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Implementation of a transistor excitation system for synchronous generators

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Abstract. Ensuring the uninterrupted and stable operation of the synchronous generators located in thermal power plants is one of the relevant tasks of today. This article scientifically substantiates that the transfer of synchronous generators to a transistor self-excitation system is the optimal option. This system has been studied by transient electrodynamic processes in operation at the stationary nominal position, increase and decrease in load, one-phase, two-phase and three-phase short circuits, intercooling short circuits in stator and rotor circuits, in the process of attenuation of the wearable magnetic field. Based on the results of this presented analysis, drawings, algorithms and feasibility calculations of the power supply of synchronous generators by ensuring stable and reliable operation of transistor excitation systems have been studied and recommended.

INTRODUCTION

Today, the uninterrupted operation of the synchronous generator in the production, transmission and distribution of electricity in large thermal power stations of the world is inextricably linked with the technical condition of their excitation system [1-5]. The use of modern semiconductor (thyristor and Transistor) self-excitation systems enables dynamic effects of synchronous generators, increased control system accuracy, and rapid detection of accidents that occur. Therefore, it was considered necessary to develop mathematical and computer virtual models of these processes for accurate study and calculation when analyzing electromagnetic processes in the operating modes of this system [6-9].

The excitation system plays an important role in ensuring uninterrupted and stable operation of synchronous generators. The excitation system of synchronous generators generates a magnetic field in the generator rotor windings and allows automatic adjustment of the voltage of the generator stator windings from the output clamps. Today, the efficiency, reliability of these systems in power plants directly affects the overall quality of operation of the generator [10-13].

EXPERIMENTAL RESEARCH

Synchronous generators' thyristor-based self-excitation system is an automatic system operating on semiconductor elements, which provides the capability to generate the required direct current for the generator's excitation winding. This system automatically detects variations in the voltage at the output terminals of the synchronous generator's stator windings and, by adjusting the thyristors' firing angle through the automatic voltage regulator, regulates the current supplied to the rotor excitation winding (Figure 1) [14-17].

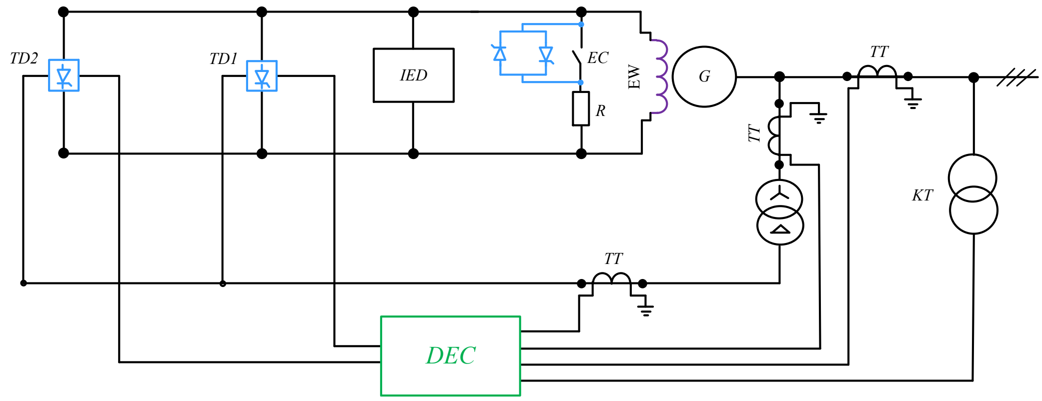


FIGURE 1. Single-line diagram of a self-excited thyristor excitation system

A thyristor-based excitation system of synchronous generators has the following components:

G – generator, EW – excitation winding, DEC – digital excitation controller, IED – initial excitation device, TD1, TD2 – thyristor converters, EC – electromagnetic contactor, KT – voltage transformer,TT – current transformer,Tr – power transformer.

Self-thyristor excitation systems of synchronous generators work on the concept of accessing energy in the output voltage across the stator winding of the generator or in a power supply system. Self-excitation of thyristors located in a thermal power plant is one of the important tasks to correctly determine the main technical parameters of the system, ensure the stability of the electrical heat and mechanical parameters of the system [18-22]. The opening characteristics of thyristors located in the excitation system are shown in Figure 2, in which it can be seen that the value of the current at the opening of the thyristors is large [23-25].

