INTEGRATION OF FAULT DIAGNOSTIC TECHNOLOGIES INTO A COMPLEX CONDITION MONITORING SYSTEM AND ITS PRACTICAL RESULTS

Dr. Jeno SZANTO Vice Pres.
College Dunaujvaros
Tancsics M. u. 1/a., H-2400 Dunaujvaros, Hungary
e-mail: szantoj@mail.duf.hu,

Dr. Istvan NAGY Ph.D. College Prof.
Delta-3N Ltd. & College Dunaujvaros,
Jedlik Anyos u. 2., H-7030 Paks, Hungary
e-mail: drnagyi@delta3n.hu,

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Abstract

We review the results of a large project for development a Maintenance Advisory System of a refinery with more than 2000 rotating machines. The system contains 18 on-line monitoring vibration diagnostic systems with a unique central database for 100 strategically most important machines and one off-line diagnostic system with an independent knowledge- and database. The machines malfunction and fault detection is based on different diagnostic technologies like 3D Vibration Analysis, Thermography, Leakage Detection, Used Oil Analysis and Ferrography. The vibration analysis system is automatic expert software. Different interactive expert systems were developed for the rest analysis techniques. The results of fault detection and malfunction analysis integrated and displayed in one software system called BDES (Board of Diagnostic Expert System), which is a complex condition monitoring system for rotating machinery. We describe shortly the ExpertALERT artificial intelligence system, as well as ThermoALERT, LeakageALERT, OilALERT, and FerroALERT interactive expert analysis software, their applications and connection to SAP PM Maintenance module of the Refinery. Operative maintenance decisions and maintenance planning is grounded on integrated fault diagnostics and severity estimation. The IFSS is a web-based Information and Fault Statistic System, which helps strategic decision making of the maintenance management using statistical analysis of identified faults in territory allocation and trending in time. The Condition Based Maintenance strategy carried out. We describe the hardware and software solutions and show practical examples.

Introduction

This paper shortly describes the results of software development, what was realized in the framework of MOL's (Hungarian Oil and Gas Company) On-line Diagnostic Project. The main goal of the project was the installation of on-line vibration monitoring systems for surveillance 100 strategically most important rotating machinery. The new on-line systems were integrated into one surveillance system, which means that, all of them work into one central database, placed on a central server computer in the server room of the Refinery Szazhalombatta.

Parallel to the on-line systems have been installed an off-line vibration monitoring system with two ExpertALERT automated asset management diagnostic software with two independent database. These databases are synchronized by replication.

The off-line and on-line databases of ExpertALERT contain the measured data, the results of data evaluation, the analysis results and the reports on the machines condition with machine faults, an estimation of fault severity, and recommendation for maintenance action.

Goal of software development

As the part of the "On-line Asset Management Project" the next software development goals were formulate:

- 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 asset management system,
- Develop a software, handling the risk matrix for rotating machinery risk classification,
- Develop a web-based information system for spreading the diagnostic information in the company's LAN,
- Develop an interface between the diagnostic systems and the SAP PM module,

- Develop a software module for scheduling of measurements,
- Develop a machine registry database developing software,

Figure 1. shows the schema of the developed software system.

