Made in Russia

TIK-RVM
Enhanced vibration
monitoring system

TIK

Research and
production
enterprise

TIK-RVM enhanced vibration monitoring system

Description

TIK-RVM is a distributed three-level emergency shutdown system (ESS), monitoring and diagnosis of the process & production facilities by vibration and mechanical condition parameters.

The system is intended for continuous measurement, display, control, storage and analysis of vibration parameters and mechanical condition of process & production facilities.

The **TIK-RVM** system is a modular and scalable system that is configured not only by function, but also by types and number of measuring channels. The **TIK-RVM** can be integrated to other measuring systems using the RS-485 and Ethernet interfaces and the Modbus RTU, Modbus TCP protocols.

The **TIK-RVM** is made of series-produced certified intrinsically safe electrical devices approved for use by the Federal Service of Environmental, Technological and Nuclear Supervision (Rostekhnadzor).

Measuring channels configuration in the system provides 10% redundancy. The redundancy can be accomplished either through additional channel in each group, or by equipping with 10% of spare parts, tools and accessories.

Scope of use

Centrifugal type pumping units, steam and gas turbines, reciprocating compressors, turbo-compressors, electrical generating sets and other equipment exposed to vibrations during its operation including equipment for the main oil pipeline facility.

Advantages

- possibility to implement a condition-based maintenance concept;
- reduction of equipment vibration diagnostics costs;
- possibility to assess the quality of the repair performed on the pumping unit;
- interoperability of system components through standard interfaces and protocols;
- ensuring of the record keeping of time-response characteristics at a time of emergency;
- improved reliability of the system as it is equipped with self-sustained measuring channels;
- high level of scalability and adjustment;
- option to use software suite remotely via local area network or the Internet.

Integration

Owing to the standard industrial interfaces, the system can be perfectly fitted into any available enterprise infrastructure. System is tailored for the particular industrial facility and is supplied as pre-set and assembled in a cabinet equipped with the internal climate control system.

TIK-RVM enhanced vibration monitoring system

Capabilities

Depending on the configuration the system is able to provide:

- automatic measurement and monitoring of the industrial equipment vibration parameters;
- computation of the signal spectral response characteristics;
- user-friendly tabulated and pictorial format of acquired information;
- information storage in nonvolatile memory;
- signals transmitting either to the automatic process control system (APCS) to implement functions of the process protection and interlocking, when the system is operating as part of APCS, or to the actuating relay, when the system is operating in self-contained mode;
- prompt automatic data gathering to implement the concept of condition-based maintenance of the mechanical equipment;
- in-field equipment diagnosis indicating possible malfunctioning assemblies and the type of fault;
- self-control ensuring serviceability check of measuring devices and interface channels without a system components disassembly;
- communication of the facility current status automatically to the operating and maintenance staff;
- flexible parameter adjustment of the system and measuring channels.

TIK-RVM structural flowchart
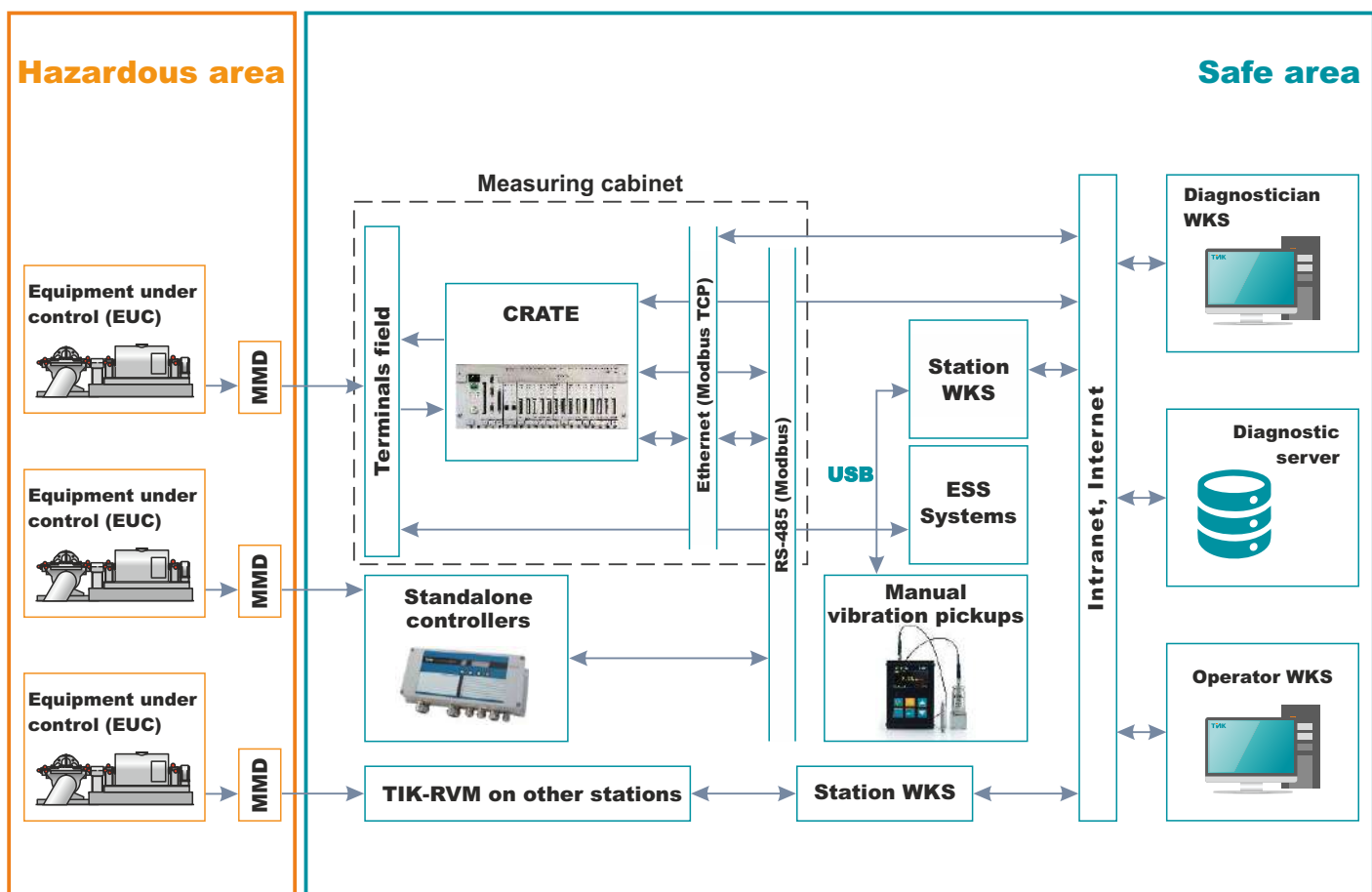
System operation principle