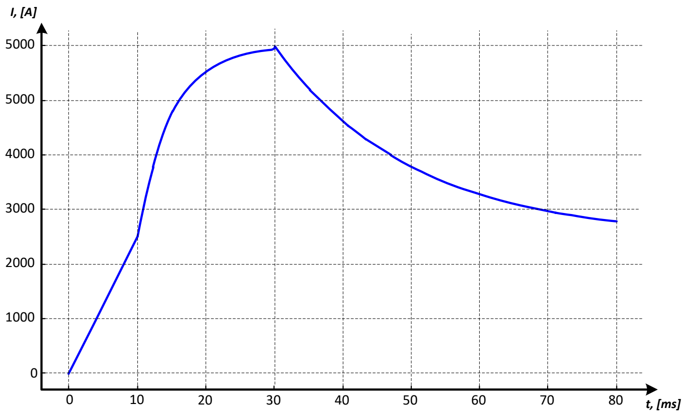


FIGURE 2. Time-dependent characteristics of thyristors in a thyristor self-excitation system

Figure 2 above shows the time dependence charactistic of the current at the face value of the angle of opening of thyristors. The graph presents a time-varying anode current, I(t), which shows how the thyristor opens under the influence of Electrical and thermal processes, and its fall into nominal operating model figure 2 above shows the time dependence charactistic of the current at the face value of the angle of opening of thyristors [26-28]. The graph presents a time-varying anode current, I(t), which shows how the thyristor opens under the influence of Electrical and thermal processes, and its fall into nominal operating mode. As a result, from the moment the control impulse of the thyristor is given through the characteristic I(t), its full opening, the formation of a persional current and the periods of thermal stabilization are clearly given. A linear increase in current in the initial 0-10 ms of the Keltriligan process is associated with a decrease in the dynamic resistance of the semiconductor. A sharp increase in the Keying range of 10-30 ms means the formation of the forsythrake current required in transient mode. The attenuation process in the last 30-80 ms range has been shown to occur in accordance with the electromagnetic time constant of the rotor windings and the thermal stability of the thyristor [29]. The above characteristics indicate that the thyristor excitation system is important in ensuring the dynamic stability of the generator [30,31].

One of the most important parameters of a thyristor self-excitation system is shown to be the change in output current I with the change in the opening angle α (in the radios) (Figure 3).

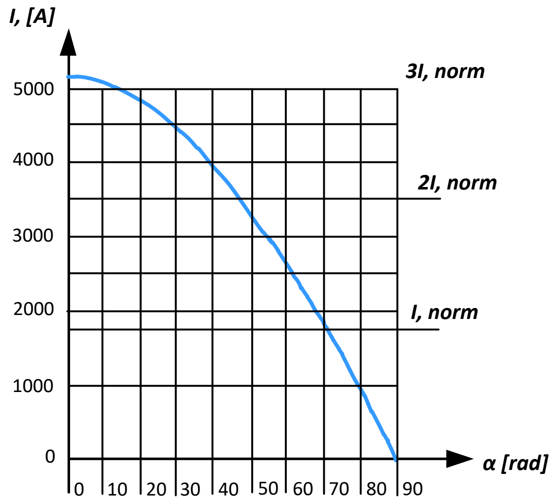


FIGURE 3. Angle dependence characteristics of thyristors of thyristor self-excitation system

In Figure 3 presented above, this characteristic is in a state fully consistent with the physical properties of the thyristor rectifier, and is one of the main indicators for the stability of the excitation system of the generator [32-61]. The most important indicators of this system are the smooth adjustment of the voltage, the ability to work reliably in the forcing mode.

The thyristor self-excitation system has the following disadvantages:

- Extinction of thyristors occurs only when the current is zero;
- Thyristors have high heat output, causing many problems in the cooling system;
- The most important indicators of this system are the smooth adjustment of the voltage, the ability to work reliable.

From the above disadvantages, it can be seen that the thyristor self-excitation systems of synchronous generators currently used in energy systems are technically losing their full potential. Therefore, it is necessary to replace them with transistor self-excitation systems with high speed, energy efficiency, as well as digital control capabilities.

RESEARCH RESULTS

In the process of such modernization, it makes it possible to increase the dynamic stability of synchronous generators, optimize the process of adjusting reactive power, and ensure the stability of the voltage in the network interaction of the generator. The self-transistor excitation system of synchronous generators is an automatic system based on the principle of digital control of the excitation current supplied to the rotor pipe of the synchronous generator through semiconductor transistors.

The This system is designed to keep the voltage of the generator in the output clamps of the stator clamps stable, to accurately adjust the reactive power, and to increase the dynamic stability of the system (Figure 4).