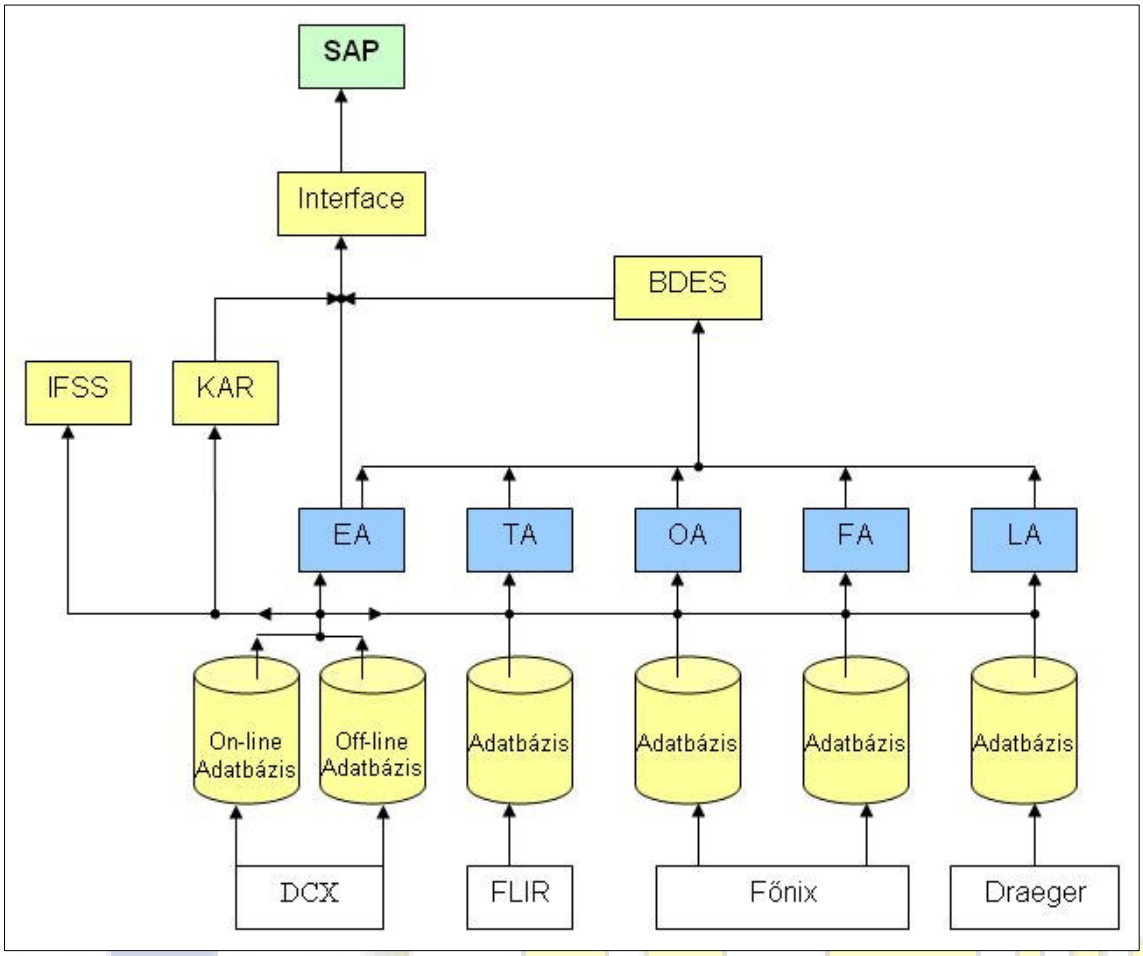

Figure 1. Schema of the software system developed for MOL Refinery

This schema does not contain the Machine Registry software, which is standalone software. The software module for scheduling measurement work is integrated into the SAP Interface.

Characteristics of the software modules

ExpertALERT™ software developed by AzimaDLI includes an imbedded rule based diagnostic system to help you screen through large amounts of data efficiently and focus on machines with problems. Although the diagnostic system is well proven and extremely accurate, a report editor is included should you wish to alter the reports or add comments.
The ability to quickly analyze large amounts of data and accurately identify machines with problems is a key element for efficient vibration services. In a typical plant, about 10 - 20 % of all machines tested will have inherent mechanical faults. Within this group, far fewer will require immediate service.

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. Customers who use this automated approach typically receive a 20:1 benefit-to-cost ratio.

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.

Expert System's Rule Base

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.

The set of features is extensive and is assembled into a matrix form known as a Component Specific Data Matrix (CSDM). Diagnostic rules are then applied to the elements of the CSDM to check for patterns which indicate the presence of a fault. A simple example is the rule for imbalance which checks the CSDM elements containing the rotational rate levels and exceedances over average and determines whether they are high in the radial direction. If so other checks determine that the problem is not misalignment or looseness and then the imbalance diagnosis is confirmed. These diagnostic rules were developed and tested on a database of tens of thousands of machine vibration tests.

