Title: SYNCHRONOUS MOTOR WITH RADIAL GAP

Fig. 1

(57) Abstract: This application refers to the motor with an electrical power supply, but without its conversion to the mechanical energy. Interactions between the stator and rotor poles are purely magnetic. In the proposed solution, the elimination of rotation electromotive force SEM excludes the described motor from the family of electric machines. Electromagnets of the stator are wound in the same direction and enclose the rotor consisting of permanent magnets mounted on the side surface of the rotor cylinder made of ferromagnetic material. Position of the rotor corresponds to the moment of switching on the supply impulse voltage. Current begins to flow through transistors and through the motor winding. In a moment, the impulse voltage is being switched off and follows the return of reactive energy, stored in the inductance of the motor winding, through diodes. The returned reactive energy is stored in the supply capacitor, increasing the voltage over the supply voltage. The next switching on of the supply impulse voltage with the opposite polarity follows, when the rotor moves by one magnet relative to the stator electromagnets and the whole work cycle is repeated.
Synchronous motor with radial gap.

This application describes synchronous, brushless electric motor and the way of its power supply.

In conventional electrical machines of this type, brushless DC motors, the driving torque is obtained by acting with a rotational magnetic field generated by the stator on permanent magnets spaced on the rotor. Stator winding is powered with three-phase voltage, synchronous with the rotation of the rotor and the moment of switching on and off the current in the stator winding depends on the angular position of the rotor. Runs of the supply voltage impulses of the motor windings have the fill equal to 100%. The stator winding is three-phase. The stator is separated from the rotor by an air gap of constant width over the entire circumference. The rotating magnetic field of the stator produces a magnetic field gradient in the air gap and it is the direct cause of mechanical action on the rotor. This interaction has an electrodynamic nature. In this case, the field gradient is formed as a result of heteropolar magnetization of adjacent stator poles, wherein the angular width of the pole or pole shoe on the stator is equal to or less than the sum of the angular width of the rotor magnet and the angular width of the gap between the magnets. Magnetic core is common for the streams of the stator and the rotor. The mechanical energy is produced by the electrical energy supplied to the stator windings. During the movement of the rotor, the magnetic field of permanent magnets
winding an electromotive force SEM directed opposite to the voltage supplied to the stator of the motor. The electric motor, like any electric machine, transforms the supplied electric energy into the mechanical one, through the induced in the stator electromotive force of rotation SEM.

A measure of the amount of electrical energy transformed into mechanical energy (rotation of the motor shaft) is the product of the motor supply current and the electromotive force (voltage) induced as a result of the rotor movement (magnets) in the stator winding. The amount of mechanical energy produced by the motor is always less than the amount of the provided electrical supply, as the power supply voltage must be higher than the opposing electromotive force SEM.

The ratio of the generated mechanical energy to the supplied electrical energy, it is an efficiency of the electric motor.

Traditional way of supplying power to the brushless motor is carried out by using a transistor bridge, three-phase, controlled by means of an optical or magnetic sensor. The sensor examines the position of the rotor relative to the stator and switches on in the correct sequence the individual phases of the supply voltage onto the winding coils. The stator produces a rotating magnetic field, synchronized with the rotation of the rotor. This requires an extensive electronics, developed in the motor control unit. The filling of runs of the changing supply voltage is at a maximum, i.e. 100% in order to obtain the highest power.

According to the invention, the feature of the synchronous motor, it is a yokeless stator consisting of individual electromagnets with winding wound in the same direction. During the flow of current impulse through the windings, there are formed the same magnetic poles on all stator electromagnets. The poles of the stator are shaped in this way that the width of the air gap varies around the perimeter of the rotor, with one pole of the stator covering two, opposite oriented poles of the rotor. The area of stator poles, in a developed view, forms a wavy shape, advantageously sinusoidal.

According to the invention, the method of power supply to the synchronous motor is characterized by application of the phase controller. The controller switches off the supply impulse from the stator windings at a time when runs out the foreseen impulse time or when the current of the impulse exceeds a set value. Depending on the time, supply impulse switches off and discharges reactive energy stored in the inductance of the stator windings to the supply capacitor and depending on the current, the supply impulse switches off and at the same time the stator winding is being shorted and the current in the stator winding is maintained until the end of the impulse time, and then the current impulse is switched off in a way as described.

