P.438154 Electric generator with internal frequency multiplier

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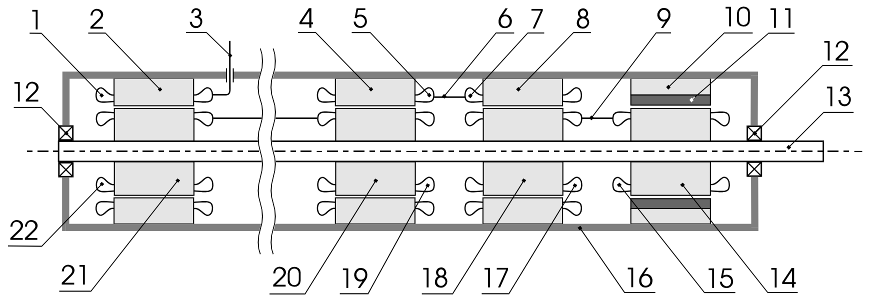
The aim of the project is to develop a construction of an electric generator with an internal frequency multiplier having higher efficiency compared to conventional AC generators. The higher values of the generated voltage and frequency without the need to increase the rotational speed of the shaft or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

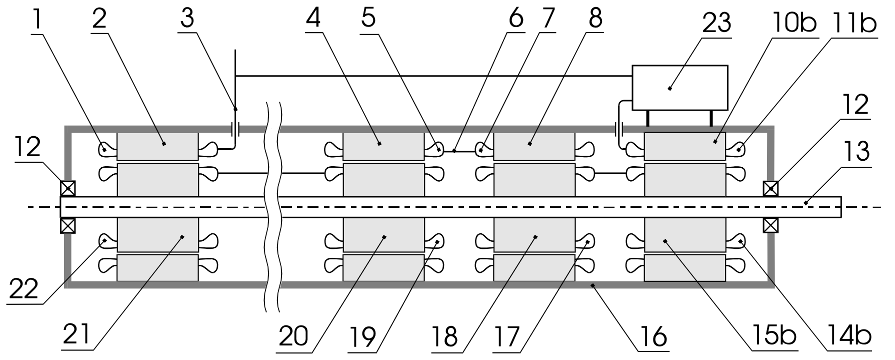
The electric generator with an internal frequency multiplier, which is the subject of the invention, is a multi-structure electric machine with one shaft, one generator structure and many frequency transforming structures. The generator structure is an alternating current electric generator, for example a synchronous generator, an asynchronous generator or an induction generator.

The essence of the invention is to obtain many times higher values of the generated voltage and frequency in relation to the voltage and frequency of conventional AC electric generators without the need to increase the rotational speed of the shaft.

An electric generator with an internal frequency multiplier (hereinafter referred to as the machine) can be made as three-phase or with any number of phases. In addition, it can act as a generator or motor.



a) variant with a synchronous generator



b) variant with an asynchronous generator

Fig. 1. Electric generator with an odd number of multiplier stages

The synchronous generator (Fig. 1a) consists of a laminated rotor core 14 mounted on a shaft 13, a three-phase rotor winding 15, a solid stator core 10 mounted in the machine body 16, and permanent magnets 11. The first stage of the internal frequency multiplier consists of a laminated core 8 mounted in the stator, a three-phase stator winding 7, a laminated core 18 mounted on the rotor shaft 13 and a three-phase rotor winding 17. The second stage of the internal frequency multiplier consists of a laminated core 4 mounted in the stator, a three-phase stator winding 5, a laminated core 20 mounted on the rotor shaft 13, and a three-phase rotor winding 19. The k-th stage of the internal frequency multiplier consists of a laminated core 2 mounted in the stator, a three-phase stator winding 1, a laminated core 21 mounted on the rotor shaft 13, and a three-phase rotor winding 22. The common shaft 13 of the generator and frequency multiplier is mounted in bearings 12.

