ISSUES OF EFFECTIVE SELECTION OF COMPENSATING DEVICES OF REACTIVE POWER

Mirsoli Uzbekov
PhD in Engineering Sciences, assistant professor,
Fergana Polytechnic Institute,
Republic of Uzbekistan, Fergana
E-mail: education.fer@mail.ru

Azamzhon Nematjonov
undergraduate,
Fergana Polytechnic Institute,
Republic of Uzbekistan, Fergana
E-mail: m.uzbekov@ferpi.uz

ВОПРОСЫ ЭФФЕКТИВНОГО ВЫБОРА КОМПЕНСИРУЮЩИХ УСТРОЙСТВ РЕАКТИВНОЙ МОЩНОСТИ

Узбеков Мирсоли Одилжанович
канд. техн. наук, доцент,
Ферганский политехнический институт,
Республика Узбекистан, г. Фергана,

Неъматжонов Аъзамжон Адхам Угли
магистрант,
Ферганский политехнический институт,
Республика Узбекистан, г. Фергана,

ABSTRACT

In the electrical circuit, the generated reactive energy is equal to the consumed one. Most industrial installations consume reactive energy, usually exceeding the coverage capacity of power plant generators. The article considers the necessary additional devices for the supply of reactive power to the power system - reactive power compensators: capacitor banks. A large number of aspects are considered both from the standpoint of economic benefits for the energy supplying organization and for the consumer of electricity.

АННОТАЦИЯ

Электрической цепи генерируемая реактивная энергия равна потребляемой. Большая часть промышленных установок потребляет реактивную энергию, обычно превышающую возможности покрытия ее генераторами электростанций. Статье расмотрена необходимые дополнительные устройства для поставки в энергетическую систему реактивной мощности - компенсаторы реактивной мощности: батареи конденсаторов. Рассмотрены большие количество аспектов как с позиций экономической выгоды для энергоснабжающей организации, так и для потребителя электроэнергии.

Keywords: energy, electricity, power supply, components of electrical energy, power, active power, reactive power, compensation of electrical energy, compensating devices, capacitor bank.

Ключевые слова: энергия, электроэнергия, электроснабжение, составляющие электрической энергии, мощность, активная мощность, реактивная мощность, компенсация электрической энергии, компенсирующие устройства, конденсаторная батарея.

When choosing a compensating device, the main issue is the choice of the capacity of the compensating device. When choosing the power of the compensating device, they strive for the correct distribution of reactive power sources and the most economical loading of the network.

The required power of the compensating device is selected taking into account the highest reactive power *Qe*, which can be transferred from the power system networks. The condition must be met:

$$Q_p - Q_k \leq Q_e \quad (1)$$

where Q_p is the calculated reactive power consumed by the enterprise, Q_k is the reactive power that must be compensated for at the enterprise.

Библиографическое описание: Uzbekov M.O., Nematjonov A.A. ISSUES OF EFFECTIVE SELECTION OF COMPENSATING DEVICES OF REACTIVE POWER // Universum: технические науки : электрон. научн. журн. 2021. 11(92). URL: *https://7universum.com/ru/tech/archive/item/12522*

The enterprise sets the mode of consumption of reactive power, taking into account its maximum loads. This requirement consists in the fact that the values of *Qe1* are set - the reactive power provided by the power system to the enterprise during half an hour during the period of maximum active loads of the system, and *Qe2* - the average reactive power transmitted from the power system network or generated to the network during the period of its lowest load.

Therefore, we can write:

$$Q_{k\,max}=Q_{p\,max}-Q_{e1} \quad (2)$$

$$Q_{k\,min}=Q_{p\,min}-Q_{e2}, \quad (3)$$

where Q_{kmax}, Q_k min are the required powers of the compensating device in the mode of maximum and minimum loads, $Q_{p\,max}$, Q_p min are the calculated reactive power of the enterprise in the mode of maximum and minimum loads.

Thus, the lack of reactive energy in the power system to cover the reactive loads of the enterprise is eliminated due to the compensating devices of the enterprise.

In order to stimulate the enterprise to implement measures to compensate for reactive power, a system of payment for electricity and consumed reactive power has been introduced.

The choice of the capacity of compensating devices and their distribution over the networks of the enterprise are made on the basis of technical and economic costs. Reduced costs for reactive power compensation:

$$Z_k=Z_{0k}+Z_{u,k1}Q_k+Z_{u,k2}Q_k^2, \quad (4)$$

where Q_k is the reactive power of the compensating device, Z_{0k} is a constant component of costs that does not depend on the power Q_k, $Z_{u,\,k1}$ are the unit costs per 1 kvar of reactive power, $Z_{u,\,k2}$ are the unit costs per 1 kvar^2 of reactive power.

Constant component of costs:

$$Z_{0к}=E_nK_{0,} \quad (5)$$

where E_n is the standard coefficient of the efficiency of capital investments, K_0 is the cost of switching equipment, control devices, etc.

On the basis of a technical and economic comparison of options, it is necessary to additionally consider the option when the compensating device is not installed at all and the enterprise will have to pay for the consumption of reactive power.

