Q No. 1

Introduction

The Popularity of 3 Phase induction motors on board ships is because of their simple, robust construction, and high reliability factor in the sea environment. A 3 Phase induction motor can be used for different applications with various speed and load requirements. Electric motors can be found in almost every Production Process today. Getting the most out of your application is becoming more and more important in order to ensure cost-effective operations. The three-Phase induction motors are the most widely used electric motors in industry. They run at essentially constant speed from no-load to full load. However, the speed is frequency dependent and consequently these motors are not easily adapted to speed control. We usually prefer d.c motors when large speed variations are required. Like any electric motor, a 3-Phase induction motor has a stator and a rotor. The stator carries a 3-Phase winding while the rotor carries a short-circuited winding. only the stator windings is fed from

3-Phase supply. The rotor windings derives its voltage and power from the externally energized stator winding through electromagnetic induction and hence the name. The induction motor may be considered to be a transformer with a rotating secondary and it can, therefore, be described as a "transformer type" a.c machine in which electrical energy is coverted into mechanical energy.

Advantages

It has simple and rugged construction.
It is relatively cheap.
It requires little maintenance.
It has high efficiency and reasonably good power factor.
It has self-starting torque.

Disadvantages

It is essentially a constant speed motor and its speed cannot be changed easily.
Its starting torque is inferior to d.c shunt motor.

Construction

The three phase induction motor is the most widely used electrical motor. Almost

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80% of the mechnical Power used by industries is Provided by three Phase induction motors because of its simple and rugged construction, low cost, good operating characterristics, absence of commutator and good speed regulation. In three Phase induction motor the Power is transferred from stator to rotor windings through induction. The induction motor is also called asynchronous motor as it runs at a speed other than the synchronous speed. Like any other electrical motor induction motor has two main Parts **i-** stator **ii-** rotor. The rotor is separated from the stator by a small air-gap which ranges from 0.4 mm to 4 mm, depending on the Power of the motor. The main body of the induction motor comprises of two major Parts.

i- Shaft for transmitting the torque to the load. This shaft is made up of steel.

ii- Bearings for supporting the rotating shaft.

iii- one of the Problems with electrical motor is the Production of heat during its rotation.

iv- For receiving external electrical connection terminal box is needed.

v- There is a small distance between rotor and stator which usually varies from 0.4 mm to 4mm. such a distance is called air gap.

Stator

Stator is a stationary Part of induction motor. A Stator winding is Placed in the Stator of induction motor and the three Phase Supply is given to it. Stator is made up of number of stampings in which different Slots are cut to receive 3 Phase windings Circuit which is connected to 3Phase AC Supply. The three Phase windings are arranged in such a manner in the Slots that they Produce a rotating magnetic field after AC supply is given to them. The windings are wound for a definite number of Poles depending upon the speed requirement as speed is inversely Proportional to the number of Poles, given by the formula:

$$N_s = 120f/P$$

where N_s = Synchronous Speed

f = Frequency

P = no. of Poles

It consists of a Steel frame which encloses a hollow. cylindrical core made up of thin laminations of Silicon Steel to reduce hysteresis and eddy current losses. The 3 Phase Stator windings is wound for a difinite number of Poles as Per requirement of Speed.

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Stator of three Phase induction motor

The Stator of three Phase induction motor consists of three main Parts:

i- Stator Frame

It is the outermost Part of the three Phase induction motor. Its main function is to support the stator core and the field windings. It acts as a covering and it Provide Protection and mechnical strength to all the inner Parts of the induction motor. The frame is either made up of die cast or fabricated steel. The frame of three Phase induction motor should be very strong and rigid as the air gap length of motor is very small, otherwise rotor will not remain concentric with stator. which will give rise to unblanced magnetic Pull.

ii- stator core

The main function of the stator core is to carry the alternating (current) flux. In order to reduce the eddy current loss, the stator core is laminated. These laminated types of structure are made up of stamping which is about 0.4 to 0.5 mm thick. All the stamping are stamped together to form stator core.

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iii- Stator winding or Field winding

The slots on the Periphery of Stator core of the motor carried three Phase windings. This three Phase winding is supplied by three Phase ac supply. The three Phases of the winding are connected either in star or delta depending upon which type of starting method is used. The slip ring three Phase induction motor are started by inserting resistances so the stator windings of slip ring induction can be connected either in star or delta.

Rotor

The rotor is a rotating Part of induction motor. The rotor is connected to the mechnical load through the shaft. Rotor consists of cylindrical laminated core with Parallel slots that carry conductor bars. Conductors are heavy copper or aluminium bars which fits in each slots. These conductors are brazed to the short circuiting end rings. The slots are not exactly made Parallel to the axis of the shaft but are slotted a little skewed for the following reason. They reduces magnetic hum or noise and they avoid stalling of motor. The winding Placed in these

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slots (called rotor winding) may be one of the following two types:

Squirrel cage rotor

The rotor of the squirrel cage three phase induction motor is cylindrical in shape and have slots on its periphery. The slots are not made parallel to each other but are bit skewed, as the skewing prevents magnetic locking of stator and rotor teeth and makes the working of motor more smooth and quieter. The squirrel cage rotor consists of aluminium, brass or copper bars. The rotor conductors are permanently shorted by the copper or aluminum rings called the end rings. As the bars are permanently shorted by end rings, the rotor resistance is very small and it is not possible to add external resistance as the bars are permanently shorted. Those induction motors which employ squirrel cage rotor are called squirrel cage induction motors.

wound rotor

In this type of induction motor the rotor is wound for the same number of poles as that of stator but it has less number of slots and has less turns per phase of a heavier conductor. The rotor also carried star delta winding similar to that of stator winding. The rotor consists of numbers of slots and rotor windings are placed inside these slots. The three end terminals are connected together to form star connection. The three ends of three phase windings are permanently connected to these slip rings. The external resistance can be easily connected through the brushes and slip rings and hence used for speed control and improving the starting torque of three phase induction motor. The rotor windings are uniformly distributed in the slots and is usually star-connected.

Q No.2

Operation Principle

In an AC motor, there's a ring of electromagnets arranged around the outside (making up the stator), which are designed to produce a rotating magnetic field. Inside the stator, there's a solid metal axle, a loop of wire, a coil, a squirrel cage made of metal bars and interconnections (like the rotating cages people sometimes get to amuse pet mice), or some other freely rotating metal part that can conduct electricity.

Unlike in a DC motor, where you send Power to the inner rotor, in an AC motor you send Power to the outer coils that make up the stator. The coils are energized in Pairs, in sequence, Producing a magnetic field that rotates arround the outside of the motor. The rotor, suspended inside the magnetic field, in an electrical conductor. The magnetic field is constantly changing (because its rotating) So, according to the laws of electromagnetsim, the magnetic field Produces or induces an electric current inside the rotor. If the conductor is a ring or a wire, the current flows arround it in a loop. If the conductor is simply a solid Piece of metal, eddy currents swirl arround it instead. Either way, the induced current Produces its own magnetic field and, according to another law of electromagnetism (Lenz's law) tries to stop whatever it is that causes it - the rotating magnetic field - by rotating as well. Electromagnetic induction is the Key to why a motor like this spins - and why it's called an induction motor. Three Phase induction motor derives its name from the fact that the rotor current is induced by the magnetic field, instead of electrical connection. The operation of a three Phase induction motors is based on the Production of rotating magnetic field.

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Three Phase Rotating Fields

The three Phase induction motor also operates on the Principle of a rotating magnetic field. The following discussion shows how the stator windings can be connected to a three-Phase ac input and have a resultant magnetic field that rotates.

Figure , views A-C Show the individual windings for each Phase. view D, shows how the three Phases are tied together in Y-connected Stator. The dot in each diagram indicates the common Point of the Y-connection. You can See that the individual Phase windings are equally Spaced arround the stator. This Places the windings 120° aPart

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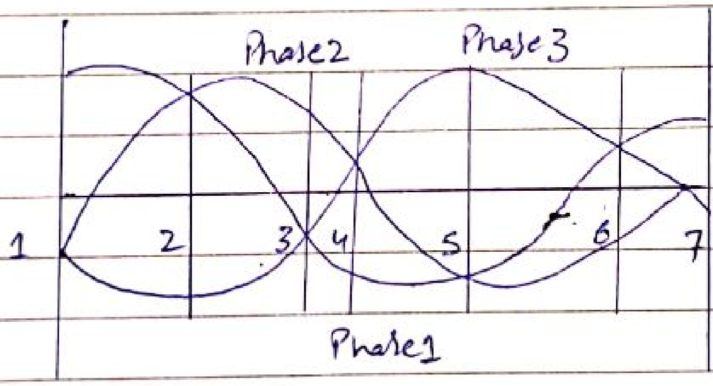
The three Phase input voltage to the stator is shown in the graph of figure . use the left - hand rule for determining the electromagnetic Polarity of the Poles at any given instant. In applying the rule to the coils, consider that current flows toward the terminal numbers for Positive voltages, and away from the terminal numbers for negative voltages.



The results of this analysis are shown for voltages Point 1 through 7. when the three-Phase voltage completes one full cycle, the magnetic field has rotated through 360°.

