



Industrial Equipment On-line Condition Monitoring and Diagnostic System

2007

Industrial equipment condition monitoring and diagnostics

Many branches of industry are currently targeted at equipment overhaul-period renewal and operating expenses reduction. Maintenance expenses form a significant part of total enterprise expenses and are occasionally comparable to profits.

The most critical and vulnerable industrial units in terms of vibration are rotor devices: electric motors, compressors, turbines, generators, drives, pumps, etc.

There are three basic maintenance strategies:

- *reactive maintenance*. In this case no monitoring is applied and maintenance takes place only after actual failures. This method leads into significant losses due to equipment downtimes, required for unforeseen damage elimination.

- *routine maintenance*. This maintenance type consists from preventive repair works according to strict schedule. This is routine method and is being used as a primary strategy at most of enterprises. Unfortunately, routine maintenance, does not allow lowering maintenance expenses significantly, because at least 50% of repairs are performed without actual need.

- *condition monitoring based maintenance*. In this strategy actual condition of equipment is monitored and maintenance takes place exactly when it is actually needed. Online condition monitoring allows repair work volumes due to methodical suppression of defect causes.

Comparative analysis of different rotor equipment maintenance methods, according to Machinery Information Management Open Systems Alliance (MIMOSA) data, revealed, that maintenance cost per unit in energy branch of USA was in 1998:

- \$24/kilowatt with reactive maintenance
- \$18/kilowatt with routine maintenance
- \$12/kilowatt with condition monitoring based maintenance

The main goal of switching to condition monitoring based maintenance is raise of reliability and lowering of operating expenses. Cost efficiency examples of switching between routine maintenance and condition monitoring based repairs according to “Briel and Kjaer” (Denmark) data for several enterprises is presented in following table:

Annual affordability of switching between routine maintenance and condition monitoring based repairs:

- Chemicals plant (Machines with rotating units) – Repairs count reduction from 274 to 14
- Petroleum refinery (Electric motors) – Maintenance cost reduction of 75 %
- Paper plant – \$ 250,000, (10 times less, than total vibration monitoring equipment expenses)
- Nuclear power plant – \$ 3,000,000 due to maintenance cost reduction, \$ 19,000,000 due to additional profits increase.

Significant worldwide experience of condition monitoring based maintenance gives following generalized estimate of efficiency:

- Maintenance expenses reduction of 75%;
- Repairs count reduction of 50%;
- Failures count reduction of 70% in first year of operation.

Technekon. Condition monitoring hardware and software for industrial equipment.

Technekon is Russian leading developer and producer of condition monitoring hardware and software for industrial equipment. During years of work, the company accumulated significant experience in technologically complex projects achievement.

Today, Technekon has advanced infrastructure, including following sub-units:

- Electronics engineering;
- Software development;
- System engineering;
- Diagnostics;
- Quality control;
- Electronic equipment production.

Technekon produces hand-held devices, allowing a periodic review of the unit followed by analysis, such as complex enterprise-level control and protection equipment - integrated systems for continuous monitoring and protection of the plant's equipment (ASTD-2 automated technical diagnostics).

Where it is necessary to use a continuous monitoring and analysis of the condition of equipment, we are able to offer systems of every complexity level to be in full compliance with the technical and economic requirements. System configuration is built strictly in accordance with the structure of the enterprise and ensures comprehensive protection and analysis of monitored equipment.

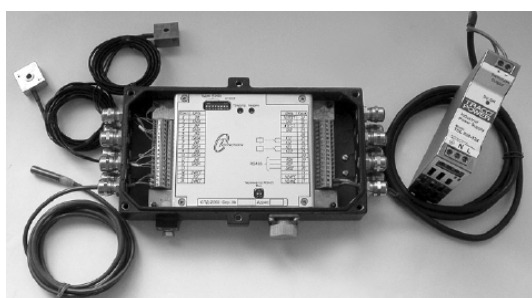
Due to the modular architecture and scalability, the introduction of online monitoring systems can be done from a simple and low cost option to a completely automated system with a maximum use of all the features (ASTD-2). ASTD-2 - automated technical diagnosis system designed for the automation of diagnostic-related personnel activities. ASTD-2 allows operating of fully automated online monitoring and diagnosis of technical equipment of the entire Enterprise. Using such systems allows move to maintenance of equipment on it's actual state.

The quality and reliability of the "Technekon" products can be proved by the fact that for more than 10 years, one of our regular customers is "Gazprom", where our automated systems of technical diagnostics and portable vibration devices have proven to be excellent tools. A large number of companies use the advantage of our portable systems for the inspection of industrial units.

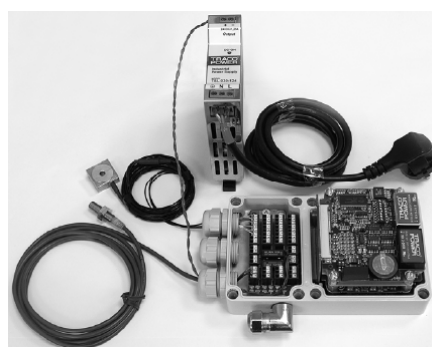
On-line monitoring and diagnostics system overview

The on-line monitoring and diagnostic system performs full control of the equipment condition, timely alerting staff on the changes and providing all necessary information for the issuance of conclusions on the condition of monitored equipment.

