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FORECASTING AND ANALYSIS OF ENERGY CONSUMPTION

Prediction – powerful statistical power management tools in the industry. In this article we examined two complementary statistical forecasting models: the corridor for a few months in advance and a model for a day ahead. The basis of the energy-saving is the systematic implementation of a wide range of technical and technological measures to be implemented in the framework of an optimal power consumption infrastructure management procedures at the system level. Energy savings can be achieved by improving the activity of the administrative apparatus. This article presents the results of the implementation of energy forecasting model, which reduces energy consumption as a whole by more than 20%. Prediction may be performed based on a static model that reflects the process of power consumption for the year ahead. Dynamic stochastic modeling allows the forecast for the medium term (5 - 7 years). The main advantage of this approach – is the formation of a fair rate of energy expenditure, taking into account fuel quality, as well as the current state of energy consumption.

Key words: energy efficiency, energy intensity, energy policy, energy consumption, the decomposition method.

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Энергоресурстарды тұтынуды талдау мен болжау

Болжау – өнеркәсіптегі энерготұтынымды басқарудың қуатты статистикалық құралы. Мақалада екі өзара толықтырушы болжаудың статистикалық модельдері қарастырылған – бірнеше айға алдын ала қарастырылған коридорлық модель және бір тәулік алды модель. Энергоүнемдеудің негізін инфрақұрылымның энерготұтынуын жүйелік деңгейде оңтайлы басқару процедураларының шеңберінде жүзеге асырулары тиіс, техникалық және технологиялық шаралардың кең кешенін жоспарлы іске асыру құрайды. Энергоүнемдеуді басқарушы аппараттың қызметін жетілдіру арқылы қамтамасыз етуге болады. Ұсынылып отырған мақалада энергия шығындарын жалпы 20%-дан артық мөлшерге қысқартатын, энерготұтынуды жоспарлау үлгілерін енгізу нәтижелері көрсетілген. Болжамдауды электротұтыну үрдісін бір жыл алдыға көрсететін, статистикалық модель негізінде орындауға болады. Динамикалық стохастикалық үлгілеу ортамерзімдік болашаққа (5-7 жыл) болжам жасауға мүмкіндік береді. Мұндай үлгінің басты қасиеті – жанармайдың сапасын ескере отырып, энергоресурс шығындарының әділетті нормасын, сонымен қатар энерготұтынудың ағымдық жағдайын қалыптастыру.

Түйін сөздер: энергия тиімділігі, энергосыйымдылық, энергетикалық саясат, энергия тұтыну, декомпозиция әдісі.

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Прогнозирование и анализ потребления энергоресурсов

Прогнозирование – мощный статистический инструмент управления энергопотреблением на промышленных предприятиях. В статье рассмотрены две взаимодополняющие статистические модели прогнозирования: коридорная на несколько месяцев вперёд и модель на сутки вперёд.

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Основу энергосбережения составляет планомерная реализация широкого комплекса технических и технологических мер, которые должны осуществляться в рамках процедур оптимального управления электропотреблением инфраструктуры на системном уровне. Энергосбережение можно обеспечивать за счет совершенствования деятельности управленческого аппарата. В предлагаемой статье представлены результаты внедрения модели прогнозирования энергопотребления, что позволяет снизить затраты энергии в целом более чем на 20%. Прогнозирование может выполняться на основе статической модели, отражающей процесс электропотребления на год вперед. Динамическое стохастическое моделирование позволяет осуществлять прогноз на среднесрочную перспективу (5 – 7 лет). Главное достоинство данного подхода – это формирование справедливой нормы расходов энергоресурсов с учётом качества топлива, а также текущего состояния энергопотребления.

Ключевые слова: энергоэффективность, энергоемкость, энергетическая политика, энергопотребление, метод декомпозиции.

Introduction

One of the main directions of the energy charter of the Republic of Kazakhstan is energy efficiency and energy saving. The rational, progressive introduction of new energy-saving technologies promises to reduce production costs and reduce the cost of production and services. Reducing energy consumption is one of the tasks the state is setting for itself today. Kazakhstan has laws «On Energy Saving and Energy Efficiency Improvement» and «On Amendments and Additions to Certain Legislative Acts of the Republic of Kazakhstan on Energy Efficiency and Energy Efficiency Improvement» [1-2]. In accordance with the program of the President, the government is developing the program "Energy Saving – 2020" in the field of energy saving [3]. The program "Energy balance-2020" is also being developed.

