Monitoring places of installation of compensating devices in the network as a means of improving energy effeciency

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Annotation. Reactive power compensation is one of the most effective measures to reduce energy losses in electrical networks. In many cases, the choice of sources of reactive power (compensating devices) is implemented already at the object design stage. However, the operating conditions are always to some extent different from the design ones, and therefore the originally adopted reactive power compensation system may not be sufficiently effective. In particular, the stage of operation is characterized by an increase in loads and network expansion. This leads to expediency, and sometimes the need to increase the power and / or number of compensating devices. Thus, the operational task of reactive power compensation arises, to which this article is dedicated.

Keywords: reactive power, reactive power compensation, condenser installation, compensation device.

Introduction.

At the present stage of development of the power industry, a transition to energy-saving technologies and various ways of reducing electricity losses, reducing the need for new generating capacity, is necessary. One of the main ways to reduce electricity losses and improve the efficiency of electrical installations is to compensate for reactive power.

The problem of reactive power compensation arose simultaneously with the practical use of alternating current, since the transfer of reactive power required for electrical installations is one of the main components of the technological losses of electricity in the power supply networks. A significant part of the active energy losses is due to the network power flow of reactive power, and their reduction can be achieved by increasing the degree of compensation of reactive power.

It is known that most power consumers, as well as electric power conversion devices, due to their physical properties, require reactive energy (necessary to create a variable electromagnetic field) for operation.

Despite the fact that active power, and therefore fuel, is not directly consumed in generating reactive power, its transmission over the network causes active energy costs, which are covered by the active energy of the generators (due to additional fuel consumption). The magnitude of these losses can be represented as follows:

$$W_{TP} = (Q^2 / U^2) \cdot R \cdot \tau ,$$

where τ - is the time characteristic of the reactive power transfer schedule.

Reactive power compensation is used for several purposes. First, it is necessary to maintain the balance of the reactive power of the load nodes. Secondly, reactive power compensation devices are used to reduce losses. Thirdly, compensation devices can be used to adjust the voltage and improve the quality standards of electricity.

The condition for normal operation and ensuring the quality standards of electricity for any electrical network is to respect the balance of total power in it (equality of electricity produced and consumed).

Imbalance of reactive power will lead to a change in the voltage level in the network. If the generated reactive power is more consumed, the voltage rises, and with a deficit of reactive power - decreases. However, in contrast to active, it is advisable not to transmit the missing reactive power from neighboring power systems, but to generate it with the help of compensation devices installed directly in this power system.

Without compensation devices installed in networks of power systems, the mode of reactive power balance at permissible voltage levels in the load nodes is not feasible.

At the stage of operation, power system requirements (Qe value) are often absent, especially for objects of relatively low power. In addition, in many cases, the problem arises of reactive power compensation in only one network node. Existing methods for optimal distribution of power compensating devices for these cases are unsuitable. As a result, a simplified approach has become widespread, according to which compensating devices are usually selected according to the condition for increasing the power factor (cosφ) to a certain accepted value.

Based on the obtained power consumption, the reactive power to be compensated is calculated from the actual current value (initial reactive power factor $tg\varphi_1$) to the target value (final reactive power factor $tg\varphi_2$).

The total power of the compensating device is determined as follows:

$$Q_{КУ} = \mathrm{P}(tg\varphi_1 - tg\varphi_2),$$

where P - is the active load power.

The power density of the compensating device is determined by the formula where:

$$k_{КУ} = \frac{Q_{КУ}}{S_{КУ}},$$

where S - installed transformer capacity.

Both at the design stage and during the operation of power supply systems, the right choice of compensating devices will allow unloading distribution lines and transformers; reduce power losses from reactive power flow; improve power quality.

Investigated object.

Considered the distribution network of the enterprise, containing the lines 35-110 kV and 6 (10) kV and transformers 6 (10) /0.4 kV (Figure 1, Figure 2).

