Squirrel Cage Induction Motors

SECTION A

In the following statements one of the suggested answers is best. Place the identifying letter on your answer sheet.

1. The rotor current in a three phase induction motor is:-

   a) zero, since no supply is connected to the rotor circuit;

   b) supplied by the d.c. connected to the rotor terminals;

   c) supplied by the a.c. connected to the rotor terminals;

   d) induced by the stator field cutting the rotor conductors.

2. A three phase winding will produce an electromagnetic field which:-

   a) rotates at a constant speed;

   b) reverses direction each cycle;

   c) reverses direction each half cycle;

   d) is stationary and constant in strength.

3. Increasing the frequency of supply to a three phase stator winding will:-

   a) cause the magnetic field to rotate faster;

   b) cause the magnetic field to rotate slower;

   c) increase the strength of the magnetic field;

   d) increase the number of poles in the stator winding.

4. To reverse the direction of rotation of a rotating magnetic field you must:-

   a) reverse the connections to alternate pole windings;

   b) reverse the phase sequence of the supply;

   c) reverse the connections to the rotor winding;

   d) reverse the connections to all pole windings.

5. The rotor current in an induction motor is:-

   a) supplied from the separate rotor supply;

   b) induced by the rotating magnetic field;

   c) supplied from the stator supply terminals;

   d) always the same frequency as the stator supply.

6. The rotor speed of an induction motor is:-

a) always slightly higher than the speed of the rotating magnetic field;

b) always slightly lower than the speed of the rotating magnetic field;

c) always the same as the speed of the rotating magnetic field;

d) dependant only on the size of the load the motor is driving.

7. A six pole three phase motor on a 50 hertz supply will have a rated speed of about:-

a) 2,800 r.p.m.;

b) 1440 r.p.m.;

c) 960 r.p.m.;

d) 720 r.p.m.

8. The motor in question 7 will have a slip speed of:-

a) 200 r.p.m.;

b) 60 r.p.m.;

c) 40 r.p.m.;

a) 30 r.p.m.

9. When a three phase motor is running on no load and one supply conductor is open circuited:-

a) the motor will stop and then start in the opposite direction;

b) the motor will continue to run in the same direction;

c) the motor will overload and burn out;

d) the motor will stop due to loss of the RMF.

10. When a three phase motor is started with one supply conductor open circuited it will:-

a) start and run normally;

b) not start and may burn out;

c) not start, but not burn out;

d) start, but the direction of rotation will be random.

It is called Single Phasing. Since one of the phases is now disconnected, current through other two phases will increase to produce the desired torque. The motor will run but would not be able to drive rated load. The uneven torque results in abnormal noise and vibration in motor. 17 Mar 2014

SECTION B

Blank spaces in the following statements represent omissions. Write the appropriate information on your answer sheet.

As load on an induction motor increases the speed of the motor will______(1)_____ and the slip speed of the motor will_____(2)_____.

Decrease, increase

The speed of the rotating magnetic field in a three phase induction motor depends on the number of poles in the winding and the______(3)_____.

Frequency

The strength of the rotating magnetic field in a three phase induction motor is equal to _____(4)_____times the______(5)_____flux produce in one of the phase windings.

Three , magnetic

The direction that a three phase induction motor rotates depends on the_____(6)_____ of the supply currents.

Frequency

When an induction motor is driving a load the speed of the motor cannot reach_____(7)_____.

Synchronous speed

If the windings in a three phase induction motor are connected in delta the current in the conductors supplying the motor would be______(8)_____the current in the motor windings.

1.7321 times

The stator core of a three phase induction motor is laminated to reduce_____(9)_____ loss and the laminations are made from silicon steel to reduce______(10)_____loss.

Eddy current , iron

The stator winding of a three phase induction motor consists of_____(11)_____ identical winding displaced by_____(12)_____degrees from each other.

Three , 120 electrical

The______(13)_____induction motor has a short circuited rotor winding.

Squirrel cage

To change the direction of a three phase induction motor the connections to any two of the______(14)_____must be changed.

Three terminals

Either the rotor slots or the stator slots are______(15)_____to reduce the noise from a three phase induction motor.

Skew

When running on no load the speed of a three phase induction motor is _____(16)_____synchronous speed.

near

SECTION C

SEE TEACHER SOLUTION

1. A six pole three phase induction motor is connected to a 60Hz supply and runs at full load at 1050r.p.m. Determine:-

a) the synchronous speed of the motor; (1 200 r.p.m.)

b) the slip speed of the motor. (150 r.p.m.)

SECTION D

1. Figure 1 represents the stator windings of a three phase induction motor and it's terminal block:-

   a) Connect the windings to the terminal block using the international standard;

   b) Connect the terminals of the terminal block so that the motor windings are connected in delta;

   c) Connect the terminal block to the supply terminals.

   d) Connect the terminal block of Figure 2 to the supply terminals so that the direction of rotation of the motor in Figure 1 is reversed.

