RISK APPROACH IN ASSET MANAGEMENT WITH PRACTICAL EXAMPLES IN OIL & GAS INDUSTRY

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Abstract

The Maintenance Planning of the reviewed Plant is based on the condition of the equipment. We give a scope of one of the newest project in Hungary for development Risk Based Maintenance strategy for industrial plans with rotating machines. The complexity of the system based on integrating different state-of-art diagnostic technologies, like Vibration Analysis, Thermography, UOA and Ferrography. The results of the analysis of complex condition monitoring systems give possibility for risk ranking of the rotating machines. We describe the substance of the automated condition-based-risk-ranking process, which results displayed in risk matrices. Using the Risk Analyzer software for all rotating equipment, we esteem actual risk rating. It gives a good foundation for Asset Management, for the risk based maintenance decision making. The reliable and automatic fault diagnostics and fault severity estimation permits of the reliable condition monitoring based maintenance planning (PdM) as well, as the condition dependent risk matrix based RBM maintenance strategies parallel engagement, unite the two strategies with gaining a lot synergy.

The on-line and the off-line condition monitoring systems, which have automatic diagnostic capability (artificial intelligence software), can become a real alternative for realizing PdM&RBM maintenance strategy. We review one realization of above up-to-date Maintenance Advisory System, and shortly present the HW and SW development as well as 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, and 18 on-line systems for the 100 most important, so called critical machines in the Refinery Szazhalombatta.

In the frame of the project important task was to integrate different diagnostic technologies into a plant-wide asset management system with complex diagnostic information (vibration diagnostics, oil analysis, IR image analysis, Ferrography, leakage detection) Another strategic aim of the project was to work out a risk matrix to support the risk based maintenance decision for rotating machines. There were managed by Delta-3N Ltd. with cooperation by College of Dunaujvaros.

Methodology of vibration diagnostic expert system

The success of the system is based on the capability of the ExpertALERT condition assessment software developed by AzimaDLI. It is an automatic rule based expert system for vibration analysis. We introduce shortly this methodology.

Azima DLI'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)

AzimaDLI 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 always economical to use triaxial accelerometers in on-line systems. The DLI methodology is flexible 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, 1600, 3200, (6400 12800 or 25600) frequency "bands" in its initial data screening process to identify machine faults. This technique of data comparison 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 subtle 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 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.

Risk matrix with automatic risk ranking

We have developed a semi-qualitative risk assessment tool, such as risk ranking. Risk Ranking is a common methodology for making risk based decisions without conducting quantitative risk analysis. Our risk ranking uses a matrix that has ranges of consequence and likelihood as the axes. The Risk Matrix has consequence or severity and frequency axis. The product of a consequence and likelihood gives an estimate or measure of risk or a risk ranking. A risk matrix is a table used to assign a score to the identified risk. For each risk identified, a score is assigned for the probability and consequence aspects. The range of 1 to 5 is used for each aspect.

Risk Probability:

1. Improbable - almost certainly will not happen
2. Remote - very unlikely to occur
3. Occasional – possible, it has happened sometimes in the past
4. Probable - probably it will happen.
5. Frequent - certainly it will happen.

Risk Consequence:

1. Almost negligible consequence - can easily put in repair.
2. Would have small effect on budget or schedule. It takes a few days to fix.
3. Noticeable effect on budget and schedule. Will require change of plan and rescheduling.
4. Serious problem which could affect credibility and integrity of project. May need to seek additional resources. May need significant project reschedule.
5. Critical project failure. Could cause project to fail.

To estimate the Risk Probability we use the results of the automatic condition analysis of the ExpertALERT rule based system. The fault severity, estimated by the expert system, we fit to the risk probability as it stated in the table 1:

Category	Estimated fault severity	Risk Probability
5	Slight	Improbable
4	Moderate	Remote
3	Serious	Occasional
2	Serious continuously	Probable
1	Extreme	Frequent

Table 1. Categories of Risk Probability

Each consequence range includes consequences for personnel safety, public safety, environmental impact, property damage or business interruptions, corporate image and legal implications.

The Risk Consequence criteria are summarized in the next table:

Category	**Risk Consequence**
A	Multiple life-threatening injuries. Major environmental impact Plant damage value in excess of $100 million
B	Single life-threatening injury. Moderate environmental impact Plant damage value in the range of $10-100 million
C	Injury requiring a physician's care. Minor environmental impact Plant damage value in the range of $1-10 million
D	Restricted to injuries requiring less, than 8 days for recovery. Heavy odor or noise complaint Contained release with local impact Plant damage value in the range of $0.1 to 1 million
E	Restricted to injuries requiring no more than first aid. Odor or noise complaint Marginal local impact Plant damage value less, than $0.1 million

Table 2. Categories of Risk Consequence

All rotating machines should be categorized on the base of the table 2. depending of the role of the machine in the technology process. The correct classification can be guaranteed, if experienced engineers and technicians help this work, who has more than 10 years practice in operation. Risk Consequence categories could be defined using other numbers and criteria.

The next step is to determine the tolerability criteria for the risk matrix. The risk matrix must have clear blocks where the risk is tolerable or intolerable. We define four risk ranking categories as it shown in the Table 3.

Risk Rank	Category	Interpretation
I	Unacceptable	Should be mitigated with engineering and/or administrative controls. Repair action must be organized immediately by Maintenance organization
II	Undesirable	Should be mitigated with engineering and/or administrative controls. Repair action must be planned for machines for the next maintenance period.
III	Acceptable with controls	Should be verified that procedures or controls are in place. Diagnostic measurements should be organized more frequently.
IV	Acceptable	No mitigation required.

