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FORECAST OF HEAT SUPPLY DAILY DIAGRAM FOR CONCRETE LOCALITY

Bronislav Chramcov
Tomas Bata University in Zlín, Faculty of Applied Informatics
Mostní 5139, 760 01 Zlín
Czech Republic

Jaroslav Balátě
Tomas Bata University in Zlín, Faculty of Applied Informatics
Mostní 5139, 760 01 Zlín
Czech Republic

ABSTRACT
The paper deals with prediction of Heat Supply Daily Diagram (HSDD) course for concrete locality. This diagram is most important for technical and economic consideration. Therefore forecast of this diagram course is significant for short-term and long-term planning of heat production. We focus also on improvement of HSDD forecast by means of inclusion of Outdoor temperature influence. For prediction of HSDD is utilized method of Box-Jenkins.
Keywords: prediction, district heating control, Box-Jenkins

1. INTRODUCTION
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. 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

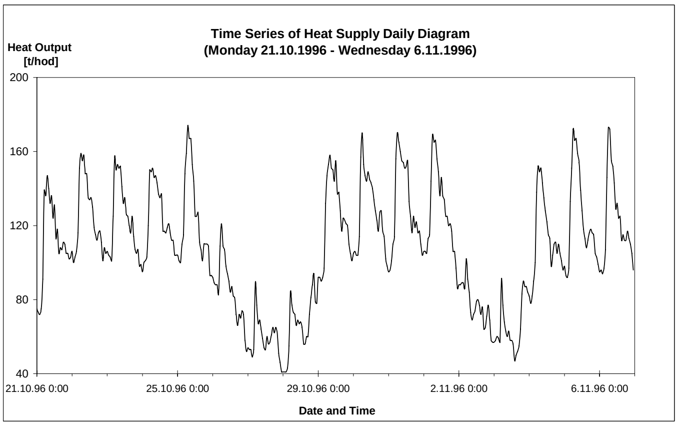

Figure 1. Heat Supply Daily Diagram for concrete locality

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. The forecast of heat supply daily diagram (HSDD) is used in this case.
In our case the forecast of HSDD is determined for two way of using:

1. The predictions of whole HSDD. The forecast of HSDD 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.
2. 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..

2. METHODS OF FORECAST – BOX-JENKINS METHOD

It is possible to use different solving methods for calculation of time series forecast. (For example: solving by means of linear models, solving by means of non-linear models, spectral analysis method, neural networks etc.)
In former times was created a lot of works, which solve the prediction of HSDD and its use for control of District Heating System (DHS). Most of these works are based on mass data processing. But these methods have a big disadvantage. It consists in out of date of real data. From this point of view is available to use the forecast methods according to the methodology of Box –Jenkinse [3]. This method works with fixed number of values, which are update for each sampling period.
This methodology is based on the correlation analysis of time series and it works with stochastic models, which enable to give a true picture of trend component and also of periodic components. Because this method achieves very good results in practice, it was chosen for calculation of HSDD forecast.
The course of time series of HSDD contains two periodic components (daily and weekly period). But general model according to BJ enables to describe only one periodic component. We can propose two eventual approaches to calculation of forecast to describe both periodic components[4].

- **The method, that uses the model with double filtration**
- **The method – superposition of models**

Pursuant to the theory and literature a program was created in Matlab. This program enables to choose available mathematical statistical model for calculation of prediction of HSDD course and it is used for forecast of HSDD, which is an essential part of control of DHS by means of Qualitative-Quantitative method. All testing and calculations are based on lot of real data. These data were obtained in specific locality.