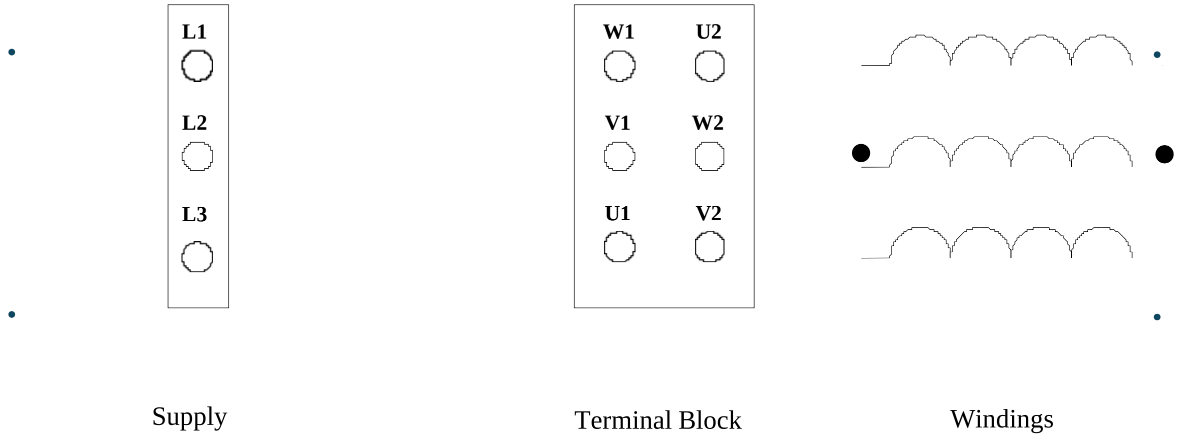


Figure 1.

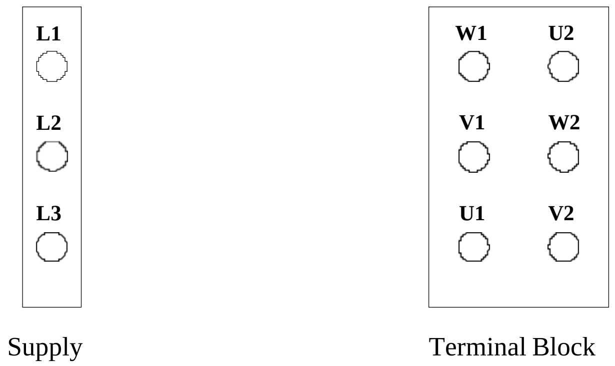


Figure 2.

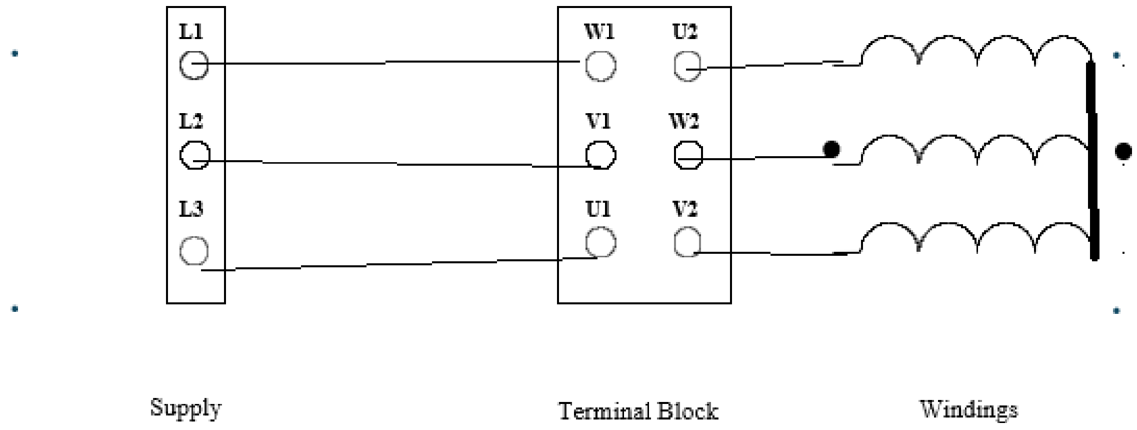
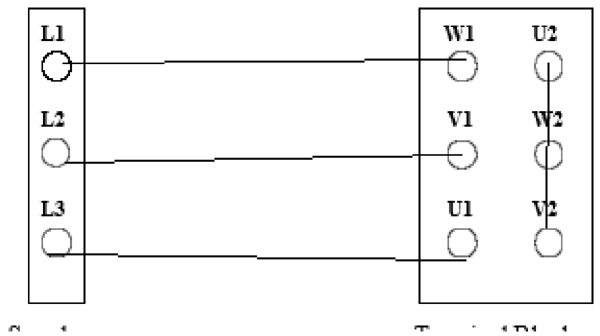


Figure 1.



