ANALYSIS OF METHODS FOR IMPROVING THE OPERATION MODES OF A SINGLE-PHASE INDUCTION MOTOR

S.S.A'zamov
Andijan State Technical Institute PhD, Associate Professor
E-mail: azamovsaidikrom1992@gmail.com
Jorakulov Bobur
Student of Andijan State Technical Institute
E-mail: joraqulovbobur402@gmail.com

Abstract: The operating modes of single-phase asynchronous motors supplied from a single-phase source in world production and enterprises, methods for improving their efficiency, reducing energy consumption and improving reliability are analyzed. The study studies the factors of power factor, heat losses and reactive power compensation at the moment of motor start-up. As a result, energy-saving control systems, methods of using phase-shifting elements and principle schemes for generating a rotating magnetic field using phase-shifting devices are presented. The structure of single-phase windings and stator core slots in the stator of a single-phase asynchronous motor and the analysis of magnetic moment graphs are highlighted.

Keywords: asynchronous motor stator windings, electromagnetic torque, reactive power consumption, pure rotating magnetic field, phase-shifting element, Mechanical characteristics.

Annotatsiya: Jahonda ishlab chiqarish va korxonalarida bir fazali manbadan ta'minlangan bir fazali asinxron motorlarning ish rejimlari, ularning samaradorligini oshirish, energiya sarfini kamaytirish va ishonchliligini yaxshilash bo'yicha takomillashtirish usullari tahlil qilingan. Tadqiqotda motorning ishga tushish momentida, quvvat koeffitsienti, issiqlik yo'qotishlari va reaktiv quvvat kompensatsiyasi qilish omillari o'rganilgan. Natijada energiya tejamkor boshqaruv tizimlari, fazani siljituvchi qurilmalar yordamida o'zaro saf, aylanma magnit maydonni hosilqilish maqsadida foydalanilgan faza buruvchi elementlarning qo'llanish usullari va prinsipial sxemalari keltirilgan. Bir fazali asinxron motorning statorida bir fazali chulg'am va staort o'zak pazlarining tuzulishi hamda magnit momentining grafiklari tahlillari yoritilingan.

Kalit so'zla: asinxron motor stator chulg'amlari, elektomagnit moment, reaktiv quvvat iste'moli, sof aylanma magnit maydon, faza buruvchi elemnt, Mexanik xarakteristika.

Аннотация: проанализированы режимы работы однофазных асинхронных двигателей, поставляемых от однофазного источника на мировом производстве и предприятиях, методы их совершенствования с целью повышения эффективности, снижения энергопотребления и повышения

надежности. В исследовании изучались факторы, влияющие на момент запуска двигателя, коэффициент мощности, тепловые потери и компенсацию реактивной мощности. В результате получены методы применения и принципиальные схемы фазовращательных элементов, применяемых с целью создания взаимосвязанного, вращательного магнитного поля с помощью энергоэффективных систем управления, устройств сдвига фаз. На статоре однофазного асинхронного двигателя показана структура Клинов однофазного сердечника и сердечника стаорта, а также анализ графиков магнитного момента.

Ключевое слово: статор асинхронного двигателя, электромагнитный момент, реактивное энергопотребление, чистое вращающееся магнитное поле, фазовращательный элемент, механическая характеристика.

Introduction

Manufacturing enterprises are considered to be one of the main factors of economic growth of countries in the world. Analysis shows that 70-75% of the generated electricity is consumed by asynchronous motors, and 20-25% of the asynchronous motors used in industrial production enterprises are single-phase asynchronous motors. The stator of a single-phase asynchronous motor has a single-phase winding, and the rotor has a short-circuited winding. The stator winding is located in 2/3 of the core slots, this system starts the asynchronous motor by creating a mutual Φμ-magnetic flux in the inductive windings of the asynchronous motor, which are symmetrically arranged with a mutual angular displacement of 900. When starting a single-phase asynchronous motor, there are many electrical devices and elements as phase-shifting elements, the most common of which is a capacitor.

