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Information System for Energy Distribution Optimization

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Abstract: **-** In today's World we have a great problem with the energy consumption and distribution. All the shortages in the energy distribution have an unpleasant effect to the society. This is especially true during the winter. Our society is still not capable to dismiss fossil fuel as the primary source of energy. Increasing demand and consumption of the fossil fuel also produce increasing amount of green house gasses. Majority of the population in the Europe needs heat to survive the winter. Individual housing heating system are known to be less effective than central heating distribution systems. Analogy from the economy shows us that all large systems are more cost effective than small one. Therefore large heat distribution systems are more effective than individual housing heating system. They are capable to optimize their operations parameters, consume less fuel, and provide better heat distribution. For optimization of the operations parameter a good information system is needed. System should predict the dynamic behavior of the system and act upon the results. The SCADA system should therefore be combined with the higher logic system which is capable to interpret the information, calculate the optimal parameters and reconfigure the operation parameters. When this internal optimization is exhausted the additional external optimization should be applied. This external optimization is the communication system between the heat distribution company and fuel - gas distribution company. Article presents the information system that enables this optimization and how it was applied in our local environment.

Key words: software development, information system, heat distribution, energy efficiency, optimization

1 Introduction

It all started with the project which should solve the problem of hydraulic analysis in the pipe network system. Both local heat distribution company and gas distribution company have similar problems. In the beginning this problem was observed as algorithmic problem and not as information system development. But when the hydraulic analysis module was developed the new demands arose. The hydraulic analysis module and algorithm alone was quite revolutionary since it enables to compute the problem on personal computer what was previously computed on super computers. But the product was not easy to use. Despite it was meant to be suitable for hydraulic experts it shows it's weaknesses since it was prone to user induced errors. It is almost unbelievable that the first application was produced without the help of computer professionals. How to produce the user friendly application was a bit too heavy problems for hydraulic researches therefore they seek the help from fellow researchers from the computer department.

At the beginning of the project the major issue was which technology for software development we should use. In the early era of Windows 95 the object technology was so new that we did not want to risk and apply the object technology development concept. OMT which is now obsolete was totally new. Even software development tools were not standardized and Windows API calls were common C. Therefore the first development started with SA/SD (Structured Analysis / Structured Design) [1, 2] technology but the implementation itself was made in C++.

When the initial success was evident the further development of the software continues [3]. The schema of the information system that is now in the operation is the following (see Fig. 1)

As we can see (see Fig. 1) in the schema almost all modules of the information system is functional and operational. The gray area "Prediction system" and its optimization module are still not finished despite the fact that this module was the one that started the information system development. Optimization module has only basic functionality. In the near future we will conduct further research in the optimization module's functions. In the article we will present the current status of the system with the highlight on the hydraulic analysis and prediction system. An external optimization was something that comes out of pure economical logic and was self evident to us because we have insight into both enterprises. But it was a demanding problem because it involves two different companies and all included and inherited problems.