3. INCLUSION OF OUTDOOR TEMPERATURE INFLUENCE

Above mentioned methods do not describe sudden fluctuation of meteorological influences. In this case we have to include these influences in calculation of prediction.
Previous works on heat load forecasting [1], show that the outdoor temperature has the greatest influence on HSDD (with respect to meteorological influences). Other weather conditions like wind, sunshine and so on have less effect and they are parts of stochastic component. For inclusion of outdoor temperature influence in calculation of prediction of HSDD was proposed this general plan:

a) The influence of outdoor temperature filter off from time series of HSDD by means of heating characteristic (function that describes the temperature-dependent part of heat consumption)
b) Prediction of HSDD by means of Box-Jenkins method for this filtered time series
c) Filtration of predicted values for the reason of inclusion of outdoor temperature influence (on the base of weather forecast)

From the previous plan is evident that the principal aim is **to derive an explicit expression for the temperature-dependent part of the heat load**. That means, we have to derive heating characteristic. It is obvious that the temperature dependence is non-linear. For relatively high outdoor temperatures, the temperature has less influence. For example, the load will almost be the same for 25 °C and 27 °C. A corresponding conclusion is also true for relatively low temperatures, e.g. whether the outdoor

temperature is -28 °C or -30 °C does not matter, the production units will produce at their maximum rate anyway.
Regarding to previous consideration we can used the temperature-dependent part of heat consumption in the form:

$$z_t^{kor} = x_1 \cdot T_t^3 - x_2 \cdot T_t \qquad (1)$$

where: z_t^{kor} is correction value of heat consumption in time t including outdoor temperature influence, T_t is real value of outdoor temperature in time t , x_1, x_2 are constants. The course of heating characteristic for constants $x_1 = 0.002$, $x_2 = 3.5$ is shown in the figure 2.

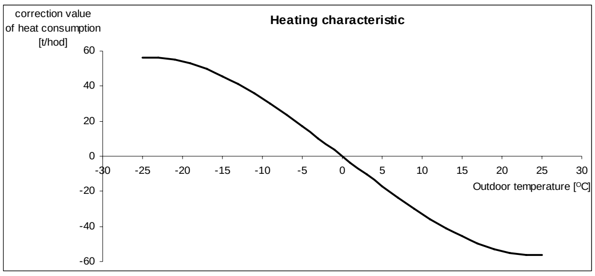

Figure 2. The sample of heating characteristic (cubic function)

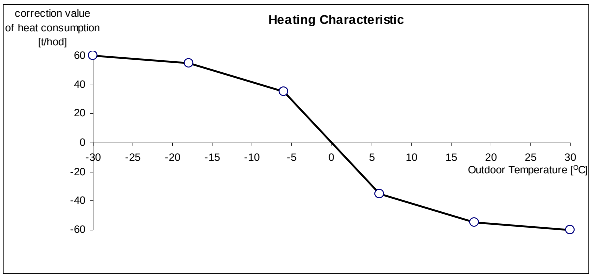

Figure 3. Heating characteristic (piecewise linear function)

The temperature dependent part can assumed to vary as a piecewise linear function, see the illustrating example in figure. 3 [5]. Here a function with five segments is used, but the number of segments can of course be chosen arbitrarily.
Given the number of segments as a N_s. and the temperature levels as $\tau_i, i = 1,...,N_s + 1$. Now we can consider the temperature-dependent part of heat consumption in the form:

$$z_t^{kor} = \alpha_i \cdot T_i + \beta_i \qquad (2)$$

where: z_t^{kor} is correction value of heat consumption in time t including outdoor temperature influence, T_t is real value of outdoor temperature in time t ,α_i is the slope of i-th segment, β_i is absolute equation term of i-th segment. Constants (x_1, x_2 and ,α_I, β_i) have to be determined for concrete locality empirically.
Filtration time series of HSDD that inputs in prediction model is defined as:

$$z_t^{filtr} = z_t - z_t^{kor} \qquad (3)$$

where: z_t^{filtr} is heat consumption in time t with filtering off the influence of outdoor temperature, z_t^{kor} is correction value of heat consumption in time t including outdoor temperature influence, z_t is real value of heat consumption in time t. Example of the course of time series of HSDD before filtration and after filtration is shown on figure 4 and figure 5.

