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Mathematical model of synchronous motors for static characteristics power loss

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Abstract

This article analyses the mathematical model of synchronous motors and its application to build statistic power characteristics. The paper presents the static characteristics of active power losses, analysing which the author comes to certain conclusions regarding the minimization of losses in the synchronous motor.

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Keywords: mathematical model; power losses; synchronous motor; static characteristics

1. Introduction

Static characteristics of the power load in the steady mode, which are representing as relation of active P (U) and reactive Q (U) power load of voltage, are widely used in the performance of a task of electricity supply.

This article describes the mathematical models of synchronous motors and their application for registration of electric energy losses in the engine and construction of static characteristics of power load losses.

There are two basic types of synchronous motors in the industry: motors with laminated poles (SMLP) and motors with a massive smooth rotor (SMMR).

SMLP motors is most common type of salient-pole synchronous motors with rate of rotation ≤ 1000 revolution per minute.

Equivalent circuit of synchronous motors in the direct (a) and quadrature (b) axes are shown in Fig. 1.

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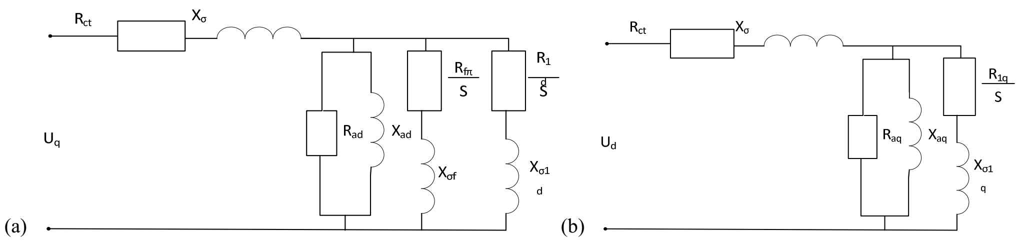

Fig. 1. Equivalent circuit of synchronous motors in the direct (a) and quadrature (b) axes.

Parameters of equivalent circuit are: R_{ad}, R_{aq}, R_{st}, R_f, R_{1d}, R_{1q} – respectively active resistance branches of the magnetizing branch on the direct and quadrature axis of the rotor, stator winding, field winding and damper winding along the direct and quadrature axis of the rotor; X_{ad}, X_{aq} – introduction resistant between the stator winding and rotor windings on the axes d and q; X_o, $X_{o\,f}$, $X_{o\,1d}$, $X_{o\,1q}$ – respectively inductive resistance of the scattering of stator, field and damper windings on the axes d and q; $R_{f\text{п}}$ – active resistant of the field winding at synchronous motors starting moment, when field windings are closed on an additional starting resistance $R_{\text{п}}$ ($R_{f\text{п}} = R_f + R_{\text{п}}$).

The algorithm of calculating the equivalent circuit parameters were described in detail in studies [1-4] and will not be given here. Only the main features of the calculation will be mention.

The active resistance of the stator winding in relative units is equal with the active power losses in this winding at the nominal mode of the synchronous motors, which form a stable proportion (an average of 0.4) of the total active power losses in the synchronous motor.

$$R_{cm} = 0,4 \cdot (1 - \eta_N) \cdot \eta_N \cdot \cos\phi_N \tag{1}$$

The main calculation expression to determine the synchronous resistance X_d is the equation for the maximum synchronous moment.

$$M_M \cdot \frac{P_N}{S_N} = P_M = \frac{E_{qN}}{X_d} \sin\delta_M + \frac{X_d - X_q}{2X_d X_q} \sin 2\delta_M \tag{2}$$

where

δ – include angle of synchronous motor, which are equal with maximum of the moment and active power P_m at the synchronous conditions;

S_n – nominal power of synchronous motor.

Other parameters of equivalent circuit of SMLP determined by the method of successive approximations of the condition that the data from catalog and calculated data are similar.

SMMR motors are the most common type of non-salient pole synchronous motor with rate of rotation ≤ 3000 revolution per minute.

SMMR motors in contrast with SMLP have following characteristic:

1. Based on the rotor symmetry in the direct and quadrature axes where are following relations [1]:

$$\begin{aligned} X_d &= X_q \\ X_{ad} &= X_{aq} \\ X_{\sigma 1d} &= X_{\sigma 1q} = X_{\sigma 1} \\ R_{1d} &= R_{1q} = R_1 \\ R_{ad} &= R_{aq} \end{aligned} \tag{3}$$