

Special Aspects of the Software Realization Concerning Permanent Health Monitoring Systems of the Overhead Catenary on Railroads of Russian Federation

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Abstract – Authors of present article describe the basic aspects of the software realization regarding Permanent Health Monitoring Systems of the overhead catenary being developed and applied on speed railroad track “Saint-Petersburg – Moscow”. Software technical features were highlighted per lower and upper level of the monitoring system structure. Comfortable technology of the monitoring system results, convenient presentation on dispatcher’s automated workstation as well as on electrical power sources spots plus on power supply services and emergency centers is being described.

I. INTRODUCTION

The most important step concerning modern technology of railroad infrastructure devices improvement is reliable Permanent Health Monitoring Systems arrangement plus constant railroad elements diagnostic. Implementation of the above systems helps us to fulfill technical condition forecast together with events of pre-failure conditions within important sites during actual service period. Such an activity shall modify the culture of railroad transportation labor and minimize men participation reckoning technical maintenance of the railroad infrastructure. In this case we see the drastic upgrade of supervision possibility based on actual needed maintenance plus the estimation of the site remaining life expectancy becomes the reality.

One of the first Permanent Health Monitoring System of Russian railroads was implemented dispatcher’s hardware and software per automated elements with telemetry [1]. Those systems appeared by the end of last century and successfully being conducted today. Automated level of data

Manuscript received November 28, 2016.

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analysis with technical condition forecast concerning railroad automatic and telemetry is rather high.

As for other systems of constant monitoring objects of railroad infrastructure and electrical power supply, the situation is not as smooth as it should be. In contrast to Permanent Health Monitoring System of railroad automatic, where electrical features of devices are being controlled only, we should take care of such important features as temperature, pressure, mechanical force, acceleration, etc. Serious fact should not be left unmentioned that automatic devices being controlled by modern permanent monitoring systems basically either centralized (placed on single station) or located within designated distances to each other (for example, movable automatic or stoplights), which simplifies the procedure of monitoring completion. As for upper railroad facilities and overhead catenary, the above-mentioned ones belong to objects located on remote distances to each other. Based on the foresaid, the arrangement of permanent systems of monitoring per sites of electrical power supply is rather complicated for the Authorities of Russian Railroads. Only periodical monitoring systems for electrical power supply points of railroad infrastructure are being installed nowadays, such as movable units together with manpower recourses.

Let us take a look at the overhead catenary [2], which is not provided by safe reserve of 100% and being functioned within Nordic severe climatic conditions such as air dynamic load snowfalls, temperature variations plus the actual pressure of a pantograph during train passage. The percentage of railroad failure regarding the overhead catenary is huge! It is more than 75% [3]. Initial feasible permanent monitoring systems within Russian Railroads were formed by the beginning of XXI century. Meanwhile, those systems are being widespread conducted on foreign railroads [4–9]. Back on 2011 we completed scientific research scope of works regarding Permanent Health Monitoring System application concerning overhead catenary systems on historical railroad track “Moscow – Saint-Petersburg” [10 – 12]. On the eve of 2016 serious amount of information was collected including the results of vibration based diagnostics, strain gauge measurements and sudden temperature drops statistic, which helps to define particular events together with overhead catenary elements pre-failure. This way Permanent Health Monitoring System of railroads became popular. Implementation of the above system is being conducted within unlimited areas of Russian Federation including being designed high speed railroad track “Moscow – Kazan – Yekaterinburg” [13].