Reactive power sources with a voltage of 6-10 kV are more economical compared to voltages up to 1 kV. However, the transfer of reactive power from a 6-10 kV network to a network up to 1 kV can lead to an increase in the number of transformers at a transformer substation, due to their additional load, transmitted reactive power, and, accordingly, to an increase in electricity losses in lines and transformers.

The capacity of the compensating device in networks with a voltage of up to 1 kV is determined at a minimum cost by choosing the optimal number of transformers of the workshop TP and determining the additional power of compensating devices below 1 kV in order to optimally reduce losses in transformers and in the 6-10 kV network that supplies these transformers.

The compensation power calculated in this way is distributed among all transformers of the shop in proportion to their reactive loads.

The approximate number of required transformers of the same optimal economic power to cover all electrical loads of the workshop with an uneven distribution of these loads over the area of the workshop is chosen by the expression:

$$n_{tr}=\frac{S_{sm}}{\beta\lambda S_{nom.t}} \quad (6)$$

where S_{sm} is the total average power of the workshop for the maximum loaded shift, $S_{nom.t}$ is the optimal economic rated power of the transformer, β is the recommended load factor of the transformers, $\lambda = cos\varphi_2/cos\varphi_1$ is the ratio of the power factors on the secondary voltage side of the transformer, respectively, after and before compensation of reactive loads.

The highest reactive power that can be transferred from a 6-10 kV network to a network with a voltage of up to 1 kV to cover the remaining uncompensated reactive power in the network up to 1 kV without increasing the number of installed transformers is determined by:

$$Q_v=\sqrt{(n\beta S_n)^2-P_{sm}^2} \quad (7)$$

where P_{sm}^2 is the active average load for the maximum busy shift.

After the approximate determination of the required power of the compensating device, the problem arises of their optimal location in the power supply system of the enterprise. The greatest effect is achieved when installing a compensating device near an electrical receiver with the highest reactive power consumption, since this leads to the maximum reduction in electricity losses. The choice of the place of installation of the compensating device determines its cost and power losses. Static capacitor banks for a voltage of 6-10 kV have the lowest cost, but when installed, the greatest losses of active power will be in the elements of the power supply system that are outside the compensation zone.

Therefore, the problem of placing compensating devices in power supply systems is multifactorial. Their optimal placement corresponds to a technically acceptable option, which ensures the lowest estimated costs. The presence of complex branching systems with a heterogeneous load leads to the need to consider a large number of options.

For power supply of large enterprises, characterized by the presence of an extensive power supply system, the following method is recommended:

1) The center of consumption of reactive loads (x_0, y_0) on the territory of the enterprise is determined;

2) On the basis of technical and economic calculations, the appropriate capacity of the compensating device Q_k is determined. In this case, there may be options:

there are no compensating devices at all on the territory of the enterprise, or compensating devices are installed at the enterprise and they must be supplemented with new ones. In the first case, the installation site should be closer to the center of consumption of reactive loads. In the second one should find a center for generating reactive power for compensating devices already at the enterprise. Further, by the method of successive approximations, the coordinates of the installation of the additional compensating device are determined so that the new center for generating reactive power is located near the center of its consumption (x_r, y_r).

3) The calculation of voltage levels during the hours of maximum and minimum loads.

Compliance with the permissible voltage deviations at the terminals of the receivers is, as a rule, the main limitation when choosing the power and location of the compensating device. To fulfill this condition, in some cases, it is necessary to use adjustable compensating devices.

If synchronous motors are the means of compensation, then this problem is solved simply by regulating the excitation. If static capacitors are used for compensation, then the adjustment can only be made stepwise, by dividing the batteries into parts. Of course, such regulation has serious drawbacks: the ability to work for some time with insufficient or excessive compensation, as well as the cost of installing additional switching equipment. But nowadays, combined compensating devices have become widespread, which combine the advantages of modulating control and low cost.

Longitudinal compensation of the inductance of the lines is called, which is realized by connecting a capacitive resistance in series in the line. This resistance compensates for the inductive resistance of the line, as a result of which voltage losses in the line are reduced.

Consider the case of a line with a load (Fig. 1). The longitudinal and transverse components of the voltage drop for the line under consideration are determined by the expressions:

$$U_{прод.\ ф} = I(R\cos\varphi + X\sin\varphi),$$

$$U_{non.\ ф.} = I(X\cos\varphi - R\sin\varphi). \quad (8)$$

With a given vector of phase voltage at the consumer U_{2f}, the voltage at the power source is determined by the vector U_{1f} (point A). If capacitors with reactance X_c are connected in series in the line, then the voltage drop in the reactance will be I (X-X_c) and the components of the voltage drop will be equal to:

$$U'_{прод.\ ф} = I(R\cos\varphi + (X - X_c)\sin\varphi),$$

$$U'_{non.\ ф.} = I((X - X_c)\cos\varphi - R\sin\varphi). \quad (9)$$

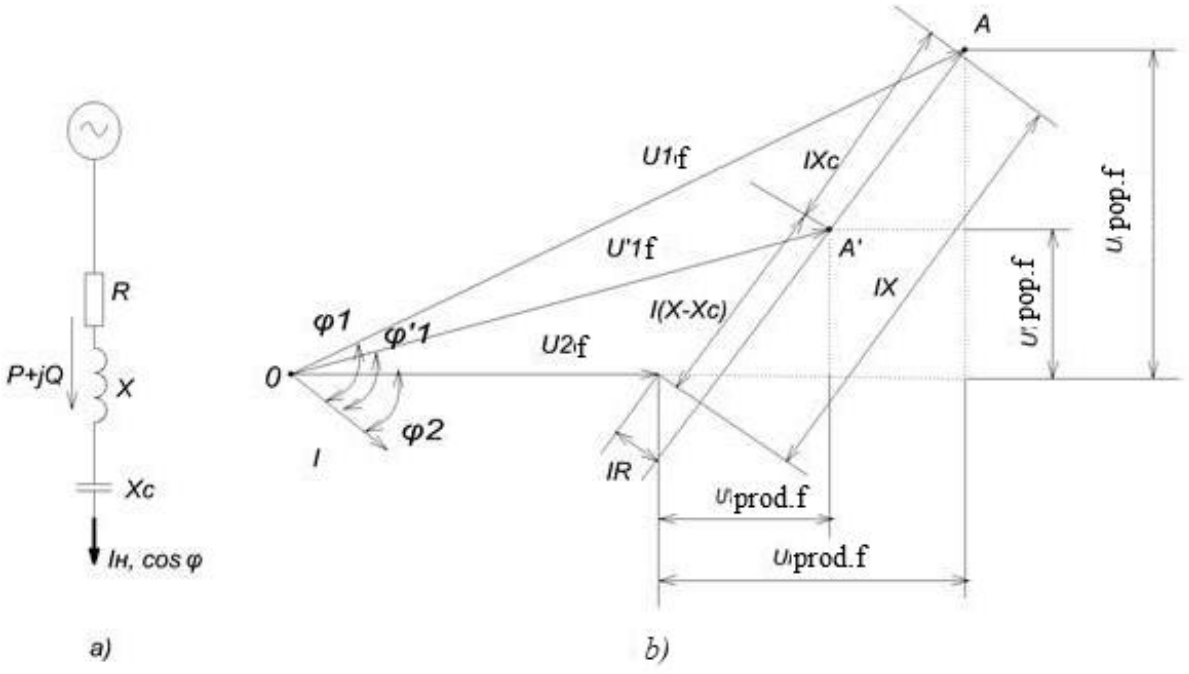

Figure 1. Network diagram and vector diagram with the use of longitudinal compensation of reactive power of the line

The required voltage at the power supply will now be equal to the vector U'_{1f}, determined at $X_c < X$ by point A'. Its value in comparison with the original has decreased, since $U_{prod.f}$ and $U_{pop.}$ f decreased due to a decrease in the reactance of the line.

With full compensation ($X_c = X$), the voltage drop will be determined only by the active resistance of the line R.

With overcompensation ($X_c > X$), the voltage loss will be close to zero and $U_{1f} = U_{2f}$. In this case, the value of X_c will be:

$$X_c = X + R ctg\varphi \quad (10)$$

The reactance of the capacitors in this case compensates not only the inductive resistance of the line, but also the voltage drop across the active resistance.

Capacitor power is determined by:

$$Q_c^2 = 3I^2 X_c, \quad (11)$$

where I is the maximum line current.

Список литературы:

1. Узбеков М.О., Тухтасинов А.Г. Измерения температуры нагрева абсорбера солнечного воздухонагревательного коллектора // Universum: технические науки: электрон. научн. журн. 2020. № 6 (75). URL: https://7universum.com/ru/tech/archive/item/9604.
2. Узбеков М.О. Тепловая эффективность солнечного воздухонагревательного коллектора с металлическим стружечным абсорбером / М.О. Узбеков, А.Г. Тухтасинов // Журн. Сиб. федер. ун-та. Техника и технологии, 2020. 13(6). С. 712-720. DOI: 10.17516/1999-494X-0260
3. Abbasov, Yo S. and Uzbekov, M O. (2018) "Experimental study of a solar air collector with an absorber from metal shavings" Scientific-technical journal: Vol. 22: Iss. 1, Article 39. URL: https://uzjournals.edu.uz/ferpi/vol22/iss1/39
4. Коновалова Л.Л., Рожкова Л.Д. Электроснабжение промышленных предприятий и установок: учеб. пособие. – М.: Энергоатомиздат, 1989. – 528с.
5. Узбеков Мирсоли Одилжанович, Неъматжонов Аъзамжон Адхам Угли Выбор напряжения по известной длине линии и передаваемой мощности // Современные инновации. 2019. №2 (30). URL: https://cyberleninka.ru/article/n/vybor-napryazheniya-po-izvestnoy-dline-linii-i-peredavaemoy-moschnosti
6. Шеховцов В.П. Расчёт и проектирование схем электроснабжения: метод. Пособие. – М.: ФОРУМ: ИНФРА-М, 2005. – 214с.