Information Support for the Procedure of Power Consumption Planning in the Municipal Water Supply System

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Abstract— **The article deals with the issue of determining the energy baseline of municipal water supply facilities, taking into consideration their actual operation conditions. The purpose of the article is to develop the principles of organization of information support for the procedures of power consumption planning and their integration into the energy management system. The formalization of the power consumption planning process has been performed based on the object-oriented technology. Classes that take into account the characteristics of the facility, water consumption, methods of planning water supply and power consumption have been formed. Description of the properties and methods of the classes has been accomplished. The architecture of the information support system for planning procedures has been proposed. WEB-oriented technologies has been suggested to use for information exchange. This allows creating a single information space, taking into consideration the actual operation conditions of the research object.**

Keywords— energy efficiency; power consumption planning; energy baseline; municipal water supply system.

I. Introduction

Energy efficiency is one of the priorities of states, individual organizations and businesses. Creation of the energy management system (EnMS) on the enterprise is one of the directions of energy performance improvement [1]. Modern EnMS contain a subsystem operative management of energy consumption efficiency - so-called Monitoring and Targeting System [2]. The identification of energy consumption dependency from significant indicators – construction of energy baseline (EnB) is in its base. At present, research of efficiency energy consumption issues in various branches are carried out by specialists and scientists. Publications on the implementation of EnMS, for example, [3], [4], [5], [6], monitoring of energy performance indicators and energy efficiency control [2], [7], [8], [9], etc. are results of these researches. However, the issues, related to construction of EnB in municipal water supply systems (WSS), which would take into consideration the particularity of functioning of the water supply facilities, remain consider insufficiently.

II. Research Methodology

Power consumption in the WSS depends on the following factors: technological process characteristics, technical characteristics, operation mode parameters and external environment conditions. The mathematical description of the connection between all factors and power consumption is complex. Degree of factors influence on power consumption is different. Its definition is a separate, quite complicated task. Water supply process is the process of transformation of electric power by electromechanical means of the municipal WSS. Formally, it is a mapping:

$$\Omega_W \xrightarrow{F_{WE}} \Omega_E , \qquad (1)$$

where Ω_W - set of models of water supply facilities; Ω_E - set of models of energy consumption; F_{WE} - functional mapping of models.

The set of models of water supply facilities could be represented as isomorphism Ω_W to some abstract set of Ψ_w:

$$\Psi_w = \langle \{M_w\}, P_1, P_2, \ldots, P_n \rangle , \qquad (2)$$

where $\{M_w\}$ - set of models of structural elements of municipal water supply system; $P_1, P_2, \ldots, P_n$ - variables that show the connections between the elements.

Similarly, the set of models of energy consumption could be represented as isomorphism Ω_E to some abstract set of Ψ_e, which is described:

$$\Psi_e = \langle \{M_e\}, P_1, P_2, ..., P_n \rangle, \quad (3)$$

where $\{M_e\}$ - set of power consumption models of the municipal WSS facilities;

From the standpoint of solving the issues of decomposition, analysis and synthesis [10], i.e. conversion $\Psi_w \to \Psi_e$ between the two models that map the process of water supply (Ψ_w) and energy consumption (Ψ_e), municipal WSS as an energy consumption object could be represented:

$$S = \langle \Psi_w, \Psi_e, P_0(\Psi_w, \Psi_e) \rangle. \quad (4)$$

For simplification, a complex system is considered as a "black box". Then submodel Ψ_w and Ψ_e could be represented as a totality of input parameters, respectively, water supply x_w and power consumption x_e, similarly, output signals y_w and y_e, changing its state z_w and z_e:

$$\Psi_w = \langle x_w, y_w, z_w \rangle; \quad (5)$$

$$\Psi_e = \langle y_w, x_e, y_e, z_e \rangle. \quad (6)$$

Creation of databases (DB) about the power consumption and technological parameters of the WSS operation mode is a prerequisite for the power consumption modeling. Special attention should be paid to monitoring environmental factors that have an influence on efficiency of the water supply and energy consumption modes. Water consumption is one of them. Water consumption is uneven and it is influenced by seasonal (that map the influence of temperature, precipitation, etc.) and social (that map the influence of changes in the way of life at workdays and weekends) external factors [11]. Organization of water supply regime has to be maximum appropriate to water consumption. Therefore, it is necessary to analyze water consumption modes, identify tends of its changes depending on the season and climatic conditions, and form the water supply graphs based on it [11].

