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Synchronous Motors with Permanent Magnets

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Abstract *— This paper analyzes the working processes of permanent magnet synchronous machines.*

Keywords — Synchronous machines; AC machines; permanent magnets asynchronous motors;

The use of permanent magnets in the magnetic systems of synchronous machines, as well as in other types of electrical machines, is due to the desire to reduce the dimensions and weight of the machine, simplify the design, increase the efficiency, improve reliability in operation.

Permanent magnets in synchronous machines are designed to create a magnetic field of excitation, and for this purpose can be used permanent magnets combined with electromagnets, through the coils of which a constant current flows. The use of combined excitation makes it possible to obtain the required adjustment characteristics for voltage and speed of rotation with a significantly reduced field power and volume of the magnetic system compared to classical electromagnetic excitation systems of synchronous machines.

Currently, permanent magnets are used at the power of synchronous machines up to one or more kilovolt-amperes. As you create permanent magnets with improved characteristics, the power of the machines increases.

Synchronous machines are AC machines. They are used as an engine and generator.

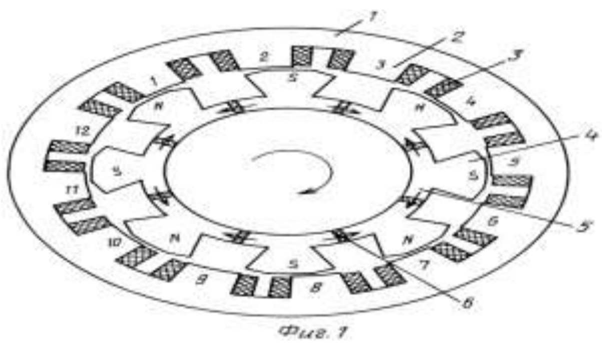
Synchronous motors are mainly used in high-power drives. Their power reaches several tens of megawatts. At thermal power plants, steel plants, mines, and Refrigerators, pumps and other mechanisms that operate at a constant speed are driven. Synchronous motors can operate with different reactive power. Thus, These engines can improve the power factor of the enterprise. However, the cost of drives with synchronous motors is higher than with asynchronous ones.

Special low-power motors are used in devices where the speed is strictly constant, electric clocks, automatic recording devices, software-controlled devices, etc.

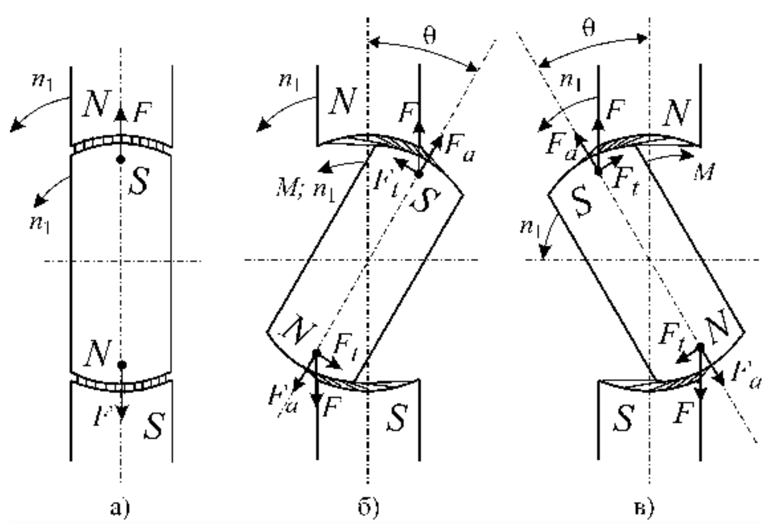
At large substations of electrical systems, special synchronous machines are installed that operate in idle mode and give only the reactive power needed for asynchronous motors to the network. These machines are referred to as synchronous compensators.

The invention relates to the use of three-phase synchronous machines for generating electricity. The device consists of a three-phase synchronous motor and a three-phase synchronous generator located on one shaft, which are made with permanent magnet excitation. The rotor and stator of the engine and generator have distinct poles. The stator windings are wound around the stator poles. Permanent magnets of excitation in the motor and generator are placed in the backs of the rotor between its poles. In the center of the poles of the generator rotor are flat compensating permanent magnets placed in planes passing through the axis of the generator.

