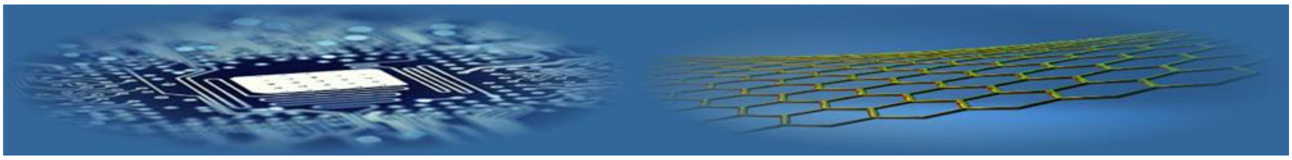

Improving the reliability of the managed of electric drives with a synchronous generator

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Abstract

The article examines the dynamic properties of the excitation control system of synchronous generator of capacity 2200kW, which comprises a converter - bridge rectifier. It was investigated the influence of the type of bridge rectifier - of thyristor symmetric bridge and of asymmetric bridge - on transient processes of synchronous generator in emergency operation. This problem was solved by numerical methods.

A mathematical model of synchronous generator excitation control system. In order to make the model of the generator excitation system has been used plugin SIMULINK mathematical software MATLAB.

During simulation were calculated currents short circuit of the synchronous generator in the case of using in system excitation a thyristor symmetrical bridge and asymmetrical bridge. Calculations have shown that the use of symmetric thyristor bridge reduces times the short circuit fivefold. This allows us to recommend used a symmetrical bridge in the electric drive system.

Keywords:

excitation system of the synchronous generator, the short-circuit mode

1 Introduction

The main element of an autonomous power system is a synchronous generator with independent excitation. To supply the field winding synchronous generator is also used synchronous generator - Synchronous exciter CB. Synchronous pathogen runs on the load via a bridge rectifier (Fig. 1) [1, 2].

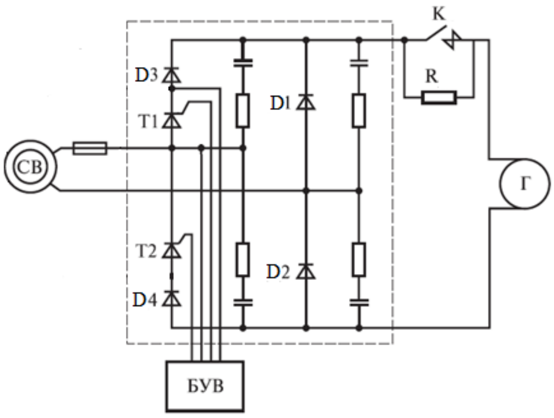

FIGURE 1 The system excitation synchronous generator. Г- is the rotor winding; CB – is the synchronous exciter; БУВ -is thyristors control unit; T1, T2 – it thyristors; D1-D4 - it diodes; K- is contact of contactor

Bridge rectifiers are widely used in industrial drives because they are rugged, reliable and economical. The bridge is an circuit that provides the same polarity of output for either polarity of input. The most widely used scheme with asymmetrical bridge. The two arms of the bridge contains a diodes D1, D2, and the other two arms contains a thyristors T1, T2. The bridge rectifier provides rectification and change current an electrical load. Capacitors provides a low impedance path to the AC component of the output, reducing the AC voltage across, and AC current through, the resistive load. Therefore, the load current and the voltage variation is reduced as compared with what would be the case without the capacitor.

Block БУВ is designed to control thyristors.

1.1 THEORETICAL BACKGROUND

The figure 2 shows a diagram of an equivalent circuit of the bridge

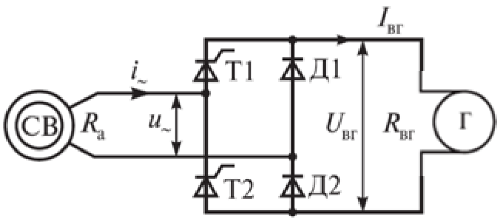

FIGURE 2 The equivalent circuit of the asymmetrical bridge: R_a - is the stator winding resistance CB; $u_{\sim}$ - is the is the stator voltage CB; $i_{\sim}$ - is the stator current CB; $U_{BГ}$ – is the rectified voltage to the excitation winding; $I_{BГ}$ – is the excitation current $Г$; $R_{BГ}$ – Is the resistance of the field winding Г

