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ASSIGNMENT I

**Question1**

1a) - A solitary stage acceptance engine doesn't have a self-beginning torque

- During light burden conditions, the force factor of the heap drops to a low worth

- The speed control of an enlistment engine is difficult to accomplish.

- Due to poor turning over torque the engine can't be utilized for applications which requires high beginning torque.

1b) According to double field revolving theory, we can resolve any alternating quantity into two components. Each component has a magnitude equal to the half of the maximum magnitude of the alternating quantity, and both these components rotate in the opposite direction to each other. For example – a flux, φ can be resolved into two components

each of these components rotates in the opposite direction i. e if one φm/2 is rotating in a clockwise direction then the other φm / 2 rotates in an anticlockwise direction.

When we apply a single phase AC supply to the stator winding of single phase induction motor, it produces its flux of magnitude, φm. According to the double field revolving theory, this alternating flux, φm is divided into two components of magnitude φm/2. Each of these components will rotate in the opposite direction, with the synchronous speed, Ns.

Let us call these two components of flux as forwarding component of flux, φf and the backward component of flux, φb. The resultant of these two components of flux at any instant of time gives the value of instantaneous stator flux at that particular instant.


Now at starting condition, both the forward and backward components of flux are exactly opposite to each other. Also, both of these components of flux are equal in magnitude. So, they cancel each other and hence the net torque experienced by the rotor at the starting condition is zero. So, the **single phase induction motors** are not self-starting motors.

1c) **Constructional features of a single phase IM**

 All the single stage enlistment engine share one development include for all intents and purpose, viz, the helper beginning winding. The beginning winding is given so that, together with the principle or working winding, the engine can animate a two stage engine to create torque at start. On account of the perpetual capacitor the assistant twisting stays in the circuit in the wake of beginning and in this way intently approximates a two-stage engine likewise when it is working under burden. Thus the term 'split stage' may appropriately be applied to all the single stage enlistment engines

  **Principle of operation single phase induction motor**

Under fixed rotor conditions (i.e, when speed N = 0 or slip s = 1), the two pivoting fields slip pass the rotor at a similar slip, s = 1 and prompting equivalent flows in the squirrel confine rotor. The two pivoting fields are of a similar quality and create equivalent and inverse electro-attractive torques bringing about net torque of zero worth. In this way the beginning torque is zero and the single stage acceptance engine is non-self-beginning. Further, the two pivoting fields initiate a resultant EMF in the stator which adjusts the applied voltage accepting low spillage impedance of the stator winding.

1d) **Torque Slip Characteristics of Single Phase Induction Motor**


From the figure, we see that at a slip of solidarity, both forward and in reverse field creates equivalent torque however the course of which are inverse to one another so the net torque delivered is zero thus the engine neglects to begin. From here we can say that these engines are not self-beginning dissimilar to the instance of three stage acceptance engine. There must be a few way to give the beginning torque. In the event that by certain methods, we can speed up the machine because of which the forward slip diminishes the forward torque will increment and the converse torque will diminish because of which engine will turn over.

From here we can presume that for beginning of single stage acceptance engine, there ought to be a creation of contrast of torque between the forward and in reverse field. On the off chance that the forward field torque is bigger than the retrogressive field than the engine pivots in forward or against clockwise course. In the event that the torque because of in reverse field is bigger contrasted with other, at that point the engine turns in reverse or clockwise heading. They are not self-beginning on the grounds that in acceptance machine a pivoting attractive field is required to deliver torque. A pivoting attractive field can delivered in the event that we have adjusted three stage supply and each stage is electrically divided 120 to one another OR we have required least two stage yet in single stage acceptance engine there is single stage supply to the stator of engine. A solitary stage supply can't deliver a pivoting attractive field yet it produce a throbbing attractive field which doesn't turn. Because of this throbbing attractive field torque can't deliver so engine isn't self-start.

1e) - Split phase induction motor.

* Capacitor start induction motor
* Capacitor start capacitor run induction motor
* Permanent split capacitor motor
* Shaded pole induction motor

## Shaded Pole Single Phase Induction Motors


The stator of the concealed post single stage enlistment engine has striking or anticipated shafts. These shafts are concealed by copper band or ring which is inductive in nature. The posts are separated into two inconsistent parts. The littler segment conveys the copper band and is called as concealed part of the post.