The state energy register has already been formed, which included more than two thousand industrial enterprises and 28 thousand state institutions. At the same time, the major 30 large enterprises plan to conduct energy audit; the energy management system is being introduced at 50 enterprises.

More than 200 industrial enterprises of the country are being modernized and are planning to invest over 300 billion tenge. From these measures at industrial enterprises it is planned to obtain an effect in saving energy resources in the amount of almost 3 million tons of oil equivalent.

For today, implementing the state policy in the field of energy saving, it has already been possible to save 2.434 million kW / h of electric power and 3199 Gcal of thermal energy in the budget sphere, which in monetary terms is 1.73 billion tenge. In addition, in energy-producing enterprises, the savings amounted to 93.36 thousand kW / h of electric power, 275.04 thousand tons of coal and 2338.5 tons. heavy fuel. At power transmission plants – 10,871.41 thousand kW / h of electricity, 68460 Gcal, or 501 million KZT. The final effect of the implemented measures for 2011 at industrial enterprises was 5237.16 thousand kW / h of electricity, or 65.4 million tenge [4].

Within the framework of the program "Energy Saving-2020" 78 different activities are planned for a total of more than 1.1 trillion tenge [3].

One of the main expense items of any large industrial enterprise is the cost of energy resources aimed at the release of heat. Thus, energy efficiency – economical consumption of energy resources in a crisis is the number one task facing industrial enterprises.

Formulation of the problem. There are two ways to solve the energy cost reduction:

1. By replacing the power equipment and heat communications, which will lead to significant financial costs and, ultimately, to the rise in price of the final product.

2. An alternative way to improve energy efficiency is to predict energy consumption in the future. This approach uses the maximum of useful statistical information of all parameters of the production process – external factors (weather, fuel quality) and internal factors are taken into account. The main advantage of this method is the issuance of an adequate energy expenditure plan for a day ahead, which allows for a factor analysis of the overestimation / understatement of the norm.

Energy efficiency – economical consumption of energy resources in a crisis is the number one task that faces industrial enterprises, factories, housing and communal services, urban heating services

The cost of the latter approach is much lower, since it requires neither expensive equipment nor the involvement of additional experts, and all the necessary data for the model are formed by: power consumption sensors, production indicators, energy consumption, fuel quality, environmental parameters and others [5].

At the moment, most of the enterprises of the RK do not use the standard (plan) of energy consumption, as a result of which:

1. There is no control over energy consumption in the shortest and average period, which creates the potential for manipulation with energy resources, and also leads to a significant increase in energy costs.

2. There is no possibility to conduct a factor analysis to identify the most energy-intensive nodes in order to reduce energy costs.

3. There is no possibility to carry out a plan-factor analysis and to identify reasons for overstating / understating the standard.

4. The presence of "flat" norms (taken from last year as a constant) does not reflect the influence of external (weather, fuel quality) and internal factors, which leads to a conflict between the operator that controls energy consumption and management.

5. There is no possibility to optimize the setting of energy consumption to improve energy efficiency.

The forecasting of energy consumption by individual market participants is important not only for the whole energy system as a whole, but also for an individual enterprise, and even for its shops and plots. The formation of a universal apparatus for modeling and forecasting power consumption and power for various levels of the hierarchy of industrial enterprises would allow reducing energy costs when buying it in the wholesale and retail energy and capacity markets, qualitatively determining the influence of various technological conditions and factors of production on energy consumption or load power, Choose the most effective energy saving strategies and the direction of measures to save electricity.

When solving the long-term forecasting problem, it is necessary to take into account a large number of factors affecting the change in the power consumption of enterprises. It should take into account the level of electrification of production processes, the pace of development and implementation of energy-saving technologies, the growth of industrial labor, the impact of meteorological and other factors.

