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THE SUPPORTING OF EXPLOITATION AND MAINTENANCE MANAGEMENT WITHIN NETWORKED TECHNICAL SYSTEMS

Marcin DĄBROWSKI
Silesian University of Technology

Abstract:
Network technical systems are complex systems, which include distribution networks with devices and engineering objects supporting their work. These kind of systems are used for media distribution, such as: drinking water, fuel, gas, heat, etc. One of specific features of this system is large territorial dispersion of technical objects within the system. The exploitation specificity of networked technical systems requires a special approach for implementing maintenance and repair work, taking into account the large territorial dispersion of their components and limited access to technical infrastructure. The features pointed above show the difference between networked technical system and the typical industrial technical objects (e.g. available in manufacturing plants). This difference also requires the use of specific IT tools for maintenance management. This article discusses examples of selected tools in this class.

Key words: *maintenance, Geographic Information System (GIS), water supply system, exploitation, networked technical system, operational events*

INTRODUCTION

Safe and reliable exploitation of the network infrastructure, regardless of its type, is one of the principal tasks of every enterprise that manage this kind of technical system. The increasing complexity of every networked technical system (NTS) as well as growing requirements of customers in relation to the standards of services – set serious challenges for the efficient removal of defects in NTS and connected with it modernization of networks. The technical condition of the network is critical not only for the efficient and reliable delivery of media distributed to end users via NTS. In many cases failures and damages of networks and fittings have a direct impact on the safety of people and their health.

In order to maintain demanded reliability of the NTS, there is a necessity for the proper technical design of the NTS, then it should be built strictly according to this design and finally – it also must be maintained properly. Other important aspect affecting the reliability are external factors influencing particular components of the NTS. All defects appearing in NTS have direct impact on the proper distribution of media via the networked system both in qualitative and quantitative meaning.

The requirements listed above can be met only by efficient exploitation of NTS. One of really important factors for that purpose is possessing complete information about NTS exploitation history. This information concerns the technical state of NTS, operating events occurring in it as well as maintenance and repair processes carried out in relation to it.

INFORMATION ASSOCIATED WITH THE EXPLOITATION OF TECHNICAL OBJECTS

The implementation of efficient and effective maintenance management system for each kind of technical system requires building a suitable way for the collecting and processing information. The need for detailed information about exploitation issues is particularly significant in maintenance of complex systems – such as discussed in this article NTS, in which this kind of information concerns a very broad and diverse area of aspects. Decision making process connected with these aspects requires taking into consideration records related to historical, current and also predicted data concerning technical tasks, management of materials and tools, available working hours, transportation as well as both economic and organizational aspects of these resources. Making good decisions in that process is possible only if the decision maker is able to use many aspects of this informational diversity. Basis for making these decisions is information about exploitation of NTS [5].

During the exploitation of NTS collecting of necessary maintenance data is the task for maintenance crews, especially: technical emergency services crew, inspection crew and repair crew. Another important group of workers collecting information about NTS are dispatchers. Their main tasks are connected with receiving reports and notifications about irregularities in the operation of the NTS. The information collected by aforementioned groups of workers is provided to maintenance managers, who use it in decision making processes concerning maintenance and repair works.

Information about exploitation issues includes a wide range of data about maintenance processes related both to area of usage and maintaining NTS. It is used in all phases of the NTS life cycle, in particular [5]:

- at the stage of recognition the needs, when it is a starting point to determine the direction for future development of distribution networks,
- during the design and construction processes, when at its basis there are performed improvements in the NTS construction in order to correct its technical features,
- in manufacturing, where this information is used for improving both processes and technology as well as for development of new technical solutions improving elements of NTS,
- in maintenance management, where it is used for planning and organization of inspection and repair work related to networks and technical objects supporting their operation.

During the life cycle of NTS, information about exploitation issues is crucial to the maintenance management phase, while in the other life cycle phases it is the factor allowing for verification and improvement of performed processes.

Collecting and processing of this information is implemented in dedicated for this purpose IT tools. In the next section of this paper there is a short review of such tools.

