Knowledge Based Maintenance – Knowledge Based Diagnostics

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Abstract

The concept, build-up and realization of a knowledge based diagnostic system are reviewed, which integrates the results of different diagnostic measurements into a unique system, like vibration, thermographs, oil analysis, ferrography, ultrasound, ..., as a basis to the Knowledge Based Maintenance. The operation of the knowledge based vibration expert system is presented, the process of the diagnosis making and working out expert advices. Will be traced the off-line and on-line versions of monitoring systems through a couple of real examples. It will be discussed the advice function of the knowledge based system, the ways of the transfer of diagnostic and maintenance information to the maintenance end-user experts. It will be shown the different ways of information-logistics: web-based, direct e-mail, and connection to the CMMS systems. It will be presented some practical examples. At the end will be discussed the possible ways of development of Integrated Diagnostic Knowledge Based Systems realized in the nearest future.

Introduction

There are three ways to maintain a piece of rotating machinery. You can wait until it breaks down, and then fix whatever failed. You can do preventive maintenance on a time -based schedule. Or you can fix whatever is getting ready to break. It is easy to figure out that the third alternative, called condition-based maintenance, is the better approach. The problem is getting a software or computer to tell you when and how it needs to be fixed.

The costly run to failure (RTF) maintenance practices are nearly disappear today, thanks to predictive maintenance (PdM) tools. In the past, the inherent limitations of RTF or periodic maintenance could quickly turn a single component failure between time-based inspection cycles into an expensive problem.

A solution to this problem is available from software specifically designed to help facility engineers evaluate the machine's condition through trending of periodic tests — such as vibration, oil analysis, ferrography, infrared thermography and ultrasound inspection. The new software simplifies the periodic testing, automates processing and analysis of the data and uses today's connectivity to distribute the latest condition assessment information to key decision makers.

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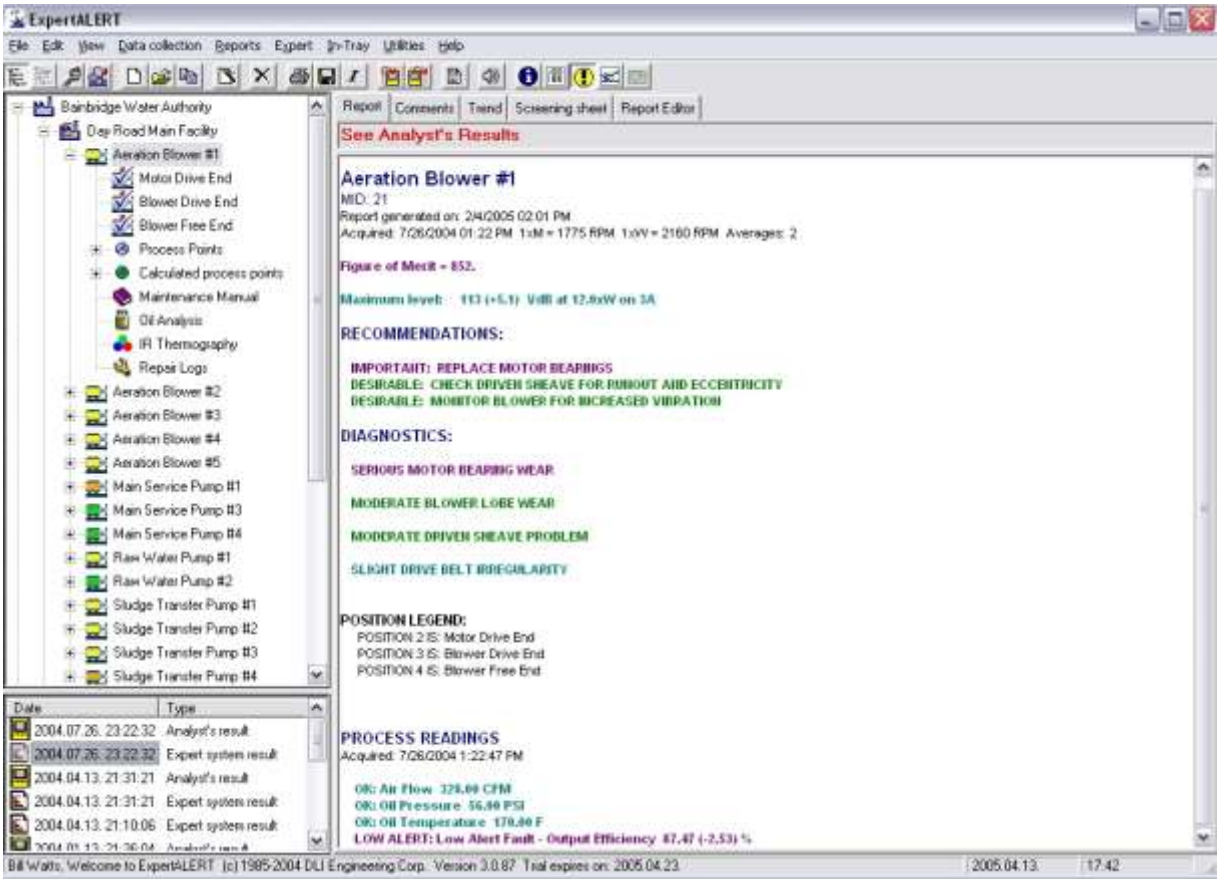

