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Increasing the Viability of Synchronous Generators with Biaxial Excitation in the Process of Self-Rocking

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ABSTRACT*:* This article provides a synchronous generator with biaxial excitation, which has a significantly higher ability to quickly dampen transient electromechanical processes in self-rocking than a conventional synchronous generator due to the ability to control the damping moment, as well as higher survivability in electromagnetic and electromechanical transients. In addition, it has been found that the transverse excitation winding makes it possible to quickly dampen transient processes in the processes of self-rocking of the generator, as a result of which the time of the oscillatory process is significantly reduced and the possibility of a quick acquisition of synchronism is increased.

KEYWORDS: Electromagnetic and electromechanical transients, self-rocking, survivability, synchronous generator.

I. INTRODUCTION

Maintaining the voltage level in a high-voltage electrical network (overhead and cable) is associated with the characteristic of this network, which is a characteristic of the generation of reactive power into the network. This leads to an excessive increase in the voltage level due to the lack of adequate reactive power compensation devices. In addition, the voltage level may increase due to incorrect distribution of reactive power between networks of different voltages. Such conditions lead to rapid wear of high-voltage electrical equipment and an increase in the accident rate. To overcome this problem, sometimes special measures are taken, leading to a decrease in the stability of the system [4]. In particular, to reduce the voltage level, power plant operators are forced to transfer the turbogenerator to the mode of reactive power consumption, in which the voltage drops slightly. But over time, turbogenerators begin to wear out quickly, because. turbogenerators are not designed for such a regime, because due to rapid heating, the frontal part of the stator and the end parts of the magnetic circuit fail [5].

Taking into account the trend of increasing energy flows through existing power lines, the problems of increasing the stability and reliability of electric power systems remain relevant.

II. METHODS

The above problems can be solved by using biaxial synchronous generators with longitudinal and transverse excitation windings on the rotor.

In biaxial synchronous generators, unlike conventional synchronous generators, the two axes in the rotor at an electrical angle of 90 degrees have the same symmetrical or asymmetrical excitation winding. In this case, synchronous generators with a non-salient pole rotor can be configured with symmetrical and asymmetrical excitation windings, and synchronous generators with a salient pole rotor can only be configured with asymmetrical transverse excitation windings.

Sometimes the symmetrically arranged transverse winding is also called the control transverse winding. It is possible to share symmetrical excitation windings under normal operating conditions or use the transverse axis excitation winding in transient processes [6]. The use of an unbalanced excitation circuit can be much more efficient, mainly in transients.

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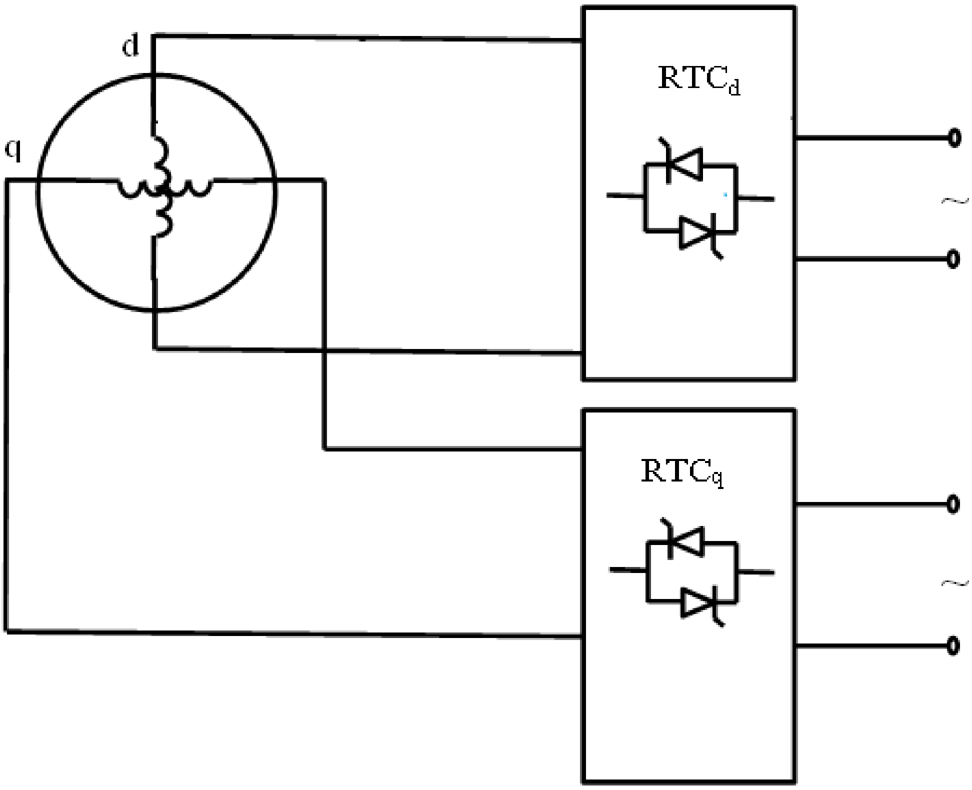