The laminated rotor core 14 is separated by an air gap from the solid core of the stator 10 with permanent magnets 11. In the three-phase winding 15, rotating in a stationary magnetic field excited by permanent magnets 11, voltages are induced with the frequency $f_1 = p_1 n_1/60$, where n_1 – rotational speed of the machine shaft 13, p_1 – number of pole pairs of the synchronous generator. The value of the voltage induced in the winding 15 is proportional to the speed n_1. The three-phase winding 15 is electrically connected by three connecting wires 9 to the three-phase winding 17. The voltage from the three-phase winding 15 is applied through these wires to the three-phase winding 17 which produces a magnetic field rotating relative to the stator at a speed $n_1 + n_2$ where n_2 – field rotation speed relative to the shaft, $n_2 = 60 f_1/p_2$, p_2 – number of pole pairs of the first stage frequency multiplier. The laminated core 18 with the three-phase winding 17 is separated by an air gap from the laminated core 8 with the winding 7. The rotating field induces in the three-phase winding 7 voltages with the frequency $f_2 = p_2(n_1 + n_2)/60 = (p_1 + p_2)n_1/60$. The value of the voltage induced in the winding 7 is proportional to the sum of the speeds $n_1 + n_2$.

The three-phase winding 7 is electrically connected by three connecting wires 6 with the three-phase winding 5. The voltage from the three-phase winding 7 is supplied through these wires to the three-phase winding 5, which generates a magnetic field rotating relative to the stator with the speed $n_1 + n_3$, where n_3 - field rotation speed relative to shaft, $n_3 = 60 f_2/p_3$, p_3 – number of pole pairs of the second stage frequency multiplier. The laminated core 4 with the three-phase winding 5 is separated by an air gap from the laminated core 20 with the winding 19. The rotating field induces in the three-phase winding 19 voltages with the frequency $f_3 = p_3(n_1 + n_3)/60 = (p_1 + p_2 + p_3)n_1/60$. The value of the voltage induced in the winding 7 is proportional to the sum of the speeds $n_1 + n_3$.

The three-phase winding 19 is electrically connected by three connecting wires to the three-phase winding of the third stage of the frequency multiplier. The voltage from the three-phase winding 19 is supplied through these wires to the three-phase winding of the third stage of the frequency multiplier, which produces a magnetic field rotating at the speed $n_1 + n_4$, where $n_4 = 60 f_3/p_4$, p_4 - the number of pole pairs of the third stage of the frequency multiplier. In the case of successive stages of the frequency multiplier, the process of electromechanical energy conversion is analogous. The frequency of the voltage induced in winding 1 is $f_{k+1} = (p_1 + p_2 + \ldots + p_{k+1})n_1/60$, and the value of the voltage induced in winding 1 is proportional to this frequency.

In the case of $p_1 = p_2 = \ldots = p_{k+1}$, the frequency f_{k+1} of the voltage at the output of the multiplier increases k+1 times in relation to the frequency f1 of the synchronous generator, while the voltage at the output of the multiplier depends on both the frequency f_{k+1} and the ratios of multiplier's respective stages. In the case of unitary ratios, the voltage is also increased k+1 times in relation to the voltage of the synchronous generator.

In the case of a 4-pole synchronous generator and 4-pole frequency multiplier stages, to obtain the machine output frequency of 50 Hz, its rotor should be driven at a speed of 1500/(k+1) rpm. In the case of a three-stage frequency multiplier, this speed is equal to 375 rpm. This is a quarter of the speed at which the rotor of a standard synchronous generator must be driven in order to obtain a voltage of the same frequency. Depending on the speed required, you can save on a mechanical transmission or install a transmission with a lower ratio and therefore higher efficiency. This is important in the case of low-speed drives, e.g. wind power turbines.

By replacing the electric generator with an internal frequency multiplier, which is the subject of the invention, with many electric machines in the amount of k + 1, the optimal operation of the electric generator thus created cannot be achieved due to significant disadvantages of its construction, in particular: greater volume and weight, higher costs and greater construction complexity, and more frequent maintenance. In the present invention, for example, there are no slip rings and brushes that complicate the design, wear out relatively quickly and require frequent maintenance.

