Instytut Badań Systemowych PAN

Raport IBS PAN / PMK i I /02/2001

Komputerowy system wspomagania decyzji operatora miejskiej sieci wodociągowej

Pod redakcją Jana Studzińskiego i Lucyny Bogdan

Warszawa 2001

Instytut Badań Systemowych PAN

Raport IBS PAN / PMK i I /02/2001

Komputerowy system wspomagania decyzji operatora miejskiej sieci wodociągowej

Pod redakcją Jana Studzińskiego i Lucyny Bogdan

Warszawa 2001

W Raporcie przedstawiono dwa artykuły będące wynikiem projektu badawczego KBN pn. Komputerowy system modelowania, projektowania i sterowania siecią wodociągową w Rzeszowie, realizowanego przez Instytut w 2001 r.

Oba artykuły omawiają strukturę, zasadę działania i funkcje systemu komputerowego wspomagającego decyzje operatora i projektanta komunalnej sieci wodociągowej. System, opracowany w IBS PAN, został wdrożony w Miejskim Przedsiębiorstwie Wodociągów i Kanalizacji w Rzeszowie.

Pierwszy artykuł (autorstwa J. Studzińskiego, L. Bogdan i D. Kaczmarskiej) był prezentowany na konferencji pn. Komputerowe Systemy Wielodostępne KSW'2001 w Ciechocinku w br. i został zamieszczony w książce pt. Rozwój i Zastosowania Technologii i Systemów Informatycznych, wydanej przez IBS PAN pod redakcją J. Studzińskiego, L. Drelichowskiego i O. Hryniewicza.

Drugi artykuł (autorstwa J. Studzińskiego i L. Bogdan) był prezentowany na konferencji pn. Advanced Simulation of Systems – ASIS'2001 w Czechach w br. i został zamieszczony w materialach konferencji pt. Proceedings of XXIIIrd International Autumn Colloquium ASIS'2001 on Advanced Simulation of Systems, wydanej przez MARQ w Ostrawie pod redakcją J. Stefana.

Spis treści

ACTA MOSIS No. 86

Proceedings of the XIIIrd International Autumn Colloquium

Advanced Simulation of Systems

Edited
Jan Štefan

Ostrava 2001

ASIS® 2001 Colloquium that took place on the 11st to 13rd September 2001 in Velké Losiny Spa, Czech Republic, was organized by the Department of Computer Science FEEI VŠB-Technical University Ostrava, Department of Computer Science of FEECS University of Technology Brno and MARQ. Ostrava.

Štefan Jan, editor
ASIS 2001, Proceedings of the XXIIIrd Autumn International Colloquium "Advanced Simulation of Systems", September 11 – 13 2001, Czech Republic – 1st Edition – Ostrava – Jan Štefan, MARQ., nám. Msgre Šrámka 6, 702 00 Ostrava, (Print: REPRONIS, Nádražní 53, 602 00 Ostrava), pages 291, Figs., (Acta MOSIS No. 86)

ISBN 80-85988-61-5

REFEREES OF ASIS 2001 PROCEEDINGS

ALEXÍK M.
BREJCHA M.
ČEŠKA M.
DOBROWOLSKI G.
HANÁČEK P.
KASPRZAK A.
KINDLER E.
KRUG W.
PERINGER P.
RÁBOVÁ Z.
RACEK ST.
STOFFOVÁ V.
ŠTEFAN J.
ZENDULKA J.
ZBOŘIL F.
ZOBEL R.

Computer Aided Decision Support System for The Operator of Municipal Water Network in Rzeszów

Jan Studziński*, Lucyna Bogdan*
studzins@ibspan.waw.pl

Abstract: In the paper the results of project of computer aided decision support system for the operator of the municipal water network in Rzeszów. The system consists of three cooperating modules: the numerical map of the water network, the monitoring system and the computer program for hydraulic calculations and for optimisation. The numerical map is based on GIS system adapted for the needs of the water network. The modules of computer system cooperate each other using the Branch Data Base, which comprise the information about the water network structure and about its elements necessary to carry out the tasks of modules such as visualisation, data processing and hydraulic calculations.

1. Description of the object. The town Rzeszów has 160 000 inhabitants. The length of the municipal net is 544 km (the water mains 49 km, the distribution network 274 km and user attachments 221 km). In the water network there are five surge tanks with capacities 1 x 3.600 m^3 and 4 x 3.000 m^3 and there are 21 pumping stations. The network is supplied from two water intakes form the river with efficiencies 37.000 m^3/day and 47.500 m^3/day. There are 12201 group consumers in the network and 80% of the net works in the ring system. The water net capacity is used in 56% because of decreasing of water demand in industrial plants. The main receivers of the water are the households. The amount of damages is about 500 damages/year and the damages are caused mainly by the age and age differences of the pipe material.

