13th HDO International Conference, Šibenik, Croatia 15-17 May, 2007

MAINTENANCE 2007

INTEGRATED DIAGNOSTIC SYSTEM FOR PREDICTIVE MAINTENANCE

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Key words:

- Maintenance
- Condition Monitoring
- PdM

ABSTRACT:

We give a scope of the newest and largest project in Hungary for establishing Integrated Diagnostic Monitoring Systems. The complex condition monitoring system contains two off-line and eighteen on-line systems. The on-line systems automatically measures and evaluate data. All of them are capable to make automated diagnosis and to give advices for maintenance. We shortly present the functions of the integrated systems and their use for maintenance.

INTRODUCTION

Developing condition monitoring and fault diagnostic systems are the main goal of the maintenance strategy of the Hungarian Oil and Gas Company. As a part of this strategy there were organized a project for installation off-line vibration diagnostic system for nearly 2000 rotating machinery in the Refinery Szazhalombatta.

The commissioning of the system was finalized in the beginning of 2003 by Delta-3N Ltd. In the first year, we can tell in the year of the learning period of the system operation, the colleagues of the MOL company achieved notable results improving the effectiveness of the maintenance practice in the refinery. As a result of the throughputs the management decided to continue the project investing into three on-line vibration monitoring systems which monitors the 10 most important rotating machines.

After one another year experience of using the results of off-line and on-line monitoring systems significant changes were experienced regarding the information endowment for maintenance of rotating machinery. The most important fact is that, the unscheduled downtime with loss of production as a consequence of the unexpected breakdown of rotating machines was reduced from 23-25 events per year to 1-2 events per year. And it is only one parameter, which is characterizes the achievements in the three years of operation. Concentrating to the most problematic faults, the maintenance organization meets less severity of possible faults. The maintenance planning become more and more capable to orga-

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nize the maintenance tasks using a good information basis regarding the condition and fault type and severity of faults of machines.

On the base of these achievements, the management of the oil company decided to continue the investment and ordered to install another 15 on-line monitoring systems for 101 most important machines. In the meantime except of the vibration monitoring other diagnostic technologies was introduced into refinery like thermography, leakage monitoring at the sealing, oil analysis and ferrography. In the frame of the new project important task is to integrate these diagnostic technologies to have all time actual complex information on the asset based on all diagnostic information. The risk based maintenance management is under development at the refinery. Therefore, in the project there was assumption to work out a risk matrix to support the risk based maintenance decision for rotating machines. The other requirement was to realize the connection to the CMMS system, which is the SAP PM.

METHODOLOGY OF VIBRATION CONDITION ASSESMENT

The success of the system is based on the capability of the ExpertALERT condition assessment software of the DLI Engineering (an ABB USA Company). It is an automated rule based expert system for vibration analysis. We introduce shortly this methodology.

DLI Engineering's methodology provides the following capabilities in the most efficient manner:

- Data Acquisition (Sensor Selection & Mounting)
- Data Manipulation (Signal Processing)
- State Detection (Baseline Profiles)
- Health Assessment (Automated Fault Diagnostic)
- Prognostic Assessment (Prioritized Repair)
- Advisory Generation (Reports & Documentation)

DLI introduced the first commercially available triaxial accelerometer for 3D vibration measurements over 20 years ago and still supports its use with all of its portable analyzers and on-line vibration monitoring systems. A triaxial accelerometer or three single axis accelerometers with mounting pad is the most efficient method available to collect a complete set of vibration data in three mutually perpendicular directions. This method of data collection for portable periodic data collection offers the following advantage:

- Fast; collect vibration data in all direction in one step
- Complete data set; simultaneously collected data contain more correlated information then the step by step collected data in three direction; besides collecting data in 3D data collectors and on-line systems support two frequency ranges, typically low range (10 x machine speed) and high range (typically 100 x machine speed
- Repeatable; the use of permanently mounted pads on each measurement locations insures repeatable data using portable data collectors, that can be accurately trended over time; the barcode labels minimizes the danger of storing data on wrong machine or measurement location.

For monitoring of critical or inaccessible machines the 3D measurements usually made using three one-directional accelerometers, or vibration is measured in 2D or one direction. It is not economical to use triaxial accelerometers in on-line systems. The DLI methodology is flexible

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enough to support data collection and analysis of 3D, 2D or single axis accelerometers, velocity probes, proximity probes or a wide variety of process sensors such as speed, motor current, temperature or pressure.