Figure 1. Scheme for controlling direct current supplied to the excitation circuit of a synchronous generator with biaxial excitation through a reversing thyristor converter (RTC)

On fig. 1 shows a schematic diagram of a biaxial synchronous generator, each excitation winding of which is connected to a reversible thyristor control system. Each excitation system consists of an overvoltage protection system, short-circuit devices or rotor winding balancing resistors, and magnetic field suppression devices. The automatic excitation control device generates control signals using a rotor position sensor, current and voltage sensors. Both excitation coils of a synchronous generator with symmetrical biaxial excitation in normal operation work together [7].
On fig. 2 shows that the magnitude of the output magnetic field and the phase of the excitation windings of a synchronous generator with biaxial excitation can be controlled using a reversing thyristor converter. With the help of such generators, it is possible to control electromagnetic and electromechanical transients in a synchronous generator through an excitation winding located on a longitudinal or transverse axis, and it is also possible to quickly dampen transients that occur during operation.
If one of the excitation systems fails, the magnetic field in the system is extinguished and this excitation winding is short-circuited, and the synchronous generator starts to work as a conventional synchronous generator with one excitation winding. When the second excitation system of a synchronous generator with biaxial excitation fails, the magnetic field in this system is turned off, the excitation circuit is short-circuited, and the synchronous generator goes into an uncontrolled asynchronous mode [1].
With the help of these generators, it is possible to effectively regulate the mains voltage in the compensation mode with full consumption of active load and reactive power in all modes of operation of the generators, without affecting the overall stability of the generator. To regulate the electromagnetic torque, which is one of the main conditions for ensuring the static stability of a synchronous generator, it is necessary to correctly and reasonably select the coupling coefficient in the control channel. To create the maximum braking electromagnetic torque during transients in biaxial synchronous generators, the excitation windings have the ability to control the directions of magnetic driving forces. To determine the optimal direction of the magnetic driving force with a strong influence of the network, when controllability is limited, by increasing or decreasing excitation using an automatic excitation control device. With the help of the voltage control channel, since the oscillations of the rotor can be controlled independently of the electromechanical processes, it is

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possible to improve the quality of regulation of the output voltage of the power plant when the excitation current has not reached its maximum value. This causes an increase in the dynamic and static stability of generators operating in parallel with the network, and leads to the provision of a normal power supply to consumers. It is possible to improve the quality of regulation of the output voltage of the power plant. This causes an increase in the dynamic and static stability of generators operating in parallel with the network, and leads to the provision of a normal power supply to consumers. It is possible to improve the quality of regulation of the output voltage of the power plant. This causes an increase in the dynamic and static stability of generators operating in parallel with the network, and leads to the provision of a normal power supply to consumers.

