

The information and computing complex “ANGARA-VS” for end-to-end modeling of water supply systems when developing development schemes, scheduling modes, and dispatching management

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Abstract. The paper presents a brief description of the problems of making technological decisions to manage the development and functioning of water supply networks in conditions of territorial, structural, and temporal disconnection of the decision-making processes at WKK enterprises. An approach to overcome such problems is proposed, based on the application of end-to-end modeling technologies and a single information space of the enterprise based on the application of the ANGARA-VS information and computing complex. Its brief characteristics and functions are given. The experience of automation of development of operational modes and dispatching management and development of perspective schemes of water supply in Municipal Unitary Enterprise "Vodokanal", Irkutsk.

1 Introduction

Modern water supply systems (WSS) of cities and settlements are unique in scale and complexity of engineering facilities. Their functioning is carried out in conditions of significant variability in the structure, parameters, and operating modes under the influence of many factors of a random and systematic nature. The adoption of effective decisions on the development and operation of WSS in these conditions becomes impossible without the use of modern methods of mathematical and computer modeling. For these purposes, many commercial software products have been developed. Among the most common, it is possible to distinguish software and computer complexes (SCC) of foreign and Russian companies: Bentley (WaterGems) [1], DHI (MikeUrban) [2], United States Environmental Protection Agency (Epanet) [3,4], Simone Research Group (Simone) [5], DNV GL (Sinergy Pipeline Simulator) [6], Polyterm LLC (Zulu Hydro) [7], Potok (Hydrograph, Teplograf) [8], and others.

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However, most of these SCCs are focused on a specific field of application (design, operation, dispatching, training) and are also closed by functions and data formats. This makes it difficult to use them for other purposes and to integrate with third-party information systems. Such a narrow focus of methodical, software, and information support is conditioned by the established practice of design and operation of TPN, in which there is a significant fragmentation of the decision-making processes for managing WSS in space, in time, as well as organizationally.

When designing such fragmentation is manifested in the episodicity (in time) and fragmentation (on the territory) of implementing projects for individual parts of a single WSS (water conduits, pumping stations, network fragments, etc.) by different design organizations. In this case, aggregated network schemes are often used. During operation, this is manifested in the disconnection of information and software (GIS, SCADA, billing systems, electronic models of WSS, etc.) being used by different services (planned, mode, dispatching, subscriber, etc.) of a single enterprise.

Collecting, entering, specifying, processing, and coordinating information circulating at different decision-making levels pertaining to a single object spends significant resources of labor and time, which ultimately reduces the effectiveness of such decisions. Recently, the requirements for developing such schemes for the WSSs of cities have been legislatively established [9], which envisage consideration of the system as a whole and presentation of results in the form of electronic models. However, the problem of developing and “end-to-end” application of unified electronic models of WSS at different levels of management is still not formalized.

In this paper, we outline the main provisions of the proposed technology of cross-cutting modeling of WSS related to the organization of a common methodological, computing and information space for different territorial and temporal levels of analysis and decision making. A brief description of the information-computational complex (ICC) “ANGARA-VS,” which can be used as a basis for the implementation of such a space, as well as practical experience of such implementation.

2 Organization of the information space

Using standard relational DBMS to store data of WSS information models and ActiveX Data Objects (ADO) technology to access them provides: 1) the ability to store and process a large amount of both the original data and the relational links between them; 2) the openness of ICE data, which, if necessary, is accessible by standard means of a specific DBMS; 3) the ability to use any of the available DBMS (running under Windows OS) without changing the code. Most often, MS SQLSERVER DBMS is used for a network, and the MS Access is used for local network. Development and description of the structure of the database are outlined in [10, 11].

In the “ANGARA” information and computing environment (ICE) developed by the authors [12, 13, 14], the technology of multilevel modeling of calculation schemes [15] was implemented, providing the possibility of decomposition of a single settlement scheme by some criterion (territorial, technological, departmental) and coordination calculations of individual fragments. The technology is based on the following principles [10]: 1) *equivalence*: when each calculation scheme can be represented in a higher-level scheme by one element for which the parameters of the aggregated characteristics of the circuit are calculated; 2) *disaggregation*: consisting in the detailed calculation results of the element representing the scheme at the upper level.

