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17/ENG04/005

ELECTRICAL/ELECTRONICS ENGINEERING

EEE326

ELECTRICAL MACHINES II TUTORIAL QUESTIONS

1a. A single phase induction motor, unlike a 3 phase induction motor, does not have a self starting torque.

b. The double revolving field theory of a single phase induction motor states that a pulsating magnetic field is resolved into two rotating magnetic fields. They are equal in magnitude but opposite in directions. The induction motor responds to each of the magnetic fields separately. The net torque in the motor is equal to the sum of the torque due to each of the two magnetic fields.

The equation for an alternating magnetic field is given as

$$b(\alpha) = \beta_{max} \sin \omega\, t \cos \alpha \ldots\ldots\ldots (1)$$

working-principle-of-single-phase-indcution-motor-eq-1

Where βmax is the maximum value of the sinusoidally distributed air gap flux density produced by a properly distributed stator winding carrying an alternating current of the frequency ω, and α is the sypace displacement angle measured from the axis of the stator winding.

As we know,

$$\sin A \cos B = \frac{1}{2}\sin(A - B) + \frac{1}{2}\sin(A + B)$$

working-principle-of-single-phase-indcution-motor-eq-2

So, the equation (1) can be written as

$$b(\alpha) = \frac{1}{2}\beta_{max}\sin(\omega t - \alpha) + \frac{1}{2}\beta_{max}\sin(\omega t + \alpha) \ldots\ldots\ldots (2)$$

working-principle-of-single-phase-indcution-motor-eq-3j

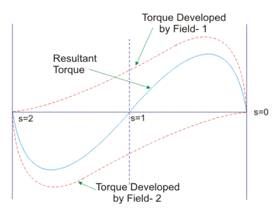
The first term of the right-hand side of the equation (2) represents the revolving field moving in the positive α direction. It is known as a Forward Rotating field. Similarly, the second term shows the revolving field moving in the negative α direction and is known as the Backward Rotating field.

The direction in which the single phase motor is started initially is known as the positive direction. Both the revolving field rotates at the synchronous speed. $\omega s = 2\pi f$ in the opposite direction. Thus, the pulsating magnetic field is resolved into two rotating magnetic fields. Both are equal in magnitude and opposite in direction but at the same frequency.

At the standstill condition, the induced voltages are equal and opposite as a result; the two torques are also equal and opposite. Thus, the net torque is zero and, therefore, a single phase induction motor has no starting torque.

c. A single phase induction motor consists of a single phase winding on the stator and a cage winding on the rotor. When a 1 phase supply is connected to the stator winding, a pulsating magnetic field is produced. In the pulsating field, the rotor does not rotate due to inertia. Therefore a single phase induction motor is not self-starting and requires some particular starting means.

d.



Torque Slip Characteristics of Single Phase Induction Motor

From the figure, we see that at a slip of unity, both forward and backward field develops equal torque but the direction of which are opposite to each other so the net torque produced is zero hence the motor fails to start. From here we can say that these motors are not self starting unlike the case of three phase induction motor. There must be some means to provide the starting torque. If by some means, we can increase the forward speed of the machine due to which the forward slip decreases the forward torque will increase and the reverse torque will decrease as a result of which motor will start.

From here we can conclude that for starting of single phase induction motor, there should be a production of difference of torque between the forward and backward field. If the forward field torque is larger than the backward field than the motor rotates in forward or anti clockwise direction. If the torque due to backward field is larger compared to other, then the motor rotates in backward or clockwise direction.

e. i.Split-phase motor.

ii.Capacitor start motor.

iii.Permanent capacitor run motor.

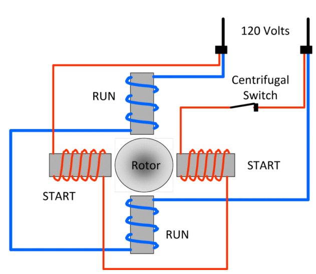
iv.Capacitor start capacitor run motor.

v. Shaded pole motor.

i. Split Phase Motor

A split phase induction motor is a single phase induction motor that has two windings called the run winding and a secondary start winding and a centrifugal switch as shown in figure 6. Split phase motors usually operates at 1/20 HP TO 1/3 HP.

These squirrel cage motors are a step above the shaded pole motors, because they can to a little more work with a heavier load attached to the shaft of the rotor.




Split Phase Motor Wiring Diagram

The split phase motor can be found in applications requiring 1/20 HP up to 1/3 HP, meaning it can turn anything from blades on a ceiling fan, washing machines tubs, blower motors for oil furnaces, and small pumps.

The centrifugal switch is a normally close control device that is wired into the start winding. The purpose of this configuration is that the motor start winding would be taken out the circuit once the motor reaches 75 to 80% of its rated speed. Even though it is considered to be a reliable motor this centrifugal switch is a moving part that sometimes fails to reengage when the motor stops spinning.

