several factors that work as a catalyst. Industrial and marine installations are increasingly interconnected by industry standard TCP/IP based networks. Transmission of wireless data is becoming cheaper and much faster. Digital storage of large data volumes is not a costly hurd-le any longer and engineers and technicians are used to work with intuitive and mobile tablets and smartphones that virtually connect them via apps to their plants, their homes and even their own health parameters. New techniques such as data mining and analytics have emerged. They enable us to quickly plough through enormous amounts of data and extract patterns and relations that were thus far hidden from sight. In this whitepaper we are exploring how these new technologies will empower technicians and engineers to efficiently and accurately predict and analyse wear and damages in rotating equipment and how these new technologies are boos-ting the effectiveness of the vibration analyst. The result is an accrued efficiency of industrial production units, marine vessels and offshore units, rendering them safer, less polluting and more profitable.

Man-machine-team

Automation and digitalisation complements the technician instead of replacing him

An important hurdle that needs to be overcome when implementing an efficient strategy for condition based maintenance, is to obtain acceptance by the technicians who need to work with the asset monitoring tools and software. Furthermore, the approach and benefits it produces needs to be understood by managers who are not necessary familiar with the technical details of vibration based condition monitoring. In the end, management will need to decide whether to apply these techniques in their industries. Ever since the first steam engine was introduced, there has been a sense of fear that machines and – more recently – robotization, digitisation and automation will become job killers. Also in the field of condition monitoring based on the analysis of vibration signals and patterns, the fear exists that artificially intelligent machines will render the analyst obsolete. When we look at the facts however, we see a chronic shortage of vibration analysts in the industry. These specialized profiles are in strong demand, but finding them is hard. Despite this, they seem to spend a large amount of valuable time collecting data, walking around and periodically measuring the same machines repeatedly. Vibration analysts must go through impressive amounts of data to recognize damage patterns and the truly 'interesting' part of their work only starts once they have found an aberrant condition, because only then do they start to really analyse the signals, coming up with hypothesis and trying to pinpoint the root cause of the issues they face. If the skill of vibration analysts could be used mainly to analyse problems rather than going through huge amounts of data or walking through the factory to collect data, then this would decuple the efficiency of the analyst and – along the way – remove the often boring part of the job. Automating the data acquisition, generating exception reports, recognizing aberrant conditions and even identifying or eliminating plausible causes for an aberrant vibration signal will certainly point the analyst in the right direction. However, the human analyst, in contrast to the automated expert system, will unconsciously apply the huge amount of unstructured information that he has accumulated over the years, which is often called 'experience' to solve the issue at hand. We are convinced that the best results will not be obtained by trying to design monitoring systems that will merely take over the tasks from the analysts but that the better approach will be to design and further develop expert systems that will enhance the skills of analysts, that will automate the data acquisition, (for instance by using online acquisition systems and cloud based platforms) and will 'clean up' and filter data identifying aberrant machine conditions or even propose a number of hypothesis that the analyst can then pick up and further pursue – or dismiss – during his analysis of the machine health problem.

By using these techniques and combining them with modern network capabilities, it is possible to monitor several production units from a central location by ana-lysts that have been unconstrained of repetitive tasks and will have more time to do what really matters, namely to analyse machinery issues and formulate solutions to eliminate the root causes of these problems.

An example; monitoring concept for wind turbines

To overcome inaccessibility and variable operating states

One of many examples that illustrates monitoring strategies that can be applied to the whole of the industry is the monitoring of wind farms. Wind turbines are quite a challenge to analyse as far as machinery health and da-mage detection is concerned. They are typically composed of a slow rotating shaft that is supported by a main bea-ring. The shaft is generally coupled with the input shaft of a gearbox (often with a planetary stage). The gearbox increases the rotational speed of the shaft and the output shaft is then coupled to a generator to generate electricity.

The challenges that occur in this specific case are related to several factors. First, the machines are located on a flexible base. Obviously, compared with machines mounted on a steel skid with a concrete base, the flexibility of the foundation for the generator, the gearbox and the main bearing is much higher. This causes relative movements between – for instance – the output shaft of the gearbox and the generator. Because the generator shaft is rotating at a higher speed, vibrations occur due to a dynamic misalignment of the shafts. Due to this, the load on bearings increases and the expected mean time between failures will be influenced negatively.

