QUARTZTEQ WHITE PAPER

Monitoring of pumps, fans and mechanical components using highly integrated wireless sensors.

Dr. Bernhard Fruth
Rajendra Nuthakki
Nicolas Junod
Quartzteq GmbH, Windisch, Switzerland

Prof. Dr. Herbert Looser
University of Applied Sciences, Windisch, Switzerland

Dr. Detlef Hummes
American University of Kuwait, Kuwait

Eid Mousa Al Mutairi
Ministry of Electricity and Water, Kuwait

HOW

TO IMPROVE ASSET LIFESPAN

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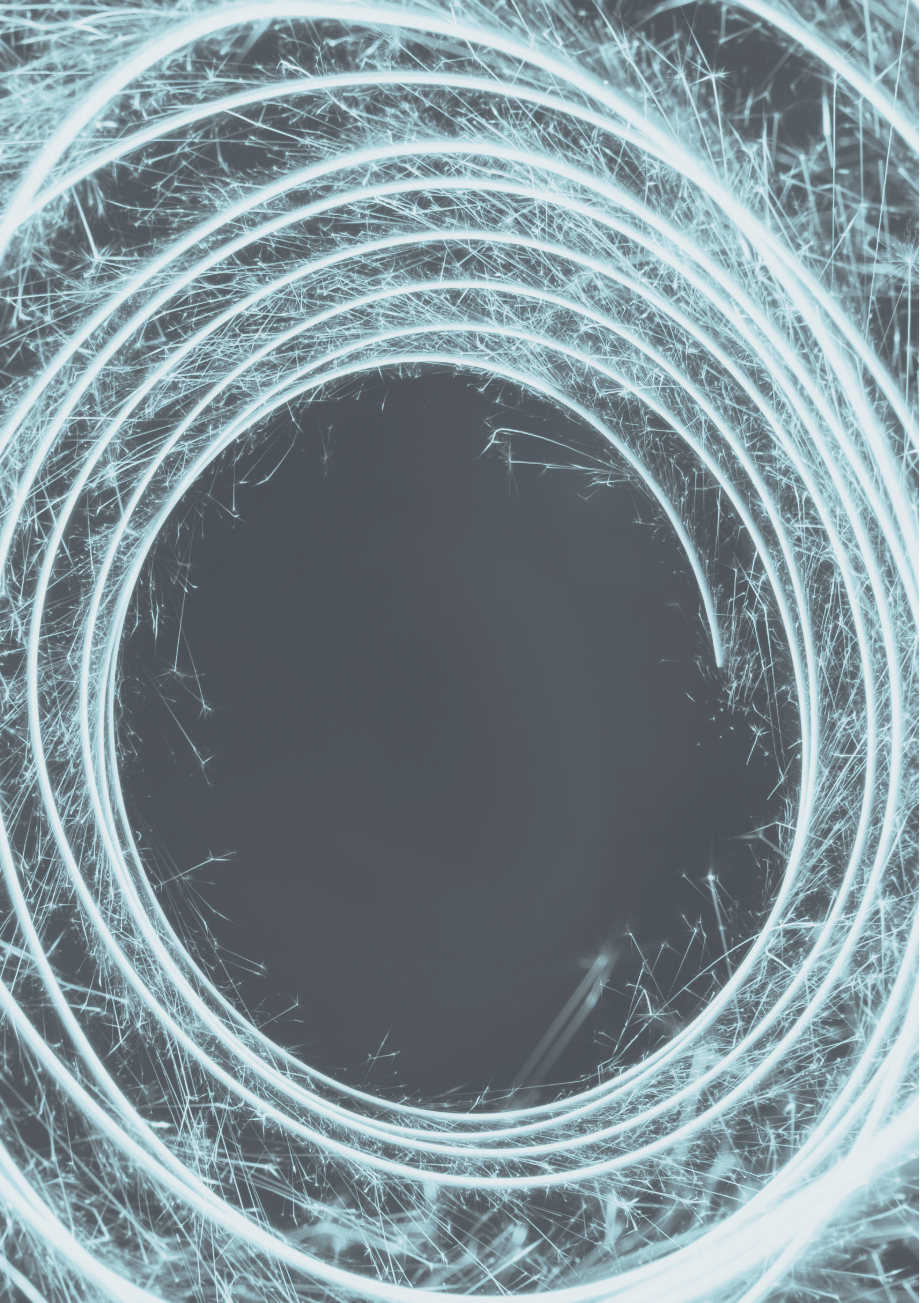

ABSTRACT

The frequency analysis of vibrations caused by rotating machines (e.g pumps / fans) can provide useful indicators of future failures. Long-term analysis can avoid expensive outages and reduce associated maintenance and service costs.

