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MODERN CONDITION MONITORING SYSTEMS

Summary. Machinery diagnostic systems have been strongly emerged in the latest years. With machine technology development more and more measurement data became available via standard PC communication channels. Modern software systems evolve from closed and specialized for given application domain to easily configurable frameworks, allowing for data interchanging with other software via open standards. ABB TrigIT may be an example of such system. It joins ABB knowledge from rotating machinery domain with modern data modeling approach. The system allows for combining in calculations measurement data coming from different sources, which enables for viewing the diagnostic problem at higher level, and for detecting dependencies and faults that were difficult to locate previously.

Keywords: diagnostics, applications.

NOWOCZESNE SYSTEMY DIAGNOSTYKI

Streszczenie. Systemy diagnostyki maszyn przeżywały w ostatnich latach rewolucyjne zmiany. Wraz z rozwojem technologii samych maszyn (jak np. napędy DCT) coraz więcej danych pomiarowych jest dostępnych za pomocą standardowych mechanizmów komunikacji komputerów PC. Systemy informatyczne przekształcają się z rozwiązań zamkniętych i specjalizowanych dla danej dziedziny w łatwo konfigurowalne platformy, pozwalające na wymianę danych z innymi aplikacjami za pomocą otwartych standardów. Przykładem takiego systemu, łączącego w sobie wiedzę ABB z dziedziny diagnostyki maszyn wirujących oraz nowoczesne podejście do modelowania danych, może być TrigIT. Pozwala on na kojarzenie w obliczeniach różnych danych pomiarowych, dotyczących danego obiektu, co umożliwia spojrzenie na problem diagnostyki kompleksowo – i wykrywanie zależności i defektów wcześniej trudnych do zlokalizowania.

Słowa kluczowe: diagnostyka, zastosowania.

1. Introduction

In the latest years IT technology is progressing. As machine technology emerged, more and more measurement data became available via standard PC communication mechanisms. Machinery diagnostic systems can now utilize new data acquisition modes and join in calculations data coming from different sources. This superimposes new requirements for such systems: they must evolve from specialized for given application, closed systems to generic, open for connectivity with other applications and easy to configure solutions. An example of such a system can be ABB TrigIT, a Condition Monitoring framework. TrigIT is a successor of ABB system for rotating machinery diagnostic, called ARMADA. This article starts with introduction to ARMADA system and presents data modeling solution applied there. Then, ABB System 800xA platform (base for TrigIT system) is briefly described. Next sections contain TrigIT overview and sample application. Summary is presented in last section.

2. What was ARMADA^{CMS}?

"Automated Rotating Machine Diagnostics Analysis" system called ARMADA CMS was not an independent software system – it was just a set of algorithms and templates that could be used with standard software that provides user interface. Main functions of Armada are presented on Fig 1.

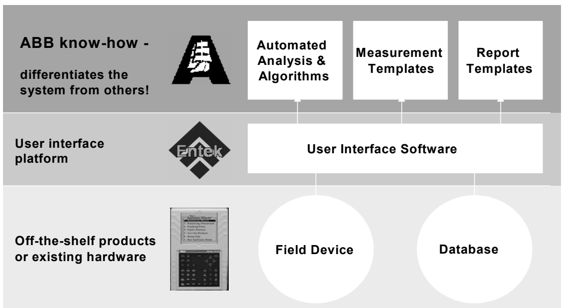

Fig. 1. Armada Functional Diagram
Rys. 1. Diagram funkcjonalny systemu ARMADA

Armada consists of several modules, among others this are the most important diagnostics packages: Machine database definition, Fast Assessment, Vibration tests, Dielectric tests and Drive system.