The off-line and on-line systems support the next signal processing:

- Spectra/FFT: general fault determination
- Time waveforms/Orbits: impacts, sleeve bearings
- Envelope analysis, demodulated spectra: rolling element bearings
- Overall amplitude: overall machine severity
- Phase: troubleshooting
- Cepstrum: harmonic family analysis

The efficiency of ExpertALERT is based on its ability to use statistical baseline data from specific machines to compare with current data. By comparing incoming spectra to statistical baseline spectra, ExpertALERT effectively uses over 800 or 1600 frequency "bands" in its initial data screening process to identify machine faults. This technique of data comparision is far more sensitive and selective than traditional methods use 6-12 frequency "bands".

The DLI's Condition Assesment software includes a rule-based, automatic diagnostic module and the necessary graphical analysis tools to confirm or analyze a wide range of machinery faults. Its diagnostic system identifies even the most stubtle patterns in the vibration data and provides repeatable, quantifiable and detailed diagnostics. Identified faults are trended over time allowing the maintenance specialists to track actual faults rather than just vibration levels. More than 4700 individual rules can recognize 956 specific machine fault patterns in 47 different machinery components.

Another benefit the methodology is its unique ability to generate a report with the next content:

- Names of the specific machine faults
- Severities of the faults (OK, Slight, Moderate, Serious and Extreme)
- Repair recommendations
- Repair priority (Desirable, Important and Mandatory)
- Details of vibration peaks concerning to identified faults

This kind of information is much more easier to interpret, than the raw spectral data that is typically presented with other vibration analysis systems. The entire process of data screening, data analysis, fault diagnostics and report generation is completely automated.

MAIN HIGHLIGHTS OF THE PROJECT

The most important tasks of the project:

- Enlargement of the numbers of on-line monitoring systems for surveillance of 101 strategically most important machines
- Develop specific expert systems for analysis the next diagnostic data: thermo images of rotating machines, oil analysis, ferrography and sealing leak detection.
- Integrate the results of ExpertALERT and the newly developed expert software into a unique system

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- Develop a software handling the risk matrix for classification of risk of rotating machinery

The quantitative characteristics of the project:

- Number of affected plants in the refinery: 9
- Number of the new SpriteMax on-line monitoring systems: 15
- Number of machines come under on-line surveillance: 101
- Number of mounted Intrinsically Safe accelerometers: 950
- Number of signals paralleled from Bently Nevada systems: 250
- Allover length of armored signal cables are: cca. 8 km
- Allover length of electricity supply cables are: cca. 6,5 km
- Allover length of communication and control cables are: 6,5 km
- Allover length of special ground cables are: 4 km
- Number of multiplexers: 110
- Number of specially developed IS TMUX units: 107

The next photo shows a SpriteMax unit and two multiplexers placed into a usual IP-67 case in an explosion proof environment.

Figure 1. SpriteMax on-line monitoring computer and two MUX-es in an electric case

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The next figure shows a TMUX unit, which is a multiplexer in a pressurized box with IS barriers in each signal channels. This product can be placed in the explosion dangerous areas. It was tested and positively qualified by the Hungarian Authority BKI to work in higher environmental temperature than -35 °C. It has electric heating starting to heat the box under -15 °C.

Figure 2. TMUX unit placed to the explosion dangerous environment

The next photo shows a rotating machine with measurement points and cabled IS accelerometers and with a TMUX near the machine.

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Figure 3. Rotating machine with measurement point and TMUX unit
The next photo shows one pickup point with three IS accelerometers.

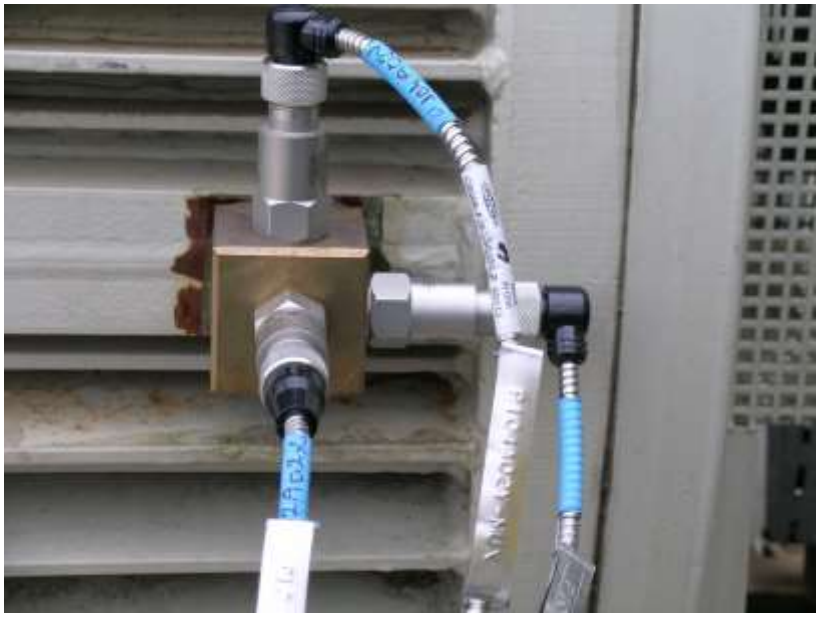

Figure 4. Measurement point on a rotating machine

One of the most important task of the project was the development of Risk Analyzer software, what can classify the risk of rotating machines, which is under off-line or on-line surveillance by diagnostic systems. The next figure shows the risk matrix with the probability and the consequence variables.

