Methods and Instruments for Power Consumption Forecasting in Electric Power Companies

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***Abstract* – The present paper proposes a solution to the analysis and forecasting of power consumption. The authors have developed forecasting methods based on a seasonal shape technique and meteorological factor consideration technique. The software is designed on the basis of the aforesaid techniques. This software is the main tool used by more than 100 electric power companies in Russia and Ukraine as well as the main tool for power consumption planning by the System Operator of the United Power System of Russia.**

***Keywords:* II-82,industrial applications of Internet technologies, II-83,web technology and SoA,CC-10,modelling**

I. INTRODUCTION

To ensure the operation of Electric Power Systems, one of the most urgent tasks is the planning of operating mode parameters and performance. The forecast values of expected power consumption by groups of consumers, individual consumers and power systems are one of the basic indices for energy grid planning and utility company activities.

Power consumption is forecasted by dispatch control centres, utilities and consumers. The forecasting technology includes methods and means for source data preparation, forecasting methods and algorithms, processing means for computed results and other processes [1], [2]. The solution described in the paper allows implementing all forecasting processes and provides the required accuracy of analyses.

II. LOAD FORECASTING METHOD

Power consumption forecasting algorithms implemented in the solution are based on the seasonal shape method [1], which allows for the analytical description of power consumption and meteorological factor variations during the year:

$$P(i)=P_0(i)+P_{seas}(i)+\ \delta P(i)+\ \gamma P(i), \quad (1)$$

where i is an hour of the day (1 ÷ 24);

P(i) is the actual power consumption;

$P_0(i)$ is a reference component defined by industrial operating cycles, daily and weekly load shape irregularities;

$P_{seas}(i)$ is the seasonal component (the seasonal shape) defined by a year-round seasonal bias. This component is primarily provided by deep seasonal oscillations of meteorological factors, i.e., temperature and illumination;

$\delta P(i)$ is the component determined by irregular variations of meteorological factors; and

$\gamma P(i)$ is the residual component determined by the effect of unaccounted factors.

The reference component $P_0(i)$ is defined by industrial operating cycles and the non-industrial power consumption minimum and represented by summer power consumption. The seasonal component $P_{seas}(i)$ is closely correlated with deep seasonal oscillations of ambient air temperature and the stable natural illumination component (daylight hours). The unique feature of the seasonal shape method is that the annual shape of the seasonal component (seasonal shape) is calculated for each hour of day separately (Fig. 1). In practice, a set of functions consisting of 24 seasonal shapes is used.

Seasonal shapes of meteorological factors (temperature, illumination) are simulated in the same way. Temperature and illumination are also represented as a sum of two components:

$$T(i)=T_{seas}+\ \delta T, \quad (2)$$

$$Q(i)=Q_{seas}+\ \delta Q, \quad (3)$$

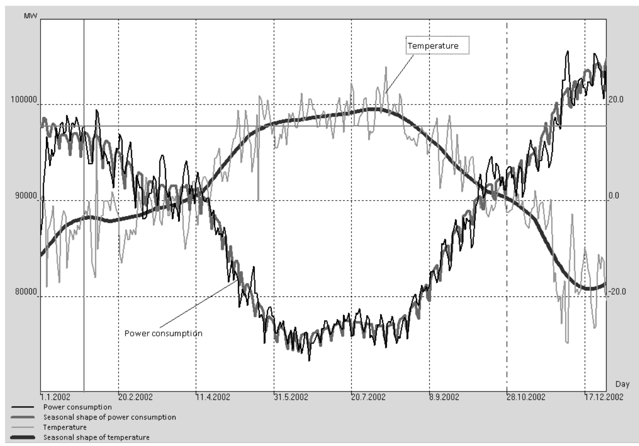

Fig. 1. Anual data of power consumption, temperature and seasonal shapes of Moscow power system for hour 20.

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where T_{seas} and Q_{seas} are seasonal components (seasonal shapes) of meteorological factors determined by regular year-round seasonal variations; and

δT, $\delta Q$are deviations of meteorological factors from the seasonal component caused by alteration in meteorological conditions.

P_{seas}, T_{seas}, and Q_{seas} are approximated by Fourier polynomials. The load dependence on meteorological factors is simulated by multiple regression equations.

Based on the method proposed, an Energostat software solution is developed as an application for MS Windows and a website. This software suite is used for the analysis and forecasting of power consumption by more than 100 electric power companies in Russia and Ukraine. It is also the reference software package for the analysis and forecasting of power consumption by the System Operator of the United Power System of Russia (SO UPS) [3].

III. Energostat Data Analysis and Forecasting Service

The Energostat Data Analysis and Forecasting Service provides tools for the analysis and forecasting of power consumption and other performance indicators implemented as a cloud service (Fig. 2) accessible for the user community.