Water consumption graph (WCG) is the main regime indicator of the water supply process. Based on the created database it is possible to analyze daily WCG, i.e. to research of graph parameters for searching similarities in water consumption and construction of set of typical water consumption graphs. The latter graphs should become the basis for construction a set of graphs of characteristic water supply modes and power consumption planning.

Therefore, the definition of EnB in the municipal WSS should consist of two stages: water supply modeling that solves the issues: water consumption forecasting, forming of typical graphs of water supply and their correction with taking into consideration the changing of social and environmental factors; construction of power consumption models with taking into consideration the typical graphs of water supply as well as technical and technological factors that have an influence on the efficiency level of power consumption.

Modern management trends provide for implementation of automated control systems of technological processes, control and accounting of energy consumption. SCADA-systems are used to ensure the functioning in real-time of the systems of collecting, processing, displaying and archiving information about the object of management. All these elements are part of the monitoring system. Consequently, the monitoring process ensures continuous obtaining of information on power consumption, technological parameters, and characteristics of operation modes of the municipal WSS facilities [8]. The introduction of energy efficiency monitoring system provides a possibility: 1) the creation of large databases that contain information on operation modes of the municipal WSS facilities; 2) the use of intellectual data analysis methods to explore information and reveal hidden regularities that determine the forming of the technological modes. It is necessary to setup procedures for the exchange of input and output data to ensure the functioning of the monitoring and power consumption planning procedures. The architecture of modern information systems has to meet policy of innovative development regardless of their area of use. Compliance with these requirements may be provided through the introduction of interacting modules: module of collection, pre-processing and data storage; data analysis module; module of making decisions and management influences. Hierarchy of production system causes hierarchy of the research problem, which is directed at improving this system [12]. Stratified representation of any complex production system and research tasks decomposition with taking into consideration hierarchical level research causes simplification of describing its facilities and procedures-algorithms, but keeps their subordination to a single goal. Stratified representation also can be used for construction of information support system of energy efficiency problem of water supply system. That is, all of its subsystems regardless of their functions are consolidated by common information space, as a result of their operation have to be forming the unified knowledge base for decision supporting concerning on improvement of the production system energy performance.

III. Results

Formalization of the procedure of power consumption planning of water supply facilities has been performed using object-oriented technology. Information field objects are modeled by the classes with combined properties and existence rules - totalities that have the same characteristics and qualities. The class contains properties of the facility (defines the data structure of the facility, the rules which facilities act), as well as methods (functions) that have access to the facility data, process of performing certain operations and tasks. The architecture of the procedure of operational control of energy efficiency is shown in Figure 1. Three categories of classes have been formed: WEB-service (a set of classes that are combined by procedure of obtaining initial information about the research object); FORMS-class (a set of classes that are combined by computational procedures and models); CONTROL-class (a set of classes that are combined by procedures of the accomplishment of the energy efficiency control). Class properties are quantitative characteristics of the research object. Class methods are the algorithms calculations, procedures, communications, actions, functions, etc. that provide the functioning of a class. Description of the properties and methods of classes are shown in the Table 1.

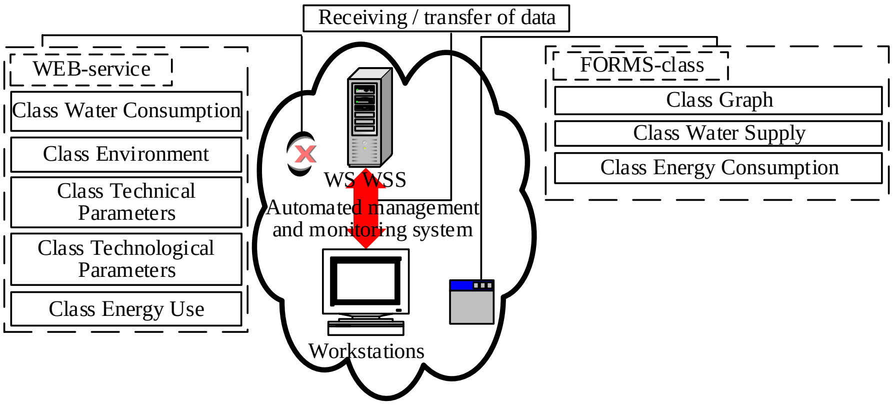

Figure 1. The architecture of operational control of energy efficiency modes of water supply facilities