Activity: When a solitary stage supply is given to the stator of concealed shaft acceptance engine an exchanging motion is created. This difference in motion actuates emf in the concealed curl. Since this concealed bit is shortcircuited, the current is created in it in such a course to contradict the primary transition. The transition in concealed shaft lingers behind the motion in the unshaded post. The stage distinction between these two motions produces resultant turning motion.

We realize that the stator winding current is rotating in nature as is the transition delivered by the stator current. So as to unmistakably comprehend the working of concealed shaft enlistment engine think about three locales

When the flux changes its value from zero to nearly maximum positive value.

* + 1. When the flux remains almost constant at its maximum value.
		2. When the flux decreases from maximum positive value to zero.

1stREGION:
When the flux changes its value from zero to nearly maximum positive value –

In this region, the rate of rise of flux and hence current is very high. According to [Faraday’s law](https://www.electrical4u.com/faraday-law-of-electromagnetic-induction/) whenever there is change in flux emf gets induced. Since the copper band is short circuited the current starts flowing in the copper band due to this induced emf. This current in copper band produces its own flux. Now according to [Lenz’s law](https://www.electrical4u.com/lenz-law-of-electromagnetic-induction/) the direction of this current in copper band is such that it opposes its own cause i.e rise in current. So the shaded ring flux opposes the main flux, which leads to the crowding of flux in the unshaded part of stator and the flux weaken in shaded part. This non uniform distribution of flux causes magnetic axis to shift in the middle of the unshaded part.

2ndREGION:
When the flux remains almost constant at its maximum value-

In this region, the rate of rise of current and hence flux remains almost constant. Hence there is very little induced emf in the shaded portion. The flux produced by this induced emf has no effect on the main flux and hence distribution of flux remains uniform and the magnetic axis lies at the center of the pole.

3rdREGION:
When the flux decreases from maximum positive value to zero –

 In this region, the rate of decrease in the flux and hence current is very high. According to [Faraday’s law](https://www.electrical4u.com/faraday-law-of-electromagnetic-induction/) whenever there is change in flux emf gets induced. Since the copper band is short circuit the current starts flowing in the copper band due to this induced emf. This current in copper band produces its own flux. Now according to [Lenz’s law](https://www.electrical4u.com/lenz-law-of-electromagnetic-induction/) the direction of the current in copper band is such that it opposes its own cause i.e decrease in current. So the shaded ring flux aids the main flux, which leads to the crowding of flux in shaded part of stator and the flux weaken in unshaded part. This non uniform distribution of flux causes magnetic axis to shift in the middle of the shaded part of the pole.This shifting of magnetic axis continues for negative cycle also and leads to the production of rotating magnetic field. The direction of this field is from unshaded part of the pole to the shaded part of the pole.

**Split Phase Induction Motor**

In addition to the main winding or running winding, the stator of single phase induction motor carries another winding called auxiliary winding or starting winding. A centrifugal switch is connected in series with auxiliary winding. The purpose of this switch is to disconnect the auxiliary winding from the main circuit when the motor attains a speed up to 75 to 80% of the synchronous speed. We know that the running winding is inductive in nature. Our aim is to create the phase difference between the two winding and this is possible if the starting winding carries high [resistance](https://www.electrical4u.com/electrical-resistance-and-laws-of-resistance/). Let us say

Irun is the [current](https://www.electrical4u.com/electric-current-and-theory-of-electricity/) flowing through the main or running winding,
Istart is the current flowing in starting winding,
and VT is the supply voltage.


We know that for highly resistive winding the current is almost in phase with the [voltage](https://www.electrical4u.com/voltage-or-electric-potential-difference/) and for highly inductive winding the current lag behind the voltage by large angle. The starting winding is highly resistive so, the current flowing in the starting winding lags behind the applied voltage by very small angle and the running winding is highly inductive in nature so, the current flowing in running winding lags behind applied voltage by large angle. The resultant of these two current is IT. The resultant of these two current produce rotating [magnetic field](https://www.electrical4u.com/what-is-magnetic-field/) which rotates in one direction. In **split phase induction motor** the starting and main current get split from each other by some angle so this motor got its name as split phase induction motor.

