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Reactive power compensation principles

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ABSTRACT. In this article, the impact of reactive power compensation on electricity quality indicators is one of the important topics, which can help improve the efficiency and economic use of electricity, the role and importance of power supply system elements and reactive power compensation in its areas of application, the reasons for the origin of high harmonica in non-linear loadings of energy devices and In the case of Ideal inductance and capacitor networks, the power factor cos φ is given in terms of values of the sprockets and tg φ, the issues of determining which part of the energy consumed is used usefully in the performance of works [1,2].

KEY WORDS: Sequential selection of the structure and parameters of compensating devices, the rated power of capacitors, compensation method, reactive power sources, centralized compensation, automatic compensation, group compensation, individual compensation, compensation systems.

I. INTRODUCTION

In addition, the limited capabilities of medium voltage networks lead to the refusal of this power utility to connect additional power or to the inclusion in the payment for these connections of the cost of reconstruction of the supply network above the balance limit. In the situation noted above, the feasibility of introducing reactive power compression units at the enterprise is already clear at the stage of technical and economic comparison. Therefore, as a rule, the introduction of capacitor devices will cost less than the reconstruction of the power supply network. In addition, in the industry and in the energy system, a procedure for calculating the values of the ratio of active and reactive power consumption is introduced, according to which the maximum values of the voltage at which the installed power of consumers is more than 150 kW, the permissible reactive power coefficient for networks 6– 35 kV is 0.4, and for networks Reactive power compensation allows the efficiency of electricity use to be increased in three main directions: increasing the power of lines and Transformers, reducing active energy wastes and normalizing voltage. Installation of compression devices allows you to reduce active losses by reducing the total current [3,4].

An increase in production capacity at industrial enterprises leads to an overload of installed electrical equipment and requires a change in the power supply system. The traditional solution to the problem is to lay additional cables or replace them with cables of a larger cross-section and install additional transformers. This approach requires large capital costs and ultimately affects the cost of the product. In addition, due to the limited capacity of medium-voltage networks, it leads to the refusal of this power supply enterprise to connect additional capacity or to include in the payment for these connections the costs of reconstructing the supply network above the balance sheet limit. In the above situation, the feasibility of introducing reactive power compensation units at the enterprise is already clear at the stage of technical and economic comparison. Therefore, as a rule, the introduction of capacitor devices will be cheaper than the reconstruction of the power supply network. In addition, in industry and the energy system A procedure for calculating the ratio of active and reactive power consumption has been introduced, according to which the maximum voltage values for 6–35 kV networks with an installed capacity of consumers exceeding 150 kW are allowed for a reactive power factor of 0.4 and for 0.4 kV networks - 0.35. Reactive power compensation allows you to increase the efficiency of using electrical energy in three main directions: increasing the capacity of lines and transformers, reducing active energy losses, and normalizing voltage. Installing compensation devices allows you to reduce active losses by reducing the total current.

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II. RESULTS AND DISCUSSIONS.

So reactive power compensation energy economical from technologies to call one possible. Electricity networks equipment excess loading with related problems not been also active in enterprises of waste decrease because of reactive power cover measures relatively short time inside it is covered. It is possible to determine what portion of the consumed energy was used effectively to perform work based on the magnitude of the reactive power coefficient. The technical and economic problem of compensating reactive power is primarily related to bringing the power factor of the receiving devices closer to one.

Thus, the total power, which determines the calculated currents and voltages of the network, consists of the active components of the power transmitted to the load and the non-active components (reactive, distortion and asymmetry), which negatively affect the operating modes of the power network and the quality indicators of electricity. Of the four components of the total power, only the active power performs useful work. The remaining three must be excluded. To compensate for them, the following are resorted to:

