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THREE PHASE INDUCTION MOTOR SPEED CONTROL: A REVIEW

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Abstract: In case of three phase AC operation, most widely used motor is Three phase induction motor as this type of motor does not require any starting device or we can say they are self-starting induction motors. This paper reviews the concept and methods of the speed control in the three phase motor.
Keyword : Speed Control , Three Phase Induction Motor .

I. INTRODUCTION

These 3 phase motor is provided with 3 three-phase AC supply and is broadly utilized in boats for heavier burdens. 3 phase induction motors are of two kinds, squirrel pen and slip ring motors. Squirrel enclosure motors are broadly utilized on boats because of their rough development and basic plan, few for example of their applications are:[1]

- Lifts
- Cranes
- Large capacity fumes fans
- Engine Auxiliary siphons
- Engine blower fan motor
- Engine room substantial burden siphons – Ballast, Fire, Freshwater, Sea Water and so on.
- Winch motor
- Windlass motor

3 Phase Induction Motor Construction

These three phase motors comprise of a stator and a rotor and between which no electrical association exists. These stator and rotors are developed with the utilization of high-attractive center materials so as to decrease hysteresis and vortex current losses.[2] Stator edge can be developed utilizing cast iron, aluminum or moved steel. Stator edge gives vital mechanical insurance and backing for stator covered center, windings and different courses of action for ventilation. Stator is injured with three-phase windings which are covered with each other at 120 degree phase move fitted into opened covers. The six closures of the three windings are brought out and associated with the terminal box so these windings are energized by three-phase primary supply.[2]

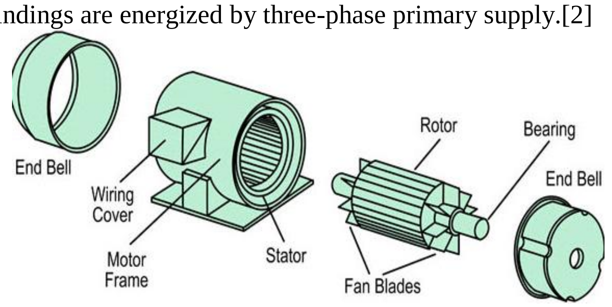

Fig 1. 3 Phase Induction Motor

These windings are of copper wire protected with varnish fitted into protected opened overlays. At all working temperatures, this impregnated varnish stays inflexible. These windings have high-protection opposition and high protection from saline climate, dampness, basic vapor, oil and oil, and so on. Whichever suits the voltage level, these windings are associated in either star or delta associations..

The rotor of three phase AC induction motor is diverse for the slip-ring and squirrel-confine induction motors. Rotor in slip-ring type comprises of overwhelming aluminum or copper bars shorted on the two finishes of the barrel shaped rotor. The pole of the induction motor is upheld on two direction at each closures to guarantee free turning inside the stator and to diminish the grating. It comprises of stack of steel covers equitably spaced openings that are punched around of its boundary into which un-protected substantial aluminum or copper bars are placed.

A slip-ring-type rotor comprises of three-phase windings are inside featured toward one side, and different closures are brought outside and associated with the slip rings mounted on the rotor shaft. What's more, for building up a high-starting torque these windings are associated with rheostat with the assistance of carbon brushes. This outer resistors or rheostat is utilized at the starting time frame as it were. When the motor achieves the typical speed, the brushes are shortcircuited, and the injury rotor functions as squirrel confine rotor.[2]

Stator of three phase induction motor is comprised of quantities of openings to build a 3 phase winding circuit which we interface with 3 phase AC source. We orchestrate the three-phase twisting in such a way in the openings that they produce one pivoting attractive field when we switch on the three-phase AC supply source.