The invention relates to the use of three-phase synchronous machines of a special design with excitation from permanent magnets, BUT 2 TO 21/27.Currently, the designs of three-phase synchronous machines (motors and generators), including those with permanent magnet excitation, are widely known. Description of the design of synchronous machines with permanent magnet excitation can be taken as a prototype of the synchronous machines offered in the present invention. The disadvantage of existing synchronous machines is that the magnetic flux generated by the permanent magnets of the rotor poles crosses the stator winding conductors located in the grooves of the inner surface of the stator. In this case, the generated electrical power in the generator is equal to the required mechanical power supplied to the generator rotor (without taking into account the energy losses in the stator and mechanical energy losses in the rotor). Similarly, the mechanical power developed by the engine is equal to the power consumed by the engine from the power source (excluding energy losses). In connection with the above the effectiveness of the existing synchronous machines adopted for the prototype, is always less than unity. The technical result, which is aimed at achieving the present invention, consists in the creation of three-phase electrical machines (motor and generator) with an efficiency greater than one unit, combined on one shaft in an aggregate that allows to provide electricity generation without the cost of any energy carriers. The device of a synchronous motor-generator (SDG) consists of a three-phase synchronous motor (TSD) and a three-phase synchronous generator (TSG) located on one shaft, placed in a common housing. The engine and generator are made with clearly defined stator and rotor poles, with stator windings (OS) wound “around” the stator poles. The stator, consisting of the stator poles (PS) and the “back” of the stator (SS), is made of sheet electrical steel. The rotor, consisting of the rotor poles (PR) and the rotor back (SR), is made of solid electrical steel. Permanent magnets of excitation (PMV) are placed in the back of the rotor).In the center of the poles of the generator rotor, flat, small-thickness compensating permanent magnets (PMCs) are additionally placed, located in a plane containing the axis of the generator. A special feature of the design of TSD motors is the small thickness of permanent magnets of excitation (2hPMP).Length of the stator poles along the inner surface of the stator (lPS) is 60 "electric" degrees; the length of the rotor poles along the outer surface of the rotor (lPR) is 120 "electric" degrees. The number of poles of the stator (mC) is a multiple of three and is equal to mC=3P, where P is the number of pairs of poles in the machine. The number of rotor poles (m P) is equal to: mP=2P.All parts of the motor and generator magnetic circuits are " unsaturated”, which allows you to take into account the magnetic resistance of only permanent magnets and air gaps. Schematic cross-sections of TSD and TSG are shown in Fig. 1



In Fig.1 the following designations are accepted:1 - ” back " of the stator (SS)
2-pole stator (PS)
3-stator windings (OS)
4-pole rotor (PR)
5 - ” back " of the rotor (SR)
6-permanent field magnets (PMV)



The principle of operation of synchronous machines is based on the interaction of magnetic fields of the stator and rotor. Schematically, the rotating magnetic field of the stator can be represented by poles of magnets rotating in space with the speed of rotation of the magnetic field of the stator $n_1 = \frac{60 f_1}{p}$ (Fig. 1). the rotor Field can also be represented as a stationarymagnet rotating synchronously with the stator field.

In the absence of an external torque applied to the machine shaft, the field axes of the stator and rotor coincide (Fig. The forces of attraction F act on the rotor along the pole axis and mutually compensate for each other. The angle between the stator and rotor field axes is zero.

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If the machine shaft is affected by a braking moment, the rotor is shifted in the direction of lagging by a $F_a = F\cos\theta$. As a result, the forces of attraction F are decomposed in $F_t = F\sin\theta$ irected along the pole axis of the rotor (axial component) and perpendicular to the pole axis $M = F_t D = FD\sin\theta = M_{max}\sin\theta$ onents are mutually compensated, and the tangential components create a torque that compensates for the external moment applied to the shaft (D - the diameter of the points of application of tangential forces). The machine operates in engine mode, compensating for the mechanical power consumed on the shaft by consuming active power from the network that feeds the stator.

If an external moment is applied to the rotor, creating acceleration, i.e. acting in the direction of rotation of the shaft, the picture of interaction of fields changes to the opposite. The direction of angular displacement □ changes to the opposite, respectively changing the direction of tangential forces and the direction of action of the electromagnetic moment. In this case, it becomes a brake, and the machine works with a generator that converts the mechanical energy supplied to the machine shaft into electrical energy, which is given to the network that feeds the stator.