TABLE I. PROPERTIES AND METHODS OF CLASSES

Class	Properties of classes	Methods of classes
Category WEB- service		
Class Water consumption	The set of data that characterize water consumption regime: season; date; type of day; value of water consumption.	Obtaining data on hourly water consumption. Forming daily WCG. Determining the volume of water consumption. Data transferring for analysis WCG.
Class Environment	The set of data that characterize environment: season; date; temperature; precipitation.	Obtaining data on value of daily temperature, amount and duration of precipitation. Fixing the date, type of day, season. Data transferring for calculation of climatic parameters.
Class Technical parameters	The set of technical parameters: passport data of units; characteristic of pipeline network.	Obtaining data on passport data of units; characteristic of pipeline network. Data transferring for calculation of energy performance indicators.
Class Technological parameters	The set of technological parameters of water supply regime: the volume of water that is pumped pumping stations; head in dictating points of the network; excess heads in the network.	Obtaining data on the volume of water that is pumped pumping stations, head in dictating points in the network, excess heads in dictating points of the network. Data transferring for organization of control procedures of water supply regime.
Class Energy consumption	The set of data that characterize power consumption. The set of data that characterize of water consumption for industrial needs.	Obtaining data on power consumption. Obtaining data on picking out of water for industrial needs. Data transferring for organization of control procedures of energy consumption regime.
Category FORMS-class		
Class Graph	WCG. Main indicators. Auxiliary indicators. Morphometric parameters.	Obtaining data on daily WCG. Calculation of main and auxiliary indicators WCG. Transformation of daily WCG in CRT. Calculation of morphometric parameters. Obtaining data on climatic factors. Calculation of climatic indicators. The combined analysis of indicators WCG. Forming of the set of similar daily WCG. Data transferring for forming of the set of typical graphs of water supply.
Class Water supply	WCG. Climatic indicators. Water supply.	Getting the set of daily WCG. Forming of the set of typical graphs of water supply. Adjustment of typical graphs with taking into consideration climatic conditions. Modelling of water supply regime. Data transferring for modelling of energy baseline. Data transferring for forming of norms and alarms.
Class Energy consumption	Power consumption. Picking out of water for technological needs.	Obtaining data on water supply regime. Obtaining data on energy performance indicators. Modelling of power consumption with taking into consideration of water supply graph. Prediction of power consumption.

The realization of each class involves the sequence of several calculated procedures. The result is the information that is collected in the database. The result of the Class Graph procedures is the formation of similar WCG groups. This allows obtaining of experimental data samples. The obtained results are used to implement the procedures of the Class Water supply and the Class Energy consumption. The result of the procedures of the Class Water supply is to plan the water supply mode. The result of the procedures of the Class Energy Consumption is to determine the energy baseline of municipal WSS. The architecture of information supporting of control procedures of energy efficiency modes of water supply facilities as a part of the overall information system of energy management of water supply company is shown in Figure 2.