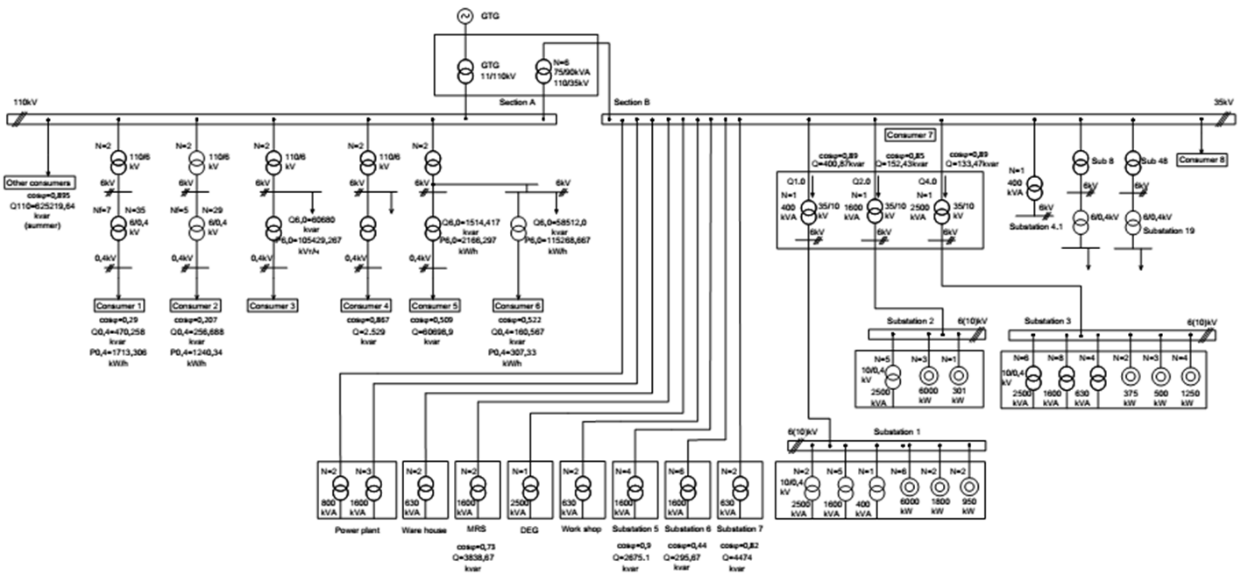

Figure 1. Scheme of single line power supply

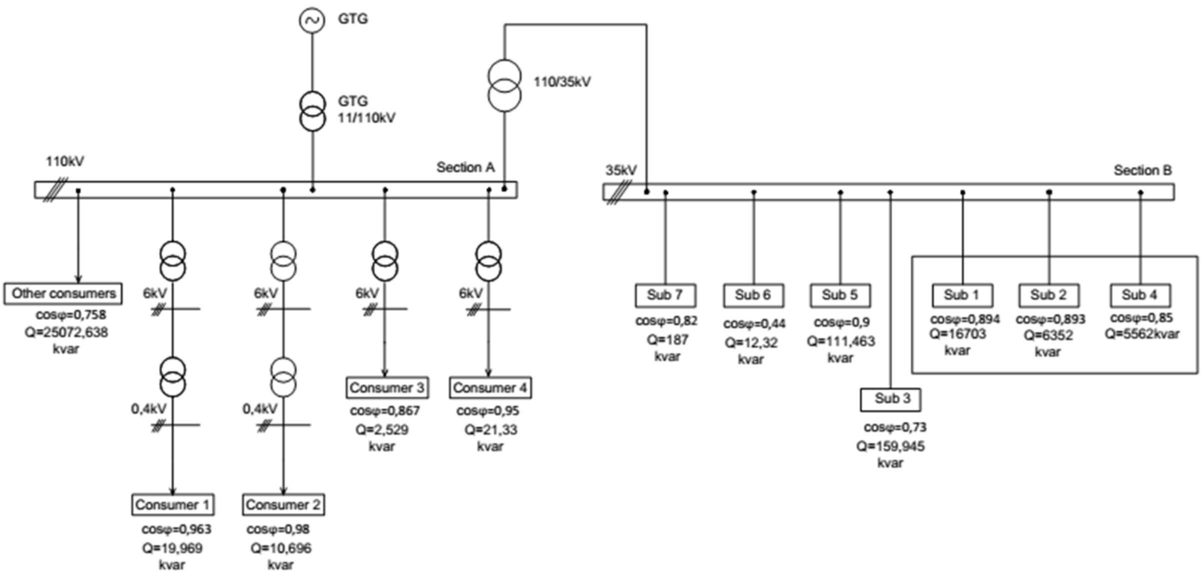

Figure 2. Scheme of simplified power supply

Three variants of reactive power compensation were considered. (Figure 3).

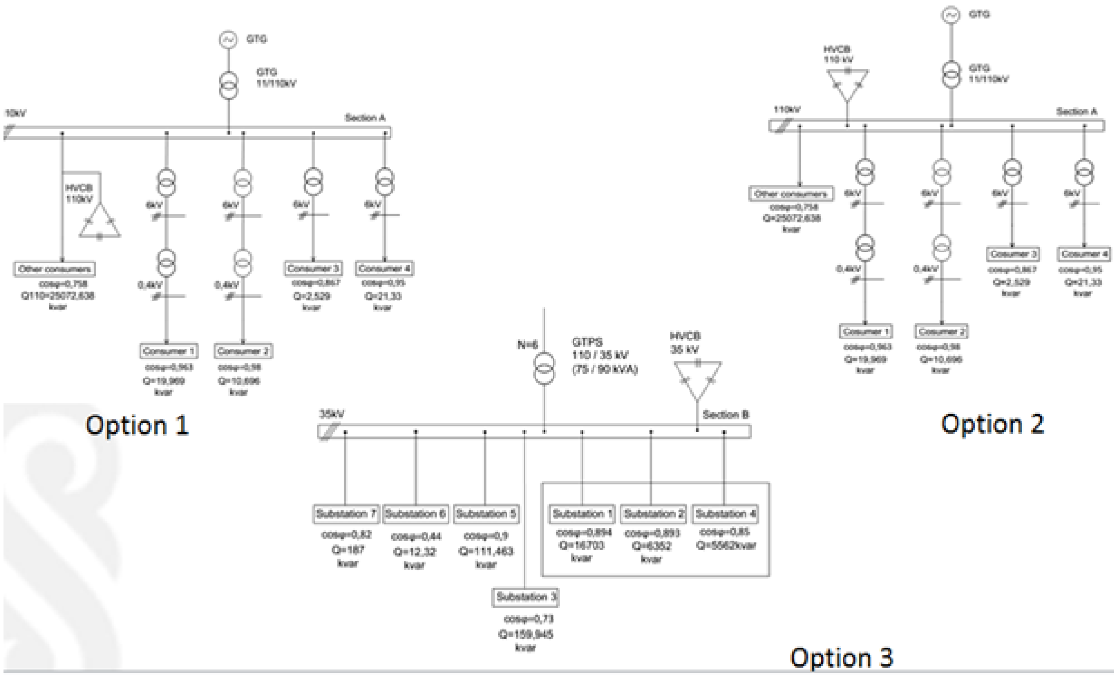

Figure 3. Calculation and selection of compensating devices

Table 1.Data on reactive power consumption of the following substations (Option 1)

№	Substation	W_P, MW.h	W_Q, Mvar.h	P_{35}, MW	Q_{35}, Mvar	S, MV.A	cosφ
			KPC				
1	Substation №1	23888	12026	33,18	16,7	37,146	0,894
2	Substation №2	9055	4573	12,58	6,352	14,093	0,893
3	Substation №4	6474	4004	8,99	5,562	10,572	0,851
Total for KPC substations:				54,747	28,617	61,775	0,887
			Other substations				
4	Substation №5	169,294	80,253	0,236	0,12	0,265	0,9
5	Substation №6	4,358	8,87	0,0605	0,013	0,061	0,44
6	Substation №7	190,97	134,220	0,265	0,187	0,324	0,82
7	MRC	122,053	115,16	0,17	0,16	0,233	0,73
Total for other substations:				0,676	0,471		
Total 35 kV tires:				55,423	29,088	62,592	0,886