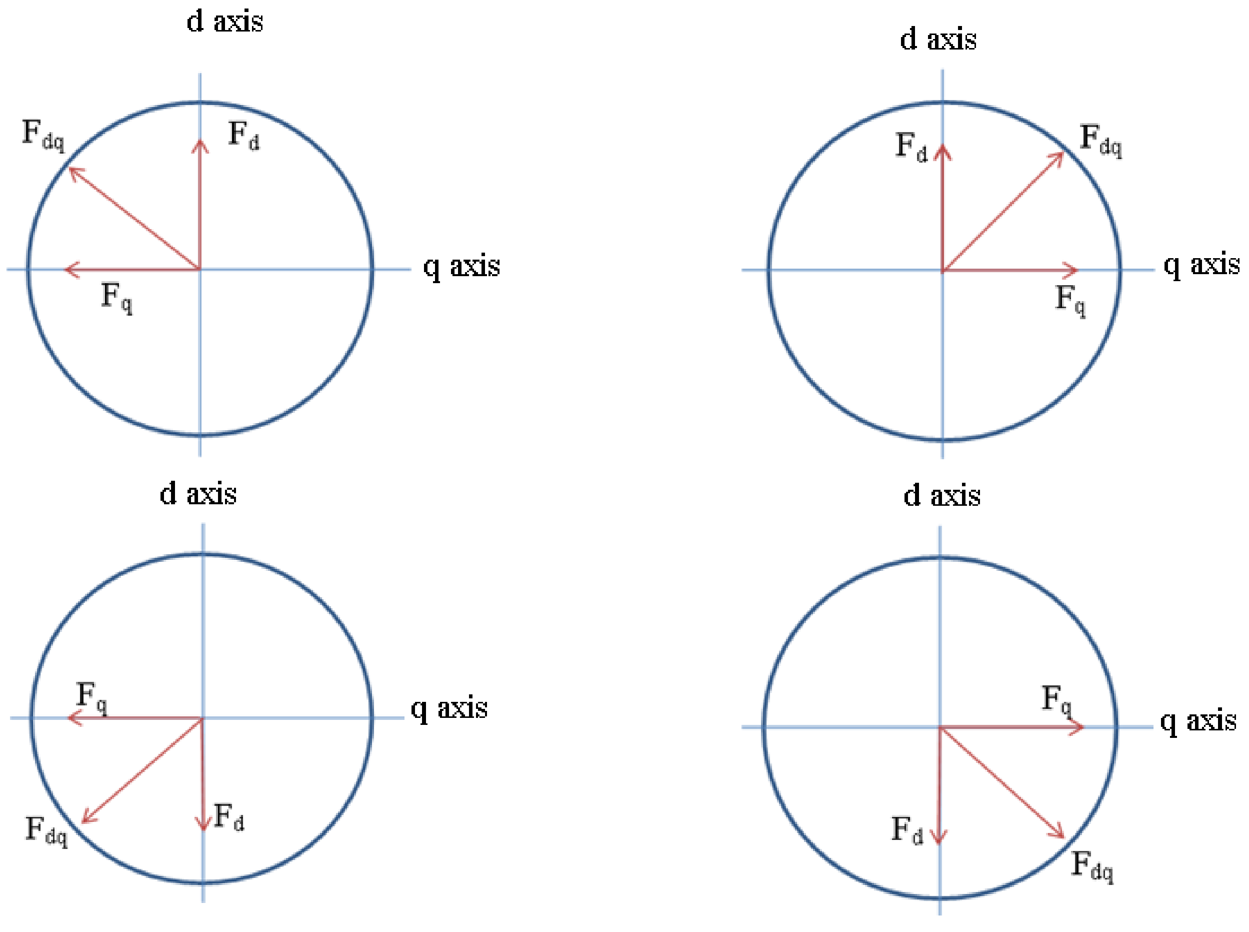

Figure 2. The ability of a synchronous generator with biaxial excitation to change the angle of the magnetization axis by controlling the current of the excitation windings located along the d and q axes