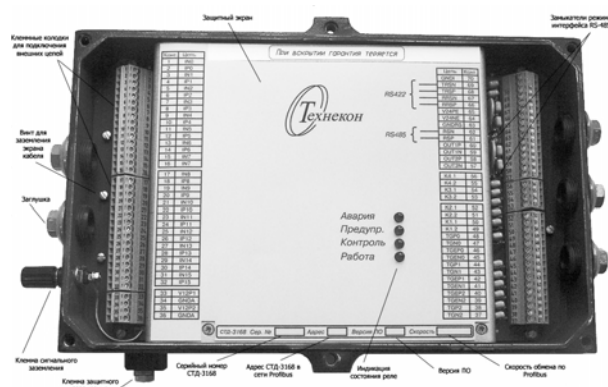
The monitoring and diagnostics system architecture is developed according the enterprise topology, the composition and characteristics of technological equipment and industrial safety requirements. At that, premise of a system is the concept of distributed monitoring and management systems, based on data collection and processing units, integrated into a single network.



CTD-2060



CTD-2160



CTD-3168

Fig.1 Data collection and digital processing units

Online monitoring and diagnostics system, installed at the object consists of following elements:

- primary converters (sensors)
- data collection and digital processing units (Fig.1)
- industry Network RS-485
- server with the appropriate software
- operator workstation with the appropriate software;
- diagnostician workstation with the appropriate software;
- operational documentation set for the system;
- software on appropriate media.

Compiled Outline scheme of the system is shown in Fig 2.

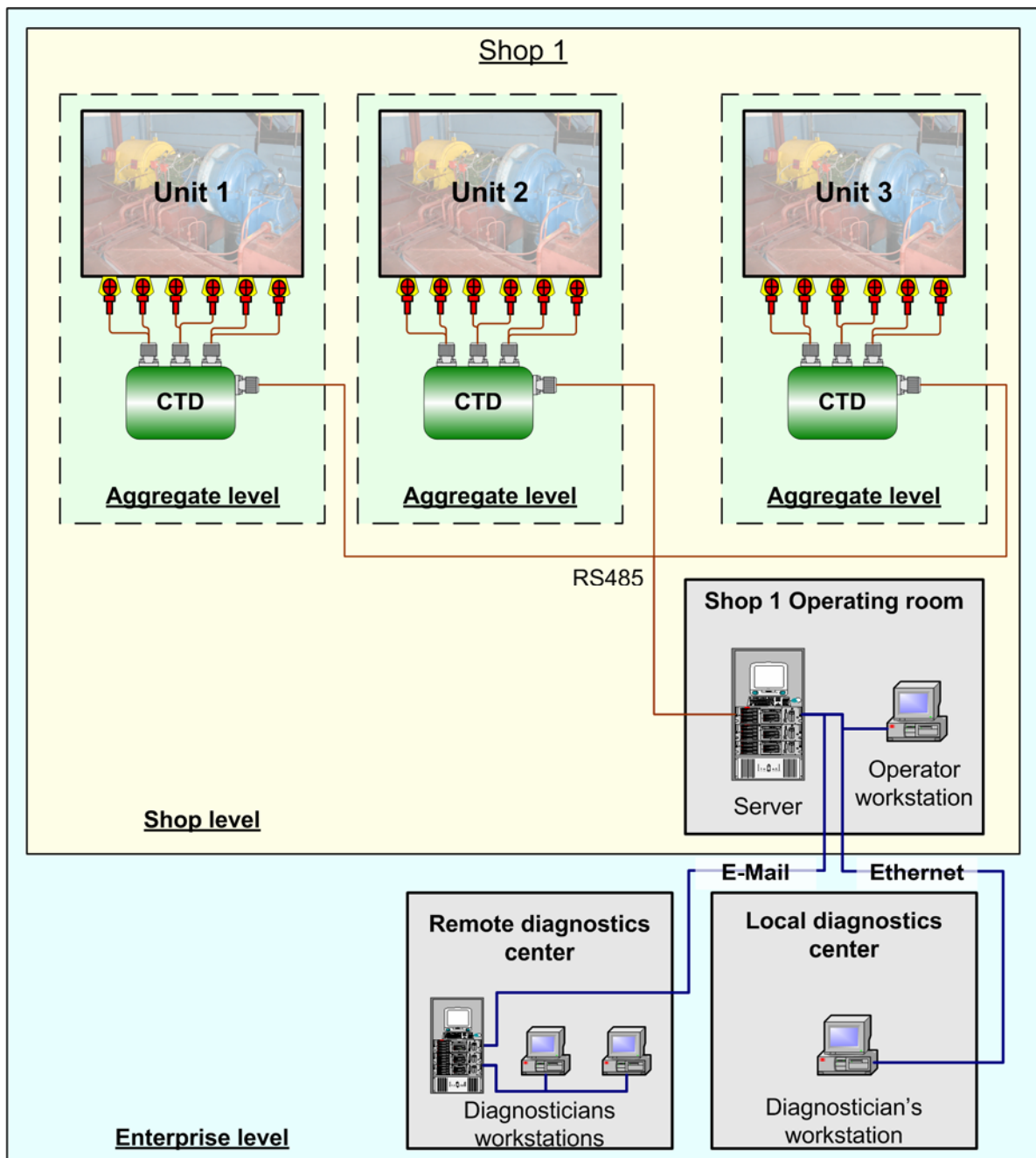


Fig.2 Compiled Outline scheme of the online monitoring and diagnostics system

The structure of continuous monitoring and diagnosis system in terms of functions and topology management of the facility is broken into three levels of the hierarchy performing appropriate functions :

- aggregate level;
- shop level;
- enterprise level;

Shop and enterprise levels have flexible architecture and allow scaling the system from simple to complex.

