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Opportunities for rationalization the electricity consumption of a port complex

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GOAL OF THE STUDY

Study of the characteristics of the power supply system of the port complex in order to identify measures to improve the operating modes. The obtained results will enable the introduction of technological solutions for rationalization the electricity supply and achieving energy savings..

METHODOLOGY OF THE INVESTIGATION

For the analysis of the energy characteristics the following methodology is synthesized and the formulas used in the analysis for determination of characteristic coefficients are presented below:

Coefficient of use on active and reactive load:

$$K_{\mathrm{ua}} = \frac{\mathrm{P_{av}}}{\mathrm{P_n}} = \frac{\frac{1}{n}\sum_{i=1}^{n} P_i}{P_{\mathrm{ntr}}} \; ; \quad K_{\mathrm{ur}} = \frac{Q_{\mathrm{av}}}{Q_{\mathrm{n}}} = \frac{\frac{1}{n}\sum_{i=1}^{n} Q_i}{Q_{\mathrm{ntr}}} \qquad (1)$$

Coefficient of the active and reactive load form:

$$K_{\mathrm{fa}} = \frac{\mathrm{P}_{av.sq}}{\mathrm{P}_{av}} = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n} P_i^2}}{\frac{1}{n}\sum_{i=1}^{n} P_i^2} \geq 1 \; ; \quad K_{\mathrm{fr}} = \frac{Q_{av.sq}}{Q_{av}} = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n} Q_i^2}}{\frac{1}{n}\sum_{i=1}^{n} Q_i^2} \geq 1 \qquad (2)$$

Coefficient of the maximum on active and reactive load:

$$\mathrm{K_{Ma}} = \frac{\mathrm{P_M}}{\mathrm{P_{av}}} \; ; \quad \mathrm{K_{Mr}} = \frac{Q_{\mathrm{M}}}{Q_{\mathrm{av}}} \qquad (3)$$

Coefficient of filling the load schedule by active and reactive load:

$$\mathrm{K_{f_{ls}}} = \frac{1}{\mathrm{K_{Ma}}} \; ; \quad \mathrm{K}_{f_{ls}} = \frac{1}{\mathrm{K}_{\mathrm{M}r}} \qquad (4)$$

Determination of power losses ΔP, in case of an even load schedule:

$$\Delta \mathrm{P}_{av} = \frac{\mathrm{P}_{av}^2 + Q_{av}^2}{U^2} . R \qquad (5)$$

Determination of power losses ΔP, in case of an uneven load schedule:

$$\Delta \mathrm{P}_{un} = \frac{\mathrm{P}_{av.sq}^2 + Q_{av.sq}^2}{U^2} . R \qquad (6)$$

Dispersion components for active and reactive power (D[P] and D[Q]) of the considered system are:

$$D[P] = P_{av.sq}^2 - P_{av}^2 \; ; \quad D[Q] = Q_{av.sq}^2 - Q_{av}^2 \qquad (7)$$

The relative difference δ(ΔP) in case of uneven load schedule is estimated using the expression:

$$\delta(\Delta \mathrm{P}) = \frac{K_{u_a}^2 . \mathrm{P}_n^2 \left(K_{f_a}^2 - 1\right) + K_{u_p}^2 . Q_n^2 \left(K_{f_r}^2 - 1\right)}{K_{u_a}^2 . \mathrm{P}_n^2 + K_{u_r}^2 . Q_n^2} . 100\ \% \qquad (8)$$

The electrical energy losses ΔW in a segment of the electrical network with active resistance R for time T can be determined using average square current $I_{AV.SQ}$:

$$\Delta W = 3.R.I_{av.sq}^2 .T \; ; \quad W = 3.R.I_{av}^2 .T + 3.R.D[I].T = \Delta W_1 + \Delta W_1 \qquad (9)$$

MAIN RESULTS FROM THE STUDY

Based on the measurements made over a long period of time with the help of network analyzers, the different types of power (P_{AV}, Q_{AV}, $P_{AV.SQ}$, $Q_{AV.SQ}$, P_M, Q_M) were determined. The characteristic coefficients K_{ua}, K_{ur}, K_{fa}, K_{fr}, K_{ma} and K_{mr} were calculated. Table 3 presents the values of these characteristics, as well as the additional active power losses δ(ΔP), due to the unevenness of the load schedules, for the studied power substations.

