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COMPARATIVE ESTIMATIONS OF THE RESULTS OF SHORT-TERM FORECAST OF THE AGGREGATE ELECTRICAL LOAD OF THE POWER POOL AT HIERARCHICAL ORGANIZATION OF THE GIVEN PROBLEM SOLUTION

The paper shows the advantages of hierarchic three-level modal of aggregate electrical load of the power pool of Ukraine for the solution of the problem of short-term forecast, stipulated by more correct account of the impact of astronomical and meteorological factors. The algorithm, experimental program of three-level short-term forecast of aggregate electrical loading of power pool has been described, the results of the forecast and their statistical characteristics have been given.

***Key words**: hierarchic three-level model, aggregate electrical loading, power pool, forecast error, lead interval.*

Statement of the problem

Characteristic feature of the solution of the problem, dealing with the short-term forecast of aggregate electrical loading (AEL), as compared with the forecast for longer lead intervals is the possibility to take into consideration the impact of external factors, this is specified by the possibility to obtain, with high probability, the correct forecast values of these factors on the required lead interval. These factors include: meteorological (air temperature, cloudiness, strength of the wind), astronomic(time of the sunrise/sunset, solar day duration) technological (operation modes of power consuming users). All this, in its turn, causes the increased requirements, regarding the quality of mathematical models of the given factors impact on electrical loading of energy system.

It should be noted that variations of weather conditions often are of local character. Thus, using in forecast models of aggregate electrical loading (AEL) temperature indices, averaged at large territories, levels of cloud amount (illumination intensity) leads to roughening of the model and distortion of the coefficients of their regressive dependences. The given paper shows the advantages of hierarchic three-level model of aggregate electrical load of the energy pool of Ukraine for the solution of the problem of the short-term forecast, connected with more correct account of meteorological and astronomic factors impact. The paper contains the algorithm and the description of the experimental program of the three-level short-term forecast of the energy pool with the account of the impact of the above-mentioned external factors separately at each hierarchic level.

At the given stage of development of technological provision and information support of the energy pool of Ukraine the problem of short-term forecast of aggregate electrical load of unified energy system (UES) could be solved using three level (utility company regional ES – unified EES) AEL models. Block-diagram of three-level solution of the problem of the short-term forecast of UEES AEL of Ukraine is given below (Fig. 1). In this case the following technological and meteorological information, available in energy pool of Ukraine, is used:

– hourly AEL values of all utility companies of the Ukraine, regional ES and unified energy system;

– values of air temperatures in all regional centers of Ukraine at the following hours of the day: 0, 3, 6, 9, 12, 15, 18, 21;

– value of daily average air temperature in all regional centers of Ukraine;

– characteristics of weather type (rain, snow, without precipitations) in all regional centers of Ukraine;

– amount of daily consumption of the energy and electric loading of power-intensive enterprises during morning and evening maximum of UES AEL of Ukraine;

– daily time of sun rise / sun set in all regional centers of Ukraine;

– forecast of air temperature and type of the weather in all regional centers of Ukraine.

The given information arrives at the common data base [1] and is used for the solution of the whole spectrum of problems dealing with the forecast of electric loading and power consumption.