Another aspect is related to safety. In most European countries, it is not permitted any longer to ascend into the nacelle while the wind turbine is in operation. Sadly, accidents have occurred so security guidelines have become very strict. Obviously, the wind turbine must be in operation to measure machine vibrations, so we need to equip the wind turbine with online monitoring systems in the nacelle. The communication between the online condition monitoring system with a remote diagnostic centre is done through a landline, a 3G/4G modem or even via satellite link, for instance for offshore wind farms.

This example shows us what the impact of automation is, because in the early years of energy generation through wind turbines, most turbines were monitored using periodic vibration measurements. Technicians had to climb into the wind turbine, all the way to the top (typically 80 meters high) and acquire the vibration data. Depending on wind conditions, this data was highly variable so a lot of manual acquisition was necessary to be able to analyse the health condition of the turbine under different operating states.
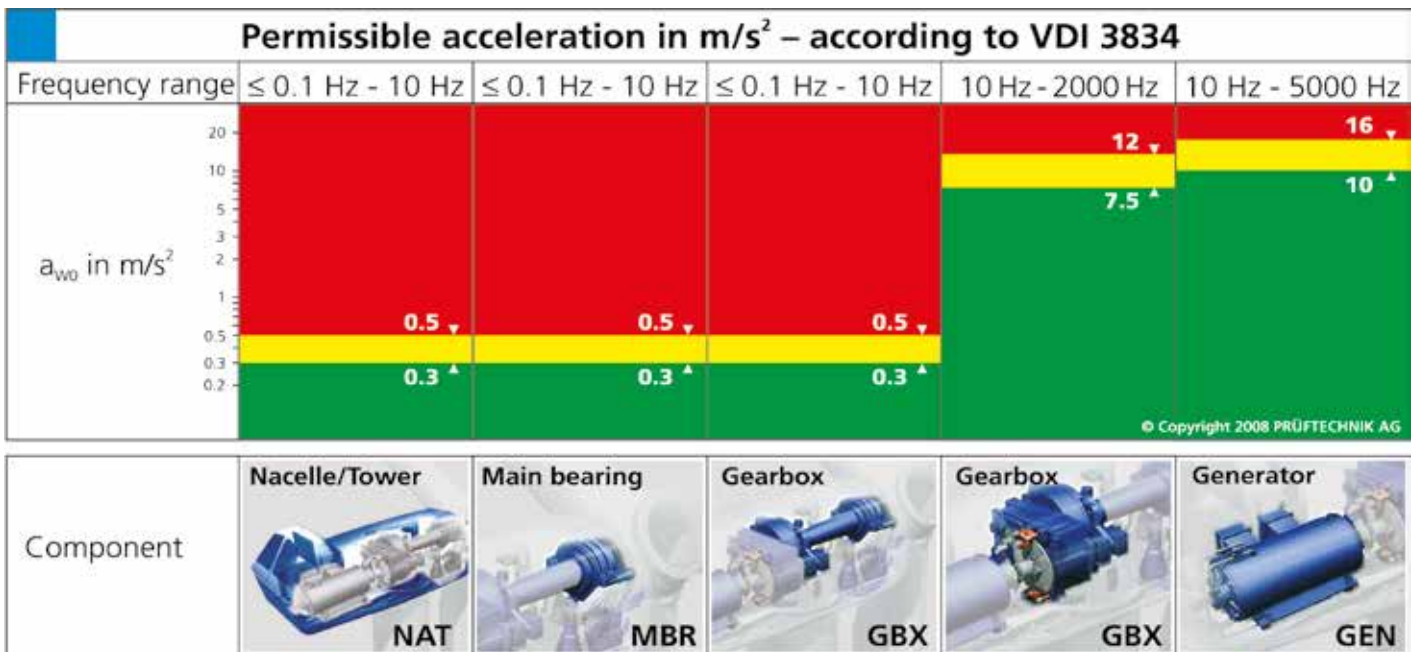
A typical wind farm has several wind turbines that are generally of a similar or identical make. By collecting a large amount of data on different turbines of the same type, it is possible to establish a 'normal' vibration pattern and apply algorithms that will identify discrepancies in the vibration signatures as well as benchmarks for the turbine operating states. Even if alarm levels have not been violated, any change or exception in a pattern will trigger a further analysis to establish the reason for the discrepancy. A typical remote diagnostic centre applying these techniques can thus easily monitor over 2000 wind turbines with only two or three analysts. The result is that the analysis process is assisted by automated processes to enable the analyst to do what he is good at, not collecting data or browsing through piles of measurement files, but to focus on the machines that need attention, even if the typical ISO alarm vibration levels have not (yet) been reached.