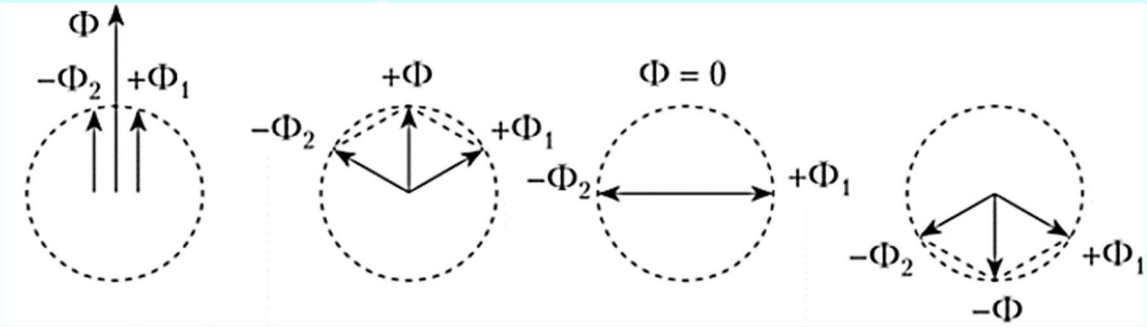


Figure 1

Graph of a single-phase asynchronous motor generating a rotating magnetic field

Phase shifting using a phase-shifting element capacitor the phase of the magnetic field is shifted using a capacitor connected in series with the winding. The capacitance of the capacitor is determined as follows:

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$$C = \frac{I_a}{2\pi f U \sin\phi}$$

where:

C — capacitor capacity (F),

I_a — auxiliary winding current (A),

f — network frequency (Hz),

U — voltage (V),

φ — phase angle.

When a properly selected capacitor is used for starting asynchronous motors supplied from a single-phase source, it increases the starting torque of the capacitor by 30–50%, improving the power factor from 0.6 to 0.85. It is known that during starting an asynchronous motor consumes five to seven times more reactive power than the nominal one, as a result of which the waste in the network and the device increases. Compensation of reactive power ensures stable and stable operation of the device and helps to save money on electricity. The mechanical characteristics of a single-phase asynchronous motor are graphically represented in Figure (b). This characteristic shows the relationship between the motor speed (n) and the electromagnetic torque (M). The graph shows that when the motor is started at zero speed, the torque also starts from zero. As the speed increases, the torque gradually increases and reaches its critical (maximum) value. After the critical point, the torque decreases and the motor continues in the stable operation section. This process shows how the motor behaves under load. With the help of mechanical characteristics, the load carrying capacity, stable operation range and efficiency of the motor are determined. Therefore, this characteristic is of great importance in selecting a motor in practice and its proper operation.

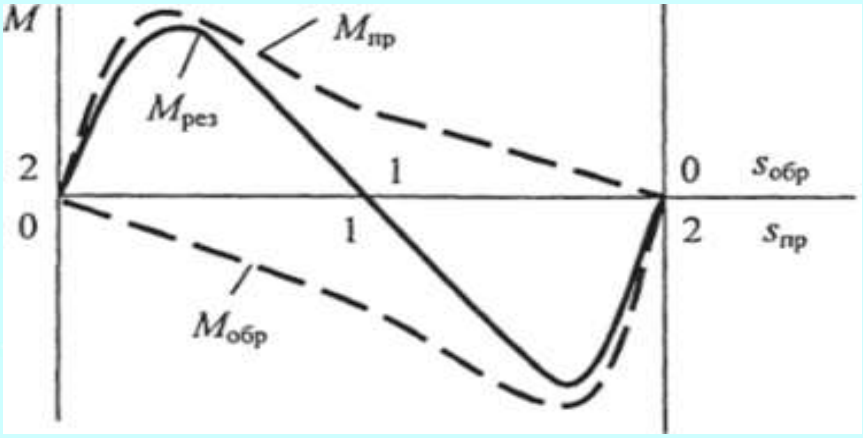


Figure 2 Slip torque graph of a single-phase asynchronous motor.