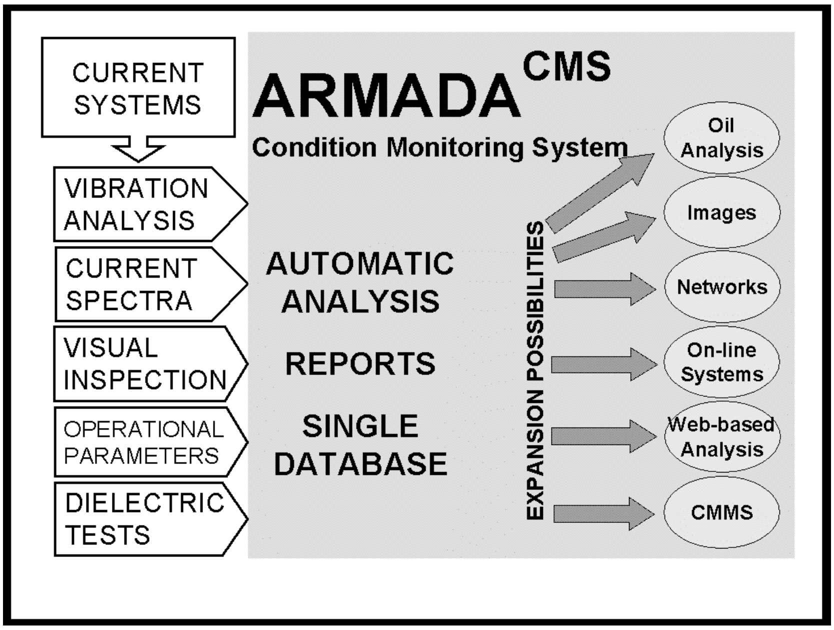

Fig. 2. Main ARMADA modules
Rys. 2. Najważniejsze moduły ARMADA

3. ARMADA modules

3.1. Machine database definition

For enabling automated analysis there was defined basic set of data for each type of rotating device (motor or pump). Engineering knowledge what to measure on what type of machine was translated into machine-readable knowledge representation. Fig 3 presents rotating machine taxonomy used to select appropriate properties for diagnosing machines. There were over 700 properties defined. Machine taxonomy with these properties is referred as “measurement templates”.

