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The optimal distribution of reactive power on synchronous generators in power plants

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Abstract

In the present conditions of operation of the electricity market, the production and consumption of reactive power by the synchronous generators in power plants shows a special importance. The paper analyzes the possibility of optimal distribution of reactive power on the synchronous generators in the case of a combined heat and power plant with 60 MW turbogenerators. The optimization problem consists in the distribution of reactive power on the synchronous generators in the power plant, knowing the reactive power exchanged with the local distribution network operator, so that the total losses of active power due to the reactive power flow in the power plant to be minimal.

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1. Introduction

Reactive power has a significant effect on system security as it is directly associated with power system voltage stability. The synchronous generators, in addition to the importance they have as active power sources, are important as sources of reactive power. Their static characteristic is favorable in terms of the voltage control scheme, and they can operate both in capacitive and inductive regime [1,2,3]. In the majority of the applications such as ancillary services and reactive power markets, it is assumed that the capability curves of the generators do not change over time and are as provided by the generator manufacture. In the paper [4], this assumption is challenged and it is

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discussed that with the generator aging, distinctive changes are appeared in the reactive capability curves due to different causes.

Having high power and being placed in important nodes in the system, they have a high efficiency for voltage regulation, influencing in this respect important consumer areas. By changing the excitation voltage, they allow the terminal voltage regulation in a relatively broad band.

Reactive power management is required to support real power shipment, providing reserve for voltage security and supplying reactive loads [5,6]. In competitive electricity market, reactive power ancillary service management is a critical task for power system operator [7,8,9].

2. Modelling the active power losses caused by the reactive power load

The practical expression for calculating the active power losses in a synchronous machine, presented in paper [10], is:

$$\Delta P_g = A_g \cdot \alpha^2 + B_g \cdot \alpha + C_g + D_g \cdot \beta^2 \tag{1}$$

where:

A_g, B_g, C_g, D_g – are constant coefficients for a synchronous machine.

The terms:

$$A_g \cdot \alpha^2 = A_g \cdot \left(\frac{Q_g}{Q_{gn}}\right)^2 \quad \text{and} \quad B_g \cdot \alpha = B_g \cdot \frac{Q_g}{Q_{gn}} \tag{2}$$

are the components of losses that depend on the Q_g reactive power supplied by the synchronous machine (Q_{gn} is the nominal reactive power of the synchronous generator). The C_g term is constant and does not depend on the variation of active and reactive power. The term:

$$D_g \cdot \beta^2 = D_g \cdot \left(\frac{P_g}{P_{gn}}\right)^2 \tag{3}$$

is a component of losses which depends on the active power load of the machine.

By dissociating the losses that depend on the reactive power in equation (1), it results the expression of the active power losses for the Q_g generated reactive power in the synchronous generator:

$$\Delta P_{rg} = A_g \cdot \left(\frac{Q_g}{Q_{gn}}\right)^2 + B_g \cdot \frac{Q_g}{Q_{gn}} \quad \text{(kW)} \tag{4}$$

The A_g and B_g coefficients are constants for a synchronous machine and can be determined based on the catalog data. Next is how to determine the A_g and B_g constants based on the catalog data.

The reactive power control generated or absorbed by the generator is achieved by modifying the excitation current, therefore the losses by Joule effect in the rotor winding are also amended. Table 1 presents the catalog data [11] of Joule losses in the rotor winding for different α loads. The Joule losses in the rotor winding were modeled using the least squares method, based on the catalog data at different loads, resulting in the following expression: