VIII. Strokovno posvetovanje Slovenskega društva za daljinsko energetiko,
Proizvodnja in distribucija v daljinski energetiki
Portorož, 30.marec – 1. april 2005

ECONOMICAL MANAGEMENT OF THE COMPLEX DISTRICT HEATING SYSTEMS

Jože Torkar, Marko Thaler*, Alojz Poredoš*, Igor Grabec*, Viktor Krajnc**

EL-TEC MULEJ, d.o.o., Bled
* Fakulteta za strojništvo, Univerza v Ljubljani / Faculty of Mechanical Engineering, University of Ljubljana
** JP Toplotna oskrba, d.o.o. Maribor

Abstract:

A reliable supply of heat for residential heating by means of district heating systems depends on faultless and stable operation. Economic success further requires high quality monitoring and control.

The paper presents a new approach to the monitoring and control of district heating systems while focussing on economic success. In this respect it is necessary to take into account a possible usage of various energy sources, with regard to energy consumption prediction and operational economic optimum, throughout the planning as well as in the managing, monitoring and maintenance of the district heating system.

In the presented paper we introduce an advanced control optimization system – ELTEC DOS – which uses the predictions of future energy consumption as the basis for an economically optimal system control. The predictions on future energy consumption are determined using a software package called INTELPRED, which is based on simulated neural networks and genetic algorithms.

The first test results of the introduced control system for the company JP Toplotna oskrba Maribor are described in the paper.

Keywords: district heating systems, dynamic optimization of operation, energy consumption forecast, simulated neural networks, genetic algorithms

1. INTRODUCTION

An economic management of complex district heating systems (DH) must embrace a rationalization of the operations of all components involved in the process of heat production and distribution. In this article one of the possible approaches to economic management of district heating systems is described. The management is based on determining the optimum supply temperature (inlet temperature of the system), the optimum flow-pressure conditions in the pipe network and the optimum heat production in the near future (a few hours to a few days in advance).

2. ECONOMIC MANAGEMENT OF COMPLEX DISTRICT HEATING SYSTEMS

An accurate knowledge of production and distribution capacities as well as of future consumptions of heat from the energy system should form the basis of economic management. The aim of the management is to fully meet consumers' needs, whilst preserving the lowest possible variable costs of production and distribution of heat.

Economic management requires accurate prediction of future heat consumptions as well as assessment of the risk of exceeding the limit values for heat consumption in the future. A forecast of the required variables is carried out with the INTELPRED software package. The calculated values are then forwarded to the economic module – ELTEC DOS – which then determines the optimum economic profile of heat production (fP(t)), supply temperature (fTd(t)) as well as a composition and time schedule for control measures, taking into account the relevant boundary conditions (Fig. 1).