Permissible acceleration in m/s² – according to VDI 3834

Frequency range	≤ 0.1 Hz - 10 Hz	≤ 0.1 Hz - 10 Hz	≤ 0.1 Hz - 10 Hz	10 Hz - 2000 Hz	10 Hz - 5000 Hz
a_{wo} in m/s²	0.5 ▾ / 0.3 ▴	0.5 ▾ / 0.3 ▴	0.5 ▾ / 0.3 ▴	12 ▾ / 7.5 ▴	16 ▾ / 10 ▴
Component	Nacelle/Tower — NAT	Main bearing — MBR	Gearbox — GBX	Gearbox — GBX	Generator — GEN

Remote access; maximize the available analysis skill

Let the data travel

Nowadays, online systems measure complex signals and normalize these readings depending on several influencing parameters such as load, speed, temperature and many others. Much more data is acquired because the monitoring system is operating 24/7. Influencing factors are logged and relevant operating states are used as an influencing input to normalize the data. The analyst is generally located several hundreds of kilometres away in a monitoring centre. He obtains all the data automatically through his digital communication network, typically the internet with VPN functionality. One analyst can efficiently monitor hundreds of machines, but only if the data that arrives in the monitoring centre is first automatically processed and stored in a database. The storage process must be automated, for instance by sending electronic messages with headers that identify the location of the wind turbine and contain the relevant data used to determine the machine health. To reduce bandwidth, the monitoring robot does not only measure and transmit the data, it also evaluates the data locally in the wind turbine and applies several rules aimed at reducing the storage density thus minimizing the data transmission volume from the measurement location to the monitoring centre. The automation does not stop once the data is stored. Due to the large number of machines in a typical plant or windfarm, a monitoring and analysis software automatically generates warnings, alarms and reports depicting the status of the machine. The analyst can then concentrate on the machines which are in alarm and focus all his or her attention on the cases that need to be dealt with.

The result is that one analyst can easily monitor a very large number of aggregates and still not feel overstressed.

The automation process described above in the example about wind farms had several advantages:

▸ No more physical, time consuming and dangerous

▸ Climbing to access the rotating equipment in the nacelle

▸ More relevant data is acquired under different operating states and at the same time, influencing parameters are collected

▸ Many aggregates, spread out over several countries, can be monitored from one single central infrastructure

▸ Large datasets of often similar or identical wind turbines are processed to find patterns that are typical for certain types of damage, which allows for benchmarking

▸ Numerous other data sources such as performance parameters and electrical parameters are added to the measurement set to paint a full picture of the asset behaviour

▸ The analyst, whose field of expertise and number of applications has vastly been broadened can focus on root cause analysis and pattern recognition to produce feedback that will be used as input for improvement projects. This so called 'proactive' approach is the philosophy that will generate most of the return because solving a problem is good, but avoiding its reoccurrence is far better

The approach used in the example above is not unique for the wind energy sector. Although every sector of activity has its own challenges and particularities, the automation techniques resulting in a much higher efficiency and profitability of the wind park can easily be applied to other sectors such as steel and aluminium production, automotive, cranes, refineries, marine and offshore installations, and many more.

Inexpensive standardized technology for safe global data exchange

Robust data security, backup and access control

Although the process explained above can be used for almost any type of machine in any type of industry, let's go back to our example above and look at another important aspect of the remote diagnostic process, namely, the data transmission. The fact that we live in a networked environment means that everything is or can be connected. A thermostatic device in a home can be controlled from a distance with an app that is connected to the internet via a 4G link. Factories, cars, schools, etc. are all connected or connectable. This generates comfort but also poses a significant threat. Therefore, connected devices often use a VPN (Virtual Private Network) to secure connections. Condition monitoring systems do the same.

An additional advantage of working through a VPN is that the IP addressing within the VPN environment can be set as such that all devices, also those located far away, appear as if they were in the same local network. The huge advantage in that case, is that the link is not only secure, but that devices such as online condition monitoring hardware can easily be reached from a distance by the software used to program it. Typically, that software will also extract and store the data and gene-rates reports. This makes the whole system transparent, safe, scalable and very easy to handle.