1f) Under stationary rotor conditions (i.e, when speed N = 0 or slip s = 1), the two rotating fields slip pass the rotor at the same slip, s = 1 and inducing equal currents in the squirrel cage rotor. The two rotating fields are of the same strength and develop equal and opposite electro-magnetic torques resulting in net torque of zero value. Thus the starting torque is zero and the single phase induction motor is non- self-starting. Further, the two rotating fields induce a resultant EMF in the stator which balances the applied voltage assuming low leakage impedance of the stator winding.

**QUESTION 2**

2a) A universal motor is a special type of motor which is designed to run on either DC or single phase AC supply . It can be applied in the following areas

* Hair dryers
* Wind trimmers
* Blenders
* Drills
* Vacuum cleaners

### 2b) Construction of Universal Motor:

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.

#### Non-Compensated Universal Motor:

The Non-compensated motor has two salient poles and it is laminated as shown in figure below.



The armature is of wound type and the laminated core is either straight or skewed slots. The leads of the armature winding are connected to the commutator. High resistance brushes are used along with this type of motor to help better commutation. An equivalent Non-compensated type Universal Motor is shown in figure below.



#### Compensated Type with Distributed Field:

The compensated type Universal Motor consists of distributed field winding and the stator core is similar to that of split-phase motor. We know that split phase motors consist of an auxiliary winding in addition to main winding. Similar to the split phase motors, the compensated type also consists of an additional winding. The compensating winding helps in reducing the reactance voltage which is caused due to alternating flux, when the motor runs with the AC supply.

 

An equivalent compensated type universal motor is shown above

2c) There is actually no difference between the two in reference to their additional features. A universal motor has its rotor and stator windings connected in series, and it can run on both AC and DC that is why it’s called universal, or sometimes a DC series motor. It is usually used in home appliances, electric tools and so on. Because it has a high speed.

**QUESTION 3**

### 3a) Principle of Operation of 3-Phase Induction Motor

The stator of the engine comprises of covering twisting counterbalance by an electrical edge of 120 . At the point when we associate the essential winding, or the stator to a 3 stage AC source, it builds up turning attractive ﬁeld which pivots at the synchronous speed. Insider facts Behind the Rotation: According to Faraday's law an emf instigated in any circuit is because of the pace of progress of attractive ﬂux linkage through the circuit. As the rotor twisting in an enlistment engine are either shut through an outer obstruction or straightforwardly shorted by end ring, and cut the stator turning attractive ﬁeld, an emf is instigated in the rotor copper bar and because of this emf a current ﬂows through the rotor conduit.

Here the relative speed between the turning ﬂux and static rotor conductor is the reason for current age; subsequently according to Lenz's law, the rotor will pivot a similar way to lessen the reason, i.e., the relative speed.

Along these lines from the working standard of three stage enlistment engine, it might be seen that the rotor speed ought not arrive at the synchronous speed created by the stator. On the off chance that the paces become equivalent, there would be no such relative speed, so no emf prompted in the rotor, and no current would be ﬂowing, and subsequently no torque would be produced. Subsequently, the rotor can't arrive at the synchronous speed. The contrast between the stator (synchronous speed) and rotor speeds is known as the slip. The revolution of the attractive ﬁeld in an acceptance engine has the bit of leeway that no electrical associations should be made to the rotor.

3b) Advantages

* Power delivered is constant
* They are self starting and more efficient
* They have a higher power factor

 Disadvantages

* Unbalanced loading ( can cause voltage fluctuations )
* Complex System (requires symmetrical components for analysis and operation )
* Phase Sequenceneeded to be kept in mind while making connections
* Poor starting torque

3c) The equivalent motor resistance referred to stator =

 R01= = 0.06+0.06 = 0.12Ω.

The equivalent motor reactance referred to stator,

X01 = = 0.2+0.22 = 0.42Ω

Motor impedance

Z01 = = = 0.437Ω.

s =
=
= 0.12

Maximum gross power output

=
=

= 143,626w or 143.63kw

3d)



Thus, at low values of slip, torque is approximately proportional to slip s and the torque slip characteristics of induction motor is a straight line as shown in the figure. The region (from s = 0 to s = sm) is called the stable region of operation and operating point of the motor should be in this region. In the stable region, the value of slip is small. Hence this region is also called as the low slip region.