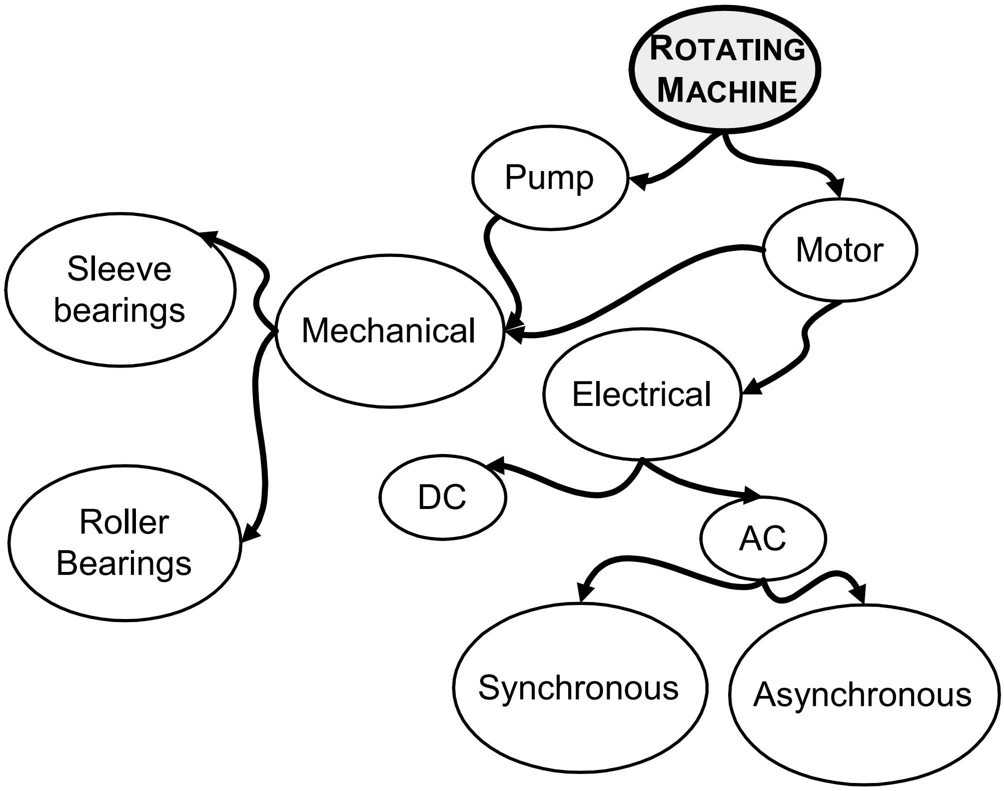

Fig. 3. Machine taxonomy
Rys. 3. Taksonomia maszyn

3.2. Fast assessment

As a first method of simple diagnosis Armada was performing rule based reasoning about machine overall state. For a quick overview of the machine condition, the user gets an output of warning messages and criticality level that reflects the condition of the machine: our diagnostic procedure has built-in algorithms and pre-defined messages that advise the status of the machine, by comparing the measured scalar data versus the machine's nameplate data, or comparing them to standard parameters, such as ISO. This was very helpful because it eliminates the need to analyze each measurement point and check manually whether it is OK or not. As a whole rule base of with over 500 rules was defined.

3.3. Vibration tests

In contrary to other diagnostics systems Armada was performing automated analysis of vibration data. Automated vibration tests are performed in following order: form measured vibration data basing on ISO RMS level alarms are fired then fault classification based on spectral analysis with principal component analysis is being performed. Vibration based condition assessment is illustrated in Fig 4.

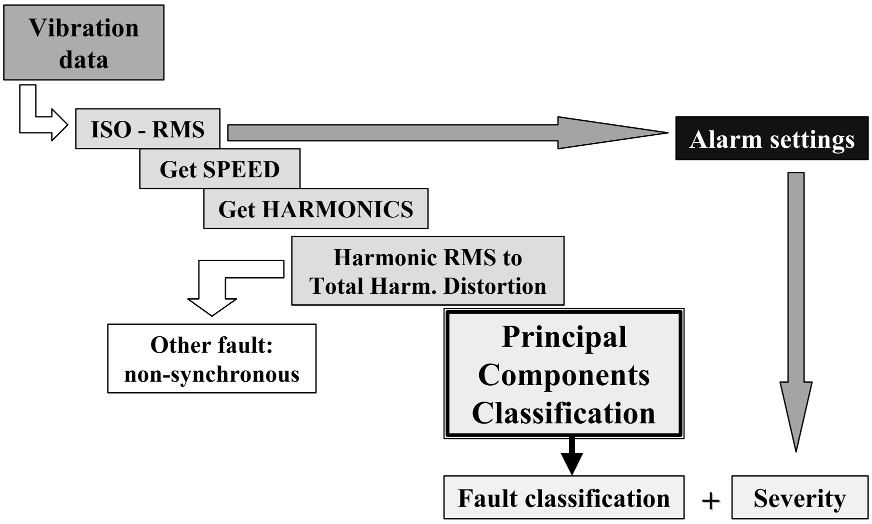

Fig. 4. Vibration based condition assessment in ARMADA^{CMS}
Rys. 4. Ocena stanu urządzenia na podstawie wibracji w systemie ARMADA

The bearing condition evaluation is based on a time domain shock pulse analysis [1].

