Chapter 3.2: Electric Motors

Part–I: Objective type questions and answers

1.	The synchronous speed of a motor with 6 poles and operating at 50 Hz frequency is _____. a) 1500 b) <u>1000</u> c) 3000 d) 750
2.	The efficiency figures for energy efficient motors (in comparison with standard efficiency motor) can be generally higher by_____%. a) 1% b) <u>3-7%</u> c) 10% and above d) 8-10%
3.	The power consumption, in case of centrifugal loads (like pump, fan, blower etc.), proportional to _____. a) speed b) square of speed c) <u>cube of speed</u> d) not applicable
4.	Which types of following motors are most efficient? a) <u>TEFC</u> b) SPDP c) Both d) None
5.	What determines the thermal loading on the motor? a) <u>Duty/Load cycle</u> b) Temperature of the winding c) Age of the motor d) Ambient conditions
6.	Unbalance in voltages at motor terminals is caused by _____. a) Supplying single phase loads disproportionately b) Use of different sizes of cables c) <u>Both (a) & (b)</u> d) None of the above
7.	With decrease in speed of the motor, the required capacitive kVAr: a) <u>Increases</u> b) Decreases c) Does not change d) None of the above
8.	Application of DC motors is generally restricted to a few load speed applications because of _____. a) cost of the motor is high b) <u>problems with mechanical commutation</u> c) Maintenance problems d) None of the above
9.	The speed of an AC motor depends on _____ . a) Frequency b) No. of poles c) <u>both (a) and (b)</u> d) None of the above
10.	The speed of the motor can be varied by _____. a) Changing supply frequency b) Changing no. of poles c) Using multi speed windings d) <u>All the above</u>
11.	Which of the following are ill suited for energy efficient motors application? a) Pumps b) Fans c) <u>Punch Presses</u> d) All the above
12.	Reduction in supply voltage by 10% will change the torque of the motor by _____. a) 38% b) <u>19%</u> c) 9.5% d) no change

13.	Five percent increase in supply frequency will change the synchronous speed by _____. a) -5%　　　b) <u>+5%</u>　　　　c) -10%　　　　d) +10%
14.	The inexpensive way to improving energy efficiency of a motor which operates consistently at below 40% of rated capacity is by _____. a) <u>Operating in Star mode</u>　　　b) Replacing with correct sized motor c) Operating in delta mode　　　d) None
15.	Which of the following needs to be measured after rewinding of motor? a) No load current　　　　　　b) winding resistance c) air gap　　　　　　　　　d) <u>all the above</u>
16.	Output power requirements of constant torque loads vary with _____. a) <u>Speed</u>　　　b) voltage　　　c) Current　　　d) power factor
17.	Which of the following is an AC motor? a) Slip ring motor　　　　　　b) Synchronous motor c) Squirrel cage Induction　　　d) <u>all of the above</u>
18.	Stray losses in an induction motor generally are _____ . a) proportional to the square of the stator current b) <u>proportional to the square of the rotor current</u> c) proportional to the rotor current d) inversely proportional to the square of rotor current
19.	Which of the following information available on name plate of a motor? a) HP rating　　　　　　　b) RPM c) Frame model　　　　　　d) <u>all the above</u>
20.	Machine tools are a typical example of a) Constant power load　　　　b) Constant torque load c) Variable torque load　　　　d) <u>a & b</u>

Part – II: Short type questions and answers

1.	Name the two important parameters that attribute to efficiency of electricity use by AC induction Motors? The important parameters that attribute to efficiency of electricity use by AC induction Motors are 1. Efficiency of the motor 2. Power Factor
2.	How do you define percentage unbalance in voltage? Percentage unbalance in voltage is defined as $[(V_{max} − V_{avg})/V_{avg}]$ x 100, where V_{max} and V_{avg} is the largest and the average of the three phase voltages respectively.