2. The numerical map of the municipal water

To work out the numerical map of the municipal water network the specialized program for creating numerical maps (GIS) was bough. The map of the water network was done on the base of vectorized geodetic maps of the town. System GEOMEDIA by *Intergraph* was bough and then adapted for the needs of water work. Such a way of work enables to be independent from the external computer firm. Such a choice causes the necessity of solving of three tasks:

1. To define the structure of object data basis applied by GEOMEDIA system for visualisation of water network and for description of its parameters.
2. To define and implement the special user functions to enable the numerical map to work as a tool to manage the water network.
3. To develop a new organizing structure in the plant to enable the fast working out the numerical map and correct using it.

The numerical map consists of the scheme of real water network and of attached describing database. To enable the map to represent the real water network all the characteristic network elements must be distinguished on the scheme and respectively all the parameters of these elements, called attributes must be set in the database. During the work out of numerical map

* Systems Research Institute, Polish Academy of Science, 01-447 Warszawa, ul. Newelska 6, Poland

the database structure must be defined. It means that the objects of database and their attributes must be designated.
.After the detailed analysis of needs of the municipal water network in Rzeszów the branch data base for water work in Rzeszów was worked out.

The special functions enable to apply the numerical map to solve the tasks realized during the exploitation of the water network.
The following special functions were defined

- Updating of the numerical map
- Geometric and describing data export/import from/to numerical map
- Identification of conflicts between different branch nets
- Disconnecting of a part of water network in case of the damage.
- Printing of exploitation and damage reports

The analysis of exploitation conditions in the plant indicates that the optimal solution for the firm using the numerical map is to create the separate numerical map laboratory. In such a place a group of people will be able to make the computer program work correctly, the current updating of numerical map work properly as well as task of exploitation of water network. Such an organizing structure was introduced in Rzeszów and the numerical map is utilized in five positions system.

3. The creation of the Branch Data Base for waterworks

Visualization of water network on computer screen is done by application of water network computer map – GIS. The format of Branch Data Base and the tools programs realizing the special functions are created on the base of bough standard implementation GEOMEDIA. The function are connected with the water-supply needs, with the way of receiving of data for creating the numerical map and with the demands of applied external computer programs cooperating with the numerical map..

The creation of the Branch Data Base Format consists on defining of water network objects and their attributes. The main objects of water works are: the water pipes, the pumping stations, tanks, user attachments, shutters, reducers and check-valves and their attributes are lengths and diameters of pipes, characteristics of pumps, geometric dimensions of tanks, the operating conditions and characteristics of Shutters, reducers and check-valves. The Branch Data Base is the base of working of all computers programs of computer system.

The data for numerical map are delivered from the geodesy department as DGN files done on the base of the municipal geodetic maps of Rzeszów, which are made in scale 1:500. That is why the tool program enabling reading DGN files, copying the graphic and describing data as well as computer visualisation to the Branch Data Base had to be written for GEOMEDIA program.. The additional program is used for data updating namely for signalling and introducing to the Branch Data Base the changes done by geodesy department in DGN files, which were previously introduced to the Base.

The described Branch Data Base is a standard enabling the visualisation of water network in a form of numerical map. But the Branch Data Base does not enable the cooperation of the numerical map with the external applications, namely with monitoring system and hydraulic model, because the Base does not consist the specific objects for these applications. Such objects are the nodes of the water network, which do not occur on the geodetic maps. That is why the next step during the creation of the Branch Data Base Format was definig the nodes and nodes attributes. The main nodes in the water network are the sources, the receivers,

montage nodes and measurement nodes. Their main attributes are pressure and the water distributions. The numerical map of the water network created directly on the base of the vectorized precincts of geodesic maps does not include the nodes as well as is topologicaly incorrect, namely not continuous and not coherent. That is why the hydraulic calculations cannot be realized on the base of it. To enable it the two new programs for topologisation of the net and for generating of hydraulic nodes (nodes generator) were added to GEOMEDIA besides the mentioned previously programs for reading DGN files and for data updating.

So the implementation of all additional programs made from GEOMEDIA the waterworks application of numerical map. It should be noticed that the three layers of numerical map are generated:

the geodesic main layer, created from DGN files delivered directly from municipal geodesy department , *the topological geodesic layer*, created from *the geodesic main layer* after checking and improving the continuity and cohesion of the water network as well as The hydraulic layer created from *the topological geodesic layer* after introducing the nodes creating in such a way a new net graph, which may be the base of the hydraulic calculations.

4. Mathematical modelling and simulation of the water network

The modelling of the water network consists of the next steps: the creation of the hydraulic model respectively to the investigated water network, obtaining the data describing the investigated water network and performing the simulation calculations and their verification on the base of the measurements.