Aggregate level

Aggregate level composition:

- Primary converters (vibration, temperature, pressure, current and other sensors)

- Linkage (if necessary)
- Data collection and digital processing units.

Following functions are held at aggregate level:

- direct measurement of the parameters being monitored
- signal processing of measurement results
- vibration level control
- measured and processed data transfer

Figure 3 shows aggregate subsystems for different aggregate types.

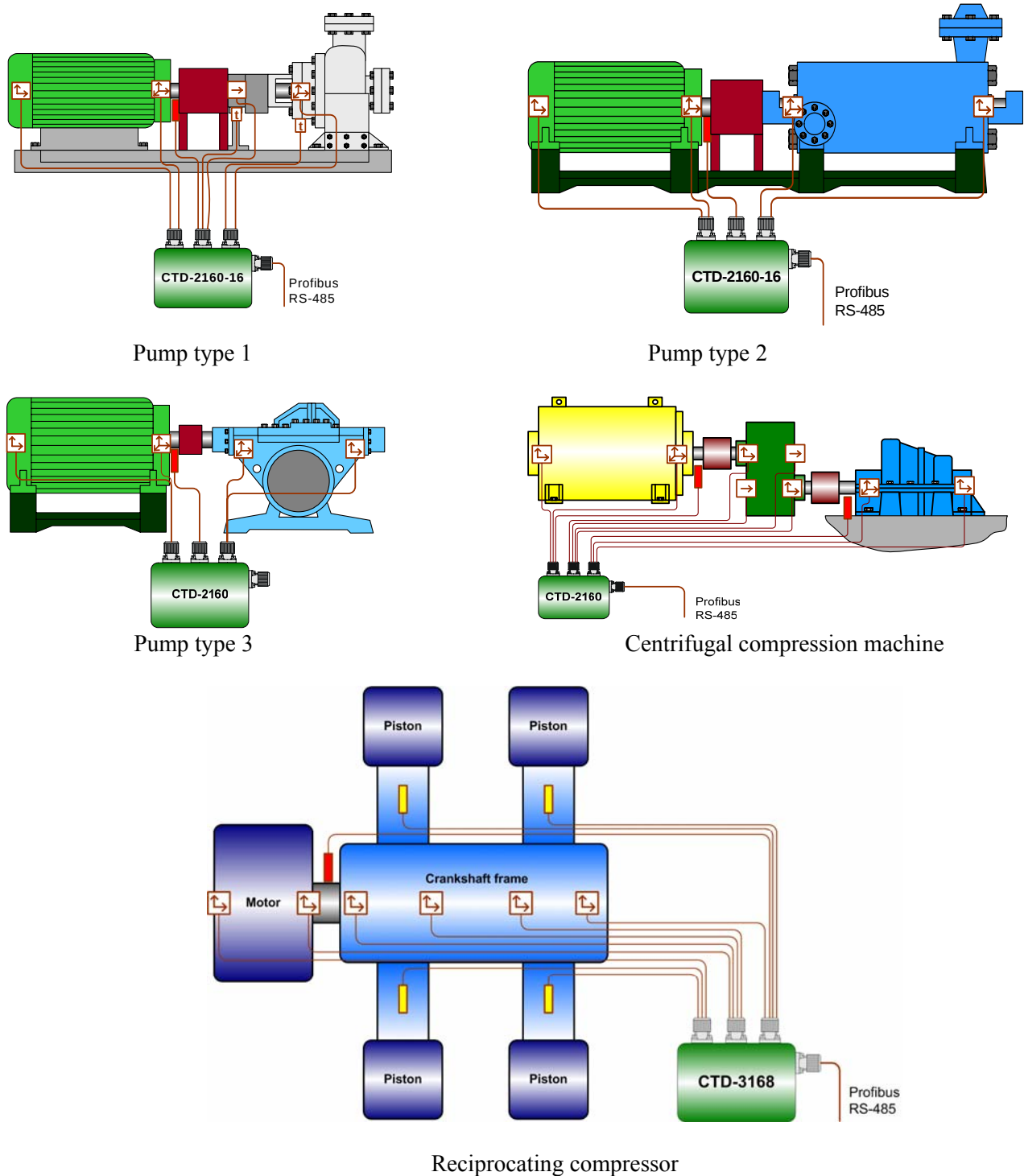


Fig.3 Aggregate subsystems example

All sensors are connected to data collection and processing units directly or through termination devices. Due to their size and simplicity of installation data collection and digital processing units can be installed directly on the machine.

CTD modules are continuously (at intervals of not more than 0.5 seconds) collecting and processing (RMS calculation and comparison to limit settings in 16 spectral bands) signal from all sensors simultaneously.

Each band has its own warning and alarm setting. Exceeding warning level triggers alarm informing staff about the need to take maintenance actions. If vibration level exceeds alarm level, the machine can be stopped automatically. If the machine is stopped - you can view information on the status of the machine just before the freeze. The time interval of looped recording is software-configurable.

Data collection and digital processing units functionality:

Control parameters calculation - for each channel up to 16 spectral bands. Length of cycle is not over 0.5 seconds.

Machine operating mode definition - determined by the speed of the shaft or RMS of vibration speed

The monitoring and alarm system - regulatory levels of vibration and parameters computed on vibration comparison.

Shutdowns data ("flight recorder") and the trends collection system - converter records calculated parameters into trends. The trends collection system is the "flight recorder". The data continues when the unit is in an operational state and stops when the unit is moving into "stopped" state

Inspections generation - the module collects waves (wave length collected is between 8192 and 65536 readings) after a command given via RS-485 simultaneously on all channels and all parameters.