III. RESULTS AND DISCUSSION

The research results of synchronous generators with biaxial excitation show that compared to conventional synchronous generators, they are able to consume more reactive power without a significant reduction in load. With parallel operation of these generators, self-rocking of the rotor rarely occurs, and transient processes quickly fade. The above results also hold for a short circuit, where the inclusion of synchronous generators with biaxial excitation in synchronous generators operating in parallel leads to a significant increase in the overall stability limit.
With strong connections in the network, the transient processes of conventional synchronous generators and synchronous generators with biaxial excitation in the group pass independently, and in this case, synchronous generators with biaxial

excitation may return to their original operating modes, but the stability of conventional synchronous generators may be violated.

Figures 3 and 4 show the transients of a conventional synchronous generator in the process of self-rocking when the automatic reserve control (ARC) device is delayed due to a short circuit in the network:

Based on the graph in Figure 3, it can be concluded that a short circuit in the network caused transients in the synchronous generator, and the output voltage of the synchronous generator fluctuated somewhat. In this case, the amplitude value of the current in transients will be somewhat larger.

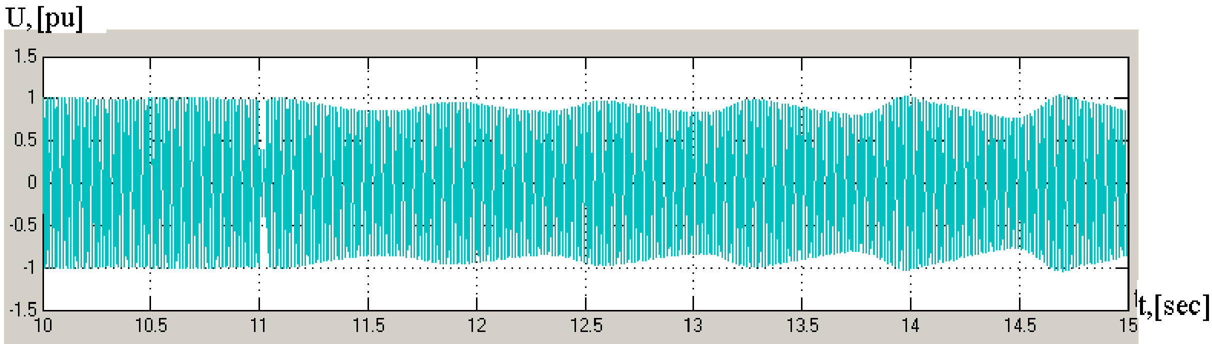

Figure 3. Change in the output voltage of a conventional synchronous generator during a short circuit in the network

As a result of the analysis of transient processes in Figures 3 and 4, it can be said that during a short circuit in the network, the transient process that occurs in conventional synchronous generators lasts a long time, and the oscillation amplitude increases, and the synchronous generator can go out of synchronism.

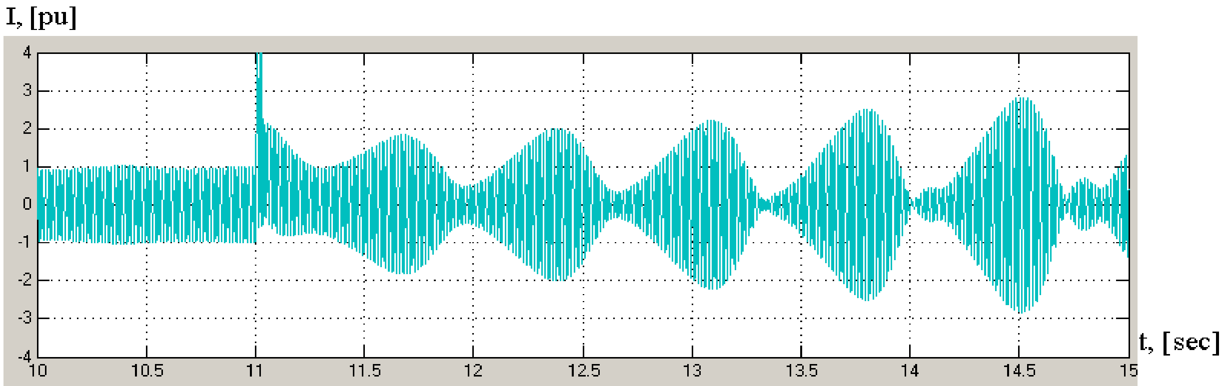

Figure 4. Change in the phase current of a conventional synchronous generator during a short circuit in the network