The own modelling program was implemented. This program uses the CROSS method for solving the nonlinear algebraical equations built for water network rings and taking into account such objects as water works pipes, water works pipes with the section distibution, water works pipes with shutters , reducers or valves, supplying nodes in the form of pumping stations or tanks, montage nodes, measurements nodes, receiving nodes in the form of tanks or being user attachments on the geodesic map, the nodes increasing the pressure in form of water supplies. The program is written in DELPHI. It has an extended interface and its own graphical editor what enables to perform the calculations and creating the water network graph on the computer screen independently on the numerical map.

The program data concerning the water network structure and its parameters are delivered from the numerical map using buffer files. The buffer files concerning pipes and hydraulic nodes are generated basing on the numerical map hydraulic layer.

The worked out modelling program has the possibility of using of nodes and section distributions. This program can also execute the statistical calculations on the base of given average day or moment distributions and can execute dynamical calculations basing on the given day hour distributions sequences. The verification of modelling program hydraulic calculations results is performed as a comparison between the program results and the monitoring system measurements.

5. The analysis of correctness of the model

The simulation calculations were performed for the chosen part of town water network using the mentioned modelling program. The monitoring system was installed for this part of the water network. This part of net had earlier created numerical map and the data could be

delivered using the Branch Base Data. The Chosen Part of the net comprised the one quarter of the town and it was about 10% of municipal water network. The results obtained from model were compared to measurements from monitoring system. The comparison analysis showed the correctness of proposed model.

6. Optimisation algorithm of water network and control algorithm in break-down states

An optimisation algorithm, which is an integral part of the modelling program, was created. It is a specialized algorithm using the specificity of water network. The optimisation task concerns the improving pressures in water network nodes in the case of exceeding given pressures limit. values. In the classical optimisation method the object function is based on the difference between the given pressure value and calculated pressure value and this function is minimised depending on water network pipes diameters values .The object function is the mean square criterion and the change of parameters takes place in the whole net what increases the calculation time in the case of large nets.

In our algorithm firstly the paths with the greatest flow resistance between supply sources and the nodes with not appropriate pressure are marked in the graph. Then the distance between the given pressure and calculated pressure in these nodes is minimised depending on the change of water network pipes diameter values only on marked paths. Such a procedure shortens the calculation time because it deals in calculations only the marked parts of the net.

.The break-down algorithm concerning situations when the break-down has place in some point of the net was performed. In such a case the proper part of the water network should be cut to avoid a loss of water. The algorithm realizes this task by indicating the closest gate valves, which should be closed to cut the water flow. The algorithm works on the numerical map hydraulic layer level. The new water network graph with the cut part of break-down is received as the result of algorithm. The hydraulic calculations for obtaining flows and pressures may be now performed on the base of this graph.

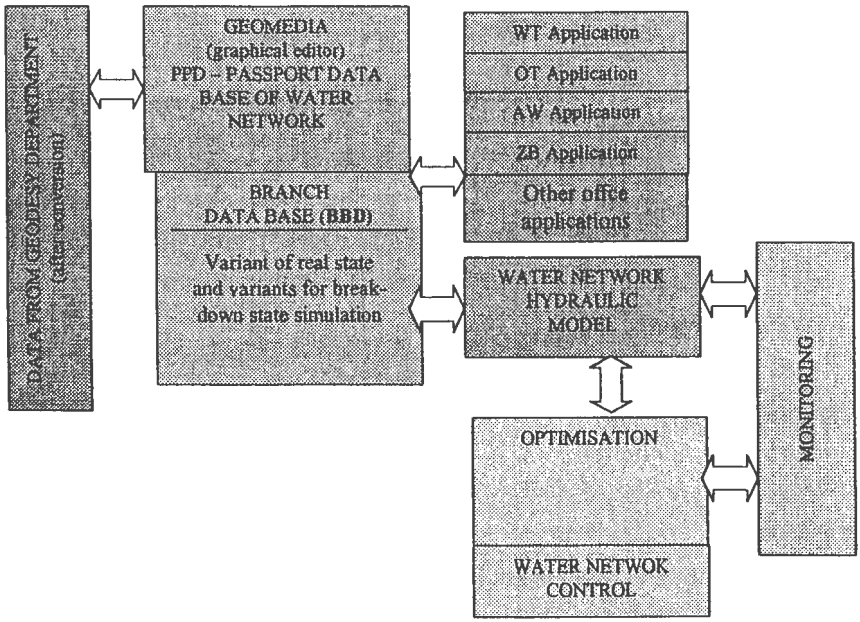
7.Computer system for operator decision support

The computer system consists of three modules performing the functions of numerical map, monitoring system and hydraulic model with optimisation algorithm. To start the monitoring system the measurements points were given as the results of hydraulic calculations in the investigated part of the water net work. The investigated area consists of 2 pressure zones separated by water supply system. There were indicated 9 measurement points, 2 water network supply points, 2 water output points (from the investigated area to not investigated net areas), 2 measurement points in the first pressure zone in the place of minimal and maximal pressure, 2 measurement points in the second pressure zone in the place of minimal and maximal pressure and 1 measurement point in water supply system separating two pressure zones.