Whilst working with our client in Kuwait on vibration issues specific to their rotating machines asset base, we looked to develop a long-term analysis solution to ultimately integrate within the clients' life extension plan.

We present a highly integrated 'vibration sensor' which incorporates all critical functions in a miniature module which can be installed virtually in all potential locations. The fully resin encapsulated module incorporates a 3-axes vibration sensor, temperature transducer, microprocessor & 'Zigbee' wireless transmitter and antenna. The wireless network is a mesh type, self-configuring network with error correction algorithms, designed for industrial applications, in safe and hazardous atmospheres.

Vibration wave shapes are acquired using a sampling frequency of up to 3.6 kHz. This allows numerical calculation of integral parameters such as; velocity, displacement and acceleration and to plot FFT vs. time. The large bandwidth and frequency resolution provides information about various failure mechanisms. The sensor modules have a very low current consumption; in operation as well as in sleep mode, allowing battery or energy harvesting power supply, and consequently a fast & convenient installation procedure (self-configuring). The sensors communicate with a computer, performing data storage and visualization, with primary warning functions for the machine operator.

Using a permanent internet connection, data can be sent to office based engineers/experts and/or a 'rule based' expert system that is currently under development. We will present details of the technology involved and results with sea water pump and fan monitoring.

This first project is part of a life extension plan and an approach to reduce maintenance cost by condition based maintenance.

INTRODUCTION

Wear and tear on your rotating machinery is inevitable - through electrical and mechanical stress, as well as the environment in which it operates. Therefore vibration measurement on rotating machines is an essential element of a condition monitoring system and can be used to predict maintenance intervals.

Nevertheless, unforeseen outages of rotating machines frequently occur despite vibration monitoring, picture 1. In many cases the sensors can only respond when a defect has already occurred and normally it is impossible to mount the vibration sensor close to the potential vibration source.

FIGURE1: *Damaged spindle of seawater pump caused by unbalance.*

The detection of additional parameters in addition to vibration provides a more effective tool to detect wear and tear of machines in time to avoid defect growth and unplanned forced outages.

Multi-parameter analysis of a wider spectrum of quantities from not only the electrical machine but also their connected mechanical engines together with innovative techniques for monitoring and diagnosis, provides an enhanced basis for risk analysis and reliability centred maintenance activity, to avoid expensive outages and reduce the cost of maintenance.

REMOTE MONITORING CONCEPT

Having remote on-line monitoring under one single platform, with condensed user information and continuous access to the data stream from experts for detailed analysis will give early warnings on risk factors developing during operation to carry out diagnosis on demand.

Data obtained during outages from a variety of additional techniques can be included; robotic inspections, NDT, alignment check, high voltage testing etc.

All data is collected into a central database and each monitoring system can be integrated into the overall remote monitoring computer; and before faults become critical, experts are informed by the remote monitoring concept to give instant support to the operator.

The structure of the remote monitoring concept is shown in Figure 2:

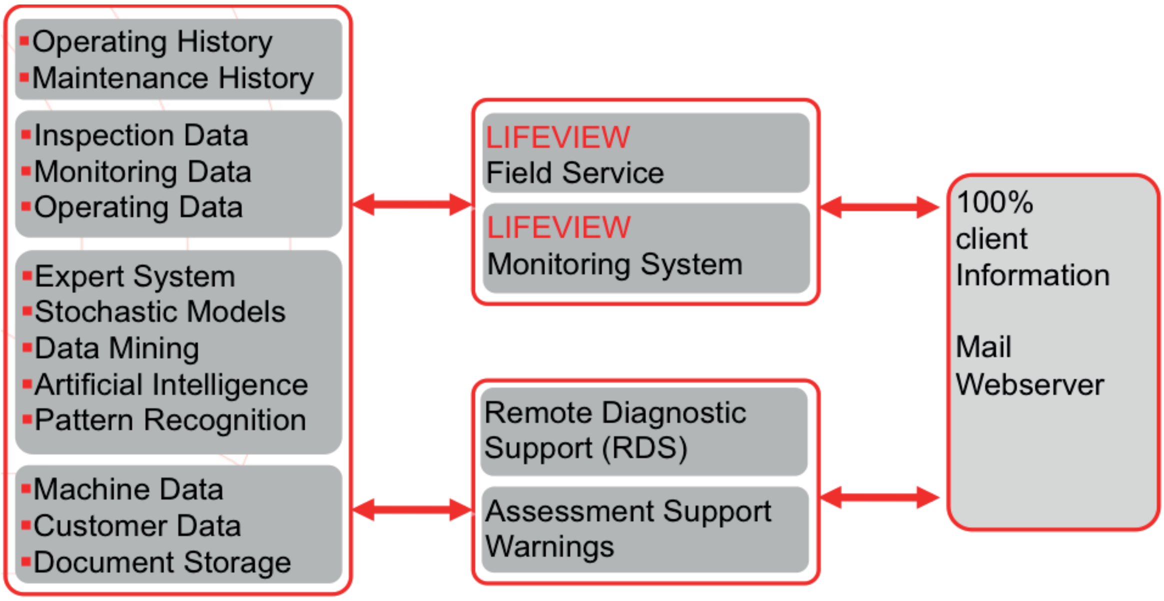

FIGURE 2: *Structure of the remote monitoring concept.*

The remote monitoring concept uses a modular approach to integrate the different condition monitoring systems:

ELECTRICAL SYSTEM:

- Partial discharge, for insulation condition monitoring. This technique is applied to motors and generators, typically from 3.3 kV and above.
- Rotor (flux) monitoring and protection (winding faults, temperature etc.)
- Shaft voltages and currents (bearing protection, rotor faults).
- Air gap and magnetic pull monitoring (typically for multi-pole machines).
- Ozone and gas monitoring (overheating, discharge activity).
- Winding vibration (causing fretting and winding failure).

MECHANICAL SYSTEM:

- Bearing vibration, rotor movement, FFT Analysis to detect various defects including:
    - Misalignment
    - Bearing damage
    - Unbalance
    - Cavitation
    - Gear mesh
- Temperature measurement, bearing temperature, air temperature

UNIVERSAL INTELLIGENT SENSOR (QVIBE)

All components and accessories of rotating machines vibrate and analysis of information within the vibration spectrum is vital in the early detection of defects to avoid catastrophic failures.

The new universal intelligent sensor QVibe was designed, Figure 3, in order to monitor vibration and temperature in critical locations that:

- Are not easily accessible
- Installation of wiring may be difficult
- Require more than one axis for monitoring
- Have strong electromagnetic interference that would deteriorate analogue signals.

The sensors are applicable for:

- All atmospheres and environments including hazardous areas, high humidity, due to hermetic encapsulations and high temperature design
- Winding and core vibration
- The detection of classical mechanical vibrations in rotating equipment
- Applications outside “classical” rotating machinery, such as transformer vibration, bushings, conveyor belts.

The highly integrated QVibe incorporates all critical functions in a miniature module which can be installed virtually anywhere. The fully resin encapsulated module includes a 3-axes vibration sensor, temperature transducer, microprocessor, “Zigbee” wireless transmitter and antenna.

The wireless network is a mesh type, self-configuring network with error correction algorithms, designed for industrial applications suitable for both safe and hazardous atmospheres.

The 3-axes vibration transducer captures wave shapes using a sampling frequency of up to 3.2 kHz. This allows to numerically calculate parameters of; velocity, displacement and acceleration as well as FFT over time.

The large bandwidth with the frequency resolution can provide information about failure mechanisms.

The internal sensor architecture is not limited to vibration and temperature transducers and can be replaced by other transducers, as ultrasound for cavitation sensors.

The sensor modules have a very low current consumption in operation as well as in sleep mode allowing battery or energy harvesting power supply and a self-configuring, and consequently, a convenient and fast installation procedure.

The sensors communicate with a computer to provide data storage and visualization of the data and primary warning functions for the machine operator.

