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ВЛИЯНИЕ КОЭФФИЦИЕНТА ЗАГРУЗКИ АСИНХРОННЫХ ДВИГАТЕЛЕЙ НА ПОТРЕБЛЕНИЕ РЕАКТИВНОЙ МОЩНОСТИ
INFLUENCE OF LOAD FACTOR OF ASYNCHRONOUS ENGINES FOR REACTIVE POWER CONSUMPTION

Аннотация: Наиболее распространенными потребителями электроэнергии на промышленных предприятиях являются асинхронные двигатели. Они составляют основную часть промышленной нагрузки. При этом асинхронные двигатели также являются крупными потребителями реактивной мощности. Они используют около 40% реактивной мощности, потребляемой в промышленных электрических сетях. Таким образом, как показал анализ, коэффициент загрузки асинхронных двигателей оказывает существенное влияние на потребление ими реактивной мощности. Уменьшение коэффициента загрузки асинхронных двигателей приводит к увеличению их коэффициента реактивной мощности, что, в свою очередь, влияет на увеличение tgφ промышленного предприятия в целом. Следует отметить, что сегодня в условиях сокращения объемов промышленного производства значительная доля реактивной мощности, потребляемой асинхронными двигателями на промышленных предприятиях, обусловлена их малой нагрузкой. При систематической недогрузке асинхронных двигателей на промышленных предприятиях в первую очередь необходимо принять меры по увеличению их загрузки путем оптимизации технологического процесса и увеличения нагрузки на производственное оборудование.

Abstract: The most common electrical consumers in industrial enterprises are asynchronous motors. They constitute the bulk of the industrial load. At this asynchronous motors are also large consumers of reactive power. They use about 40% of the reactive power consumed in industrial electrical networks. Thus, as the analysis showed, the load factor of asynchronous motors has a significant impact on their consumption of reactive power. Decrease in coefficient loading of asynchronous motors leads to an increase in their reactive power factor, which, in turn, affects the increase tgφ of the industrial enterprise as a whole. It should be noted that today, in conditions reduction in industrial production volumes a significant share of reactive power consumed by asynchronous motors at industrial enterprises is due to their low load. In case of systematic under loading of asynchronous motors at industrial enterprises, first of all measures must be taken to increase them loading by streamlining technological process and increasing the load on production equipment.

Ключевые слова: асинхронные двигатели, реактивная мощность, потребители электроэнергии, коэффициент нагрузки, частота вращения

Keywords: asynchronous motors, reactive power, electrical consumers, load factor, frequency rotations

Introduction. The modes of adjustable motors, unlike conventional electric machines, are characterized by given ranges of possible maximum changes in energy consumption, rotation speed, voltage and other energy parameters. In this regard, when developing engines and their operation, it is necessary to set not specific values of these parameters, but their ranges of change.

It is the operating modes of asynchronous engines often have a significant impact influence on the total reactive power consumed by an industrial enterprise, and how consequence, on the value of the reactive coefficient power tgφ of an industrial enterprise, the value of which is normalized in [2] depending on the level of the rated voltage of the electrical network. In this regard, it seems appropriate to analyze the reactive power consumption of asynchronous motors with in order to further develop recommendations for their rational operation, which would be aimed at natural reduction reactive power consumed by electric motors, and, ultimately, to reduce the value of tgφ of the industrial enterprise as a whole.

Setting the main issue. In general, the reactive power consumed by an asynchronous motor consists of two components: reactive power magnetization *Q0*, spent on creating no-load magnetic flux, and reactive power of stray fields *Qp* and is determined by formula (1):

$$Q_{AM} = Q_0 + Q_p = Q_0 + Q_{nom} \cdot k_l^2 , \qquad (1)$$

where *Qnom* is the loss of reactive power in an asynchronous motor due to dissipation at rated load, kVar; *kl = P/Pnom* – load factor of the asynchronous motor in terms of active power; *P* – active load power of the asynchronous motor, kW; *Pnom* – rated power of the asynchronous motor, kW.