The ICE “ANGARA” has three ways of supporting the relational links of the multi-level information models of the TPN [11]: 1) *hierarchical*: each element can be represented by its own lower-level calculation scheme; 2) *parallel*: from the separate schemes of the

lower level, a new more detailed scheme is formed, containing relational links with the initial schemes of different levels; 3) *nested*: the elements of the lower-level scheme have a relational connection with the boundary elements of the generalizing circuit element at the upper level. This allows the user to work at any time with a schema with the required granularity.

3 Computing space

The basic tasks for all stages of WSS management are the tasks of calculating modes (flow distribution), at the stage of circuit design, and when planning the modes under dispatching control. Having once developed a mathematical model and created a universal software module that implements it, it can be applied at all stages:

1. *When working on development schemes* and designing a WSS, they are used for the purposes of: 1) analyzing the capacity of the existing system for prospective loads (as a rule, only the maximum water consumption mode is checked, other modes are overlooked); 2) checking the admissibility of the WSS operation in non-project modes (calibration calculations); 3) analyzing and justifying the reliability of the supply of consumers after the implementation of the WSS design options. Thus, at the design stage, multivariate hydraulic calculations are very widely used.

2. *When a WSS is being operated* in order to: 1) analyze the admissibility and rationality of existing regimes; 2) identify the causes of existing violations, “system bottlenecks”, etc.; 3) development of rational schemes for zoning the system; 4) development of work schedules for pumping stations, reservoirs, and other structures; 5) determine the rational locations for installing pressure regulators, determining their “settings”; 6) determine the network’s capabilities to connect new customers; 7) analyze consequences of possible accidents and development of dispatch schedules for their management; 8) analyze the reserves of network capacity for fire extinguishing purposes, etc.

3. *In the process of dispatching management* in order to check management decisions for the period of liquidation of consequences of accidents or repair and restoration works [16].

4 Characteristics of the SCC “ANGARA-VS” as a means of automating the hydraulic analysis of water supply systems

The SCC “ANGARA-VS” is intended for modeling the hydraulic modes of WSS. The SCC allows solving information, computational, and analytical problems within a single user interface, including: 1) creating and maintaining information databases on WSSs of cities and settlements; 2) analyzing the existing WSS regimes, established schemes for their operation; giving rationale for optimization activities; 3) assessing the consequences of changing the structure and parameters of the system under management.

The SCC “ANGARA-VS” consists of two main parts: 1) the ICE “ANGARA” performs the function of the main user interface; 2) the SCC “ANGARA-VS” performs design tasks.

In Figure 1, the interface of the ICE “ANGARA” with an example of the WSS scheme is presented.

Information functions of the ICE “ANGARA” include: 1) a visualizer of settlement schemes and data; 2) an editor of plans (terrain, buildings, structures, etc.); 3) an editor of schemes (water supply networks, structures, etc.); 4) a data editor (parameters of the calculation schemes’ elements, etc.); 5) a handler for starting and executing settlement tasks.

Information on the settlement scheme can be presented to the user in various ways: in the form of a diagram, a table with data on all the same elements, forms with data on the specified element, as signatures directly on the diagram, in the form of graphs and diagrams.

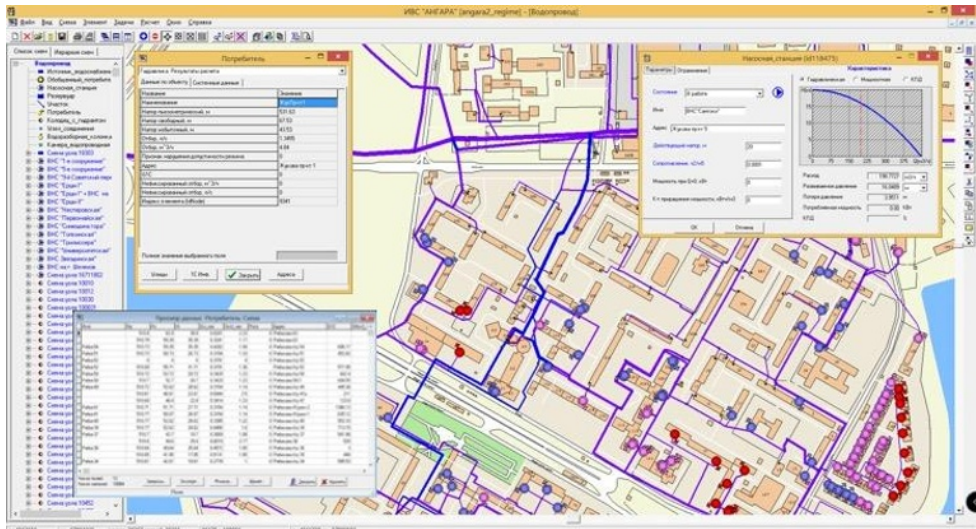


Fig.1. Interface of ICE “ANGARA”, with an example of the scheme of water supply network.

