PERIODICA POLYTECHNICA SER. CIVIL ENG. VOL. 41, NO. 2, PP. 135–145 (1997)

SOFTWARE PACKAGE FOR CONTROLLING WATER SUPPLY SYSTEMS

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Received: Jan. 20, 1997

Abstract

Research projects established in the last 5 years in the field of water supply, at the Department of Water and Wastewater Engineering, outlined a new result to achieve: the entire technical information system of a waterworks company. Although we could not solve this comprehensive and extremely difficult problem, we tried to define all the tasks and describe the possible solutions. During the project described in this paper we accomplished a well-defined task, which is important in the development of the information system of waterworks. The objective is the optimization of energy costs. The solution of this task and the development of the software package supporting the control of water supply systems were prepared on the basis of available theoretical and practical knowledge, and experiences in software development related to control of water supply systems.

Keywords: water supply, controlling, software package.

1. Introduction

The system outlined below was established by the computer software developed at the Department of Water and Wastewater Engineering and distributed in Hungary. Beside the software development and practical implementations several research projects were carried out in the field of development of water supply system operation, automatic operation control (tasks and conditions) and optimization methods of operation, for example:

- Optimization of Water Supply Network Operation
  Research report, 1982, sponsor: BAZ County Waterworks
- Investigation about the Optimization of the Water Supply System Operation in Veszprém
  Research report, 1986, sponsor: Veszprém County Waterworks
- Development of Automatic Operation Control of Water Supply Systems
  Research report, 1986–90, sponsor: Veszprém County Waterworks

– Information Systems in Water Supply and Sewerage Systems
Research report, 1991–92, sponsor: Pécs Waterworks

By the proceeding of the developments all these research projects outlined a new result to achieve: the entire technical information system of a waterworks company. Although we could not solve this comprehensive and difficult problem, we defined all the tasks and described possible solutions (see *Table 1*).

Table 1
Time schedule of the project

Number	Task	Deadline	Sponsor
1.	Preliminary study, technical establishment of the overall system plan	30.06.1992	Waterworks
2.	Overall system plan Definition of tasks, modules, subsystems, database structure	31.12.1992	Waterworks
3.	Development of detailed system plans for subsystems: possible strategies and pumping schedules, the selection of the optimal strategy	30.06.1993	Nat. Comm. of Technical Developm., Waterworks
4.	Program coding and testing Documentation, installation Final report	31.12.1993	Nat. Comm. of Technical Developm., Waterworks

The major objective of the our study was to arrive at a software system which can be used in the practice to develop control strategies which minimize the costs of energy.

During the project described in this paper we accomplished a well-defined task, a core-task, which is very important in the development of the technical information system of a waterworks. The solution of this task and the development of the software package supporting the operative operation control of water supply systems were established by the routine in software development, the broad theoretical knowledge and experience in operation control gathered throughout the research projects and other expertise.

This project was sponsored by 12 Hungarian waterworks and the National Committee of Technical Development through a 'Research and Development' sponsorship (December 1991). At the same time as the application for this sponsorship was filed, the development of the VSZR was started with the support of the Veszprém County Waterworks. The study on the technical part of the Comprehensive System Plan was accomplished in December 1991.

Taking into account the limited extension of paper the review of literature is neglected. However, the most important references which would be interesting for researchers are listed in the References.

2. A Brief Overview of Tasks, Introduction of the Developed Program Modules

The tasks of the water supply system and of the operation company can be arranged into the following groups:

Technical Activity

Technical activities can be classified according to their frequency as follows:

- routine tasks of the **daily operation control.** It covers the direct supervision and control of operation process and the handling of the pipe breaks and breakdowns.
- **middle term tasks:** the examination of energy contracts, the pump checking, design of maintenance work.
- **long term tasks:** reconstruction and development activity.

Administrative Activity

Although these tasks are not included in the software package, some examples are mentioned below.

- tasks concerning the collection of water charges from the customers
- mandatory and expedient activity of the company management (e.g. registering as prescribed by the accountancy law)

2.1. Daily Operation Control Tasks in Water Supply

What is the operative control of a water supply system?