Table 3. Risk Ranking Categories

The risk ranking matrix :

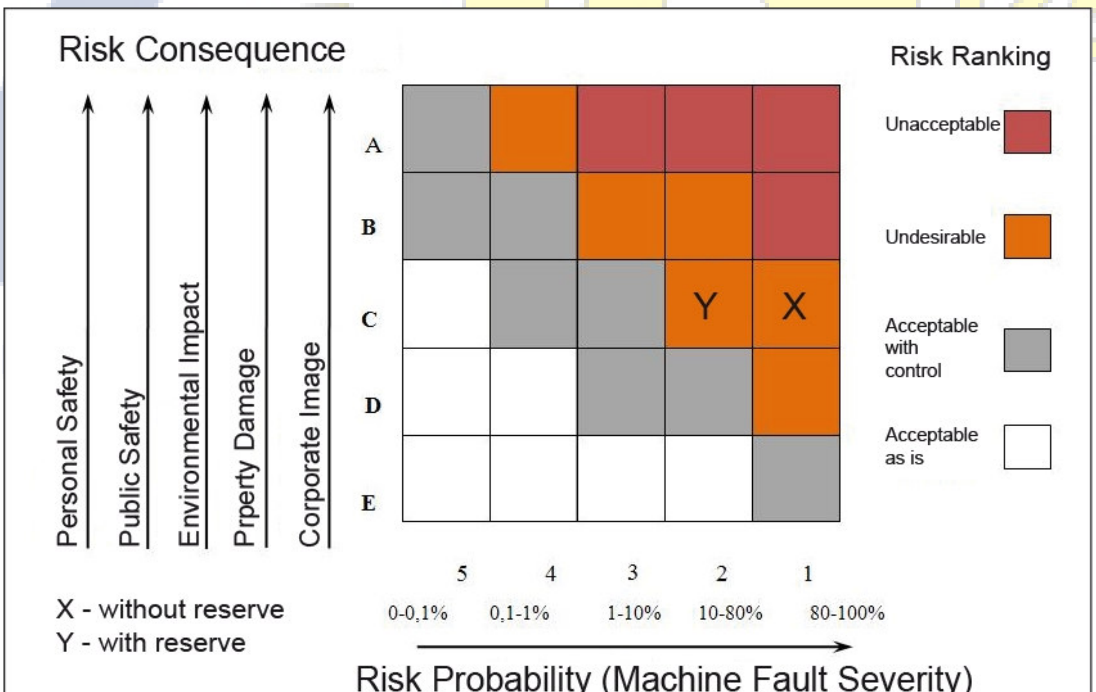

Figure 1. The Risk Analyzer; risk matrix of rotating machines

One of the most important tasks 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 1 shows the risk matrix with the probability and the consequence variables.

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.

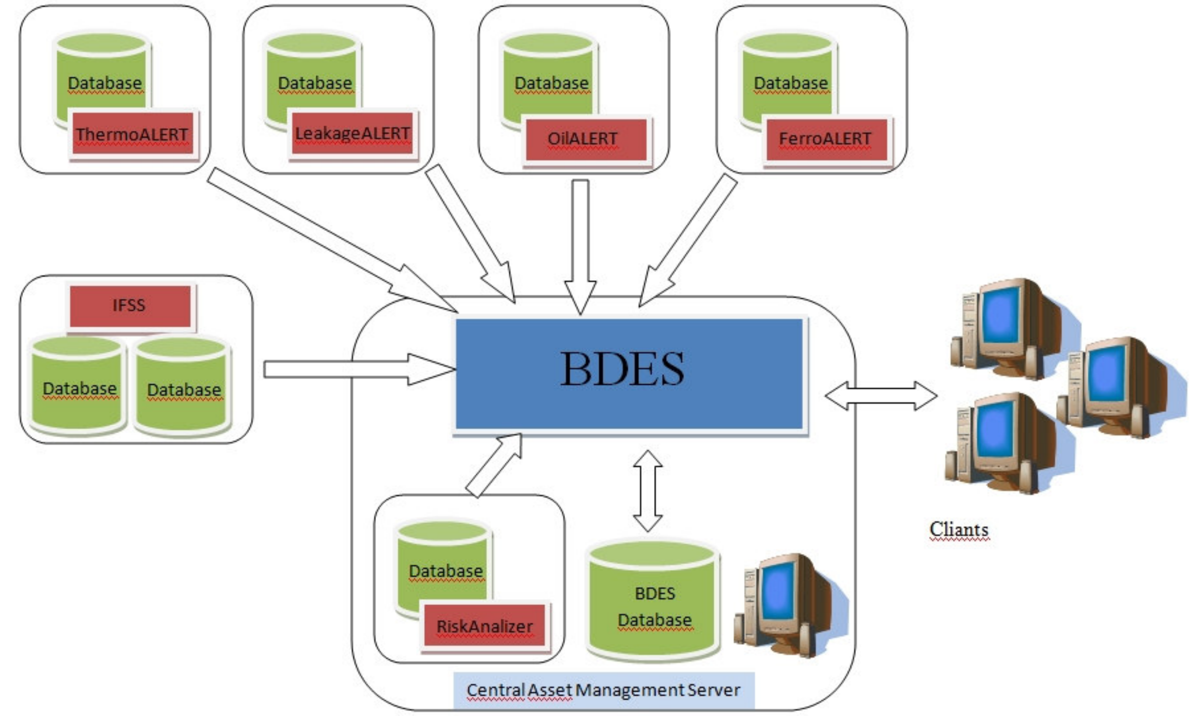

Figure 2. Schema of Diagnostics Expert Systems

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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