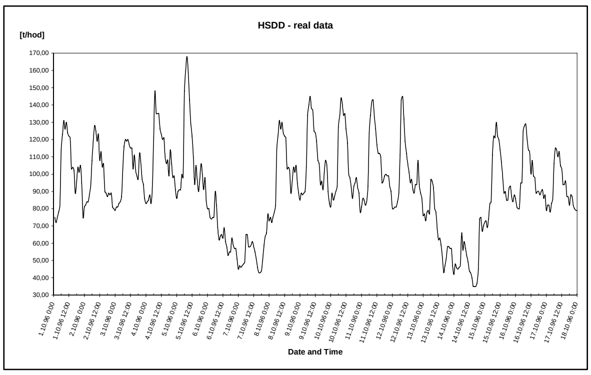

Figure 4. The course of HSDD before filtration

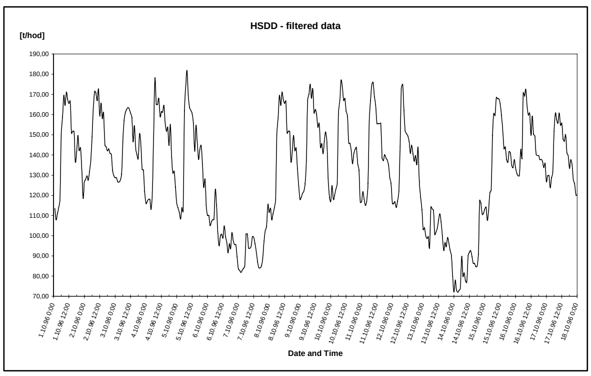

Figure 5.The course of HSDD after filtration

After prediction calculation of filtering off time series is necessary to filtrate the predicted values for the reason of inclusion of outdoor temperature influence (on the base of weather forecast). We can define this operation in the form:

$$z_t^+ = z_t^{filtr+} + z_t^{kor} \tag{4}$$

where: z_t^{filtr+} is predicted value of filter off time series of heat consumption in time t, z_t^{kor} is correction value of heat consumption in time t including outdoor temperature influence, z_t^+ is predicted value of heat consumption in time t. The value z_t^{kor} is obtained by application of the equation (1) or (2) for this operation. We use weather forecast (temperature forecast).

d) Concrete Results of HSDD prediction

We use real data measured in concrete locality (in our case in the city Zlin) for calculation. In this case we realized the calculation of HSDD prediction for Saturday 2.11. 1996. In this time we can observed the perceptible increasing the outdoor temperature compared to days before. The samples of results of HSDD prediction are shown in the figure 6 and 7.

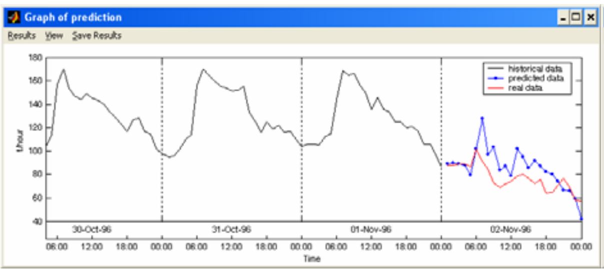

Figure 6. The course of HSDD prediction without inclusion of outdoor temperature influence

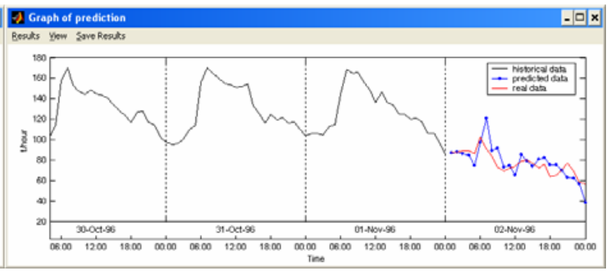

Figure 7. The course of HSDD with inclusion of outdoor temperature influence

4. CONCLUSION

The paper presented a method for inclusion of outdoor temperature influence in calculation of HSDD prediction. This prediction of HSDD is necessary for qualitative-quantitative control method of hot-water piping heat output – Balátě system.

5. ACKNOWLEDGEMENT

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