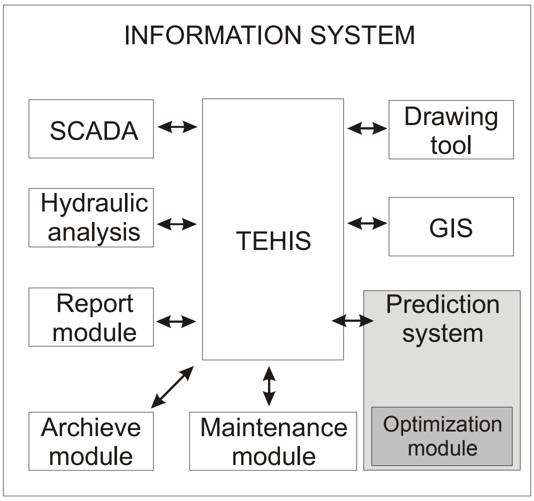

Fig. 1: Schema of the information system

2 Problem solution

The problem of hydraulic analysis is not trivial. It can be applied on different type of network (open and close loop). In many cases existing software application are unable to resolve redundant connection. They usually perform the transformation of network graph to tree graph and then perform the calculation. The pressure drop of the incompressible fluid flow in pipe transmission systems is a function of line and local energy losses defined by the Darcy-Weisbach equation [4, 5, 6]. Pressure drops of incompressible fluids can be also determined by some other equations: the Hazen-Williamson, the Manning and the Gauckler-Manning-Strickler equation, but they are less appropriate for calculation. At the beginning of our project such calculations was made on supercomputers and takes days of calculation for city area networks. Since we have no access to the super computers we tried to build one or hire one. Very soon we dismiss this possibility and start searching the solution of optimization of algorithm that could be less processing power demanding. For the hydraulic (flow - pressure) analysis of fluid flow (low-pressure, medium-pressure and high-pressure gas, overheated steam, saturated steam, liquids and two-phase flows) several numerical methods were used at University of Maribor, Faculty of Chemistry and Chemical Engineering [4,5,6,7] but the LTM method (Linear Theory Method) was proved as the most suitable for flow - pressure calculation of conditions in pipe transmission systems. With this method the non-linear Darcy-Weisbach equation (see Equation 1) is linearised via pressure as follows:

$$q_{v,i} = \left|p_i - p_j\right|_{k+1} \cdot \sqrt{\frac{1}{K_{ij} \cdot \left|p_i - p_j\right|_k}} \tag{1}$$

where
$i = 1, 2, 3, .., n$;
$j = 1, 2, 3 ., n$; and
$k = 1, 2, 3, .., m$

K is coefficient of Darcy-Weisbach equation, k presents number of iteration, ***m*** presents maximum number of permitted iteration, ***n*** presents number of nodes, ***p*** presents fluid pressure in Pa and $\boldsymbol{q_v}$ presents volume flow in m^3/s.

Solution of the system of linearised non-linear hydraulic equations (see Equation 1) runs implicitly by assuming the initial node pressures in first step of iteration and by correcting them in every subsequent solution until the chosen relative accuracy is reached. The essential principle of the LTM algorithm is the implicit solution of the non-linear matrix calculation, which shows that the number of full elements in the matrix (elements other than zero) decreases by percentage with the size of the pipe network in comparison with the void elements (the matrix is sparse). As we already mentioned above, for the numerical solution of such matrix calculations ordinary numerical methods are not very suitable, so we developed a special numerical algorithm. As a result, we manage to perform hydraulic analysis on ordinary computers that lower the cost of calculation extremely. Analysis of computer program shows that we could speed up program execution even further if we perform some computer tricks. Revised and changed program perform very well. With this new program we could perform hydraulic analysis of

whole city network in real time (see Fig. 2). That opens the door for optimization of running costs.
In our case the running costs depends on different issues [8, 9, 10]:

- Fuel cost;
- Fixed costs; and
- Variable costs

Since it is necessary to assure that only legally permissible amount of waste gases is produced the heat transmission company is limited to use only gas or light fuel oil for heating the water. Primarily they use gas and storage of light fuel oil is a reserve if something goes wrong with the gas distribution.
Fixed costs consist of many subtypes:

- Operation costs of sensors and pumps
- Maintenance costs.
- Other fixed costs.

We find out that sensors and connection grid were very expensive [10]. Sensors are needed for feedback of the state of the hydraulic state of the network. If we are able to perform the hydraulic analysis with fewer sensors we could lower the costs of operation. Indeed we find out that our algorithm was capable to perform hydraulic analysis in given ranges with fewer sensors. Connecting the SCADA system to the analysis module we are able to perform real time analysis of network and even reconfigure running parameters for better performance.

Pumps are used for rectification of hydraulic flow in the network. If you apply pumps of hunch bases you can be sure they are not positioned on optimal (and needed) points on the network. It even may happen that pumps create zero flow in some segments of network. There are two ways to solve this problem [11]:

- Measurement or
- Hydraulic analysis

Measurement means installing new sensors for flow control. Sensors are expensive, installation cost is expensive and when you receive the results you still don't know what to do to correct the problem of insufficient flow.