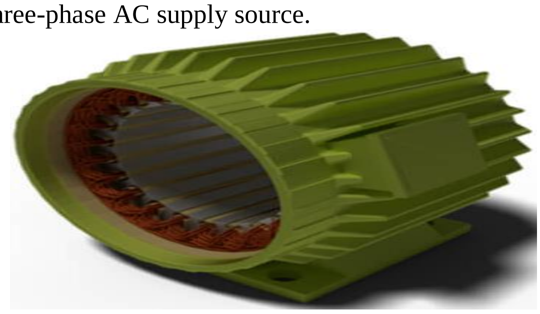

Fig 2 Stator

Rotor of three phase induction motor consists of a Rotor of three phase induction motor comprises of a tube shaped overlaid center with parallel openings that can convey conductors. The channels are substantial copper or aluminum bars fitted in each opening and shortcircuited by the end rings. The spaces are not exactly made parallel to the pivot of the pole however are opened somewhat slanted in light of the fact that this course of action diminishes attractive murmuring commotion and can abstain from slowing down of the motor.[3]

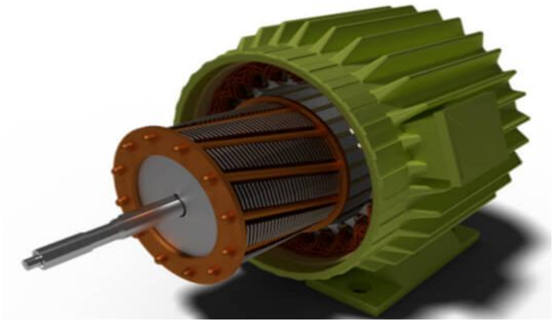

Fig 3 Rotor of three phase induction motor

II. DIFFERENT SPEED CONTROL METHODS

Rotor speed $N_r = \frac{120f}{P}(1-S)$ eq. (1)---------- (1.5)

In this way, the speed of an induction motor relies upon slip 'S', stator frequency 'f' and the quantity of shafts 'P' for which the windings are wound.

From condition 1, the speed of IM can be differed by fluctuating the slip 'S' or number of shafts 'p' or frequency of supply. The various strategies for speed control of induction motor can be extensively grouped in to scalar and vector control techniques. In this work, scalar control techniques are utilized. Thus just subtleties of scalar techniques are talked about here. The clarification of vector control strategy is past the extent of this proposition. The scalar techniques for speed control [6] can be named

- Stator voltage control
- Frequency control
- Stator voltage and frequency control i.e Volts Hertz control
- Rotor voltage control
- The first three methods are the basic methods of speed control and are explained in detail as follows:

2.1 Stator voltage control method

An exceptionally straightforward and practical technique for speed control is to differ the stator voltage at steady supply frequency. The three-phase stator voltage at line frequency can be controlled by controlling the switches in the inverter. As observed from the condition the created torque is corresponding to the square of the stator supply voltage and a decrease in stator voltage will deliver a decrease in speed.

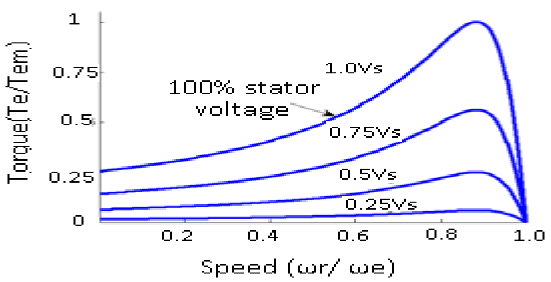

Fig.4 Speed-Torque characteristics with variable stator voltage

The notable highlights of stator voltage control strategy are:

- For low-slip motor, the speed range is low.
- Not appropriate for steady torque load.
- Poor power factor.
- Utilized essentially in low power applications, for example, fans, blowers, divergent siphons, and so on.

2.2 Frequency control method

The torque and speed of induction motors can be controlled by changing the supply frequency however keeping the voltage consistent. On the off chance that the frequency is diminished keeping voltage consistent, at that point immersion of air-hole flux happens.

At low frequency, the reactance will diminish and the motor current might be excessively high. On the off chance that the frequency is expanded over its evaluated worth, at that point the air hole flux and rotor current reductions correspondingly, the created torque likewise diminishes. Because of these reasons this technique for control is seldom utilized.

The torque speed characteristics with frequency control [7] are shown in Fig.5.