According to the invention, the motor is supplied from DC current source through the transistor bridge of “H” type with feedback diodes. The control of revolutions and power of the motor is carried out by changing the supply voltage and/or the length of supplying impulses phase. In the case of phase control, it is necessary to leave some time to discharge reactive energy stored in the inductance of the stator winding. The reactive energy discharge current also produces useful driving torque.
The aim of the invention is to develop an electric motor, synchronously supplied and to eliminate in its function the formation of rotation electromotive force SEM. The impact of stator poles on the rotor poles and obtaining the driving torque, in the proposed solution is based on purely magnetic action. The example of the motor according to the invention is shown on Figure 2, Figure 2 and Figure 3 shows the developed view of the motor at the different positions of the rotor, Figure 4 shows a motor controller diagram, Figure 5 shows the voltage and current runs at a time control and Figure 6 the voltage and current runs at a current control.

Designations on drawings:

1. stator electromagnet
2. stator electromagnet winding
3. rotor magnet
4. ferromagnetic base of the rotor magnets
5. plastic sleeve
6. rotor of the motor
7. air gap
V1 – V4....transistors
D1 – D5....diodes
L....inductance of the motor winding
K....controller
SF....photocell signal input
LEM....current sensor
C....supply capacitor
Uc....voltage of the supply capacitor
U....supply voltage
i....supply current
t....time axis
t1....moment of switching on the supply impulse voltage
t2....moment of switching off the supply impulse voltage
t3....moment of switching off the lower supply transistors
t4....moment of supply current decay

The example of the motor execution is shown on (Fig. 1). Electromagnets of the stator (1) have winding (2) wound in the same direction. Winding connection is in series, at a current flow through the winding, on the electromagnets pole shoes there are always formed the same magnetic poles. Electromagnets (1) of the stator enclose the rotor consisting of permanent magnets (3) mounted on the side surface of the rotor cylinder (4) made of ferromagnetic material. Element (5), it is a filling between the motor shaft (6) and the base (4) of permanent magnet (3). This
This filling is made of plastic. (Fig. 2) shows the motor in a developed view. Position of the rotor corresponds to the moment of switching on the supply impulse voltage \( t_1 \) on the diagram (Fig. 5). Current begins to flow \( i_j \) through transistors \( V_1 \) and \( V_2 \) or \( V_3 \) and \( V_4 \) and through the motor winding \( L \). Supply current increases to the value \( i_z \).

At the time \( t_2 \), the position of the rotor relative to the stator is as on (Fig. 2), the impulse voltage is being switched off and follows the return of reactive energy stored in the inductance \( L \) of the motor winding, through diodes \( V_3 \) and \( V_4 \) or \( V_4 \) and \( V_2 \). At the time \( t_4 \) the current in the motor winding decays. The returned reactive energy is stored in the supply capacitor \( C \), increasing the voltage \( U_d \) over the supply voltage \( U_a \). The next switching on of the supply impulse voltage with the opposite polarity follows, when the rotor moves by one magnet relative to the stator electromagnets and the whole work cycle is repeated. The motor in the position, as on (Fig. 1), has no starting torque and a mechanical impulse in any direction is needed to initiate the work.

At a start of the motor, the supply current \( i_j \) exceeds the limit value for the winding and to a signal from the current sensor \( LEM \), the controller will switch off the upper transistors \( V_1 \) and \( V_3 \) of the transistor bridge and the motor winding \( L \) will be shorted. The controller \( K \) will switch off the lower transistors at the time \( t_4 \). Because the permanent magnets \( S \) are shorted by the stator electromagnets pole shoes \( 1 \), they do not cause axial magnetisation of their cores. This allows to maintain a constant inductance of the motor winding \( L \) and to eliminate the formation of rotation electromotive force in the motor winding.
Patent claims.

1. According to the invention, the synchronous motor consisting of the stator and the rotor with permanent magnets mounted on the side surface of the cylinder-rotor, characterized by the stator consisting of separate cores not connected by a yoke, wound in the same direction and connected so, that during the flow of current impulse, all poles of the stator are mono-polar, wherein the air gap between poles of the stator and the rotor has a variable width and a pole or a pole shoe of the stator covers two, inversely oriented magnets of the rotor.

2. According to the claim no. 1, the synchronous motor is characterized by the air gap between the rotor and the stator, which forms a wavy shape, advantageously sinusoidal.
Fig. 6
**INTERNATIONAL SEARCH REPORT**

**International application No**
PCT/PL2015/000133

**A. CLASSIFICATION OF SUBJECT MATTER**

INV. H02K21/16
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched: (classification system followed by classification symbols)
H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database consulted during the international search (name of database and, where applicable, search terms used)
EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<td>US 6 583 531 B1 (ASANO YOSHINARI [JP] ET AL) 24 June 2003 (2003-06-24) column 3; figures 1, 3; column 4; figure 6</td>
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Date of the actual completion of the international search
18 January 2016

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Authorized officer
Brandt, Isabelle
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