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Reduce electricity consumption of industrial enterprises during periods of maximum load expediency

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ABSTRACT: The article analyzes the influence and level of the main groups of consumers on the unevenness of the daily graphs of the electricity demand of the energy system, taking into account the time period of the demand periods in them, saving the electricity consumed as a result of the effective use of time-differentiated tariffs, the consumption demand for electricity of the specified zones of the day compliance with the modern needs of management is analyzed, the possibilities of increasing the reliability of existing devices in consumers and electricity supply organizations due to the reduction of peak periods are considered.

KEY WORDS: control system, Predictive analysis, dispatching control systems, efficient operation.

I. INTRODUCTION

The most important problem of modern energy is energy saving, that is, efficient use of fuel and energy resources. The rapid depletion of existing natural fuel reserves will lead to a sharp increase in their cost and accordingly increase in the cost of products produced by enterprises [1].
When the system of time-differentiated and applied to electricity consumers, the annual consumption volume will not be the same. As we know, the main demand period of consumers for electricity is mainly in the morning and evening period of the day (Fig.1).

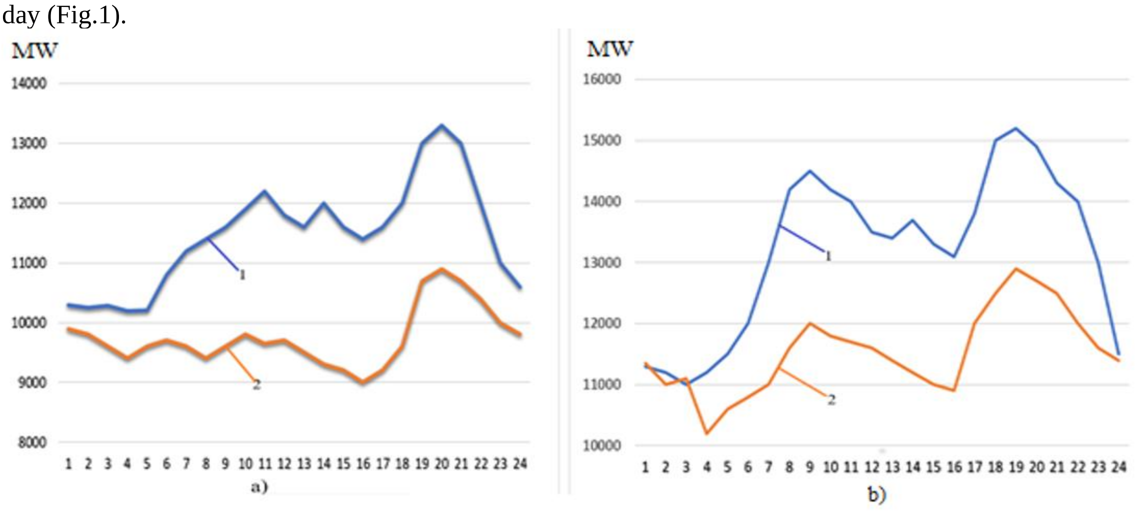

Fig1. A schematic diagram of the electric power system (a-June, b-September) 1- working day, 2- weekend

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In the current environment, the interaction between the energy system and industrial consumers is increasing. Feedback on the mechanism of operation of this complex is carried out through modes of electricity consumption, their rationalization is of great national economic importance, as it ensures saving of capital investments and fuel and energy resources, reducing the price of electricity and improving its quality [2].
It is desirable to reduce the amount of consumption of production enterprises at the time of maximum load, which ensures the reduction of the costs of the enterprise in the execution of the production plan (Δ3).