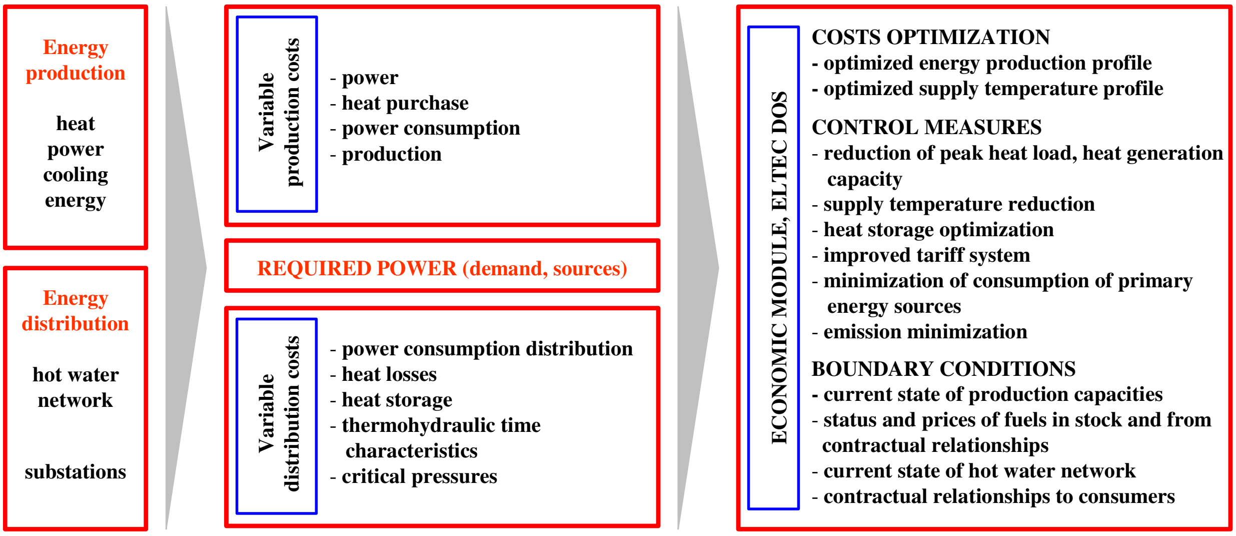

Figure 1: Structure and aims of economic management of complex DH systems

3. ELTEC DOS SOFTWARE PACKAGE

The ELTEC DOS (Dynamic Optimization of Systems) software package is designed (Fig. 2) to allow great adaptability to various configurations of different district heating systems. The main modules and their characteristics are described below.

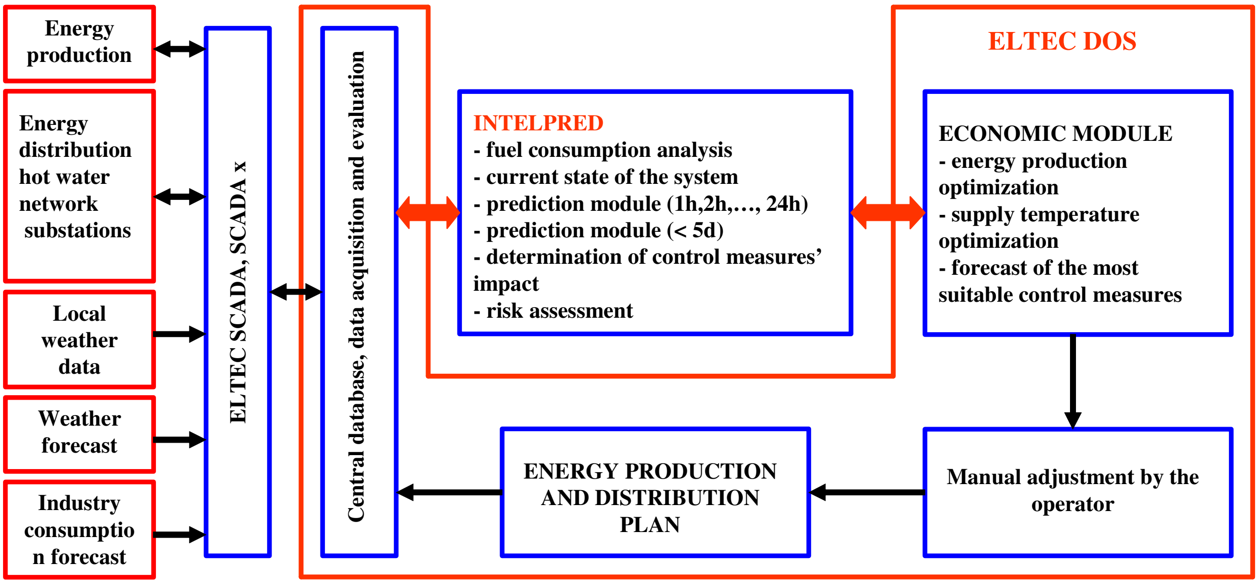

Figure 2: Diagram of the ELTEC DOS software package structure

3.1. CENTRAL DATABASE

In the central database the following data are recorded:

- current state of production sources (flow rate, capacity, supply temperature, etc.)
- current state of the hot water network (pressure and temperature values in different segments of the network)
- current state of district heating substations (load, secondary supply temperature)
- current local weather data (temperature, wind speed, insolation, etc.)
- short-term and long-term weather forecast (temperature, wind speed, insolation, etc.)
- short-term and long-term prediction of heat consumption for industrial consumers (demand, secondary supply flow pipe temperature, etc.) and
- control measures according to the production and distribution plan.

Data exchange between the central database, SCADA (Supervisory Control and Data Acquisition) systems, INTELPRED software package and the ELTEC DOS software package is carried out via a standard ODBC (Open Database Connectivity) driver.

3.2. INTELPRED

The INTELPRED software package enables energy consumption forecast in all types of district heating systems. It is based on methods of simulated neural networks and genetic algorithms. On the basis of available data on the operation of the selected district heating system, INTELPRED creates a model of system operation and response to control measures. In so doing, it determines the connections between the individual environmental variables' values and energy consumption in the system. On the basis of the system's current state and the given predicted future values of certain environmental variables, the software forecasts future system operation and assesses the risk of exceeding the set energy consumption limit values in the future. The estimated forecasts and risk of exceeding the energy consumption limit values in the future form the basis for the determination of the economically most appropriate heating system control. A detailed description of the INTELPRED software package is given in the bibliography [1].