3.4. Current spectra

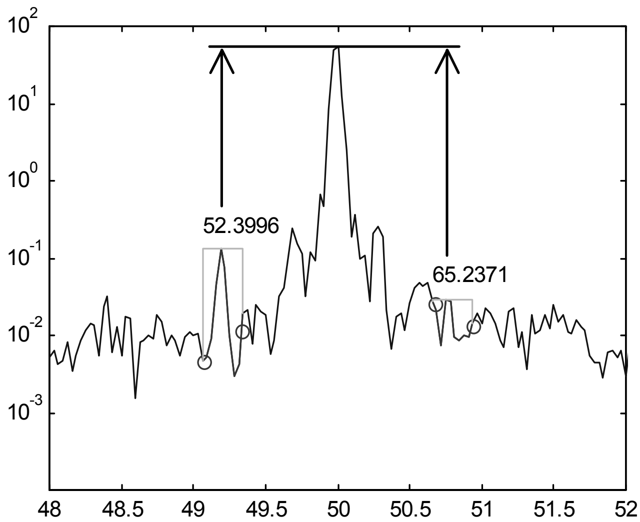

Fig. 5. Current Spectra in ARMADA^{CMS}
Rys. 5. Widmo prądu w systemie ARMADA

This test can be applied to asynchronous motors to diagnose rotor defects.

Current spectra analysis relies on comparison of the slip frequency sidebands in the current spectra to the mains frequency related peak in the spectrum. The software extracts the peak values automatically and returns value as derived from the dB of side bands compared to the central frequency. It therefore refers to defects such as broken rotor bars. This value can be trended to observe changes in the motor condition.

3.5. Other elements mains

In general installation and mains can significantly shorten lifetime of electrical motor. In integrated diagnostics approach mains is treated as yet another machine to test. There where defined several things to measure and diagnose basing on quality of mains. This is summarized in Table 1.

Table 1

Mains diagnostics

Name	Alarms	Cause
THD	• 6% yellow • 8% red	Converter, neon lamps, furnace, weak transformer
Voltage distortion (transients)	• >30% yellow • >50% red,	Converter
Phase voltage asymmetry	• > 5%	Grounding fault

4. From ARMADA to TrigIT

Continuous progress in IT technology puts new requirements on software. Modern systems must be open, easy to extend and integrate easily with other applications. Armada approach became insufficient.

To deliver more reliable CM solutions, the off-line measurements done periodically (that Armada was designed to work with) are not sufficient. Especially that currently sensor devices become smaller and are often integrated with monitored devices. That makes real time, on-line monitoring relatively easy and attractive. Moreover, strict integration with ENTEK user interface makes Armada difficult to modify or extend with new functionality.

From these reasons, Armada seems a close and specialized solution for special types of condition monitoring.

Modern Condition Monitoring solutions are required to be open environments that are easy to extend with new (often unpredictable during base system development) functionality, easy to integrate with other applications (e.g. control or asset optimization applications) and must be able communicate with various measurement sources (either on and off-line) from different vendors.

5. TrigIT condition monitoring integrated with System 800xA

TrigIT represents such CM system that goes a step further beyond Armada. It is a generic framework for condition monitoring and (as a successor of Armada system) is filled with algorithms for specific devices, especially for pumps, motors and other rotating devices. TrigIT can be easily tailored to various condition monitoring applications, like drive monitoring or windmill turbines monitoring systems.

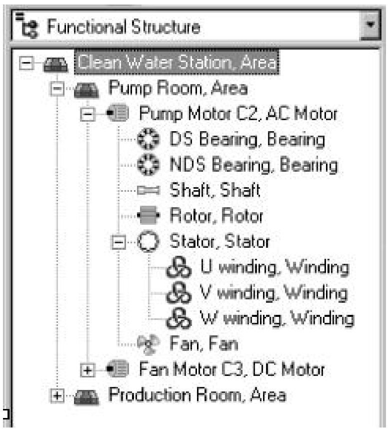

Fig. 6. System 800xA abstraction of Real objects
Rys. 6. Model obiektów rzeczywistych w System 800xA

The framework itself is implemented on the base of ABB System 800xA platform, unique ABB solution unifying various applications in a single framework and allowing them to communicate with each other in a well-defined way. Extended Automation System 800xA is real time automation system, but additionally it extends the reach of the traditional automation systems beyond control of the process to achieve the productivity gains necessary to succeed in today's business markets. For the first time, this scope is accessible from a single user interface that is configured to present information and provide interaction in a context appropriate to all user disciplines.