II. STRUCTURAL SCHEMA OF PERMANENT MONITORING SYSTEM

Structural schema of Permanent Monitoring System composed of hierarchy structure of several functional levels (Fig. 1) [11]. Lower level of the system consists of diagnostic sensors located within compensator cables as well as on middle anchorage spot. Due to the fact that those sensors are located within open air during service period, strict requirements are essential regarding service condition terms including extra subsystem of solar plus lithium batteries per reliable power supply were designed. Subsystem of power supply is the unique one for the reason of steady energy delivery for the period of 10 years without battery exchange plus compares to Permanent Monitoring System of railroad automatic, any cables are not needed, which is the actual advantage of our system. Within the diagnostic sensor, fulfilled inside the rigid frame, on printed section microcontroller is imbedded together with set of sensors (oscillation diagnostic and temperature). External sensors are connected by means of special ports, (for instance, mechanical stress gauge). Microcontroller of the gadget is being conducted the initial processing of diagnostic data and transport it via radio channel with designated frequency 868.7MHz to concentrator of nearby line of automated workstations. Connection level is the second within hierarchy and it is unique one as well thanks to self protocol of data transmission application. Similar channel per Permanent Monitoring Systems of railroad sites is being applied on JSC "Russian Railroads" for the first time ever! For specialties of the network data transmission, see [14]. Upper level of the system is presented by concentrator of linear station as well as by central stations

concentrators plus Monitoring Situation Center. At this level automated dispatcher's work stations are located with power supply sources together with technologists of monitoring centers and directing staff. The system received data shall be processed via comfortable form and to be presented to end-user.

Software is the most important intellectual part of modern Permanent Monitoring System the overhead catenary for diagnostic data processing fulfillment with afterward presentation it to end-user. Without application of convenient software the system would be heap of diagnostic equipment, cables and hardware only! The present article is aimed at software specialties clarification being developed by authors of Permanent Monitoring System of the overhead catenary.

III. SOFTWARE OF PERMANENT MONITORING SYSTEM

2.1. Software structure

Our software of the subsystem of data transportation together with upper level of monitoring results processing and presentation it to user is the core of Permanent Monitoring System including the essential diagnostic function.

The developed software does not compose any special commercial platforms and modules which require licensing procedure fulfillment. Our software for Server may be installed on the most Linux worldwide distributed operational systems including those certified in Russian Federation. Concerning data bases, you may apply as commercial software programs as well as widespread products such as MySQL or Russian made PostgreSQL.