On hazardous area sites the primary transducers (sensors) are to be installed in the hazardous area and are to be connected to intrinsically safe circuits of the man-machine devices (MMD) or controllers.

The controller shall be installed outside the hazardous area.

A monitored parameter is measured by the sensor and is converted by the MMD into a unified signal that is further transmitted to the TIK-PLC 241 ver.02 controller input. There the signal is filtered, digitized and pre-processed, and then it is transmitted to an Interface Module (IM) through internal crate bus (RS-485). Crate is the box that contains modules and TIK-PLC 241 ver.02 controllers.

By means of output relays module (ORM) the Interface Module produces discrete warning and emergency threshold alarms, as well as the measuring channel and crate malfunction signals. Discrete input module (DIM) provides inputs of discrete signals on rotating equipment operation modes into the crate. With a view to provide redundancy, the crate includes two IMs, each module having one Ethernet interface channel (ModBus TCP protocol) and one RS-485 interface channel (Modbus RTU protocol) to exchange information with APCS. Communication across digital channels can be maintained using any external device supporting the above-mentioned interfaces.

Analog Output Module (MA-14) is designed to transmit values measured by TIK-PLC 241 ver.02 controllers in the form of unified 4-20 mA signals. These signals can be used for data display, recording and processing outside the system.

Output relay signals of the controller are used for machine condition warning sent to ESS.

Discrete input channels are used to manage the machine operation modes and to reset relay outputs (acknowledgement).

Display and data analysis software has been designed using SCADA systems. Functions of measured parameters analysis are defined by the project. A database management system (DBMS) is used for data archiving, storage and acquisition. Different projects can employ different SCADA systems and different DBMSs depending on the customer requirements.

Main components of the system

- primary transducer (IKV-1 apparatus; DVAXXX sensors; DV-1; DS-X; optional - channels for measuring pressure, temperature, flow; channels for measuring chemical parameters, etc.);
- process interface unit (PIU);
- terminal box;
- TIK-PLC 241 ver. 02, TIK-PLC 371 controllers etc.;
- modules in the crate;
- connecting link and equipment;
- uninterruptible power supply unit;
- direct current power supplies;
- display device (computer);
- software packing (optional - with vibration diagnostics module).

Technical specifications

Interface

Speed of the digital interfaces of the system
Ethernet . . . . .up to 100 Mbit/s (Modbus TCP)
RS-485 . . . . .up to 115.2 kbit/s (Modbus RTU)
System input signals (for one crate)
analog inputs 4-20 mA 14
analog inputs =12V, ~2V 14
discrete inputs 8
System output signals (for one crate)
analog outputs 4-20 mA 14
independent relays of alarm system and emergency shut-down .12
System supply voltage, V. . . . .
. . . . .not more ~220±10%(=24V±10%)
Power consumption system, W, not more 700
(for one cabinet with built-in PC)

Explosion protection

Type . . . . .intrinsically-safe circuit
Marking . . . . [Exib]IIC

System specification

Number of cabinets per diagnostic system . . . . .up to 2
Number of units serviced by one cabinet . . . . up to 8 (16)*
depending on the unit
Number of crates per cabinet . . . . .up to 8
Number of controllers per one cabinet . . . . .up to 14

Design parameters

Overall dimensions of the cabinet (HxWxD), mm . . 2000x800x600
Weight of assembled cabinet, kg, not more 100

Demonstrated reliability and warranty

Average time between failures, hour 10 000
Average lifetime, year 10
Installed system resource - at least, hour 80 000
Warranty, month 18

TIK-RVM architectural layers

Vibration transducers DVAXXX, DS-X, IKV-1 apparatus

Level of primary transducers

At this level, vibration acceleration, vibration velocity and displacement DVAXXX/DS-X sensors series and IKV-1 apparatus are used, as well as any standard vibration transducers with a unified type of output signal.All vibration sensors supplied as part of the TIK-RVM system have a high degree of protection from external influences, and can also be equipped with a plug-in connection to facilitate repair, technical and metrological services.

The vibration acceleration sensors have a frequency range from 2 to 10.000 Hz, which allows the use of the measuring channel for spectral diagnostics.

Level of programmable logical controller

The programmable TIK-PLC 241 ver. 02 and/or TIK-PLC 371 controller are used as basic elements.

TIK-PLC 241 is a high-performance controller with a large number of interfaces that performs the functions of interrogating sensors, mathematical processing of the measured signal and transmitting it to MI.TIK-PLC has analog 4-20 mA current inputs and two analog voltage inputs (ICP). The current inputs and two analog voltage inputs (ICP). The controller is programmed in the top level language, which allows you to quickly reconfigure its internal logic to meet changing requirements and tasks.