How Split Phase Motors Operate

To start a split phase motor the start and the run windings has to be connected in parallel

At 75% full speed the centrifugal switch opens, disconnecting the start winding.

Since the start winding is disconnected from the circuit, the motor is operating through the run winding.

To remove power from a split phase motor at 40% full load speed the centrifugal switch closes. Powering off the motor.

ii. Capacitor Motors

Single phase capacitor motors are the next step in the family of single phase induction motors. Capacitors motors contain the same start and run winding as a split phase motor does with the exception of the capacitor which gives a motor more torque on startup or when it is running. The purpose of the capacitor is to return voltage to the system when there is no voltage being produced and DAC sine wave of a single phase system.

In the AC single phase system there is only one voltage wave form and during one cycle of the sick 60 cps that it takes to produce voltage no voltage is produced at two points. It is the job of the capacitor to fill this void so the motor is always seeing a voltage which means a lot of torque is produced when the motor is running.

The three types of capacitor motors are capacitor start, capacitor run, and capacitor start and run motors.

Capacitor Start Induction Motor

Capacitor start induction run motors, as seen in figure 7, is a single phase induction motor with the capacitor is connected in series with the start winding and the centrifugal switch of the motor. This configuration gives the motor past starting power but the application does not require a lot of power doing the runtime. During the runtime the inertia of the load plays a big part in the motor operation when there is a problem with the motor it is usually due to a bad capacitor. The motor will generally not rotate unless an outside force spins the shaft; once it is started it will continue to operate fine until power is removed from the motor.

Capacitor start motors are generally found in AC units, large blower motors, and condenser fans. The capacitor of these motors are sometimes built onto the motor or located remotely away from the motor primarily making it easier to replace.

Capacitor Motor Operation

Has a start winding, run winding, and centrifugal switch that opens at 60 to 80% full load speed.

The start winding and the capacitor are no longer in use once the centrifugal switch opens.

The capacitor is only used for high torque starting.

Capacitor Run Induction Motor

Capacitor run induction motors, as seen in figures 10 and 11, are much like the capacitor start induction run with the exception of the start winding and run winding stay in the circuit at all times. This type of motor requires low starting torque but needs to keep a constant torque while running. This type of motor can sometimes be found in the air-conditioning compressor. The start winding is permanently connected to the capacitor in series.

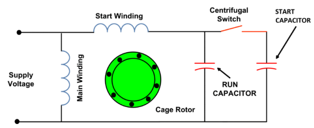
Capacitor Run Operation

Uses a lower rated capacitor because the capacitor is in the circuit at full load speed at all times.

Used for higher running torque.

Capacitor Start-Capacitor Run Induction Motor

Capacitor start capacitor run induction motors are single phase induction motors that have a capacitor in the start winding and in the run winding as shown in figure 12 and 13 (wiring diagram). This type of motor is designed to provide strong starting torque and strong running for applications such as large water pumps.




Capacitor Start-Capacitor Run Motor Wiring Diagram

Capacitor Start-Capacitor Run Motor Operation

Consist of two capacitors

One capacitor is connected in series with the start winding; the other capacitor is connected in series with the run winding.

Both capacitors have different values.

Capacitor start and run motor has the same starting torque and higher running torque because there is more capacitance.

Larger value capacitor to start, and lesser value capacitor to run.

f. This theory for single phase states that a stationary pulsating magnetic field can be resolved into two RMF, each of equal magnitude but rotating in the opposite direction.

The induction machine responds to each magnetic field separately, and the net torque in the motor is equal to some of the torque due to each of the two magnetic fields.

The equation for an alternating magnetic field whose axis is fixed in space is given by:

$$b(\alpha) = \beta_{max} \sin \omega t \cos \alpha$$

$$b(\alpha) = \frac{1}{2}\beta_{max} \sin(\omega t - \alpha) + \frac{1}{2}\beta_{max} \sin(\omega t + \alpha)$$

Working Principle of a Single Phase Induction Motor

βmax is the maximum value of sinusoidally distributed air gap flux density. 'B' represents the equation of revolving field moving in the positive α direction, and 'A' represent equation of revolving field moving in a positive direction. The field moving in the positive α direction is called the forward rotating field and in negative α direction is called the backward rotating field.

It is therefore concluded that a stationary pulsating magnetic field can be resolved due to two rotating magnetic fields both of equal magnitude and moving at synchronous speed in the opposite direction at the same frequency as the stationary magnetic field.

The theory based on such a resolution of an alternating field into two counter-rotating fields is called the Double revolving field theory of single phase induction machine.

2a.The universal motor is a type of electric motor that can operate on either AC or DC power and uses an electromagnet as its stator to create its magnetic field.

ii. Portable drill machine.

Used in hair dryers, grinders and table fans.

A universal motor is also used in blowers, polishers and kitchen appliances.

b. Construction of a universal motor is very similar to the construction of a DC machine. It consists of a stator on which field poles are mounted. Field coils are wound on the field poles.