Fig. 1. Diagnostic report, technology integration

Asset Condition Monitoring Expert System

Usually 80-90% of the machines in a typical plant will have no serious mechanical faults, so we do not have to waste time on machine parts that have no need for replacement. The up-to-date PdM programs employ expert systems to reveal machine test-results that look acceptable, allowing analysts to focus only on those machines that may have faults. The time saved by not manually reviewing the data from every single machine in a plant is significant.

ExpertALERT can process hundreds of vibration measurements in just a few minutes, leaving maintenance experts and managers with a fault diagnosis, severity indicator and repair recommendations on each machine. The diagnostic engine uses an empirical, rule based, logic system that uses a wide variety of data types, a few advanced "proprietary" methods and previous machine history to formulate its conclusions. It uses more than 4500 rules for identification more than 650 different machine faults.

The system, developed by DLI Engineering Corp. (an ABB owned company), is empirically based on more than 20,000 machine tests collected annually since the early 1980's and the system continues to evolve today as new machine types are encountered and added to the system. Currently it is installed and operating successfully in hundreds of plants around the world covering industries ranging from breweries to aircraft carriers, pharmaceutical companies to computer chip makers, and nuclear power plants to oil refineries.

ExpertALERT™ is one of the most advanced machine condition assessment vibration analysis software, to allow expanding capabilities by streamlining analysis and routine processes. The automated analyses of data and multi-user access to results have dramatically increased the "speed of information distribution" among the utility's maintenance group. The ability to get complete results

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to the right people quickly to support timely maintenance management decisions is another favored benefit since the senior test engineer is personally responsible for reviewing all machine faults and repair recommendations.

ExpertALERT was originally designed for and continues to analyze thousands of machine tests per month. The needs of a successful condition assessment program demanded to build these capabilities:

- Intuitive graphical user interface that is simple to learn and operate
- Setup wizards reduce set up time and increase configuration accuracy
- Automated diagnostics accurately predict faults
- Automated bearing fault identification without requiring bearing make and model number
- Multi-level fault severity and prioritized repair recommendations improve repair planning
- Advanced reporting tools produce professional reports
- Better machine performance determination through ALERT's calculated process points feature
- Integration of other PdM technologies, reports, documents, spreadsheets, inspections, manuals, linked to machine records
- Online monitoring, walk-around vibration collection and operating log collection in one system

ExpertALERT provides objective results that help the user manage increasing workload. Its diagnostic system identifies even the most subtle patterns in the vibration data, and provides repeatable, quantifiable and detailed diagnostics. Identified faults are trended over time, allowing tracking actual faults, rather than just vibration levels.

