# ASSET MANAGEMENT AND PRODUCTION RELIABILITY HELPED BY E-MAINTENANCE ADVISORY SYSTEM

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**Key words:**

- Reliability,
- Asset management,
- E-maintenance,
- Fault diagnostics

***ABSTRACT:***

*E-maintenance Advisory System, showed by the authors, focuses on helping companies achieve two major benefits. First, when the reliability of systems and assets are optimized, product throughput and quality will increase. This increase has been proven to result in high ROIs. Second, optimizing the effectiveness of maintenance processes (planning, scheduling, execution, etc.) will result in a reduction in the cost of maintenance.*
*We have developed Asset Management solutions that have proven to be highly effective in reducing asset downtime and increasing plant profitability. The range of profitability depends upon the plant's current level of performance. Our Asset Management assessments clearly show where the real opportunities for growth reside.*
*We describe the structure of the software system, show concrete example of the working system with its practical results.*

## INTRODUCTION

All companies, which are interested in use of the off-line condition monitoring of their rotating machinery for realization of the condition based maintenance strategy and the risk based work selection, but do not want invest into hardware and software of monitoring systems and well-educated personal operating these systems, can use the remote PdM & RBM Reliability Service.

The PdM & RBM Reliability Service was developed and introduced into the machine condition inspection market in Hungary by Delta-3N Ltd (www.delta3n.hu). This Remote Reliability Service is based on a Complex Condition Monitoring System, which integrates the results of different type of diagnostic inspection technologies, like vibration analysis, thermography, Used Oil Analysis, Ferrography, leakage monitoring.


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In this model a service company does the measurements, makes the analysis and handles the database. The companies, which order the service can rich their database through the Internet using a browser protected by password.

## E-MAINTENANCE SOFTWARE SYSTEM

The next figure shows the screen of the developed software system:


Figure 1. The screen of PdM & RBM Remote Maintenance Advisory software system

## CHARACTERISTICS OF THE SOFTWARE MODULES

**ExpertALERT™ software** developed by AzimaDLI **(**www.azimaDLI.com **)**includes an imbedded rule based diagnostic system to help you screen through large amounts of data efficiently and focus on machines with problems. The distinguishing feature of AzimaDLI's rule-based, automated diagnostic system is that it identifies problem machines and focuses on manually reviewing the data from these machines. This approach is far more efficient than analyzing data from every single installed machine.

The diagnostic system contains over 4,500 individual fault templates. These templates are based on empirical data acquired from hundreds of thousands of machine tests conducted over more than twenty years. They can be applied to more than forty general machine component types, including motors, pumps, fans, blowers, gearboxes, compressors, generators, turbines and machine tools.

The system analyzes machine test data in a matter of seconds and produces a concise report that lists specific mechanical faults, the severity of each fault and an overall recommendation

Compared with systems that simply indicate that a machine is in 'alarm' mode, this very informative diagnosis illustrates how AzimaDLI turns data into information.

The expert system uses triaxial narrow band spectra from several points near the bearings of the rotating components of the machines. The speed of each component is determined, then features are extracted from the spectra and diagnostic rules are applied to the features. Feature extraction goes beyond determination of the vibration levels at specified frequencies. Algorithms group harmonics and subharmonics to help determine looseness characteristics. Cepstrum based methods are used to determine if non shaft synchronous peaks are bearing tones. Envelope detection is even used in some applications to determine the existence of bearing faults. Furthermore, the feature extraction process is different for each component type. The kinds of features extracted when checking signals from a motor are different than those extracted when examining a pump or a compressor.

## IFSS™ : INFORMATION AND STATISTICAL ANALYSIS

IFSS™ (Information and Fault Statistic System), developed by Delta-3N Ltd. is a web based software, provides the most efficient and cost-effective means of getting important data to the people who need it. Users can access and review automated diagnostic reports, machine history, trends and raw vibration data directly through a standard Internet browser. The active server database is visible on the web, thereby allowing any number of authorized individuals to access information of interest without having to purchase proprietary software.