IFSS™ - Information & Fault Statistics

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. Web Connect employs the replication technology to allow remote sites to synchronize with a database on a central web server. 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.

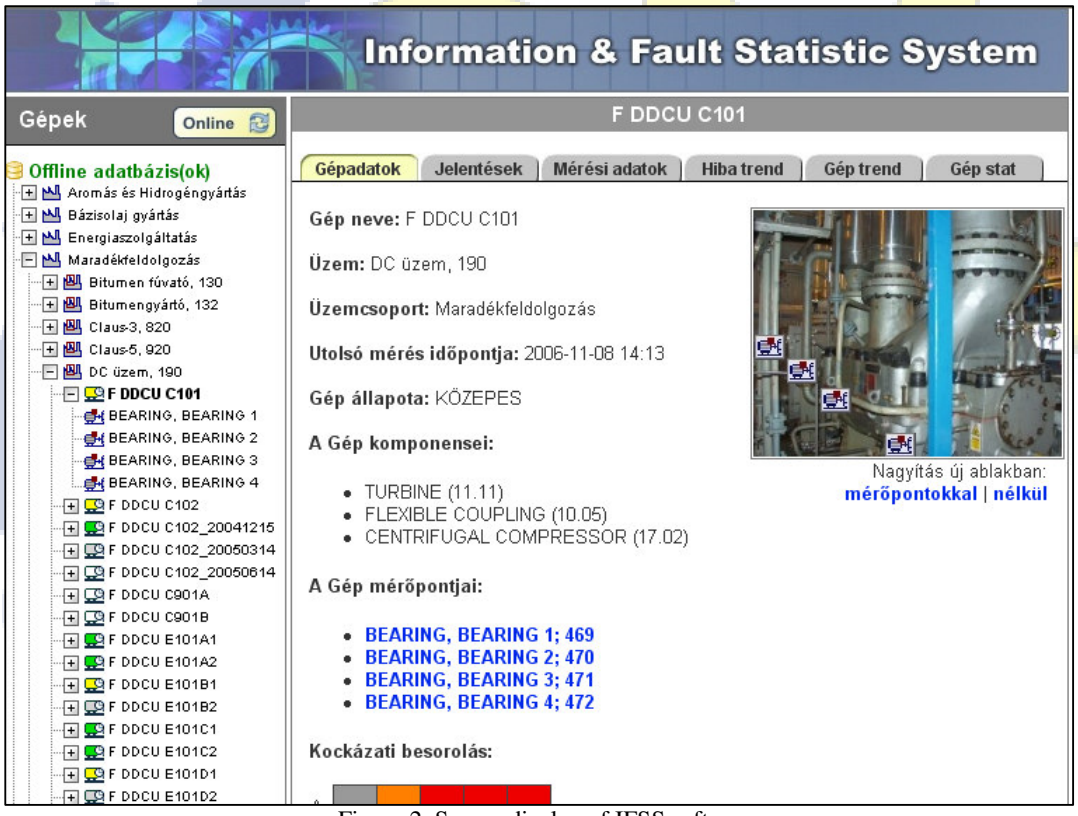

Figure 2. Screen display of IFSS software

Via IFSS, the central 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.