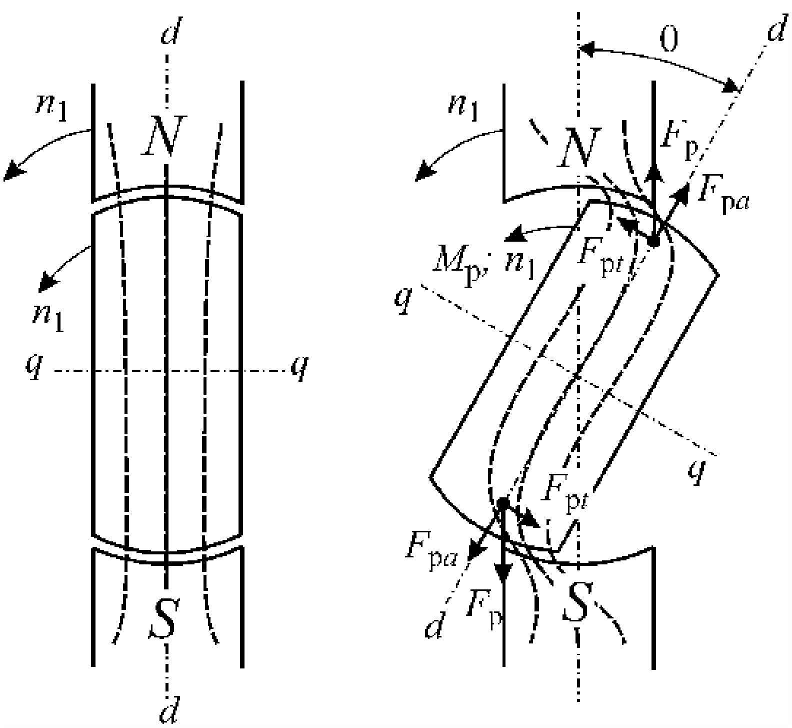

Рис. 2

Ina synchronous machine, a falling moment may occur even if the rotor does not have its own magnetic field. Let us assume, for example, that the field winding of a single-pole rotor is disconnected from the power supply. Then the picture of the magnetic field of the machine will have the form shown in figure 2. Here the clearly polarized rotor is connected to the d-q coordinate system in such a way that the d-d axis is aligned with the symmetry axis in the direction of maximum magnetic conductivity, and the q-q axis with the direction of minimum magnetic conductivity. The d-d axis also coincides with the axis of the magnetic field of the excited rotor and is called the longitudinal axis, and the q-q axis, respectively, is called the transverse one.

In the absence of an external moment, the yavnipolar rotor will take a position where the longitudinal axis will coincide with the axis of the poles of the magnetic field of the stator. This position corresponds to the minimum magnetic resistance for the magnetic flux of the stator.

If the machine shaft is subjected to braking torque, the rotor will deflect by an angle □. In this case, the magnetic field of the stator is deformed, because the magnetic flux will tend to close along the path of least resistance. The magnetic flux is determined through magnetic lines of force, i.e. lines whose direction at each point corresponds to the direction of action of the force, so the deformation of the field will lead, just as in the case of an excited rotor, to the appearance of the resulting tangential force F_{pt}. The difference from an excited rotor will be that the tangential force will be a function of the double angle □. This difference occurs due to the fact that an excited rotor can have only one stable equilibrium position at $\theta = 2k\pi;\ k = 0,1\ldots$, and an unexcited rotor can be in equilibrium at $\theta = k\pi;\ k = 0,1\ldots$.

The torque generated in a machine with an unexcited rotor due to tangential forces is called the reactive torque and its dependence on is expressed as a function $M_p = F_t D = FD \sin 2\theta = M_{p\max} \sin 2\theta$.

It is obvious that a necessary condition for the occurrence of a reactive moment is the magnetic asymmetry of the rotor.

The processes discussed above in a synchronous machine clearly demonstrate the principle of reversibility of electric machines, i.e. the ability of any electric machine to change the direction of energy conversion to the opposite. In synchronous machines, it is enough to change the direction (sign) of the load moment on the shaft to switch from engine mode to generator mode.

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