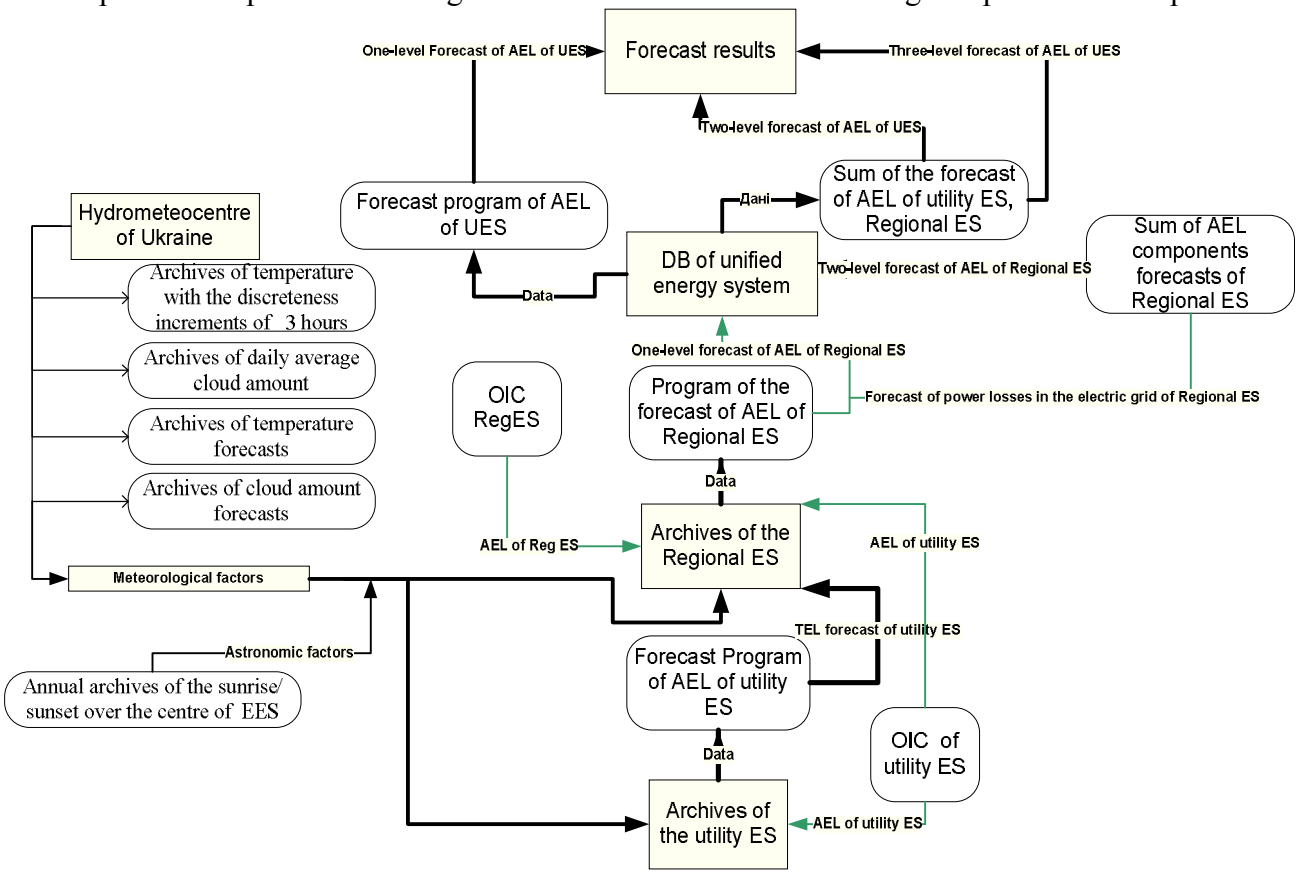

Fig. 1. Block-diagram of three-level solution of the problem of AEL of short-term forecast of unified energy system of Ukraine

Algorithm of three-level short-term forecast of AEL of the energy pool of Ukraine

The detailed description of the algorithm of three-level solution of the problem, dealing with short-term forecast of energy pool AEL is given below:

1. For each utility company the archives of AEL prehistory are formed according to UIC data, also the archives of real and forecast values of meteorological and astronomic factors over the territory of the regional center according to the information of Hydrometeocentre are formed.

2. Identification of the mathematical model of the aggregate electrical loading of each utility company, that provides additive decomposition of AEL of the utility ES with the selection of the following components is carried out on retrospective data:

$$P_{i,j} = P_{i,j}^{bas} + P_{i,j}^{week} + P_{i,j}^{meteo} + P_{i,j}^{res}, \quad (1)$$

where $P_{i,j}$ – is real electric loading of energy system at j^{th} hour (j=1 … 24) of i^{th} day (i=1 ... N – total number of prehistory days); $P_{i,j}^{bas}$ – basic component of AEL of energy system at j^{th} hour (j =1 ... 24) of i^{th} day; $P_{i,j}^{week}$ – week component of energy system AEL, that describes week oscillations of electric load; $P_{i,j}^{meteo}$ – meteorological component, that describes the impact of the ambient temperature and cloud amount on electric load of energy system; $P_{i,j}^{res}$ – is the residual component of AEL of j^{th} hour, i^{th} day.