The main advantages of the use of cloud technologies in forecasting are as follows:

- A possibility to use the Forecasting Service tools from different places (at work, at home etc.), from different hardware platforms and from any devices with web access, including mobile devices;
- No software is required at the client side; therefore, administration and support costs are reduced;
- Simple data interchange among various users databases in the cloud; and
- Quick access to suitable forecasting tools provided to various enterprises (utility, grid and generating companies, their branches and large consumers).

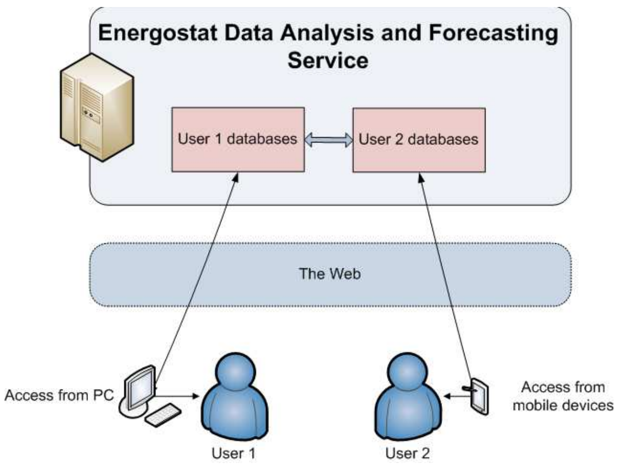

Fig. 2. Access to the Energostat Data Analysis and Forecasting Service.

The basic functions of the Forecasting Service are as follows:

- Preparation of the parameter structure in the database;
- Loading data for analysis –from text files, MS Excel files, XML layouts, SCADA and other sources;
- Data viewing and analysis, statistical analysis and meteorological factor effect investigation;
- Forecasting and analysis of forecast accuracy;
- Data exchange among users, branch and subdivision data integration in central offices; and
- Report generation.

The functionality of the Forecasting Service can be used by any enterprise operating in the electric power industry and other branches of the industry, where the monitoring of parameters over the course of the day is required alongside with the statistical analysis and forecasting functions. General-purpose software for processing daily shapes can be applied to a broad class of parameters plotted at a resolution of 1h and 30min. For long-term planning tasks, data processing tools of monthly, quarterly and yearly resolution are available.

Statistical tools provide the statistical analysis for different time ranges selected, from several days to several years, by particular days of the week that allow detecting certain regularities or trends. The following calculations are implemented:

- Reference statistics – mean, mean dispersion, square deviations, packing factors and daily shape irregularities;
- Parameter increments relative to the previous period with respect to the number of business days and holidays, also normalised to the same meteorological conditions; and
- Indices of meteorological factor effects on power consumption and other parameters.

The analysis may be both general for a time series and for hours of the daily shapes.

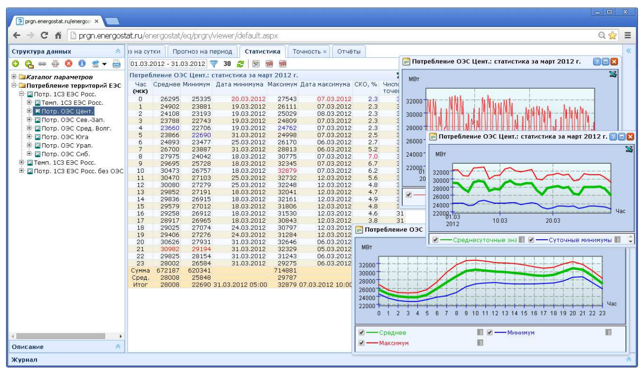

Fig. 3. Statistical analysis of daily shapes of power consumption.

The tables of statistical estimate results and plots of statistical factors, correlation and autocorrelation function curves may be printed and exported to MS Excel (Fig. 3).

IV. The Experience of the Solution Usage by the System Operator of the United Power System of Russia

The System Operator of the United Power System of Russia (SO UPS) is a specialised organisation with a single-person regulatory approach to centralised operational dispatching management of the technological mode of the UPS of Russia. The general hierarchy of SO divisions consists of the Central Dispatching Office, 7 branches, Interregional Dispatching Offices (IDOs), 59 branches and Regional Dispatching Offices (RDOs).

One of the basic SO functions is the optimal planning of daily performance schedules for power plants and distribution grids of the United Power System of Russia. The forecasting task of power consumption is the key element of the entire planning cycle and the basis for further reliability of the power system states. To accomplish this task, the SO experts use a specialised version of the Energostat Data Analysis and Forecasting Service, the Hierarchical Forecasting System (HFS) [4], [5]. Apart from the power consumption analysis and forecasting, the complex is used for SO dispatching centres business process planning support integrating activities of experts from all branches on the unified distributed platform.

In accordance with the planning policy, the RDO and IDO experts make a power consumption forecast for individual power districts of their dispatching centres (Fig. 4).