TYPES OF SUPPORTING TOOLS FOR MAINTENANCE MANAGEMENT

Within the area of NTS maintenance management there is a variety of tools, of which four main groups can be pointed:

- tools for registering all maintenance and repair works, allowing to support the procedures of performing work orders. Usually these tools store inventory data about all technical objects and that is why they also enable analyses of the technical, economical and organizational aspects related to management of these objects. In this area the following classes of IT systems are commonly used: Enterprise Resource Planning (ERP) or Computerized Maintenance Management system (CMMs), which sometimes can be also called Enterprise Asset Management (EAM) [3],
- tools for monitoring of the technical state of the networks as well as diagnostic supervision over the operation of network systems. This group includes Supervisory Control and Data Acquisition (SCADA) systems. Some of the tools in this group, in addition to the collection, processing and visualizing of data about working parameters of networks, also allow for remote control of objects installed in these networks [6]. This feature is particularly important in the case of network systems in which there is a large distance between the monitored object and the place of decision-making.
  To this group of supporting tools can be also included systems for carrying out the detection of irregularities occurring on the network and helping to find locations of these problems [9, 11, 12],
- tools allowing the identification of attributes and spatial localization of technical objects in the network. Tools of this class are based on Geographic Information System (GIS), which in addition to the typical inventory features and displaying maps of networked infrastructure – it also gives mechanisms for supporting decision-making process within exploitation of NTS [1, 2, 4],
- IT tools allowing for processing and analysis of maintenance data concerning technical objects in the network [7, 8].

The next section of this paper includes an exemplary procedures of performing maintenance works using selected supporting tools.

PROCEDURES FOR SUPPORTING THE EXECUTION OF MAINTENANCE WORKS

In order to present an exemplary procedures for supporting the execution of maintenance works, there has been chosen one of the NTS – water supply system.

Supporting the implementation of maintenance and repair orders

In enterprises that have implemented CMMs, the procedures of maintenance and repair works have their reflection in this system. Fig. 1 presents the general scheme of procedure for carrying out the typical work order in CMMs class tool – in this example the "Repairs and Technical Service module" (RTS), a part of ERP software called Egeria.

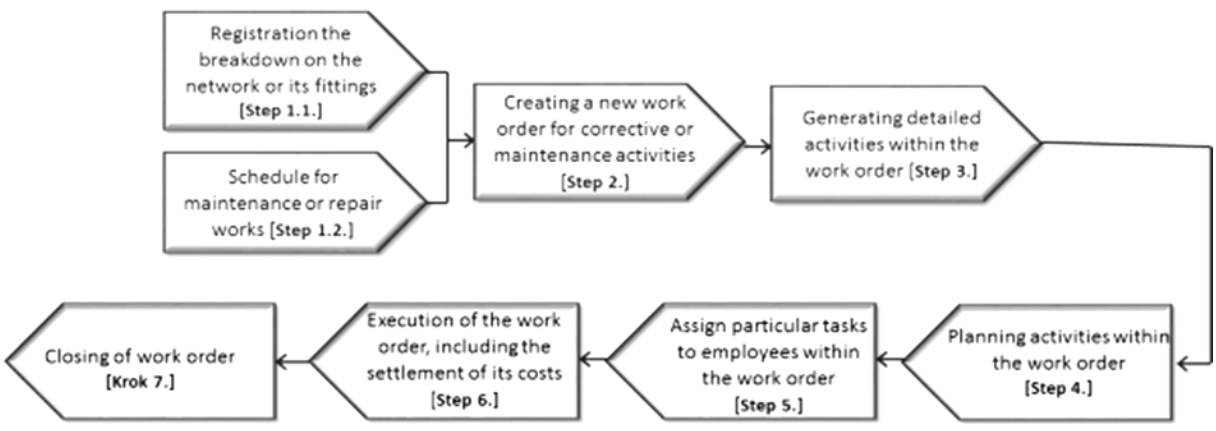

Fig. 1 The general scheme of execution the work order in RTS module

Supporting procedures for management of unintentional operational events (breakdowns) and intentional operational events (planned maintenance and repair works) performed within RTS module are almost identical (Fig. 1). The difference is that in the case of breakdown the work order is generated at the base of dispatcher's notification (step 1.1), while in the case of planned maintenance or repair works – the maintenance activities are performed at the base of prepared schedule (step 1.2). Pozostałe kroki realizacji zleceń obsługowych (steps 2-7), przebiegają według podobnego porządku. The remaining steps of execution maintenance and repair works (steps 2-7), run by a similar order. That is why this paper presents one exemplary procedure of supporting the operational events handling within RTS module. This example illustrates an unintentional operation event in the form of valve breakdown, which manifested itself in water leakage on surface of the ground.