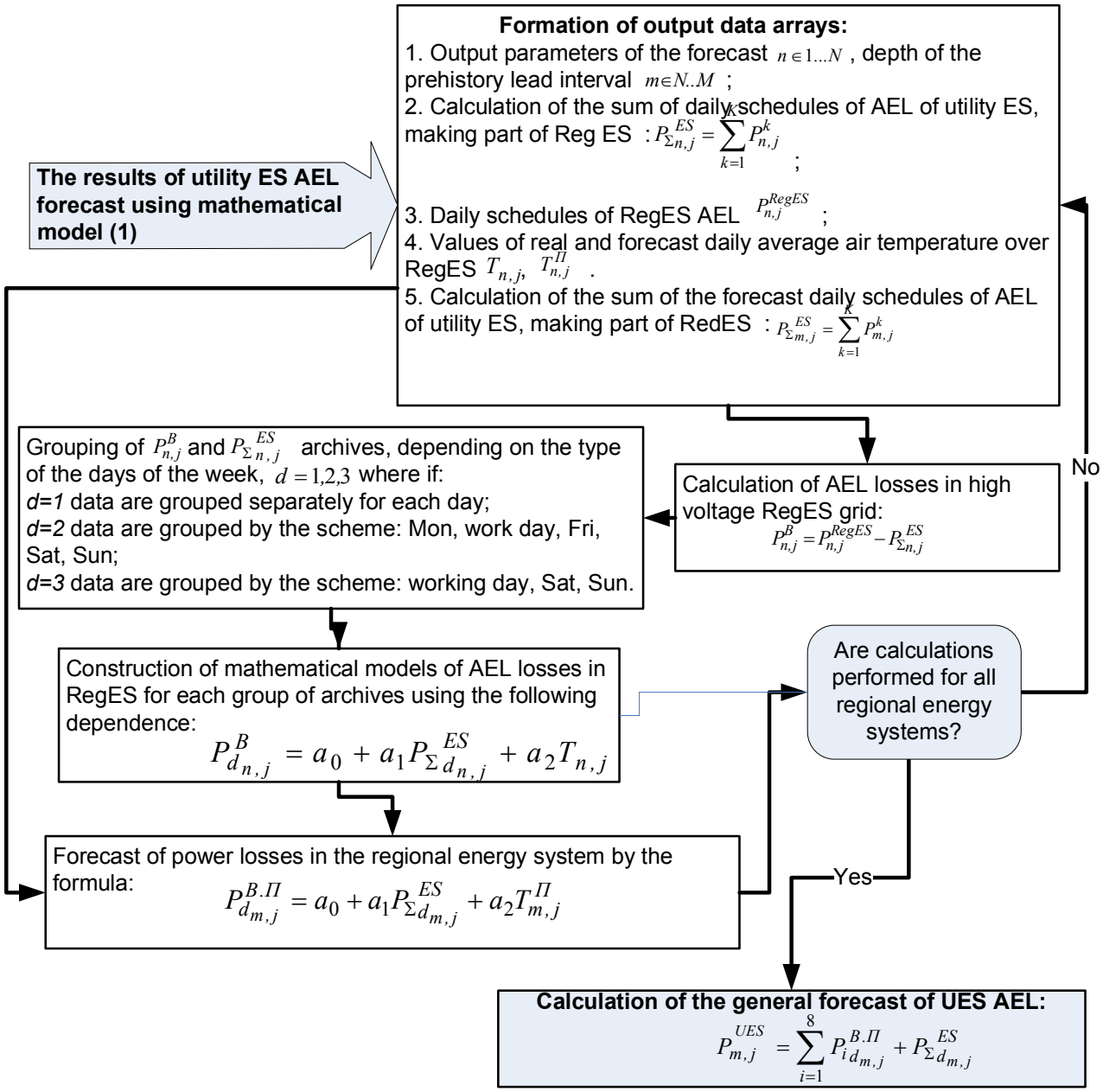

Fig. 2. Block-diagram of AEL two-level forecast of the regional energy system

Calculation of each of the components of the given model is performed according to the algorithm, given in [2, 3].

3. On the basis of mathematical model (1), using the forecast data of meteorological factors, the forecast of hourly values of aggregate electrical loads of the regional energy system is carried out. The forecast values of AEL of utility ES are sent to the level of the corresponding regional energy systems.