As the slip increases torque increases and attains its maximum value when s = R2/X2. This maximum value of torque is also known as break down or pull out torque. When a further increase in slip occurs due to increase in load beyond the point maximum torque

Thus at higher values of slip (i.e. the slip beyond that corresponding to maximum torque) torque is approximately inversely proportional to slip, s and the torque slip characteristics of induction motor is rectangular hyperbola as shown in the figure. The region (extending from s = sm to s = 1) is called unstable region. In this region with the increase in load, slip increases but torque decreases. The result is that the motor could not pick up the load and slows down and eventually stops. In the unstable region, the value of slip is large so this region is also called as the high-slip region.

3e)

20 Rps = rpm = 20 x 60 = 1200rpm

15rps = rpm = 15 x 60 = 900 rpm

Ns =

=

F’= sf

F’= 0.25 x 60 = 15Hz

Ns-Nr = 1200 -900 = 300

F’= SF

0.1 X 60 = 6Hz

**Question 4**

* 4a) – Changing the number of stator poles
* By injecting emf in rotor circuit
* Changing the applied voltage
* Changing the applied frequency
* Constant v/f control of induction motor

4b)

* Direct On-Line Starter (DOL)
* Rotor resistance starting
* Stator resistance starting
* Star Delta starting

4c) STATOR RESISTANCE STARTING

 In this method, external resistances are connected in series with each phase of stator winding during starting. This causes voltage drop across the resistances so that voltage available across motor terminals is reduced and hence the starting current. The starting resistances are gradually cut out in steps (two or more steps) from the stator circuit as the motor picks up speed. When the motor attains rated speed, the resistances are completely cut out and full line voltage is applied to the rotor. This method suffers from two drawbacks. First, the reduced voltage applied to the motor during the starting period lowers the starting torque and hence increases the accelerating time. Secondly, a lot of power is wasted in the starting resistances. Thus while the starting current reduces by a fraction x of the rated-voltage starting current (Isc), the starting torque is reduced by a fraction x2 of that obtained by direct switching. The reduced voltage applied to the motor during the starting period lowers the starting current but at the same time increases the accelerating time because of the reduced value of the starting torque. Therefore, this method is used for starting small motors only.

DIRECT ON-LINE STARTER

This method of starting in just what the name implies; the motor is started by connecting it directly to 3-phase supply. The impedance of the motor at standstill is relatively low and when it is directly connected to the supply system, the starting current will be high (4 to 10 times the full-load current) and at a low power factor. Consequently, this method of starting is suitable for relatively small (up to 7.5 kW) machines. Note that starting current is as large as ﬁve times the full-load current but starting torque is just equal to the full-load torque. Therefore, starting current is very high and the starting torque is comparatively low. If this large starting current ﬂows for a long time, it may overheat the motor and damage the insulation.

**QUESTION 5**

5a) There could be many reasons to test an induction motor.

* To find out if it works.
* To test for reliability
* To see how much performance margin it has
* . To see if it works according to its specifications

5b) **SIMILARITIES**

* In the slip ring motor, the rotor winding is short circuited through the slip rings.
* the shaft of the motor is locked so that it can’t move and the rotor winding is short circuited.

**DIFFERENCES**

* in a short circuit test as the motor is no load the power factor is very low whch is less than 0.5 while the block rotor test is conducted at low voltage because if the applied voltage was normal voltage then the current flowing through the stator windings were high enough to overheat the windings and damage them
* in a blocked rotor test the rotor is blocked so that it can’t move, a voltage is applied to the motor, and the resulting voltage, current and power are measured while in a short circuit test the test is performed at a rated frequency and with balanced polyphase voltages applied to the stator terminal

5c) **SIMILARITIES**

* The open circuit and no load test are performed for determining the parameter of the transformer like their efficiency, voltage regulation, circuit constant
* Open circuit test or no load test on a transformer is performed to determine 'no load loss (core loss)' and 'no load current

**DIFFERENCES**

* A open circuit test is conducted when the secondary of the transformer is kept in open condition without connecting any load with it. Thus there will not be any current in the secondary coil. While A no load test is conducted shorting the secondary terminals. Thus there will be huge current flow in the secondary coil when voltage is applied in the primary.
* The purpose of the open circuit test is to determine the no-load current and losses of the transformer because of which their no-load parameter are determined. While the no load test determines the copper loss occur on the full load. The copper loss is used for finding the efficiency of the transformer.
* 5d) Ac motor winding continuity test
* power supply test
* Insulation resistance test
* Ac motor winding resistance test

**Power Supply Test**

For three phase motors, the expected voltage for a 230/400V system is 230V phase to neutral and 400V between each of the three phase supply lines. Check that the correct voltage is applied to the motor using a multimeter. Ensure the terminal for power supply is in good condition. Check the connection bar for terminal (U, V, and W). three phase motors, connection type is either Star (Y) or Delta.