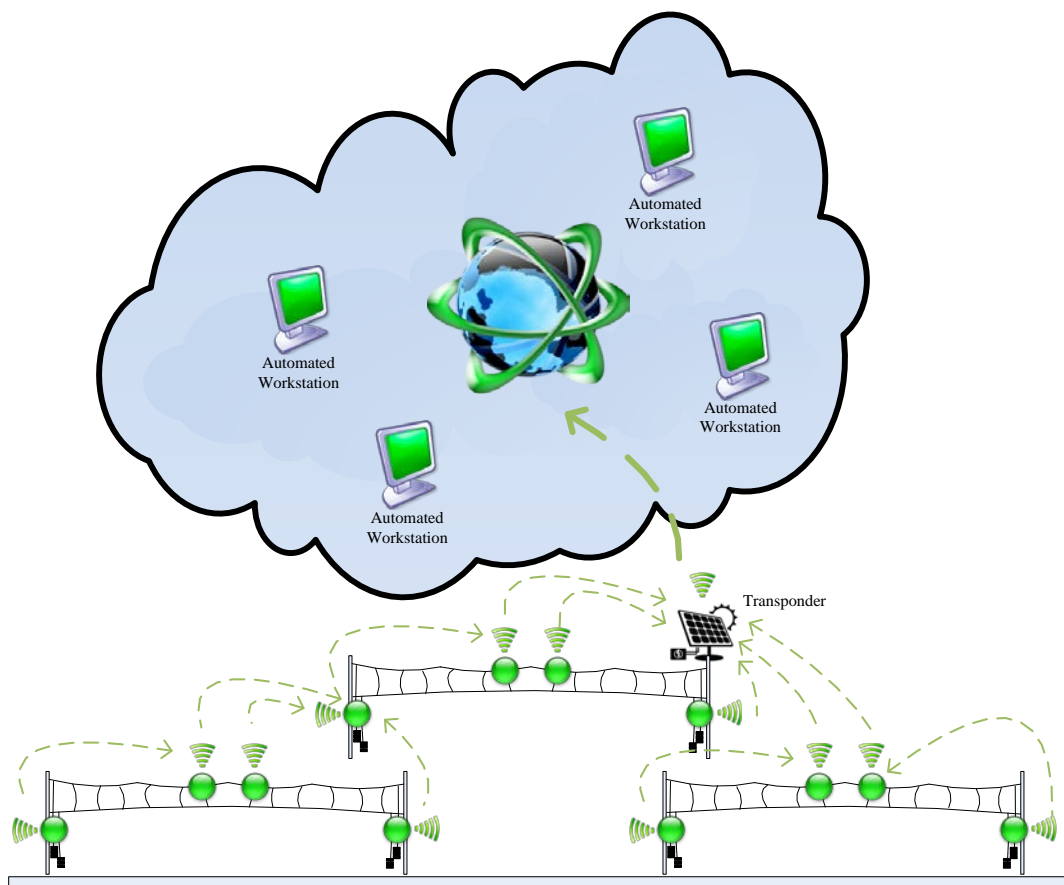


Fig. 1. Structural schema of Permanent Monitoring System of the overhead catenary

Software part of the monitoring system was arranged by means of technology Client-Server and composed of program module sets conventionally divided via two categories:

1. Software of lower level per data accumulation, delivery and system devices management;
2. Software of upper level for reliable data storage with data access arrangement.

Software of lower level composed of concentrator software targeted at message accumulation from sensors via radio channel either by cables and server per data from sensors storage and processing from information concentrators.

Server system of lower level must ensure data messages transportation via local network of JSC "Russian Railroads" as well as reliable storage of received data on designated servers. Our protocol of data transportation was actually developed for tasks of monitoring systems, which allows arranging the network of data delivery including automated topology reconfiguration, which helps us to improve the performance of the monitoring system itself including minimization of sensor energy power supply together with augmentation of the messages velocity without user's disconnection [14]. The above feature is the key advantage factor compared to industrial networks such as: "LoRaWAN" and "Strizh" [15, 16].

The Server itself shall ensure coordination within entire devices of the monitoring system together with self diagnostic operation (controls the total connected devices) plus it must ensure the adjustment and control of remote existing devices.

Let us highlight the specialties of the developed low level software:

- specialized protocol per coordination with entire system components including the coordination via selected radio channel;
- subsystem of total data logging;
- export subsystem of the info to exterior data bases;
- integrated software system per the entire connected devices updating performance.

Fulfilled software of upper level is composed of data base SQL with automated workstations for dispatchers, electrician services together with power supply department and monitoring office. Data base SQL, completed as protected reliable information storage of the system itself plus the info of being controlled elements within any particular needed moment. Server with data base shall ensure total data storage as well as data access to required information for designated system users such as: dispatchers, mechanics and various level of franchise. As for nowadays, we did manage the cooperation with two widespread MS SQL Server and MySQL data bases. In case of emergency, the system shall be adapted to Postgre SQL data base. Developed automated workstations may be installed locally either to be arranged via cloud. Automated workstations must ensure the access to data for responsible on-duty operator of electrical power supply as well as for dispatcher of Monitoring and Diagnostic Center. Our designed automated workstations composed of entire set of functions required for work procedure improvement for the department of electrical power supply as well as for dispatchers and IT administrators. Actual functions of

automated workstations for particular user may vary depending on permitted level of access and needed tasks. For standard process window of system operator, see Fig. 2.

Relating to software upper level specialties:

- 1) For administrators:
 - automatic software deployment system;
 - automatic upgrading of the software;
 - system user administration;
 - system threshold administration per various types of events (access for designated staff only with any alteration to be approved by railroad authorities);
 - system user actions monitoring.
- 2) For users:
 - users authorization;
 - system events presentation in real time mode;
 - data presentation by means of table or graphical form;
 - archive preview per any particular time;
 - system self diagnostic;
 - graphical and sound notices;
 - user's actions record;
 - access to technical documentation of user's control performance via built-in software facilities.

For general schema of upper level software modules, see Fig. 3.

2.2. Main process window of software shell

Let us consider a typical operation mode of the automated workstation monitoring system software shell. Total devices are operating steady, and there are no critical events. The facilities being controlled equipped with the monitoring system are highlighted on the schema with a green color. The facilities being monitored are as follows in the order of enlargement: support, constant tension section, service area, electrification and power supply division, as well as the rail track (see Fig. 2).