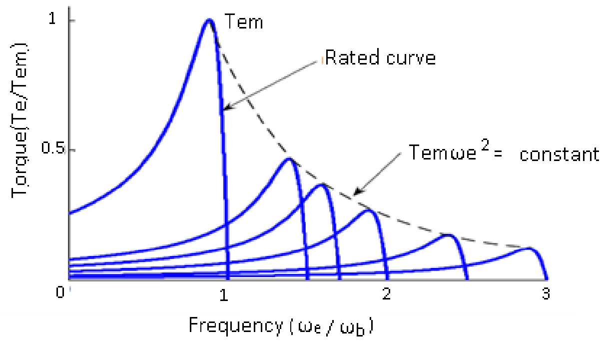

Fig. 5 Speed-Torque characteristics with variable frequency control

2.3 Volts Hertz (V/F) control method

The consistent V/F control technique is the most famous strategy for Scalar control. In the event that an endeavor is made to lessen the supply frequency at the evaluated supply voltage, the air hole flux Ψm will in general soak, causing inordinate stator current and twisting of flux wave.

In this manner, the area underneath the base or evaluated frequency ought to be accompanied by the relative decrease of stator voltage in order to keep up the air hole flux steady. On the off chance that the proportion of voltage to frequency is kept steady, the flux stays consistent. By shifting the voltage and frequency the torque and speed can be changed. The torque is typically kept up steady while the speed is differed. This plan is generally utilized in the trains and mechanical applications. The motivation behind the volts hertz control plan is to keep up the air-hole flux of AC Induction motor consistent so as to achieve higher run-time productivity.

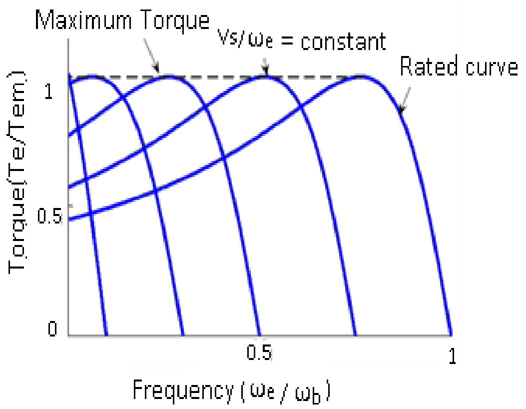

Fig.6 Speed-Torque curves with constant V/F ratio

In induction motor is practically a consistent speed motor, that implies, for the whole stacking extent, change in speed of the motor is very little. Speed of a DC shunt motor can be fluctuated in all respects effectively with great effectiveness, however in the event of Induction motors, speed decrease is accompanied by a comparing loss of productivity and poor power factor. As induction motors are broadly being utilized, their speed control might be required in numerous applications. Diverse speed control techniques for induction motor are clarified beneath.

Induction motor speed control from stator side
1. By changing the connected voltage:
From the torque condition of induction motor,
Rotor opposition R2 is steady and on the off chance that slip s is little, at that point (sX2)2 is small to the point that it very well may be disregarded. Consequently, T ∝ sE22 where E2 is rotor incited emf and E2 ∝ V

Consequently, T ∝ sV2, which implies, whenever provided voltage is diminished, the created torque diminishes. Henceforth, for giving a similar burden torque, the slip increments with abatement in voltage, and subsequently, the speed diminishes. This technique is the most effortless least expensive, still once in a while utilized, on the grounds that
1. large change in supply voltage is required for generally little change in speed.
2. large change in supply voltage will result in an enormous change in flux thickness, henceforth, this will bother the attractive states of the motor.
3. By changing the connected frequency
Synchronous speed of the turning attractive field of an induction motor is given by,
where, f = frequency of the supply and P = number of stator posts.
Thus, the synchronous speed changes with change in supply frequency. Actual speed of an induction motor is given as N = Ns (1 - s). Nonetheless, this technique isn't generally utilized. It might be utilized where, the induction motor is provided by a committed generator (with the goal that frequency can be effectively fluctuated by changing the speed of prime mover).

Likewise, at lower frequency, the motor current may turn out to be excessively high because of diminished reactance. Furthermore, if the frequency is expanded past the appraised worth, the most extreme torque created falls while the speed rises.