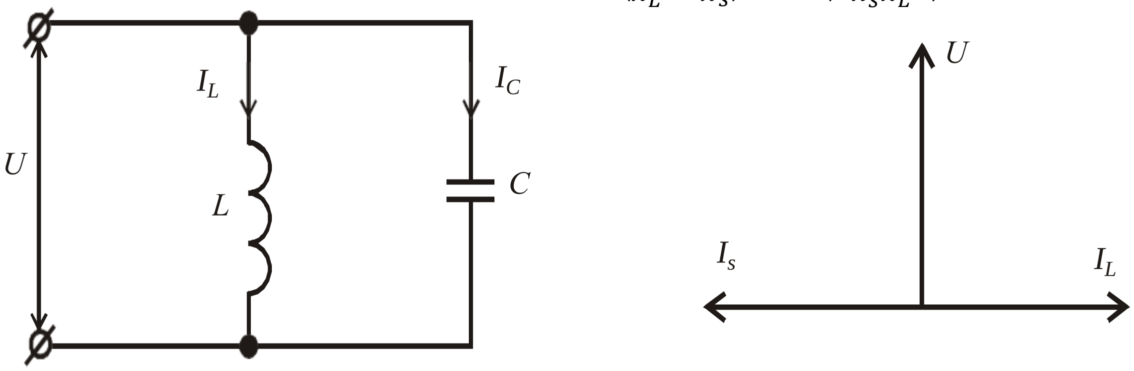
- reactive power sources;
- high harmonic filters;
- symmetrical devices.

In the following chapters, the issues of compensating reactive power in the distribution networks of industrial enterprises will be discussed. When considering ideal inductive and capacitive circuits, it was shown that the instantaneous power of a circuit with a capacitance is negative compared to the instantaneous power in an inductive circuit. This fact is of great practical importance [5].

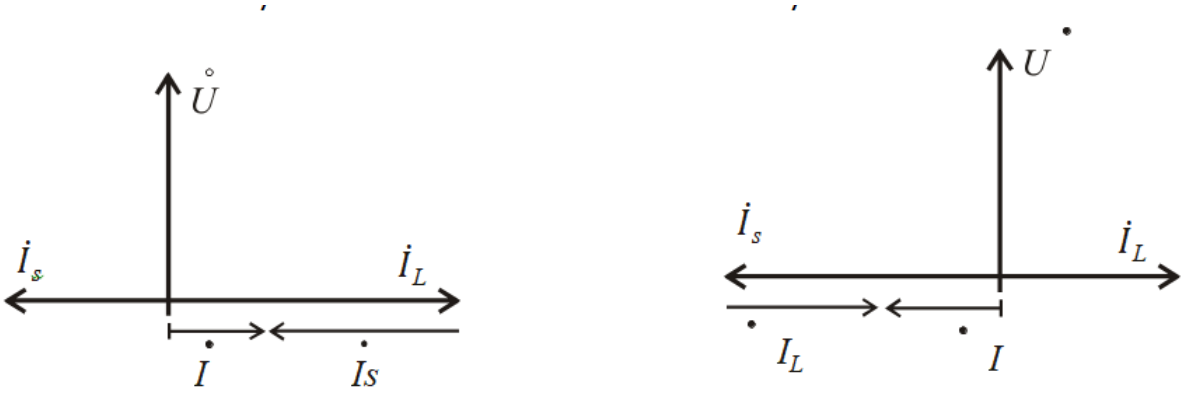
In the unbranched part of the circuit in Figure-1

$\dot{I}$ −are the branched parallel parts of the same circuit $\dot{I}_L$ and $\dot{I}_s$ is equal to the geometric sum of the currents. If the inductive conductance is b_L and the capacitive conductance is b_s , then figure 1.

$$\dot{I} = \dot{I}_L + \dot{I}_s = \dot{U}(b_L - b_s) = \dot{U}\left(\frac{1}{x_L} - \frac{1}{x_s}\right) = \dot{U}\left(\frac{x_s - x_L}{x_s x_L}\right) \qquad (1)$$



a) b)



v)

g)

Figure 1. Schematic of a branched circuit with inductance and capacitance (a), current and voltage vector diagrams (b, v, g)

If $x_c = x_L$In the case of , the current in the unbranched part of the circuit $\dot{I}$is zero. This mode is called the resonance of currents. The vector diagram of the currents and voltages of this mode is shown in Figure 1b. If $x_s < x_L$, then the current is inductive in nature, and $x_c > x_L$at it is capacitive in nature. The vector diagrams for these two cases are shown in Figure 1v and Figure 1g.

