PREDICTION OF THE HEAT SUPPLY DAILY DIAGRAM VIA ARTIFICIAL NEURAL NETWORK

The paper deals with the utilization of time series prediction for control of technological process in real time. An improvement of technological process control level can be achieved by time series analysis in order to prediction of their future behavior. We can find an application of this prediction also by the control in the Centralized Heat Supply System (CHSS), especially for the control of hot water piping heat output.

Knowledge of heat demand is the base for input data for operation preparation of CHSS. Term "heat demand" is instantaneous required heat output or instantaneous consumed heat output by consumers. It is possible the heat demand divide in:

- air temperature dependent
  - heating
  - ventilating
  - air-conditioning
- air temperature independent
  - preparation of domestic hot water
  - food preparation
  - production purpose

Term "heat demand" relates to term "heat consumption". It express heat energy, which is the customer supplied in a specific time interval (generally day or year).
The course of heat demand and heat consumption can be demonstrated by means of heat demand diagrams. Most important are:

- **heat supply daily diagram**, which demonstrates the course of requisite heat output during the day. (See fig.1)
- **duration heat demand diagram** – Y - coordinates represent heat demand and distance from zero represents duration of corresponding heat demand. At present there are known duration heat demand diagrams daily and yearly.
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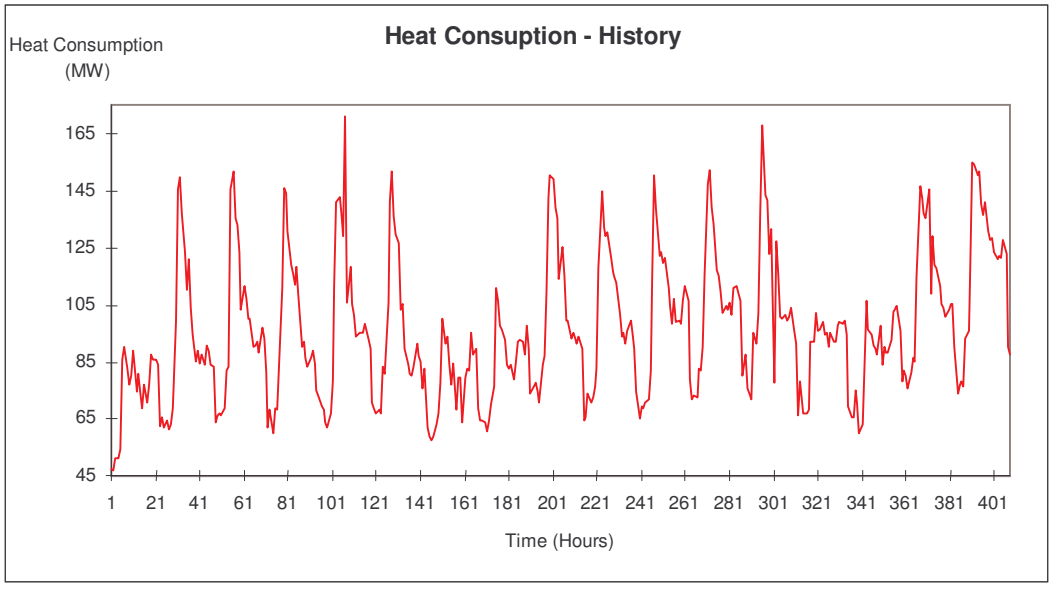

Fig. 1. Heat Supply Daily Diagram

These diagrams are most important for technical and economic consideration. Therefore forecast of these diagrams course is significant for short-term and long-term planning of heat production. It is possible to judge the question of peak sources and namely the question of optimal distribution loading between cooperative production sources and production units inside these sources according to time course of heat demand.

In our case the forecast of HSDD is determined for two way of using:

The predictions of whole HSDD. The forecast of HSDD (see fig.1) of whole CHSS is utilized for the purpose of heat production control and thus for the purpose of the optimal distribution loading between cooperative production sources and production units inside this sources. The main purpose of forecast is the short-term preparation of production during 24 hours, when we determine minimal heat consumption and fuel consumption. It conduces to economy and ecology operation.

The prediction is determined for continuous acquisition of needy heat output ahead of the time. It is depend on transport delay, namely in the range of 2 up to 16 hours depending on distance of heat sources from consumers, it is different for each locality. The "Qualitative-quantitative method of hot-water piping heat output control - Balátě system" enables to eliminate this transport delay by means of instantaneous and continuous acting of qualitative and quantitative parts of control method. The prediction of HSDD course is an essential part of this solution.