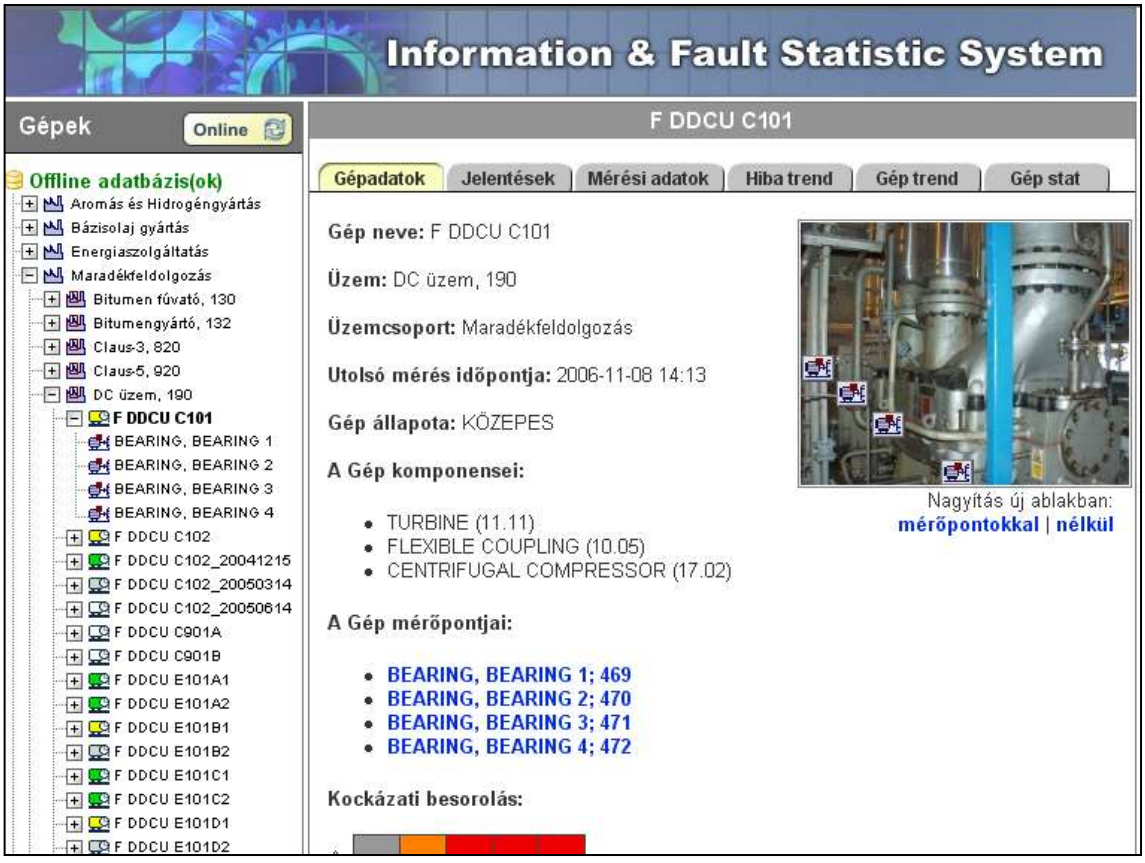


Figure 2. Screen display of IFSS software


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Via IFSS, the customer's office of maintenance can make statistical analysis of fault occurrences information from databases of the Plant-wide Asset Management System of different sites or the whole company and compare to the fault statistics of other plants or groups of sites.