II. LITERATURE SURVEY

The mathematical expression of this is as follows:

$$\Delta З = a\ \Delta P - У(\Delta P); \tag{1}$$

$$0 \leq \Delta P \leq \Delta P entr; \tag{2}$$

where: a - is the price of 1 kW·h of electricity at the time of maximum load of the energy system;
У(ΔP) – additional costs of the enterprise related to regulation of energy consumption of technological devices;
Changing the tariff price regimes for periods of "peak" (maximum) consumption of electricity depends on the annual costs of the enterprise:

$$З_0 = Х_0 + n_0 T_0 \gamma_0 + P_0 a + n_0 T_0 d_0; \tag{3}$$

where: $Х_0$ – annual production costs, sum/year;
n_0 – period of change of hours in working mode, hours;
T_0 – planning of annual working hours in the enterprise;
γ_0 – the price of electricity consumed per unit product before the tariff change, sum;
P_0 – the power consumed during the period of maximum load of the energy system before the voltage change, kW;
a – amount of payment for 1 kW·h during the maximum load time, kW·sum;
d_0 – electricity consumption per unit of output obtained from mode change, kW·h.

If the power consumed in peak periods (ΔP) is reduced by changing the operating mode of the enterprise, the annual consumption power (aΔP) of the enterprise is also reduced. However, this may lead to a decrease in the production volume of the product. In order to maintain the overall production plan, underproduction during periods of peak consumption can be compensated by overproduction during nighttime (off-peak) periods.

$$n_0 T_0 = n_1 (T_0 - T_3) + n_3 T_3 = n_0 \alpha_1 (T_0 - T_3) + n_3 \alpha_3 T_3; \tag{4}$$

where: T_3 – the duration of the enterprise's electricity consumption during the "peak" period of the energy system;
α_1 – coefficient of electric energy used for the maximum hourly output of the energy system in the maximum periods;
α_3 – coefficient of electric energy consumed for the hourly minimum produced product in the maximum periods of the power system.

III. METHODOLOGY

Changing the mode of operation of the enterprise leads to a change in the total annual costs (while maintaining the annual plan). These costs can be expressed as follows:

$$З_1 = \Delta K(E + p) + \Delta Ф + Х_0 + n_0 \gamma_0 \times [\alpha_1 \beta_1 (T_0 - T_3) + \alpha_3 \beta_3 T_3] +$$

$$+(P_0 - \Delta P)a + n_0 d_0 [\alpha_1 \beta_4 (T_0 - T_3) + \alpha_3 \beta_6 T_3] b; \tag{5}$$

where: ΔK – additional capital values after the change in the mode of operation;
E – efficiency ratio of capital investments, taking into account payments;
p – depreciation rate;
ΔФ– change of work mode;

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β_1 – coefficient that takes into account the volume of consumption of raw materials and materials in the production unit during the changed working hours;

β_3 – coefficient that takes into account the volume of consumption of raw materials and materials in the production unit at the time of maximum load;

β_4 – coefficient that takes into account the change in energy consumption when production is changed in the interval T0-T3;

β_6 - coefficient that takes into account the change in energy consumption when production is changed T3;

The annual economic effect of reducing the load at peak times of the power system is determined by the following expression:

$$\Delta З = a\Delta P + n_0\gamma_0[T_0(1-\alpha_1\beta_1) + T_3(\alpha_1\beta_1 - \alpha_3\beta_3)] + n_0 d_0[T_0(1-\alpha_1\beta_4) +$$

$$+T_3(\alpha_1\beta_4 - \alpha_3\beta_6)]b - \Delta K(E+p) - \Delta\Phi; \quad (6)$$

If $\Delta З>0$, it is desirable to reduce the amount of electricity consumption of the energy system of the enterprise at the time of maximum load.

IV. EXPERIMENTAL RESULTS

After a series of transformations, the appropriateness of the energy system for the enterprise in periods of maximum load is expressed as follows:

$$a > \frac{\Delta K(E+p)+\Delta\Phi}{\Delta P} + \frac{n_0\gamma_0}{\Delta P}[T_0(\alpha_1\beta_1 - 1) + T_3(\alpha_3\beta_3 - \alpha_1\beta_1)] + \frac{n_0 d_0}{\Delta P}[T_0(\alpha_3\beta_4 - 1) +$$

$$+T_3(\alpha_3\beta_6 - \alpha_1\beta_4)]b; \quad (7)$$

The drop in energy consumption during the night or semi-peak periods (T0-T3) changes the electricity consumption:

$$\Delta Э_{1,2} = n_0 d_0 (T_0 - T_3)(1-\alpha_1\beta_4); \quad (8)$$

During the period of maximum consumption (T3) of the energy system

$$\Delta Э_3 = n_0 d_0 T_3(1-\alpha_3\beta_6); \quad (9)$$

Change in total electricity consumption

$$\Delta Э_\Sigma = n_0 d_0[(T_0 - T_3)(1-\alpha_1\beta_4) + T_3(1-\alpha_3\beta_6)]; \quad (10)$$