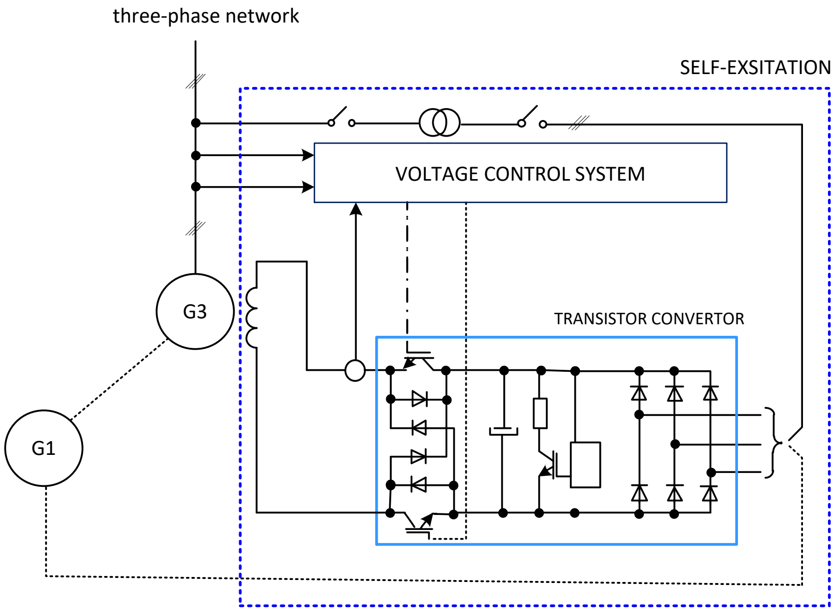
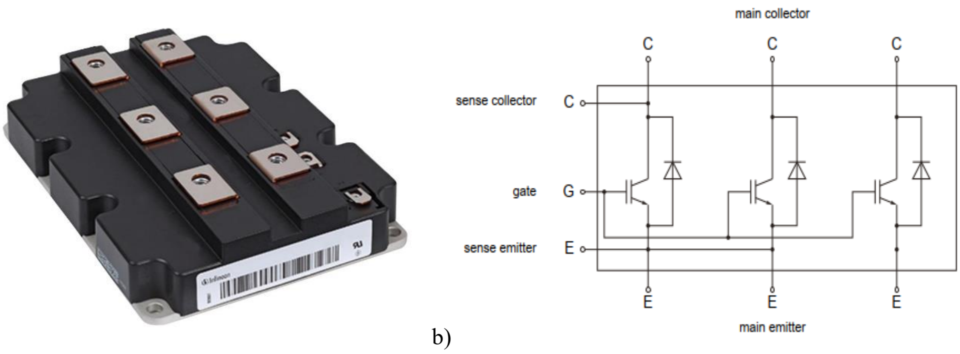


FIGURE 4. Single-line diagram of a self-transistor excitation system

The excitation system in Figure 4 above consists of a diode rectifier, a rectified voltage smoothing capacitor filter, a bipolar extended pulse modulating constant current voltage transducer whose constant current in the output clenmas is fed to the excitation system of the synchronous generator. The model also used protective elements consisting of a resistor connected parallel to the condenser.

Through this model, it will be possible to enable synchronous generators to prevent their resulting accidents. Also, the matimatic classification of synchronous generators as well as the air gap is carried out on the principle of separation of the magnetic flux into separate parts of the synchronous generator, taking into account the change. The inter-section interconnections of the generator are taken into account by voltage as well as by current sources. The transistor excitation system, which replaces the thyristor self-excitation system described above, is shown in general view in Figure 5.



a) b)

FIGURE 5. General view of the transistor to be introduced: a, appearance of a 1MBI2400U4D-170 type transistor block; b, single-line diagram of the transistor.

The type 1MBI2400U4D-170 transistor is an IGBT module designed for high current and voltages, based on the advanced requirements of a modern power supply system, which provides the opportunity to significantly improve the overall performance of the generator when introduced in place of thyristor excitation systems. U-Series IGBT technology, which has high switching speed, low transient losses, high precision safe operation and thermal stability through this module, takes the dynamic and static properties of the generator excitation system to a new level of improving the quality of energy (Figure 6).

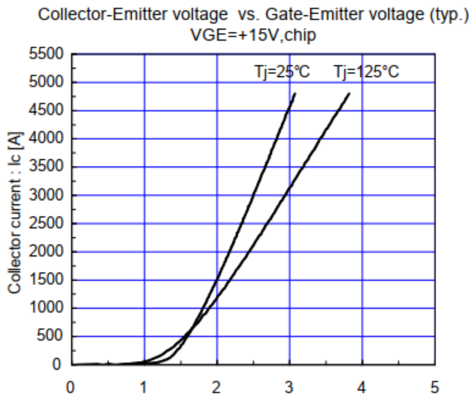


FIGURE 6. Graph of the dependence of the emitter voltage of a transistor on the current passing through the collector

TABLE 1. Comparative criteria of self-commutated thyristor and transistor excitation systems of synchronous generators