3.3. ECONOMIC MODULE

On the basis of the forecasted consumption and the minimal supply temperature, the heating system's economic module simulates several different strategies for system control. Once the simulations are completed it chooses the control strategy that ensures the minimum of a cost function. The cost function takes into account the following parameters:

- current operating conditions (current output of facilities, stand-by mode, operational mode, etc.)
- short-term and long-term consumption forecast (thermal power, minimal supply temperature)
- heat tariff system
- power tariff system
- costs of primary energy sources
- contractual restrictions
- start-up costs
- operation costs etc.

Based on this data a schedule of different control measures is determined and an energy production and distribution plan established.

3.4. ENERGY PRODUCTION AND DISTRIBUTION PLAN

The system operator can accept or correct the proposed control measures. After his examination a short-term energy production and distribution plan is drawn up. The data are transmitted to the central ELTEC DOS database, where they are subjected to various system control tools.

4. THE MAIN COMPONENTS OF THE DISTRICT HEATING SYSTEM

An accurate knowledge of the operations of all system elements and of their interconnection is a prerequisite for achieving optimum results.

4.1. DISTRICT HEATING SUBSTATIONS

The operation quality of a substation and data exchange with the control centre can to a large extent influence the operating efficiency of the whole DH system. To achieve the optimum substation operation parameters, it is of crucial importance to correctly plan, execute and control the secondary system and elements of substation whose core is the electronic regulator [2, 3, 4]. Some important functions which must be locally provided for by the electronic regulator of the district heating include:

- set-up of at least a 3-point heating characteristic to accurately describe a facility's characteristic
- set-up of different parallel displacements in different heating modes
- reference step for a change over from reduced to normal heating mode
- reference step for a change over from normal to reduced heating mode
- calculation of compensated outdoor temperature
- calculation of the heat station' daily, monthly and yearly efficiency factor (Fed, Fem, Fey)
- limitation of the maximum temperature in the primary return flow pipe
- limitation of the maximum connected load and
- limitation of the maximum flow rate.

The heat station efficiency factor enables a fast detection of those consumption points in the DH system where its functioning could be improved with minor interventions at the primary or secondary side.

Listed below are the data necessary for optimal system management, which must be sent to the control centre by the electronic regulator:

- reference and actual temperature in the secondary supply flow pipe
- primary supply and return temperature values
- current load
- current flow rate
- cumulative energy use in the defined period
- cumulative flow in the desired period and
- primary supply and return flow pipe pressure values.

Data on the state of the system are gained via a remote monitoring and control system for substations. The main advantages of this system are:

- alerting of irregularities in operations (improvement of the quality of the service, reduction of repair costs)
- data archiving (overseeing system operations, complaint settlement) and
- on-line execution of control measures (optimization of operations, lower operational and maintenance costs).

4.2. DISTRICT HEATING NETWORK

District heating networks are generally complex piping networks, composed of numerous straight sections, junctions or loops. Specialized software packages like HACM, Stanet etc. enable static hydraulic analysis of different types of piping networks [5, 6, 7]. The data obtained are crucial for the design of the hot water network, determination of the optimum configuration of pumping stations, detection of critical points in the system and assessment of possibilities for consumption extension.

For optimal management of the system the pipe network models must be simplified by grouping into individual units. In this way the model can be simplified by 80-95% without any significant deterioration in accuracy [8]. However, it is important to preserve some important characteristics of the network, such as the volume of the medium in the pipe network, time lags, mass flow, heat losses and pressure conditions. The simplified model must agree with the real model to a certain level of accuracy, especially as regards pressure conditions and heat transfer dynamics.

