P.438147 – Electric generator of special design with internal motor drive

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Description of the current state of the art together with its assessment and indication of literature

A typical electric machine comprises a stator assembly which is a stationary structure and a rotor assembly with a drive shaft which rotates relative to the stator assembly. The stator of a conventional AC induction or synchronous machine contains windings, while the rotor, depending on the type of machine, contains permanent magnets or electromagnets or windings in the form of coils or a cage. There are also known electric machines with inverted roles of the stator and rotor, which include, among others, conventional DC machines. The stator and rotor of a synchronous or induction machine are configured to cooperate with each other to produce a rotating magnetic field which generates the induced voltages in the windings of the machine.

One of the disadvantages of conventional AC electric machines is that the voltage induced in the windings and its frequency are directly or closely correlated with the rotational speed of the rotor, which means that in order to increase the value of the induced voltages and their frequency, machines with a significant rotational speed must be used, which results in an increase in the mechanical energy supplied to the shaft and may contribute to a decrease in the efficiency of the electric machine. Analogous problems related to the correlation of rotational speed and induced voltage apply to DC machines. Another disadvantage is that the control of high-speed electric machines is complicated because the higher the speed of rotation, the more complicated it is to control and/or keep it constant.

There are also known propulsions of electric generators, e.g. wind turbines, which are characterized by low rotational speed and in order to increase it, a mechanical transmission must be used. Therefore, there is a need for electrical machines that can generate voltages of the appropriate value and frequency at low rotational speeds.

In addition to the described single-rotor machines with increased rotational speed, there are also known from patent descriptions two-rotor electric machines, e.g. [1], in which the effect of increasing the voltage induced in the windings and its frequency occurs. These are machines driven counter-rotating by two independent turbines [2, 3, 4] or transferring the mechanical power from one rotor shaft to another through a mechanical transmission [4, 5]. In the second solution, the effect of increasing the voltage induced in the windings and its frequency was achieved by using counter rotation between the conductor and the magnetic field, thus increasing the mutual speed while maintaining a low shaft speed. Therefore, by rotating in opposite directions, the efficiency of the machine is increased due to the fact that the same output voltage is produced at a lower input speed. The use of a gear-based drive unit into a two-rotor generator with a single drive shaft resulted in a higher mutual speed of both rotors compared to the mutual speed between stator and rotor in a conventional type generator while maintaining the same rotational speed of the drive shaft. Simultaneously, the increased mutual speed of the rotors in the two-rotor generator, while maintaining an equivalent torque on the shaft of both types of generators, increased the output power of the two-rotor generator compared to the conventional generator.

The present invention makes it possible to increase the efficiency of the machine in a purely electric way, i.e. without the need for a double external drive or a mechanical transmission. Replacing the mechanical transmission with an electric drive results in the reduction of unfavorable phenomena associated with the use of a mechanical transmission, e.g. backlash or energy losses in the transmission, especially when multiplying the speed.

It is generally known that increasing the voltage of alternating current electric machines, associated with a simultaneous increase in frequency, allows for obtaining a higher output power while maintaining the same design parameters of the magnetic circuit and the armature winding, i.e. the number of turns and the cross-section of the wires, and as a result, the geometric dimensions of the machine do not change.

The aim of the project and indication of the issue being the subject of the project, solution to the indicated issue (the essence of the project), an example of implementation with the specification of means and methods of implementation, expected technical and utility effects of the solution, expected benefits and sources of their creation

The aim of the project is to develop a construction of a special-design electric generator with an internal motor drive and higher efficiency compared to conventional AC generators. Higher values of the generated voltage and frequency without the need to increase the rotational speed of the shaft or the same voltage and frequency at a lower speed define this higher efficiency, which is obtained by a different method than in two-rotor generators known from patent descriptions. Another goal is to develop a compact electric machine that is economical to manufacture.

The electric generator of a special design with an internal motor drive, which is the subject of the invention, is a multi-structure electric machine with one shaft, two generator structures and one motor structure. Both generator structures are described as the main generator and the auxiliary generator, respectively. The essence of the invention is to obtain an increased rotational speed of the rotor of the second generating structure in relation to the externally set rotational speed of the rotor of the first generating structure. The invention therefore allows for higher generated voltages and frequencies than conventional AC generators without having to increase the rotational speed of the shaft.

