УДК 621.317.7 DOI: 10.34031/ES.2022.2.001

ОЦЕНКА СНИЖЕНИЯ ПЛАТЫ ЗА ПОТРЕБЛЕНИЕ ЭЛЕКТРОЭНЕРГИИ ПРИ СНИЖЕНИИ ПОЛУЧАСОВОГО МАКСИМУМА

Альзаккар А., Грачева Е.И.

Казанский государственный энергетический университет, Казань

Аннотация

В связи с высокими ценами на энергоресурсы энергетическая составляющая в себестоимости продукции может быть весьма значительной и на энергоемких промышленных предприятиях достигать 60 % и более. Для ее снижения нужно не только рационально использовать энергоресурсы, разрабатывать и реализовывать мероприятия по их экономии, но и правильно заявлять ожидаемые показатели электропотребления на расчетный период (месяц, квартал, год), которые указываются в договоре с энергоснабжающей организацией на снабжение электрической энергией. В данной работе показан расчёт о приведенных затратах; оценка снижения платы за потребление электроэнергии при снижении получасового максимума; оценка ущерба при регулировании максимума мощности.

Ключевые слова: *Получасовой максимум, мощность, двухставочный тариф, потребление, продукция.*

EVALUATION OF THE REDUCTION OF THE FEES FOR THE CONSUMPTION OF ELECTRICITY WHEN THE HALF-HOUR MAXIMUM REDUCES

Ahmad Alzakkar, Elena Gracheva

Kazan State Power Engineering University, Kazan

Abstract

Due to high prices for energy resources, the energy component in the cost of production can be very significant and reach 60% or more at energy-intensive industrial enterprises. To reduce it, it is necessary not only to rationally use energy resources, develop and implement measures to save them, but also correctly declare the expected indicators of electricity consumption for the billing period (month, quarter, year), which are indicated in the contract with the energy supply organization for supply of electrical energy. This paper shows the calculation of the reduced costs; assessment of the reduction in fees for electricity consumption with a decrease in the half-hour maximum; assessment of damage in the regulation of maximum power.

Keywords: *Half-hour maximum, power, two-part tariff, consumption, production.*

Introduction

Industrial and equivalent consumers with a connected power of 750 kVA and more pay for electricity consumption at two-rate tariffs [1, 2], which are systems of price rates that are used to pay for electricity (power). At the same time, the maximum power (declared or actual) during the hours of the greatest loads of the power system is one of the indicators of power consumption) [3].

The maximum half-hour average electrical load of an industrial enterprise is calculated according to the equation [4]:

$$P_{max} = P_{av} + \beta\sigma; \quad (1)$$

where Pav is the average value of the enterprise's half-hour load;
β: is a statistical coefficient;
σ: is the standard deviation.

Materials and Methods

In the general case, with a two-part tariff, the choice of parameters β and P_{max} is carried out according to the criterion of the minimum change in the total costs of the enterprise per day on average:

$$\Delta З = \Delta П_{\Sigma} + C = \Delta П_1 + \Delta П_2 + \Delta П_3 + C; \quad (2)$$

where ΔП1 – change in payment for declared contractual power;
ΔП2 – changing the fee for exceeding this power;
ΔП3 – change in payment for consumed electricity;
C – product cost.

Then the cost of undersold products C = 0, the payment for consumed electricity does not depend on the declared power ($\Delta P_3 = 0$) and criterion (2) takes the form [5, 6]:

$$\Delta З_1 = \Delta П_1 + \Delta П_2; \quad (3)$$

The value ΔП1:

$$\Delta П_1 = \frac{a}{n}\left(P_{max} - P_{cp}\right); \quad (4)$$

where a: is the basic rate of a two-part tariff; n=365 days.

The value of ΔP_2 is found taking into account the penalty factor k_{pen}:

$$\Delta П_2 = 2k_{pen}\frac{a}{n}\rho\left[P_{av}^{t} - P_{max}\right]; \quad (5)$$

Where P^t_{av}: is the average value of the truncated set of half-hour load values exceeding the half-hour maximum; ρ (P > Pmax) = 0.6587 at β = 1 [7].