Tutorial 8 NAME:

SLIP-RING INDUCTION MOTORS

SECTION A

In the following statements one of the suggested answers is best. Place the identifying letter on your answer sheet.

1. An advantage of wound rotor induction motors is:-
   a) high starting current and torque;
   b) low starting torque with low current;
   c) low starting current and high starting torque;
   d) high starting current and low starting torque.

2. The rotor and stator windings of a slip ring induction motor must have the same:-
   a) number of phases;
   b) number of poles;
   c) number of poles and phases;

d) connection method (star or delta).

3. The rotor windings of a slip ring induction motor are connected to an external:-

   a) source of a.c. supply;
   b) source of d.c. supply;
   c) variable resistance;
   d) star delta starter.

4. The rotor and stator windings of a slip ring induction motor are normally connected:-

   a) rotor in star and stator in delta;
   b) rotor in delta and stator in delta;
   c) rotor in star and stator in star;
   d) rotor in delta and stator in star.

5. The rotor current in a slip ring induction motor:-

   a) is constant at all loads;
   b) increases as load increases;
   c) decreases as load increases;
   d) varies independent of load.

6. Resistance is added to the rotor circuit of a slip induction motor to:-
   a) increase torque at lower speeds;
   b) reduce current during starting;
   c) reduce the speed of the motor;
   d) all of the above.

7. An eight pole, 50 hertz slip ring induction motor running at 720r.p.m. with the slip rings short circuited has a slip percent of:-
   a) 60%;
   b) 15%;
   c) 6%;
   d) 4%.

8. The motor in question 7 will have a slip speed of:-
   a) 780 r.p.m.;
   b) 280 r.p.m.;
   c) 60 r.p.m.;
   d) 30 r.p.m.

9. A squirrel cage induction motor with a high resistance rotor, compared to one with a lower resistance, would have:-
   a) a lower full load slip and greater starting torque;
   b) a higher full load slip and greater starting torque;
   c) a lower full load slip and smaller starting torque;
   d) a higher full load slip and smaller starting torque.

   The resistance of the squirrel-cage rotor has an important effect on the operation of the motor. A high-resistance rotor develops a high starting torque at low starting cur rent. A low-resistance rotor develops low slip and high efficiency at full load.

10. In a squirrel cage induction motor with dual cage rotor:-
    a) the inner cage has the higher resistance and carries the greater current at starting;
    b) the outer cage has the higher resistance and carries the greater current at starting;
    c) the inner cage has the higher resistance and carries the least current at starting;
    d) the outer cage has the higher resistance and carries the least current at starting.

Rotor of a double squirrel cage motor has two independent cages on the same rotor. The figure at left shows the cross sectional diagram of a double squirrel cage rotor. Bars of high resistance and low reactance are placed in the outer cage, and bars of low resistance and high reactance are placed in the inner cage.

SECTION B

Blank spaces in the following statements represent omissions. Write the appropriate information on your answer sheet.

The emf induced in the rotor winding of a slip ring induction motor is a maximum at _____(1)_____.

Running

Adding resistance to the rotor circuit of the slip ring induction motor at starting _____(2)_____the starting current taken by the motor and_______(3)_____the available starting torque.

Reduce, increase

If two of the three leads connecting the slip rings of the slip ring induction motor to it's starting resistors are reversed the direction of rotation of the motor will be _____(4)_____.
Reverse

The unit of torque is the______(5)_____.

N-m

The direction that a three phase induction motor rotates depends on the______(6)_____ of the supply currents.

Sequence

When the torque required by the load on an induction motor is increased the speed of the motor______(7)_____,decrease the slip speed_______(8)_____ increase the voltage induced in the rotor conductors_______________(9)_____ increase which causes the current in the rotor conductors to _____(10)_____. increase This causes the strength of the rotor magnetic field to _____(11)_____,increase which causes the motor output torque to increase (12) to meetthe increased load demand on the motor.

The_______(13)_____ wound rotor induction motor has a wound rotor winding which is always star _____(14)_____connected to allow the connection of_______(15)_____ external resistance during starting to_________________________(16)_________ reduce starting current and_____(17)______________________ increase starting torque.

SECTION C
SEE TEACHER SOLUTIONB

1. A 4 pole three phase induction motor is connected to a 50Hz supply and runs at a full load slip of 4%. If the motor is delivering 33.16 newton metres of torque to the load at this speed with an efficiency of 83.3 percent and a power factor of 0.86 determine:-
   a) the synchronous speed of the motor; (1 500 r.p.m.)
   b) the slip speed of the motor; (60 r.p.m.)
   c) the rotor speed of the motor; (1440 r.p.m.)
   d) the output power of the motor; (5kW)
   e) the input power of the motor; (6kW)
   f) the line current from the 415 volt supply. (9.71A)

SECTION D

1. Figure 1 represents the incomplete circuit diagram of a three phase slip ring induction motor and it's supply:-
   a) Connect the stator windings in delta;
   b) Connect the rotor windings in star;
   c) Complete the required connections, including the supply and starting resistors, for the motor to start and run.