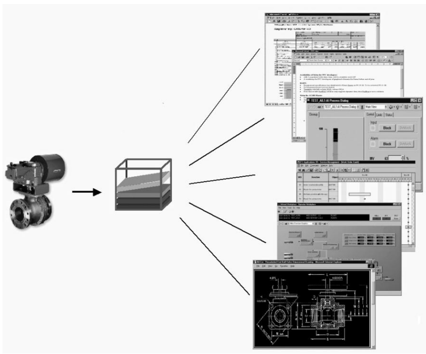

Fig. 7. Aspect Object idea
Rys. 7. Idea Obiektów Aspektowych

The design of System 800xA is based on modular extension and dynamic object structures. The object-oriented approach for abstracting real objects and idea of Aspect Objects (Fig 6 and Fig 7) allows for intuitive integration of different subsystems, methods and approaches.

But the most important feature of TrigIT is its departure from traditional model of condition monitoring system-focused on custom diagnostic domain. Traditional methodology operates on low abstraction level–monitored device is modeled and seen through its measurement points and measurements. And so the software for managing vibration data categorizes "world" from the point of view of the vibration measurement points (horizontal, vertical vibrations etc). From the other side this solution cannot be simply translated to the point of view of the electrical current measurement.

TrigIT uses different approach, based on ABB Aspect Objects. Thanks to it each monitored "real world object" is transferred into Aspect Object (or hierarchy of objects), which has measurement points defined, holds its data and performs calculations accordingly to predefined rules. Such calculation rules may be defined similarly to Microsoft Excel formulas, and may use all information stored for given object – that means various measurements data, historical data etc.

Further, calculated values (and/or data) can be verified by easily configurable conditions (defining state of the machine). Both state and variables are exposed to the System 800xA platform either as alarms and events or as variables that may be used by other applications.

The potential strength of the other important feature of TrigIT - combining measurement values that come from different analysis domains in calculations - can be explained on the example of ACS-600 drive monitoring.

5.1. ABB ACS-600 drive monitoring

ABB ACS-600 is a low-voltage frequency converter built in DTC technology. It has the following features:

- IP 21 protection class,
- compact design,
- harmonic filtering choke inside,
- long life time cooling fan and capacitors,
- extensive, programmable I/O,
- inputs galvanically isolated,
- three I/O and fieldbus extension slots inside,
- alphanumeric, multilingual control panel,
- large power terminals allowing use of over sized or aluminum cable.

As a modern device it has industrial computer with real time operating system working with hard time limits imposed by machine rotating cycles. It has specialized interface designed for on-line monitoring. ACS-600 measures or calculates all operation signals in real time and exposes them through OPC. The sample signals are: motor speed, output frequency, output current, output voltage, torque, motor power, DC bus voltage, fault signals for overspeed, brake lift etc. ACS-600 also allows for setting almost all operational parameters via OPC (actions like start, stop, quick-stop, or control parameters like brake control, enable/disable/configure loggers etc.)

Because of the built-in monitoring features like signals measurement, internal warnings and faults detection (when some parameters are not in specified range), quick loggers that can store parameter's values in short timestamps (like 10ms) after some condition occurs such drive monitoring is ideal for TrigIT application. Let's examine hypothetical system in which motor (controlled by ACS-600) is connected to the pump (or any other rotating device).

All the signals from the drive are exposed to the System 800xA platform through OPC. If there are vibration sensors on the pump, signals might be also available in the System 800xA.

TrigIT is in this configuration able to gather selected data from these OPC devices in two general modes:

– scheduled, in which data is gathered in some period of time,
– on change, this means TrigIT gathers data when the signal changes.

The basic mode is scheduled mode. After gathering new data (e.g. once per minute), TrigIT performs some calculations that can mix data from different signals. For instance TrigIT may modify vibration spectrum analysis depending on the rotating speed, analyze torque or current motor power in the context of pump outlet (if there is such sensor).