The further research consists on inclusion of weather influences in calculation of HSDD forecast. By means of testing has been showed that course of HSDD time series is dependent not only on daily period (fluctuation during the day), weekly period (heat consumption loss on Saturday and Sunday) and yearly fluctuation (spring, summer, autumn, winter) but also on meteorological data. Firstly we take into account of barometric pressure, outdoor air temperature and wind velocity.

Among the most important tools for prediction of time series are ARIMA models, genetics algorithms and artificial neural networks. The time series of heat consumption mainly contains these components: deterministic tendency, deterministic periodicity with constant cycle and sometimes deterministic chaotic and random ones.

The energy time series predictions were tested by means of the ARIMA model by the SIBYL program, by means of genetic algorithms by the GeneHunter program and by means of artificial neural network by NeuroForecaster program.

The calculation of HSDD prediction was made by means of artificial neural network. We have used the software Neuroforecaster by firm of New Intelligent Business Software for calculation. Some windows of program environment are shown in figures 2, 3 and 4.

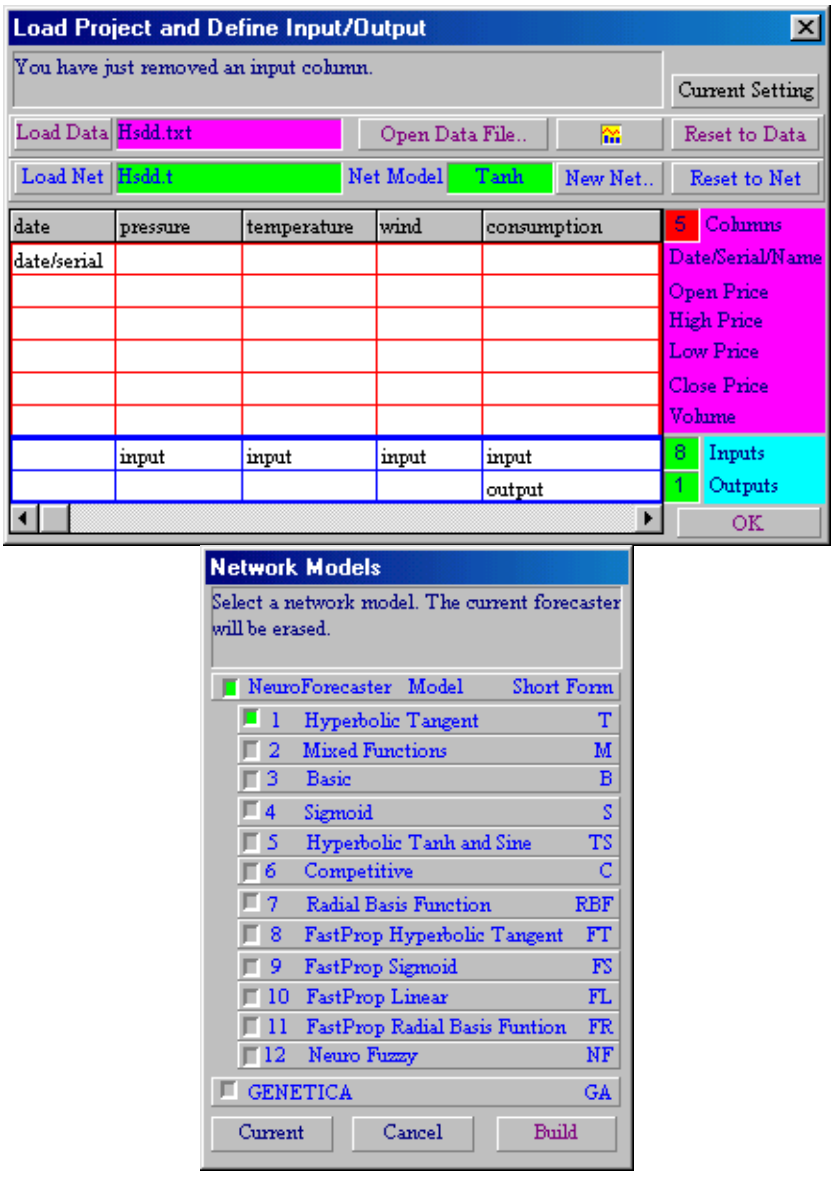

Fig.2. Selection of Inputs, Outputs and Transfer Function

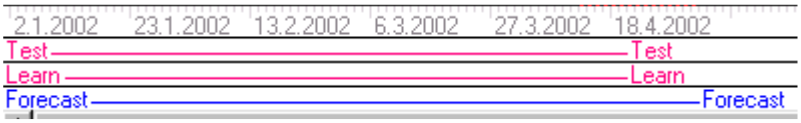

Fig. 3. Selection of Data for Testing, Learning and Forecasting

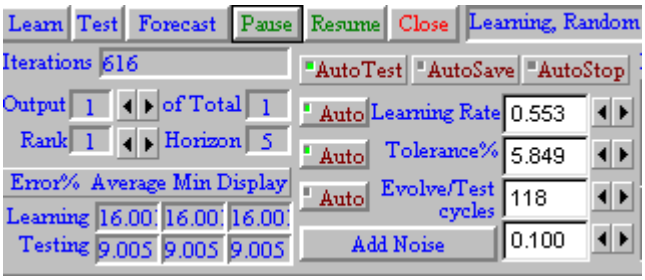

Fig. 4. Result Table of Testing and Learning

In the following we are going to present a sample of calculation of HSDD by means of neural network. We use real data of heat consumption for the city of Olomouc in MW from 0:00 on 1.11.98 to 23:00 on 17.11.98. That represents 408 values by hourly sampling. We will make prediction for 48 hours ahead. In this example the neural network with these parameters have been used:

- 4 layers of network
- "Back propagation" algorithm for learning
- 200 values have been used for learning
- transfer function – "Hyperbolic Tangent"

Calculation have been made for:

1. prediction of HSDD without inclusion of meteorological influences
2. prediction of HSDD with inclusion of meteorological influences (The course of barometric pressure, outdoor air temperature and wind velocity is shown in figure 5,6).