Taking into account (1) to (5), the minimized functional (2) takes the form:

$$\Delta З_1 = \frac{a}{n}\left(P_{max} - P_{av} + 2k_{pen}\left[\frac{1}{2} - \Phi(u)\right]\left[P_{av} - P_{max} + \sigma^2\varphi(u)\right]\right); \quad (6)$$

Results

Fig.1 shows the dependences of changes in total costs and their components on quantiles β at the main rate: a = 9760 rub/kw; n = 365 days; σ = 200 kw and different values of the penalty factor. Calculations are made in rubles.

Discussion

For a reasonable choice of the quantity and, accordingly, the declared maximum half-hour, it is necessary to openly disclose the functional dependence of the economic effect on the influencing factors, in particular, taking into account the probabilistic characteristics of the half-hour load.

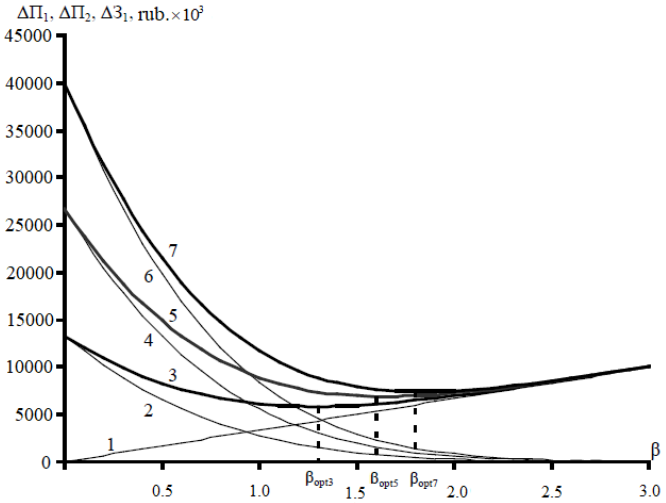

Fig. 1. Change in the total costs of the enterprise in the absence of restrictions on loads:
$1-\Delta\Pi_1;\ 2-\Delta\Pi_2,\ k_{pen}=5;\ 3\ -\ \Delta 3_1,\ k_{pen}=5;\ 4-\Delta\Pi_2,\ k_{pen}=10;$
$5-\Delta 3_1,\ k_{pen}=10;\ 6-\Delta\Pi_2,\ k_{pen}=15;7-\Delta 3_1,\ k_{pen}=15$

The optimization criterion (1) in this case takes the form ($\Delta\Pi_3 = 0$):

$$\Delta 3_2 = \Delta\Pi_1 + \Delta\Pi_3 + C; \tag{7}$$

where ΔP_3 is the daily change in the payment for consumed electricity;

$$\Delta\Pi_3 = b\,\rho\left(\mathrm{P} > \mathrm{P}_{\max}\right)\Delta W_{\Sigma}; \tag{8}$$

where b is the additional rate of the two-part tariff for the consumed kw-hour of electricity;

$\Delta W\Sigma$ is the total daily change in power consumption:

$$\Delta W_{\Sigma} = \Delta W_1 + \Delta W_2 + \Delta W_3; \tag{9}$$

The components of the total daily measurement of electricity consumption are:

1) Daily average decrease in power consumption $\Delta W1$ during the time of limiting the maxima of the half-hour load:

$$\Delta W_1 = \frac{2\sigma}{\sigma_{\upsilon}}\sqrt{2\pi}\left(\sigma + 2\pi\left(1-\tau\right)\varphi_{н}\left(u\right)\left[\mathrm{P}_{ср} - \mathrm{P}_{\max}\right]\right); \tag{10}$$

2) Additional daily average electricity costs:

$$\Delta W_2 = d\,\Delta W_1; \tag{11}$$

3) Daily average increase in power consumption during load dip hours:

$$\Delta W_3 = k\,\Delta W_1; \tag{12}$$

The cost of products not released per day due to load restrictions is determined as follows:

$$C = \left(1-k\right)y\,\rho\left(\mathrm{P} > \mathrm{P}_{\max}\right)\Delta W_1; \tag{13}$$

where y: is the specific damage.