First of all let us define the task of a water supply system:

The task of the water supply system is to meet the customers' justified demands (quantity, quality, pressure) continuously and in the most cost-effective way.

This definition, of course, is very general. It does not make clear what the term 'satisfy continuously the customers demands' requires. To meet this demand not only the continuous operation of the system elements must be ensured, but the occurring breakdowns (e.g. pipe breaks) must also be eliminated.

The task of the operative control is to ensure the continuous operation of the system elements and to eliminate the breakdowns of the system continuously.

Within the operative operation control these two tasks are usually supported by two separate organizations:

Control Room Staff

The task of the control room staff is to supervise, control and ensure the continuous operation of the network elements, equipment and plants. It is also in charge of the detection of the breakdowns in the system and of the alarming of the breakdown–pipe break staff. The control room staff carries out its work according to the operation directions which usually have got two main aims:

- to ensure a quiet, well-balanced operation without customer complaints
- to minimize the energy cost

Breakdown–Pipe Break Staff

The task of the breakdown–pipe–break staff is to eliminate the malfunctions of the elements and equipment of the water supply system as quickly as possible. This activity must be carried out in a way that both the number of customers without service and the duration of the repairing should be minimal.

The tasks of the control room staff can be divided into two parts:

Operation checking task: it means that the data describing the condition of the system are continuously controlled by the staff. The aim of this activity is first to detect any malfunctions or breakdowns, second to recognize deviations from the designed operation schedule.

Process control task: it means that the staff intervenes in the system operation if

- interventions must be carried out according to the operation directions;
- deviations from the designed operation schedule that can cause breakdown are recognized, and the breakdown can be avoided by intervention;
- breakdown is detected and the damages can be reduced by the intervention (provided that control measures can reduce the results of the breakdown).

Data and signals required by the operation control are transferred to the control room ON-LINE (on cable or VHF) or OFF-LINE (by phone or VHF). The control room staff decides about the interventions and can take measures ON-LINE or OFF-LINE. Besides measures requiring decisions by the control staff interventions can also be taken by local automatic devices. The supervision of these devices can be achieved as described above, but they do not require measures by the staff in periods without breakdowns.

The activity of the control room staff can be effectively supported by a computer-based ON-LINE monitor-control system which is able to accomplish checking and operation control tasks. It collects, transfers, displays and in some cases stores data and signals required by the control of the processes in the water supply system. In this paper we often refer to this type of hardware-software system, therefore we use the abbreviation of Process Control System, PCS (according to the terminology of the Budapest Waterworks).

2.2. The Tasks of the VSZR

In the design process of the VSZR the fact that the potential users may be on different technical levels of development in checking and process control must have been taken into consideration. Therefore the VSZR must have been developed in a modular form in order to let the users choose a software package suitable for their development level.

We do not state that the developed VSZR can substitute by any means a Process Control System. The VSZR does not deal with such basic tasks of operation and transfer technology as connection with remote devices and sub-centrals, data transfer through networking, modem application. We emphasize that a limited application of the VSZR is possible even simultaneously with an ON-LINE checking and process control system. The accomplished system is suitable for the following:

1. Support of the activity of the control room staff in operative operation control.
2. Support of middle- and long-term technical tasks.
   We discuss these tasks in details below.

2.2.1. Support of the Control Room Staff Activity

The traditional task of the control room staff is the accomplishment of the operation schedule described in the operation directions. Obviously, the more complicated the water supply system the less able the operation directions are to handle all the possible real and unexpected situations in the operation. Therefore one of the basic tasks of the VSZR is to design an operation strategy that considers actual conditions and restrictions. The operation strategy has two different levels:

- to choose an operation algorithm (schedule) from predefined ones;
- to determine and to rank possible operation algorithms which meet the operation conditions (actual water levels in the tanks, pump operation, other restrictions).

We worked out solutions for both tasks in the VSZR.