If ΔE>0 in the expressions (8) - (10), then the size of the load in the operating mode, that is, the consumption of electricity, decreases, if ΔE<0, the consumption of electricity increases.

The annual expenses of the enterprise until the transition to the operation of the tariff regime classified by daily (annual, seasonal) periods are expressed as follows:

$$З_0 = X_0 + n_0\gamma_0(T_1 + T_2 + T_3) + n_0 d_0(T_1 b_1 + T_2 b_2 + T_3 b_3); \quad (11)$$

where: T_1 – the duration of the night period;

T_2 – the duration of the half "peak" period;

T_3 – "peak" means the duration of time of maximum loads of the energy system;

b_1, b_2, b_3 – prices of 1 kWh of electricity in night, semi-peak and peak periods;

After changing the periods of electricity consumption (due to the increase in electricity prices during "peak" periods), the period of maximum loads will decrease:

$$З_1 \Delta K(E+p) + X_0 + \Delta\Phi + n_0\gamma_0(\alpha_1\beta_1 T_1 + \alpha_2\beta_2 T_2 + \alpha_3\beta_3 T_3) +$$

$$+n_0 d_0(\alpha_1\beta_4 T_1 b_1 + \alpha_2\beta_5 T_2 b_2 + \alpha_3\beta_6 T_3 b_3); \quad (12)$$

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where: α_1,α_2, α_3 – T_1, T_2 and T_3 factor that takes into account production during hourly load periods;

β_1, β_2, β_3 - T_1, T_2 and T_3 coefficient that takes into account the change in the consumption of raw materials and materials in production during hourly loading periods;

β_4, β_5, β_6 – T_1, T_2 and T_3 coefficient that takes into account the change in the specific energy consumption when changing it in hourly load periods.

Annual economic efficiency is achieved if the consumption of 1 kW·h during the load period is transferred to the time (T3, T2) and to the less valuable time (T1, T2):

$$\Delta З = n_0 d_0[T_1 b_1(1-\alpha_1\beta_4) + T_2 b_2(1-\alpha_2\beta_5) + T_3 b_3(1-\alpha_3\beta_3)] +$$

$$+n_0\gamma_0[T_1(1-\alpha_1\beta_1) + T_2(1-\alpha_2\beta_1) + T_2(1-\alpha_2\beta_2) + T_3(1-\alpha_3\beta_3)] - \Delta K(E+p) - \Delta \Phi; \qquad (13)$$

In this case, the electricity consumption during the night, semi-peak and peak (T1, T2, T3) periods changes to the following value:

$$\Delta Э_1 = n_0 d_0 T_1(1-\alpha_1\beta_4); \qquad (14)$$

$$\Delta Э_2 = n_0 d_0 T_2(1-\alpha_2\beta_5); \qquad (15)$$

$$\Delta Э_3 = n_0 d_0 T_3(1-\alpha_3\beta_6); \qquad (16)$$

The total change in electrical energy is expressed as follows:

$$\Delta Э_\Sigma = n_0 d_0[T_1(1-\alpha_1\beta_4) + T_2(1-\alpha_2\beta_5) + T_3(1-\alpha_3\beta_6)]; (17)$$

If the change in the mode of expressions (14) - (16) is increased, the consumption of electric energy is reduced [3].

V. CONCLUSION

Thus, the introduction of electricity consumption management in industrial enterprises, which depends on electricity tariffs, allows to reduce the cost of paying for electric energy resources, reduce the variability of the electric loads of the enterprise and, as a result, increase the reliability of industrial electricity supply and reduce the price of manufactured products.

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