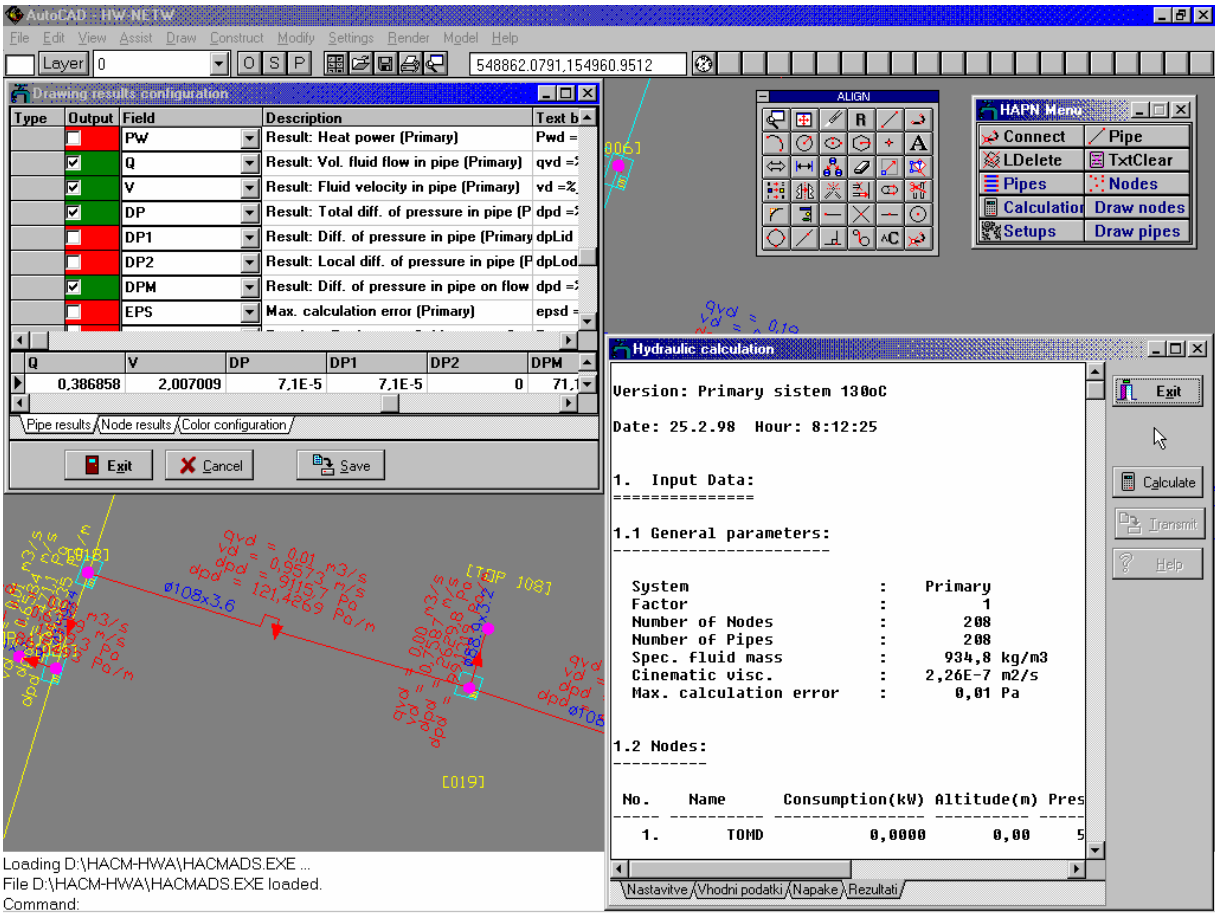

Fig. 2: Hydraulic Analysis of Pipe Network

3 Additional optimization

When all optimization inside one company is reached a new optimization can be found in the connection between different companies which are naturally bonded with their business. Local heat transmission company have reached the agreement with local gas distribution company to electronically exchange operational data. This enables those two companies to gain additional profit. Gas transmission company must plan the consumption of gas in advance. They buy gas from larger company that covers whole country. They have to pay for the required gas but if they need more gas then they demand in advance they pay penalties. It is not possible for a nation wide company to give infinite amount of gas and more consumption from one distributor might prevent other to get their planed amount of gas. During the analysis of the problem we find out it is possible to apply reserves of light fuel oil of the heat distribution company to prevent over consumption of gas from the gas distribution company.

Both companies can benefit from such information interchange. When other heat distribution companies in our country find out about our cooperation they started to observe and evaluate our approach. Main problem for existing companies are in their already established information system which were poorly designed. They still hesitate to start development. But new companies which were not bonded with previous information systems have applied our principles and have find themselves very competitive in modern society. Therefore we proved our approach and willing to test it further. As a result we also started with development of our version of technical information system (see Fig. 3) capable to connect otherwise less cooperative SCADA, GIS and pure business oriented information systems together. Here we present just one look on it, see [5] for more details on this.