Consistent V/F control of induction motor
This is the most well known technique for controlling the speed of an induction motor. As in above strategy, if the supply frequency is decreased keeping the evaluated supply voltage, the air hole flux will in general immerse. This will cause over the top stator current and bending of the stator flux wave. Along these lines, the stator voltage ought to likewise be decreased in relative to the frequency in order to keep up the air-hole flux consistent. The greatness of the stator flux is corresponding to the proportion of the stator voltage and the frequency. Subsequently, if the proportion of voltage to frequency is kept consistent, the flux stays steady. Additionally, by keeping V/F consistent, the created torque remains roughly steady. This technique gives higher run-time productivity. In this manner, dominant part of AC speed drives utilize steady V/F technique (or variable voltage, variable frequency strategy) for the speed control. Alongside wide scope of speed control, this technique likewise offers 'delicate begin' capacity.

4. Changing the quantity of stator posts
From the above condition of synchronous speed, it very well may be seen that synchronous speed (and thus, running speed) can be changed by changing the quantity of stator shafts. This strategy is commonly utilized for squirrel confine induction motors, as squirrel confine rotor adjusts for any number of stator posts. Change in stator shafts is achieved by at least two free stator windings twisted for various number of posts in same openings.

For instance, a stator is twisted with two 3phase windings, one for 4 posts and other for 6 shafts. for supply frequency of 50 Hz

I) synchronous speed when 4 post winding is associated, Ns = 120*50/4 = 1500 RPM

ii) synchronous speed when 6 shaft winding is associated, Ns = 120*50/6 = 1000 RPM

Speed control from rotor side:

1. Rotor rheostat control
This strategy is like that of armature rheostat control of DC shunt motor. However, this technique is just relevant to slip ring motors, as expansion of outer opposition in the rotor of squirrel enclosure motors is preposterous.

2. Cascade operation
In this strategy for speed control, two motors are utilized. Both are mounted on an equivalent shaft with the goal that both keep running at same speed. One motor is fed from a 3phase supply.

Motor An is known as the primary motor and motor B is known as the helper motor.
Let, Ns1 = frequency of motor A
Ns2 = frequency of motor B
P1 = number of shafts stator of motor A
P2 = number of stator shafts of motor B
N = speed of the set and same for the two motors
f = frequency of the supply
Presently, slip of motor A, S1 = (Ns1 - N)/Ns1.frequency of the rotor initiated emf in motor A, f1 = S1f

Presently, helper motor B is provided with the rotor incite emf in this manner, Ns2 = (120f1)/P2 = (120S1f)/P2.
Presently putting the estimation of S1 = (Ns1 - N)/Ns1
At no heap, speed of the helper rotor is practically same as its synchronous speed.
for example N = Ns2.
from the above conditions, it tends to be acquired that
With this technique, four distinct speeds can be acquired

1. at the point when just motor A works, comparing speed = .Ns1 = 120f/P1

2. at the point when just motor B works, comparing speed = Ns2 = 120f/P2

3. in the event that commulative falling is done, speed of the set = N = 120f/(P1 + P2)

4. in the event that differential falling is done, speed of the set = N = 120f (P1 - P2)

3. By infusing EMF in rotor circuit
In this strategy, speed of an induction motor is controlled by infusing a voltage in rotor circuit. It is essential that voltage (emf) being infused must have same frequency as of the slip frequency. Notwithstanding, there is no confinement to the phase of infused emf. In the event that we infuse emf which is in inverse phase with the rotor incited emf, rotor opposition will be expanded. On the off chance that we infuse emf which is in phase with the rotor initiated emf, rotor opposition will diminish. Along these lines, by changing the phase of infused emf, speed can be controlled. The principle favorable position of this technique is a wide fierceness of speed control (better than average just as underneath typical) can be achieved. The emf can be infused by different techniques, for example, Kramer framework, Scherbius framework and so forth.

III. CONCLUSION

This paper reviews the concept of the 3 phase induction motor and also discuss in bried regarding the various methods of its speed control methods which are used for controlling the speed of the 3 phase motor.

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