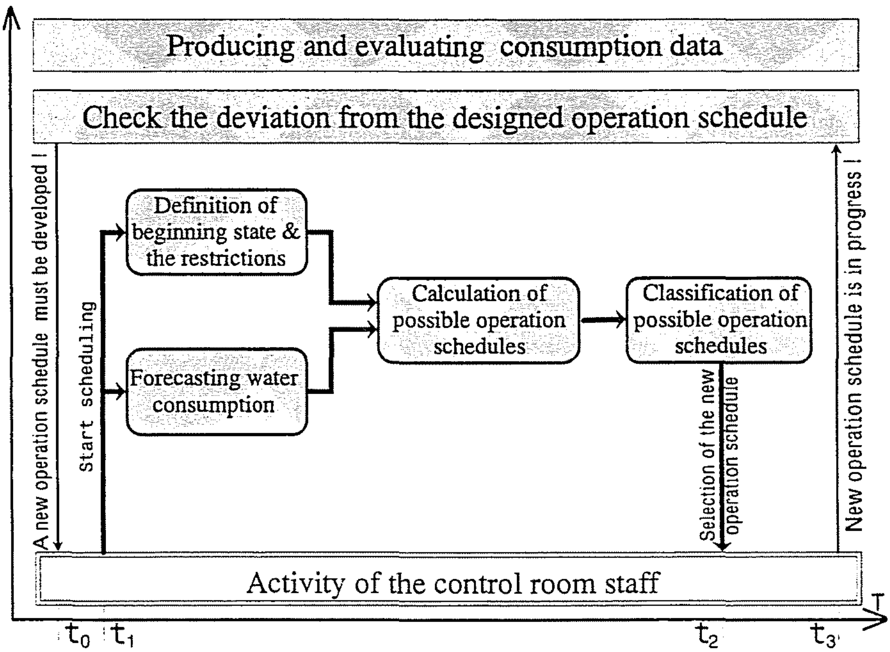

Fig. 1. Support of the activity of the control room staff

The activity of the control room staff is supported by the following options available in the VSZR (*Fig. 1*).

1. Processing the data of the mathematical model describing the water supply system;
2. Producing and evaluating water consumption data;
3. Developing water consumption forecast;

4. Planning the daily minimal-cost operation schedule ensuring the safety of supply, applying network calculation models and considering the scheduled maintenance, the repair works in progress.

2.2.2. Support of Middle- and Long-term Tasks

During the consultation with the waterworks experts on the VSZR that directly supports the operative operation control, its completion with two subsystems was suggested which are to support the middle- and the long-term tasks. The suggested subsystems are the following:

1. Examination of pump stations and revision of energy contracts;
2. Support of the reconstruction activity.

To solve these tasks the system must be able to store and process the measured and breakdown data and arrange them for statistical evaluation.

3. Description of Methods and Technology Applied in the Software Development

All the engineers and programmers who have got many years' experience in software development know that a development work with fixed deadline requires detailed and cautious planning and scheduling. In this project the three phases of planning took two years while the program coding took only half a year.

The planning of the software began with a study in which we summarized all the theoretical knowledge that established the development of the VSZR. In the second phase we worked out an overall system plan which consists of the following parts:

1. OBJECT AND TERMINOLOGY DEFINITION
2. DETERMINATION OF TASKS
3. APPLICABLE METHODS IN THE TASK SOLUTION
4. APPLICATION CONDITIONS OF THE SYSTEM
5. STRUCTURE OF THE SOFTWARE SYSTEM

5.1. Data handling of the mathematical model describing the water supply system
5.2. Connection with the process control system, handling of the measured and consumption data
5.3. Operation schedule design
5.4. Display of the measured data and results of simulation
5.5. Data storage
5.6. Pump selection and control

5.7. Support of the long-term technical tasks

The following questions arose during the development of the overall system plan:

- What hardware and operation system is required by the VSZR?
- What user interface should be used?
- What data base management and file format are appropriate?

The answers to these questions are determined by the following requirements:

- The price of the hardware and software required for the application should not exceed 500 000 HUF;
- Only those operation systems can be considered that support the most advanced graphical interfaces;
- The applied file format should fit the file format of one of the generally used relation data base management systems.
- The operation system should support multitasking and network operation.

On the basis of these requirements we selected the IBM OS/2 operation system and the file format of the dBASE III data base management system.