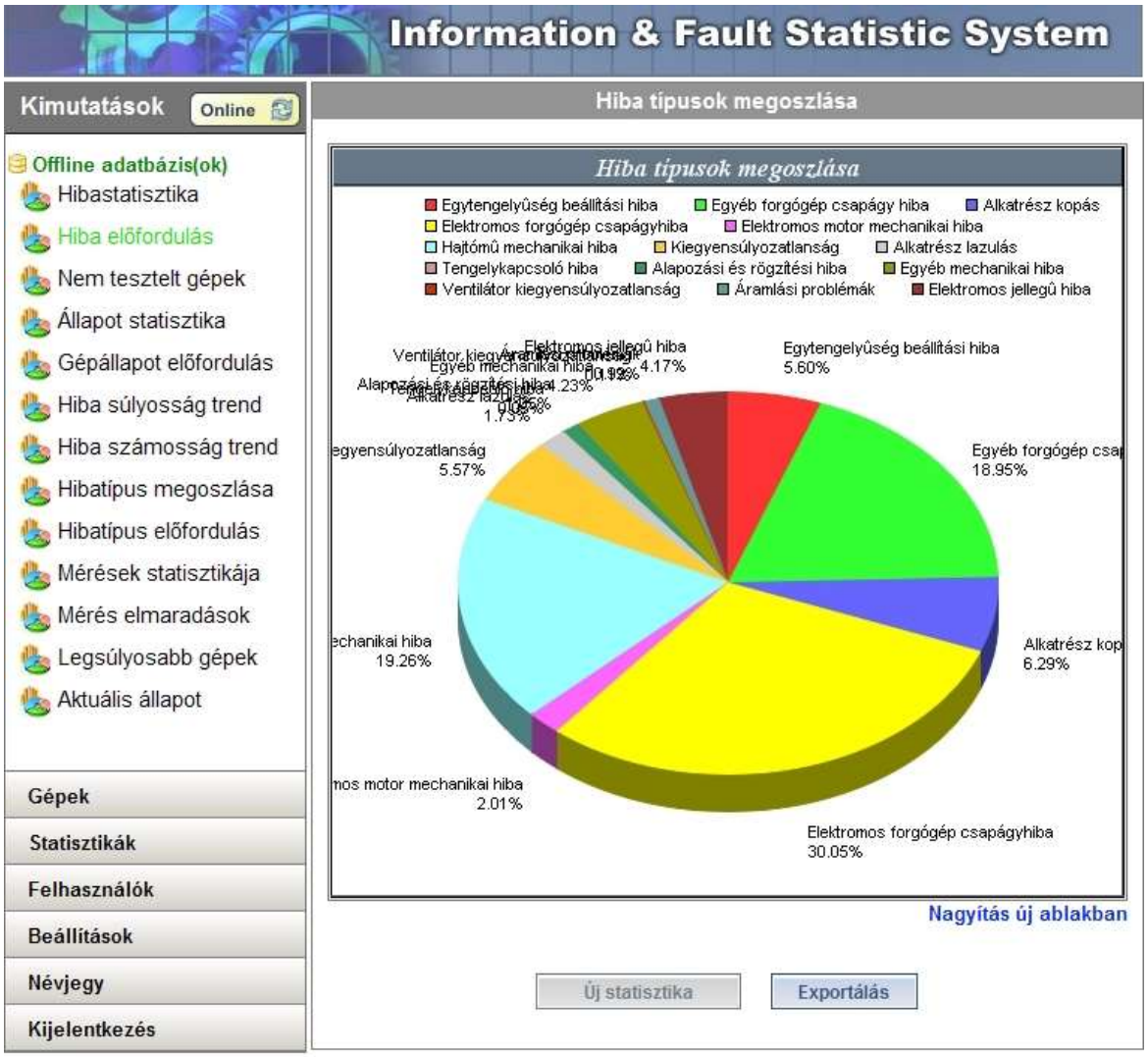


Figure 3. Display one of the result of IFSS software (fault statistics)

## Diagnostic Technology Integration

The **BDES** software connects individual expert systems, thus the most important data can be displayed on one screen in integrated form. This shows the total image of the real condition of machines. The latest machine test results are displayed on a common screen with a color coded small rectangle. Detailed reports can be obtained by clicking on the specific signs.