As a result of the analysis of transient processes in Figures 5 and 6, we can say that the transient process that occurs in synchronous generators with biaxial excitation during a short circuit in the network does not last long and quickly decays. In this case, the amplitude value of the current during transients is much lower.

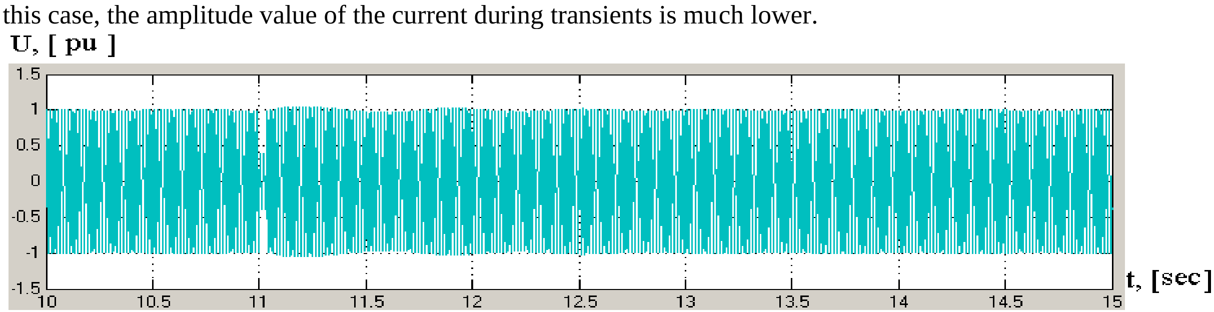

Figure 5. Output voltage of a synchronous generator with biaxial excitation during a short circuit in the network

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As we mentioned above, the biaxial excitation synchronous generator has two excitation windings, therefore, its survivability increases, since if the transverse excitation system fails, it continues to operate as a conventional synchronous generator using the longitudinal excitation system.

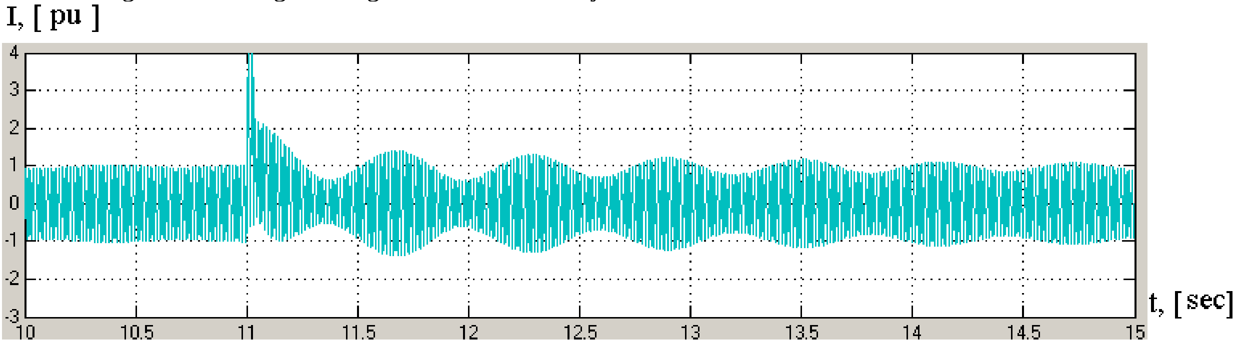

Figure 6. Change in the phase current of a synchronous generator with biaxial excitation during a short circuit in the network

