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Limitations in the economic distribution of reactive power between the generators

***Abstract**. An approach to take into account the limits for the distribution of the reactive load between generators has been discussed. An actual limits due the heating of butt packages of steel of the stator of synchronous generators for the optimum partition of the reactive load is taken into consideration.*

***Streszczenie.** W pracy podjęto próbę uwzględnienia ograniczeń przy rozdziale mocy biernej pomiędzy generatory. Uwzględniono ograniczenia wynikające z nagrzewania statora generatora synchronicznego do optymalizacji rozdziału mocy biernej. (**Ograniczenia w ekonomicznym rozdziale mocy biernej pomiędzy generatory**)*

Keywords: Synchronous generator, reactive load, optimum partition
Słowa kluczowe: generator synchroniczny, moc bierna, optymalny podział mocy

Problem consideration

Economic distribution of reactive power between generators is usually conducted taking into account the stability conditions and the heating of the butt-end packages of the stator steel. These limitations are shown on the chart of admissible modes of turbogenerators (TG) [1]. They are located within the zone of reactive power consumption.

However, as it was revealed in [2], the actual boundary of limitations under the terms of heating of butt- end packages of steel of the stator shifts towards positive values of reactive power. This paper is dedicated to the economic distribution of reactive power under this particular condition.

Analysis of the latest research

In the works [3, 4] economic distribution of reactive power between asynchronous AT ASTG-200 and synchronous TG (STG) of type TGV-200 i TGV-200 M (Ukrainian classification) can be found. It was carried out taking into account the limitations under stability conditions and the heating of butt-end packages of steel of the generator that is shown on the chart of admissible loads of TG.

The study of the electric load charts at Burshtyn HPP (Ukraine) in the maneuvering modes along with the analysis of damage of extreme packages of steel of the stator TG, (which led to the damage of the stator winding) has shown [2] that the damage of the butt-end packages of the stator steel takes place at positive and negative values of reactive power, which are considerably different from the maximum allowable one. Fig. 1 shows a fragment of the chart of the admissible modes of TG TGV-200M, TGV-200 under heating of butt-end packages of the stator steel within the zone of small excitation current. The damage of TG № 6, 8, 9, 11 at Burshnyn HPP was studied.

Fig. 1 shows that the zone of damage of this TG is considerably shifted to the right respectively to the curve 1 which was obtained during the thermal testing at the plant.

The damage often occurs in the maneuvering modes, when active load and $\cos\varphi$ increase and go down. Therefore it should be accepted that the curve 2 is a maximum allowable boundary within the zone of small excitation and it is shifted considerably to the right respectively to the curve 1. Under this condition the minimal reactive load is approximately +20 Mvar.

These circumstances are taken into account under the operating conditions of a HPP. The optimization of the simultaneous operation of STG and ASTG lies in the redistribution of the total reactive load between them in order to satisfy the following criteria:

- to provide the functioning of STG with the capacity factor sufficient enough to ensure the necessary stability margin of their operation and to avoid overheating of the butt-end zones of the steel of the stator;
- to achieve the minimum value of total losses of active power from the reactive power in generators and block transformers.

Using [3], and considering the minimal reactive load for STG to be equal to +20 Mvar [5], the specialists working at the power plant issued the schedules of reactive load between TG, which operate on 330kV buses for different compositions of the working generators and gave them to the personnel. Such schedules are not ideal but give the operating personnel a chance to analyze the operating regime consciously.

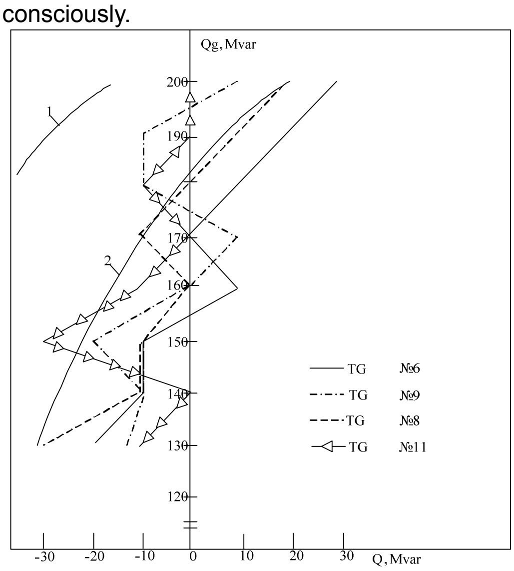

Fig.1. Admissible and actual operating limits of TG TGV-200 and TGV-200V in the area of under-excitation:1-plant limits under heating of extreme packages,2-actual reliable limitations

Research objectives

It is important to show in this work how to take into consideration the change of boundary of admissible loads under condition of heating of butt-end packages of the stator steel in zone of small excitation currents for the distribution of the reactive load.