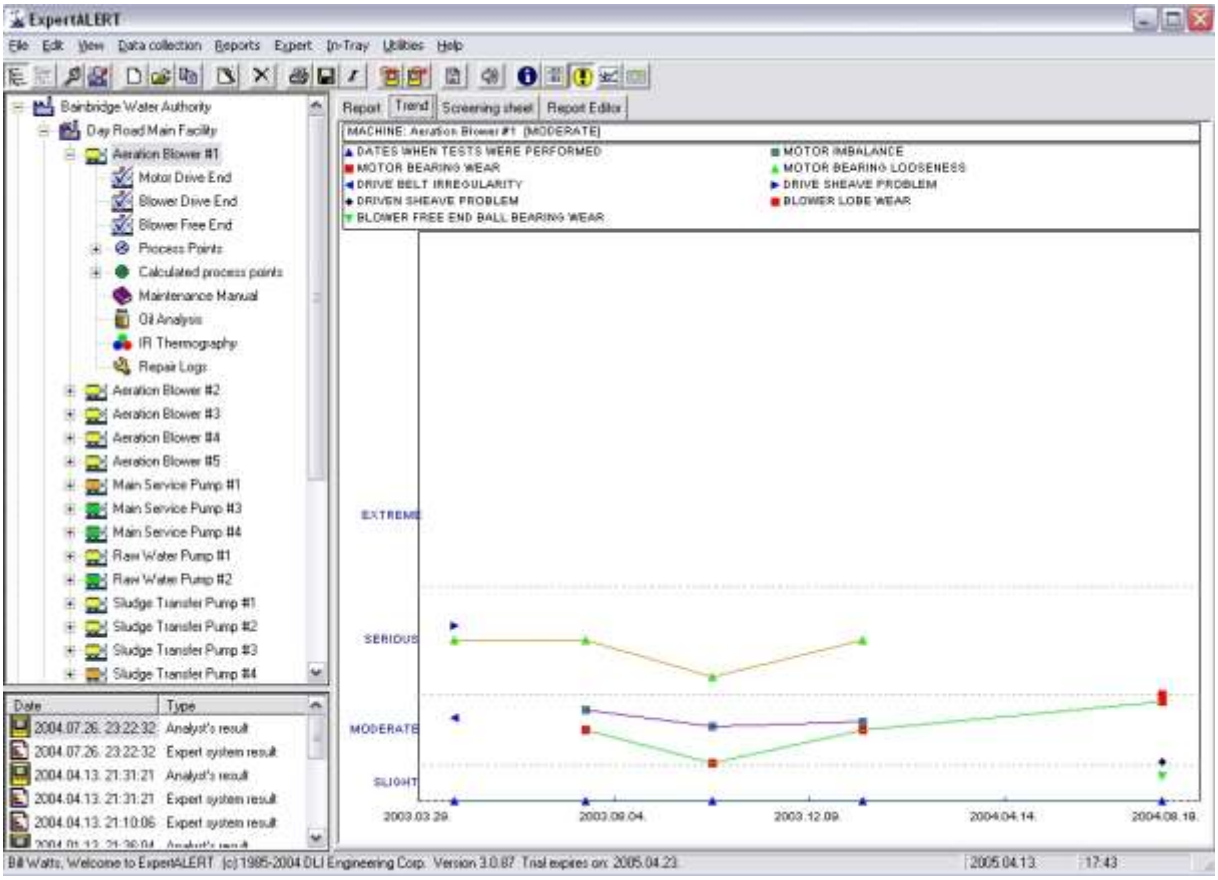

Fig. 2. Fault trend over time.

Even the most advanced analysts appreciate the quality of the diagnostic output, as it directs them to subtle and specific items that may be easily overlooked by a busy analyst. Accurately segregating the

good machines from the problem machines, ExpertALERT frees the analyst to spend more time reviewing the problems.

The vibration analysis module of the software was expanded recently by a few new features, raising the capabilities of the expert system.

The new version of *Cepstrum Analysis* is essentially a spectrum of a spectrum and is useful for extracting periodicities from a spectrum. Cepstrum is used by BearingALERT™ to automatically extract bearing tones from a spectrum.

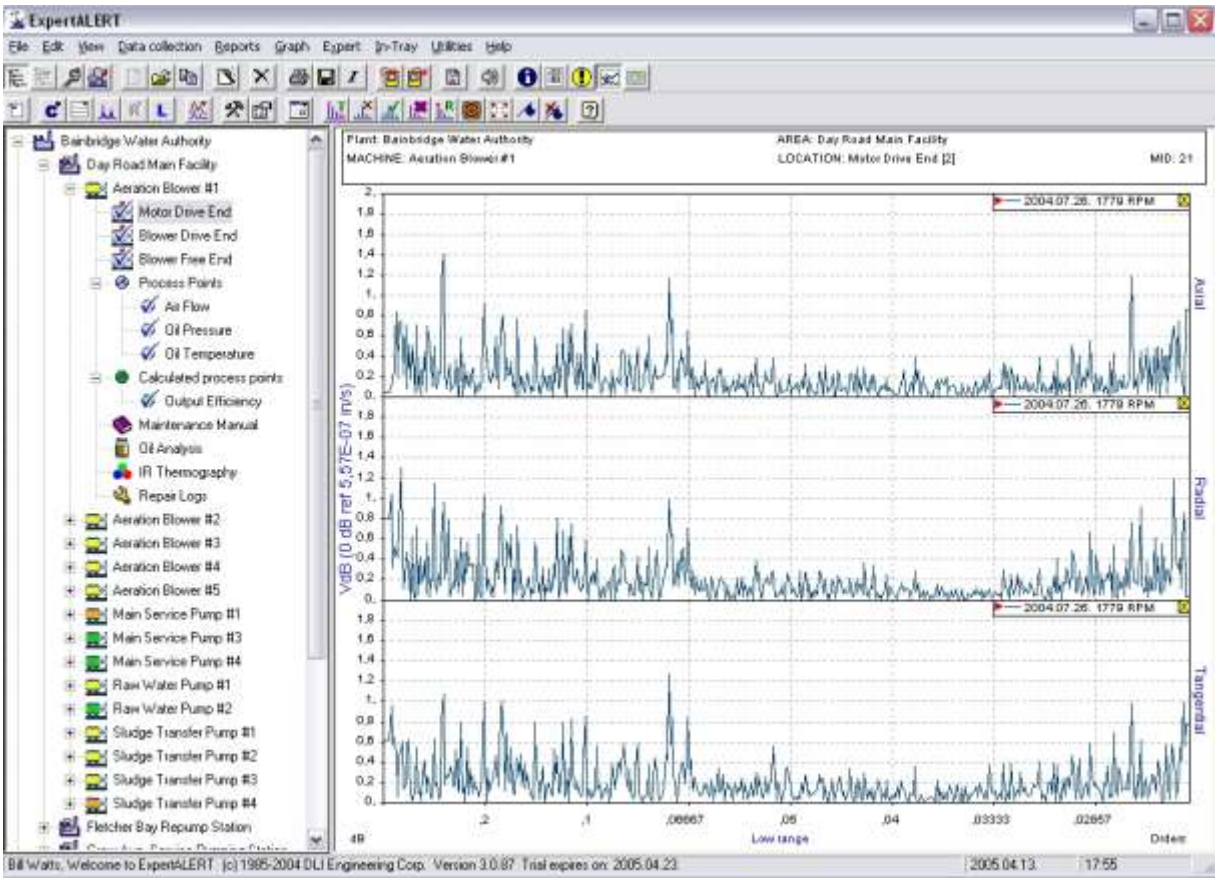

Fig. 3. Cepstrum analysis.

The *Bode Plots* (1X amplitude vs. RPM and 1X phase vs. RPM) used to identify critical shaft speeds, very informative tool in "run up" and "coast down" tests.

The Proximity Probe Analysis is a useful tool in some cases. ExpertALERT is capable to analyze the full orbits, 1x filtered orbits, Poincare map, Animated orbits. In addition of the power spectrum, the full spectrum can give additional information to the condition monitoring. Proximity probes are often used to monitor journal bearings. Orbit plots describe the motion of the shaft centerline in a 2D polar plot. The Full Spectrum is to the Orbit what the spectrum is to a time waveform. The Full Spectrum contains the same information as the orbit but is preferred by some for analysis and trending.

Vector plot formats maintain aspect ratios, meaning that the plot will look correct no matter how large or small the user make it. The ability to print these plots to small files makes them easy to email, embed in MS Word or Web pages or share with associates who do not have ALERT software. The plots can be viewed using any image viewing software.

Up to 4 bearings can be assigned to each test location. The BearingALERT™ does not require bearing information to diagnose bearing wear. A machine may have up to 99 test locations. For the most

possible bearing fault identification ExpertALERT supports the multiple demodulation filters. Demodulation is useful for detecting faults in rolling element bearings and gearboxes. It is especially useful for slow speed shafts. Time Synchronous Averaging is useful for troubleshooting gearboxes.