A networked infrastructure also allows to tap into other data sources than the vibration readings alone. As we mentioned before, operating states depending on certain machine states such as the speed a shaft rotates, the power a motor delivers or wind speed acting on a wind turbine can all affect the vibration readings. We can measure all relevant parameters needed to normalize the vibration readings ourselves of course, but maybe we don't need to, because they might already be available online. One example is temperature and atmospheric pressure. These parameters can be very important influencing parameters for certain processes and are readily available through data brokers that connect to a server that contains such data. These values can then be used in combination with vibration readings for normalisation purposes.
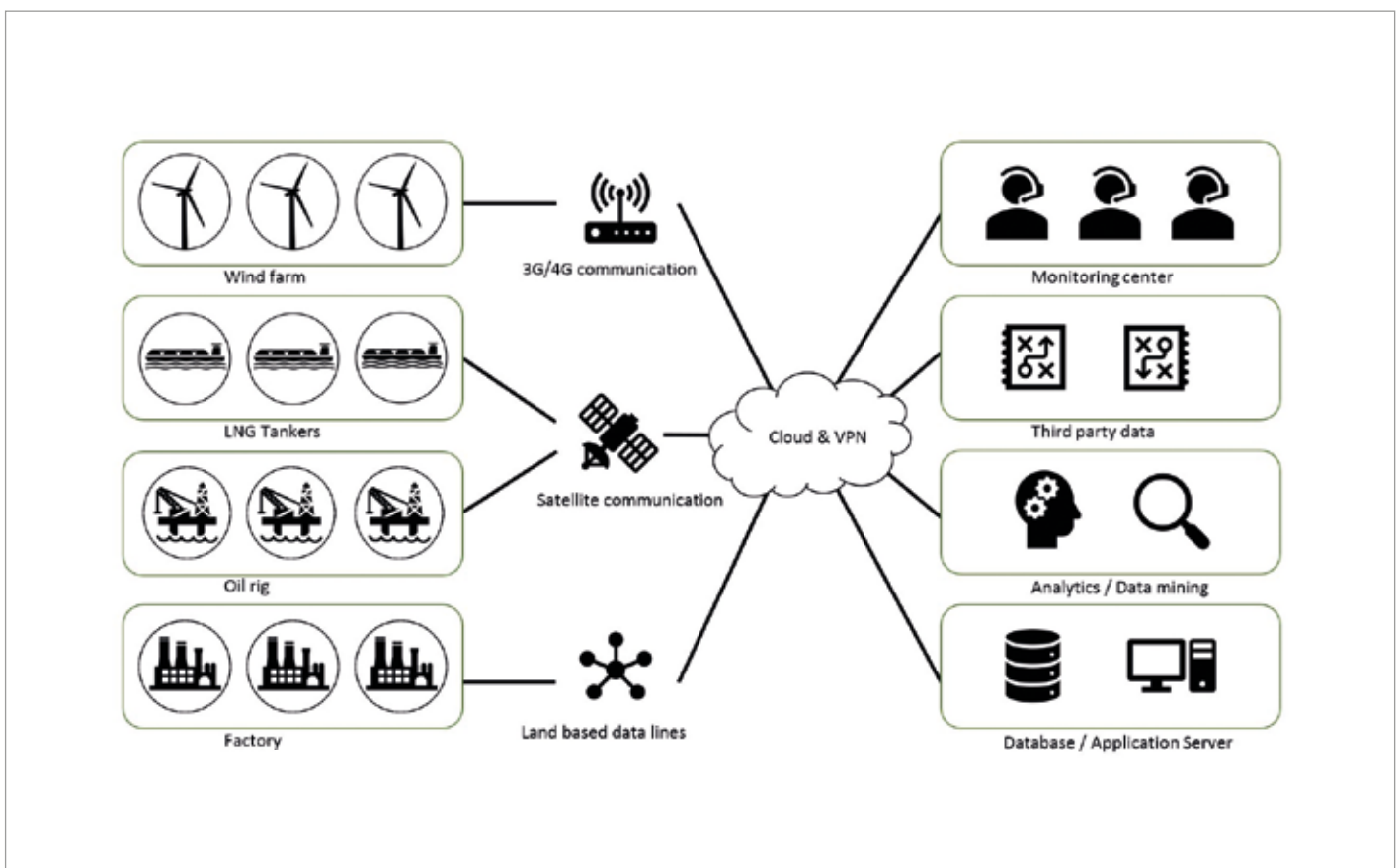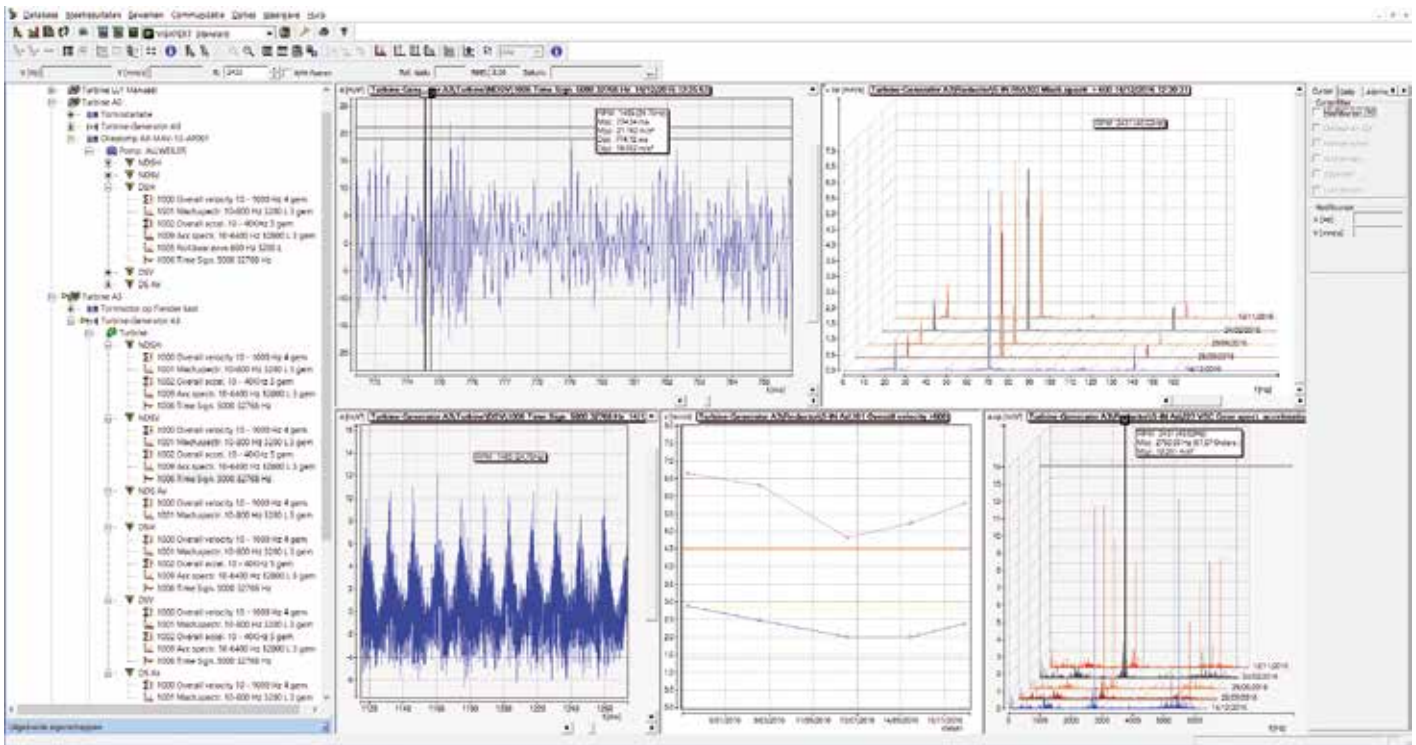
Condition monitoring software suite for programming, storage and analysis of machine condition data