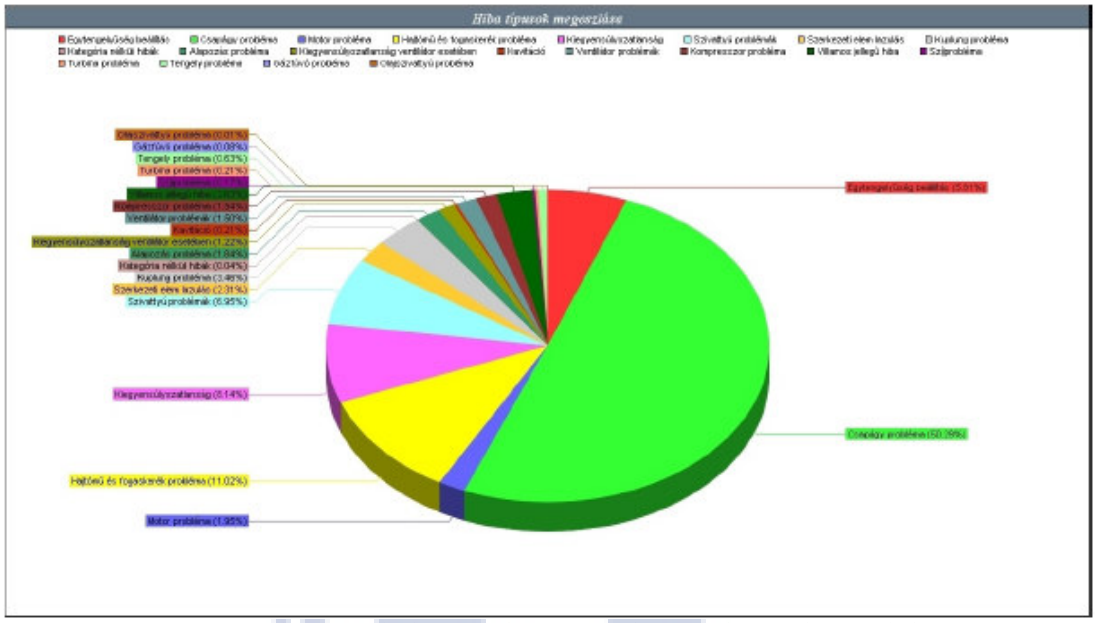

Figure 3. Display one of the result of IFSS software (fault statistics)

Diagnostic Technology Integration

The **BDES** software connects individual experts 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.

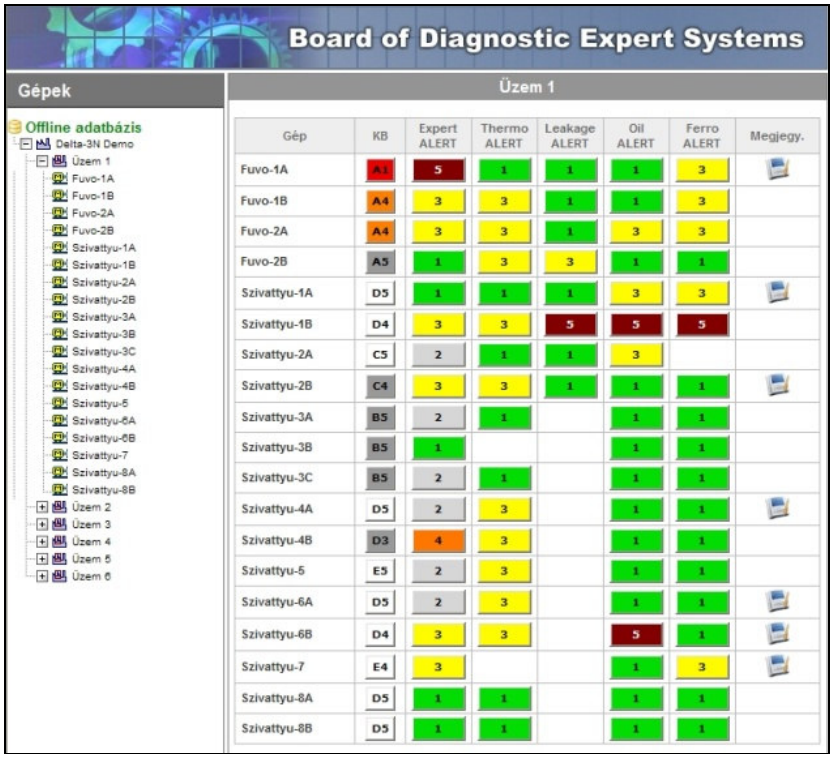

Figure 4. Screen display of BDES software

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.