Data exchange with industrial control department – transfer of values of parameters being monitored via RS-422 interface.

Transferring data to server - through RS-485 with 115200 baud rate.

Table 1. Data collection and digital processing units specifications

	CTD-3168	CTD-2160	CTD-2060
Common parameters			
Power supply	24 V DC		
Power consumption	< 8 W	< 8 W	< 10 W
Initialization delay	< 30 Sec.		
Power outage protection	Module configuration is stored in nonvolatile memory		
Dimensions	280x206x52.5mm	190x100x81mm	220x145x50mm
Weight	3,25 kg	1,8 kg	3,4 kg
Operating temperature	-40 to +55 C		
Humidity	98% at 35 C		
Atmospheric pressure	608 – 800 millimeter of mercury		
Vibration channels parameters			
Input channels	16 vibration channels + 3 tacho-channels	16 vibration channels + 3 tacho-channels	6 vibration channels + 1 tacho-channels
Parameters calculation period	0.1 s	0.5 s	0.4 s

	CTD-3168	CTD-2160	CTD-2060
Sensors	accelerometers, proximeters	ICP accelerometers	
Status indication	LEDs: "Control", "Work", "Warning", "Alert"	LEDs : «Alert» и «Warning»	
Vibration speed RMS range	0.1...100 mm/s		
Vibratory displacement amplitude	0.1...250 um		
FFT resolution	3200 lines	1600 lines	3200 lines
Upper frequency	8 kHz	10 kHz	
Lower frequency	0.5 Hz	10 Hz	
Maximum number of spectrum bands	12 fixed + 4 adjustable, for each channel	6 fixed + 10 adjustable, for each channel	
Dynamic range	72 dB		
Internal noise level	< 4 mV		
Bandpass flatness	±2.0 %		
Tachochannels parameters			
Number of tachochannels	3 tachochannels (several recordings per turn)	3 tachochannels (several recordings per turn)	1 tachochannels
RPM range	150 - 18000 rpm	180 - 18000 rpm	60 - 18000 rpm
RS485 interface parameters			
Data transfer speed via RS485	115 200 bod		
RS422 interface parameters			
Data transfer speed via RS422	19 200 бод		
alarm relay (dry connectors)			
Number of relays	4 (Control, Work, Warning, Alarm)	2 (Warning, Alarm)	
Closed state resistance		< 1,5 Ohms	
Switched current		< 0.5 A	
Switched voltage		200 V	
Switched power		10 VA	

Shop level

Shop level includes:

- *Server*, soft hardware unit collecting and storing information received from the aggregate subsystems, running data processing algorithms, as well as giving users access to information.

– *Shift engineer (Operator) workstation*, soft hardware unit providing visual monitoring of technical condition, and alarming on it's changes.

All information from the modules is automatically transmitted to a server via Profibus RS485 interface (distance from the modules to the server up to 1200 meters without repeaters).

In accordance with the requirements specification software VibroDesigner SCADA gets fully configured and placed on the server (Server package) and operator's workstation (Client package).

The server collects all information from the CTD modules automatically with a period of 1 to 5 seconds. Also server provides storage and data transmission to the operator (online via Ethernet) and diagnostician (several times a day via Ethernet or e-mail).

Server functions:

- *Condition data collecting* - data is collected through CTD-modules inquiry with the period 1 -5 seconds.
- *Daily trend generation* - with a configurable period of 1-5 sec. the condition data is written into the daily trend file.
- *Automatic generation and storage of shift engineer (operator) reports* - a report file of a coordinated format is generated with data from the CTD-modules.
- *Automatic generation and storage of files with inspection data* - an inspection file is generated for all working units in the shop on data from the modules.
- *Automatic generation and storage of data files for diagnostician reports* - a file with the data for the diagnostician report is generated for all plant units using the data obtained from the CTD-modules of the shop.
- *Automatic generation and storage of data files for aggregates shutdowns* – When the state of the unit changes from "Work" to "Stop" a single file with the shutdown report is generated.
- *Automatic data files transfer to diagnostician workstation* - pre-stored data files (files with inspection data, diagnostician reports data files and shutdowns records files) are being sent to the diagnostician workstation. Files are sent either via through e-mail or over LAN.

Operator workstation

All the information is being transferred to the operator's workstation in accordance with the system configuration. The display shows the condition of all units; the parameters for each unit can be monitored at each location (not only the overall level, but by bands, absolute and relative), a families of band trends (daily trends), run-outs. In case of exceeding the limit, color alarm indication is shown making rapid determination of the point exceeded allowed levels. There is also an opportunity to create and print reports.

Operator Panel consists of the equipment generalized state display area and the three main screens ("shop", "Aggregate", "Trends"), there is also the possibility of opening an additional window for viewing and printing shift engineer reports.