Process parameters such as temperature, pressure and flow rate are useful indicators of machine health that complement vibration analysis. These parameters may be hand entered in the software, collected via sensors or integrated via OPC. Users may now include measured parameters in equations to calculate items such as efficiency, pressure differentials, flow rates and other indicators of machine and process health. Linear speed measurements may be converted to RPM (such as in a paper machine) and used to normalize vibration data. Process point trend plots can be customized.

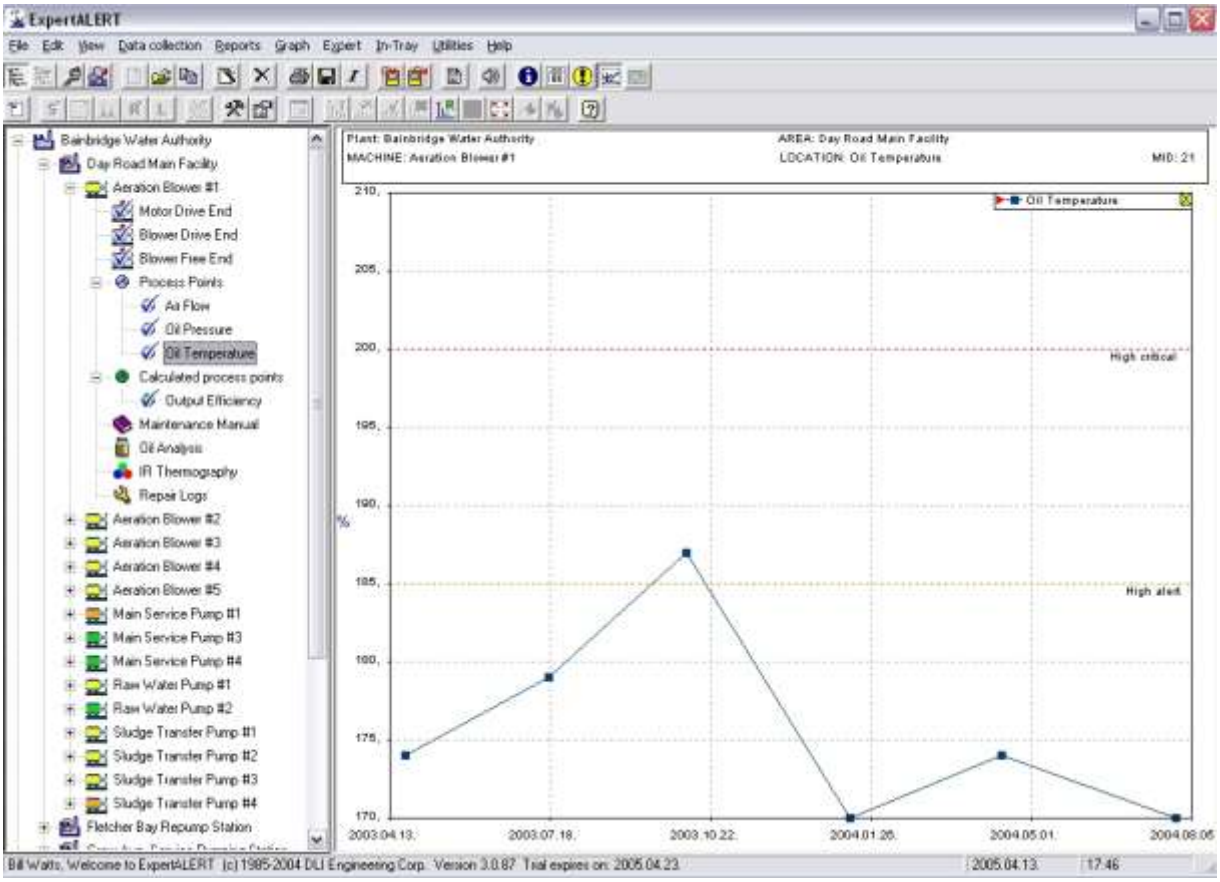

Fig. 4. Process point trend over time.