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Generation of rotating magnetic field (RMF)

When a 3-Phase winding is energized from a 3-Phase supply, a rotating magnetic field is Produced. This field is such that its Poles do no remain in a fixed Position on the stator but go on shifting their Positions around the stator. For this reason, it is called a rotating field. It can be shown that magnitude of this rotating field is constant and is equal to 1.5 ϕm where ϕm is the maximum flux due to any Phase. Consider a three Phase winding displaced in a Space by 120° supplied by three Phase A.C supply. The flux each Phase current is also sinusoidal in nature and all three flux are separated from each other by 120° if the Phase sequence of winding is 1-2-3. then the mathematical equation for the instantaneous values of the fluxes $\phi 1, \phi 2, \phi 3$ can be given as:

$$\phi_1 = \phi m \sin(\omega t) = \phi m \sin\theta$$
$$\phi_2 = \phi m \sin(\omega t - 120°) = \phi m \sin(\theta - 120°)$$
$$\phi_3 = \phi m \sin(\omega t - 240°) = \phi m \sin(\theta - 240°)$$

As windings are indentical and supply is balanced the amplitude of each flux is same i.e ϕm. The wave from three fluxes are shown in figure. Assume Positive direction mean whenever

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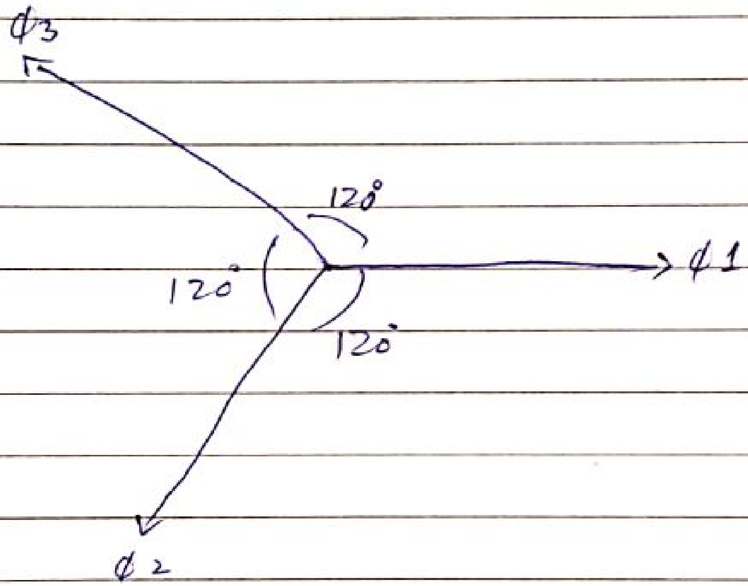
the instantaneous value of flux is Positive vector diagram is must be represented along its assumed Positive direction, and if flux has negative instantaneous value then must be represented in opposite direction to the assumed Positive direction, in vector diagram.



Assumed Positive direction

Let $\phi 1$, ϕ_2 and $\phi 3$ be the instantanteous values of fluxes. The resultant flux ϕT, at any instant is given by Phase combination of ϕ_1, ϕ_2 and ϕ_3 at the instant. let us find out ϕT at four different instant 1, 2, 3 and 4. respectively at $\phi = \omega t = 0°, 60°$; $120°$ and $180°$.

Case 1: when $\phi = 0°$

$\phi_1 = \phi m \sin(\omega t) = \phi m \sin 0° = 0$

$\phi_2 = \phi m \sin(\omega t - 120°) = \phi m \sin(0° - 120°) = -0.866 \phi m$

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$\Phi_3 = \Phi m \sin(\omega t - 240^\circ) = \Phi m \sin(0^\circ - 240^\circ) = 0.866 \Phi m$

$\Phi T = \Phi 1 + \Phi 2 + \Phi 3$

So the magnitude of the resultant flux is 1.5 Φm time the maximum value of flux.

Case 2: Φ = 60°

$\Phi 1 = \Phi m \sin(\omega t) = \Phi m \sin 60^\circ = 0.866 \Phi m$

$\Phi 2 = \Phi m \sin(\omega t - 120^\circ) = \Phi m \sin(60^\circ - 120^\circ) = -0.866 \Phi m$

$\Phi 3 = \Phi m \sin(\omega t - 240^\circ) = \Phi m \sin(60^\circ - 240^\circ) = 0$

$\Phi T = \Phi 1 + \Phi 2 + \Phi 3$

$\Phi T = 2 * 0.866 \Phi m * \cos 30^\circ = 1.5 \Phi m$

So the magnitude of resultant flux is 1.5 Φm time the maximum value of flux.