The third phase of the software development was the elaboration of the detailed system plan. The main steps are described as follows:

1. SOFTWARE ENVIRONMENT OF DEVELOPMENT
2. THE GENERAL STRUCTURE OF THE VSZR DATA BASE
3. STRUCTURAL DATA OF THE WATER SUPPLY SYSTEM AND THEIR PROCESSING
4. THE BREAKDOWN-PIPE BREAK SYSTEM

4.1. The database of the breakdown-pipe break system
4.2. The functions of the breakdown-pipe break system

5. PROCESSING OF MEASURED DATA

5.1. Measured basic data (describing the network) and their processing
5.2. Data transfer to VSZR from the ON-LINE control system

6. PROCESSING OF CONSUMPTION DATA

6.1. Processing of the consumption and pumping data
6.2. Statistical evaluation of zone consumption data

7. DEVELOPMENT OF OPERATION SCHEDULES

7.1. Project definition, project handling
7.2. Definition of beginning state and restrictions
7.3. Simulation

8. PUMP SELECTION AND CONTROL
8.1. Data preparation
8.2. Processing of the network characteristic curves
8.3. Pump selection
8.4. Processing of the network characteristic curves
9. SUPPORT OF LONG-TERM RECONSTRUCTION ACTIVITY
9.1. Physical model of the system
9.2. Consumption model
9.3. Pumping, boosting model
9.4. Program for data preparation
9.5. Evaluation of operation schedules
10. POTENTIAL OPERATION OPTIONS OF THE VSZR

4. Summary

With the development of the VSZR a new, state-of-the-art system was created which exceeds the technical, software and hardware level of the present Hungarian practice. By the VSZR system a well defined aim is set for the waterworks which – if accomplished – will bring technical improvement about. The main results of the development,

- Integration of water supply network hydraulic programs in a unique software system for support the activities of control room staff, to create optimal operation schedules.
- The ordered collection and preparation of on-line measured data to operation scheduling.

From the very beginning of the project we emphasize the importance of theappropriate training of the users. This is one of the key aspects of the project. In order to strengthen to human side of the system application we maintained a direct and close relationship with the experts of the supporting waterworks. We visited all the companies and consulted about everything related to the operation control. At least one month before accomplishing a section we organized an overall consultation. On these meetings we obtained several valuable ideas, suggestions and created a close relationship with those persons who can be the driving force of this enterprise in the future. According to our business policy this software development project was only the first step of a long-term contribution with the waterworks.

After accomplishing the software development we worked out the plans of our future activity concerning the VSZR. The main topics are described as follows:

1. DESCRIPTION OF THE DISTRIBUTED SOFTWARE PACKAGE
1.1. Program modules and functions, application possibilities
1.2. Application requirements
1.2.1. Hardware and software requirements
1.2.2. Technical training of the users
1.2.3. Technical preparation of the VSZR application
2. PROGRAM SECURITY
3. SOFTWARE WARRANTY, MAINTENANCE, NEW VERSIONS
4. SOFTWARE DEVELOPMENT
5. OTHER ACTIVITIES RELATED TO THE VSZR
5.1. Distribution, marketing
5.2. Training
5.3. Individual software development demands
5.4. Consultation
5.5. Distribution of documents, textbooks

This future plan was accepted by the sponsor waterworks, and they ensured the future cooperation with the involvement of the National Association of Waterworks (as representative) and the HydroConsult, Ltd. (distributor). We hope that the development of the VSZR will be a story of success, and all the persons involved will maintain their enthusiasm to push forward this enterprise.

Acknowledgement

The modelling and controlof water supply systems has a twenty-year tradition at the Department of Water and Wastewater Engineering, TUB. All the developments achieved until now have been based on the scientific activities of Mr. Károly Bozóky-Szeszich, who was an active leader until his death in 1986. Achievements described in this paper could not have been accomplished without Him.

This project was sponsored by twelve waterworks in Hungary and the National Committee of Technology Development through a research and development grant. The technical staff of the waterworks has added their own valuable experiences to the present development which isalso acknowledged.

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