Gains in Integration

While maintenance success stories rely on the powerful data collection and process tools, the breakthrough benefits result from the integration of this important maintenance data into one seamless source of concise information.

The DLI Engineering's ExpertALERT is an integrated environment, a software platform, that combines vibration analysis, used-lubricant analysis, ferrography infra red (IR) thermography, ultrasound inspection libraries and even visual inspections (input via portable data collection instruments) to provide a single view of the maintenance status of a plant's machinery. By utilizing one common platform to combine and compare various data sources, a cross-technology scoring can be achieved.

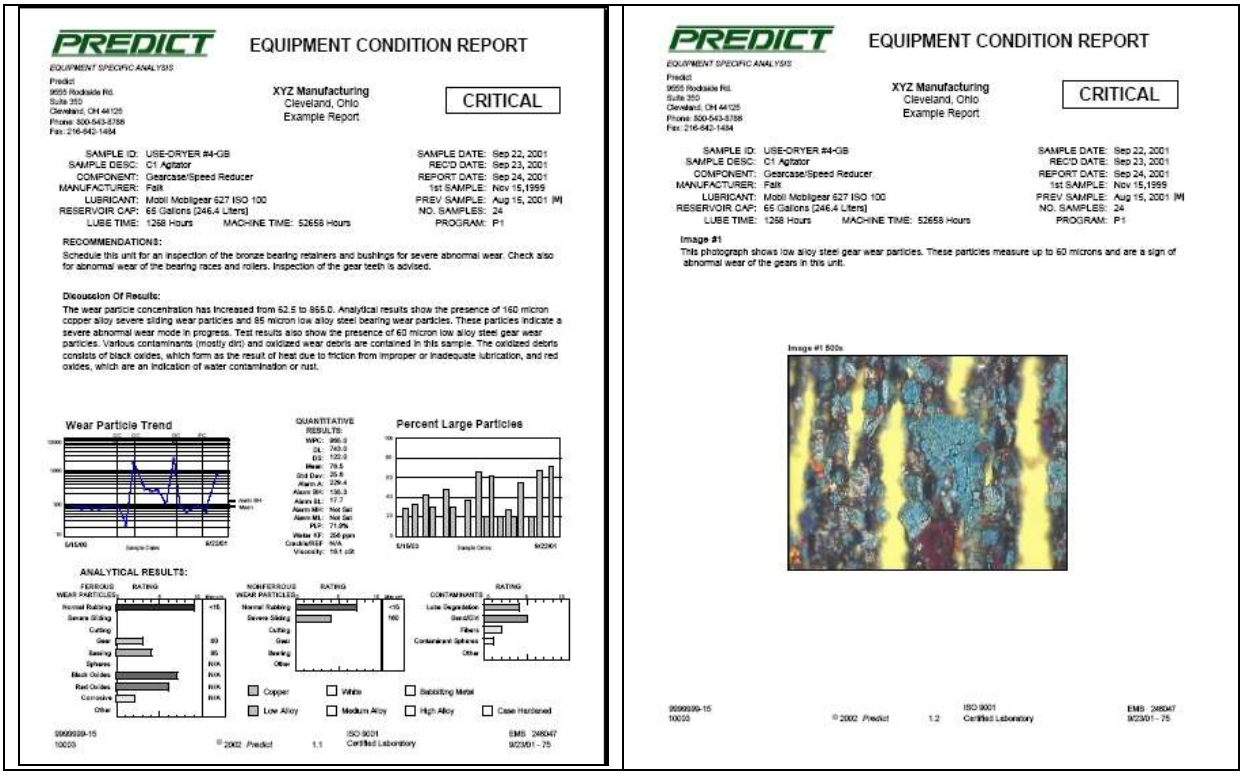

Fig 5. Oil Analysis and Ferrographyc report.

This yields a prioritized ranking so that facility managers can schedule plant-wide repairs in order of urgency. Reports can be customized to include detailed plots and images to justify comprehensive, program-management decisions.

Off-line and On-line monitoring

The number of regularly tested machines in a PdM monitoring program may grow so large in many plants that the quantity of machines picked up in the exception reports could overwhelm the human experts capable for detailed condition analysis. In this cases the automatic expert system based off-line monitoring systems can resolve the problem, handle the enormously large amount of vibration measurement, evaluate data, tuning the raw data into information on the condition of monitoring rotating machines.