4. The archives of AEL prehistory by the data of UIC as well as the archives of real and forecast values of meteorological and astronomic factors over the territory of RegES by the data of Hydrometeocentre are formed for each of the 8th regional ES. One-level forecast of regional energy systems AEL is performed in the same way, using mathematical model (1), identified on retrospective data of RegES.

5. Losses in high-voltage grid of the regional energy system stipulate the imbalance between total electric losses of all utility companies, making part of it and AEL of RegES. The above-mentioned

imbalance is rather important and, according to the data of the year 2007, on average (totally for UES) was 2030 MW (9.6% of average load of UES of Ukraine). Regarding the value of power consumption and meteorological conditions, considerable fluctuations of imbalance values within the limits of 890 – 5170 MW (4.2 – 24.6%) are observed. Thus, while forecasting of AEL daily schedules of upper levels of energy pool of Ukraine (regional and Unified ES) on the basics of the data of utility companies, these losses must be taken into account as separate component of the mathematical model (1).

Algorithm of the two-level forecast of RegES AEL is presented in the given block-diagram (Fig. 2).

Forecast values of the electric load of regional energy system, obtained applying one- and two-level method of the forecast are transferred at the level of energy pool.

7. At the level of energy pool the following calculations are performed:

– one-level short-term forecast of energy pool AEL, using mathematical model (1), identified on retrospective data of UES;

– addition of one-level forecasts of regional energy systems AEL;

– addition of two-level forecasts of regional energy systems AEL.

Results of the research

Experimental program of hierarchic multifactor forecast of AEL of the energy pool of Ukraine and energy systems, making part of it, was developed according to the above-mentioned algorithm by lead interval from 1 to 7 days. The program uses database, that contains technological and meteorological information, described above, and enables to perform the following calculations:

1. Forecast of electric load of the energy pool of Ukraine, using the AEL data of utility companies, regional energy systems and UES (one-, two- and three-level forecast).

2. Forecast of electric load of regional energy systems (one and two-level).

3. Forecast of AEL of the utility companies (one-level forecast).

The impact of meteorological factors is taken into account at the corresponding hierarchic level.

The results of hierarchic forecast of AEL of UES of Ukraine in the period from 01.02.2010 till 28.02.2010 are given in Fig. 1 and Table 1 – 2. Calculations were carried out, as a rule, weekly, lead interval was seven days. As input data daily graphs of AEL of UES, regional and utility energy systems and the above-mentioned values of meteorological factors at the corresponding hierarchic level were used. The parameters of mathematical model of AEL (architecture of meteorological component model, time of cloud amount registration, type of input data of air temperature (daily average or hour), variant of AEL grouping by the type of the day of the week and necessary length of the prehistory were chosen, proceeding from the criterion of minimum error of the forecast at the interval of 25 – 31.01.2010. Real retrospective data were used as the forecast values of meteorological factors.