The variety of influencing factors, the complexity of the forecast of these factors themselves, does not allow to uniquely determining the optimal forecasting method for solving this problem. The very process of changing consumption is a time series. To date, many methods for predicting time series have been developed, such as extrapolation methods, econometric and regression methods, Box-Jenkins methods (ARIMA, ARMA), expert methods, and others. Statistical models of forecasting – for several months and a day ahead. The first is intended for the formation of long-term planning of probable energy consumption scenarios, which will also take into account the effect of planned repairs in the future. The second model serves to monitor and account for energy consumption for the next day.

For industrial enterprises, the cost of paying for energy resources is a significant part of the budget. The corridor model was developed that allows forming two scenarios of energy consumption to solve this problem: minimum and maximum based on historical data and due to expected environmental conditions.

After the introduction of models in the industry, the operators were given clear fair energy consumption rates, taking into account internal and external factors. In addition, every time the operator significantly overstated the norm, a working group was initiated to identify the reasons for the overstatement. With the use of factor analysis, those factors (causes) were distinguished, due to which the norm was overstated. As a result, orders were issued aimed at reducing the energy consumption of production. The introduction of the model made it possible to make timely adjustments to the production process and reduce energy consumption by 20% – from 41.3 to 33.3 unit fuel.

The planning period is the period of a smooth reduction of energy costs to the initial level of fluctuations. Thus, the corridor model is a flexible tool for planning, accounting, control and management of energy efficiency.

The model for the day ahead is a working tool for the daily forecast of the norm for the next day and for monitoring energy costs in the production. The daily forecast allows carrying out the plan-factual analysis, "encouraging" the operators involved in the reduction of energy resources, and also responding in a timely manner to extraordinary situations. Below are the main advantages of the model for a day ahead:

1. The model takes into account external (weather, fuel quality) and internal factors of the process of heat energy release.

2. The model chooses the best combination of factors, some factors may lose significance for the forecast over time, for example, the sensor fails.

3. The model is dynamic – it is constantly adapting (adjusted according to the newly introduced data) to the new conditions of the energy consumption mode (wear of communications is taken into account; accidents in some areas are taken into account, etc.).

4. The model takes into account the forecast error for the last few days and corrects the forecast for a more accurate rate.

5. Robust methods for estimating model parameters – model predictions are resistant to the presence of emissions in the initial data [1-3].

6. The model gives recommendations for optimizing the circuit of power consumption.

7. The model warns about extraordinary situations – sharp fluctuations of both factors and energy resources.

8. The model allows you to do a factor analysis – the reasons for rejecting the fact from the plan.

High quality of the forecast is achieved due to flexible adaptation to the constant change in the production process.

In the process of using the "model for a day ahead", the operator is faced with the task of keeping within the set energy consumption rate. In the case when the actual costs are significantly lower than the norm (lower by 2%), the operator is subject to a bonus. When the operator exceeds the norm by more than 2%, a working group is initiated to conduct a factor analysis of the causes of excess of the norm. As a result, a directory of possible causes leading to increased energy consumption is generated. With the help of optimizing the model for the day ahead, the recommended settings for maintaining an economical mode of energy consumption are formed, which gives an additional 2% energy savings. Simulation modeling of energy consumption allows you to assess the effect of implementing a model for a day ahead in the long term. At the heart of this approach is only one assumption that the operator will fit into the daily rate of energy expenditure.

For the purposes of analyzing the accuracy of a set of forecast values, it is convenient to use the following particular case of the above criterion (1), based on a certain type of sample of forecast years. Namely, it is convenient to use a sample of M consecutive years l (i) starting from the year following the forecast year k: l (1) = k + 1, l (2) = k + 2, ..., l (M) = k + M. In this case, we obtain a relative standard deviation, depending on two parameters-the forecasting year k and the forecast horizon M:

$$\sigma(k,M)=\sqrt{\frac{1}{M}\sum_{j=1}^{M}\left(\frac{V_{прогн}(k,k+j)}{V_{факт}(k+j)}-1\right)^2} \quad (1)$$

Note that, often, in the published forecasts, the values of the predicted values are given with an interval of five years. At the same time, they also show the average annual growth rates at these intervals. In this case, the values of the forecast values in the interim years can be obtained by linear interpolation. This makes it possible to work with annual samples l, consisting of a number of consecutive years, which is very convenient.