5d)Applied Voltage per phase, V= 400V, No load line current=3A

No load phase current=3/√3= √3A, Input on no load= 645W

Stator copper loss=45W, windage and friction loss=183W

Total stator core loss= 645-45-183=417W

No load p.f, cosᶲ==0.2

No load line current on energy=

Magnetizing component of no load line current,

Energy component or no load phase current,

No load resistance,

No load phase current,

No load reactance,

Short Circuit Voltage=200V, short circuit stator line current=12.0A

Short Circuit stator phase current=6.928A, Input on short circuit= 1660W

Equivalent resistance per phase as referred to the primary,

Equivalent reactance per phase as referred to the primary,

Power factor on short circuit,

Short Circuit current with normal voltage applied of 400 V across the stator,

**Question 6**

6a) The principle of operation of synchronous generator is electromagnetic induction. If there exists a relative between the flux and conductors, then an emf is induced in the conductors. If the rectangular turn rotates in clockwise direction against axis a-b as shown in the below completing 90 degrees rotation the conductor sides AB and CD comes in front of the respectively. Thus, now we can say that the conductor tangential motion is perpendicular to from north to south pole. So, here rate of flux cutting by the conductor is maximum and induces current in the conductor, the induced current can be determined using Fleming’s right hand rule. Thus, we can say that from A to B and from C to D. If the conductor is rotated in a clockwise direction for another 90 come to a vertical position. Now, the position of conductor and magnetic flux lines are parallel to each other and thus, no flux is cutting and no current will be induced in the conductor. Then, while the conductor rotates clockwise for another 90 degrees, then rectangular turn comes to a horizontal position as shown in the below fig conductors AB and CD are under the N-pole and S-pole respectively. By applying Fleming current induces in conductor AB from point B to A and current induces in a conductor CD from. So, the direction of current can be indicated as A – D – C – B and direction of current for the position of rectangular turn is A – B – C – D. If the turn is again rotated towards vertical position, then the induced current again reduces to zero. Thus, for one complete revolution of rectangular turn the current in the conductor reaches to maximum & reduces to zero and then in the opposite direction it reaches to maxim to zero. Hence, one complete revolution of rectangular turn produces one full sine wave of cu conductor which can be termed as the generation of alternating current by rotating a turn inside a magnetic field. Now, if we consider a practical synchronous generator, then field magnets rotate between the stationary armature conductors. The synchronous generator rotor and shaft or turbine blades are mechanically coupled and rotates at synchronous speed. Thus, the magnetic flux cutting produces an induced emf which causes the current flow in armature conductors. Thus, for each winding the current flows in one direction for the first half cycle and current flows in the other direction for the second half cycle with a time lag of 12 displaced by 120 degrees).

6b)S/MVA rating=10MVA,, p.f=0.8, , f=50Hz, number of poles=2

Induced emf is given as;

So;

Recall;

Hence,

ii.) maximum power,

iii.) Maximum torque,

6c) Parallel operation of generators is by far the most common form of operation. Generators may be operated in parallel on a small scale, e.g. two or three generators operating in parallel to provide power to a remote community, or large scale, e.g. the north american power grid

Benefits of parallel operation include

1. Redundancy: failure of one unit does not affect the integrity of the power supply, generators may be taken out of service for preventative maintenance
2. Scaling: many units can combine to provide a power demand, rather than requiring fewer very large generators
3. Resource management: generators can be located and operated to best meet the generating conditions, instead of having to be located and operated to meet the requirements of a local load. An example of this may be a nuclear power plant, which may take many weeks to bring up to full operating conditions. Using a nuclear generating station at full power to meet a "base load" with smaller more rapid response generators is one way to supply fluctuating load requirements.
4. Efficiency: Generators operating at full load are more efficient than those operating at low loads. It is more efficient to meet a changing load by adding or removing smaller generators than having a single large generator operating inefficiently.