The procedure for handling this type of operational events starts by registration the occurrence of breakdown. The dispatcher usually gets a notification about the breakdown and at that base he creates a proper record in RTS module (step 1.1). Event Registration Form available in RTS module is shown in Fig. 2.

Then the registered breakdowns are forwarded to the appropriate department of water supply enterprise, where required work orders for repair activities are created (step 2). In described case it is the Department of Network Exploitation. At this stage the detailed repair and auxiliary activities are added to the work order (step 3). These activities will be performed during the realization of work order (Fig. 3).

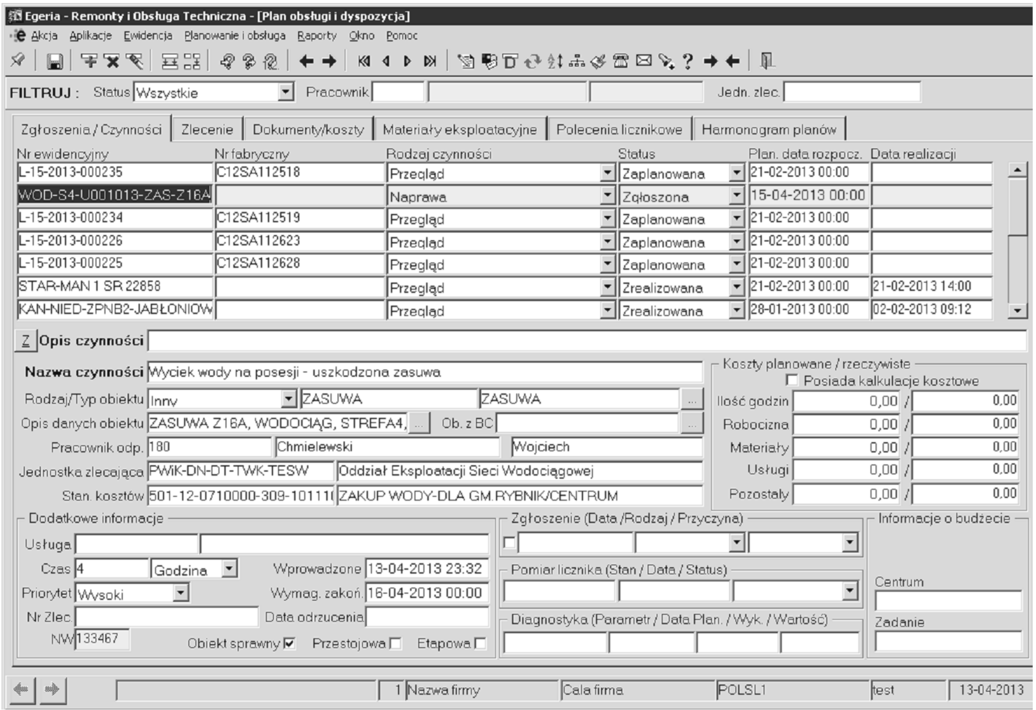

Fig. 2 Event Registration Form available in RTS module

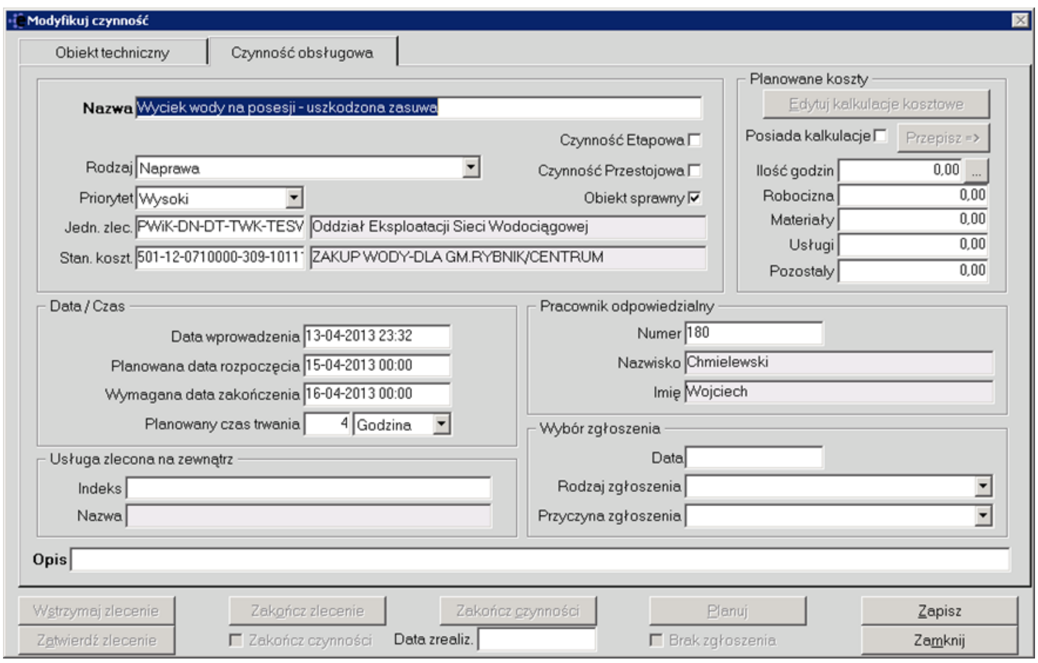

Fig. 3 New maintenance activity form generated in RTS module

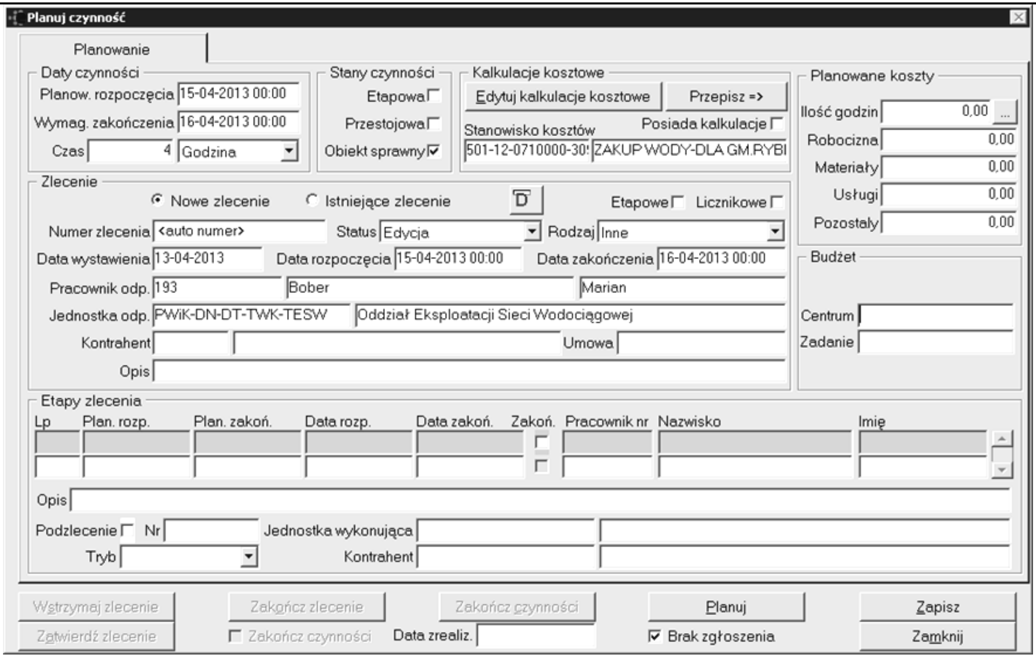

Fig. 4 Planning maintenance activity form generated in RTS module

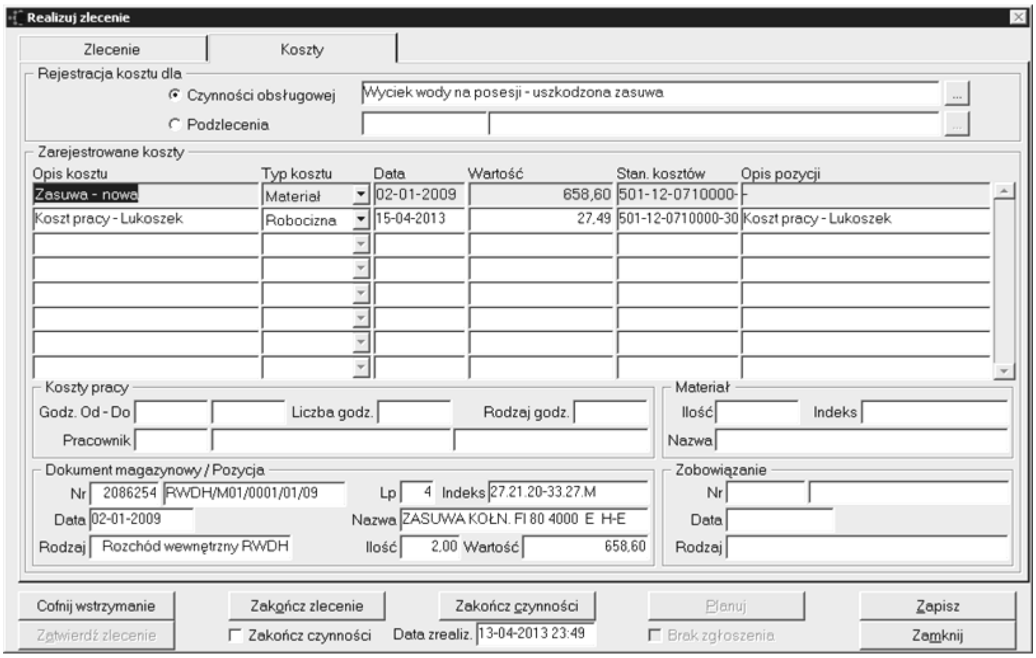

Fig. 5 The implementation of repair activities form

As part of the work order for removing the breakdown of the valve, the following detailed operations are created: closing the inflow of water, preparing trench, installation of new valves, flushing of the networks and finishing works.

The next step, after the creation of detailed activities, is their planning (step 4). As a result of this step all generated activities are assigned to the work order concerning the exchange of damaged valve (Fig. 4).