Figure 5. The Risk Analyzer; risk matrix of rotating machines

You can see the schema of the integrated diagnostic system on the next figure. Each software has its own database. The expert systems communicate with ExpertALERT receiving for further use the results of automatic analysis. All results of expert analysis created by ExpertALERT, ThermoALERT, OilALERT, FerroALERT and LeakageALERT are displayed in BDES (Board of Diagnostic Expert Systems) software as well as the result of risk qualification of machine pinpointed by Risk Analyzer software.

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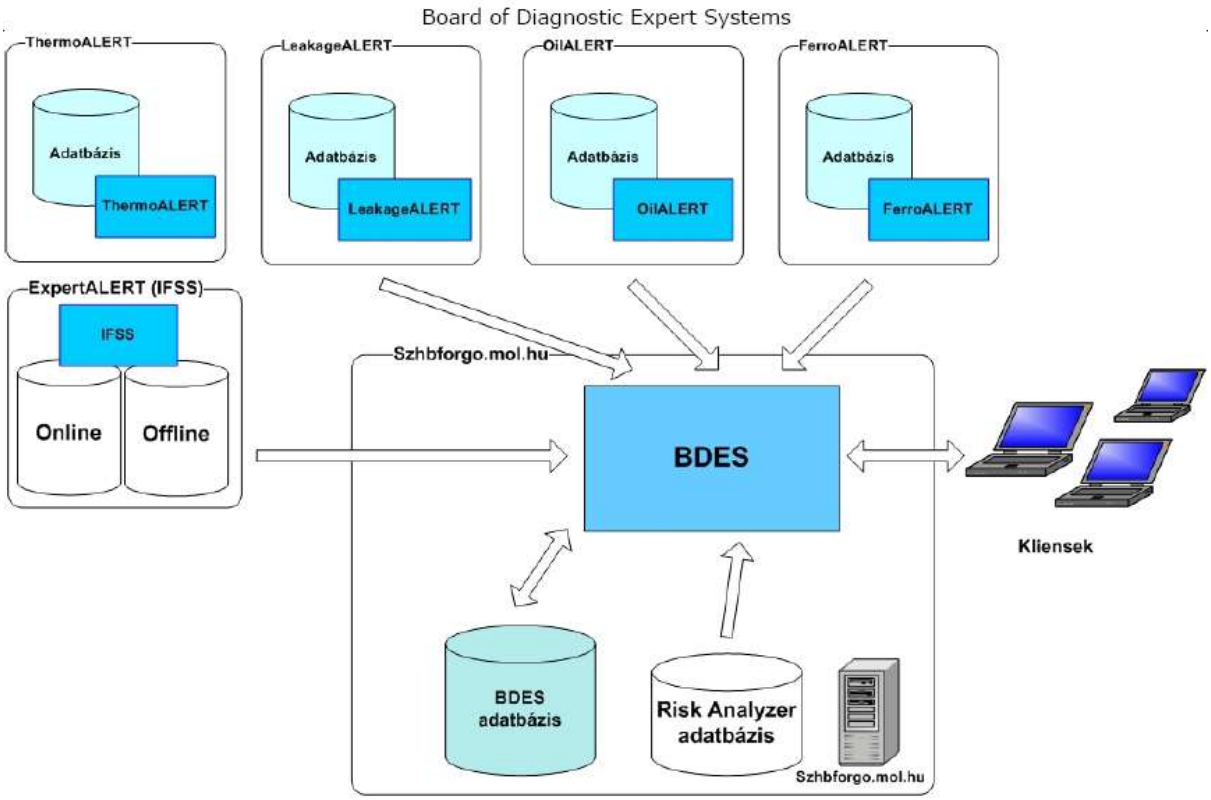

Figure 6. Schema of Diagnostics Expert Systems

CONCLUSION

The project was accomplished approximately under one and a half year successfully. The development of the data- and knowledge base was finalized. The 15 SpriteMax on-line systems work into one on-line database separate from the off-line database. The on-line measurements are made continuously for the 101 strategically most important rotating machines of the refinery. As the result of software development all diagnostic expert systems, the BDES and the risk analyzer tested and are ready for work. The results of analysis are sending to SAP PM system every day, and the actual and historical data could be rich throw corporate network using a usual browser.

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