ANALYSIS OF SYNCHRONOUS MOTOR EXCITATION SYSTEMS

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ABSTRACT

At present, to regulate the excitation current of synchronous electric motors at industrial enterprises, mainly static (usually thyristor) and brushless excitationsystems are used. Circuits with a DC generator on the shaft of a synchronous motor (SM) are currently practically not used.

Keywords: synchronous motor, excitation system, brushless excitation system, static excitation system.

Currently, to regulate the excitation current of synchronous electric motors in industrial enterprises, mainly static (usually thyristor) and brushless excitation systems are used. Circuits with a direct current generator on the shaft of a synchronous motor are practically not used at present.

Modern static excitation systems are thyristor converters powered by a separate excitation transformer connected to the same bus section from which the synchronous motor is powered. Direct current from such systems is supplied directly to the excitation winding.

Automatic static controllers with excitation have a digital control system that implements the operating algorithm of the PID, PD or PDD2 controller. The regulator may have a control loop: voltage, power factor (cos ϕ), stator reactive current. Other types of adjustments can also be made, which are typically a combination of these three.

Static drivers are designed to activate forced excitation of the motor when the voltage in the bus section drops below a preset value. The boost factor in relation to the rated output voltage is from 1.5 to 2. Static excitation systems are characterized by high speed: excitation boost is introduced in a time of about 0.02-0.06 s.

A modern brushless excitation system for a synchronous motor also includes a static converter, but the motor excitation winding is powered from an additional synchronous generator (the so-called subexciter) installed on the motor shaft through uncontrolled rectifiers (Figure 1).

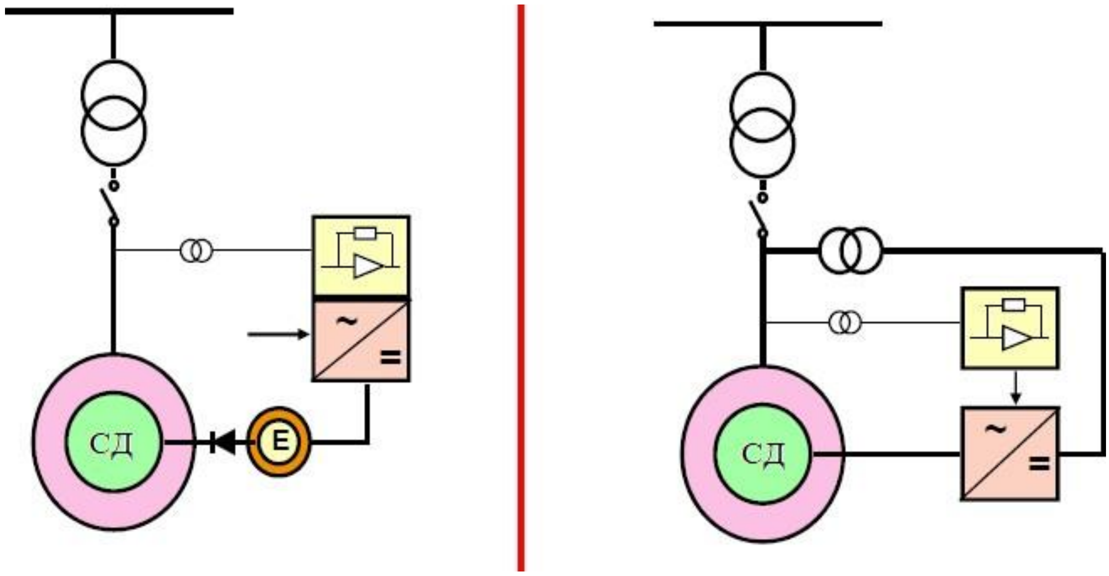

Figure 1 – Simplified block diagram of a brushless exciter (left) and a static exciter (right)

A synchronous motor is an inverted machine, the field winding of which is stationary and is powered by a thyristor converter. Thus, by controlling the excitation current of the motor, the thyristor exciter controls the excitation current of the synchronous motor. Such excitation systems have a significant advantage - the absence of brush contacts, which increases the reliability of the engine and allows the production of such engines in an explosion-proof design. Brushless excitation systems are often used at gas pumping stations of main gas pipelines. The thyristor regulator implements the same control laws that are used in static exciters. The disadvantages of brushless systems are low performance and lower quality of maintaining the operating parameters of a synchronous motor compared to static systems. Electrically excited synchronous machines can be divided according to their excitation systems into brushed and brushless.

The excitation system depends on the application; A brushed excitation system is used when high dynamic performance is required, while the advantage of brushless excitation systems is that they require less maintenance. Brushless excitation systems are typically used in marine drive applications where the dynamic requirements are not too stringent, but maximum reliability is required and maintenance is difficult. A synchronous machine with a brushless excitation system is shown in Figure 2.