Table 2. Data on the reactive power consumed by OL-135 and OL-136 (Option 2)

№	Substation	W_P, MWh	W_Q, Mvar.h	P_{35}, MWh	Q_{35}, kvar	S, MV.A	cosφ
1	OL (135+136)	209634	18052,3	29115,834	25072,639	38423,548	0,758

Table 3. Data on the consumed reactive power of the following substations and given to other consumers on OL-135, OL-136 (Option 3)

№	Substation	W_P, kW.h	W_Q, kvar.h	P_{35}, kW	Q_{35}, kvar	S, MV.A	cosφ
1	OL (135+136)	209634	18052,3	29115,834	25072,639	38423,548	0,758
2	«Consumer 1»	51319,166	14377,75	71,277	19,969	74,128	0,963
3	«Consumer 2»	37210,228	7700,63	51,681	10,696	52,775	0,98
4	«Consumer 3»	46764,144	15357,6	64,951	21,33	68,363	0,95
5	«Consumer 4»	3162,878	1820,4	4,393	2,529	5,069	0,867
6	Load from 35 kV tires			55423	29088	62592	0,886
Total:				84731	54215	100591,3	0,84

Table 4. Summary table for the considered options CRM

№	Options	Before compensation					After compensation			
		P, MWt	Q, Mvar	S, MW.A	cosφ	Q_{HVCB}, Mvar	P, MWt	Q, Mvar	S, MW.A	cosφ
1	HVCB on tires 35 kV substations that power SUBSTATION	55,423	29,088	62,592	0,886	5	55,423	24,09	60,43	0,918
2	HVCB on the outgoing line 110 kV "other consumers"	29,115	25,072	38,423	0,758	10	29,115	15,07	32,784	0,89
3	HVCB on 110 kV GTU tires	84,731	54,215	100	0,84	10	84,731	44,21	95,573	0,887

Results.

Both at the design stage and during the operation of power supply systems, the right choice of compensating devices will allow unloading distribution lines and transformers; reduce power losses from reactive power flow; improve power quality.

At the same time, it should be noted that the obtained results should be considered only as a first approximation to the solution of the problem of optimizing the choice of installation sites for compensating devices. For a more accurate solution of this task, it is also necessary to take into account additional restrictions (on permissible voltage levels in network nodes, on operation modes of compensating devices, on load stability, etc.), introducing them into the objective function as optimization criteria and turning to solving a multicriteria optimization problem . A multi-criteria approach will allow a comprehensive approach to the problem of selecting installation sites for compensating devices, to more accurately describe its conditions, thereby obtaining solutions in the most relevant real-world use of a multi-criteria approach to solving the problem of optimizing the choice of installation sites for compensating devices requires an in-depth feasibility study. In particular, when choosing the best ways to compensate for reactive power, you should take into account the cost of electricity and compare it with the cost of compensating devices. According to the results of the economic analysis, it will be possible to determine the optimal ratio between the reactive power consumed by the enterprise from the grid of the energy supplying organization and the reactive power generated by the compensating devices installed at the industrial enterprise. In addition, the electrical load schedule of an enterprise should be taken into account and the choice of the appropriate optimal method of reactive power compensation for each zone of the load graph should be made.

Conducting an in-depth technical and economic analysis with the subsequent construction of a computer model of the power supply system of an industrial enterprise and the solution of the problem of multi-criteria optimization will determine the most optimal ways of compensating reactive power in industrial electrical networks.

Thus, the choice of optimal installation sites for compensating devices and the optimization of the reactive power compensation process in industrial electrical networks as a whole is today an urgent practical task. Optimization of the reactive power compensation process will minimize the power losses in electrical networks caused by reactive power overflows, reduce the cost of industrial enterprises for electricity, increase the capacity of electrical networks and will contribute to the realization of energy-saving potential at industrial enterprises.

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