Here, the short-circuited winding acts as a damper coil, therefore, in this mode, the limit of dynamic stability of the biaxially excited synchronous generator is large enough, and the synchronous generator can quickly enter into synchronism and rotor oscillations can quickly be extinguished due to the magnitude of the damping moment. This ensures reliable operation of synchronous generators during transients. Therefore, synchronous generators with spiritual excitation are considered to be more reliable in transients compared to conventional synchronous generators. If the longitudinal excitation system of this generator also fails, then its longitudinal excitation circuit is also short-circuited, and the synchronous generator switches to work in the asynchronous generator mode.

The magnetic field created by the excitation windings disappears, so the synchronous torque also decreases to zero, the torque on the turbine is constant for the first minute, and the generator speed increases, and as a result, an alternating current flows equal to the slip frequency from both closed rotor excitation windings, this current is the rotating magnetic field created by the stator winding creates an asynchronous torque and tries to slow down the rotor.

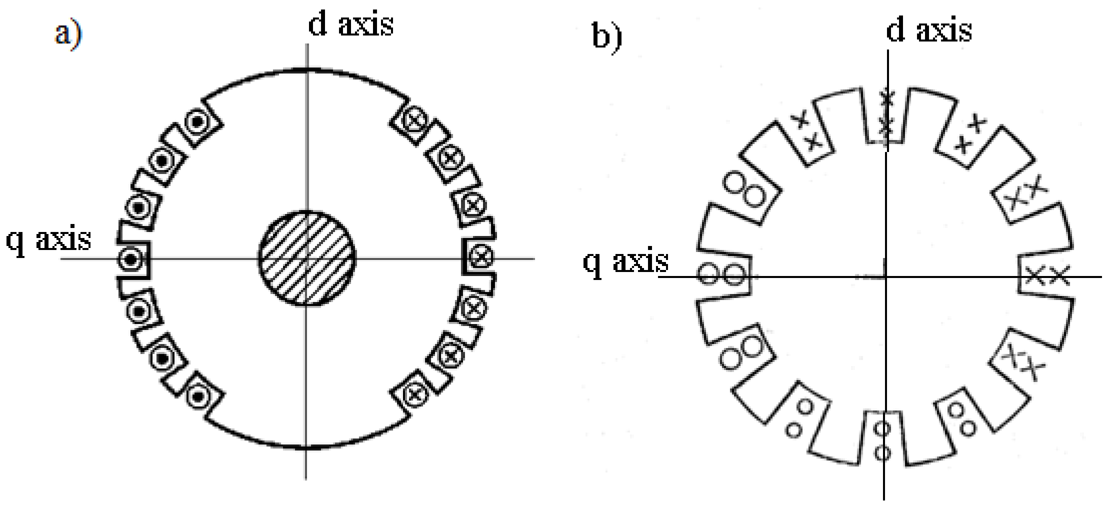

Figure 7. View of the rotor of a traditional and synchronous generator with biaxial excitation: a) traditional b) biaxial excitation

The turbine speed controller reduces the steam supply to the generator in order to maintain the speed of the turbogenerator, resulting in a slight reduction in generator slip and active power fed into the grid. In this case, the stator voltage decreases slightly depending on the load, because reactive power is not supplied here, but consumed.

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IV. CONCLUSION

In the conducted scientific research, it was found that in the processes of self-rocking of a synchronous generator with biaxial excitation, the ability to quickly dampen transient electromechanical processes due to the ability to control the damping moment is much higher than that of a conventional synchronous generator, and the ability to work stably in electromagnetic and electromechanical transients.
It has been established that the transverse excitation coil makes it possible to quickly extinguish transients in the processes of self-rocking of the generator. As a result, due to a significant reduction in the time of the oscillation process and an increase in the ability to enter into synchronism, an increase in the stable operation of a synchronous generator with biaxial excitation in electromagnetic and electromechanical transients was achieved. .

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