Each measuring channel operates completely independently of the others. The fault tolerance of the system components involves the issuance of signals to stop the equipment only in case of exceeding the vibration level on several channels.

TIK-PLC 371 additionally has a channel for connecting a thermal transducer.

Controllers for **vibration diagnostics** were developed for emergency protection of Main Line Pump, which affected their structure - high speed of response to changes in input signals, complex relay operation algorithms, consideration of unit operation modes, hardware independence of controllers, duplication of internal buses and power supply systems.

TIK-PLC 241 version 02

Top Level - Software

At the top level of the system, there is an industrial workstation (operator's automatic workstation) with an installed SCADA-package and, optionally, a specialized TIK-Expert module for vibration diagnostics (diagnostician / technologist's automatic workstation).

Basic mnemonic diagram

The TIK-RVM system software performs the following functions:

- display of the object mnemonic scheme with the current values of the measured parameters;
- self-checking of measuring channels;
- event logging;
- provision of reports of several types;
- data exchange with other systems through unified protocols and interfaces;
- registration and storage of changes in parameters (trend lines);
- run a fast access for spectral analysis;
- calculation and visualization of signal spectrum;
- protection against unauthorized access;
- distribution of access rights for different user groups;
- inform personnel about emergency and warning situations.
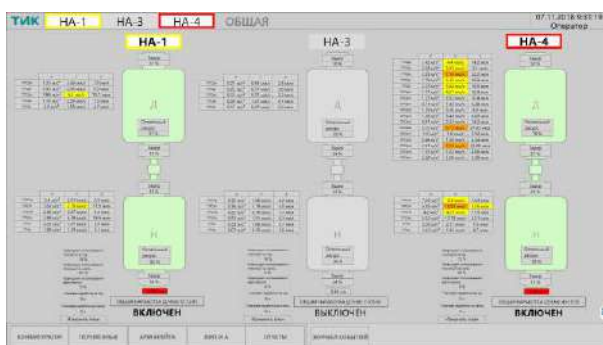
By a separate order, it is possible to add automatic diagnostics functions, predict unit output for repairs, repair quality assessments, remote system management, and distributed use.

It is possible to use update of software package (including diagnostic rules) remotely over a local network or the Internet.
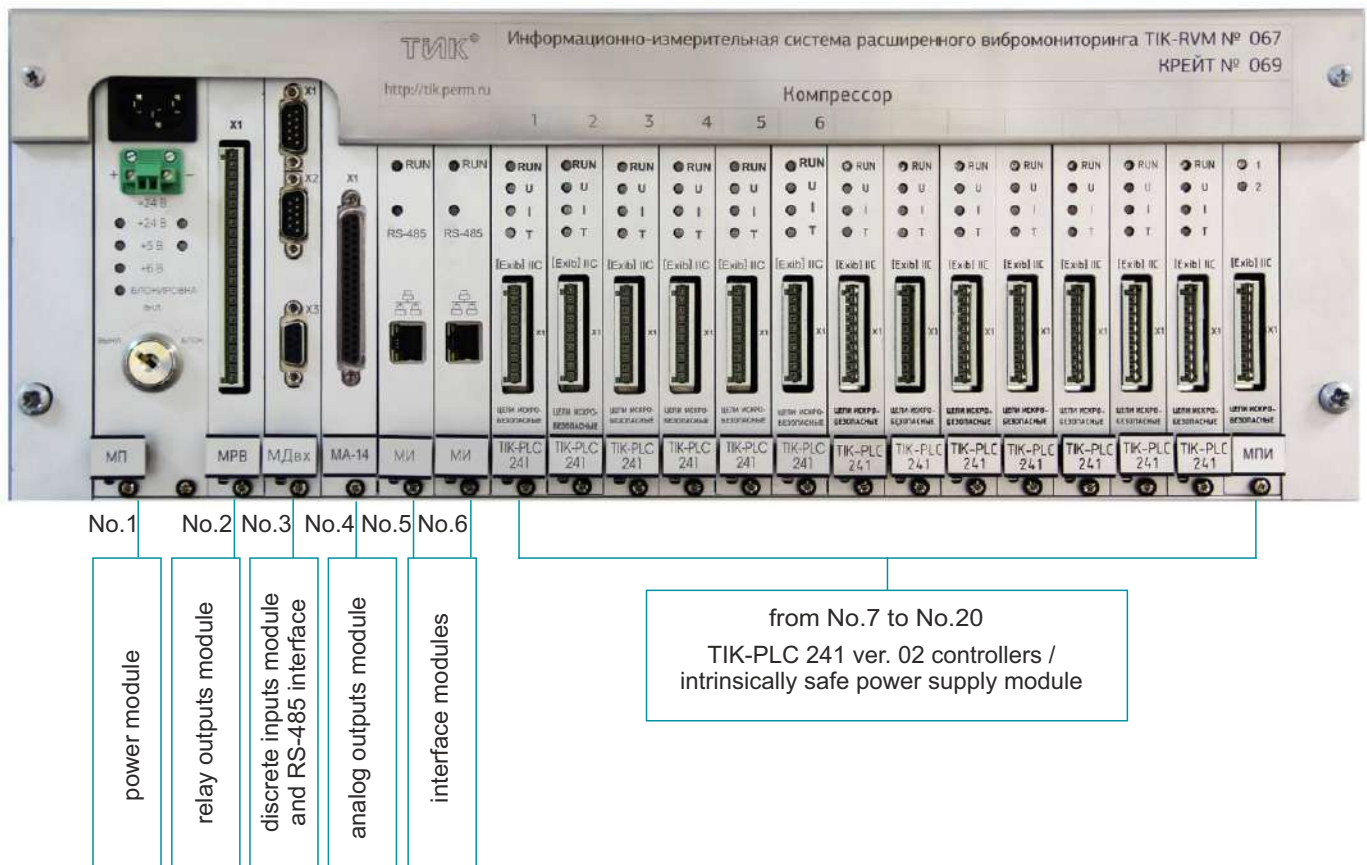
TIK-RVM based on TIK-PLC 241 ver.02 controller

Description

The **TIK-RVM** system, which is built around **TIK-PLC 241 ver. 02** controller, has a range of advantages and one of them is modularity. Modules are mounted into special case called crate.