The asynchronous generator (Fig. 1b) consists of a laminated rotor core 15b mounted on the shaft 13, a three-phase rotor winding 14b, a packaged stator core 10b mounted in the machine body 16, and a three-phase stator winding 11b. The laminated rotor core 15b is separated by an air gap from the laminated stator core 10b. In the three-phase winding 14b, which rotates in a rotating magnetic field excited by the winding 11b supplied from the frequency converter 23, voltages are induced with the frequency $f_1 = p_1 n_1/60 \pm f_{inv}$, where n_1 – rotational speed of the machine shaft 13, p_1 – number of pairs of poles of asynchronous generator, f_{inv} – generator supply frequency from the frequency converter. The value of the voltage induced in the winding 14b is proportional to the frequency f1. The three-phase winding 14b is electrically connected by three connecting wires to the three-phase winding 17. The voltage from the three-phase winding 14b is applied through these wires to the three-phase winding 17, which produces a magnetic field rotating at a speed of $n_1 \pm 60 f_{inv}/p_1 + n_2$, where $n_2 = 60 f_1/p_2$, p_2 – number of pole pairs of the first stage of the frequency multiplier. The laminated core 18 with the three-phase winding 17 is separated by an air gap from the laminated core 8 with the winding 7. The rotating field induces in the three-phase winding 7 voltages with the frequency $f_2 = f_1(1 + p_2/p_1)$. The value of the voltage induced in the winding 7 is proportional to the frequency f_2.

The three-phase winding 7 is electrically connected by three wires 6 to the three-phase winding 5. The voltage from the three-phase winding 7 is supplied through these wires to the three-phase winding 5, which produces a magnetic field rotating at the speed n1 + n3, where $n_3 = 60 f_2/p_3$, p_3 - the number of pole pairs of the second stage of the frequency multiplier. The laminated core 4 with the three-phase winding 5 is separated by an air gap from the laminated core 20 with the winding 19. The rotating field induces in the three-phase winding 19 voltages with the frequency $f_3 = p_3(n_1 + n_3)/60 = (p_1 + p_2 + p_3)n_1/60$. The value of the voltage induced in the winding 7 is proportional to the sum of the speeds $n_1 + n_3$. The three-phase winding 19 is electrically connected by three connecting wires to the three-phase winding of the third stage of the frequency multiplier. The voltage from the three-phase winding 19 is supplied through these wires to the three-phase winding of the third stage of the frequency multiplier, which generates a magnetic field rotating at the speed $n_1 + n_4$, where $n_4 = 60 f_3/p_4$, p_4 - the number of pole pairs of the third stage of the frequency multiplier. In the case of subsequent stages of the frequency multiplier, the process is analogous. The frequency of the voltage induced in winding 1 is $f_{k+1} = (p_1 + p_2 + \ldots + p_{k+1})n_1/60$, and the value of the voltage induced in this winding is proportional to this frequency.

In the case of p1 = p2 = … = pk+1, the frequency fk+1 of the voltage at the output of the multiplier increases k+1 times in relation to the frequency f1 of the asynchronous generator, while the voltage at the output of the multiplier depends on both the frequency fk+1 and the ratios of multiplier's respective degrees. In the case of unitary ratios, the voltage also increases k+1 times in relation to the voltage of the asynchronous generator.

The construction and operation of the generator with an even number of frequency multiplier stages (Fig. 2) are analogous to the previously described generator with an odd number of multiplier stages (Fig. 1).

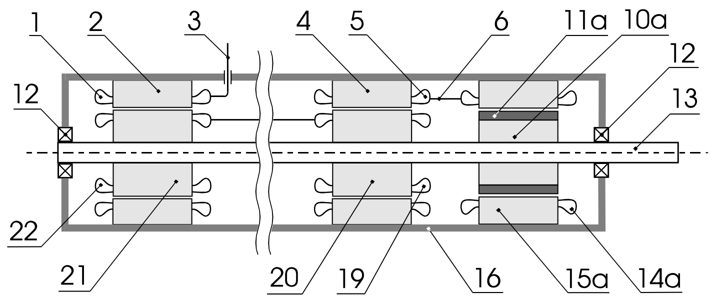


Fig. 2. Electric generator with an even number of stages of the frequency multiplier – a variant with a synchronous generator