Our own set of conventional signs has been developed for the purpose of diagnostics information displaying. The entire area of the overhead catenary equipped with a continuous monitoring system is shown via lines. The catenary supports and their numbers per each track, in the vicinity of which the diagnostic devices are installed, are shown in black squares connected via lines with the main section of the facility under monitoring. Each constant tension section is shown as an oval with a Roman numeral corresponding to its index. Black squares, corresponding to supports, are evenly distributed between all constant tension sections, i.e. per three supports. Two end section supports and a support in the area of a midpoint anchoring. Thus, the railway line section comprising 36 constant tension sections (per 6 diagnostic devices on each) is equipped with the system. Diagnostic tools themselves are not indicated on the schema. In the occurrence of an event, the overhead catenary facilities that have been affected are being shown only, i.e. it may be constant tensions section itself and the influences on the compensating devices separately. They are conveniently shown on the schema via gray triangles divided into two halves (the upper part corresponds to the compensator loads on a catenary cable, and the lower part corresponds to the compensator loads on the overhead conductor).

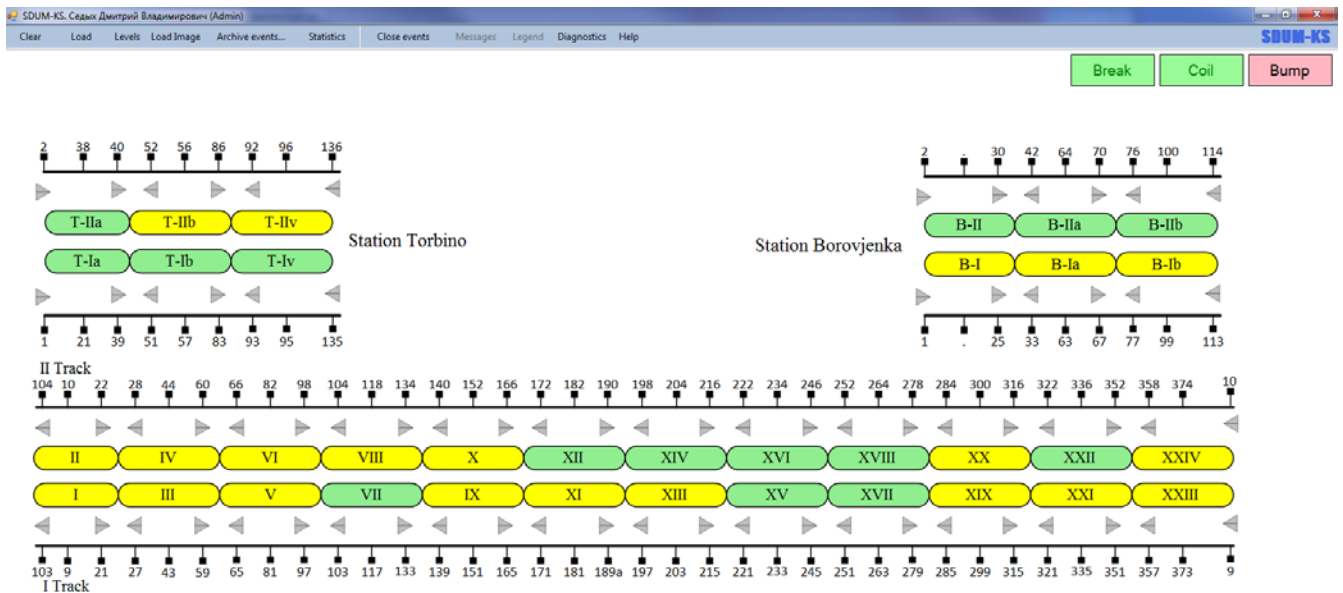


Fig. 2. Main process window of automated workstation for monitoring performance