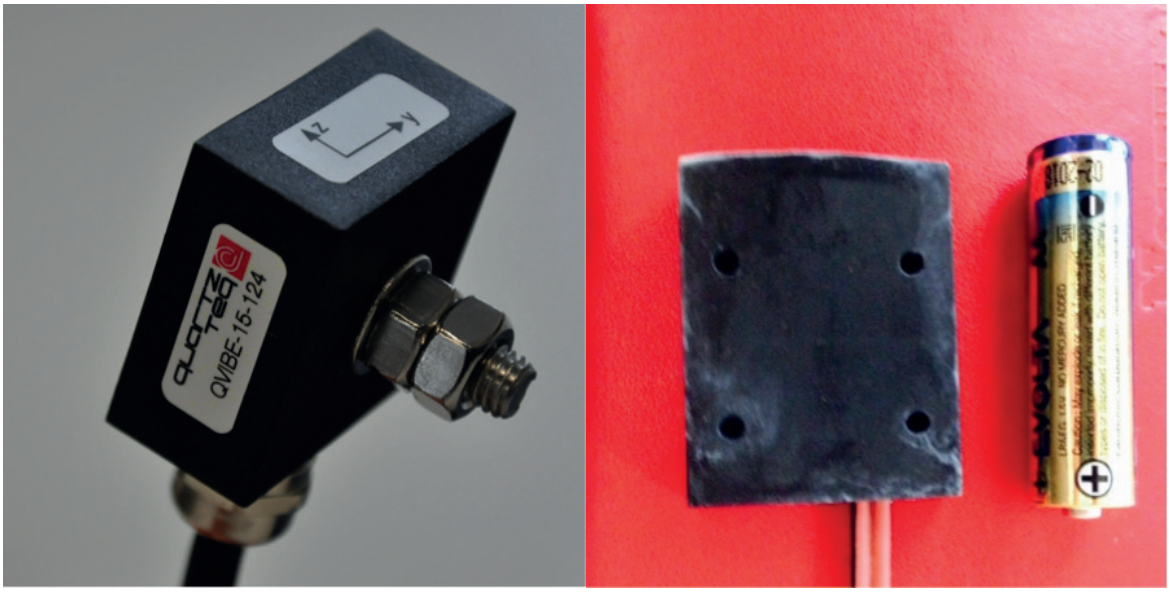

FIGURE 3: *QVibe, universal intelligent sensor, showing screw mount and glue mounts*

Electrical and operational	Sensors: Acceleration	Sensors: Temperature
Power consumption: ≤ 80mW	Axes: 3 (x,y,z)	Sensitivity: ±1°C
Power supply range: 4 to 36VDC	Range: ±12 g	
Operating temperature: -20 to 105°C	Sensitivity: 3mg	
Dimensions: 3.5 × 2.5 × 0.4 cm	Burst sample rate: 3200 Hz	
Network: 2.4 GHz, 100m, >65000 nodes possible, 250kb/s	Resolution: 13 bit	

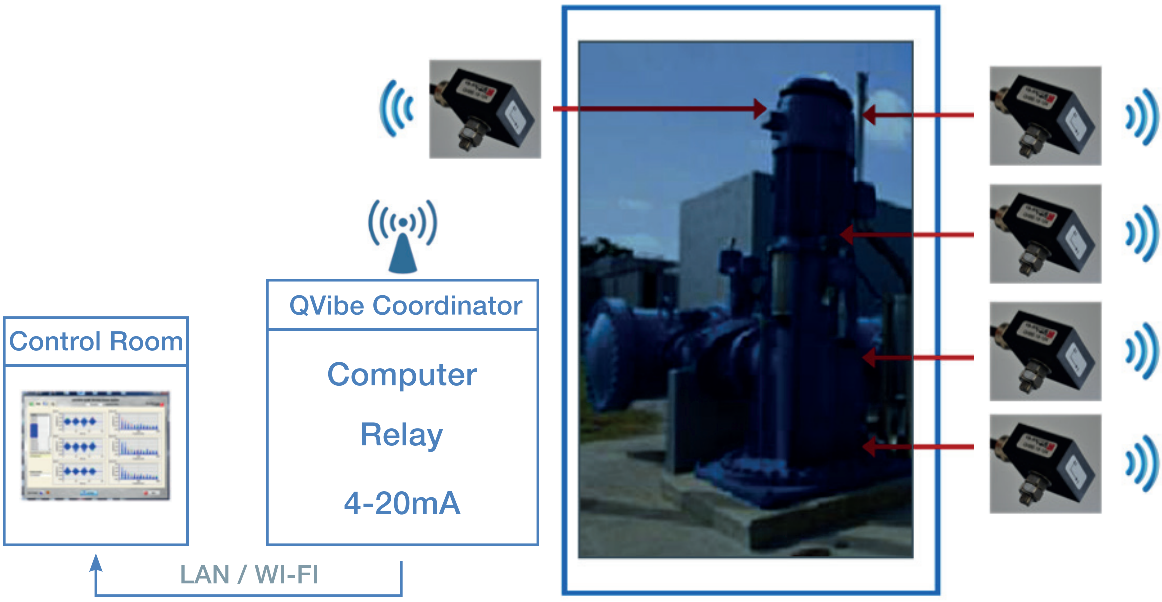

FIGURE 4: *Installation block diagram (e.g. vertical pump)*

QVibe can be installed directly on the casing of the pump; screwed or adhesive mounted to suit the frame condition, and can be powered by various power supplies:

- Battery pack (must be replaced every six months)
- Solar panel pack including battery
- Fixed DC power supply.

The sensors communicate with a co-ordinator QVibe via a wireless mesh network, as figure 4. The mesh network allows any sensor to be a repeater and extend the distance range between the coordinator and the sensors.

The QVibe co-ordinator also works as a network manager, collecting the data from the different QVibe sensors and processing it in order to deliver quantities for analysis.

Connecting the co-ordinator to internet, for example by using a 3G adapter or any existing internet connection, allows any authorised user to access to all data.

Alarms can be automatically sent by email when a measurement parameter exceeds a threshold level. Local outputs (e.g. relay, 4-20mA) can be connected to the control room.