Thereafter, layouts with the power consumption forecast are submitted by the RDOs to the IDOs and then by the IDOs to the CDO. The power consumption of forecasted UPS areas is analysed by the CDO experts. Night minimum, daylight and secondary peak demands are estimated and corrected as required.

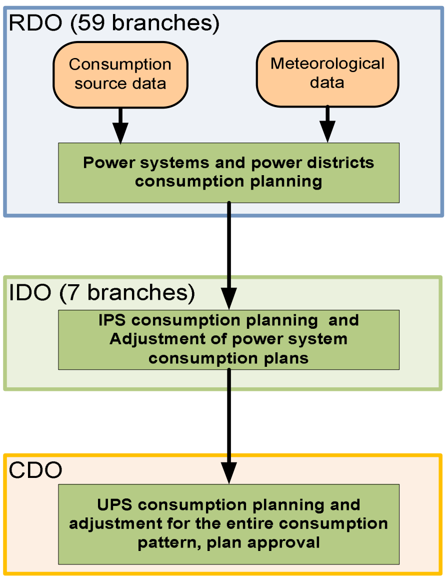

Fig. 4. Planning sequence in SO UPS.

Verified forecast values are fed back to the IDOs, where the total power consumption by territories is distributed by nodes of the UPS model. Planning is performed in cycles 2 hours to 4 days in advance.

In the HFS development, considerable attention is devoted to its operational reliability. The complex consists of 67 real-time interacting servers connected by the unified transport system. The reliability of HFS hardware platform is ensured due to the arrangement of failover clusters. Information storage systems and computing systems are reserved. If a hardware failure occurs, the system changes over to the reserved hardware. Source data required for forecasting are obtained from the SCADA database installed in each SO branch. Meteorological factor data are among the most urgent parameters of influence for power consumption forecasting. Specialised AS "Meteo" software has been developed for the processing of these data [6]. This software analyses the completeness and reliability of the meteorological data and performs the statistical analysis, including the assessment of data forecast quality.

V. Forecast Accuracy

Considering the meteorological factor effect is of importance for making forecasts of power consumption. Table 1 and 2 shows basic parameters of forecast accuracy for Moscow power system and the UPS of Russia:

MPE – assembly average of forecast relative error;

MAPE - average modulus of forecast error; and

RMSE – mean square forecast error.

TABLE I. Relative Errors of Load Forecast, %, for Moscow Power System over the Period of 1 January 2013- 31 March 2014

Advance in days	With regard to temperature			With no regard to temperature		
	MPE Dmean	*MAPE $\lvert D\rvert$mean*	*RMSE Mean sq. error*	*MPE Dmean*	*MAPE $\lvert D\rvert$mean*	*RMSE Mean sq. error*
1	-0,10	1,23	1,76	-0,11	1,69	2,35
2	-0,13	1,47	2,06	-0,13	2,31	3,13
3	-0,16	1,59	2,19	-0,15	2,72	3,64
4	-0,19	1,65	2,27	-0,16	3,01	4,03
5	-0,22	1,72	2,36	-0,16	3,25	4,36
6	-0,25	1,82	2,48	-0,17	3,46	4,64
7	-0,27	1,92	2,61	-0,17	3,66	4,90
8	-0,30	2,02	2,73	-0,19	3,85	5,14
9	-0,31	2,13	2,83	-0,21	4,04	5,36
10	-0,34	2,22	2,91	-0,24	4,20	5,57
11	-0,35	2,31	2,99	-0,26	4,37	5,77
12	-0,37	2,39	3,08	-0,28	4,53	5,98
13	-0,40	2,47	3,19	-0,28	4,68	6,17
14	-0,42	2,56	3,29	-0,28	4,84	6,36

TABLE II. RELATIVE ERRORS OF LOAD FORECAST, %, FOR THE UPS OF RUSSIA OVER THE PERIOD OF 1 JANUARY 2013- 31 MARCH 2014

With regard to temperature			**With no regard to temperature**		
MPE Dmean	***MAPE |D|mean***	***RMSE Mean sq. error***	***MPE Dmean***	***MAPE |D|mean***	***RMSE Mean sq. error***
-0.12	1.03	1.42	-0.12	1.71	2.44

The results obtained clearly show that temperature consideration provides significant improvement in the accuracy of calculations. The necessity of meteorological data consideration increases with the advance time of analysis. This is explained by increasing temperature deviations in forecast days from an actual day temperature in advance.

VI. CONCLUSION

The paper describes a solution to the analysis and forecasting of power consumption and other operating mode parameters. The authors have developed forecasting models based on a seasonal shape technique and meteorological factor consideration technique. The software is elaborated as an application for MS Windows and the website, and is used by more than 100 electric power companies in Russia and Ukraine. It is also used as a main tool for power consumption planning by the System Operator of Russia. Mean square errors of power consumption forecasting for the UPS of Russia are about 1.4%. The solution is available at the website of Energostat Ltd., www.energostat.ru.

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