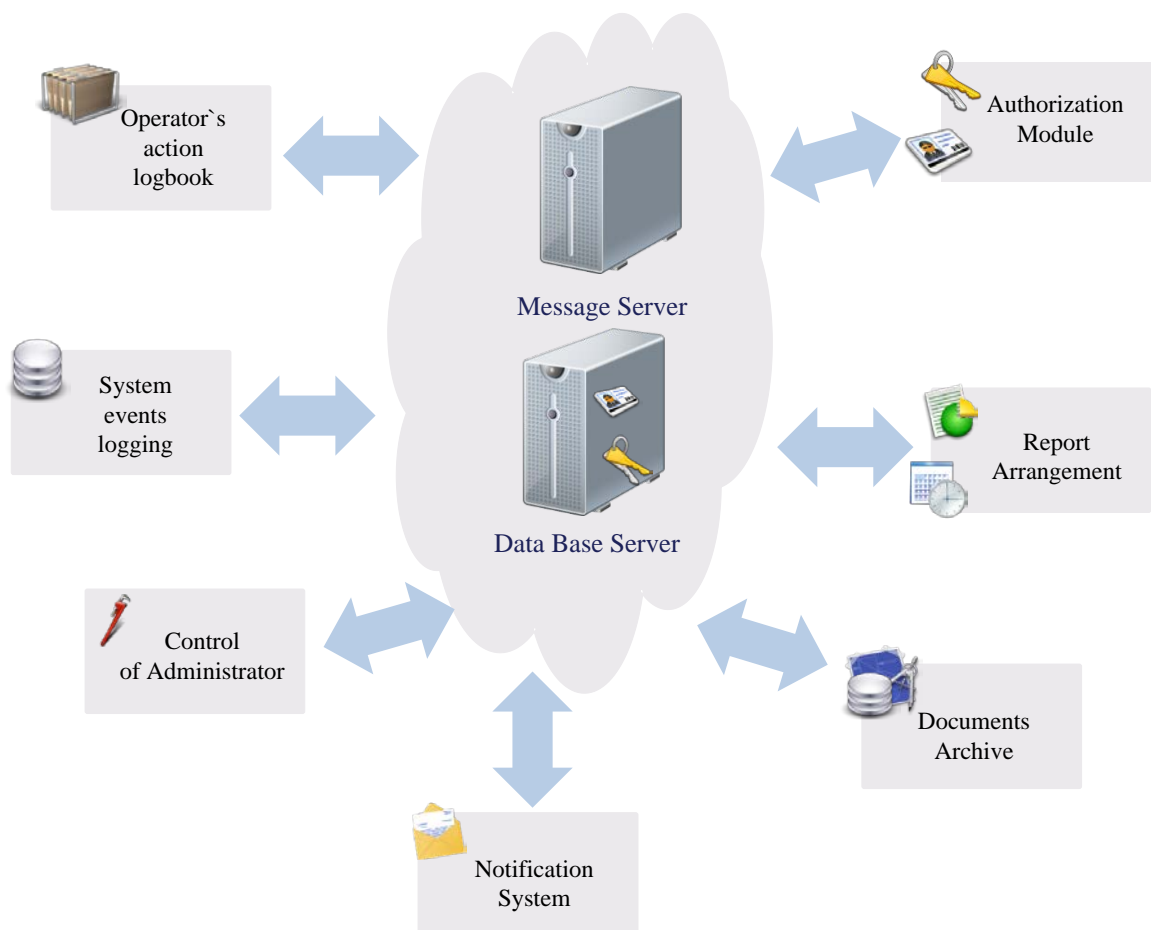


Fig. 3. Upper level software module structure

Total types of messages are recorded in the monitoring system message output area (the lower part of the screen on the process window, Fig. 2). New messages are always added to the top of the list, while the list itself is shifting down.

Basic data and operational information is displayed directly on the mnemonic schema, that is, when the event has occurred, the facility, where it has happened, is highlighted with a specified color (yellow or red by default, depending on the danger level; a yellow color corresponds to pre-failure condition, and a red color corresponds to

break-down condition). Illumination action takes place at total visible levels of a hierarchy. Besides, alarm sounds every second when a troubling event (accident or pre-failure situation) has occurred and real time and date is also designated over the event flashing unit. If there are several events then the date and time of the last of these actions is indicated. Until then as the user confirms the event preview, the event will continue to flash up via a color which has been set for it. A user can make a note about the event viewing, but it will be highlighted with the appropriate color till the moment of acknowledgement. The occasion is considered to be fully resolved when an operator confirms its view and fulfillment of actions regarding it.

System settings enable to the display the events to the user upon occurrence of the above-mentioned events.