The TIK-RVM operation within the crate is based on the principle, where each module fulfils special functions. Main functions of the controller are signal receiving and processing, when signals are sent by primary transducers via MMD, as well as data distribution to IM. Interface module generates control signals sent to relay outputs module according to the formed configuration. The interface module also processes discrete inputs and shares data via digital communication interfaces through the discrete inputs and RS-485 interface modules.

Crate structure

No.1 — power module
No.2 — relay outputs module
No.3 — discrete inputs module and RS-485 interface
No.4 — analog outputs module
No.5, No.6 — interface modules

from No.7 to No.20
TIK-PLC 241 ver. 02 controllers /
intrinsically safe power supply module

Power supply module (PSM)

converts AC or DC voltage into stabilized DC supply voltages of function module (+24V, +6V, 5V).

To be installed into the slot No.1.

Relay output module (ROM)

contains 12 dual relay channels (in order to provide a reliable signal generation, each channel includes two output relays) with seven normally open (NO) and five normally closed (NC) contact groups.

The module front panel has 24-pin connector to connect external circuits.

To be installed into the slot No. 2.

TIK-RVM based on TIK-PLC 241 ver. 02 controller

TIK-RVM based on TIK-PLC 241 ver. 02 controller

is designed to receive external discrete signals. Module serves as well for the connection of external digital RS-485 Interface (Modbus RTU communication protocol). All the electronics of digital interface is located in IM. This module also contains non-volatile generator of system time.

The module front panel has the X1, X2 and X3 connectors to plug in external circuits. The DB-9M male is used to connect discrete inputs and DB-9F female is used to connect RS-485 interface.

To be installed into the slot No. 3.

Analog output module (MA-14)

is designed to transmit to the external automation and recording systems of the following values measured by TIK-PLC 241 ver. 02 controllers:
• instantaneous values of vibration acceleration;
• RMS of vibration velocity (4-20 mA);
• axial offset;
• signal from sensors with 4-20 mA output; in the form of 4-20 mA circuit signal.

The module front panel has a connector for external circuits.

To be installed into the slot No. 4

Interface module (IM)

performs:
• measurement data capture and storage (RMS of vibration velocity, vibration acceleration instantaneous values, axial offset, input current) made by TIK-PLC 241 ver. 02 controllers;
• discrete inputs processing;
• relay outputs control;
• storage of set points necessary for crate functioning in the non-volatile memory;
• data communication via digital interfaces (Ethernet and RS-485);
It is possible to perform "hot swapping" of the module without failures in operation. For the sake of redundancy the crate has two Ims.
The module front panel locates:
• RUN and RS-485 LED lights;
• ethernet connector;
• module "soft" start/cut-off switch.

To be installed into slots No. 5,6 (main, stand-by).

TIK-PLC 241 ver. 02 controller

is designed to record and process signals received from primary transducers.

In addition, the controller acts as intrinsically safe barrier and sensors power source. Controller features generation of warning and emergency threshold alarms, as well as access control channels masking.

The controller front panel locates:
• RUN, U, I, T LED lights (temperature channel is not employed);
• X1 connector to plug in external intrinsically safe circuits;
• controller "soft" start/cut-off switch.
  RUN LED is used for the controller status indication. U, I, T LEDs are used to indicate the voltage and circuit loop input measuring channels status respectively.

Maximum 14 TIK-PLC 241 ver. 02 controllers are to be installed into slots No.7 to No.20.
Controllers quantity is determined by the necessary number of measuring channels in the system. To ensure readout collection from several crates a **Timing Module (TM)** is installed instead of one of the controllers. Therefore the system can be scaled.

Intrinsically safe power supply module (SPM)

is intended for energizing MV-6/MS-6 Man-Machine Device (MMD). The module has two independent supply channels rated at ±6.8V with the load capacity of ±25mA each. The output supply voltage accuracy within the entire load range is ±5%.
The front panel locates:
• LED light indicating supply voltage presence in channel "1";
• LED light indicating supply voltage presence in Channel "2";
• X1 connector for external circuits.
The module front panel has a 10-pin connector to plug in external circuits.

Module is to be installed into slots No.7 to No.20 inclusive.

Top Level, Software

At the top level of the system, there is an industrial workstation (operator's automatic workstation) with an installed SCADA-package and, if necessary, a specialized expert program (TIK-Expert module) used to carry out vibration diagnostic analysis of dynamic equipment.

To ensure flexibility and extensibility, the TIK-RVM system software is also modular.Upgrading and adding modules that extend the functionality of the complex, reconfiguring the entire complex.

The main modules of the system with the vibration diagnostics function are:

- system configure;
- authorization server;
- rules server;
- I/O server (OPC, Modbus TCP, Modbus RTU);
- data processing center;
- interworking module with system users (operator's automatic workstation);
- report generation and printing module;
- OPC UA server;

The role of the DBMS in software

DBMS in the TIK-RVM system occupies a central place and carries out the functions of storing the system configuration, diagnostic information, historical data and other information necessary for the operation of the system. All users of the system are connected to a single DBMS (SQL), which ensures data integrity and ease of building additional workplaces.

Restoration of the database in the event of an accident of the equipment is ensured by restoring from backup copies, the creation of which takes place both on schedule and on demand. Also, a transaction mechanism is used that prevents data integrity in the event of a break in communication with the database or other actions that can lead to damage or loss of data.