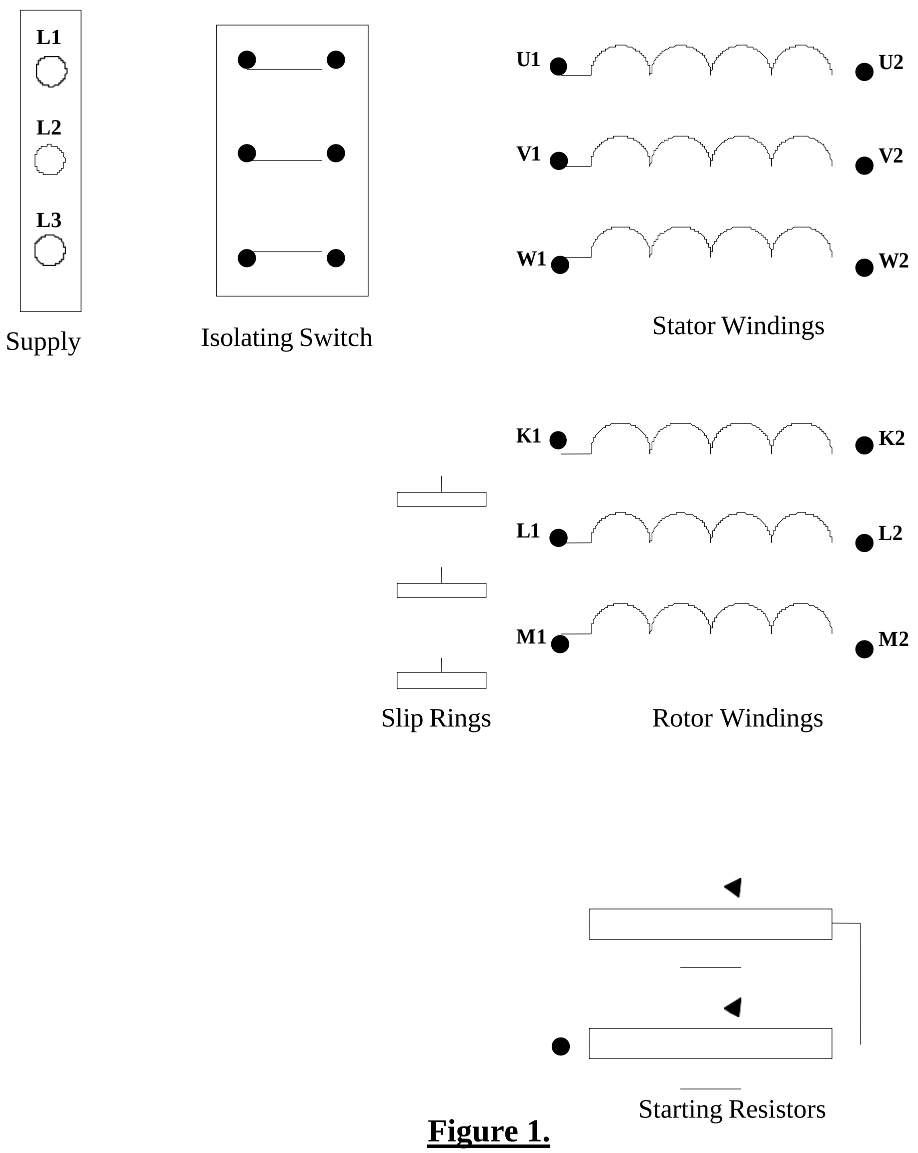
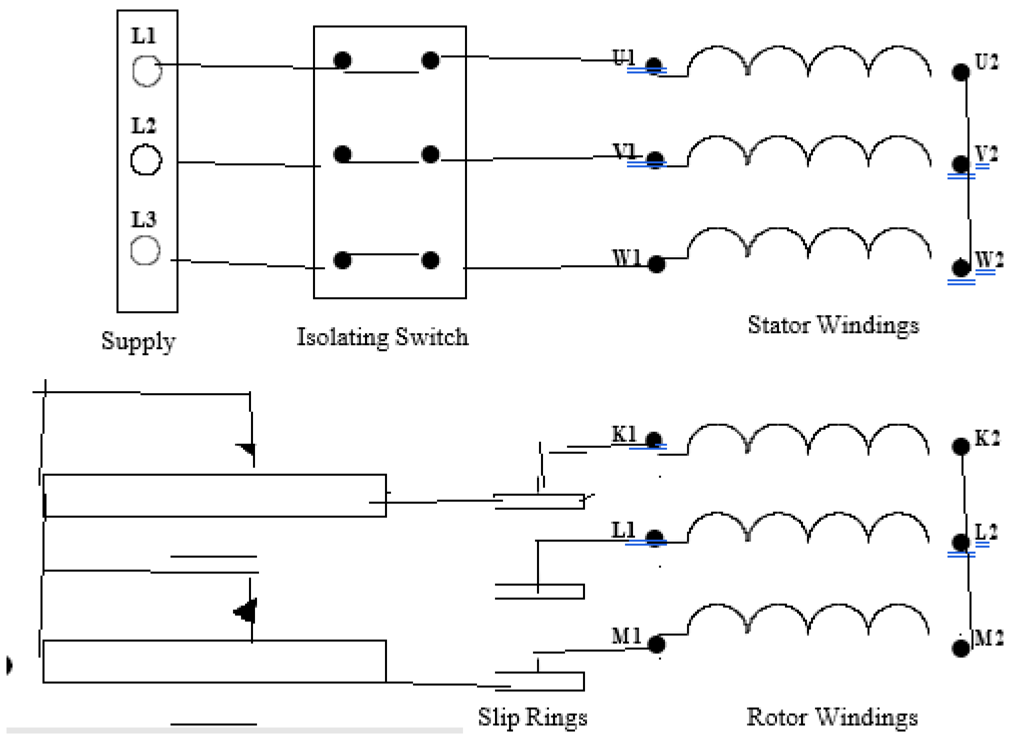