The first case is conventionally called as “No events.” It is a normal operational mode of the monitoring system when all sensors of the diagnostic devices are in proper condition (Fig. 2). The facilities being controlled, which are equipped with the monitoring system, are indicated on the mnemonic schema with a green color. The displaying schema itself can contain any quantity of levels and may be more detailed to each system sensor, if needed.

The “failure detection” is the second event. The above-mentioned occasion is recorded upon detection of the incidents with a critical load level on the overhead catenary (breakage of a catenary wire either a contact cable). The background color of the facility being monitored changes to red. The text “Breakage” appears within the process cell instead of the facility name. Event data automatically pops up on the automated workstation monitor screen: it is added to the top of the list of events, as well as displayed on the graphical schema of an area being controlled. A sound is reproduced via speaker in order to draw the user’s attention (Fig. 4).

“Cable wire breakage detection” (in fact, it is not actually a breakage, but a load increase, for example, a humming blow of the collector shoe) is the third event of the system. Information about this news is added to the top of the list of events as in the case of the event of the preceding type, and the speaker reproduces the sound in order to draw the operator’s attention. The background color of the facility being monitored changes to orange. The text “Conductor” will be displayed in the cell instead of the facility name.

The fourth event is associated with the “detection of a strong impact on the overhead catenary” (in fact, it is also not a cable breakage or conductors damage, but it is a load increase, such as a humming blow by means of a collector shoe). Similarly to the above-mentioned events, the information about occurrence of the accidents of this type is added to the top of the list of events, and an audio signal is reproduced via the speaker. The background color of the facility being controlled changes to yellow. The text “blow” will be recorded within the cell instead of the facility name.

Any message contains the following information:

- occasion ID in the system (its unique number) to be put in square brackets;
- event occurrence time;
- type of incident (train passing, critical load, etc.);
- triggered sensor name;
- sensor installation place (e.g., pole number).

Following the occurrence of events with the levels above the steady one (normal operation mode of devices), the user has to work out an event, check the data on the events, record the actions taken and then an audible alarm and light indication can be switched off at this section. After acknowledging the occasion the color mode will return to the “default” colors until the occurrence of the following critical news within the system.