Main elements of the system:

- general system mnemonic scheme;
- unit mnemonic scheme;
- instrumentation and controls mnemonic scheme;
- reports;
- access view;
- trend lines;
- event log;
- histograms;
- *TIK-Expert (*optional)*.

General system mnemonic scheme

On the main mnemonic scheme displays the current status of all workshop units.

When warning or alarm events occur, an indication appears on the scheme, which has several degrees of priority depending on the malfunctions descriptions.

When the color indication displays on the general mnemonic scheme appear, it is possible to call the window with the list of detected defects. Also in this window displays are further recommendations for eliminating defects.

The software also has **a decision block** that issues diagnostic messages to the main screen based on:

- diagnostic signs status;
- diagnostic signs trend lines;
- diagnostic signs spectrum.

Unit mnemonic scheme

BIn the lower part of the mnemonic scheme navigation buttons are located. On the mnemonic scheme you can see the current state of the unit assemblies, the values of the measured parameters (vibration, temperature, pressure, etc.), total operating time.

The mnemonic diagram displays the date and time of the unit on / off and indicators of operating time, which allow you to visually determine how much time is left before the current, average and capital repairs.
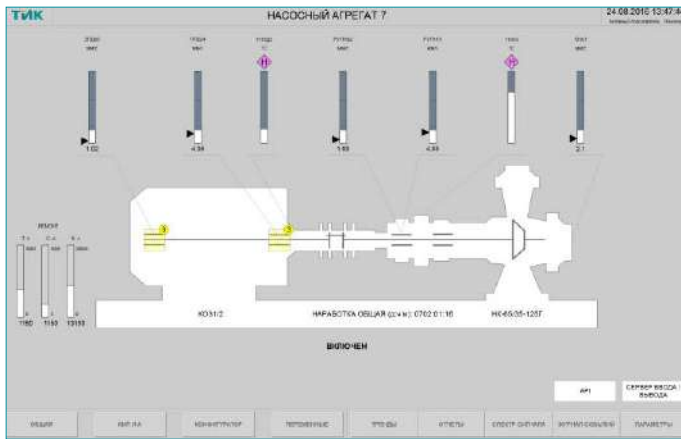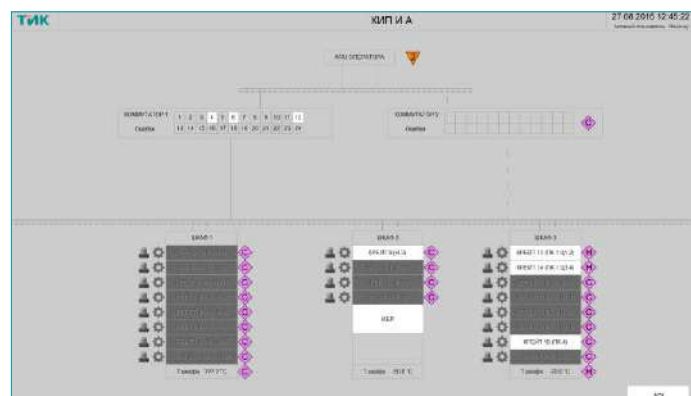

Clicking on "Total Runtime" opens the window of Runtime on all assemblies.

Also, defective assemblies are tinted with icons with different color gradation depending on the defect descriptions.

Instrumentation and controls mnemonic scheme

This mnemonic scheme displays system service parameters.

Reports

The software package has the ability to display information about the state of the selected object, its trends, spectra, protocols of the technical condition, both for the entire equipment of the installation, and for the units in a certain state.

List of system reports:

- dynamic equipment status report;
- equipment vibration control report;
- metrology report;
- statistical report;
- bearing assemblies Runtime report;
- SCADA package report.

Access view

The module "Access view" is designed for mathematical processing and graphical analysis of signals from various sensors, as well as for diagnosing defects in dynamic equipment.
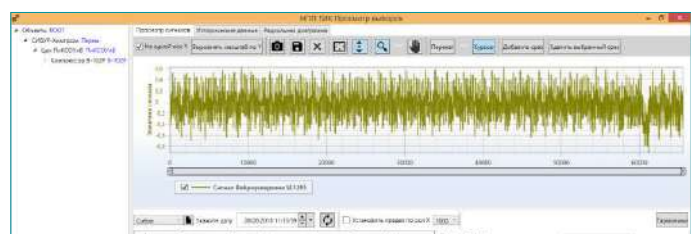
Trend lines

Clicking on "Trend lines" button appears a pop-up window to select the trend lines: vibration acceleration trends, vibration velocity trends, vibration displacement trends, temperature trends and archival trends.
Trend lines display the change in the measured parameter in time.

This section contains a sub-menu "generate a report", which displays the readings of the sensors of the selected parameters for the specified period, as well as the maximum and average values for each of these parameters.
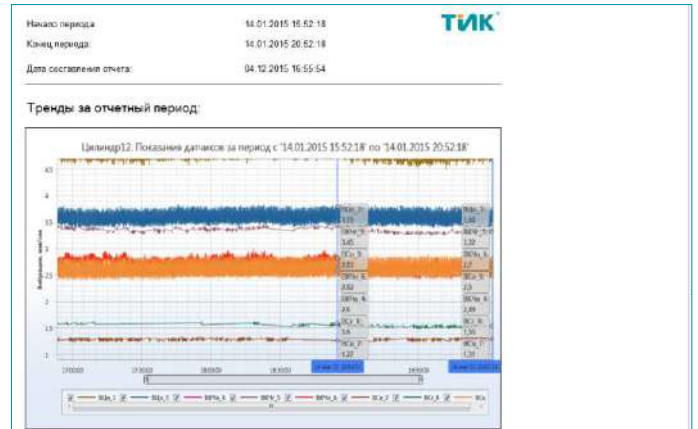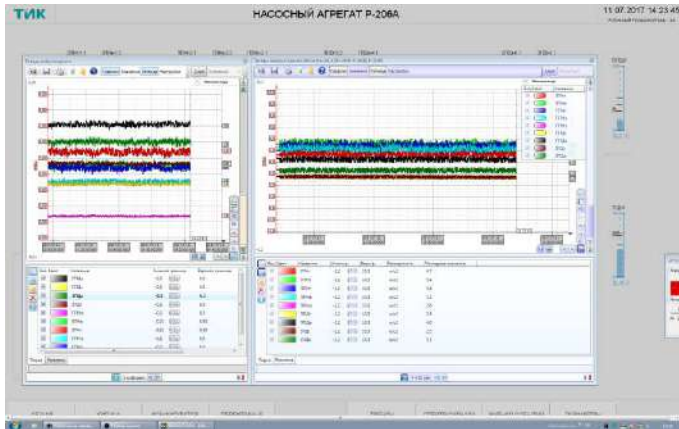
Event log