The average output voltage of the bridge rectifier depends on the control angle of the thyristors α and is determined from the expression:

$$U_{\text{ВГ}} = U_{\text{ср}} \cdot \frac{1+cos\alpha}{2} - \Delta U_R - \Delta U_{\text{В}} - \Delta U_X, \quad (1)$$

where $U_{cp} = \frac{2\cdot\sqrt{2}}{\pi} \cdot U, B$ – is average rectified voltage (thyristor firing angle α = 0);

$\Delta U_R, B$ - is voltage drop by resistance an rectification circuit;
$\Delta U_B, B$ - is the voltage drop across the diodes;
$\Delta U_X, B$ - this is the voltage drop of the switching thyristors.

Meaning ΔU_B very little; therefore the expression (1) can be written:

$$U_{\text{Вг}} = U_{\text{ср}} \cdot \frac{1+cos\alpha}{2} - \Delta U_R - \Delta U_X. \quad (2)$$

The value ΔU_X for single-phase bridge rectifier:

$$\Delta U_X = \frac{x_s \cdot I_{\text{Вг}}}{\pi}, \quad (3)$$

where x_s - is the resistance of the thyristor.

The value ΔU_R is a voltage drop across active resistance the armature winding for synchronous exciter

The value ΔU_R can be expressed as follows:

$$\Delta U_R = R_a \cdot I_{\text{ср}}. \quad (4)$$

The average current in the windings of the armature of the synchronous exciter I_{CP} is expressed:

$$I_{\text{ср}} = I_{\text{Вг}} \cdot k_{\text{пр}}, \quad (5)$$

where k_{np} - is the conductivity factor rectifier.

Conductivity factor is a variable quantity; k_{np} depends on the ratio current at the input / output and switching angles valves of the rectifier. The coefficient is determined from the ratio of current in the stator winding CB and average current in the field winding Г:

$$\begin{cases} I_{\text{ср}} = I_{\text{Вг}}\left(1 - \frac{\alpha+\frac{\gamma_2}{2}}{\pi} + \frac{2\gamma_1}{3\pi}\right); \\ I = I_{\text{вг}} \cdot \\ \cdot\sqrt{1 - \frac{\alpha+\frac{2}{3}\gamma_2}{\pi} + \frac{2\gamma_1(1+2cos^2\gamma_1)-3sin2\gamma_1}{4\pi(1-2cos\gamma_1)^2}} \end{cases}, \quad (6)$$

where k_{np} – is γ_1 and γ_2 angles are switching thyristors T1 and T2.

Hence we obtain the formula for the coefficient of the conduction

$$k_{\text{пр}} = 1 - \frac{\alpha+\frac{\gamma_2}{2}}{\pi} + \frac{2\gamma_1}{3\pi}. \quad (7)$$

Thyristors control angles are determined from the following expressions:

$$cos\gamma_1 = 1 - \frac{I_{\text{Вг}}}{I_{\text{к}}}, \quad (8)$$

$$cos(\alpha+\gamma_2) = cos\alpha - \frac{I_{\text{вг}}}{I_{\text{к}}}, \quad (9)$$

where I_K - is short-circuit current.

Its value is defined by the relationship:

$$I_{\text{к}} = \frac{\pi}{2} \cdot \frac{U_{\text{ср}}}{x_s} = \frac{\sqrt{2}U}{x_s} = \frac{(U)m}{x_s}. \quad (10)$$

Thus, the voltage across winding excitation synchronous generator $U_{B\Gamma}$ can be expressed as:

$$U_{\text{вг}} = U_{\text{ср}}\frac{1+cos\alpha}{2} - R_a k_{\text{пр}}(\gamma_1,\gamma_2,\alpha)I_{\text{Вг}} - \frac{2x_s I_{\text{Вг}}}{\pi}. \quad (11)$$

Also, the voltage $U_{B\Gamma}$ can be determined through the resistance $R_{B\Gamma}$:

$$U_{\text{Вг}} = I_{\text{Вг}} \cdot R_{\text{Вг}}. \quad (12)$$

Equating expressions (11) and (12) and performing the conversion, we get the following:

$$U_{\text{ср}}\frac{1+cos\alpha}{2} - \frac{2x_s I_{\text{Вг}}}{\pi} = I_{\text{Вг}}R_{\text{Вг}} + k_{\text{пр}}I_{\text{Вг}} \cdot R_a. \quad (13)$$

Figure 3 shows the characteristic of the control rectifier $U_{B\Gamma} = f(\alpha)$.