The most cost-effective approach to maintenance management is to go online and have all of the analysis functions conducted by off-site experts or in some central location within the organization. On-line vibration diagnostic systems, with remote monitoring capabilities, facilitate this type of work and spare the cost of sending technicians to the plant to collect data. It also saves the plant from being reliant on its own in-house predictive maintenance experts or provides the option of consolidating this knowledge in one office.

Reliable expert system technology also assists the move to the online analysis as the system can be left to itself to monitor the machinery. The analyst only needs to get involved when a fault has been detected. Modern communication technologies allow the monitoring system to alert anyone and everyone as soon as a problem has been detected, via email, text pagers or by popping up a live message on a computer screen at a remote monitoring station. The system can also close relays to cause alarms to sound, lights to flash or a control system to be signaled. Expert diagnostics are accurate enough to inform interested parties of the specific type of fault the machine has and the severity of that fault. Lower level data may also be accessed in order to confirm the problem.

You can find below the schema of on-line vibration monitoring system of NPP Paks:

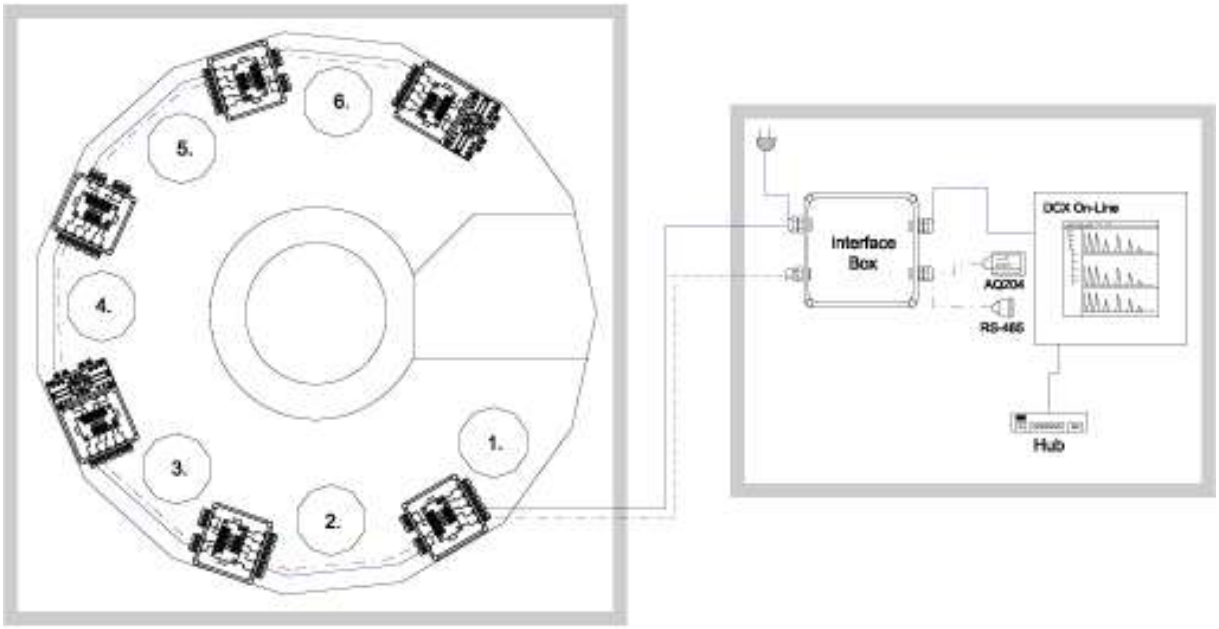

Fig. 6. Schema of on-line vibration diagnostic system at NPP Paks.

Figure shows the schemas of three On-line Vibration Monitoring Systems at MOL, Hungarian Oil and Gas Company. The on-line Monitoring Systems use one central database placed on one central Vibration Diagnostic Server.