The diagram in Figure 1 shows that $x_c < x_L$the current$\dot{I}$ In the unbranched part of the circuit, less current flows than the network current consisting of inductance $\dot{I}_L$. In this case,

$$\dot{I}_L = \dot{I} + \dot{I}_s , \qquad (2)$$

Load losses of active power formulae 3

that is, by introducing a capacitance into the circuit in parallel with the inductance, it compensated for the inductance's need for reactive current to generate a magnetic field, thereby reducing the amount of reactive current consumed by the inductance from the source. In this case, energy exchange occurs between the inductance and capacitance of the circuit, with only the uncompensated part of the energy being exchanged between the inductance and the power source.

The reactive power in the unbranched part of the circuit is plotted for Figure 1a:

$$Q = U = I = U\,(IL - Is) = U\,(U\ bL - U\ bs) = U^2\ (bL - bs) =$$

$$= \left(\frac{U^2}{x_L} - \frac{U^2}{x\ s}\right) = QL - Qs \qquad (3)$$

The reactive power obtained in Q_L this expression (3) represents the uncompensated part of the reactive power. Q_sThe power can be called the compensated power or the power of the compensation device.

In general, the reduction of reactive power circulating between the power source and the consumer, as well as the reduction of reactive current in generators and networks, is called reactive power compensation.

In Figure 2, the principle of compensating the magnetizing current using the capacity current is explained with a vector diagram. The capacitor's capacity, which is connected in parallel to a load consisting of resistive (r) and inductive (L) elements, is chosen in such a way that the current Is passing through it is as close as possible in absolute value to the magnetizing current I_L consumed by the inductance. The connection of the capacitor (Figure 2b) allows for reducing the phase shift angle between the current and the load voltage, thereby increasing the power factor. By increasing the capacity, the reactive power of the load can be fully compensated.

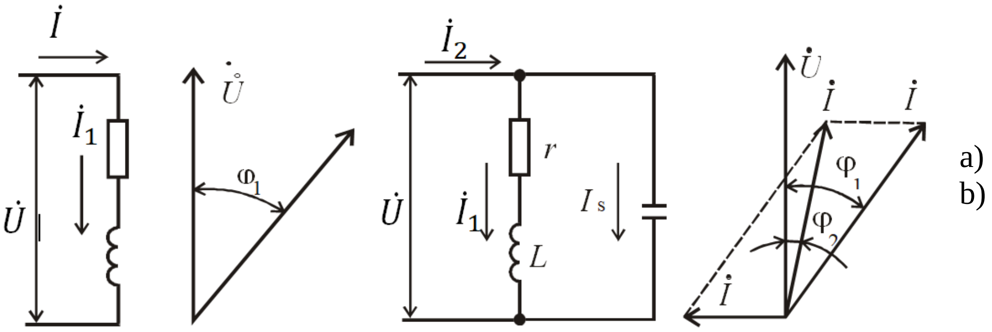


Figure 2. The principle of compensation of reactive magnetizing current: a-scheme before compensation, j $_1$ -this is a phase shift angle between current I 1 and U voltage; β-compensation scheme. j $_2$ - phase shift angle between current I 2 and voltage U (j $_2$ < j $_1$) decreases and the power factor increases (cos j $_2$ > cos j $_1$)

To estimate the reactive power consumption, $\cos\varphi = {}^{P}/_{S}$ the power factor, which is one of the main quality indicators of the operation of alternating current electrical devices, is introduced. However, this coefficient does not fully reflect its consumption, since $\cos\varphi$ —at close values of is still very large. For example,$\cos\varphi = 0{,}95$ With a high value of , the reactive power consumed by the load is 33% of the active power consumed (table). $\cos\varphi =$ At 0.7, the amount of reactive power consumed is almost equal to the amount of active power in table 1.