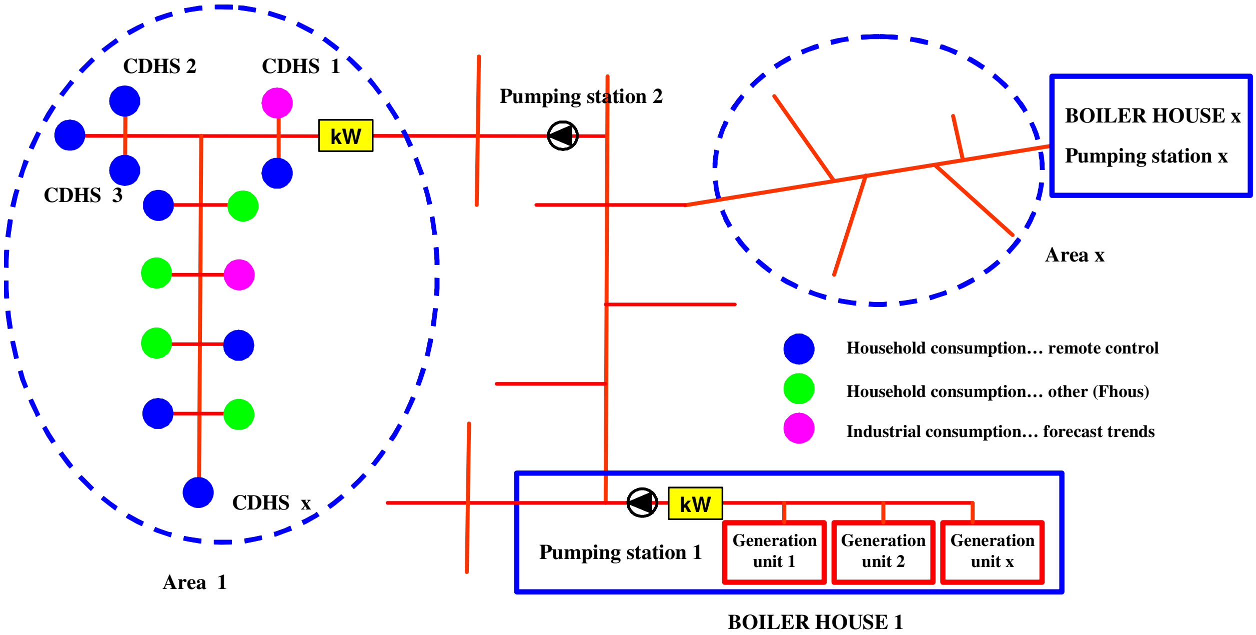

Figure 3: Simplification of the pipe network

The data on the state of the system, arranged according to units, form the inputs to the central database of the ELTEC DOS system. Consumption and lowest supply temperature forecast is established according to individual units. Knowing the heat transfer dynamics (static model, measurements) and the current pressure conditions in the pipe network (measurements), we can determine the temperature time profile and the necessary flow rate value for individual network units. These data are the input for the pumping station controllers which control the frequency controllers of the pumps. Controlling pumping stations on the basis of the known required flow rate [9], rather than on differential pressure based control, has become established practice world-wide. In this way, power savings in the range of 25-30% may be achieved.

4.3. ENERGY PRODUCTION

Heat may be produced separately or be co-generated together with electricity (CHP). In both cases it is important to have the optimum management of energy production with respect to profit, with all technical boundary conditions provided for [10]. The aim of the optimum production control is to produce as much heat as possible from low-cost and environment-friendly sources. To achieve this goal, two elements are extremely important, namely:

- choice of the right configuration of production sources at the time of installation planning, considering the hourly profile of consumption in the hot water network and

- establishment of and optimum energy-production plan, in accordance with high-quality short-term and long-term prediction of heat consumption and minimum supply temperature (ELTEC DOS, INTELPRED).

On the basis of the predicted consumption and minimum supply-temperature profile and considering the minimal cost function, the economic module prepares a heat production plan.

Figure 4 shows the consumption of heat in the network of the company TOM (Javno podjetje Toplotna Oskrba Maribor d.o.o.). The dashed line indicates the consumption levels in 2004. The diagram shows that up to a heat demand of approx. 7 MW, heat was produced from a cheaper source in comparison with 2003. This result was achieved thanks to the choice of a suitable combined heat and power production facility (CHP: Qel=3 MW, Qth=3 MW) and the storage of surplus heat capacities in the pipe network.