From formula (1) it follows that reactive power *Q0* does not depend on the load, while reactive power *Qp* varies proportionally to the square of the load factor of the asynchronous motor. In [3] formulas are given to determine components of reactive power *Q0* and *Qp* consumed by an asynchronous motor. Based on these formulas, as a result of a series of mathematical transformations, we obtained a formula for determining the reactive coefficient asynchronous motor power:

$$tg\varphi = \frac{\frac{\dot{I}_0}{\dot{I}_{nom}} \cdot R + (tg\varphi_{nom} - \frac{\dot{I}_0}{\dot{I}_{nom}} \cdot R) \cdot k_l^2}{\eta_{nom} \cdot k_l} , \qquad (2)$$

$$R = \sqrt{1 + tg^2\varphi_{nom}} ,$$

where *I0* is the no-load current of the asynchronous motor, A; *Inom* – rated current of the asynchronous motor, A; *tgφnom* – nominal coefficient reactive power of an asynchronous motor; *ηnom* – rated efficiency (efficiency) of an asynchronous motor.

From formula (2) it is clear that the reactive power factor of an asynchronous motor depends on the value of its load factor. That's why for the purpose of assessing the impact of load factor of asynchronous motors for their consumption of reactive power, the relative values of the no-load current of asynchronous motors were determined, and then, in accordance with formula (2), the values of their reactive coefficient power at different values of load factor *kl* in the range from 0 to 1. Initial of the data for the calculations were the catalog data of electric motors given in [4, 5] and in manufacturers' catalogs. We considered asynchronous motors of the 4A and AI series of the basic design with rated power

0.06–250 kW with various synchronous frequency rotations that have become widespread at industrial enterprises. According to the results calculations for each of the considered electric motors, graphs of the dependence of the reactive power factor on load factor *tgφ = f (kl)*.

As calculations have shown, the value of tgϕ of asynchronous motors significantly depends on the relative value of their no-load current. In during the analysis of the obtained results, it was established that the relative value of the no-load current and the *tgφ* value turned out to be approximately the same for groups of asynchronous motors series 4A with synchronous speed *n*=3000 rpm in the rated power ranges 0.09–0.25 kW, 0.37–4 kW, 5.5–45 kW and 55–250 kW and for AI asynchronous motors with that the same synchronous speed in the ranges rated power 0.09–0.25 kW, 0.37–4 kW, 5.5–45 kW and 55–90 kW. This allowed us to approximate the dependences *tgφ = f (kl)* for the given groups of asynchronous motors using a power approximating function.

In this case, the coefficient of determination *R2* turned out to be close to unity, which indicates a high degree of closeness to the approximation of experimental data by the selected approximating function. Approximated graphs

The dependences *tgφ = f (kl)* for asynchronous motors of the 4A and AI series of the main version with a synchronous rotation speed n = 3000 rpm are shown in Fig. 1 and 2 respectively. Similar calculations were carried out for asynchronous motors of the 4A and AI series of the basic design with synchronous rotation speeds n = 1500; 1000; 750 rpm, and according to the results calculations for these electric motors also approximated graphs were built dependences *tgφ = f (kl)*.

Analysis of the dependence graphs tgφ = f (kl) showed that the loading of asynchronous motors significantly affects their consumption of reactive power. This dependence is manifested in the fact that with a decrease in the load factor of asynchronous motors, the value of their tgφ, and, consequently, the amount of reactive power they consume, increases. At the same time, as follows from the dependence graphs in Fig. 1 and 2, a significant increase in tgφ of asynchronous motors is observed when they are loaded at less than 40–45% of the rated power. When the load on asynchronous motors decreases to less than 10% of the rated power, there is a sharp increase in tgφ and reactive power consumed by the electric motors. In this case, the value of tgφ of asynchronous motors at low loads is several times higher than the value of the reactive power factor normalized in [2]. Based on this, we can conclude that the reactive power consumption of asynchronous motors depends on their load to a much greater extent compared to power transformers [6].

From the graphs in Fig. 1 and 2 it is easy to see that the value of the reactive power factor of asynchronous motors also increases with a decrease in their rated power. This is due to the fact that the design of asynchronous motors is such that with a decrease in their rated power, the relative size of the air gap and, accordingly, the relative value of the reactive power they consume.