The activities scheduled in previous step are then assigned to the proper maintenance crew, which was determined to perform the work order (step 5). Formally the assignment of tasks included in work order involves confirmation of acceptance by the person responsible for its implementation. If there are several maintenance activities within one order, they can be assigned to different workers to perform.

The next step in described procedure is the implementation of repair activities by the maintenance crew, which is responsible for the execution of work order (step 6). In RTS module there is a dedicated form for collecting data at this stage (Fig. 5).

The form contains data about starting and finishing time of repair works as well as details about the progress in the implementation of scheduled activities. In the "costs tab" there are total cost of the work order, including both cost of the materials and equipment used during the repair works as well as cost of labor.

The last phase of the described process of work order realization (step 7) is its closure. This last step is performed after finishing all repair works assigned to the particular work order. The closure of work order is recorded in RTS module.

The activities pointed in steps 2-5 require specialized knowledge about the specificity of repair works and their required range. That is why all data at the stage of preparing the work order should be registered in RTS module by the managers of exploitation department. On the other hand the data generated during the steps 6 and 7 is collected by employees carrying out particular activities. The study also shows that the quality of information about exploitation issues highly depends on the functionality and intuitiveness of the supporting software [10].

Monitoring of the water supply network parameters

Managing of such dispersed and complex infrastructure, belonging to the water supply system, requires monitoring the working parameters of its key elements and critical points. Examples of such objects are pumping stations and hydrophore installations, that have regular measurements of the parameters of their work and at that basis the required control interventions are performed. The most common interventions concern control and regulation of water pressure distributed through the pipes. These and many other tasks are performed by maintenance crews using SCADA telemetry system.

SCADA system plays an important role in detecting and signaling any irregularities appearing in the operation of the water supply network. These irregularities can mean the leakage of water from the water supply network.

In the case of occurring the irregularities in working of water supply system – the adequate notification is displayed on the synoptic screen by highlighting the district where the problem has been registered. In addition, this event is announced by the audible alarm. In order to check the exact location of the incident, there is the possibility of narrowing the displayed areas within pointed districts.