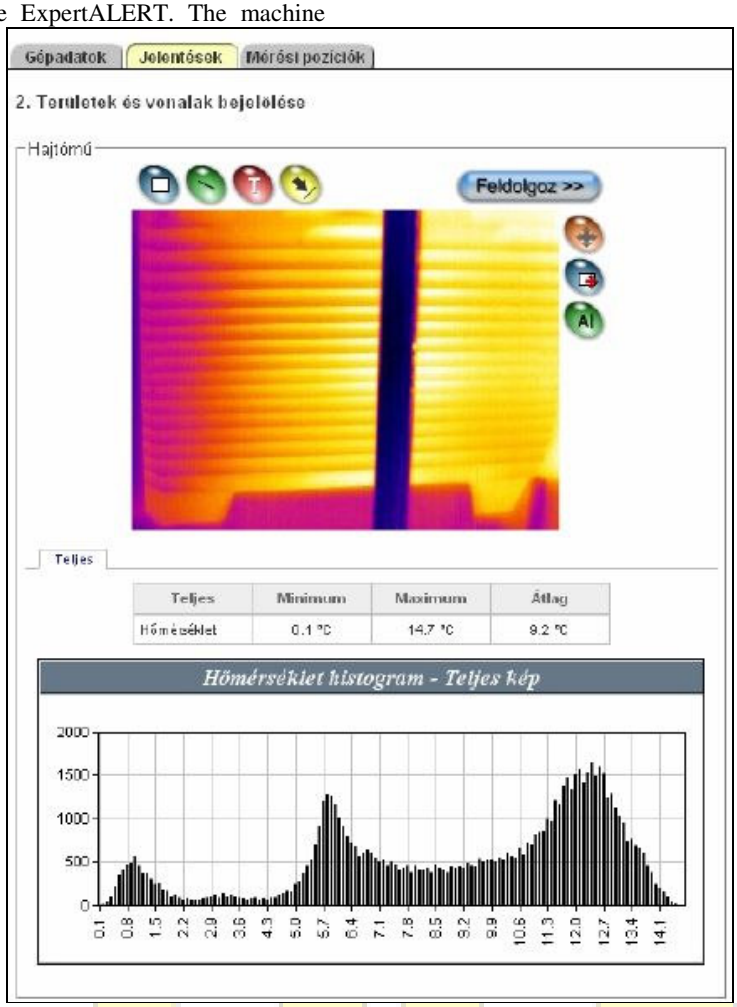

Figure 5. Screen display of ThermoALERT

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.

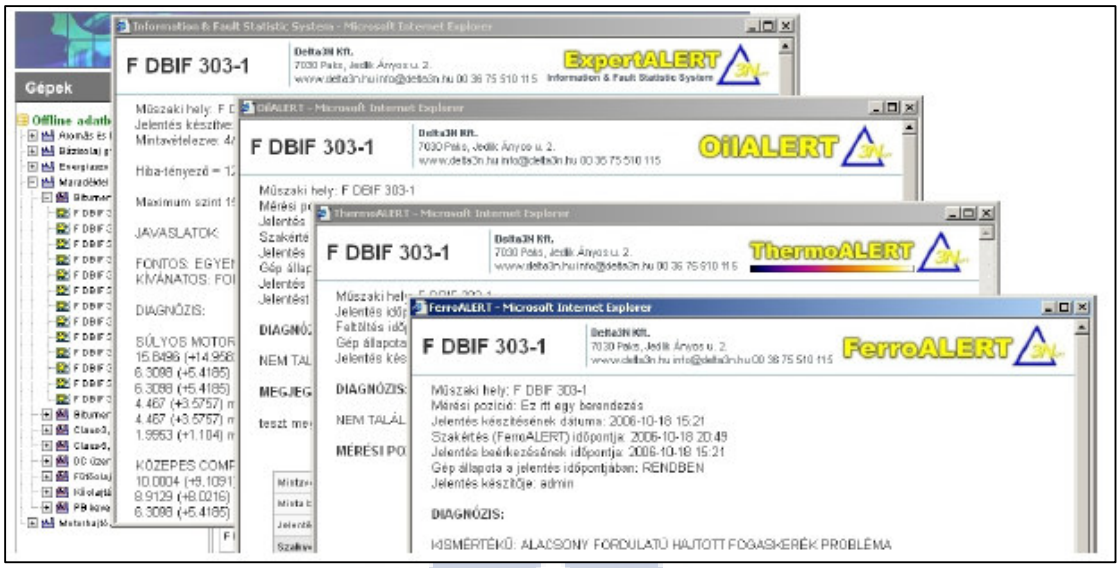

Figure 6. Reports of expert systems

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) approach takes into consideration not only the technical aspects of fault formation and development, 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.