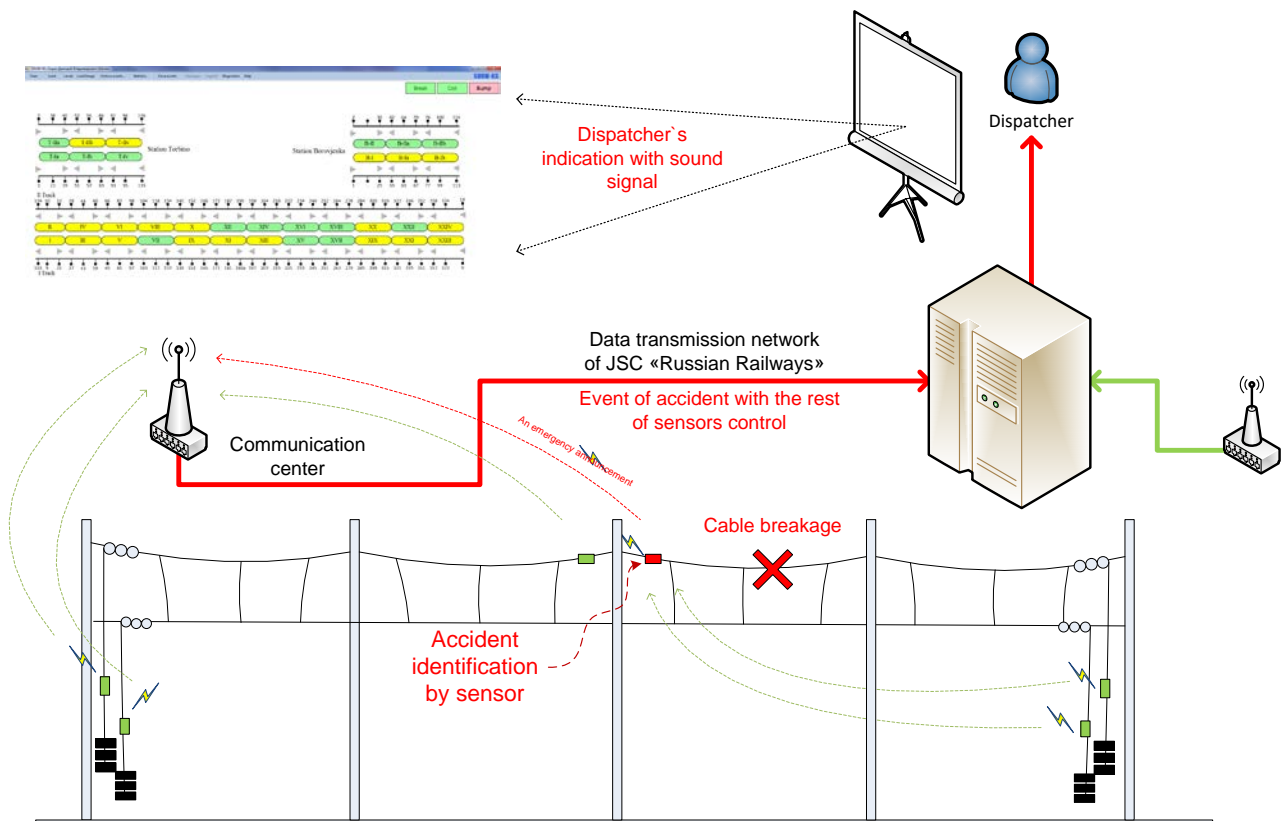


Fig. 4. Main process window of monitoring system automated workstation upon detection of catenary wire breakage

2.3. Archival data handling

Automated workstation has built-in functions of preparing the reports on the occurred accidents. "Event archive" section is intended for this purpose. A special unit of report preparation is starting up when activating the above-mentioned section. The report can be printed and exported into Microsoft Excel via built-in facilities. The report contains the following fields:

- "#" level of the event, from zero to three per default (the higher the number, the greater the "anxiety" of the event);
- "Alarm level" (text box describing the type of accident);
- "Sensor" (name of a sensor from which the signal was received);
- "Place" (sensor installation location coinciding with the catenary support number as a rule);
- "Date" (date of event occurrence by the hour of the database server);
- "Time" (Time of event occurrence within the accuracy of thousandths of a second by the hour of the database server);
- "Duration" (duration of the impact on the overhead catenary in seconds);
- "X" (the maximum value of the vibration sensor acceleration motion along the X axis);
- "Y" (the maximum value of the oscillation sensor acceleration motion along the Y axis);
- "Z" (the maximum value of the vibration sensor acceleration motion along the Z axis);

Report management module includes standard mechanisms for data filtering and grouping similar to standard features of electronic work sheets. For example, all news may be grouped by dates and the events may be displayed from the specific catenary support only. To do this, it is necessary to drag the column header to the table header based on which there is a need to group the data. To perform filtering, please, hover the required column or use the data sampling filter (Fig. 5).

A special view mode regarding the entire data on the facilities under diagnostics either devices (Fig. 6) is intended for more detailed studying the causes of the events. The report itself has built-in printer output facilities and tools of exporting into all commonly used data formats.

Upgrade of the software of the upper and lower levels is being fulfilled nowadays for supporting the work with the new monitoring tasks due to expansion of the system functionality:

- continuous monitoring of overhead catenary cables tension force;
- permanent monitoring of catenary supports installation angle.

Besides, the diagnostic functions and methods of data displaying are being upgraded for new monitoring directions. Special language and facilities of describing the mnemonic schemes have been developed for displaying the monitoring data both on the PC screen and on the video walls of monitoring centers. Storage subsystems, mnemonic schemas and events displaying subsystem are constructed in such a way that makes it possible to display virtually any data concerning monitoring, both for energy supply issues and for the tasks of other facilities.

IV. CONCLUSION

Software utilities are essential safety components of the continuous monitoring and functional diagnosis system. It is not enough just to obtain a diagnostics information, but it is also important to perform its primary processing, fulfill data transferring to the central station, as well as display it to the user in an easy and understandable form. These are the important properties that a developed software shell of the lower and upper levels of railroad overhead catenary continuous monitoring system has. Application of monitoring system software utilities makes it possible for technical staff of electrification and power supply divisions to promptly respond to fault events (occurrence of pre-failures and disasters), as well as to make well timed recommendations for the employees serving overhead catenary. All of the abovementioned, in combination with the existing maintenance and repair work activities, provides an opportunity to improve the operation of non-reserved overhead catenary facilities, as well as to enhance the transportation process reliability plus safety level augmentation as a whole.