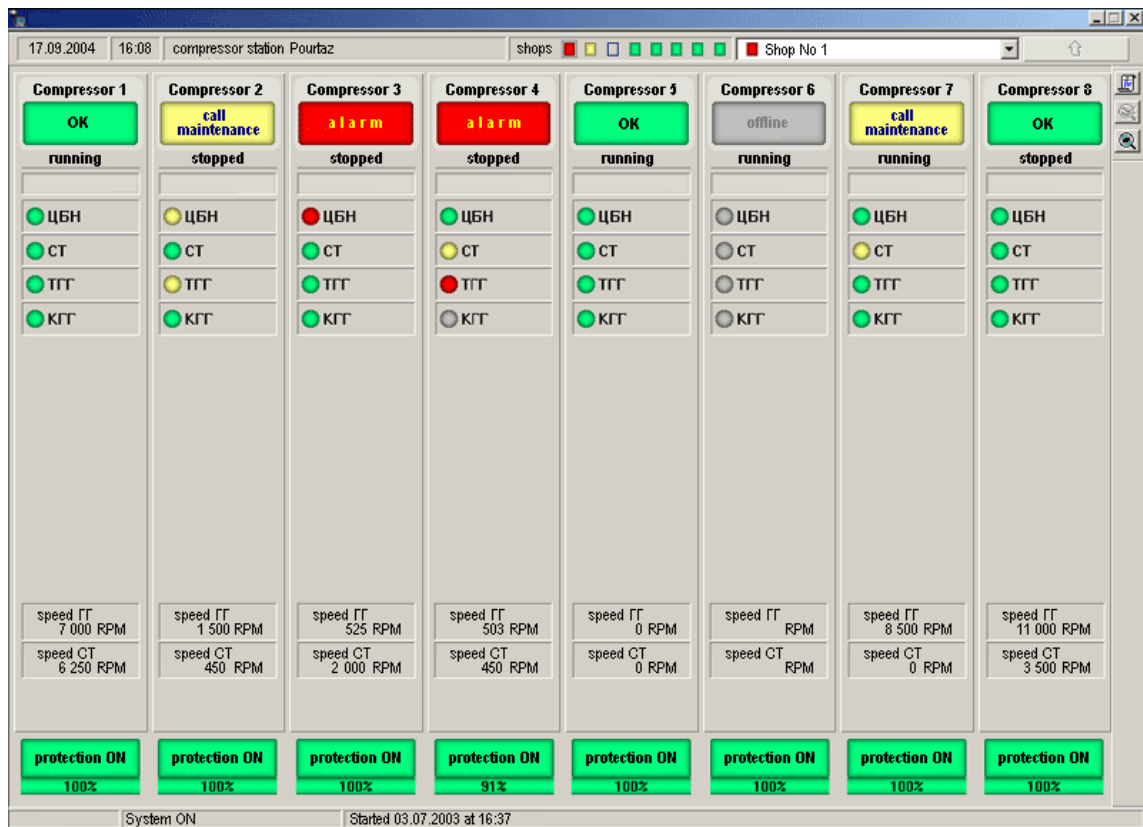


Fig 4. Operator Panel. “Shop” screen



Fig.5 Operator panel “Aggregate” screen

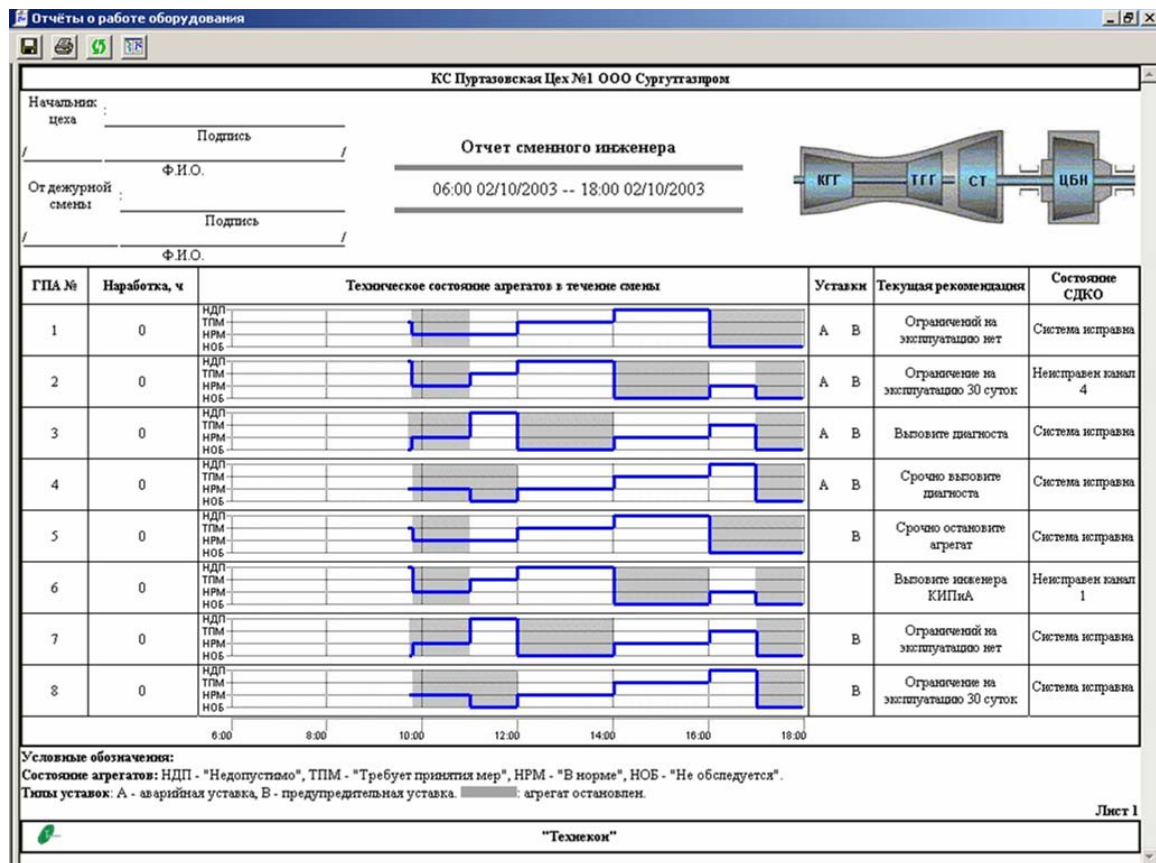


Fig. 6 Operator reports window

Enterprise level

Enterprise level includes:

- *Diagnostician workstation*, soft hardware unit, providing detailed analysis of diagnostics data about technical condition of units

Ethernet and TCP/IP are used for the connection to the server.