A further advantage of an intelligent wireless (distributed) sensor system; it has virtually limitless expansion capacity. To increase the number of QVibe sensors the central computer acting as a central database data logger for all inputs does not need to be expanded by wiring or other electronic modules.

LIFEVIEW: DATA LOGGING, ANALYSIS AND ALARM

The whole system is controlled as an initiative through a graphical user interface (GUI), which is also accessible remotely by experts.

The transducer monitoring software is installed inside the QVibe sensor, so any computer or tablet can be used for accessing the data.

The primary monitoring function is always trending, as figure 5. This shows displays of trend data of x, y, z vibration data from a multitude of sensors, useful for comparison. Physical quantities can be displacement, speed, or acceleration, RMS, full spectrum, or peak from only a part of a spectrum.

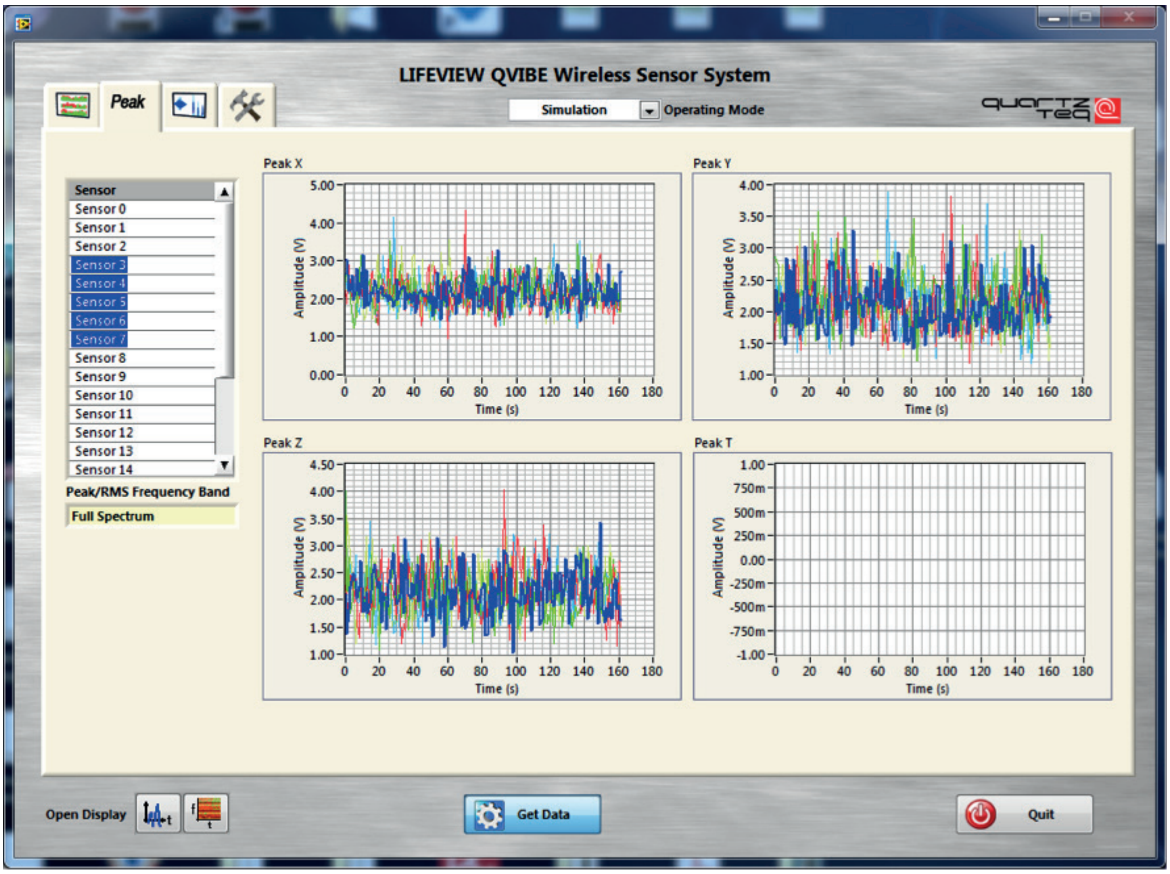

Figure 5 : *LIFEview Trend display*

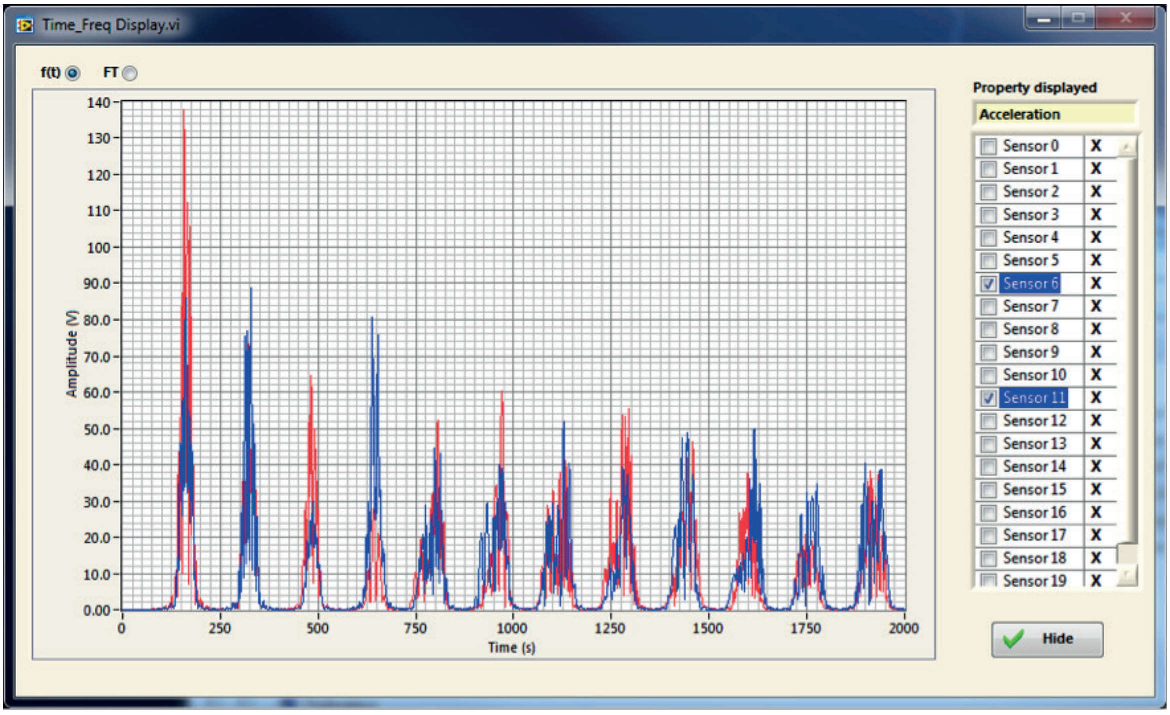

Figure 6: *FFT Spectrum*

High resolution and sampling rate allows the calculation of high-resolution frequency spectra. Detailed analysis of the spectra allows expert diagnosis to find the root cause of any defect identified.

Present research concentrates on feature extraction and the use of the LIFEView expert system for enhancing interpretation.

Currently, root cause analysis is performed by specialists, who evaluate the data, after warnings issued by exceeding pre-set thresholds. Therefore the advanced GUI representations within LIFEView allow the interpretation of the data to find alarm causes.

One of the most important tools is the spectral flow diagram, which is an FFT spectrum of vibration data over time.

