Analysis of thyristors in the excitation system of synchronous generators

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Abstract. This article presents a scientific analysis of the electrical charactyristics of thyristors applied to the excitation system of synchronous generators located in thermal power plants. Scientific insights have been studied through key parameters of thyristors such as current and voltage charactistics, the state of pulses Fed to the control electrode, and their rate of change, additive processes, and temperature control of thyristors. It has also been experimentally studied the transient processes of thyristors, the state of blocking, the angle of opening, and their effect on the operating modes of the excitation system. As a result, it is possible to prevent the efficiency of the semiconductor thyristor excitation system, the stability of the dynamic stationary, the tolerance of voltage fluctuations, as well as their state in accident modes.as also been experimentally studied the transient processes of thyristors, the state of blocking, the angle of opening, and their effect on the operating modes oors.

INTRODUCTION

Currently, the stable and uninterrupted operation of synchronous generators used in large-capacity thermal power plants and hydroelectric power plants in our country plays an important role in ensuring the reliability, efficiency of the entire power supply system. The excitation system from the main constructive elements of the synchronous generator is important in ensuring the automatic adjustment of the voltage of the generator, the control of reactive power and the stability of the electromagnetic field in the stator windings [1-6]. Therefore, in large power generators, the speed of the excitation system, the accuracy of operation, as well as the control system directly affect the control of the operating modes of the entire energobloc [7,8].

Today, thyristors made up of semiconductor elements are widely used in excitation systems, with conventional contact ring electric machine excitation devices fully replacing. The speed of thyristors at high switching, resistance to large currents and voltages, ease of control from the control electrode consists in applying them to modern fast automatic voltage adjuster systems. One of the widely used models of semiconductor thyristor excitation systems is the high-power thyristor brand T383-2500/32, which is characterized by conducting rectified currents up to 2500 A, withstands a blocking voltage of up to 3200 V, and high thermal stability.ne of the widely used models of semiconductor thyristor excitation systems is the high-power thirst [9-15].

EXPERIMENTAL RESEARCH

An urgent task is the deep study of the dynamic reaction of thyristors in conditions of transient processes occurring in synchronous generators, increased load, fluctuations in the symmetrical and symmetrical consumption of voltage, as well as in-depth study of the dynamic reaction of thyristors in the conditions of accident modes. The opening angle of thyristors is α, the delay in addition to subtraction, The Shape of the control pulses, the change in voltage and currents have a direct effect on the electromagnetic stability of the excitation system. Therefore, the study of the electrical, dynamic and thermal characteristics of large-power thyristors of brand T383-2500/32 is important not only theoretically, but also practically [16-18].

Figure 1 of the T383-2500/32 branded thyristors located in the thyristor excitation system of the synchronous generator provides a principled outline, showing the functional nodes of the common block, connection schemes and stamps of measuring devices [19-21].

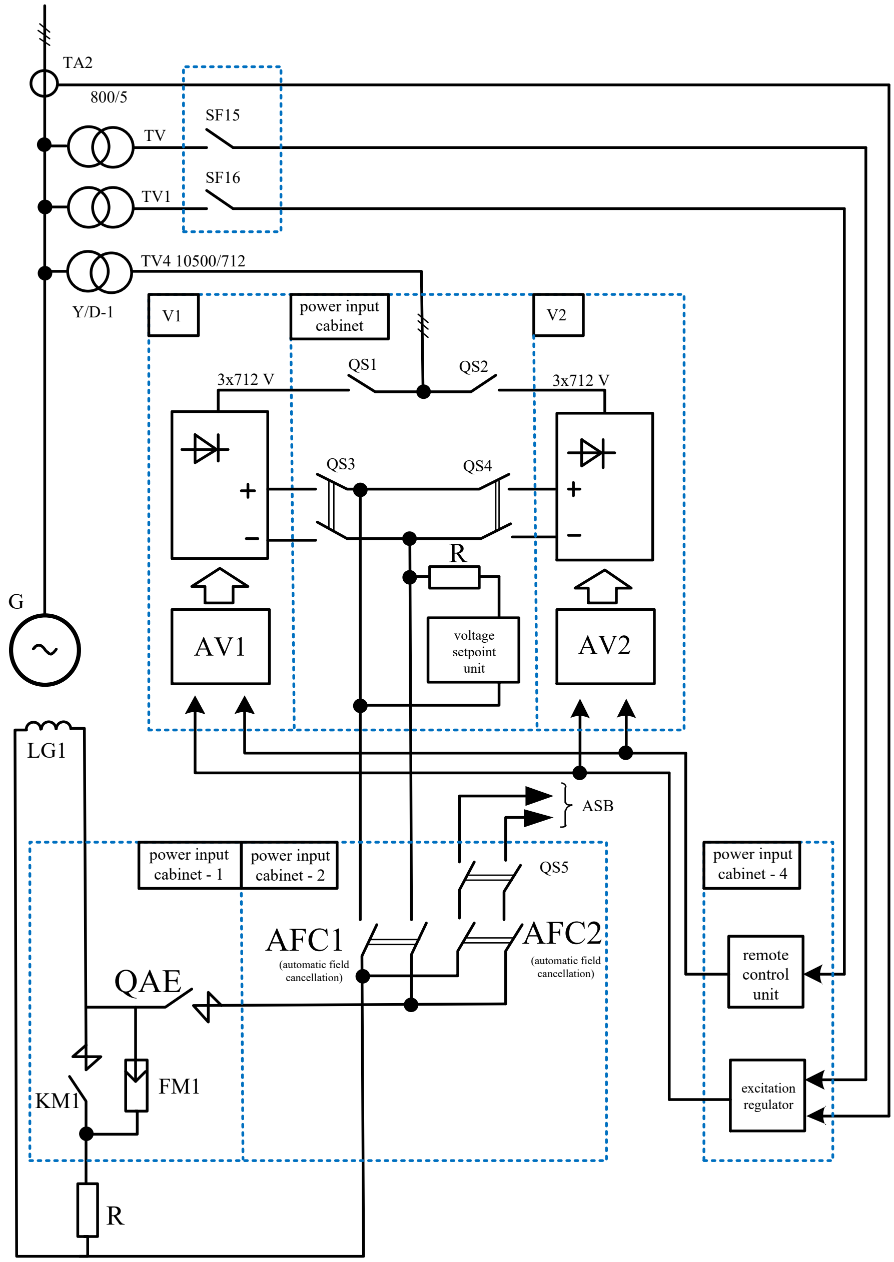


FIGURE 1. Single-line principal diagram of thyristor excitation system T383-2500/32

Figure 1, shows the determination of the main parameters of thyristors, the analysis of their modes of operation. The circuit used a T383-2500/32 branded thyristor, with this thyristor being a low-frequency, tablet-view large-power semiconductor radio element shows the determination of the main parameters of thyristors, the analysis of their modes of operation [22,23]. The circuit used a T383-2500/32 branded thyristor, w.

Average nominal rectifier current of the thyristor:

$$I_n = 2500 \text{ [A]};$$

This value reliably controls the excitation current of the synchronous generator.

The voltage drop is calculated by the following expression:

$$U_n = U_{p-n} + r_T I_T \ [V];$$

where: U_{p-n} - is the static representation of the p-n transition, r_T - is the internal resistance;

Waste of thyristors power;

$$P_t = U_t I_t = U_{p-n} I_T + r_T I_T^2 \ [Vt];$$

Here, the power loss expression allows for the calculation of the thermal regime and the selection of a cooling system (Table 1).

TABLE 1. Electrical parameters of the T383-2500/32 thyristor.

Average direct current			I_{TAV}	2500 A		
Repetitive pulse voltage in the closed state			U_{DRM}	2200-3200 V		
Repetitive pulsed reverse voltage			U_{RRM}			
Shutdown time			T_q	320, 400, 500 mks		
U_{DRM}, U_{RRM}, V	2200	2400	2600	2800	3000	3200
Voltage class	22	24	26	28	30	32
T_j, ^{0}C	-60÷125					

In Table 1 of the above, thyristor quenching time by dynamic parameters is in the T_j = 320-500 mks range, where an industrial frequency of 50-60 Hz can be achieved with sufficient acceleration in Phase control processes in three - phase rectifiers [24-28].

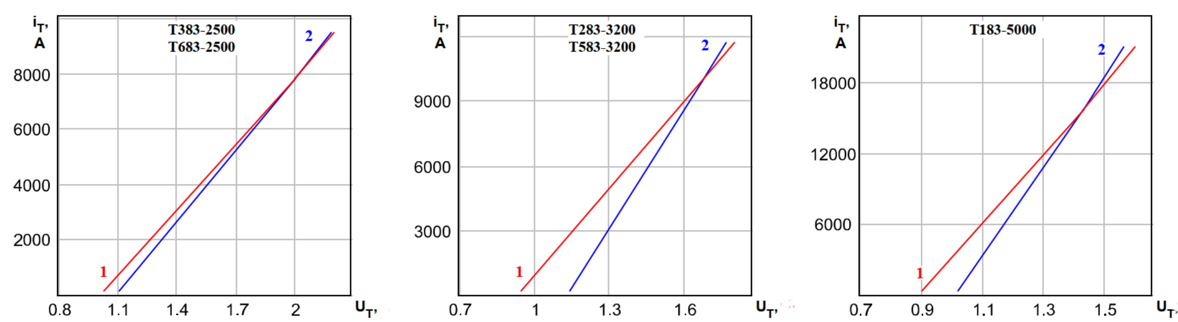
RESEARCH RESULTS

At a relatively small value compared to the delay in the switching process, the thyristor's automatic voltage allows accurate and smooth adjustment of the angle α controlled by the tuning device. This increases the stability of the synchronous generator voltage and reduces the increase in reactive power during transient processes.

T383-2500/32 branded thyristor:

- designed for high current and voltages;
- the width of the possibility of maintaining dynamic stagnation;
- thermal stability as well as the size of the working temperature range;
- stronger mechanical as well as more reliable for electrical effects.

This thyristor plays an important role in ensuring the dynamic stability of the generator, the sensitivity of the voltage adjuster, as well as the continuous operation of the entire excitation system (Figure 2).



a) b) c)

FIGURE 2. Graph of the dependence of the volt-ampere characteristics of a thyristor on the temperature; a) T383-2500 for thyristor; b) T283-3200 for thyristor; c) T183-5000 for thyristor.

Maximum permissible transition temperature, T_{jm} (1), current-voltage at temperature, T_j=25 °C (2), I_T=3,14 I_T, boundary characteristic.

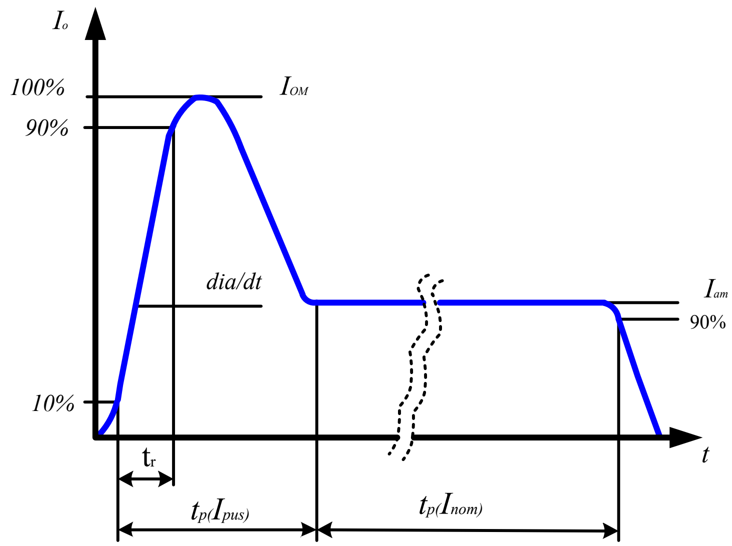


FIGURE 3. Time-dependent graph of the thyristor control pulse

In the figure above, when the excitation system is started, the current initially reaches a large value at a certain time interval, starting with a small value. At this stage, the current growth rate will be determined by di/dt and will depend on the reactive values of the excitation system elements, the control system and the capabilities of thyristor amplifiers [32-61]. The current reaches the maximum value of the I_{max} value, maintaining that value for a short period of time. This process allows the generator to form the magnetic flux generated in the initial magnetic field and ensure synchronization with the load [25-34].

There is an opportunity to model the thyristor excitation system of a synchronous generator in a MATLAB/Simulink environment, the electrical circuit of which is shown in Figure 4. The transient processes of the thyristor based on the imitation model to be created, the effect of the synchronous generator on reactive power compensation, dynamic stability as well as the ability to adjust voltage.

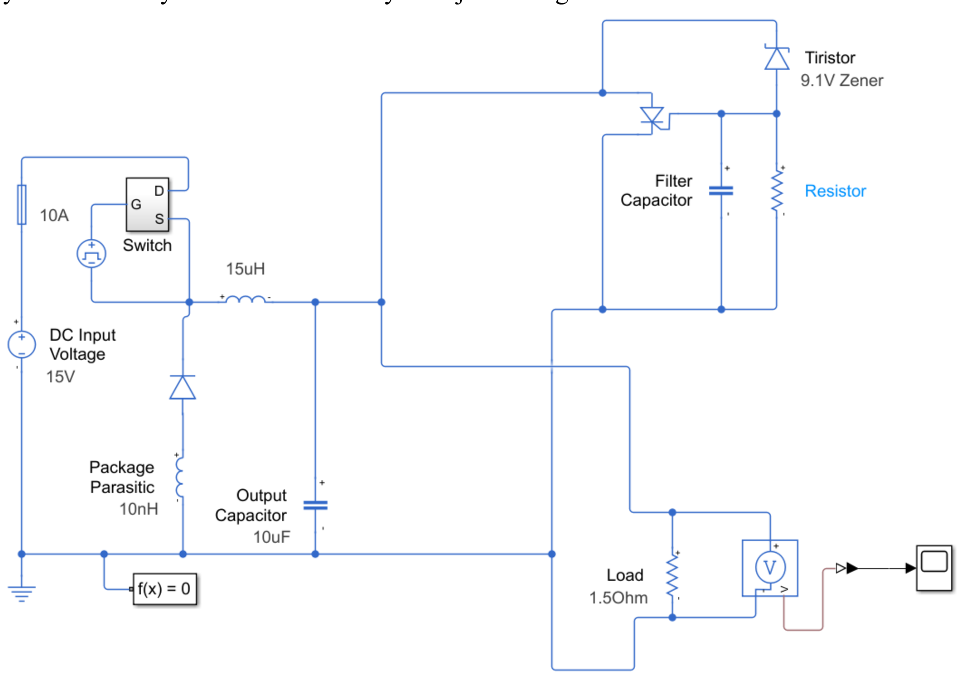


FIGURE 4. MATLAB/Simulink model of a thyristor excitation system of a synchronous generator

Figure 4 above shows the imitation scheme of the operation of the thyristor in the castrated virtual circuit. It has the ability to spy on processes such as the transfer of energy through switching, accumulation in a magnetic field, straightening through a thyristor, filtering through capacitors, and avoiding over-voltages using protective elements.

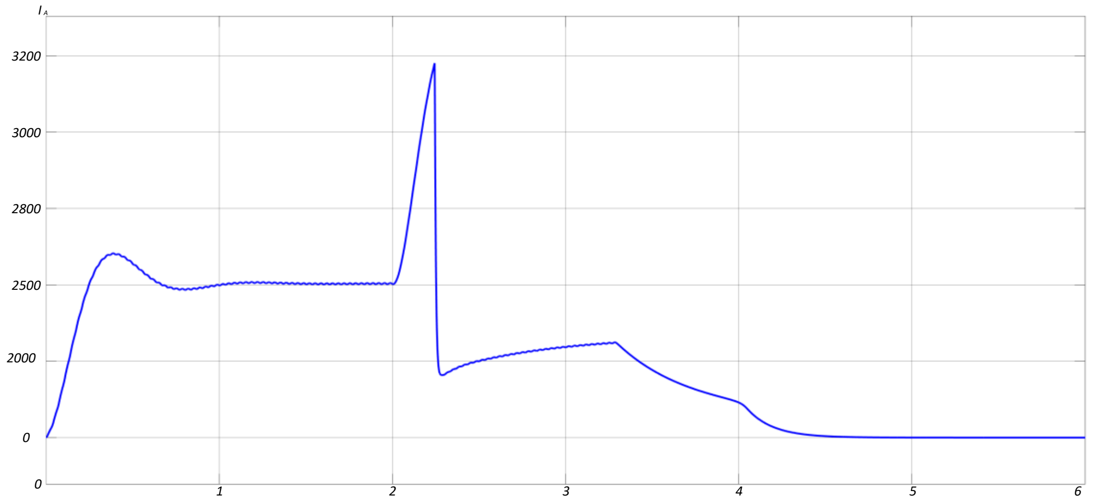


FIGURE 5. Graph of the time dependence of the excitation current generated in thyristors

The figure above shows the dynamics of the change in Current by time when the excitation system is running. The characteristic of the current in such a way was assessed the control of the automatic control system of the synchronous generator, which occurs in transient processes, as well as the state of electromagnetic processes affected by loading. We can see from the graph the excitation current of the synchronous generator that a rapid rise in the value of the current is observed. In this process, the excitation works in connection with the formation of a magnetic field in the Marsh, as well as the supply of the initial excitation energy by the control system. Current fluctuations in the early period are explained by electromagnetic inertia, the effect of inductance, as well as delays in the feedback loop of the automatic adjuster.

CONCLUSIONS

In conclusion, it can be argued that the analysis of the electrical, dynamic and thermal properties of thyristor devices used in the excitation system of synchronous generators is indicated. The scientific article theoretically analyzed the static characteristics of thyristors, the voltage drops in conduction, the blocking voltage, the average current capacity, the pulse parameters required for the control electrode, as well as the switching and shutdown times through the dynamic parameters. In the MATLAB/Simulink environment, a mathematical model of a thyristor excitation system was developed, simulating transient processes in different operating modes. The results of the simulation were compared with the parameters of the real device, and the correlation between them was determined to be no more than 5-7%, determining the sufficient accuracy of the model the MATLAB/Simulink environment, a mathematical model of a thyristor excitation system was developed, simulating transient processes in different operating modes. The results of the simulation were co.

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