All the information automatically passed to diagnostician's workstation several times a day (defined at system configuration) and remains in the database, according to the structure of the enterprise. Diagnostician software installed at workstation ("VibroDesigner standard") allows performing a detailed analysis of the condition of the units and making conclusions on the units condition and generate reports.

Diagnostician workstation functions:

- *Real time data view* - you can switch from viewing archived data to real-time viewing of data.
- *Automatic inspections and diagnostician reports recording into diagnostic database* – file, obtained from the server and saved through automatic processing are automatically recorded into diagnostics databases.
- *Diagnostician report viewing* – diagnostician report contains information on the status of the plant during the past day and enables rapid detection of units with the changed conditions.
- *Databases archiving* – the data is archived for the creation of a single archive of diagnostic data for the entire period of operation of the park equipment.

- *Failure location and causes identifications* – our software “VibroDesigner” allows extensive Graphical analysis of the inspection data.

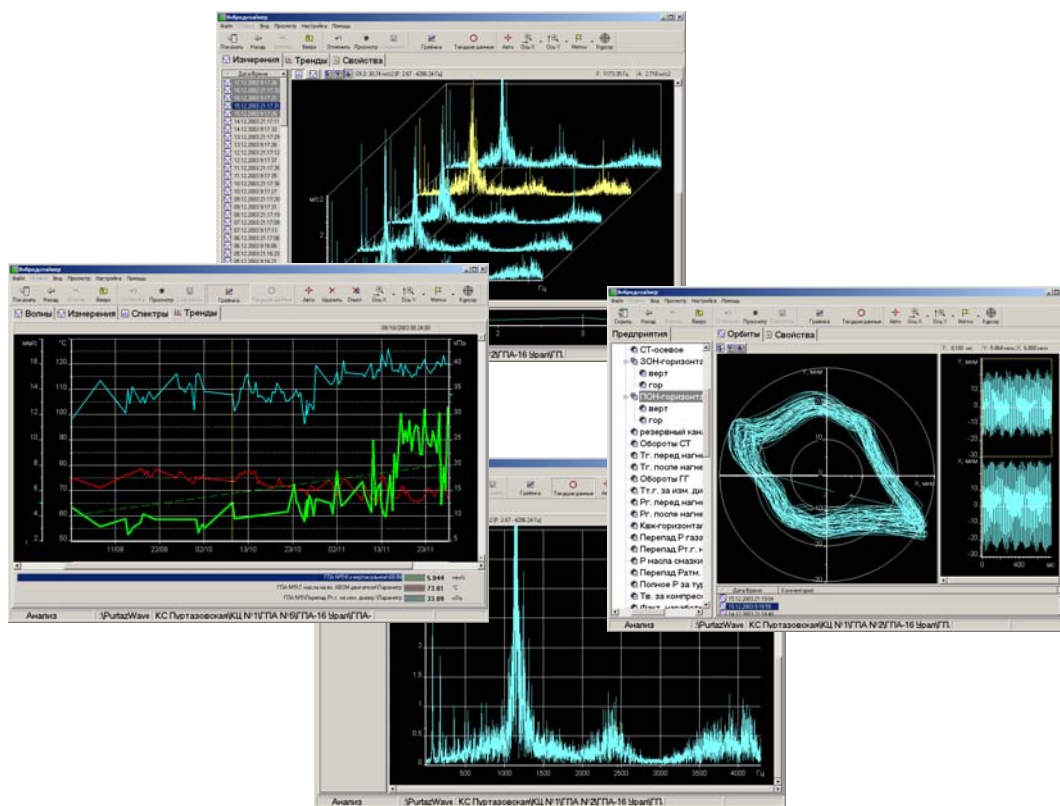
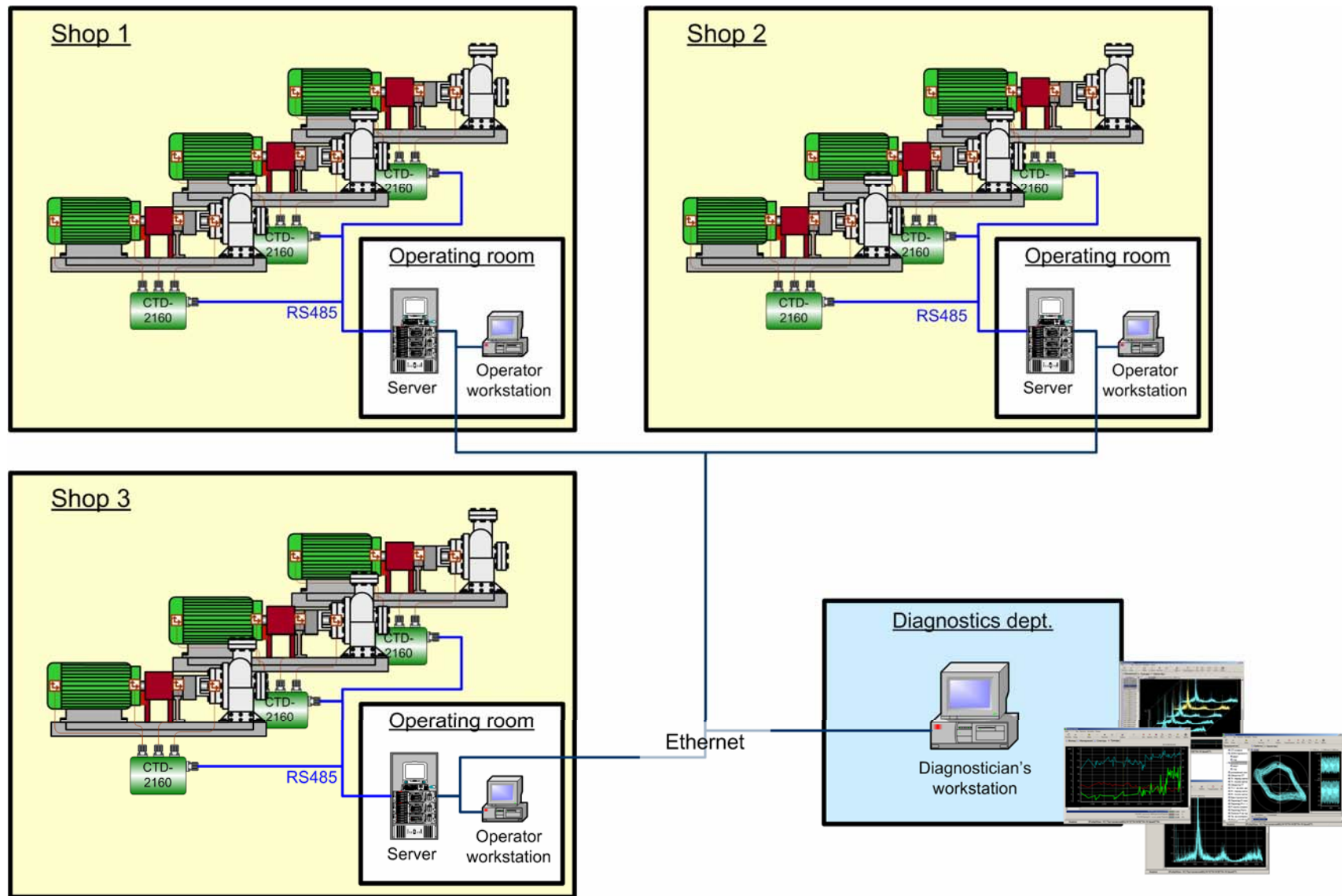
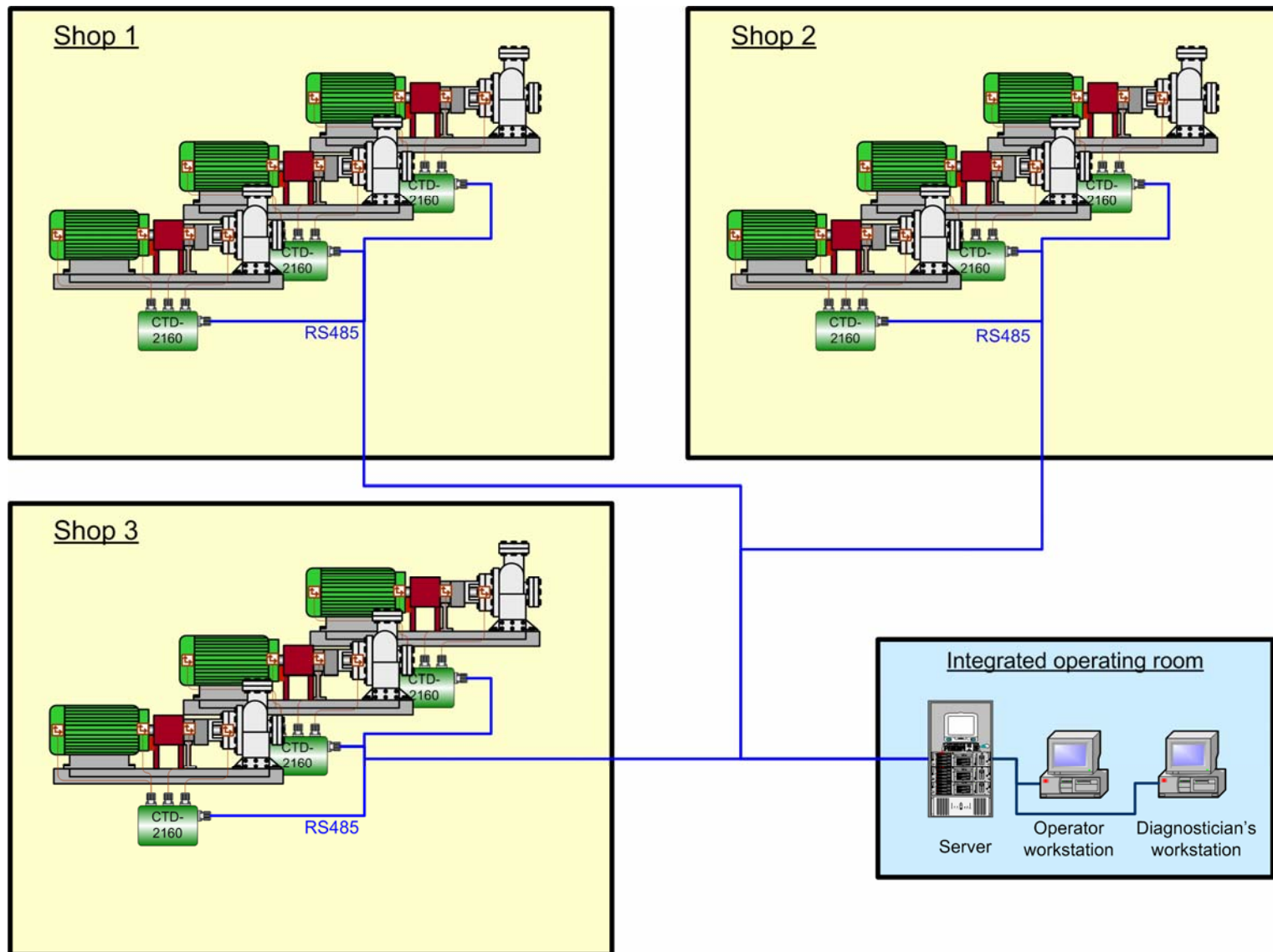