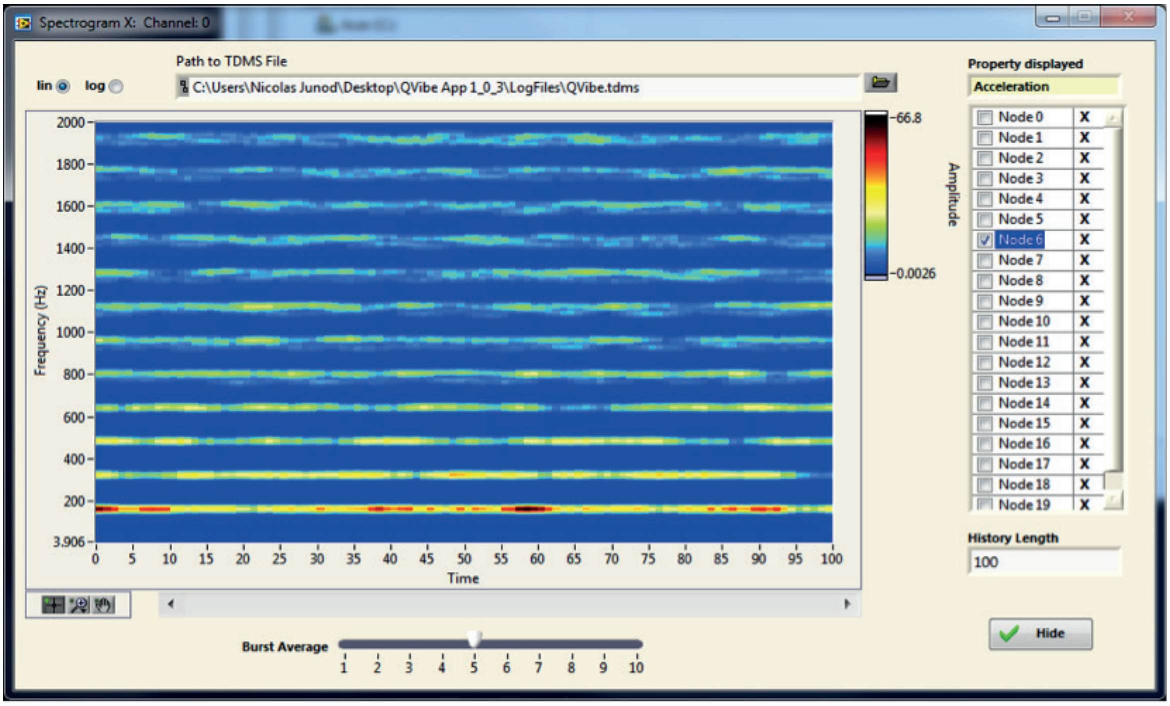

Figure 7: *Frequency spectrum trend*

The spectral flow, figure 7, patterns, instabilities and fluctuations within the data to be easily identified. Burst average functions enhance the data precision and statistical stability, figure 8, and simplifies vibration wave shape signal analysis for detection of impacts.

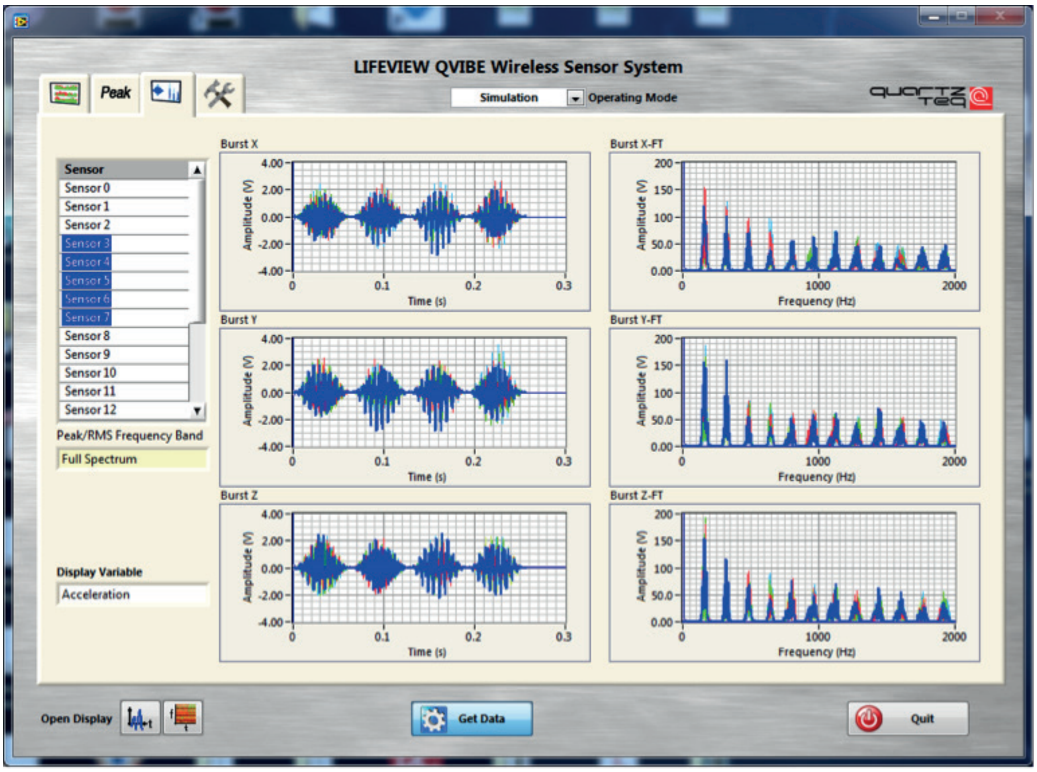

Figure 8: *Burst data and FFT*

Another form of representation is the peak level display, figure 9, which shows the overall state of integral (RMS) vibration and looks at all maximum and actual values at once in real time.