Table 1. Energy characteristics for all control points

TS	In	P_n kW	Q_n kVAr	K_{ua}	K_{ur}	K_{fa}	K_{fp}	$K_{ма}$	$K_{мр}$	δ(ΔP)
New mechan. workshop	1	504	378	0.09	0.09	1.60	1.60	2.45	3.65	336.43
Transf. station	1	1000	750	0.06	0.01	1.03	1.02	11.06	1.46	22.94
	2	1000	750	0.05	0.09	1.6	1.58	2.45	3.65	336,43
	3	1000	750	0.19	0.14	1.10	1.11	3.77	1.93	7.57
TS 11	1	800	600	0.01	0.01	1	1	0.43	1.14	104.53
TS 10	1	800	600	0.15	0.17	1.16	1.26	2.35	2.14	45.20
	2	800	600	0.03	0.01	1.15	1.16	9.36	3.57	31.30
TS 9	1	800	600	0.03	0.05	1.50	2.09	4.59	11.90	254.89
	2	800	600	0.33	0.24	4.36	7.99	69.01	69.01	2812.48
	3	800	600	0.02	0.04	2.14	2.71	4.69	9.98	161.16
Komi	1	800	600	0.01	0.07	1.7	1.76	4.91	4.69	217.36
Terminal 4	1	504	378	0.03	0.01	1.05	1.12	7.64	4.18	12.76

The coefficients of the maximum on active and reactive load, take values respectively $K_{ма}$ = (1,26 ÷ 69,01) and $K_{мr}$ = (1,14 ÷ 69,01) and it can also be said that their variation is inadmissible and inexpedient. Such a regime of change of these coefficients means that at certain moments the maximum-continuous load can cause significant prolonged overloads of the power transformer;

The coefficients of the form of active and reactive load for the studied transformer stations vary in the range K_{fa} = (1.03 ÷ 4.36) and K_{fr} = (1.02 ÷ 7.99). For some transformer stations, these coefficients assume drastically high values. The reason for this is usually the dynamic impact loads caused by the crane systems. In general, these coefficients have inflated values, which is a reason to plan technical measures to minimize them;

The coefficients of use by active and reactive load for the different transformer stations have very low values, respectively K_{ua} = (0.01 ÷ 0.33) and K_{ur} = (0.01 ÷ 0.24). This means that the usability of electricity consumers is relatively low and it is necessary to propose measures to reduce their capacity;

The additional active losses from uneven load δ (ΔP) change in the range (0.55 ÷ 2812) %, as the largest value δ ($ΔP_{max}$) = 2812.48 % is registered for TP9, input 2. These losses are too high and it is necessary to implement measures to regulate the load schedules of the various power transformers.

For industrial sites of this type, especially in the mode of reduced load, it is expedient and effective to use methods related to shifting the start of work of different nodes, groups of users or individual users in them. This approach has two main effects: minimizing the maximum-continuous loads P_m and minimizing the additional active power losses δ(ΔP).

CONCLUSIONS

In the power stations of the power supply system of the site, the load of the electrical equipment is quite dynamic, but with a low utilization factor and an increased probability of overloading the power transformer due to high values of the maximum - continuous load Pm. These negative phenomena adversely affect the work of consumers, communication and protection elements and the reactive power compensation system.

Analysis of the results for δ (ΔP) shows that these losses for some TA have quite high values. Their minimization can be done by shifting the time for switching on users so as to obtain an equalization of the load schedule.

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