A separate problem of statistical analysis is the estimation of the statistical error caused by the variation in the sample used in the analysis of forecasts.

Forecasting can also be performed by G-methods (Gauss-methods based on Gaussian mathematical statistics), Z-methods (Zipf methods based on zipf mathematical statistics) and synthetic GZ-methods, organically combining their advantages. The latter suggest the implementation of a preliminary fine GZ-analysis (Gauss-Zipf analysis) [4-5].

GZ-analysis can be implemented in two versions, the first of which is a simplified heuristic, and the second is the main criteria. Heuristic variant as the main method of forecasting is applied only for estimating calculations, and on rather small databases. In addition, with its help at a preliminary stage, the so-called GZ-matrix of prediction methods, which is necessary for the procedure of aligning key parameters of the criteria variant of GZ-analysis, is synthesized.

For the prediction of power consumption of objects by G-methods, the models of autoregressive moving average, time series decomposition, as well as various variations of methods are used based on the analysis of the singular spectrum of the time-series trajectory matrix. The heuristic GZ-method possesses the highest (in a certain sense, absolute) accuracy. The criterion variant of the GZ-prediction method is significantly better than any single G– or Z-method (it seems that this is typical for any techno enosis). From G-methods the best method is based on the decomposition of time series. The error in predicting the power consumption for the year ahead using the procedures of criterion GZ-analysis for individual objects can be 4-10%. However, the forecast error as a whole does not exceed 1.5-2%, which meets modern requirements.

Conclusions

In this article, methods for predicting energy consumption were presented: for a day ahead and a quarter ahead. Models are built on historical data – it analyzes how much expense was in the past with similar internal parameters and external conditions, depreciation of equipment and communications is taken into account.

At the stage of statistical analysis and construction of an empirical model of the process of power consumption, deep processing of data on the power consumption of objects is carried out, which includes interval estimation, forecasting and rationing. Forecasting of power consumption by objects is carried out using Gaussian and zipf (G– and Z-) methods. A more subtle analysis of the rank parametric distribution, carried out with the help of GZ-analysis procedures, allows to significantly improve the forecasting efficiency. The error in predicting power consumption using the procedures of criterion GZ-analysis for individual objects can be 4-10%. In this case, the forecast error as a whole, as a rule, does not exceed 1.5-2%.

The main advantage of this approach is the formation of a fair rate (plan) for energy resources, taking into account weather conditions, fuel quality, and the current state of the energy consumption loop. Models are built on historical data – it analyzes how much expense was in the past with similar internal parameters and external conditions, and also takes into account the wear and tear of equipment and communications. Models are constantly adapting to new conditions, which guarantees the adequacy of standards in the future in all possible scenarios.

Литература

1 Закон РК «Об энергосбережении и повышении энергоэффективности».

2 Закон «О внесении изменений и дополнений в некоторые законодательные акты Республики Казахстан по вопросам энергосбережения и повышения энергоэффективности».

3 Программа «Энергобаланс – 2020»

4 Воронцов К. В., Егорова Е. В. Динамически адаптируемые композиции алгоритмов прогнозирования. – М.: Искусственный интеллект, 2006. – 280 с.

5 Башмаков И.А. Разработка комплексных долгосрочных программ энергосбережения и повышения энергоэффективности: методология и практика.– М., 2013. – 361 с.

References

1 Zakon R K Ob energosberejenii I povushenua energoeffectivnostu

2 Zakon R K O vnesenuu izmenenu I dopolnenunu v nekotorue zakonodatelnu aktu Respubliku Kazakhstan po voprosam energosberejenua u povichenua energoeffectivnostu

3 Programma energobalanse 2020

4 Voroncov K. V., Egorova E. V. Dinamicheski adaptiruemye kompozicii algoritmov prognozirovanija. – M.: Iskusstvennyj intellekt, 2006. – 280 s.

5 Bashmakov I A Razrabotka kompleksnuh dolgosrocnuh program energosberegenua u povushenua energoeffectivnostu metodologua u practica: – Moscva, 2013.-361 s.