Main ideas

In order to determine the optimal distribution of reactive load at the power plant between separate generators it is important to solve the optimization problem. The solution conditions are as follows:

1. Goal equation is $\Delta P \to min$, or $Z \to min$, where ΔP are losses of active power from the reactive power flow, Z are given losses,

2. The coupling equation $\Delta P_i(Q_i)$, where i is the number of the power source.

3. The restrictions equation is a balance equation of the reactive load and the power caused by the reactive power sources:

$$Q_н - \Delta Q - \sum_{i=1}^{n} Q_i = 0. \quad (1)$$

4. Optimization equation based on the method of Lagrange multipliers under condition of neglecting of the reactive power losses ΔQ is as follow:

$$\lambda = \frac{\partial \Delta P}{\partial Q_i} = idem \text{ , or} \quad (2)$$

$$\lambda = \frac{\partial Z}{\partial Q_i} = idem. \quad (3)$$

If under condition of butt-end zones heating the reactive load of the generators parts should be constant and positive, the conditions 3 and 4 can be written down as

$$Q_1 + Q_2 + \cdots + Q_n + Q_{nconst} + Q_{(n+1)const} = Q_c;$$

$$\lambda_1 = \lambda_2 = \lambda_n = idem; \quad (4)$$

$$\lambda_{nconst} = \lambda_{(n+1)const} = 0.$$

If there is one TG which can consume reactive load at the power plant we see that

$$Q_1 + Q_{2const} + \cdots + Q_{nconst} + Q_{(n+1)const} = Q_c; \quad (5)$$
$$\lambda_1 = \lambda.$$

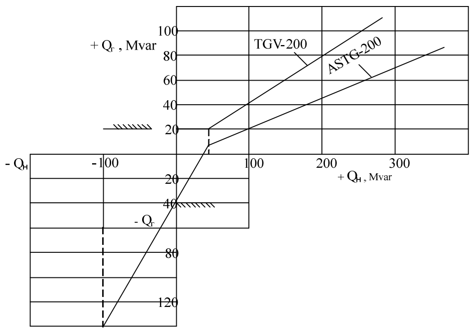

Fig. 2.Dependence of the optimal reactive power of TG on the reactive load for the correlation of the blocks 1xASTG-200-2UZ+2xTGV-200

The heating of the butt-end zones is mainly determined by the machine design, accepted electromagnetic load and the intensity of cooling and it can be eliminated in new machines. Between clamping flanges and clamping fingers of the butt zone of the magnetic wire of the stator a non-magnetic screen is installed that weakens the penetration of the magnetic field into the extreme packages of the magnetic wire. This reduces the possibility of unacceptable overheating of the butt-end zones.

For machines under exploitation the acceptable operation boundary in zone of small excitation should be slightly shifted to the right. This peculiarity should be taken into consideration while distributing the reactive power. Such a shift of boundary of acceptable heating of extreme packages can be determined on the basis of the operation experience and thermal experiments.

Fig. 2 provides an example of the distribution of reactive power between TG in the combination 1xAST-200+2xTGV-200, and Fig. 3 between TG - 2xASTG-200+1xTGV-200M+2xTGV-200.

As it is shown in the Fig.2 and 3, in order to eliminate the heating of the end zones of TG TGV-200 and TGV-200M, ASTG-200 consumes a considerable amount of reactive power, especially when the load has the negative character. In Fig. 2 i 3 zones of load where the heating of the butt packages of steel of the stator for TG TGV-200 and TGV-200M is observed, are highlighted.

The curves of the loss of active power from reactive power in ASTG-200, TGV-200M, [6] were used while calculating the economic distribution of the reactive load.

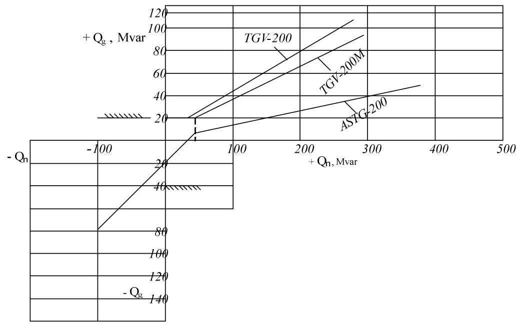

Fig. 3. Dependence of the optimal reactive power of TG on the general reactive load for the correlation of the blocks 2xASTG-200-2UZ+1xTGV-200M+2xTGV-200

Conclusions

1. An approach how to take into account the actual boundary of limitations under heating of butt-end packages of the stator steel for TG TGV-200 i TGV-200M within the economic distribution of reactive power between STG and ASTG-200 was proposed.

2. The examples of the above mentioned limitation boundaries and how to take them into account are given.

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