SECTION 7. Mechanics and machine construction.

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ASYNCHRONOUS MOTOR - OPERATING PRINCIPLE AND DEVICE

Abstract: *The article deals with the use, principle of operation and features of asynchronous electric motors and the main criterion.*
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Introduction

The greatest contribution to the creation of induction motors was made by Galileo Ferraris and Nikola Tesla. In 1888 Ferraris published his research in an article for the Royal Academy of Sciences in Turin, in which he outlined the theoretical foundations of an asynchronous motor. Merit of Ferraris is that, making an erroneous conclusion about the small efficiency of an induction motor and the inexpediency of using alternating current systems, he drew the attention of many engineers to the problem of improving asynchronous machines. The article by Galileo Ferraris, published in the magazine Atti di Turino, was reprinted by an English magazine and in July 1888 caught the eye of the graduate of the Darmstadt Higher Technical School, a native of the Russian Empire, Mikhail Osipovich Dolivo-Dobrovolsky. Already in 1889 Dolivo-Dobrovolsky received a patent for a three-phase asynchronous motor with a squirrel-cage rotor of the "squirrel wheel" type (German patent No. 51083 dated March 8, 1889, entitled "Anker für Wechselstrommotoren"), and in 1890 - patents in England No. 20425 and Germany No. 75361 for a phase rotor with rings and starting devices. The invention disclosed an era of mass industrial application of electrical machines. Currently, the asynchronous motor is the most common electric motor.[1, p 4]

Materials and Methods

Advantages and disadvantages of an induction motor with a short-circuited rotor in comparison with other types of machines:

Pluses:
- Ease of manufacture.
- Relative cheapness.
- High reliability in operation.
- Low operating costs.
- The ability to connect to the network without any converters
- All of the above advantages are due to the lack of mechanical switches in the rotor circuit and led to the fact that most of the electric motors used in industry are asynchronous machines with a short-circuit rotor.

Disadvantages:
- A small starting moment.
- Significant inrush current.
- Low power factor.
- The complexity of speed control with the necessary accuracy.
- The maximum speed of the motor is limited by the network frequency.
- Strong dependence of the electromagnetic moment on the supply network voltage.
- The most perfect approach to eliminating the above drawbacks is to feed the motor through a frequency converter, in which control is performed using complex algorithms.[2, p 56]

Asynchronous motor - operating principle and device

Modern three-phase asynchronous motors are converters of electrical energy into mechanical. Due to its simplicity, low cost and high reliability, asynchronous motors are widely used. They are present everywhere, this is the most common type of engines, they are produced by 90% of the total number of engines in the world. Asynchronous electric motor has truly made a technical revolution in the whole world industry.[2, p 58]

The huge popularity of asynchronous motors is associated with the simplicity of their operation, cheapness and reliability.

An asynchronous motor is an asynchronous machine designed to convert the electrical energy of an alternating current into mechanical energy. The very word "asynchronous" means not simultaneous. This means that for induction motors the rotational frequency of the stator magnetic field is always greater than the rotor speed. Asynchronous motors operate, as is clear from the definition, from an alternating current network.
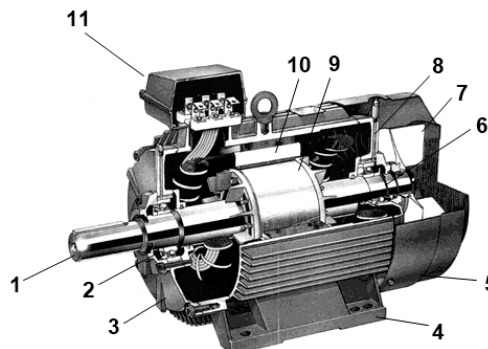

Picture- 1. Asynchronous motors

In the figure: 1 - shaft, 2,6 - bearings, 3,8 - bearing shields, 4 - paws, 5 - fan casing, 7 - fan impeller, 9 - squirrel cage rotor, 10 - stator, 11 - terminal box.

The main parts of the induction motor are the stator (10) and the rotor (9).[3]

The stator has a cylindrical shape, and is assembled from sheets of steel. In the grooves of the stator core, stator windings are laid, which are made of winding wire. The axes of the windings are shifted in space relative to each other by an angle of 120°. Depending on the voltage supplied, the ends of the windings are connected by a triangle or a star.
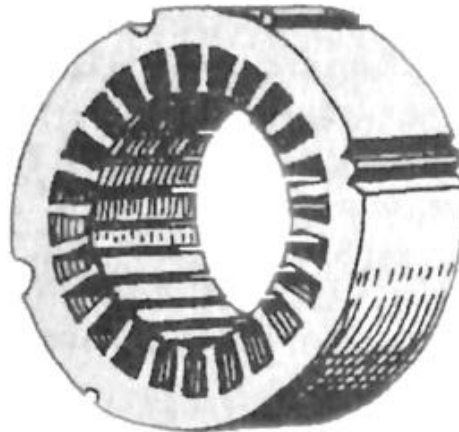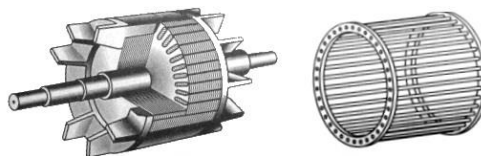