The event log describes all events that occurred with the system. The operator interface allows the log to be sorted according to various characteristics for the convenience of searching for the required event.

Histograms

This section is available only for piston compressor control systems. This mnemonic scheme allows you to view the real value of vibration acceleration and vibration displacement of the rod.
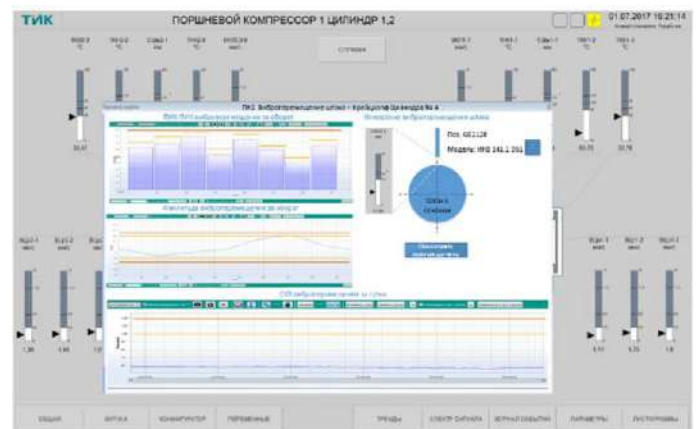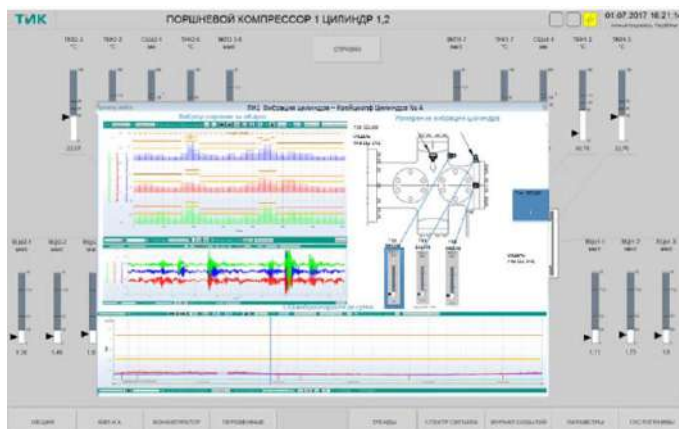
Maintenance diagnostics

The TIK-RVM system allows you to quickly collect and analyze the parameters of the measured signals, as well as perform diagnostics of the technical condition of the units, both from the current values of the measured parameters and from the module messages.

The module provides automatic processing of the collected information in order to assess the technical condition of the monitored equipment and to identify the following faults:

Group 1. Rotary machines faults (rotary pumps):
- rotor imbalance;
- impellers faults;

Group 2. Bearings faults:
- lack of (low quality) oil (lubricant);
- skew;
- slackening;
- outer cage fault;
- internal cage fault;
- rolling element fault;
- gas-oil separation plant fault;

Group 3. Power transmission faults:
- coupling faults;

Group 4. Unit faults:
- shaft alignment faults;

Group 5. Electrical faults:
- stator faults;
- rotor faults;

Group 6. Temperature faults:
- thermal overload;
- heat supply inequality;

Group 7. Piston compressors faults:
- piston compressors valves faults;
- piston compressors motion work faults;
- piston compressors rod seal wear;
- piston compressors ring wear.

Configurator

TIK-Expert installed at the diagnostic station allows diagnostics of the equipment, both in automatic and manual mode.

In **the automatic mode** system independently performs algorithmic transformations, reads the necessary data by a command from the server and checks the fulfillment of conditions.

In **the manual mode** the tools are:
- sampling frequency;
- cutoff frequency of low and high filters frequency;
- filter criteria to calculate the envelope;
- criteria to calculate the rotational components.
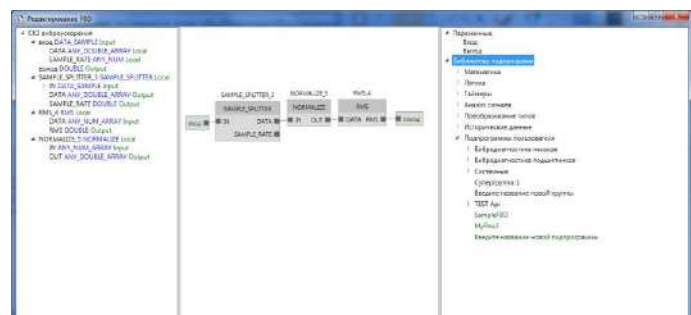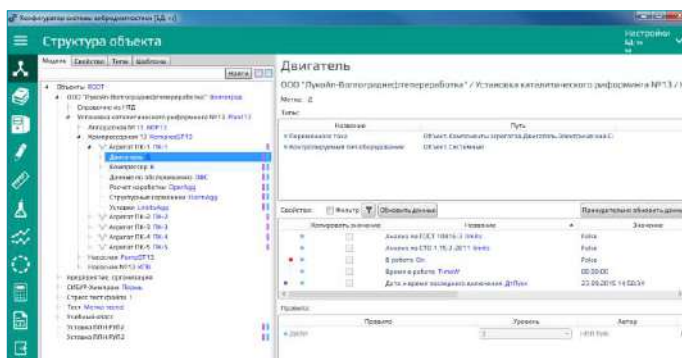
TIK-Expert

Diagnostic and Prediction Methods

The expert program performs diagnostics and prediction based on the most modern methods, including the use of "artificial intelligence", built on the principles of "neural network".

