MODEL OF SYNCHRONOUS GENERATOR FOR REMOTE PERTURBATION

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Introduction

The model of the synchronous generator with damper windings is described with the system of six differential equations. Two first are written for direct and quadrature stator windings. Three next equations are written for the rotor windings. Direct and quadrature damper windings and excitation winding are included into the rotor windings. Sixth, the differential equation is nonlinear. This equation describes the relationship of inertia, electromagnetic and mechanical torques acting on the rotor shaft. The solution of these equations is not an easy task. However, the art of modelling is not the ability to solve complex equations, but the ability to lossless main, the main features of the phenomenon to transform the original complex system into a simpler, guided by the conditions faced by the system under study. Therefore, the aim of this paper is to study the model of the generator in an environment where the original complex system can be simplified, but without losing the basic characteristics of the model.

If the point of application of the disturbance is far from the generator, the generator is allowed in the equations do not take into account the electromagnetic transients in the damping circuits. Because damping circuits shorted and, consequently, their currents are only free - aperiodic component which decays rapidly, without having to wait for the disturbance. Due to the large inertia of the rotor speed of the rotor changes slowly, so we can assume that there is no slip . And equations to describe the transient generator take the form [1, 3]:

$$\begin{aligned} &Ri_d + \frac{x_d}{\omega_0}\frac{di_d}{dt} + x_q i_q + \frac{1}{\omega_0}\frac{dE_q}{dt} = -u_d; \\ &-x_d i_d + Ri_q + \frac{x_q}{\omega_0}\frac{di_q}{dt} - E_q = -u_q; \qquad (1) \\ &T_r \frac{d}{dt}\left[(x_d - x'_d)i_d + E_q\right] + E_q = e_r; \end{aligned}$$

Here E_q – quadrature-axis synchronous voltage is proportional to the excitation current i_f. This value is to be determined. T_r – time constant of the circuit excitation closed loop circuit of the stator. i_q, i_d – direct and quadrature токи статора. $e_r = U_f x_{ad} / x_f$ – electromotive force proportional to the stator voltage. x_q, x_d, x'_d, r – the main technical data of the machine: synchronous reactance in the direct and quadrature axes, direct axis transient reactance, resistance of the stator winding, respectively.

When the solution of differential equations (1) it is more convenient to use the continuously changing value E'_q – quadrature-axis transient electromotive force. It is proportional to flux linkage ψ_f of the exciting circuit. And to determine changes abruptly synchronous electromotive force E_q to use a ratio [4, 5]:

$$E'_q + i_d x'_d = E_q + i_d x_d = u_q$$

It also can ignore the transients in the stator windings of the generator, considering that the appearance of the disturbance in the stator windings originated steady state. On the rotor of the generator is only one path - the excitation winding, oriented along the axis *d* (direct-axis of the rotor), and the equation becomes:

$$\begin{aligned} &-x_q i_q - R i_d = u_d; \\ &E'_q + x'_d i_d - R i_q = u_q; \\ &T_{d0}\frac{dE'_q}{dt} + E'_q - i_q(x_d - x'_d) = E_{qe}. \end{aligned} \tag{2}$$

Thus, the system of algebraic and differential equations describes the assumptions made transients in salient-pole synchronous generator without damping circuits. . Algebraic equations are obtained from the steady state of the system (2) by equating to zero the derivatives of the equation *d / dt = 0*.

The solution is divided into 3 stages

1. Determine the dependence of stator currents i_q, i_d от on the stator voltage u_q, u_d and transient electromotive force E'_q

$$\begin{cases} i_q = \dfrac{-x'_d u_d + E'_q r - u_q r}{x'_d x_q + r^2} \\ i_d = \dfrac{-x_d E'_q + x_q u_q - u_d r}{x'_d x_q + r^2} \end{cases} \tag{3}$$

2. Next, find the values $E'_{q\,np}$ in the steady state, substituting instead of the current i_d its current expression (4)

$$E'_q - i_d\left(x_d - x'_d\right) = E_{qe} \rightarrow$$

$$\rightarrow E'_q + \frac{E'_q x_q - x_q u_q + u_d r}{x'_d x_q + r^2}\left(x_d - x'_d\right) = E_{qe}$$

The result is:

$$E'_{q\,np} = \frac{x_q u_q x_d - x_q u_q x'_d - u_d x_d r + u_d x'_d r + E_{qe} x_q x'_d + E_{qe} r^2}{x_d x_q + r^2}$$

Solve differential equations to determine the transition EMF $E'_q(t)$ при известных напряжения статора. under certain stator voltage. Pre present equation to normal form

$$\frac{dE'_q}{dt} = -\frac{\left(r^2 + x_q x_d\right)E'_q}{T_{0d}\left(r^2 + x_q x'_d\right)} + \frac{E_{qe}}{T_{0d}} + \frac{\left(x'_d - x_d\right)\left(u_d r - u_q x_q\right)}{T_{0d}\left(r^2 + x_q x'_d\right)}$$

From the last equation it follows that the time constant of the transition process is equal to the value of the expression;

$$T = \frac{T_{0d}\left(r^2 + x_q x'_d\right)}{\left(r^2 + x_q x_d\right)},$$

This expression, neglecting the stator resistance is converted to a known relation:

$$T'_{0d} = \frac{T_{0d} x'_d}{x_d}$$

3. The third stage is solution of the system of differential equations. The construction of plots and interpretation of results [2]. To solve the system (6) we use *MathCAD* program using function ***rkfixed() –*** Runge-Kutta method of order 4. With the help of the inverse transform Park - Gorev phase stator currents will be obtained [5, 6]

Conclusions

Models of synchronous generators proposed in the work lead to do the following conclusions:

If the place of application disturbance is in a remote location of a synchronous generator we can ignore fast transients occurring in the damping circuits and the contours of the stator.

Calculations of the transient processes of the synchronous generator on the proposed model show that after restart may be that repeated shortcircuit conditions are more difficult as initial conditions, that is, the current during the second circuit achieves greater value.

If the place of application disturbance is at a point close to the synchronous generator, than by the calculation mode in the generator model the transients in the stator windings should be taken into account.

The proposed model is in good agreement with the known fact that at the initial stage of the transient stator currents have doubled frequency harmonics.

The use of models is possible in networks containing synchronous generators and for the design of objects containing generators.

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