№	Operating modes of the excitation system	Advantages of a self-commutated thyristor excitation system	Advantages of a self-transistor excitation system
1.	Principle of operation	Using a controlled rectifier, the direct current is adjusted by the opening angle (α) of the thyristors.	On the basis of extended pulse modulators, the opening-closing frequency of transistors is controlled.
2.	Main control element	Semiconductor thyristor	Semiconductor transistor
3.	Management system	Analog, automatic voltage regulator	Digital automatic voltage regulator (via microprocessor)
4.	Power source at startup	self-excitation (from the stator chimes of the generator	Independent or self-excitation (works synchronously through digital control)
5.	Control speed (response time)	Slower, 10–20 ms	Very fast, 5–10 µs
6.	Voltage adjustment accuracy	± 2,5 - 3,0 %	± 0,5 - 1,0 %
7.	Forsyning opportunity	2 - 2.5 times	3 - 3,5 times
8.	Heat losses	High, 15–20 %	Low, 5 - 8 %
9.	Cooling system	Mandatory (water or air, through large radiators)	Compact, low heat dissipation, modular cooling system
10.	Harmonic distortions	5-, 7-, 11-, 13- harmonica noticeable	Due to its control based on extended pulse modulators, harmonics are less than 3 %
11.	Reactive power management	There may be noticeable vibrations	Dynamic stability is high, reactive power is accurately adjusted
12.	Protection in case of an accident	Analog protection (relay, temperature sensors)	Internal protection (short-circuit, overheat, overcurrent, EMC filtrlar)
13.	Maintenance	Complex, parts wear-resistant	Easy, modular replacement is possible
14.	Efficiency (η)	90 - 93 %	96 - 98 %
15.	Mainly application areas	Old-type thermal power plants and hydroelectric power plants	In new thermal power plants and renewable energy systems
16.	Stable service life	10 - 12 years (requires thyristor replacement)	15 - 20 years (module easy to replace)
17.	Technological level of the system	Analog, semi-automatic	Digital, fully automated
18.	Energy efficiency	Lower (more heat and reactive losses)	High (energy efficient, stable output)

As can be seen from the graph in Figure 6 above, the collector-emitter voltage of the 1MBI2400U4D-170 IGBT module is seen in the collector current linkage chrematistic, this link is determined by the transition resistance of the semiconductor channel inside the transistors can be seen from the graph in Figure 6 above, the collector-emitter voltage of the 1MBI2400U4D-170 IGBT module is seen in the collector current linkage chrematistic, this link is determined by the transition resistance of the semiconductor channel inside the transistor. At low temperatures (Tj=25°C), the transition resistance of the transistor is small, leading to an increase of Ic=5000 A at values of Vj=2-3 v. When the temperature increases (Tj=125°C), the mobility of the carriers decreases, resulting in a decrease in the maximum value of the collector current to 4,500 A. This module scientifically demonstrates the temperature sensitivity of the module, the importance of thermal management, and the advantages of IGBTs in high-current modes of the excitation system.

In contrast to thyristor systems of synchronous generators, in transistor excitation systems, current and voltage are smoothly adjusted by the extended implosion modulation method. This control allows you to quickly change the electromagnetic field of the generator in real time. As a result, the response rate of the system is high, while the fluctuations in the output voltage are minimal (Table 1).

The reliable, stable and more efficient operation of large-capacity synchronous generators located in thermal power plants will largely depend on the design of their excitation system. Some disadvantages are observed today in the operation of thyristor rectifiers located in the excitation system. As a result of the one-way control of thyristors, inertia at the opening time, high thermal load and sensitivity to control impulses, it is observed that the excitation system has insufficient tolerance to the breakdown of dynamic processes. As a result of this, in the event of an accident, a decrease in the stability of the synchronous generator and a decrease or expectation of voltage can lead to a violation of the quality of electricity [42,43].

As a result of the research carried out, the introduction of a transistor IGBT excitation system instead of a thyristor self-excitation system significantly improves the performance of the generator. The ability to control transistors in the exhaust system increases the quality of the excitation process of synchronous generators through the possibility of speed at high switching, low heat losses and smooth adjustment of the output current through extended implosion modelers.

CONCLUSIONS

In conclusion, it can be said that transistor self-excitation, due to the fact that the switching speed of the systems is 50-100 times higher than that of the thyristor, further accelerates the possibility of adjusting the voltage in transient processes of the generator as well as stable holding. This increases the tolerance of the synchronous generator to emergency operating modes and reduces the likelihood of loss of synchronism connecting the network to the synchronous generator. Voltage losses by switching to transistor rectifiers reduce by 25-35%, thus leading to an increase in the energy efficiency of the excitation system, an increase in the overall useful operating coefficient of the synchronous generator by 0.5-1.0%. For large-capacity synchronous generators, these indicators lead to very large annual energy savings. As transistor self-excitation systems integrate with modern digital control units, the capabilities of real-time monitoring, diagnostics and protection functions expand. This results in a significant reduction in problems such as failures observed in thyristor systems - puncture of the thyristor, loss of control impulses, accidents that occur in the thermal system.

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