Descriptions of respective structures of a special-design electric generator and rotating fields, as well as the relationship between the velocities of the rotating field and the frequencies of the voltages induced in the windings, were based on the literature [6] and the authors' own knowledge. The construction of a special-design electric generator with an internal motor drive - a variant with an induction motor is shown in Fig. A. The main generator consists of stator laminated core 5 with a three-phase winding 3 embedded in the body 4 and a solid rotor core 7 with permanent magnets 6 embedded on the outer surface of the rotor 9. The internal motor consists of a laminated core 15 with a three-phase winding 1 mounted on the outer surface of the rotor 10 combined with the shaft 11 and a laminated core 14 with a squirrel-cage winding 2 mounted on the inner surface of the rotor 9. The auxiliary generator consists of a laminated rotor core 12 with a three-phase winding 17, mounted on the shaft 11 and a solid stator core 13 with permanent magnets 16, embedded in the body 4 of the generator of a special design. The rotors 9 and 10 are mounted in bearings 18 and 19, respectively, and corresponding bearings on the driving side of the generator of a special design. The bearings are embedded in the casing 4.

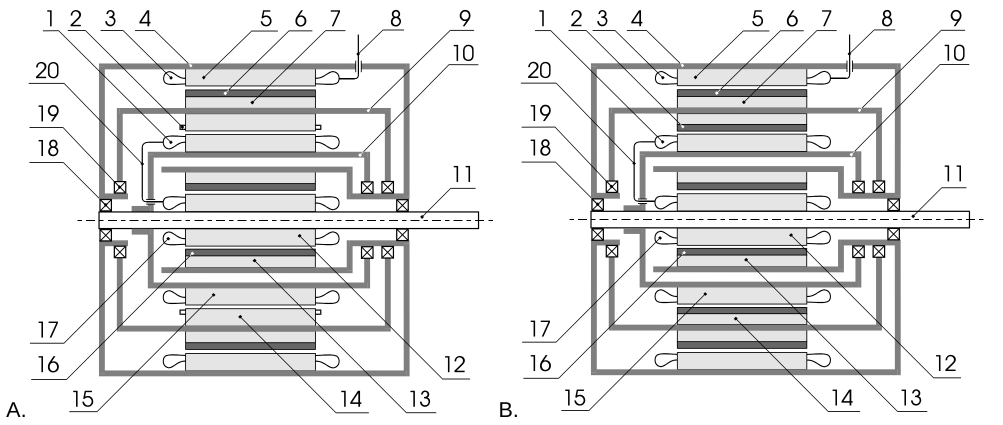

Fig. Electric generator of a special design with an internal motor drive: (a) variant with an induction motor, (b) variant with a synchronous motor, where: 1 - three-phase winding of the internal motor placed in slots, 2 - squirrel-cage winding of the internal motor or permanent magnet of the internal motor, 3 – three-phase main generator armature winding placed in slots, 4 – generator body, 5 – main generator stator laminated core, 6 – permanent magnet mounted to the main generator rotor, 7 – solid main generator rotor core, 8 – power cables, 9 – main generator rotor, 10 – generator rotor combined with shaft, 11 – generator shaft, 12 – rotor laminated core of auxiliary generator, 13 – solid core of auxiliary generator stator, 14 – laminated core of internal motor with squirrel cage winding or solid core with permanent magnets, 15 - laminated core of the internal motor with three-phase winding, 16 - permanent magnet mounted to the stator of the auxiliary generator, 17 - three-phase winding of the rotor of the auxiliary generator, 18 - bearing of the shaft of the generator of a special design (the second bearing is on the opposite side shaft), 19 – main generator rotor bearing (the second bearing is on the driving side of the special-design generator), 20 – connecting cables.