When in the SCADA system an alert is displayed, dispatcher firstly selects district from the main screen, in which an alarm has occurred, and then he is browsing to the narrowed area of the district in order to be able to see more details of this part of water supply network (Fig. 6). It the narrowed area dispatcher can notice all technical objects and critical points on the water network, that are monitored. After selecting a particular object – the detailed parameters characterizing his work are displayed (Fig. 7).

The screen presented in Fig. 7 shows the parameters of the measuring devices, recording flows and pressures in the well where the network of water supply enterprise connects to the main water supplier for the city.

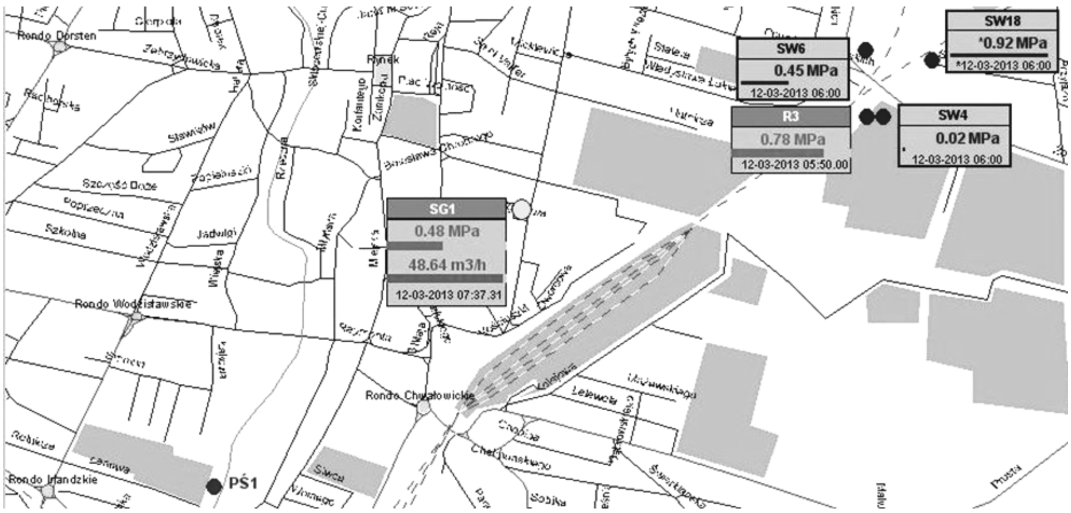

Fig. 6 The narrowed area pointing localization of registered alert

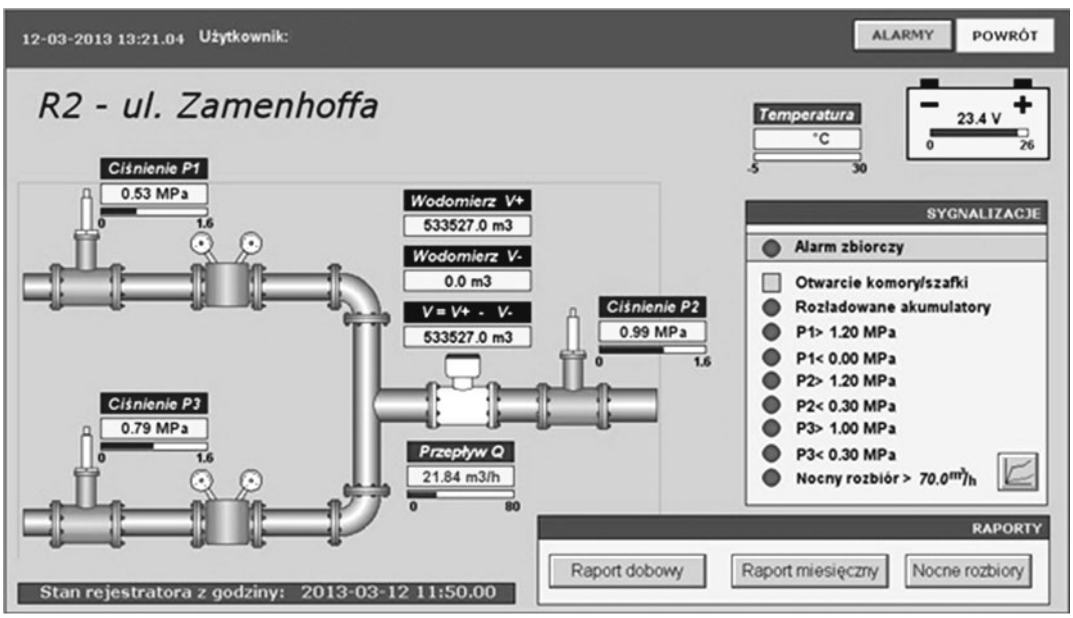

Fig. 7 Screen showing the parameters of the selected point on the network

In the described well there is mounted main water meter, recording the amount of purchased water by the water supply enterprise. Moreover in this well there are also flow meter registering the speed of water flow in the pipes as well as two pressure regulators for reducing the pressure of water intake and separating it into two districts within the feed zone. Pressure regulators have the ability to be remotely adjust, depending on the preset control parameters. Exceeding the minimum and maximum thresholds for individual flow meters or water meter, results in the appearance of an alert registered via SCADA system. In addition, at the base of registered measurements the dispatcher has the ability to analyze reports for the night water consumption and both daily and monthly summary reports concerning all recorded parameters.

The analysis of recorded measurements give the possibility to observe irregularities in the operation of the water network. Then this information is provided to the appropriate exploitation department, which subsequently carry out activities aimed at explaining the causes of these abnormalities.

CONCLUSION

Planning the handling of an intentional operational event is the subject of two main decision aspects, affecting the determination of service or repair cycles for water supply system technical facilities. The first of these aspects is the technical condition of the water supply system elements as well as the official technical standards recommending the frequency of maintenance or repairs works. The second aspect influencing the determination of repair cycles, are the conditions resulting from the regulations required by law (e.g. the frequency of fire hydrants inspections, electrical inspections of equipment in pumping stations, etc.).