Table 1. **The amount of reactive power consumed is almost equal to the amount of active power**
The value of reactive power $\cos\varphi$ depends on (as a percentage of active power)

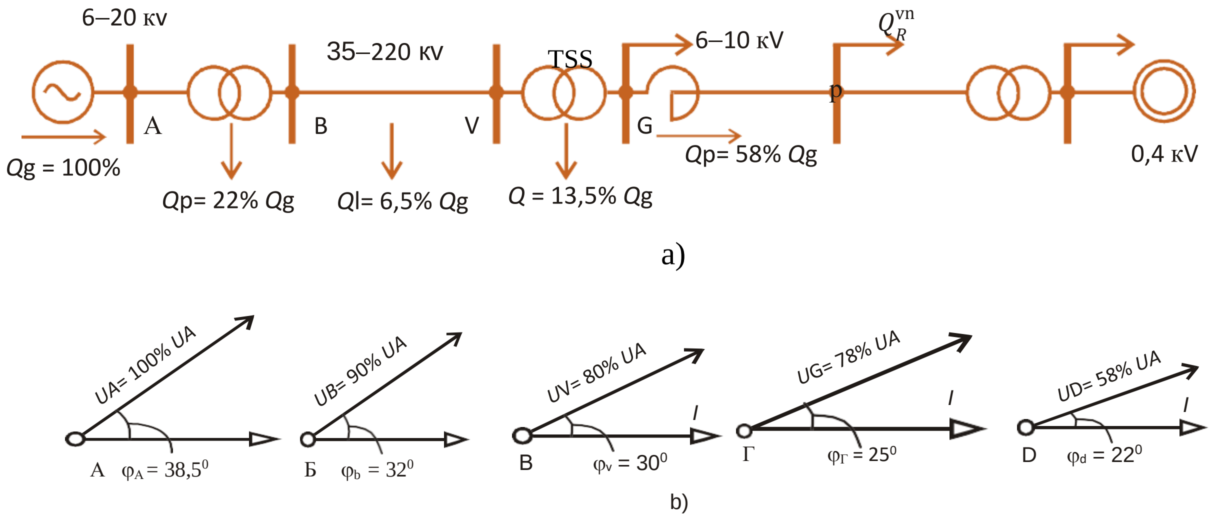
cos j	1.0	0.99	0.97	0.95	0.94	0.92	0.9	0.87	0.85	0.8	0.7	0.5	0.316
tg j	0	0.14	0.25	0.33	0.36	0.43	0.484	0.55	0.6	0.75	1.02	1.73	3,016
$Q = P$ tg j %	0	14	25	33	36	43	48.4	55	60	75	102	173	301.6

One of the more successful indicators characterizing the amount of reactive power consumption is the reactive power coefficient .

$$tg\varphi = \frac{Q}{P}$$

Based on the values of the power factor cosj and $tg\varphi$, it is possible to determine what portion of the consumed energy is effectively used for performing work. The technical and economic problem of compensating or covering reactive power primarily requires bringing the power factor of the receiving devices closer to one.

The distribution of reactive power losses in an equivalent power transmission station is shown - vector diagrams of currents and voltages for the consumer and nodes A–D of this transmission are given in Figure 3. Even with cos j = 0.927 (j = 22 ^{0}) for consumers, all sections of the power transmission are heavily loaded with reactive power: for 1000 kW of active power, 800 kVAr of reactive power is required from the station at the beginning of the transmission and 400 kVAr at the end. This leads to an increase in the current loads of the networks and, as a result, to an increase in the cost of network construction, waste of electricity and deterioration of voltage quality due to the loss of network elements [6].



a)

b)

Figure 3. Changes in reactive power flow on the power transmission bus of the receiving substation power plant – bus (a), changes in voltage and phase shift of current and voltage (b)

III. CONCLUSION

Reactive power is consumed not only by electricity consumers of enterprises, but also by elements of the supply network, 42% of the reactive power of the system falls on their share in the form of D Q losses. Of the 100% of reactive power generated in the power system, 22% is lost in step-up transformers of power plants and autotransformers of voltage-increasing substations of the 110-750 kV power system, 6.5% is lost in the lines of the district networks of the system, 13.5% of losses are lost in step-down low-voltage transformers, and only 58% of the total reactive power falls on the 6/10 kV buses of consumers. The large load on the reactive power of power plants leads to an overcurrent of generators, even during hours when, due to the active load, some of the generators can be turned off in reserve, which leads to the need to use them specifically for the production of reactive power.

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