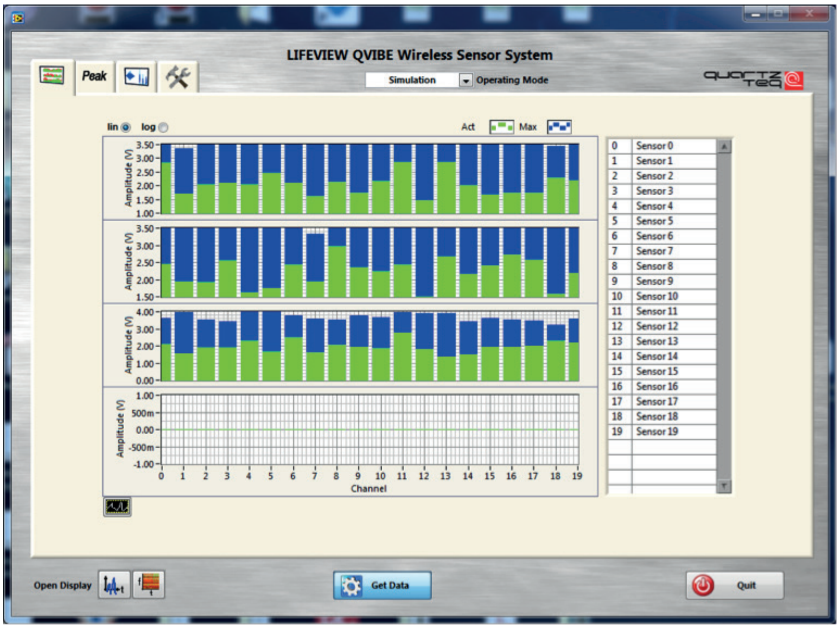

Figure 9: *Peak Overview*

Some phenomena have specific spectral areas, especially gear boxes, pumps and electrical machines. A warning message can be generated when a measurement parameter exceeds a threshold level. Alarm threshold levels can be determined depending on the frequency as shown in Figure 10.

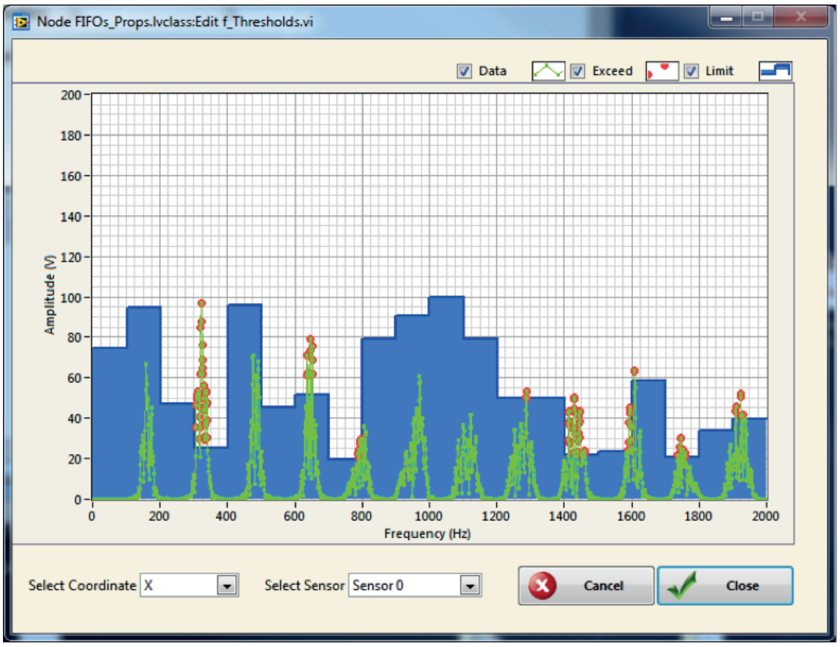

Figure 10: *Warning threshold*

Figure 11: *Monitoring of 16 Seawater pumps in Kuwait*

In order to track these and inform the operator, characteristic values are extracted from spectral areas, which are defined based on known characteristic models and initial analysis.

The alarm levels can be specifically adapted to the needs of a unit and instead of globally triggering on level, concise mathematical models can be used.

For example, early damage of the bearing or unbalance will be detected at an early stage. This early detection and diagnosis allows continued operation, but enables the proper planning for shut down and ordering of spare parts. In the case of monitoring multiple units (figure 11), reliability centred maintenance can avoid unnecessary outages and systematic failures can be detected.

The wireless system, QVibe, is a platform for a development towards multi-parameter distributed monitoring systems virtually unlimited in number of channels and measurement parameters. In conjunction with LIFEView's GUI giving advanced diagnostic data presented in a way to simplify complex operational data, allows for advanced notification of specific failure modes and gives notice to plan outages for rectification.

The limitless expansion capacity allows for condition monitoring of a range of operation parameters and targeted alarm levels, with remote expert access available to aid diagnosis, allowing operational time, and time between outages, to be safely increased.

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Dr. Bernhard Fruth (correspondence)
bernhard.fruth@quartzteq.com

Quartzteq GmbH
Dorfstrasse 69
5210 Windisch
Switzerland

24 Hr Support
+44 (0) 8705 002 003

Tel: +41 56 560 2060
lifeview.europe@quartzteq.com
www.quartzteq.com

quartz teq