Figure 1.



Tutorial 9 **NAME:**

Induction Motor Load

CHARACTERISTICS

SECTION A

In the following statements one of the suggested answers is best. Place the identifying letter on your answer sheet.

1. Copper loss in an induction motor is due to:-

   a) hysteresis in the stator and rotor cores;
   b) eddy currents in the stator and rotor core;
   c) resistance of the stator and rotor windings;
   d) friction and windage loss in the motor.

2. The efficiency of an induction motor on no load is:-

   a) 100 percent;
   b) about 50 percent;
   c) about 10 percent;
   d) zero percent.

3. The mechanical losses on no load in an induction motor include:-

   a) hysteresis in the stator and rotor cores;
   b) eddy currents in the stator and rotor core;
   c) resistance of the stator and rotor windings;

d) friction and windage loss in the motor.

4. The difference between the input power to a motor and the output power from a motor is the:-

a) total loss given off as heat;
b) electrical loss given off as resistance;
c) mechanical loss given off as friction;
d) magnetic loss given off as inductance.

5. An increase in rotor current in an induction motor:-

a) reduces stator current to keep stator flux constant;
b) reduces power factor due to rotor inductance;
c) reduces motor efficiency due to increased losses;
d) causes stator current to increase to maintain stator flux.

6. The no load current of an induction motor is shown on a phasor diagram as:-

   a) the magnetising current and the iron loss current;
   b) the rotor current and the stator current;
   c) the copper loss current and the iron loss current;
   d) the copper loss current and the magnetising current.

7. As the load on an induction motor increases:-

   a) both the efficiency and the power factor improve;
   b) efficiency increases but power factor decreases;
   c) efficiency decreases and power factor decreases;
   d) efficiency decreases but power factor increases.

8. The stator component of current due to rotor current is:-

   a) equal to the rotor current and in phase with the rotor current;
   b) dependant on the turns ratio and in phase with the rotor current;
   c) equal to the rotor current and opposite in phase to the rotor current;
   d) dependant on the turns ratio and opposite in phase to the rotor current.

9. Most induction motors are designed to have maximum efficiency:-

   a) when rotor resistance equals rotor inductive reactance;
   b) close to full load as most motors run at this load;
   c) at starting to give increased starting torque;
   d) at about half of full load as a compromise.

10. In a squirrel cage induction motor:-

   a) iron losses vary as the square of the load while other losses are almost constant;
   b) stator losses vary as the square of the load while other losses are almost constant;
   c) rotor losses vary as the square of the load while other losses are almost constant;
   d) copper losses vary as the square of the load while other losses are almost constant.

SECTION B

Blank spaces in the following statements represent omissions. Write the appropriate information on your answer sheet.

Copper losses in a squirrel cage induction motor occur in______(1)______while hysteresis and eddy current losses occur in______(2)______. Mechanical losses occur due to______(3)______and______(4)______.

Winding, core, friction ,windage

If voltage and frequency supplying an induction motor remain constant then the ______(5)______losses and______(6)_____losses remain relatively constant. The variable______(7)_____loss varies in proportion to the_______(8)_____.

Hysteresis , Eddy current , copper, current

Maximum efficiency occurs when the______(9)_____losses equal the _____(10)_____losses while maximum torque occurs when the_______(11)_____ equals the______(12)_____.