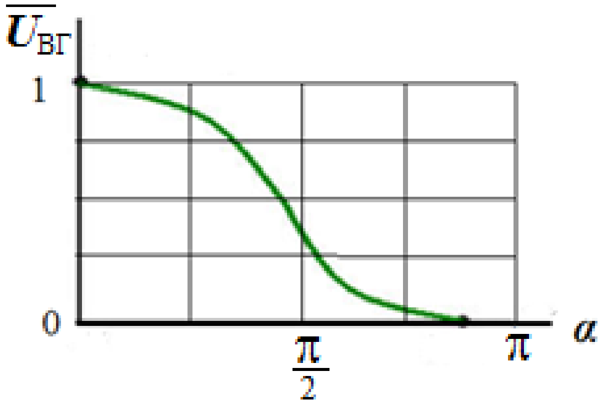

FIGURE 3 Control characteristic rectifier in relative units

$\overline{U_{B\Gamma}} = f(\alpha)$ relationship shows that for any value of the angle of the voltage $\overline{U_{B\Gamma}} \geq 0$.

If the generator excitation system uses a symmetric bridge, can get a negative voltage $U_{B\Gamma} < 0$ (Fig. 4).

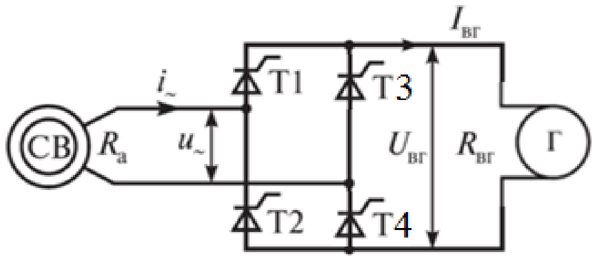

FIGURE 4 The equivalent circuit of the symmetrical bridge

This is very important in the short-circuit conditions.

The negative output voltage of the rectifier will quickly reduce the short-circuit current. This theory was tested using a simulation model of the thyristor excitation circuit of synchronous generator.

2 Simulation results and conclusions

Figure 5 presented a simulation model of a system of excitation synchronous generator with a symmetrical bridge. Modelling carried out in the annex Simulink Matlab package (Fig. 5) [3, 4].

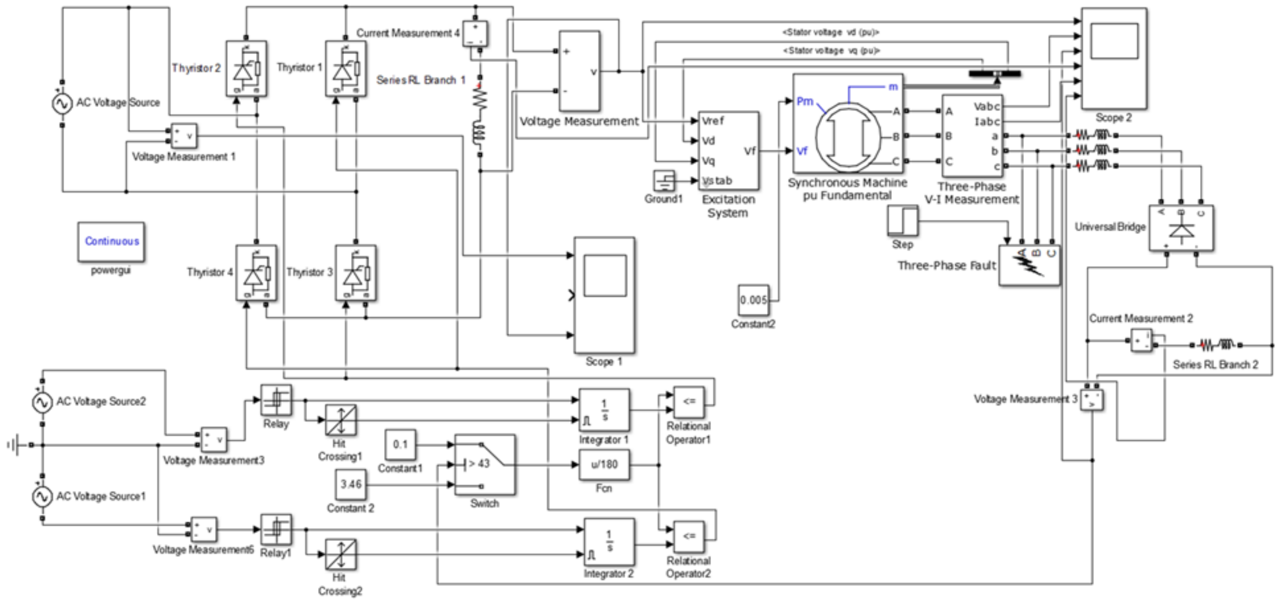

FIGURE 5 Simulation model of excitation system synchronous generator with a symmetrical bridge

Here is a self-contained energy system locomotive power 2200kWt. As the exciter of this system uses a single-phase synchronous generator. Exciter runs on the load via bridge rectifier. The load of exciter it is the winding exciter of traction synchronous generator. Traction synchronous generator runs on an electric motor (active-inductive load) through a three-phase bridge. The model simulates short-circuiting on output the three-phase bridge. Results are presented in Fig. 6.

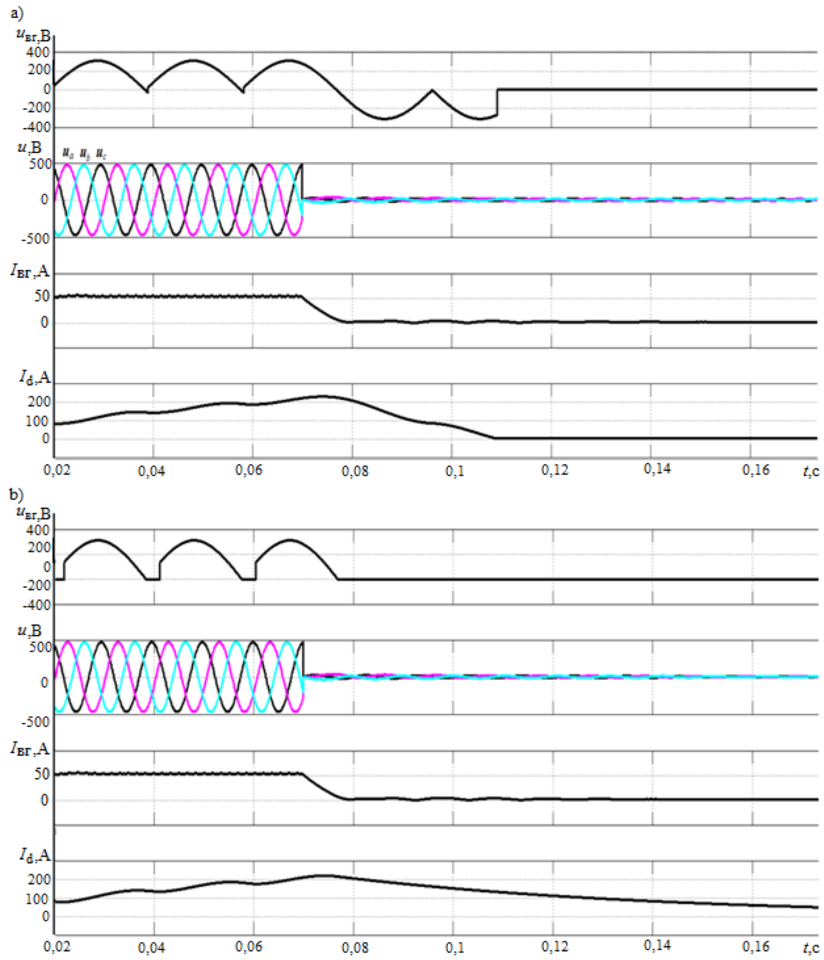

FIGURE 6 The results of the short-circuit mode simulation in circuit with a asymmetrical bridge (a); the results of the short-circuit mode simulation in circuit with a symmetrical bridge (b):*u* – is phase voltage of the generator; I_d – is generator load current

Calculations have shown that the use of symmetric bridge reduces times the short circuit fivefold. This allows us to recommend used a symmetrical bridge in the electric drive system.

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