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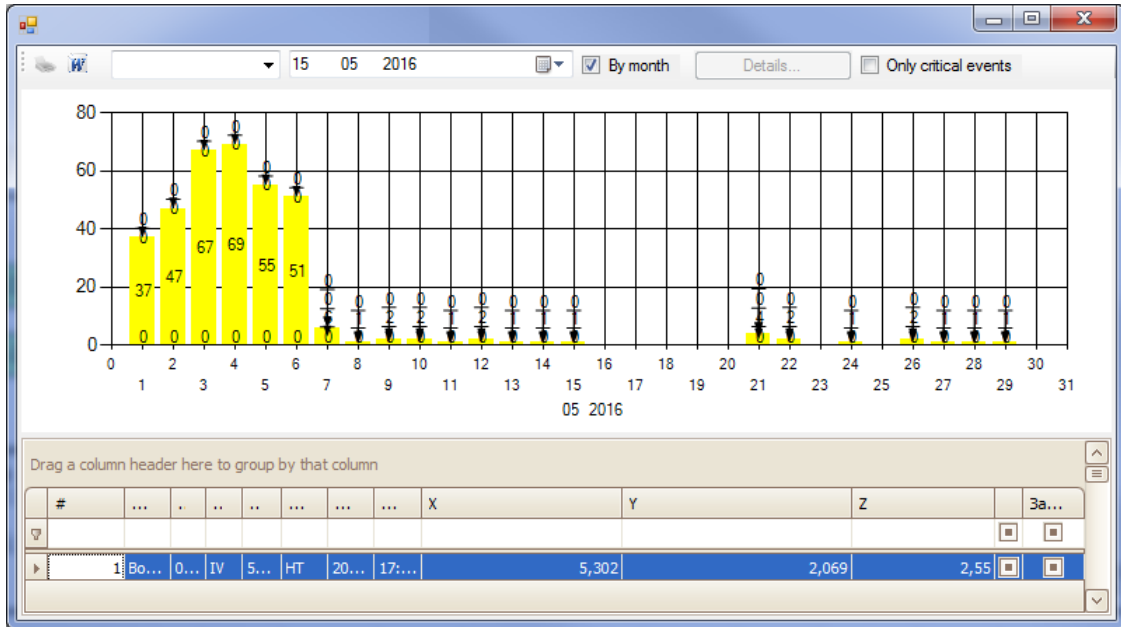


Fig. 5. Events archive process window

Item	Temperature	Battery	Last Net Status
Place: B-I			
00110049	+17.0	3483	2016.04.25 13:01:03
001100BF	-1.0	3554	2016.03.03 05:05:09
001100C2	+24.0	3672	2016.08.17 11:11:18
001100C5	+24.0	3628	2015.07.06 11:11:01
001100C6	+22.0	3554	2016.08.17 11:11:52
001100C7	+0.0	2498	2016.01.31 18:06:46
Place: B-Ia			
00110050	+3.0	2566	2016.02.29 14:02:34
00110059	+13.0	2300	2016.03.26 15:03:06
001100CC	+13.0	2532	2016.02.18 11:11:58
001100D2	+16.0	2114	2016.05.30 23:11:55
001100DD	+22.0	2073	2016.04.08 11:11:58
001100E4	+0.0	2642	2016.01.27 15:03:06
Place: B-II			
0011003C	+25.0	3688	2015.07.06 10:10:25
0011003E	+23.0	3597	2016.08.17 11:11:36
00110040	+17.0	3228	2016.08.07 09:09:55
00110042	+28.0	3452	2016.08.01 11:11:23
00110043	+24.0	3653	2015.07.01 16:04:10
00110045	+24.0	3640	2016.08.17 11:11:31
Place: B-IIa			
Place: B-IIb			
Place: B-XXIII			
Place: B-XXIV			

Fig. 6. Diagnostic information view window