It is worth pointing that in the case of NTS the decisions concerning technical rehabilitation of distribution networks can not only be of a technical or economic reasons. Very often these decisions are also subject to political issues due to the fact that they are made by managers strongly associated with the local government through various ownership and control relationships. In particular this case occurs in water supply and sewage enterprises, which are usually under the strong control of local government unit (these enterprises very often take the form of budgetary establishments under the control of the municipality).

While planning the renovation of water supply networks several criteria are taken into account, include: the amount of pipe breakdowns per kilometer of network, the fact whether the section of the network has been fully depreciated (as an asset), the age of the water pipes, material from which they are made, the diameter of the pipes, etc. Very often water supply system repairs are performed by the way the other ground works, conducted in the immediate vicinity of it, e.g. building a new road or renewing road surface, also replacing other underground installations (electric cables, pipes of heating distribution system, etc.) carried out by enterprises managing those systems. In such situations, the repairs of water supply system are carried out before their technically justified need.

Supporting of unintentional operational events management is performed at the base of received notifications about failures or occurred interruptions in the continuity of water supply to consumers.

Maintenance and repair processes carrying out within NTS have their reflection in IT tools for supporting these processes. First basic IT tool of that kind is Supervisory Control and Data Acquisition (SCADA) system, which is used for monitoring of the crucial technical facilities and for their current diagnostic. Diagnostic information concerning the occurrence of unintentional operational event along with the notification received from the third party – are the factors causing intervention aimed at the failure removing.

The second main IT tool used within maintenance area is CMMs class system. In this IT tool there are registered operational events occurring in technical objects included in the network system. The collected data represents the history of exploitation and gives the opportunity for variety of analyses concerning the effectiveness of this expliotation.

Information collected in the two aforementioned types of supporting IT tools, does not exhaust the range of information useful for decision-making process within maintenance management of NTS. Taking into account exploitation specificity of NTS and the number of variables affecting the normal operation of the network, according to the author of this paper – indicated above range of data should be extended of information about the external environment of NTS.

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dr inż. Marcin Dąbrowski
Silesian University of Technology, Faculty of Organization and Management
Institute of Production Engineering
Roosevelta 26-28, 41-800, Zabrze, POLAND
e-mail: marcin.dabrowski@polsl.pl

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