The rotor laminated core 12 is separated by an air gap from the stator solid core 13 with permanent magnets 16. In the three-phase winding 17, rotating in a stationary magnetic field excited by permanent magnets 16, voltages are induced with the frequency $f_1 = p_1 n_1/60$, where n_1 – rotational speed of shaft 11 of a special-design generator, p_1 – number of pole pairs of the auxiliary generator. The value of the voltage induced in the winding 17 is proportional to the speed n_1. The three-phase winding 17 is electrically connected by three wires 20 to the three-phase winding 1. The voltage from the three-phase winding 17 is applied through these wires to the three-phase winding 1, which generates a magnetic field rotating at the speed $n_1 + n_{1s}$, where $n_{1s} = 60f_1/p_s$, p_s - number of pole pairs of the internal motor. The laminated core 15 with three-phase winding is separated by an air gap from the laminated core 14 with the squirrel-cage winding. The rotating field induces voltages in the bars of the cage 2, which force the current to flow in the closed squirrel-cage winding. As a result of the interaction of the magnetic fields, an electromagnetic torque is produced, which drives the rotor 9 with a rotational speed $n_1 + n_s$, where n_s - the rotational speed of the internal motor depends on the electromagnetic torque according to the mechanical characteristics of the motor. A solid core 7 with permanent magnets 6 is mounted to the outer surface of the rotor 9 and rotates at a rotational speed $n_1 + n_s$. It is separated by an air gap from the stator laminated core 5 of the main generator. Voltages are induced in the three-phase winding 3 as a result of the rotating magnetic field excited by permanent magnets 6. The frequency of the voltage induced in the winding 3 is $f_2 = p_2(n_1 + n_s)/60$, where p_2 – the number of pole pairs of the main generator. Moreover, the value of the voltage induced in winding 3 is proportional to the sum of the speeds $n_1 + n_s$.

The construction of a special-design electric generator with an internal motor drive - a variant with a synchronous motor is shown in Fig. 2. The main generator consists of a stator laminated core 5 with three-phase winding 3, embedded in the body 4 and a rotor solid core 7 with permanent magnets 6, embedded on the outer surface of the rotor 9. The internal motor consists of a laminated core 15 with a three-phase winding 1, mounted on the outer surface of the rotor 10 combined with the shaft 11 and a solid core 14 with permanent magnets 2, mounted on the inner surface of the rotor 9. The auxiliary generator consists of a laminated rotor core 12 with a three-phase winding 17, mounted on the shaft 11 and a stator solid core 13 with permanent magnets 16, embedded in the body 4 of the generator of a special design. The rotors 9 and 10 are mounted in bearings 18 and 19, respectively, and corresponding bearings on the driving side of the generator of a special design. The bearings are embedded in the casing 4.

The laminated rotor core 12 is separated by an air gap from the stator solid core 13 with permanent magnets 16. In the three-phase winding 17, rotating in a stationary magnetic field excited by permanent magnets 16, voltages are induced with the frequency f1 = p1n1/60, where n1 – rotational speed of shaft 11 of a special-design generator, p1 – number of pole pairs of the auxiliary generator. The value of the voltage induced in the winding 17 is proportional to the speed n1. The three-phase winding 17 is electrically connected by three wires 20 to the three-phase winding 1. The voltage from the three-phase winding 17 is applied through these wires to the three-phase winding 1, which excites a magnetic field rotating at the speed n1 + n1s, where n1s = 60f1/ps, ps - number of pole pairs of the internal motor. The laminated core 15 with three-phase winding is separated by an air gap from the solid core 14 with permanent magnets. As a result of the action of the magnetic fields, an electromagnetic torque is generated which drives the rotor 9 with a rotational speed n1 + n1s. A solid core 7 with permanent magnets 6 is mounted to the outer surface of the rotor 9 and rotates at a rotational speed n1 + n1s. It is separated by an air gap from the stator laminated core 5 of the main generator. Voltages are induced in the three-phase winding 3 as a result of the rotating magnetic field excited by permanent magnets 6. The frequency of the voltage induced in the winding 3 is f2 = p2(n1 + n1s)/60, where p2 – the number of pole pairs of the main generator. Moreover, the value of the voltage induced in winding 3 is proportional to the sum of the speeds n1 + n1s.

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