Case 3: Φ = 120°

$\Phi 1 = \Phi m \sin(\omega t) = \Phi m \sin 120^\circ = 0.866 \Phi m$

$\Phi 2 = \Phi m \sin(\omega t - 120^\circ) = \Phi m \sin(120^\circ - 120^\circ) = 0$

$\Phi 3 = \Phi m \sin(\omega t - 240^\circ) = \Phi m \sin(120^\circ - 240^\circ) = 0.866 \Phi m$

$\Phi T = \Phi 1 + \Phi 2 + \Phi 3$

$\Phi T = 2 * 0.866 \Phi m * \cos 30^\circ = 1.5^\circ$

So the magnitude of resultant flux is 1.5Φm time the maximum value of flux.

Case 4: when Φ = 180°

$\Phi 1 = \Phi m \sin(\omega t) = \Phi m \sin 180^\circ = 0$

$\Phi 2 = \Phi m \sin(\omega t - 120^\circ) = \Phi m \sin(180^\circ - 120^\circ) = 0.866 \Phi m$

$\Phi 3 = \Phi m \sin(\omega t - 240^\circ) = \Phi m \sin(180^\circ - 240^\circ) = -0.866 \Phi m$

$\Phi T = \Phi 1 + \Phi 2 + \Phi 3$, $\Phi T = 2 * 0.866 \Phi m * \cos 30^\circ = 1.5 \Phi m$

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Q No. 3

i- Direct on-Line Starter (DOL)

The Direct on-Line Starter is the simplest and the most inexpensive of all starting methods and is usually used for squirrel cage induction motors. It directly connects the contacts of the motor to the full supply voltage. The starting current is very large, normally 6 to 8 times the rated current. The starting torque is likely to be 0.75 to 2 times the full load torque. In order to avoid excessive voltage drops in the supply line due to high starting currents, the DOL starter is used only for motors with a rating of less than 5Kw. There are safety mechanisms inside the DOL starter which provides protection to the motor as well as the operator of the motor.

The DOL starter consists of a coil operated constactor K1M controlled by start and stop push buttons. On pressing the start push button S1, the contactor coil K1M is energized from line L1. The three mains contacts (1-2), (3-4), and (5-6) are closed. The motor is thus connected to the supply. When the stop push button S2

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is Pressed, the supply through the contactor K1M is disconnected. since the K1M is de-energized, the main contacts (1-2), (3-4), and (5-6) are opened. The supply to motor is disconnected and the motor stops.

ii- Star-Delta Starter

The star delta starting is a very common type of starter and extensively used, compared to the other types of the starters. This method used (to) reduced supply voltage in starting. The method achieved low starting current by first connecting the stator winding in star configuration, and then after the motor reaches a certain speed, throw switch changes the windings arrangements from star to delta configuration. By connecting the stator windings, first in star and then in delta, the line current drawn by the motor at starting is reduced to one-third as compared to starting current with the windings connected in delta. At the time of starting when the stator windings are start connected, each stator phase gets voltage $V_L/\sqrt{3}$, where V_L is the line voltage. Since the torque developed by an induction motor is proportional to square of the applied voltage, star delta starting reduced the starting torque to one-third that obtainable by direct delta starting.

Auto Transformer starter

The operation principle of auto transformer method is similar to the star delta starter method. The starting current is limited by (using a three phase auto transformer) reduce the initial stator applied voltage. The auto transformer starter is more expensive, more complicated in operation and bulkier in construction when compared with the star-delta starter method. But an auto transformer starter is suitable for both star and delta connected motors, and starting current and torque can be adjusted to a desired value by taking the correct tapping from the auto transformer. When the star delta method is considered, voltage can be adjusted only by factor of $1/\sqrt{3}$. brief operation of auto transformer as:

1- operated by a two position switch i.e. manually / automatically using a timer to change over from start to run position.

2- In starting position supply is connected to stator windings through an auto-transformer which reduced applied voltage to 50, 60, and

70% of normal value depending on tapping used.

3- Reduced voltage reduces current in motor winding with 50% tapping used motor current is halved and supply current will be half of motor current. Thus starting current taken from supply will only be 25% of the taken by DOL starter.

4- For an induction motor, torque T is developed by V2, thus on 50% tapping, torque at starting is only $(0.5V)^2$ of the obtained by DOL starting. Hence 25% torque is produced.

5- Starters used in lager industries, it is larger in size and expensive.

6- Switching from start to run positions causing transient current, which can be greater in value than those obtained by DOL starting.

Rotor Impedance Starter

This method allows external resistance to be connected to the rotor through slip rings and brushes. Initially, the rotor resistance is set to maximum and is then gradually decreased as the motor speed increases, untill it becomes zero. The rotor impedence starting mechanism is usually very bulky and expensive when compared with other methods.

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It also has very high maintenance costs. Also, a considerable amount of heat is generated through the resistors when current runs through them. The starting (impedance) frequency is also limited in this method. This will decrease the starting current, increases the starting torque and also improves the power factor.

Date: ....

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Course

Electrical machines (II)

NLT Notes