In single-phase asynchronous motors, part of the power drawn from the network is spent on reactive power. To reduce it, compensation capacitors are used:

$$Q_c = P(\tan\phi_1 - \tan\phi_2)$$

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where:

Q_c — compensated reactive power,

P — active power,

φ_1, φ_2 — power angles before and after compensation.

Method: Electronic control systems optimize the speed, torque and heat losses of single-phase motors controlled by inverters by changing the voltage and frequency. In such systems:

Energy consumption is reduced by 15–25%,

Motor heating temperature is reduced by 10–15°C,

Operation smoothness increases.

1. The main sources of losses in single-phase asynchronous motors are phase imbalance and reactive power.

2. When using capacitor phase shifting and compensation methods, the useful energy efficiency increases by 0.15–0.25 units.

3. Electronic control and automatic protection systems extend the service life of the motor and reduce maintenance costs.

4. In the future, the efficiency of single-phase motors will be further increased with inverter and artificial intelligence-based control systems.

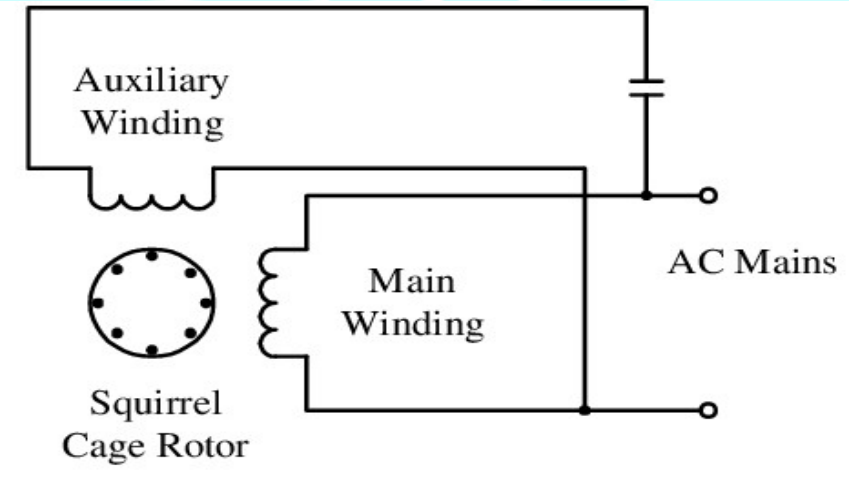


Figure 3 Capacitor starting circuit of a single-phase asynchronous motor equipped with a starting coil (d); K is a switch.

A characteristic feature of a single-phase asynchronous motor is that it cannot create a rotating magnetic field when directly connected to a single-phase network. Therefore, an additional coil and a capacitor are used to start the motor. Figure (d) shows such a capacitor starting circuit.

In the above circuit, in addition to the main stator coil, there is a starting (auxiliary) coil, which is connected through a capacitor. When the motor is started using a switch, the auxiliary coil is connected to the circuit and a phase shift is created. As a result, a rotating magnetic field is created in the stator, and the motor has a high starting torque. After the motor reaches the required speed, the auxiliary

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coil is disconnected by the switch and the motor continues to operate only at the expense of the main coil.

Conclusion: The article summarizes theoretical and experimental studies aimed at increasing the efficiency of single-phase asynchronous motors. During the study, the structural features of asynchronous motors, the interaction of electrical and mechanical parameters, the analysis of the torque-dependent graph of the load characteristic, and the influence of power supply conditions on efficiency were analyzed in detail. The results obtained showed that in order to increase efficiency, it is necessary not to be limited to one way, but to implement complex measures aimed at structural optimization, electrical control algorithms, reactive power compensation, and reducing mechanical losses. It was also confirmed that the adaptation of phase control and capacitor starting schemes significantly improves the load-dependent efficiency profile. From an economic and environmental perspective, measures to increase motor efficiency reduce electricity consumption, while at the same time reducing operating costs and the risk of thermal failures. Considering the share of single-phase asynchronous motors in total energy consumption, especially in industrial and domestic applications, improving efficiency at the individual level can provide significant energy savings at the system level.

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