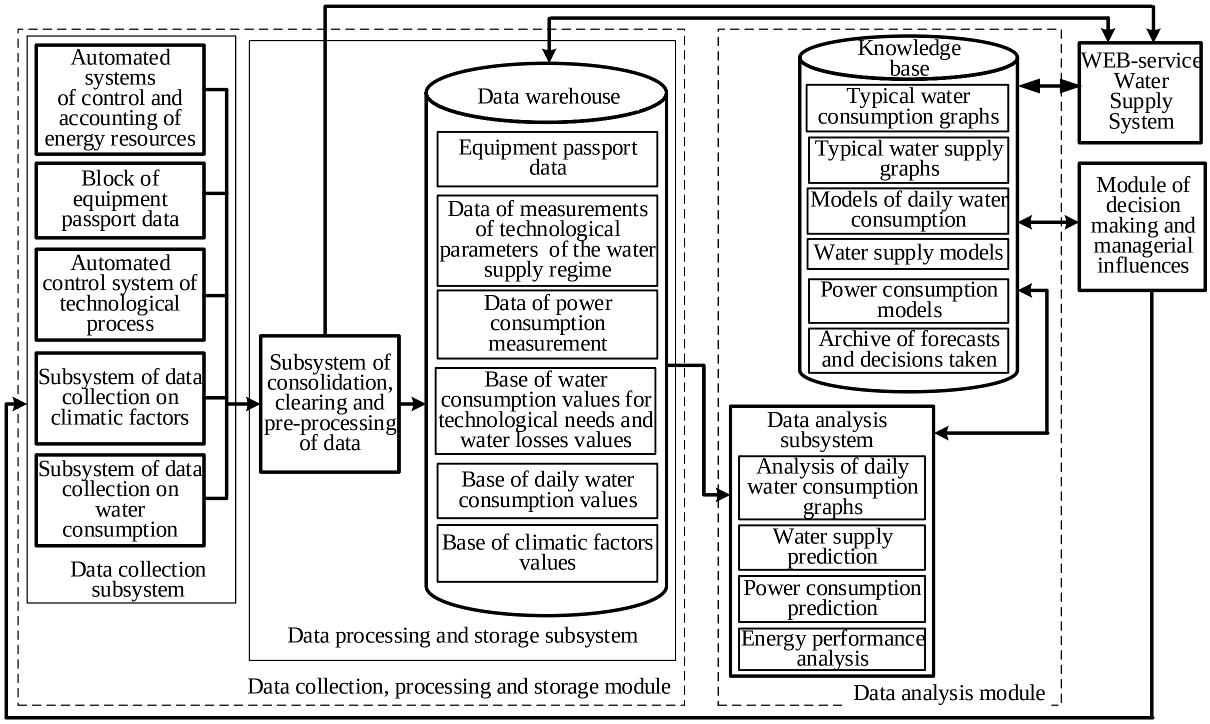

Figure 2. The architecture of operational control of energy efficiency modes of water supply facilities

Availability of automated control systems simplifies the collection and processing of information. Their connection to the Internet provides communication between control points and the central enterprise server. This will allow realizing the consolidation of data in a single information system. The set of the existing structural and functional relationships in municipal WSS indicates the sequence of sample information and order of the necessary calculations.

IV. Conclusions

Defining EnB in municipal WSS has to be carried out by being based on statistics, which is accumulated in the data-base monitoring system, take into consideration the actual conditions of its functioning, and the influence on the character of the daily water consumption of social and weather factors. It is appropriate to use Web-oriented systems. This will allow to create a single information space and to ensure the ability to process information about the modes parameters and power consumption of water supply facilities.

References

[1] European Commission Integrated Pollution Prevention and Control (IPPC), “Reference Document on Best Available Techniques for Energy Efficiency”, Seville: Institute for Prospective Technological Studies, European IPPC Bureau, 2009, 430 p.

[2] J. Pooley, “Quick Start Guide to Energy Monitoring & Targeting”, Effective Energy Management Guide, 2005. Available: http://www.oursouthwest.com/SusBus/susbus9/ m&tguide.pdf

[3] I. Dzene, I. Polikarpova, L. Zogla, and M. Rosa “Application of ISO 50001 for Implementation of Sustainable Energy Action Plans”, Energy Procedia, Vol. 72, pp. 111-118, June 2015. doi.org/10.1016/j.egypro.2015.06.016

[4] P. Karcher, and R. Jochem, “Success factors and organizational approaches for the implementation of energy management systems according to ISO 50001”, The TQM Journal, vol. 27 (4), pp.361 – 381, 2015. doi.org/10.1108/TQM-01-2015-0016

[5] Marvin T. Howell, “Effective Implementation of an ISO 50001 Energy Management System (EnMS)”, Milwaukee, United States: ASQ Quality Press, 2014, 177 p.

[6] M. Majerník, M. Bosák, L.Štofová, and P. Szaryszová, “Innovative model of integrated energy management in companies”, Quality innovation prosperity, vol. 19/1, pp. 22-32, 2015. doi.org/10.12776/qip.v19i1.384

[7] J. Flizikowski, and K.Bielinski, “Technology and Energy Sources Monitoring: Control, Efficiency, and Optimization”, USA: IGI GLOBAL, 2013

[8] L. Davydenko, V. Rozen, V. Davydenko, and N. Davydenko, “Formalization of Energy Efficiency Control Procedures of PublicWater-Supply Facilities”, Advances in Intelligent Systems and Computing, vol. 543, pp. 196-202, 2017.

[9] T. Kulcsar, M. Balatonb, L. Nagyb, and J. Abonyi, “Feature Selection Based Root Cause Analysis for Energy Monitoring and Targeting”, Chemical Engineering Transactions, vol. 39, pp.709-714, 2014. doi.org/10.3303/CET1439119

[10] Анфилатов В.С,Ємельянов А.А., Кукушкин А.А. Системный анализ в управлении / Под ред. А.А.Ємельянова. – М.: Финансы и статистика, 2002. – 268 с.

[11] V. Rosen, and N. Davydenko, “Formation of the set of characteristics of the actual regime of water consumption in municipal water supply systems”, Energy: economics, technology, ecology, no. 3, pp. 85-92, 2015. doi.org/10.20535/1813-5420.4.2015.55633

[12] L.V. Davydenko “Indicators system creation for the energy efficiency benchmarking of municipal power system facilities”, Problemele energeticii regionale, no. 1 (27), pp. 58-70, 2015.