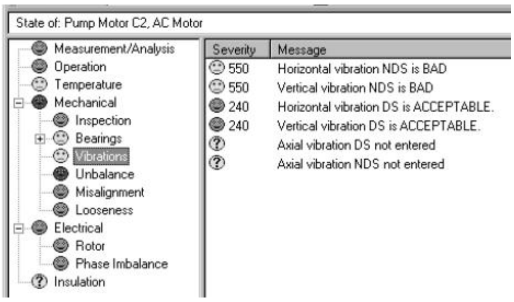

Fig. 8. Sample status of the machine
Rys. 8. Przykładowa prezentacja stanu urządzenia

The results are then compared to the predefined conditions describing state of the machine (Fig 8). Each condition can be compound of several values' limits (measured or calculated) and define its own alarm or warning message.

The other scenario is that TrigIT is connected to the property (e.g. Machine Status Word) in the "on-change" mode. In such case drive may report an error depending on the built-in condition checking, transfer it directly to TrigIT which may in turn take some specific actions like reporting the error to the operator screen or gather greater number of input signals (e.g. including loggers data), or even change the drive operation parameters, like stop the device.

Here comes out the strength of the System 800xA platform and application integration. Alarms are common to the platform, so any other application that is watching current alarms and events is informed that device is in abnormal state and can perform other actions like sending e-mail, SMS or calling a technician.

The feature that allows for combining many different signals in calculations of the state of the machine has more advantages. Assuming that one have many motors working as a single production line, TrigIT would be able to measure parameters of all devices, selecting ones that parameters are over or under the medium value of the other drives, detecting probable faults that would not be necessarily detected by the monitoring of the single device.

6. Summary

Thanks to ABB System 800xA technology TrigIT condition monitoring system allows for intuitive and easy configuration for different applications. As each monitoring device is represented as Aspect Object, data collected on it can come from various sources. All Aspect Object information is available for TrigIT calculations, so it can perform complex analysis and state monitoring, with joining different information sources. This openness, generosity and complex approach stand for the strongest advantages of TrigIT system and place it between modern diagnostic solutions.

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Omówienie

Systemy diagnostyki maszyn przeżywały w ostatnich latach rewolucyjne zmiany. Wraz z rozwojem technologii samych maszyn (jak np. napędy DCT) coraz więcej danych pomiarowych jest dostępnych za pomocą standardowych mechanizmów komunikacji komputerów PC. Systemy informatyczne przekształcają się z rozwiązań zamkniętych i specjalizowanych dla danej dziedziny w łatwo konfigurowalne platformy, pozwalające na wymianę danych z innymi aplikacjami za pomocą otwartych standardów. Przykładem takiego systemu, łączącego w sobie wiedzę ABB z dziedziny diagnostyki maszyn wirujących oraz nowoczesne podejście do modelowania danych, może być TrigIT. Pozwala on na kojarzenie w obliczeniach różnych danych pomiarowych, dotyczących danego obiektu, co umożliwia spojrzenie na problem diagnostyki kompleksowo – i wykrywanie zależności i defektów wcześniej trudnych do zlokalizowania. W artykule przedstawiono wybrane rozwiązania i metody diagnostyczne zrealizowane w systemie, takie jak:

- proste ocenianie maszyny (Fast Assessment),
- analiza wibracji (Vibration tests),
- analiza prądu (Current spectra),
- analiza zasilania,
- diagnostyka parametrów falownika ACS 600.

Praca zawiera także opis ewolucji systemu monitorującego od rozwiązania pozwalającego na okresową kontrolę urządzeń do systemu pozwalającego na monitoring ciągły. Dzięki zbudowaniu aplikacji w oparciu o platformę 800xA rozwiązanie może łatwo współpracować z każdym systemem używającym protokołu „Open Process Control” (OPC). Współpraca ta może być zarówno jako klient, jak i serwer OPC. W ten sposób system może być wpisany w całość struktury informatycznej przedsiębiorstwa.

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