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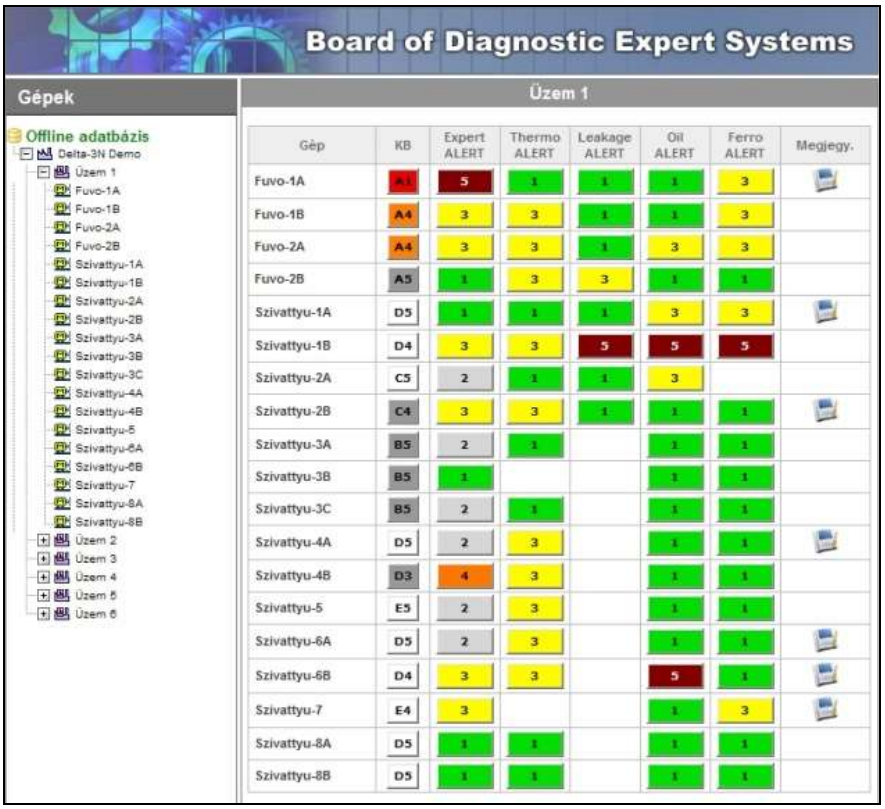


| Gép | KB | Expert ALERT | Thermo ALERT | Leakage ALERT | Oil ALERT | Ferro ALERT | Megjegy. |
|---|---|---|---|---|---|---|---|
| Fuvo-1A | A1 | 5 | 1 | 1 | 1 | 3 | |
| Fuvo-1B | A4 | 3 | 3 | 1 | 1 | 3 | |
| Fuvo-2A | A4 | 3 | 3 | 1 | 3 | 3 | |
| Fuvo-2B | A5 | 1 | 3 | 3 | 1 | 1 | |
| Szivattyu-1A | D5 | 1 | 1 | 1 | 3 | 3 | |
| Szivattyu-1B | D4 | 3 | 3 | 5 | 5 | 5 | |
| Szivattyu-2A | C5 | 2 | 1 | 1 | 3 | | |
| Szivattyu-2B | C4 | 3 | 3 | 1 | 1 | 1 | |
| Szivattyu-3A | B5 | 2 | 1 | | 1 | 1 | |
| Szivattyu-3B | B5 | 1 | | | 1 | 1 | |
| Szivattyu-3C | B5 | 2 | 1 | | 1 | 1 | |
| Szivattyu-4A | D5 | 2 | 3 | | 1 | 1 | |
| Szivattyu-4B | D3 | 4 | 3 | | 1 | 1 | |
| Szivattyu-5 | E5 | 2 | 3 | | 1 | 1 | |
| Szivattyu-6A | D5 | 2 | 3 | | 1 | 1 | |
| Szivattyu-6B | D4 | 3 | 3 | | 5 | 1 | |
| Szivattyu-7 | E4 | 3 | | | 1 | 3 | |
| Szivattyu-8A | D5 | 1 | 1 | | 1 | 1 | |
| Szivattyu-8B | D5 | 1 | 1 | | 1 | 1 | |

Figure 4. Screen display of BDES software

**ThermoALERT** is a software tool for thermographic image analysis, generating expert reports retrieving data and making temperature trends. ThermoALERT has its own, separate database, but it is also connected to the database of the ExpertALERT. The machine faults revealed by vibration analysis can be confirmed by thermography. An automatic report-generating function is available for a quicker analysis or evaluation of similar thermografic images.