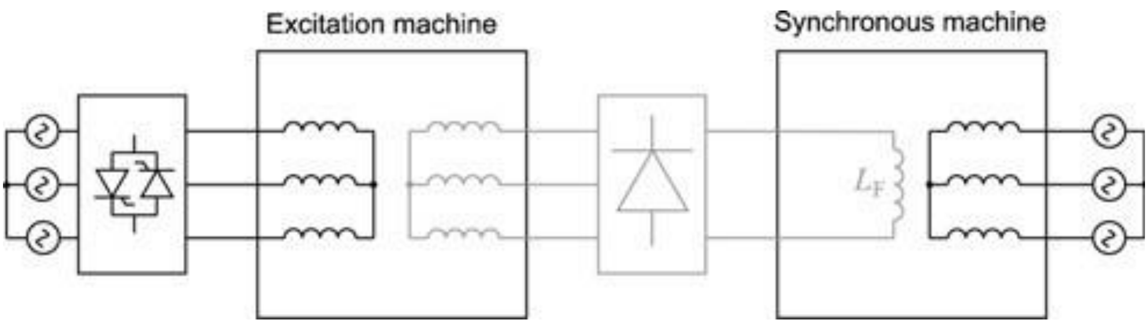

Figure 2 – Synchronous machine with brushless excitation system

The purpose of field current control is to set the power factor of the machine to a desired value and maintain machine stability during transient conditions. The created simulation model can be used to simulate the impact of excitation system dynamics on a synchronous machine during transient conditions. The finite state machine model gives an accurate description of the rotor circuit currents of the excitation machine. A simple time constant does not describe the excitation system well enough. The time constant for increasing and decreasing the field current is different from each other due to the free-running condition. It is not possible to make the drive current drop using a negative drive voltage with a diode bridge.

The brushless excitation system consists of an excitation machine, that is, a traditional three-phase wound-rotor induction machine mounted on the main shaft of the machine and powered by an AC-to-AC converter, and a diode rectifier connected to the rotor of the excitation machine. The use of a wound rotor excitation machine fed by an AC-AC converter allows the generation of excitation current also at zero speed, which is a significant advantage compared to other type of excitation method. A thyristor pair converter is considered, since it is a traditional converter for the excitation machine of a large synchronous machine. The rotor of the excitation machine is connected to the shaft of the synchronous machine. The stator flux of the exciting machine rotates in the direction opposite to the direction of rotation of the synchronous machine. Consequently, the slip of the exciting machine is always greater than unity. The excitation machine is powered by a power converter using a thyristor pair, which is connected to the stator connectors of the synchronous machine or to an external network.

The excitation machine receives energy partly from the supply network and partly from the axis of the synchronous machine when operating with a slip greater than unity. There are two additional pairs of thyristors to change the direction of rotation of the field when the direction of rotation of the synchronous machine changes. If a synchronous machine is used as a generator, one pair of poles can be equipped with permanent magnets to allow the generator to be expanded also in isolated network operation. The rotor currents of the excitation machine are rectified and supplied to the excitation winding of the synchronous machine using a six-pulse diode bridge rectifier. A complete diagram of the excitation system is shown in Figure 3.

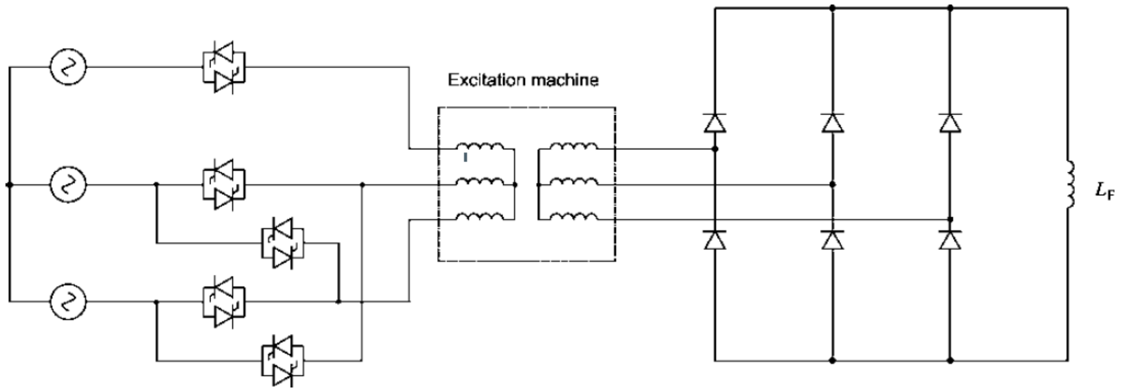

Figure 3 – Complete diagram of the excitation system

The thyristor power converter in the stator circuit and the diode rectifier in the rotor circuit cause strong nonlinearity in the excitation system. Currents and voltages are not sinusoidal, which makes modeling difficult.

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