Constant, Variable, rotor resistance , rotor reactance

If a motor running on full load has some load removed the speed of the motor _____(13)_____slightly, causing a_______(14)_____in rotor voltage, a _____(15)_____in rotor current, a_______(16)_____in rotor flux and a _____(17)_____in torque. The motor will settle to a constant speed when _____(18)_____equals______(19)_____.

Increase, decreasing, reduction, reduction, decrease , the slipping flux, increasing flux

The maximum torque occurs when rotor resistance and rotor reactance are equal, i.e. R2 = S X2, So, Sm = R2/X2 , Where, Sm is the slip at maximum torque. torque required to run the load at that speed.

SECTION C

SEE TEACHER

1. A 4 pole three phase 415 volt 50Hz squirrel cage induction motor runs at 1460 r.p.m. while delivering 9 kilowatts to its load at a maximum efficiency of 88 percent. If the power factor of the motor at this load is 0.86 lag determine:-
   a) the input power to the motor; (10 227W.)
   b) the line current taken by the motor; (16.55A.)
   c) the torque delivered to the load; (58.9Nm.)
   d) the losses in the motor; (1 228W.)
   e) the copper losses in the motor. (614W.)

2. A 415V squirrel cage induction motor delivers 116 Nm of torque when started on full voltage. The voltage to the motor must be reduced to 320 volts to limit starting current in line with supply authority requirements. Determine the starting torque at the reduced voltage. (69Nm.)

SECTION D

1. Figure 1 is a set of performance curves for a 5kW, 6 pole 415 volt squirrel cage induction motor. From the curves determine:-
   a) Line current, speed and efficiency at rated load;
   b) Input power, line current and power factor at no load;
   c) Speed and efficiency when stator current is 8 amperes.

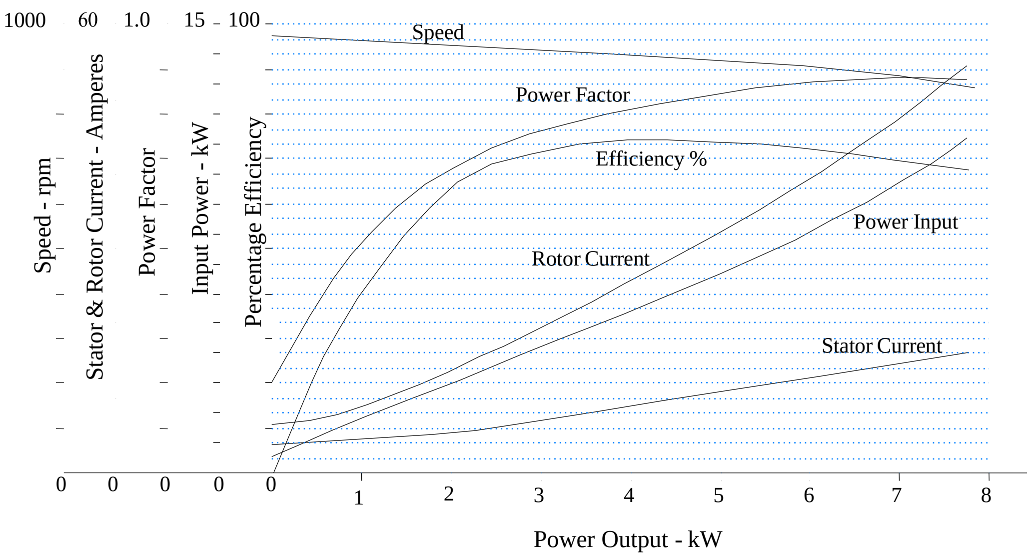


Figure 1

2. Figure 2 is a phasor diagram of a squirrel cage induction motor which shows three components of current in the motor. If the load component of stator current is one third of the rotor current complete the phasor diagram to determine:-
   a) the current scale for the stator currents; (10mm = 1A)
   b) the no load current and power factor; (1.7A @ 0.352lag)
   c) the load component of stator current; (3A @ 16.7^{O}lag)
   d) the total current taken from the supply at this load; (4.26A)
   e) the power factor of the motor at this load. (0.815lag)

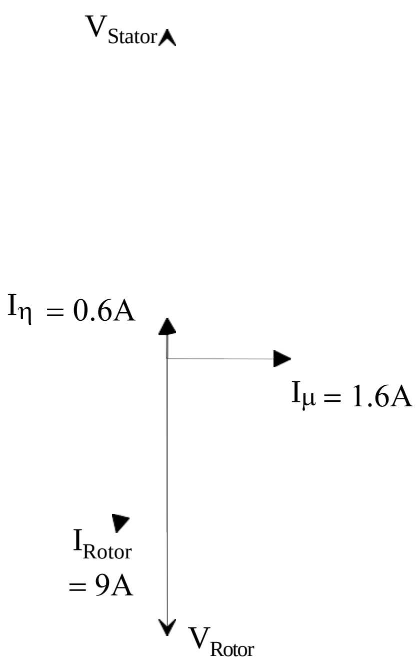


Figure 2

Tutorial 10 **NAME:**

Induction Motor Starting

SECTION A

In the following statements one of the suggested answers is best. Place the identifying letter on your answer sheet.