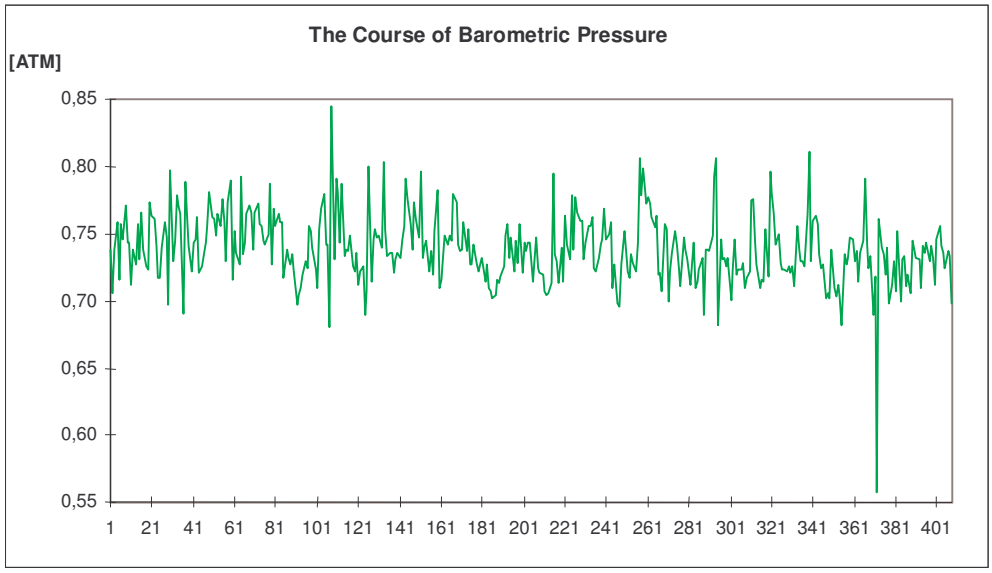

Fig. 5. The Course of Barometric Pressure

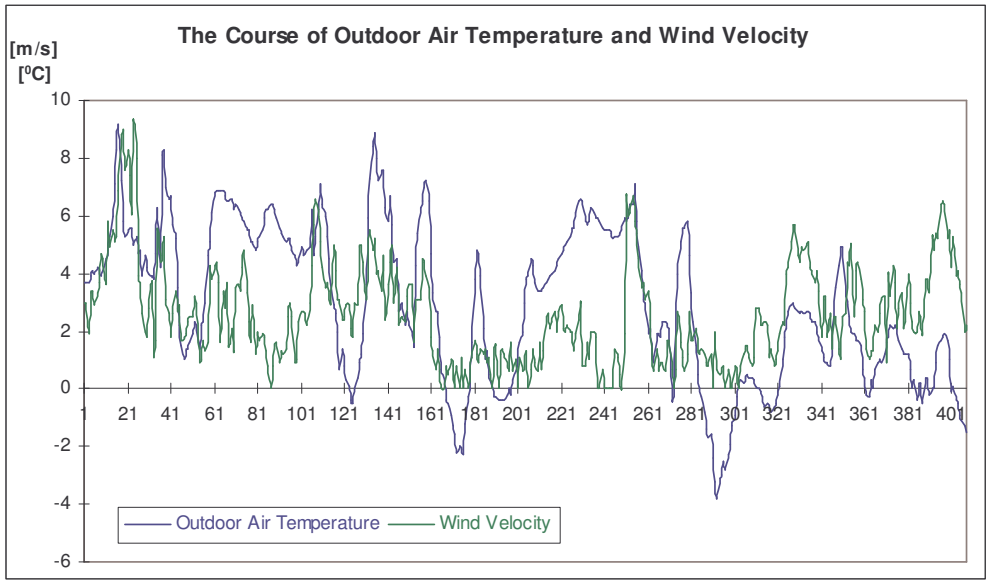

Fig. 6. The Course of Outdoor Air Temperature and Wind Velocity

The results of calculation of HSDD forecast are present in figure 7. The actual values are shown by square line, the predicted values, where the weather data were not included in calculation, are shown by circle line and the predicted values, where the weather data were included in calculation, are shown by triangle line.

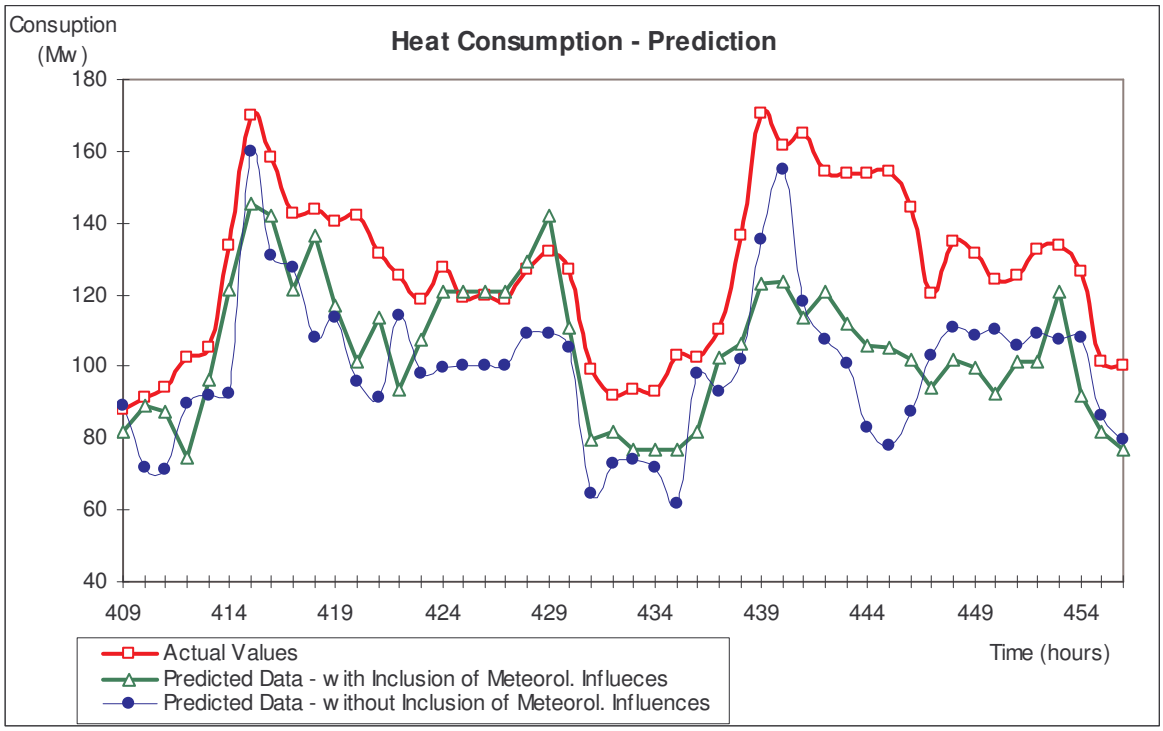

Fig. 7. Results of HSDD Forecast

The better results, which give 22 % more precise predicted values, were given when the weather data were included to the inputs of calculation (Mean Average Predicted Error MAPE = 0.169) in comparison when the weather data were not included to the inputs of calculation (MAPE = 0.206). Therefore it is better to use for the calculation of prediction of heat consumption not only the past values of heat consumption, but also barometric pressure, outdoor air temperature and wind velocity.