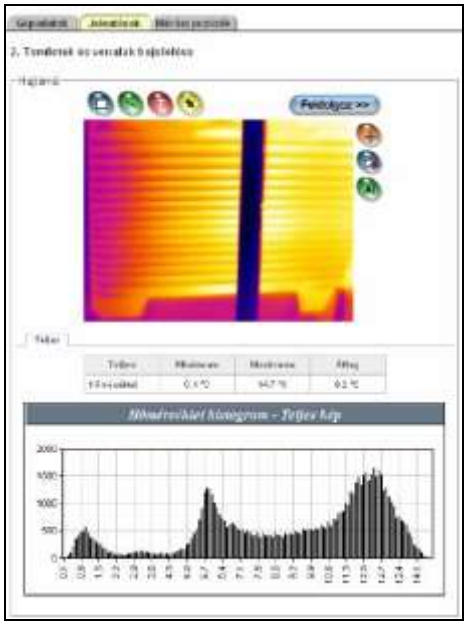

Figure 5. Screen display of ThermoALERT


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The task of **LeakageALERT** is to store results of leakage measurements of rotating equipment in a central database, as well as to create statistics and trends. By using this software there is an opportunity to compare the results of leakage measurement with the results of other diagnostic technologies.

The main objective of the **OilALERT** software is the structured storage of oil-analysis expert reports, as well as display of data, statistics and trends. The software not only stores measured data, but it also prepares analysis, monitors exceedences of limits and provides us compare data to the results of other diagnostic techniques.

**FerroALERT** stores the results of Ferrographic analysis and provides the opportunity for further data-analysis and making reports. It is also possible to confirm the existence of machine faults revealed by vibration diagnostics or to amplify them with the results of Ferrographic measurements. Trend-analysis of monitored parameters provides further information regarding the fault development within the machine.

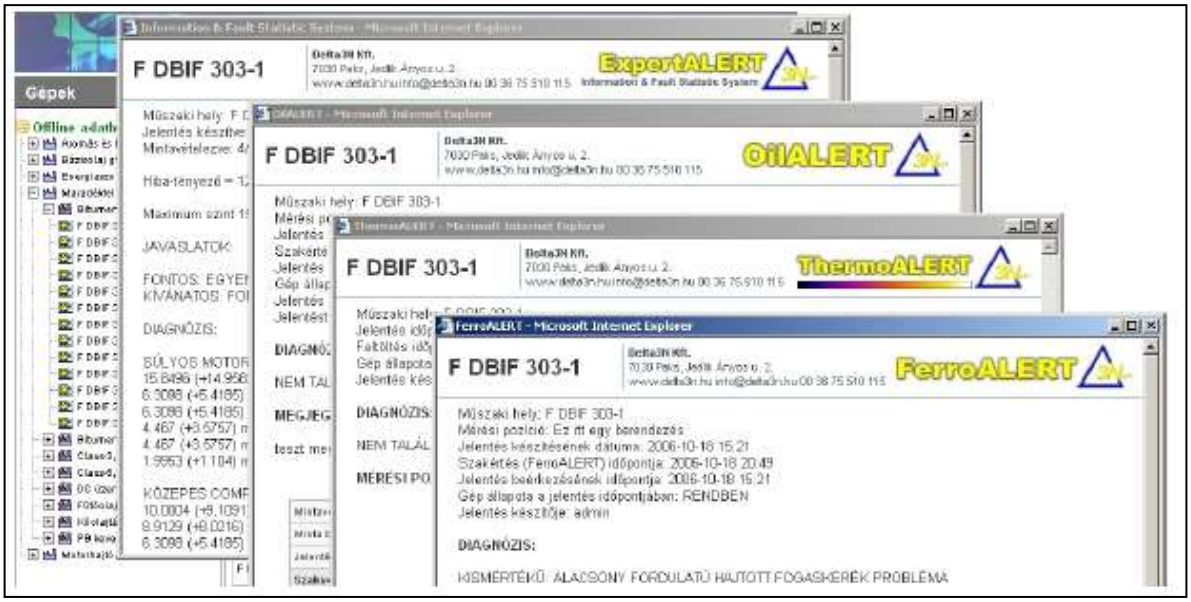


Figure 6. Reports of expert systems

## Risk Analyzer

The Risk Analyzer software helps maintenance decision-making by considering complex technical and economic information. In order to do that, likelihood of fault development should be defined, which requires a reliable, practical database and the possibility of a certain risk should be estimated. The Risk Based Maintenance (RBM) or Risk Based Work Selection (RBWS) approach takes into consideration not only the technical aspects of machine condition, but also reckons with their consequences in terms of safety and environmental issues, as well as the economic effects in terms of loss in production.