The SCC provides the following computational functions:

- Equivalent pressure and power characteristics of all HCs according to the specified characteristics of the switched-on pumps, taking into account changes in their parameters;
- Mode of operation of pumps, which is designed to determine the developed head, capacity, power consumption, and efficiency of all pumps included for each HC according to the specified mode of operation of the HC as a whole;
- Flow distribution is designed to determine the costs and pressure losses in the network sections, as well as pressures and costs in the connection nodes of sources and storage tanks. The SCC supports two types of calculations: with fixed loads (to analyze the network capacity at a given load of water consumption) and with non-fixed loads (for analysis of the degree of consumer security and analysis of fire-fighting modes);
- Coefficients of local resistances are designed to automate the calculation of the sum of these coefficients for a pipeline section by choosing a specific combination of typical local resistances.

The computational modules for computing the flow distribution are characterized by: 1) high speed (several seconds for circuits containing tens of thousands of elements); 2) the ability to calculate networks of arbitrary configuration (branched, multi-loop) and structure (with arbitrary number and location of NS, sources, reservoirs, water consumption units, units with selection for firefighting, and generalized consumers with a non-uniform load); 3) accounting for various pipe materials, local resistances, combinations of pumps with different characteristics; 4) control over the correctness of the initial data set; 5) guarantees on the convergence of the computational process.

Models of modern pipeline systems of cities contain tens of thousands of elements and hundreds of thousands of parameters, which greatly complicates the analysis of such systems. The most graphic way of interpreting the initial data and the results of calculations is the graphical representation. The SCC allows: 1) to quickly detect bottlenecks in the scheme by highlighting them with color, size, animation; 2) to build special graphics

(piezometric, characteristics, etc.) to identify the causes of violations in a customary form for engineers; 3) to use elements of business graphics (columnar, linear, pie charts); 4) to use the mechanism of “templates” to save and reuse typical operations.

5 Practical application of “ANGARA-VS” for end-to-end modeling of WSS in Irkutsk

In the Municipal Unitary Enterprise “Vodokanal,” Irkutsk, the SCC “ANGARA-VS” was installed in the mode calculation group [17, 18]. For several years it was possible to create a complete database, including the plan of the terrain, schemes, and parameters of water supply and sanitation networks. A calculation model was tuned and calibrated. On the basis of the electronic model, the regime group rationalized the operation scheme, which resulted in the installation of pressure regulators on the water supply network, zoning of the network, changing the parameters of the pumping stations, which made it possible to reduce the costs of operating the system and reduce the accident rate. The results of development of operational modes are actively used in the dispatching service: 1) as a guide for maintaining the regime and an information basis for communicating with consumers; 2) to check switching options for emergency situations; 3) to develop a switching plan. The availability of a well-functioning electronic model allowed conducting a full analysis of a large number of options in the shortest possible time and to develop a perspective scheme of water supply in Irkutsk for a perspective up to 2025 [19].

The introduction of the dispatcher’s journal in the dispatching service allows to update the electronic model based on the results of the work of the repair teams. The single information space of the enterprise being created on the basis of the SCC “ANGARA” [20] made it possible to use a single database not only for modeling at different time stages, but also for simultaneous access of various services within the enterprise and external consumers (management companies, city administration, supervisory agencies, etc.).

6 Conclusion

In the context of a brief analysis of modern software for calculating the WSS modes and the disconnection of the decision-making processes for managing the WSS modes, the characteristic and the main capabilities of the SCC “Angara-VS” are outlined, which allows them to be overcome. The principles of information and computational space formation are also described in details. The possibility of using the “end-to-end” WSS modeling at different time levels is demonstrated: the development of schemes, design, planning and analysis, dispatching management. The experience of using the technology of modeling in Municipal Unitary Enterprise “Vodokanal” in Irkutsk is also described.

The research was carried out within the framework of the III.17.4.3 project of the Basic Research Program of the SB RAS (AAAA-A17-117030310437-4) with the financial support of the Russian Foundation for Basic Research and the Government of the Irkutsk Region within the framework of the scientific project No. 17-48-380021.

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