Fig.2 shows the results of $\Delta З_2$ calculations.

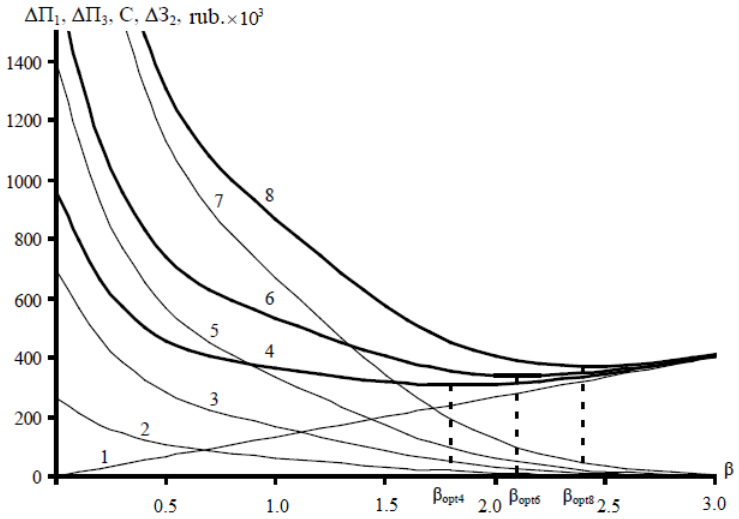

Fig. 2. Change in the total costs of the enterprise:

$1-\Delta П1;\ 2-\Delta П3;\ 3-C,\ y\ =\ 12500\ \text{rub.}/(kw\cdot h);\ 4-\Delta З_2,\ y\ =\ 12500\ \text{rub.}/(kw\cdot h);$

$5-C,\ y\ =\ 25000\ \text{rub.}/(kw\cdot h);\ 6-\Delta З_2,\ y\ =\ 25000\ \text{rub.}/(kw\cdot h);$

$7-C,\ y\ =\ 50000\ \text{rub.}/(kw\cdot h);\ 8-\Delta З_2,\ y\ =\ 50000\ \text{rub.}/(kw\cdot h)$

Extra rate:

$$a=9760\ \text{rub.}/(kw\cdot h);\ b=4700\ \text{rub.}/(kw\cdot h);\ n=365\ \text{day};$$

$$\sigma=200\ \text{kw};\ k_{pen}=10;\ d=0;\ k=0;\ \alpha=10^{-4}c^{-1}$$

Conclusion

A method was tested for selecting the half-hour maximum load of an industrial facility according to a standard that takes into account payment for the declared contractual power during peak hours of the power system, consumed electricity and damage caused by product arrears when determining the operating load.

Библиографический список

1. Шагидуллин А.В. Эффективность замены низковольтных коммутационных аппаратов на примере промышленного предприятия. известия высших учебных заведений // Проблемы энергетики. 2017. № 19(3-4). С. 89-95. EDN: ZBTJAF
2. Валеев И.М., Альзаккар А.М.Н. Гармоники и их влияние при определении метода компенсации реактивной мощности в электрических сетях // Вестник Казанского государственного энергетического университета, 2020. № 12. С. 24-39. EDN: KLADJU
3. The impact of electrical interconnection between countries on the stability of electrical power systems / A. Alzakkar, M.V. Vladimirovich, Y. Samofalov et al. // 4th International Youth Conference on Radio Electronics, Electrical and Power Engineering (REEPE). M.:IEEE, 2022. P. 1-6. DOI: 10.1109/REEPE53907.2022.9731442
4. Петухова Н.Н. Регулирование максимума нагрузки промышленного предприятия // Современные материалы, техника и технология. Курск: ЮЗГУ, 2021. С. 337-339. EDN: UKSIRQ
5. Обоскалов В.П., Машенина Н.В. Определение расчетных нагрузок промышленных предприятий вероятностными методами // Новые информационные технологии в образовании. Екатеринбург: РГППУ, 2015. С. 115-119. EDN: UJODIF
6. Alzakkar A., Hassan F.A., Mestnikov N. Support of Frequency Stability in Electrical Power System at Voltage 400 kV in Syria // Advances in Automation II: Proc. of the International Russian Automation Conference. Cham: Springer, 2021. P. 891-902. DOI: 10.1007/978-3-030-71119-1_86