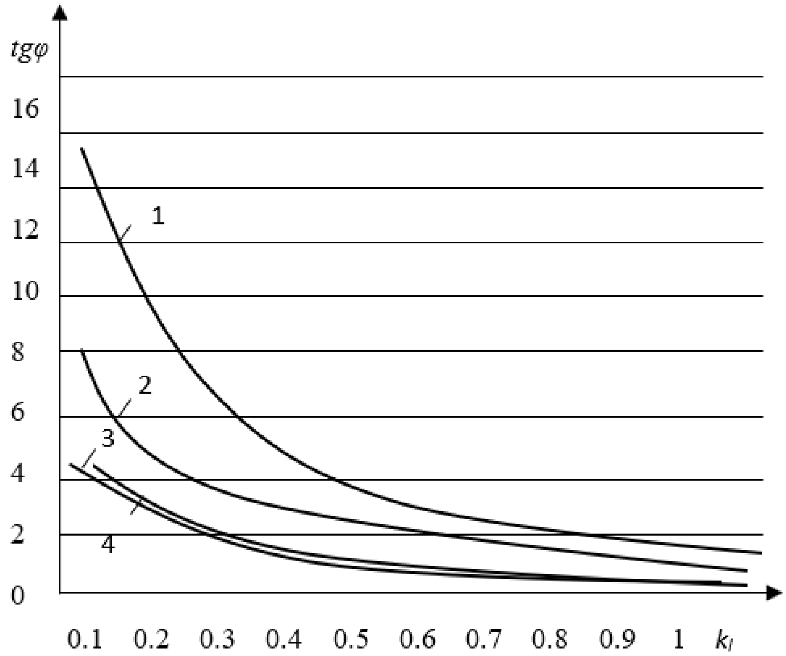

Figure 1. Graphs of the dependence tgφ = f (kl) for asynchronous motors
of the 4A series of the basic design with a synchronous rotation speed n = 3000 rpm:
1 – 0.09–0.25 kW; 2 – 0.37–4 kW; 3 – 5.5–45 kW; 4 – 55–250 kW

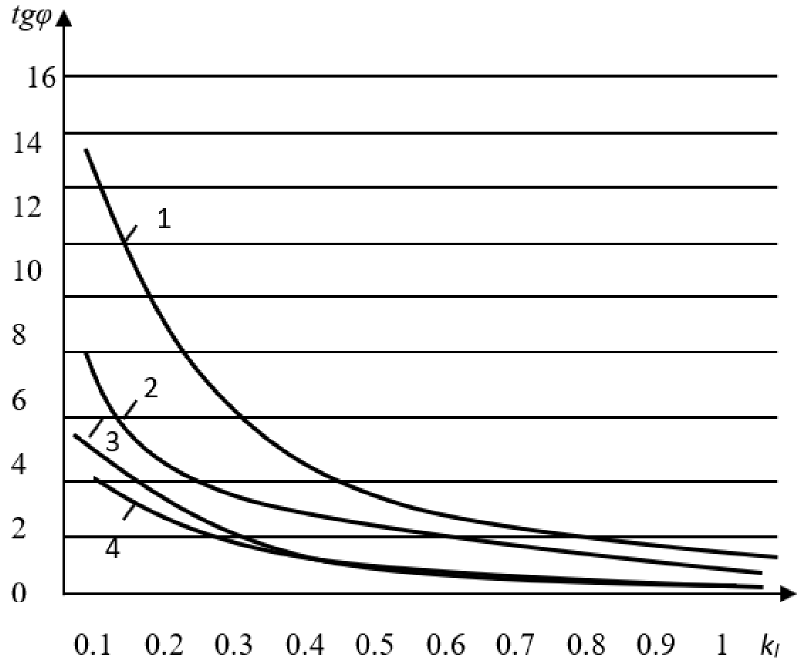

Figure 2. Graphs of the dependence tgφ = f (kl) for asynchronous motors of the AI series of the basic design with a synchronous rotation speed n = 3000 rpm: 1 – 0.09–0.25 kW; 2 – 0.37–4 kW; 3 – 5.5–45 kW; 4 – 55–90 kW

In addition, comparison of dependence graphs tgφ = f (kl) for asynchronous motors of series 4A and AI made it possible to establish that asynchronous motors of the 4A series have a higher value reactive power factor compared to asynchronous motors of the AI series (this is especially true for low-power electric motors).