The water flows and the pressure are measured in the points of water inflow and outflow asa well as in water supply system. Only the pressures are measured in the rest measuring points. PROCON system based on the original German system using the controllers by SIEMENS was bought to perform the monitoring system.

The measurement transmission system from measurement points to the computer with PROCON program installed is based on GSM system. The system works in the computer net consisting of tree computers.

The computer system scheme [4]



During testing the tool programs connected with numerical map and enabling the cooperation among the numerical map, the hydraulic model and the monitoring system, it appeared that the additional program modules performing managing functions and some other functions, would be useful. There are the following additional preferable modules (applications):

WT Application –program for technological conditions maintenance

OT Application – program for technical receivers, which cooperates with WT Application

AW Application – program for break-down maintenance and water network inspection maintenance

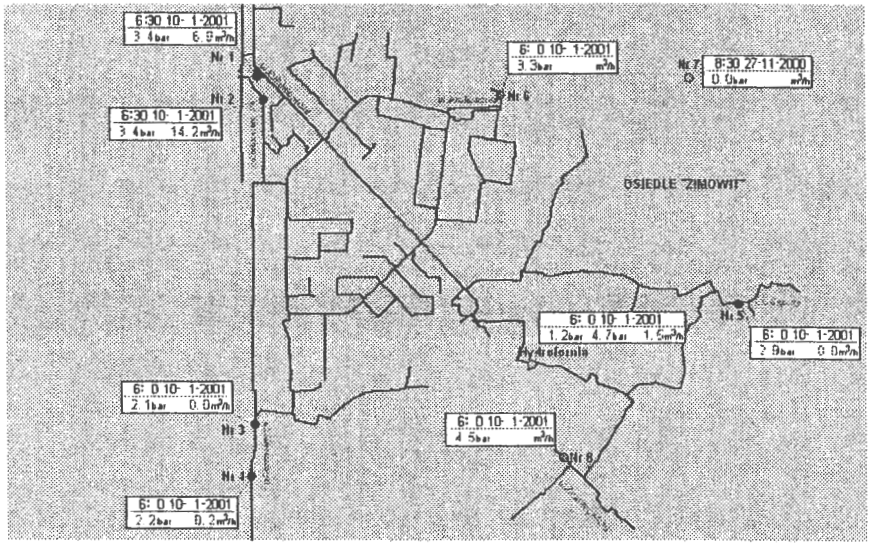
ZB Application – program for water sewage disposal maintenance

Other Application – office software

The presented computer system consists of seven computers in which three computers cooperate with numerical map, two computers are used for monitoring system maintenance and the last two computers are used for the maintenance of hydraulic model and and optimisation program. The data transmission is done using the the GSM system. It is an innovation solution in the water networks monitoring systems. It secures the transmission reliability but unfortunately it is not cheap. It is why the economical scheme of measurement data transmission was worked-out. In this scheme if the measured flows and pressures do not exceed given limit values the transmission takes place only in some chosen time moments. There are now the following hours 6:00, 14:00 and 22:00.

In the case when the limit values are exceed or for the operator demand the alarm mode transmission may start any moment. In such a way the transmission costs are minimal if the water network works in regular mode.

The measurement points scheme in monitoring system [4]



8. Remarks

The presented system is original system for municipal water network using the possibilities of integral system. The numerical maps, hydraulic models and monitoring systems work autonomously in some Polish water networks as independent programs and the possibilities of cooperation of this programs in one system are not used.

8.References

1. Studzinski J., Bogdan L.: Computer aided modelling, optimisation and control of the large municipal water net. In: Simulation and Modelling: Enablers for better Quality of Life. Proceedings of 14th European Simulation Multiconference ESM'2000, Ghent May 23-26, 2000, Ed. R.v.Landeghem, 586-588.
2. Straubel R., Studzinski J.: Computer aided planing and operating of the water networks in Koenigs-Wusterhausen and Rzeszów. Proccedings of 4th International Conference in Water Supply and Quality, Kraków 11-13 wrzesień 2000, Ed. M.M.Sozański, 43-54.
3. Studzinski J., Bogdan L.: Sophisticated computer tools for simulation and optimisation of municipal water networks. Proceedings of 12th International Colloquium ASIS'2000 on Advanced Simulation of Systems, Ostrava 12-16 September 2000, Ed. J.Stefan, 247-251.
4. Kaczmarska D.: Wnioski eksploatacyjne z pilotowego wdrożenia komputerowego systemu modelowania, sterowania i projektowania sieci wodociągowej w Rzeszowie. Raport 1/9/01, MPWiK Rzeszów, 2000.