7. Кретов Д.А., Рузанов Р.В. Прогнозирование электропотребления энергосбытовой компании с использованием искусственной нейронной сети //Инженерный вестник Дона. 2015. Т. 35, № 2-1. С. 20. EDN: UGRUIX

References

1. Shagidullin, A. V. (2017). Effektivnost' zameny nizkovol'tnykh kommutatsionnykh apparatov na primere pro-myshlennogo predpriyatiya. izvestiya vysshikh uchebnykh zavedeniy [The effectiveness of the replacement low-voltage switching devices on the example of industrial enterprise]. *Power engineering: research, equipment, technology, 19(*3-4*)*, 89-95. [In Russian]
2. Valeev, I. M., & Alzakkar, A. (2020). Garmoniki i ikh vliyaniye pri opredelenii metoda kompensatsii reaktivnoy moshchnosti v elektricheskikh setyakh [Harmonicas and their Influence When Determining the Method of Compensation of Jet Power in Electrical Networks]. *Vestnik of Kazan State Power Engineering University, 12 (45),* 24-39.
3. Alzakkar, A., Vladimirovich, M. V., Samofalov, Y., Ildar, I., & Valeev, I. (2022). The impact of electrical interconnection between countries on the stability of electrical power systems. In *Proc. from Conference on Radio Electronics, Electrical and Power Engineering* (pp. 1-6). IEEE. https://doi.org/10.1109/REEPE53907.2022.9731442
4. Petukhova, N. N. (221). Regulirovaniye maksimuma nagruzki promyshlennogo predpriyatiya [Regulation of the maximum load of an industrial enterprise]. *Sovremennye materialy, tekhnika i tekhnologiya* (pp. 337-339). YuZGU. [In Russian]
5. Oboskalov, V. P., & Mashenina, N. V. (2015). Opredeleniye raschetnykh nagruzok promyshlennykh predpriyatiy veroyatnostnymi metodami [Determination of the design loads of industrial enterprises by probabilistic methods]. *Novye informacionnye tekhnologii v obrazovanii* (pp. 115-119). RGPPU. [In Russian]
6. Alzakkar, A., Hassan, F. A., & Mestnikov, N. (2012). Support of Frequency Stability in Electrical Power System at Voltage 400 kV in Syria. In *Proc. from Advances in Automation II* (pp. 891-902). Springer. https://doi.org/10.1007/978-3-030-71119-1_86.
7. Kretov D. A., & Ruzanov, R. V. (2015). Prognozirovaniye elektropotrebleniya energosbytovoy kompanii s ispol'zovaniyem iskusstvennoy neyronnoy seti [Forecasting the power consumption of an energy retail company using an artificial neural network]. *Engineering Bulletin of the Don. 35, 2-1*, 20. [In Russian]

Сведения об авторах

Альзаккар Ахмад, аспирант, ФГБОУ ВО «Казанский государственный энергетический университет». E-mail: ahmadalzakkar86@gmail.com
SPIN-код: 8365-5180
ORCID: 0000-0002-8355-189X

Грачева Елена Ивановна, доктор технических наук, доцент по кафедре ЭПП, ФГБОУ ВО «Казанский государственный энергетический университет».
E-mail: grachieva.i@bk.ru
SPIN-код: 2676-5593

About authors

Ahmad Alzakkar – Master of Technology and Technology, graduate student of the Institute of Electric Power Engineering of Kazan State Power Engineering University.
E-mail: ahmadalzakkar86@gmail.com
ORCID: 0000-0002-8355-189X

Elena I. Gracheva, Doctor of engineering sciences, Professor of the Department "Power Supply of industrial enterprises" (EPP) Kazan state power engineering University (KSPEU). E-mail: grachieva.i@bk.ru