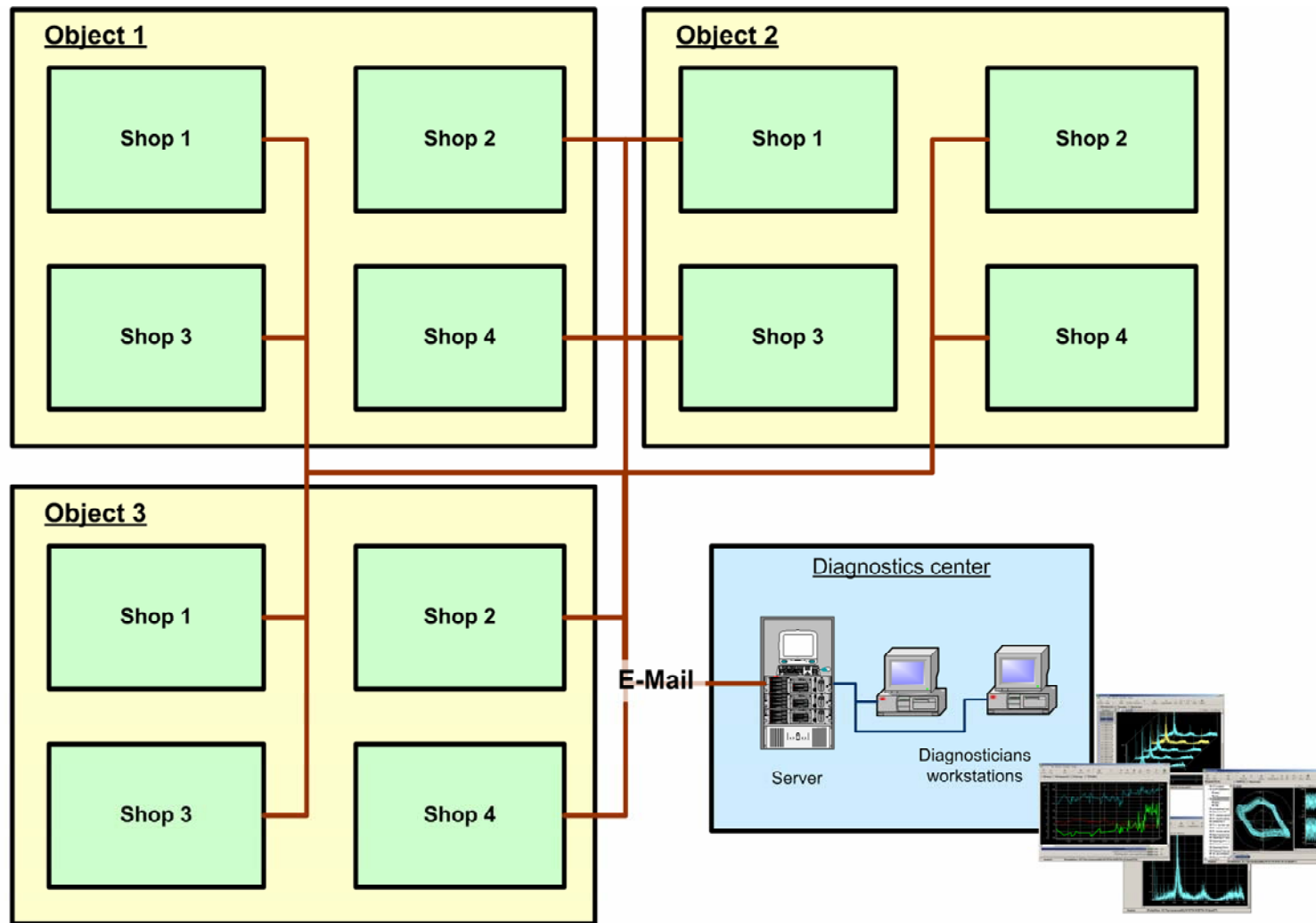
Fig. 7 Visual analysis in “VibroDesigner Standard” software



Example 1. Server and operator's workstation is installed in each shop's operating room. Data for further analysis and making conclusion about equipment condition is transferred over enterprise LAN to the integrated diagnostics department.



Example 2. Condition information for each unit monitored is transferred to the integrated operating room, where server, operator's workstation and diagnostician's workstation are installed.



Example 3. If there are several objects included in the enterprise, equipment condition information is automatically transferred to common remote diagnostics center. At each object server and operator's workstation is installed either at each shop or at the integrated operating room.