This is largely due to the fact that in asynchronous motors of the AI series, more high-quality cold-rolled electrical steel. As a result of this, the losses in the steel of asynchronous motors are reduced, and at the same time the magnitude of the reactive magnetizing power is reduced, consumed by electric motors [7].

If after implementation of these measures rated power of asynchronous motors remains significantly overestimated in relation to their load power, then it must be done replacement of lightly loaded asynchronous motors electric motors of lower rated power. Based on experience in operating asynchronous motors, it is believed that if their average load is less than 45% of the rated power, then replacing asynchronous motors with less powerful ones is appropriate. When loading asynchronous motors more than 70% of the rated power, we can consider that replacement in the general case inappropriate. In the event that the average load of electric motors is 45–70% of the rated power, then the feasibility of their replacement must be confirmed by technical and economic calculations [3]. Dependency Analysis *tgφ = f (kl)* for asynchronous motors of series 4A and AI confirms the validity of these recommendations.

If it is impossible to replace lightly loaded asynchronous motors with electric motors of lower rated power, it may be advisable to reduce the voltage by their clamps. Reduced voltage supplied to the windings of an asynchronous motor, to a certain minimum permissible value leads to a decrease in the reactive power consumed by the electric motor due to a decrease in the magnetizing current. At the same time active power losses are reduced and, consequently, the efficiency of the electric motor increases [8].

On in practice, the following methods are known to reduce voltages in lightly loaded asynchronous motors: switching the stator winding from triangle to star; sectioning of stator windings; reducing the voltage in networks feeding asynchronous motors by switching branches of a workshop transformer.

The result. Among the measures aimed at rationalizing the operation of asynchronous motors are can also be attributed to the duration limitation idle move. If the idling intervals of asynchronous motors are sufficient are large, it is advisable to turn off the electric motors from the network. Active consumption and especially reactive power is significantly reduced.

Thus, carrying out activities to rationalization of the operation of asynchronous motors industrial enterprises should have is aimed at a natural reduction in the amount of reactive power they consume, a decrease in $tg\varphi$ of asynchronous motors and, thus, should help maintain standardized values of the reactive coefficient power in industrial electrical networks and a significant increase in the overall energy efficiency of industrial enterprises.

Список литературы:

1. Kolesnikov, A. I. Energy saving in industrial and municipal enterprises: Educational allowance / A. I. Kolesnikov, M. N. Fedorov, Yu. M. Varfolomeev. – M.: INFRA-M, 2005. – 124 p.
2. The procedure for calculating the ratio of active and reactive power consumption for individual energy receiving devices (groups of energy receiving devices) of electrical energy consumers, used to determine the obligations of the parties in contracts for the provision of services for transmission of electrical energy (energy supply contracts): approved. By order of the Ministry of Industry and energetics of Russia Federation No. 49 of 02/22/2007: entry into force from 04/20/2007.
3. Krasnik, V.V. Automatic devices for compensation of reactive loads in electrical networks enterprises. – M.: Energy, 1975. – 112 p.
4. Handbook of Electrical Machines: In 2 volumes / under general. ed. I. P. Kopylova and B. K. Klokova. T. 1. – M.: Energoatomizdat, 1988. – 456 p.
5. Katsman, M. M. Handbook on electrical machines: Textbook. aid for students education educational institutions prof. education. – M.: Academy, 2005. – 480 p.
6. Efremenko, V. M. Analysis of the influence of the load of power transformers on the consumption of reactive power / V. M. Efremenko, R. V. Belyaevsky // Vestn. Kuzbass State those. Univ., 2009. – No. 6. – P. 46–48.
7. Shikhalieva S.Y. Two-rotor asynchronous motor / Problems of Mechanical Engineering and Automation, International Journal, IMASH RAS and NTP, NIAT, Russia. Moscow. 2018. -No. 1. –P. 64-68.
8. Shikhaliyeva S.Y. Two rotor asynchronous electric motor with rotation frequency regulation / International Journal on Technical and Physical Problems of Engineering (IJTPE), September, 2023. –No. 3. –P. 9-16.