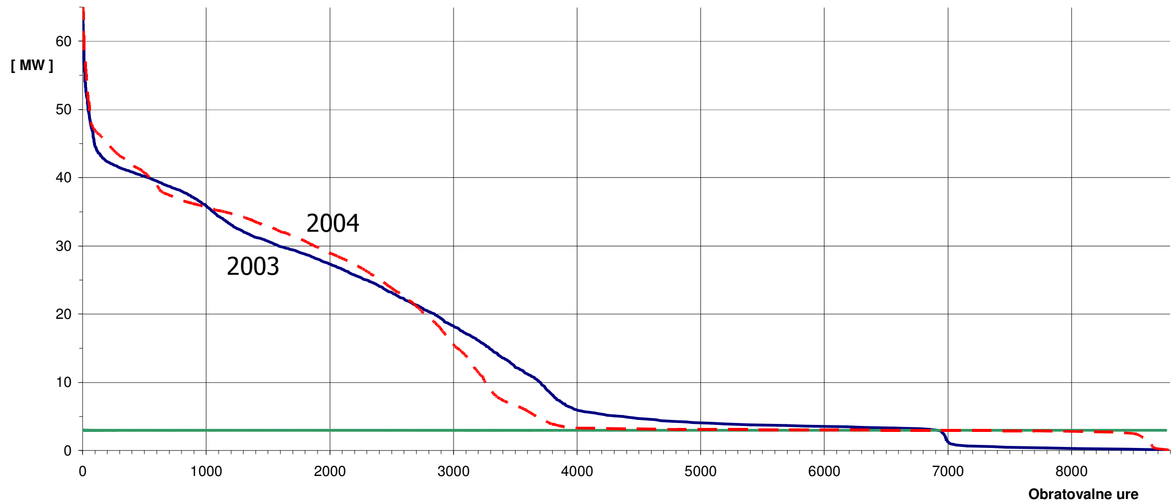

Figure 4: Hourly profile of heat consumption in the TOM network

5. CONCLUSION

Consumers are demanding ever improving services at lower prices. The market for energy sources is open or has been opening. Heat producers and distributors must be ever more competitive, which is possible with greater efficiency and flexibility. The required return on investment can be achieved by taking good organization measures and by cutting heat production and distribution costs.

The products of EL-TEC MULEJ (KTP BLED, ELTEC TP-01, ELTEC TP-03, ELTEC SCADA) have so far provided heat distributors with effective monitoring and control of consumption points. In the last two years our development work in cooperation with the Faculty of Mechanical Engineering, Ljubljana, and the Faculty of Chemistry and Chemical Engineering, Maribor, has been directed towards the development of products and services for economical management of heat production and distribution. One of the results of this development work is the ELTEC DOS software package, which operates on the basis of the most accurate possible heat consumption forecasts (INTELPRED) and chooses control measures with regard to the minimum of the cost function, while ensuring the stability of the system's operation.

All of the operational tests are being executed on a medium-size district heating system (Qconsumption = 94 MW), in cooperation with the company Javno podjetje Toplotna oskrba, d.o.o. Maribor. Currently, two INTELPRED modules, the data acquisition module and the consumption prediction module, are in the operational test phase. The development of the phase 1 of the economic module is scheduled to be concluded by autumn 2005, while conclusion of operational testing of the entire system is scheduled in the 2005/06 heating season. In 2006 the ELTEC DOS software package with the accompanying services will be ready for launch onto the market. The values of production and distribution savings are expected to range from 2% (summer operations) to 7% (winter operations).

Equipped with powerful software and armed with expertise, we intend to offer complex services to heat distributors, thus taking over our share of responsibility for the efficient use of energy in district heating systems as well as for the better utilization of renewable sources and heat from combined heat and power plants (CHP).

6. BIBLIOGRAPHY

[1] Thaler M., Poredoš A., Grabec I., Torkar J.: Napoved rabe energije kot osnova za vodenje daljinskih energetskih sistemov, VIII zbornik SDDE, Portorož, marec 2005
[2] Robič M., Torkar J.: Sistem daljinskega nadzora in upravljanja toplotnih postaj, III zbornik SDDE, Portorož, marec 2000, pp.139-148.
[3] Torkar J., Robič M., Erklavec M.: Odprti sistemi avtomatizacije - LONWORKS, IV zbornik SDDE, Portorož, marec 2001, pp.155-164.
[4] Torkar J., Jakl A., Goričanec D., Perc A., Robič M.: Dinamično optimiranje obratovanja vročevodnih sistemov, V zbornik SDDE, Portorož, marec 2002, pp.57-66.

[5] Krope J., Goričanec D.: Analysis of Pipe Networks Including Pumps, Energy and Buildings, Lausanne 17, 1991, pp.141-145.
[6] Goričanec D., Krope J.: Pretočno-tlačna analiza procesnih omrežij v odvisnosti od stopnje odprtosti ventilov, Strojniški vestnik, Ljubljana, 33, 1987, 10-12, pp.179-180.
[7] Krope J., Goričanec D. and Garbai L.: Optimal Design of Processing Networks, Hungarian Journal of Industrial Chemistry, Budapest 23, 1995, 3, pp.161 -165.
[8] Boehm B.: Simple models for operational optimisation, News from DBDH, 3/2002, pp.10-15.
[9] Moller H., Widell E., Ribickis L., Hansen I.: Energy efficient pump control, News from DBDH, 4/2002, pp.30-33.
[10] Munck A.: Optimisation of operational planning in CHP plants, News from DBDH, 4/2002, pp.26-29.