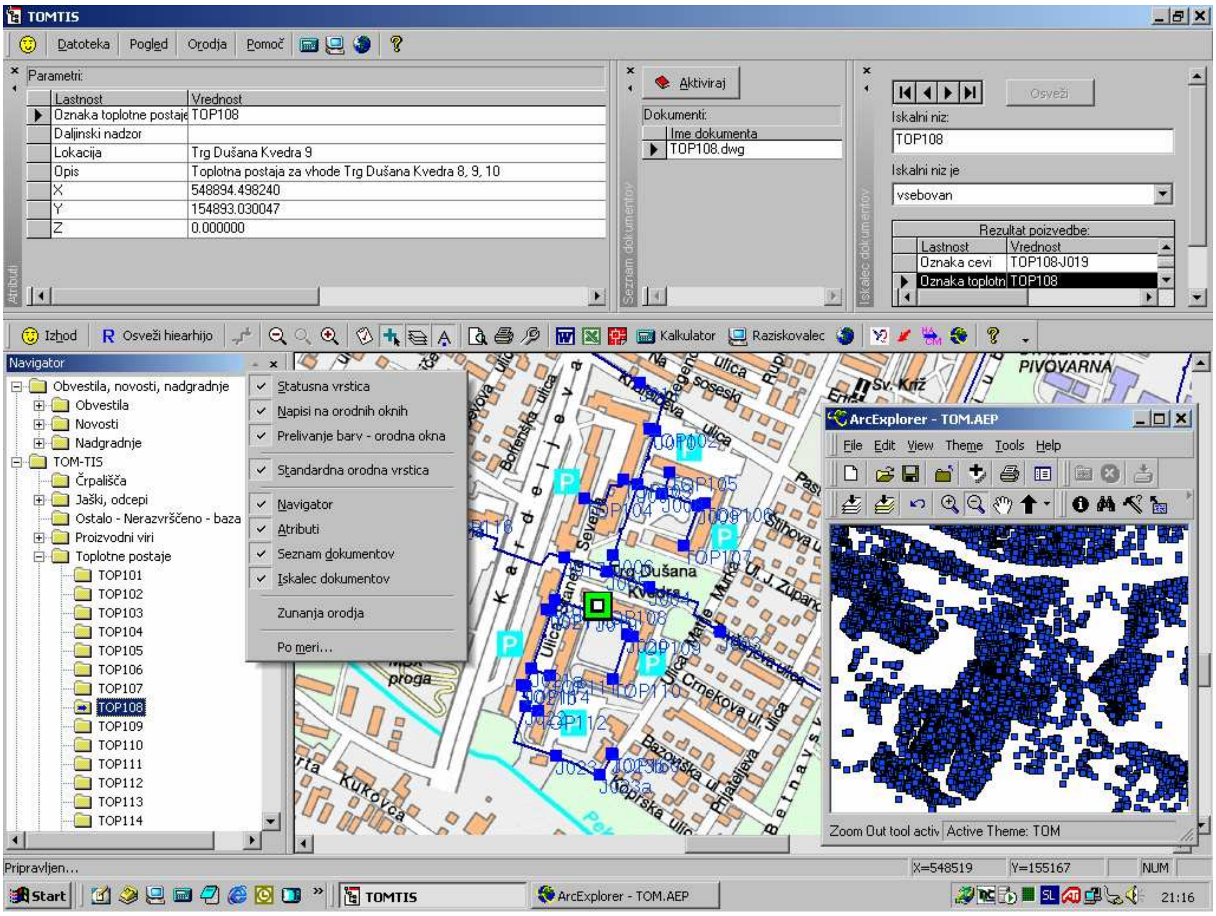

Fig. 3: Technical information system

4 Conclusion

Non renewable fuel is still running the world. In the near future this has to change but till then we need to use what nature stored in past millenniums wise. Times when our society could waste energy uncontrollably are over. Now we need to squeeze out every available bit of energy and make it our life habit. In cold climate it is necessary to heat living and working spaces. We aim to provide central heating for most of citizens in metropolitan area because it is generally more efficient than individual heating. To minimize the cost and maximize the effect we need to make optimization in operation parameters of heat transmission companies. But when we can no longer make optimization inside the company we need to find business to business optimization. In most cases it is not visible at first sight but careful analysis uncovers possibilities for benefits in both interconnected companies. We were able to establish information link between heat distribution company and gas distribution company for mutual benefit. The future of optimization is covered in B2B information systems which enable tighter cooperation between interested companies. They do not only exchange pure business information, but also real-time decisions. Decisions are supplied from an automated special-purpose decision make modules embedded into their technical information systems.

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