Interface to CMSS (SAP PM)

The CMMS Interface watches the condition monitoring database, and when a machine condition "event" takes place the CMMS Interface transmits the new machine condition information to CMMS on the network. Information that is managed by the CMMS Interface include machine condition status, fault diagnostic summaries, specific fault severity trends, test status, overall vibration and machine risk ranking. CMMS Interface works automatically, and maintains machine condition dynamically.

On-line Condition Monitoring

DLI Watchman® SpriteMAX is a permanently installed online monitoring data acquisition unit.
AzimaDLI Watchman® SpriteMAX™ runs on a Windows® XP Embedded platform, and because of this it can be easily adapted to take advantage of evolving computer technology to enhance its capabilities. In addition, the system is easily customized for different applications and is equipped to accommodate wireless network and cellular communications capabilities.
It is based on 4-channel data acquisition hardware that can be multiplexed in increments of 16 channels, providing a capacity of up to 512 channels. Even though up to 512 channels can be monitored from each unit, the design philosophy of the system makes it advantageous to locate individual units on or near the machines of interest and network them via IEEE 802.11 Standard networks (WIFI).

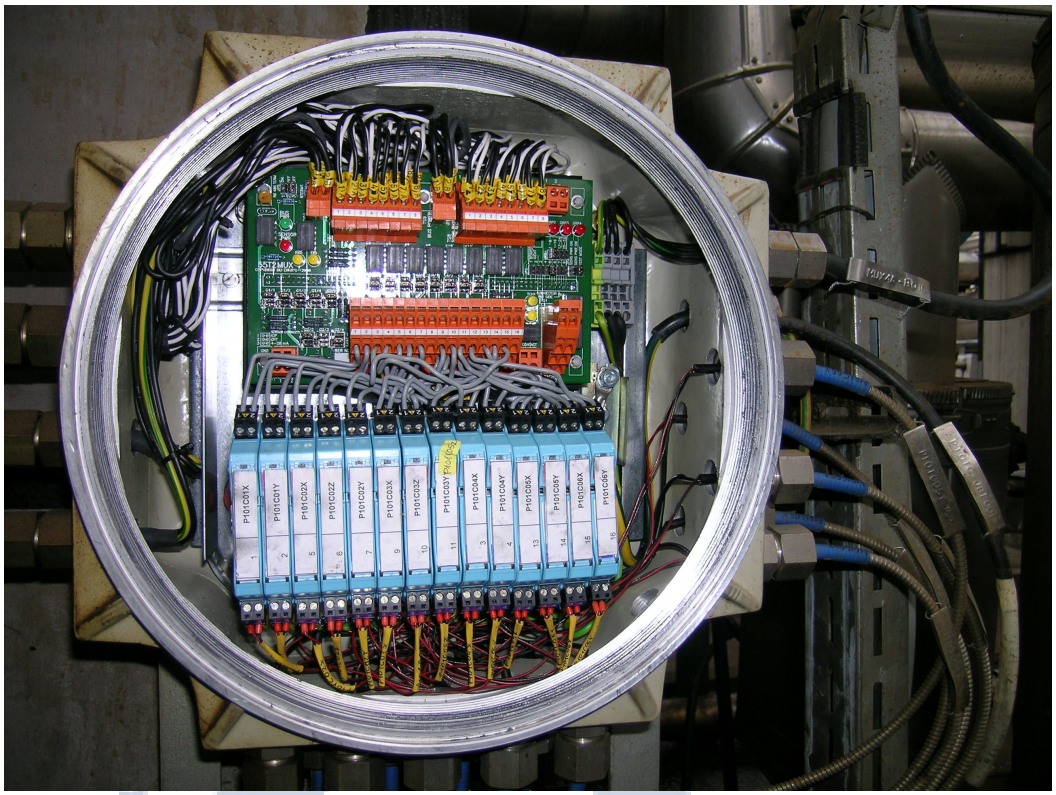

Figure 7. Explosion proof multiplexer unit

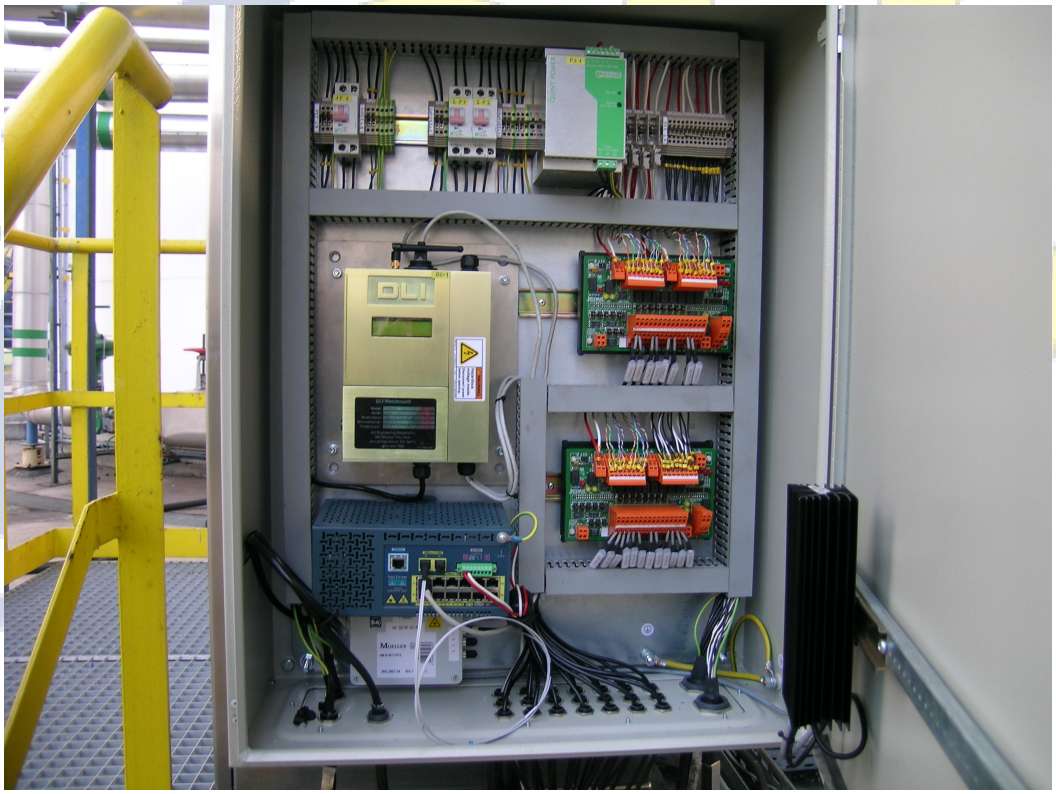

Figure 8. SpriteMAX On-line monitoring unit

It is important to note that SpriteMAX is not a protection system, nor a simple alarm system, and is not designed to shut down a machine in the event of an alarm. It can, however, be used with protection systems if this functionality is required.

CONCLUSION

The software system was developed by Delta-3N Ltd. and integrated into one Asset Management System. The whole software system was tested successfully and installed at Hungarian Oil- and Gas Company's largest refinery in the time of commissioning of on-line vibration monitoring systems. They are in operation.

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AUTHORS

Jenő SZÁNTÓ Dr. Vice President of College Dunaújváros, Táncsics Mihály u. 1/a. H-2401 Dunaújváros, Hungary, Phone: +36 (25) 551216, Fax: +36 (25) 412620, e-mail: szantoj@mail.duf.hu, Web site: www.duf.hu

István NAGY Dr. Ph.D. College Professor, College Dunaújváros, Director of Delta-3N Ltd. Jedlik Ányos u. 2. H-7030 Paks, Hungary Phone: + 36 (75) 510115 Fax: +36 (75) 510114, e-mail: drnagyi@delta3n.hu, Web site: www.delta3n.hu)