1. The overload device in a motor stater provides:-
   a) protection against short circuits inside the motor;
   b) overload protection for the motor and its supply conductors;
   c) short circuit protection for the motor supply conductors;
   d) all of the above.

2. Thermal overloads need to cool after tripping before they can be reset. This is:-
   a) a problem because the motor cannot be turned back on immediately;
   b) overcome by using magnetic overloads to allow faster reset times;
   c) to prevent the circuit breaker at the switchboard from tripping unnecessarily;
   d) to allow the motor windings to cool before being reconnected to the supply.

3. The motor starter that **does not** reduce the starting current to a squirrel cage induction motor is:-
   a) the direct on line motor starter;
   b) the star delta starter;
   c) the primary resistance starter;
   d) the auto transformer starter.

4. The main problem with starting large squirrel cage induction motors direct on line is:-
   a) starting torque is greater if a primary resistance starter is used;
   b) the large starting current causes fluctuations in the supply voltage;
   c) the large starting current will cause the motor windings to burn out;
   d) the motor may not produce enough starting torque to start the load.

5. The problem with starting squirrel cage motors with any of the voltage reduction starters is:-
   a) the motor must have all six winding ends brought out to the terminal block;
   b) six wires must be run between the switchboard and the starter;

c) reducing the voltage causes an even greater reduction in starting torque;

d) the increased starting torque may damage the load or couplings.

6. The thermal overload used on motor protection:-
   a) interrupts all overloads very quickly;
   b) only isolates short circuits instantly;
   c) allows slight overloads for longer periods;
   d) takes several minutes to isolate any overload.

7. A motor started with a star-delta starter with overloads fitted between the motor and starter would:-
   a) require a thermal overload with six bimetallic elements;
   b) require an overload current rating equal to rated current times $\frac{1}{\sqrt{3}}$
   c) require an overload current rating equal to rated motor current;
   d) require an overload current rating equal to rated current times $\sqrt{3}$

8. An advantage of differential thermal overloads over normal overloads is:-
   a) they can detect the difference between a short circuit and overload fault;
   b) they will protect the motor from loss of one phase of the supply;
   c) they can be used on single, two or three phase motors;
   d) they can also protect against loss of load (ie underload);.

9. Stop buttons and thermal overloads use normally closed contacts because:-
   a) if they get dirty and will not close the machine will not start (fail safe);
   b) normally closed contacts operate quicker than normally open contacts;
   c) normally open contacts would need to be connected in parallel;
   d) normally closed contacts stay cleaner as the dirt cannot get in.

10. AS/NZS 3000 Clause 4.2.1.2 would be satisfied if:-
   a) an automatic reclosing overload device protects the motor under all conditions;
   b) the isolating switch can be locked in the off position if not located next to the motor;
   c) the motor on a saw bench was controlled by a DOL starter operated by pushbuttons;
   d) copper losses vary as the square of the load while other losses are almost constant.

SECTION B

Blank spaces in the following statements represent omissions. Write the appropriate information on your answer sheet.

All starters incorporate one or more______(1)______overload protection_to control the motor and

______(2)_____wiring__to protect the motor from_(3) overload _____.At the beginning of themotor circuit (switchboard) either______CB (4)_________or_____ ______(5)Overload protection _________are used to provide________overload (6)short circuit _______protection for the circuit conductors and the motor.

Starting current to larger motors is required by the_______(7)______Supply Authority to be limited to reduce______(8)fluctuation ____in the supply. If this is the case the _____________________(9)motor ________ cannot be used. However, one of the _____________________(10)reduced voltage _______type starters may be used, depending on current limits and starting torque requirements.

If additional remote pushbuttons are added to a starter all start pushbuttons, which are of the normally______(11)open ___________________contact type, are connected in ___________________(12)parallel _________________andall stop pushbuttons, which are of the normally_(13)close _contact type, are connected in___(14series)______.

When started DOL the starting current of the squirrel cage induction motor is ______(15)2____to_______(16)______7 times rated current while starting torque is about ______(17)3____times rated torque. If starting current is reduced the starting torque is reduced in proportion to the______current (18)____. If the reduction of torque is excessive a

_Slip ring______(19)_induction motor may need to be used.