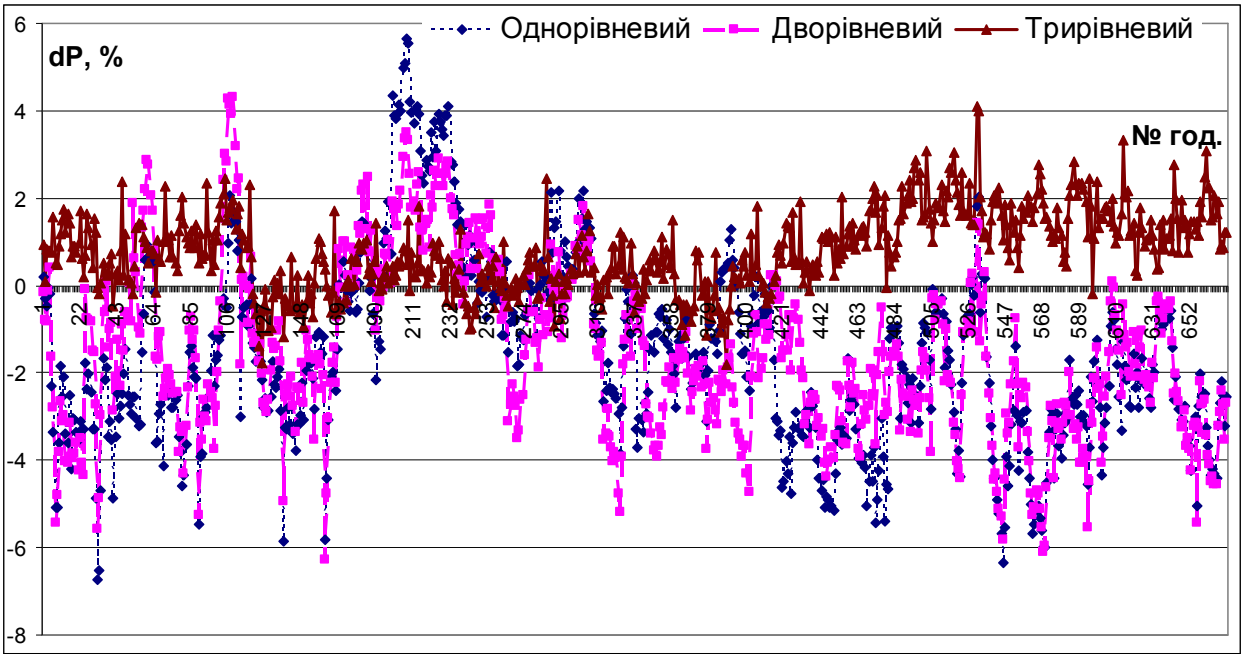

Fig. 3. Error of UES AEL of Ukraine forecast for the period from 01.02.2010 till 28.02.2010

Table 1

Statistical characteristics of the forecast error of hourly values of UES of Ukraine AEL for the period from 01.02.2010 till 28.02.2010

	One-level	Two-level	Three-level
Mean error, MAPE |%|	2.27	2.13	0.95
Minimal error, |%|	0.00	0.00	0.00
Maximum error, |%|	6.73	6.27	4.11
Root-mean-square error, %	2.13	1.95	0.89

Distribution of the forecast error, |dP|, %, of AEL of UES for the period from 01.02.2010 till 28.02.2010 by its value. Total volume of the sample is 672 hours.

Table 2

One-level, %	Two-level, %	Three-level, %	|dP|, %
24.3	22.8	58.8	|dP|<=1
21.3	25.3	31.8	1<|dP|<=2
23.2	26.6	8.5	2<|dP|<=3
18.8	16.4	0.7	3<|dP|<=4
7.9	6.5	0.1	4<|dP|<=5
4.6	2.4	0.0	5<|dP|

According to the results obtained three-level method of the forecast using the data of utility companies, provides considerably higher accuracy both by mean/root-mean-square error and by maximum error. The usage of three-level method in case of accurate forecast of meteorological factors in 90.6% of cases provided the error less than 2%. Considerable errors (>4%) occurred only in one case. It should be noted that, according to the results obtained, two-level method of the forecast is the best alternative to one-level method.

Conclusions

1. Hierarchic mathematical model of aggregate electrical loading of the energy pool has been improved as a result of the division into part and modeling of power losses in High-Voltage Overhead Transmission Line (HVTL) of the regional energy systems. Usage of the given model

provides the possibility of three-level forecast of AEL of the energy pool using the data of the utility energy systems.

2. Experimental program of short-term forecast of daily schedules of aggregate electrical loading of energy pool of Ukraine, regional and utility energy systems has been developed. Service possibilities of the program and hierarchic data base enable to perform calculations of hour values of AEL of the above-mentioned energy facilities by lead interval up to 7 days taking into account the impact of meteorological factors separately at each hierarchic level.

3. Comparative calculations of energy loading forecast of the energy pool showed the advantages of hierarchic (two- and three-level) approach, as compared with one-level, to the solution of this problem both by accuracy and reliability of the results obtained.

REFERENCES

1. Черненко П. А. Обработка и анализ информации для иерархического прогнозирования электрических нагрузок / П. А. Черненко, А. И. Заславский, А. В. Мартынюк // Праці ІЕД НАНУ. – 2006. – Вип. 2 (14). – С. 47 – 49.

2. Черненко П. О. Багаторівневе короткострокове прогнозування сумарного електричного навантаження енергооб єднання / П. О. Черненко, О. В. Мартинюк // Вісник Вінницького політехнічного інституту. – 2011. – № 2. – С. 74 – 80.

3. Черненко П. О. Підвищення ефективності короткострокового прогнозування електричного навантаження енергооб'єднання / П. О. Черненко, О. В. Мартинюк // Технічна електродинаміка. – 2012. – № 1. – С. 63 – 70.

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