The Risk Analyzer software developed by Delta-3N Ltd. constructs a strategic classification (risk ranking) of the monitored machines, and ensures that this classification can be accessible

at any moment. It works from the database of ExpertALERT. The automatic diagnostics is the assumption of the automatic risk ranking for rotating machinery.

**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:** the likelihood that this risk will happen

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** the consequence if this risk was to happen

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


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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** | Onsite or offsite: Potential for multiple life-threatening injuries or fatalities.<br>Environment: Uncontained release with potential for major environmental impact<br>Property: Plant damage value in excess of $XXX million |
| **B** | Onsite or offsite: Potential for a single life-threatening injury or fatality.<br>Environment: Uncontained release with potential for moderate environmental impact<br>Property: Plant damage value in the range of $XX-XXX million |
| **C** | Onsite or offsite: Potential for an injury requiring a physician's care.<br>Environmental: Uncontained release with potential for minor environmental impact<br>Property: Plant damage value in the range of $X-XX million |
| **D** | Onsite: Potential restricted to injuries requiring less, than 8 days for recovery.<br>Offsite: Heavy odor or noise complaint<br>Environment: Contained release with local impact<br>Property: Plant damage value in the range of $0.X to X million |
| **E** | Onsite: Potential restricted to injuries requiring no more than first aid.<br>Offsite: Odor or noise complaint<br>Environment: Marginal contained release with local impact<br>Property: Plant damage value in the range of less, than $0.X 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 large 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 as is | No mitigation required. |

Table 3. Risk Ranking Categories


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The risk ranking matrix

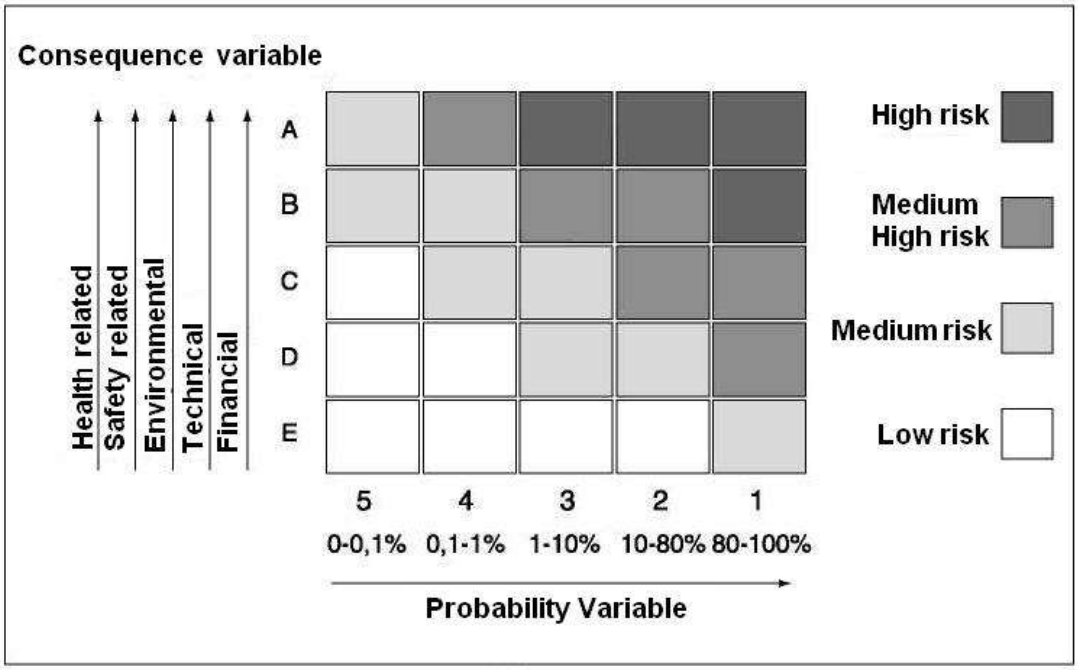


Figure 7. The Risk Analyzer's risk matrix of rotating machines

## CONCLUSION

The E-maintenance Advisory System developed and installed at Delta-3N Ltd. gives possibility for companies to use the most advanced technologies for condition based maintenance and risk based work selection without large capital investment. It gives the same economical advantages and possibility for every size of companies to begin and run a condition monitoring and risk based maintenance program for optimization of plant availability and asset management in the framework of a service contract.

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