However, the whole magnetic path (stator field circuit and also armature) is laminated. Lamination is necessary to minimize the eddy currents which induce while operating on AC.

The rotary armature is of wound type having straight or skewed slots and commutator with brushes resting on it. The commutation on AC is poorer than that for DC. because of the current induced in the armature coils. For that reason brushes used are having high resistance.

3a. The three-phase AC induction motor is a rotating electric machine that is designed to operate on three phase supply. This 3 phase motor is also called as an asynchronous motor. This AC motors are of two types: squirrel and slip-ring type induction motors. The principle of operation of this motor is based on the production of rotating magnetic field.

b. Induction Motor Advantages:

Induction motors are simple and rugged in construction. Advantage of induction motors are that they are robust and can operate in any environmental condition

Induction motors are cheaper in cost due to the absence of brushes, commutators, and slip rings

They are maintenance free motors unlike dc motors and synchronous motors due to the absence of brushes, commutators and slip rings.

Induction motors can be operated in polluted and explosive environments as they do not have brushes which can cause sparks

3 phase induction motors will have self starting torque unlike synchronous motors, hence no starting methods are employed unlike synchronous motor. However, single-phase induction motors does not have self starting torque, and are made to rotate using some auxiliaries.

These advantages in induction motors make them more prominent in industrial and domestic applications.

Induction Motor Disadvantages:

Some of the disadvantages of induction motors compared to dc motors and synchronous motors are:

3 phase induction motors have poor starting torque and high have in rush currents. Therefore these motors are not widely used for applications which require high starting torques like traction systems. Squirrel cage induction motor have poor starting torque. Starting torque in the case of slip-ring induction motor is comparitively better because of the presence of external resistor in the rotor circuit during starting. Other important disadvantage of Induction motor is that it draws high inrush currents causing large momentary voltage dip during starting of the machine. High inrush currents can be reduced by employing some starting methods in induction motor

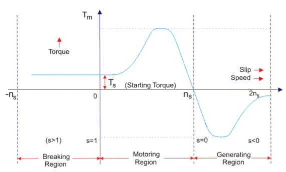
Induction motors always operate under lagging power factor and during light load conditions they operate at very worst power factor (0.2 to 0.4 lagging). Some of the disadvantages of poor power are increase in I2R losses in the system, reduction in the efficiency of the system. Hence some power factor correction equipments such as static capacitor banks should be placed nearto these motors to deliver the reactive power to them.

One of the main disadvantages of induction motors is that speed control of induction motors are difficult. Hence for fine speed control applications dc motors are used in place of induction motors. Due to advance in power electronics, variable frequency drives using induction motors are used in industries for speed control now a days.

These are some of the disadvantages associated with induction motors.

d. The torque slip curve for an induction motor gives us the information about the variation of torque with the slip. The slip is defined as the ratio of difference of synchronous speed and actual rotor speed to the synchronous speed of the machine. The variation of slip can be obtained with the variation of speed that is when speed varies the slip will also vary and the torque corresponding to that speed will also vary.

The curve can be described in three modes of operation-




Torque Slip Curve for Three Phase Induction Motor

Torque slip curve for three phase induction motor

The torque-slip characteristic curve can be divided roughly into three regions:

Low slip region

Medium slip region

High slip region

Motoring Mode

In this mode of operation, supply is given to the stator sides and the motor always rotates below the synchronous speed. The induction motor torque varies from zero to full load torque as the slip varies. The slip varies from zero to one. It is zero at no load and one at standstill. From the curve it is seen that the torque is directly proportional to the slip.

That is, more is the slip, more will be the torque produced and vice-versa. The linear relationship simplifies the calculation of motor parameter to great extent.

## Generating Mode

In this mode of operation induction motor runs above the synchronous speed and it should be driven by a prime mover. The stator winding is connected to a three phase supply in which it supplies electrical energy. Actually, in this case, the torque and slip both are negative so the motor receives mechanical energy and delivers electrical energy. Induction motor is not much used as generator because it requires reactive power for its operation.

That is, reactive power should be supplied from outside and if it runs below the synchronous speed by any means, it consumes electrical energy rather than giving it at the output. So, as far as possible, induction generators are generally avoided.

## Braking Mode

In the Braking mode, the two leads or the polarity of the supply voltage is changed so that the motor starts to rotate in the reverse direction and as a result the motor stops. This method of braking is known as plugging. This method is used when it is required to stop the motor within a very short period of time. The kinetic energy stored in the revolving load is dissipated as heat. Also, motor is still receiving power from the stator which is also dissipated as heat. So as a result of which motor develops enormous heat energy. For this stator is disconnected from the supply before motor enters the braking mode.

If load which the motor drives accelerates the motor in the same direction as the motor is rotating, the speed of the motor may increase more than synchronous speed. In this case, it acts as an induction generator which supplies electrical energy to the mains which tends to slow down the motor to its synchronous speed, in this case the motor stops. This type of breaking principle is called dynamic or regenerative breaking.