It is useful to use another measured data, which influence the heat consumption and the course of HSDD for obtaining the more precise prediction. The data of wind direction, outdoor humidity and sunshine can be covered up, too. For those purpose it was provided and installed weather station by firm Conrad.

This weather station enables to measure air temperature, wind velocity, wind direction, exposure (intensity of solar radiation), air humidity and air pressure. The program for monitoring measured data in real time is also a part of weather station. This program enables data acquisition and data processing on PC. Sample of program environment for measuring and monitoring weather influences is in the figure 8. This weather station will be used for next research. It should help in inclusion of the next meteorological data for calculation of HSDD forecast.

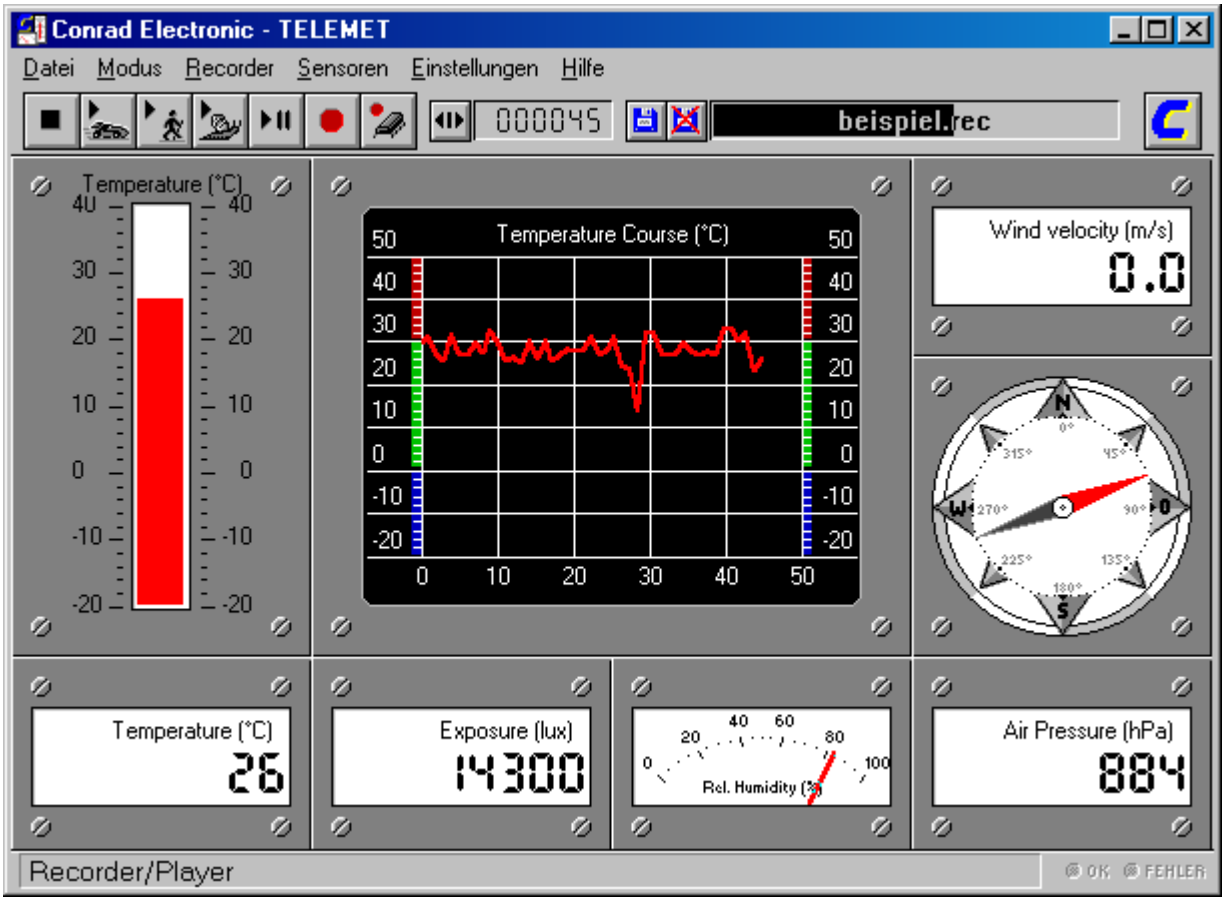

Fig. 8. Environment for Measuring and Monitoring Weather Influences

The prediction enables us to make a decision making process more efficient.