Picture- 2. Rotor

Rotors of the induction motor are of two types: a short-circuit and a phase rotor.[4, p 566]

The short-circuited rotor is a core, recruited from sheets of steel. In the grooves of this core molten aluminum is poured, resulting in the formation of rods, which are short-circuited by end rings. This design is called a "squirrel cage". In heavy-duty engines, copper can be used instead of aluminum. The squirrel cage is a short-circuited winding of the rotor, hence the name itself.[4, p 571]

Picture- 3. Short-curved rotor and squirrel cage.

The phase rotor has a three-phase winding, which practically does not differ from the stator winding. In most cases, the ends of the windings of the phase rotor are connected to a star, and the free ends are brought to the contact rings. By means of brushes that are connected to the rings, an additional resistor can be introduced into the winding circuit of the rotor. This is necessary so that the active resistance in the rotor circuit can be changed, because this helps reduce the large inrush currents. More information on the phase rotor can be found in the article - an induction motor with a phase rotor.[5, p 613]
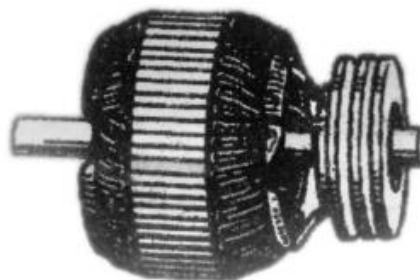
Picture- 4. rotor

Principle of operation

When a voltage is applied to the stator winding, a magnetic flux is created in each phase, which varies with the frequency of the applied voltage.

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These magnetic fluxes are shifted relative to each other by 120 °, both in time and in space. The resultant magnetic flux is thus rotating.[5, p 615]

The resultant magnetic flux of the stator rotates and thereby creates in the conductors of the EMF rotor. Since the rotor winding has a closed electrical circuit, a current appears in it, which in turn interacts with the stator magnetic flux, creates the starting torque of the motor, which tends to rotate the rotor in the direction of rotation of the stator magnetic field. When it reaches the value, the braking torque of the rotor, and then exceeds it, the rotor starts to rotate. Thus there is a so-called slip.[6, p 216]

Slip «s» is a value that indicates how much the synchronous frequency **n1** of the stator magnetic field is greater than the rotor speed **n2**, in percent.

$$s = \frac{(n_1 - n_2)}{n_1} \cdot 100\ \%$$

Slip is an extremely important quantity. At the initial moment of time it is equal to one, but as the rotational speed **n2** of the rotor increases, the relative frequency difference **n1-n2** becomes smaller, as a result of which the EMF and current in the conductors of the rotor decrease, which entails a decrease in the torque. In the idling mode, when the engine runs without load on the shaft, the slip is minimal, but with increasing static moment, it increases to the value of «s» - critical slip. If the engine exceeds this value, a so-called overturning of the engine may occur and result in its unstable operation. Slip values lie in the range from 0 to 1, for general-purpose asynchronous motors it is in the nominal mode - 1 - 8%.[6, p 208]

As soon as there is a balance between the electromagnetic moment causing the rotation of the rotor and the braking torque created by the load on the motor shaft, the process of changing the values will cease.

It turns out that the principle of operation of an induction motor is the interaction of the rotating magnetic field of the stator and the currents that are induced by this magnetic field in the rotor. Moreover, the torque can occur only in the event that there is a difference in the rotational frequencies of the magnetic fields.[6, p 209]

Methods for controlling an asynchronous motor

Under the control of an induction AC motor is meant a change in the rotor speed and or its torque.

The following methods for controlling an induction motor are available:

☐ rheostat - the change in the rotational speed of an induction motor with a phase rotor by changing the resistance of the rheostat in the rotor circuit, in addition it increases the starting torque and increases the critical slip;

☐ frequency - the change in the frequency of rotation of an induction motor by changing the frequency of the current in the supply network, which entails a change in the rotational speed of the stator field. The motor is switched on via a frequency converter;

☐ switching windings from the star to the triangle during the start-up of the engine, which reduces the starting currents in the windings by about three times, but at the same time, the time decreases;

☐ pulse - power supply of a special kind;

☐ the introduction of additional EMF according to or counter-directed with the frequency of sliding into the secondary circuit;

☐ changing the number of pole pairs, if such switching is provided constructively;

☐ a change in the amplitude of the supply voltage, when only the amplitude of the control voltage changes. Then the control and excitation voltages remain perpendicular;

☐ phase control is characterized by the fact that the change in rotor speed is achieved by changing the phase shift between the excitation and control voltage vectors;

☐ The amplitude-phase method includes two described methods; inclusion of stator reactors in the feed circuit;

☐ inductive resistance for a motor with a phase rotor.[7, p 13]

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