Without using the term, we entered the field of IoT applications that has the power to connect all 'things' whether through a VPN and – more importantly – to access relevant information without having to generate all of it. Currently we are still at the beginning of this evolution, but the rate at which it picks up speed is impressive. Although the typical factory is not 'smart' yet, we're getting there and so are systems that predict, analyse and communicate machinery health.

Powerful software and easy to use dashboards; a good marriage

The best of both worlds

When using condition monitoring systems, we typically find one specialised software associated with it. This condition monitoring software can be installed locally or on a (cloud based) server and will most probably be linked with a database. For instance, a SQL database.

The condition monitoring software is used to generate a model of the topology that needs to be monitored with online or offline data collectors. Usually these models include a tree like structure with a definition of the machines and machine parts that need to be measured, what to measure, how often and what to do when alarm and warning levels are exceeded. The software also generates measurement routes, sends them to a data collector or an online system and collects the measurement results once the measurements have been completed.
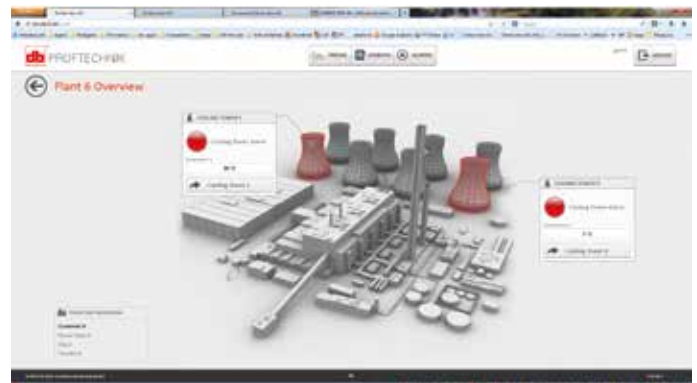
The signals and overall values are then stored in the database and a reporting engine generates exception and analysis reports. Typically, the application also contains a set of tools to analyse the data and decision support routines that assist the technician in his analysis process. This is the typical – often standalone – way of working. Although the usage of such software is essential for the condition monitoring system to work, not all users may have a need for it. For instance, if a process engineer who monitors a steel mill wants to know when a machine is in alarm, then all he needs to see is a warning and maybe a value that indicates by how much an alarm has been exceeded. He will most probably not analyse time signals and spectra right away because this is typically something a specialized technician does. Furthermore, he will not reprogram measurement routines and alarm levels either. If he obtains the information and the values that are important to him, then he will have sufficient information to act upon. Furthermore, being confronted with a richly featured software may have a confusing effect since he is not trained to handle such a system. What he needs in other words is a clear and simple visualisation that gives him an overview of what is happening. A dashboard is ideal for that purpose and can also access data that is not strictly generated by the condition monitoring system itself.

Therefore it is important for the condition monitoring hardware and software to be open and accessible by third party systems. In the next topic, we will elaborate on this property.