The list of methods for diagnostics and prediction used in the TIK-Expert module:

- vibration velocity level control;
- assessment of the residual life of elements by analyzing the envelope of the spectrum of vibration acceleration ;
- assessment of the technical condition of bearings on the coefficient of "kurtosis" of the vibration acceleration signal;
- assessment of the technical condition of vibration levels in the frequency bands;
- assessment of the technical condition of the full spectrum;
- assessment of the technical condition of wavelet decomposition;
- assessment of the technical condition using a trained neural network;
- linear regression prediction;
- rediction using trained neural network.

The data collected by the system can vary considerably depending on the object. The end result of the diagnosis and prediction depends on the quality and amount of data. The functionality of the system allows you to process and compare any data with settings, standards, or among themselves, or with identical data from other units.

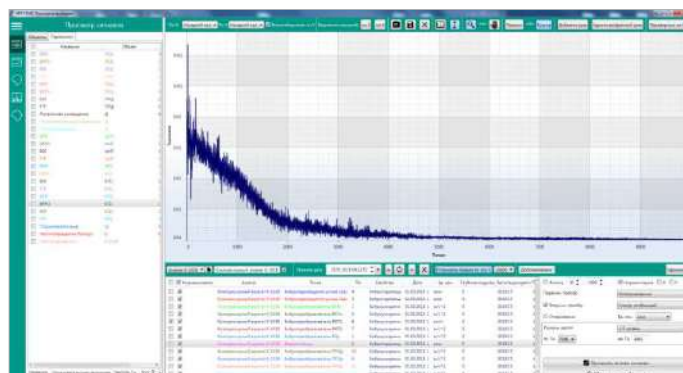Prediction results are displayed in a user-friendly format on mnemonic scheme.