Why do we use slip ring induction motor?
Therefore, slip-ring induction motors are typically used where loads require high starting torque or good speed control. They are used in cranes, hoists, compressors, printing presses, large ventilation fans, and loads requiring speed control, such as for driving lifts and pumps.17 Feb 2022

SECTION C
SEE TEACHER SOLUTION

1. A three phase 415 volt 22 kilowatt delta connected squirrel cage induction motor has a rated line current of 45 amperes and a rated full load speed of 1440 r.p.m. If the motor takes six times rated current, and provides 150 percent of full load torque when started direct on line determine:-

   a) the rated torque produced by the motor; (145.9Nm.)
   b) the starting current taken by the motor; (270A.)
   c) the starting torque delivered by the motor; (218.9Nm.)
   d) the phase current at starting in each winding when connected in delta; (155.9A.)
   e) the current in each winding, and the line current taken from the supply if they were re-connected in star to the supply. (90A.)
   f) the starting torque if the motor were connected in star (hint:- torque produced is

proportional to **phase** voltage squared, ie $T_2 = T_1 \, x \, \left(\frac{V_2}{V_1}\right)^2$ (72.95Nm)

SECTION D

1. Figure 1 is a Torque - Speed curve for a particular motor which takes 140 amperes from the supply when started direct on line. The supply authority requires the starting current to be reduced to a maximum of 100 amperes. To do this the motor voltage is reduced to 0.7 of normal voltage using resistors in series with the motor at starting (primary resistance starter).
   a) Calculate the effect that the reduction of starting voltage would have on the starting torque of the motor; (Hint - reduction of torque = (reduction of voltage)^2).
   b) On Figure 1, draw a new Torque - Speed curve for the motor at the reduced voltage. (Hint - the curve will be reduced vertically by the proportion calculated in (a))
   c) At the reduced voltage would the motor still be able to start:-
      i. the fan (Load A)?
      ii. the pump (Load B)?

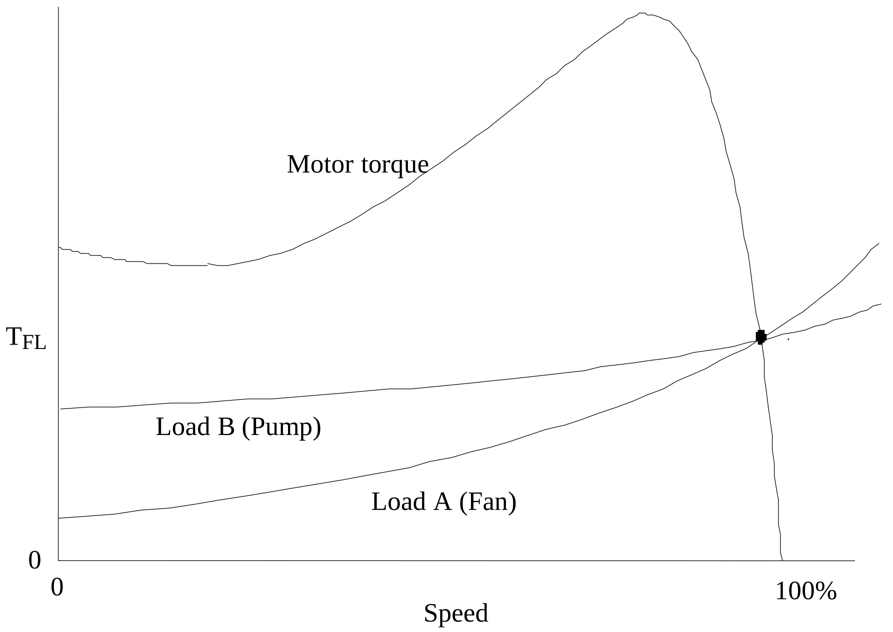


Figure 1

Rotor of a double squirrel cage motor has two independent cages on the same rotor. The figure at left shows the cross sectional diagram of a double squirrel cage rotor. Bars of high resistance and low reactance are placed in the outer cage, and bars of low resistance and high reactance are placed in the inner cage.

Overload and Overcurrent Protection – Basic Motor Control

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While **overloads** are **allowed** for a **short** time (usually **minutes**), **prolonged overloads** will **use thermal** action to cause a **protective** device to trip.

How do you calculate overload setting for a star-delta starter?
To calculate the thermal overload setting = Actual motor nameplate current ÷ 1.7 x 1.1 (10% safety margin to prevent spurious tripping). NOTE: Due to the large range of the thermal overloads on the Trip Class 20 star delta starters, please make sure the thermal overload is adjusted correctly to suit the motor.

What is the overload rating of the star-delta starter?
This configuration of the overload is described as "inside the delta loop". The overload will be rated at 0.58 x Motor Full Load Current (Inom).15 July 2013

For overloads, differential and non-differential types differ in how they trip (release).

Differential is considered to be a higher sensitivity relay as it has phase failure detection. When a difference between two or more of the phases exceeds the Overload relay (OLR) setting it will trip.

Non-differential type is usually more economical. Electrically speaking, if one bi-metallic strip heats up enough to open then the other 2 remaining poles must also heat up enough to trip the OLR. This can extend the time that it takes for the OLR to trip.

If the pushbutton malfunctions,the contact behaves as open so that there is no power flow. This makes the operator troubleshoot the system. This makes the motor remain safe in off condition due to improper stop push button functionality.