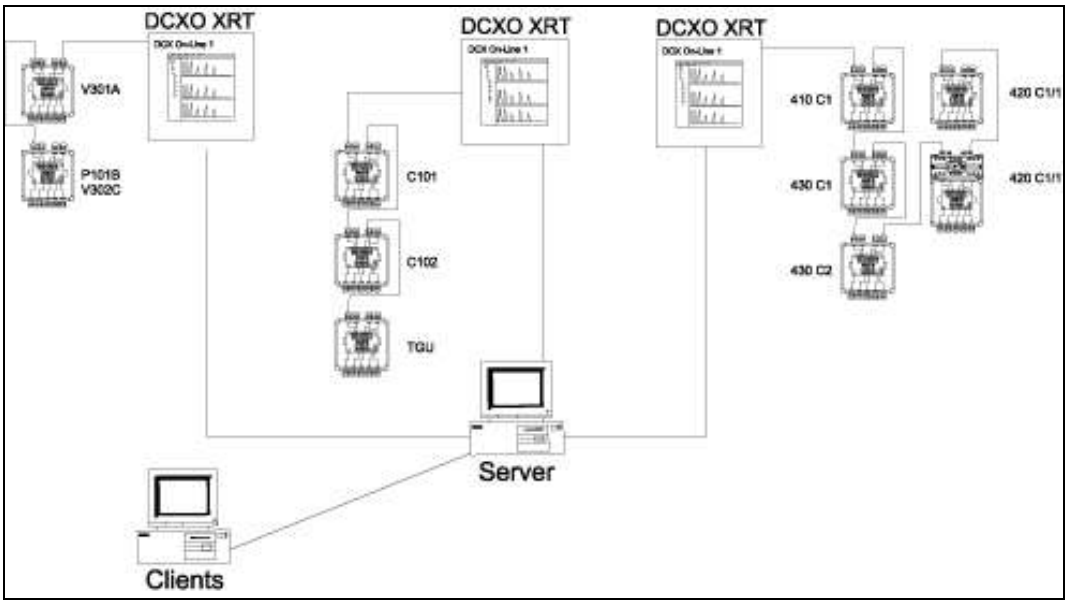

Fig. 7. . Schema of on-line vibration diagnostic system atMOL Hungarian Oil and Gas Company

Information Delivery

The current result of Predictive Maintenance (PdM) management software now delivers instantaneous decision-making power for those engineers and plant managers who want to gain the maximum capability of their assets while saving maintenance costs. Capable of instantly analyzing and interpreting vibration data, along with ferrography, used-lubricant analysis, ultrasound measurements and visual inspections, the modern PdM software not only delivers integrated and prioritized information to plant managers in their offices, but throughout the entire organization via enterprise-

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Fig. 8. Expert system's web pages.

wide "electronic in-trays," text messages, pager alerts, and even HTML pages accessible via a common Web browser.

The open database structure makes possible to connect to databases other information systems, like CMMS systems.

Today's new networking technologies offer more power and transparency. XML, OPC, and Microsoft's DCOM and .NET are breaking down the barriers of integration and distributed computing.

DLI Engineering's online software permits facility managers to find out the status of monitored machinery simply by log-in their network to view real-time vibration data or obtain a complete diagnostic analysis. Under such topology, the online system is simply another node on the plant's LAN. An Active-X component can even be installed on selected computers so that maintenance alert messages automatically pop-up on the screen. Additionally, electronic "in-trays" can be configured, resulting that only the status of critical, process machines will be delivered to the user.

We have the technology to send results over the Internet and through electronic wireless connections like digital cell phones and pagers. The information gets to the right people.

Conclusion

The biggest maintenance savings come from the reduction in total maintenance work made possible by avoiding unnecessary maintenance. With a limited number of maintenance hours available, being able to 'work smart' and optimize maintenance hours is crucial. Managing equipment this way will help to stay competitive.

The primary objectives of predictive maintenance are to reduce unscheduled downtime and channel limited maintenance funds where they are most effective.

The complex evaluation of different analysis results multiply the effectiveness of asset condition identification and decision regarding the maintenance actions.

Technology Integration is an important aspect of a successful condition monitoring program. In ALERT™, the user now has an easy way to link relevant information to a machine in the database. With a simple mouse click, users can access infra red thermography images, oil analysis results, ferrography reports, ultrasound readings, maintenance manuals, digital images, historical reports, repair logs etc. The most important aspect of the integration technology is that it is not dependent on the 3rd party software being used.

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