There are different criteria for the withdrawal of residual resource and time, according to the smallest, average, and other algorithms.
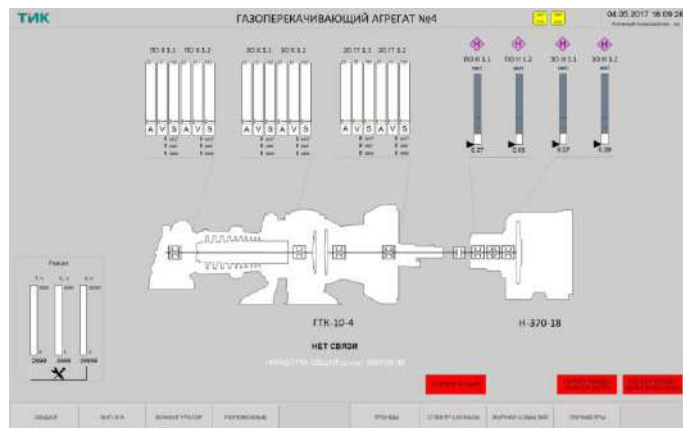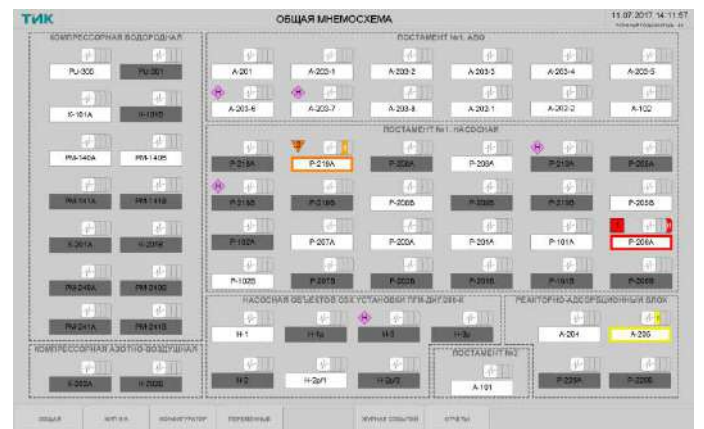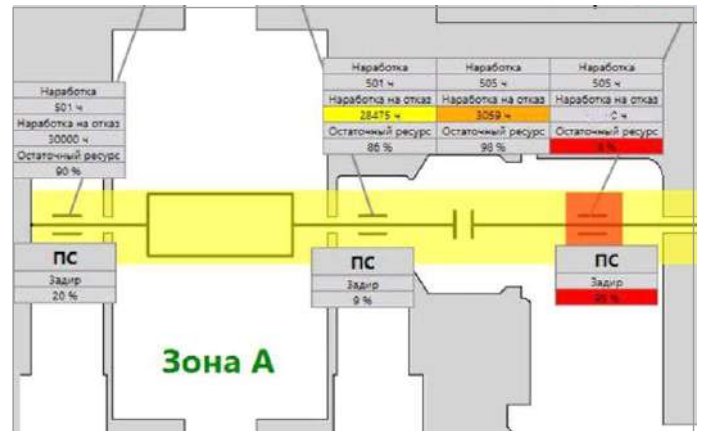
An example of the gas-compressor unit mnemonic scheme
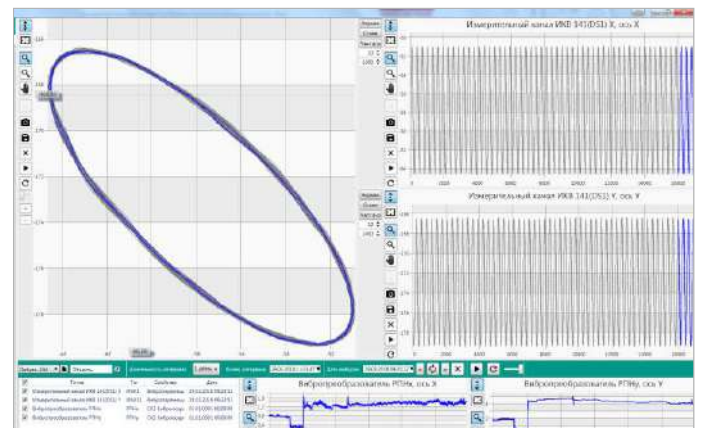
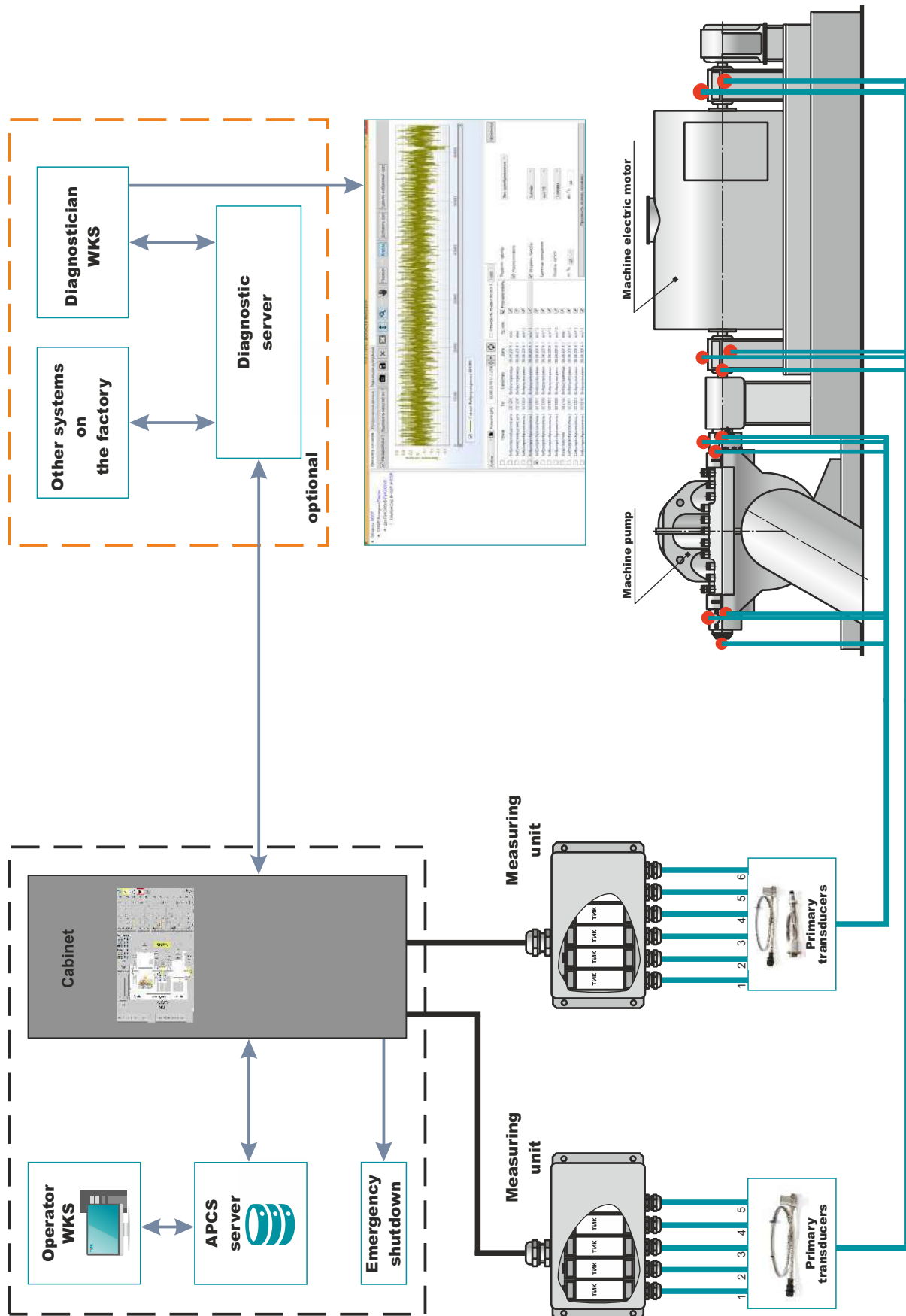*An example of "Orbit" screen*

An example of "Envelope spectrum" screen

TIK-Expert. Object structure example

TIK-RVM application diagram for critical machines monitoring

Approval documents

Pattern Approval Certificate of Measuring Instruments
OC.C.28.004.A №37936 for the TIK-RVM information and measuring systems
of extended vibration monitoring.

Pattern approval certificate No. 90229-23 for the TIK-RVM information
and measuring system of extended vibration monitoring.

Statement of compliance ЕАЭС № RU Д-RU.РА09.В.70444/23
the TIK-RVM information and measuring system of extended vibration monitoring.
Meets the requirements of the Technical Regulations
Customs Union TR CU 020/2011 "Electromagnetic
compatibility of technical means",
TR CU 004/2011 "About the safety of low-voltage equipment".