The end of closed system architectures

The future is open and inclusive

The examples above all illustrate that the power of digitalisation and the usage of new pattern recognition techniques based on analytics engines will only work if we use an open system architecture. Processed vibration data needs to be accessible by analytics, data mining engines and dashboard. Cloud based software solutions will need to interact with a vast amount of data from different sources. The fact that a solution is cloud based will enable it to connect to other data sources, but if suppliers of condition monitoring systems close their systems to others then we lose the ability to harvest the benefits of big data models. For every vendor to develop its own analytics engine is not an option. Large companies such as IBM, SAP or Gene-ral Electric have invested billions in the development of these general tools, which are available on the market and applicable for more than just condition monitoring related applications only. The condition monitoring systems of the future are one important piece of the puzzle when dealing with industrial and marine asset lifecycle management. They allow us to efficiently implement the assessment of machine health and are a cornerstone of the reliability centered maintenance approach, but there are more layers to be considered and therefore the future will be open and (data) inclusive both upstream and downstream.
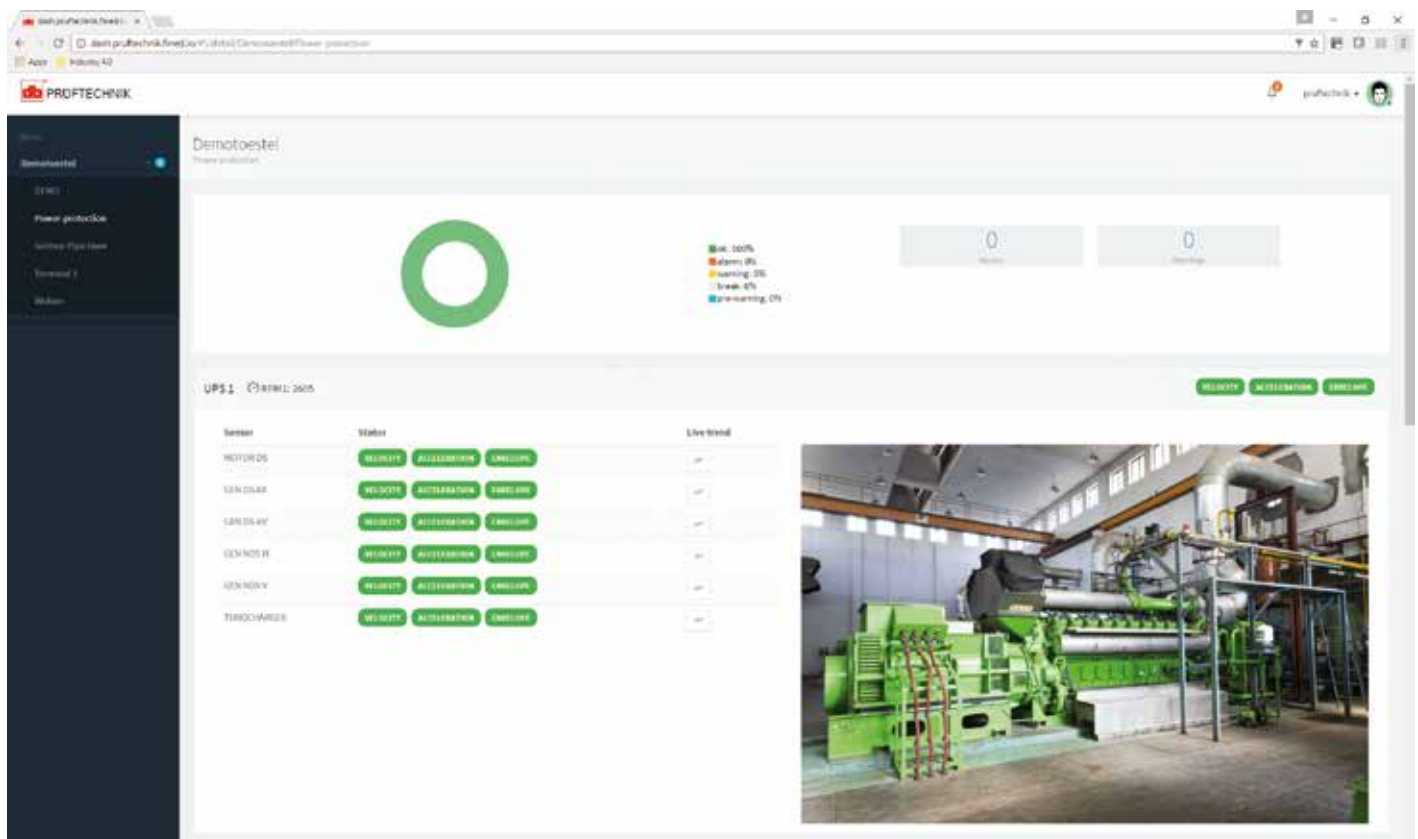
Conclusion

Condition monitoring solutions used as non-destructive tools for machinery health monitoring, trouble shooting and root-cause analysis have been and still are invaluable tools for an efficient asset management program. The past few years however, a ra-pid development has taken place in this traditionally slow and technical sector. The availability, decrease in price, ease of use and integration of systems through industry standard wired and wireless networks have multiplied the benefits these techniques offer. The combination of a 'skilled technician' with decision support tools have impressively multiplied the vo-lume of useful work that can be done while automating tasks that are generally boring such as the creation of exception reports, the collection of data in the field and the need to go through vast volumes of data manually. We expect to see a further development in combination with so called 'Industry 4.0 smart factories' or 'autonomous ships' accompanied by new tools for analytics. In the same way the industrial internet of things is developing, also industrial machines will be able to communicate with each other without human intervention. A powerful condition based maintenance framework perfectly integrates within such an environment. This does not mean that human intervention becomes obsolete, at the contrary! By using human skills that are difficult to automate and combine these skills with analytic engines and processing features of advanced soft- and hardware systems, we will finally be able to harvest the full power of condition monitoring as never before, and at the same time render the work of analysts more efficient for the company and more meaningful for the technician.

For both the analyst and for the technilogical development related to the automated condition based maintenance the best is yet to come!

Remote condition monitoring
Let the data travel

Contact

If you are interested in the rotating asset monitoring possibilities and the remote diagnostic services for your industrial or marine installations, feel free to give us a call for an overview of practical implementations and 'remote diagnostic case histories' that directly relate to your application.

▶ AC and DC motors
▶ Centrifugal pumps
▶ Blowers
▶ Cooling towers
▶ Wind turbines
▶ Industrial gearboxes
▶ Oil tankers
▶ Container and gantry cranes
▶ Dredgers and pipe layers
▶ ATEX and nuclear environments
▶ Military applications
▶ Marine propulsion
▶ Etc…

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