3.	Why is it beneficial to operate motors in star mode for under loaded motors?
	For motors which consistently operate at loads below 50 % of rated capacity, an inexpensive and effective measure might be to operate in star mode. A change from the standard delta operation to star operation involves re-configuring the wiring of the three phases of power input at the terminal box.
	Operating in the star mode leads to a voltage reduction by a factor of '$\sqrt{3}$'. Motor output falls to one-third of the value in the delta mode, but performance characteristics as a function of load remain unchanged. Thus, full-load operation in star mode gives higher efficiency and power factor than partial load operation in the delta mode. However, motor operation in the star mode is possible only for applications where the torque-to-speed requirement is lower at reduced load.
4.	What is the thumb rule for installing capacitors to motor terminal?
	The size of capacitor required for a particular motor depends upon the no-load reactive kVA (kVAR) drawn by the motor, which can be determined only from no-load testing of the motor. In general, the capacitor is then selected to not exceed 90 % of the no-load kVAR of the motor. (Higher capacities could result in over-voltages and motor burn-outs). Alternatively, typical power factors of standard motors can provide the basis for conservative estimates of capacitor ratings to use for different size motors.
5.	Write some applications of constant torque and variable torque loads.
	Constant Torque Loads: Conveyors, rotary kilns, constant displacement pumps
	Variable torque loads: Centrifugal pumps and fans.
6.	What is an energy efficient motor?
	An "energy efficient" motor produces the same shaft output power (HP), but uses less input power (kW) than a standard-efficiency motor.
7.	What is synchronous speed and how to determine the % slip of a motor?
	The speed of a motor is the number of revolutions in a given time frame, typically revolutions per minute (RPM). The speed of an AC motor depends on the frequency of the input power and the number of poles for which the motor is wound. The synchronous speed in RPM is given by the following equation, where the frequency is in hertz or cycles per second:
	a) $\quad \text{Synchronous Speed (RPM)} = \dfrac{120 \times \text{Frequency}}{\text{No. of Poles}}$
	b) $\quad$ Slip (%) = [(Synchronous Speed−Full Load Speed)/Synchronous Speed] x 100
8.	List down some of the important parameters that influence the motor selection?
	The following parameters influence the motor selection:
	(a) Torque requirement/load characteristics
	(b) Ambient operating conditions
	(c) Anticipated switching frequency
	(d) Reliability
	(e) Inventory
	(f) Price
	(g) efficiency
9.	What are the types of losses in any motor?
	The losses in any motor are shown below:

	Fixed Loses – core loss, friction & windage loss. Variable Losses - Copper & Stray Losses
10.	Write the relation to determine the energy savings by motor replacement with energy efficient one. kW savings = kW output x [$1/\eta_{old} - 1/\eta_{new}$]
11.	What steps should an energy manager take to minimize voltage unbalance? 1. Balancing any single phase loads equally among all three phases 2. Segregating any single phase loads which disturb the load balance and feed them from a separate line/transformer
12.	Comment on 'construction aspects' how an "energy efficient motor" is different from a "standard motor"? Energy efficient motors have the following positive features compared to standard motor: ☞ Higher quality low loss laminations for magnetic circuit ☞ More & better quality copper in the windings. ☞ Better quality insulation ☞ Optimised air gap between the rotor and stator. ☞ Reduced fan losses. ☞ Closer matching tolerances A greater core length
13.	A 440 V, 20 HP 3-ph motor operates at full load, 88% efficiency and 0.65 power factor lagging: A. Find the current drawn by the motor B. Find the real and reactive power absorbed by the motor A. P_{in} (Input power) = 20 x 746 / 0.88 = 16955 W I_L (Input current) = 16955 / ($\sqrt{3}$ x 440 x 0.65) = 34.2 A B. PF = 0.65 ∴ = $\cos^{-1}$(0.65) = 49.5^o (also sin 49.5 °C = 0.76) P (kW) = $\sqrt{3}$ x V_L x I_L x cos 49.5^o = $\sqrt{3}$ x 440 x 34.2 x 0.65 = 16.95 kW Q (kVAr) = $\sqrt{3}$ x V_L x I_L x sin 49.5^o = $\sqrt{3}$ x 440 x 34.2 x 0.76 = 19.8 kVAr S (kVA) = $\sqrt{3}$ x V_L x I_L = $\sqrt{3}$ x 440 x 34.2 = 26.1 kVA {Note also: $S^2 = \sqrt{(P^2+Q^2)}$}
14.	A 4-pole 415 V 3-phase, 50 Hz induction motor runs at 1440 RPM at .88 pf lagging and delivers 10.817 kW. The stator loss is 1060 W, and friction & windage losses are 375 W. Calculate A. Slip B. Rotor Copper loss C. Line current D. Efficiency

Answer:		
	Supply frequency (f)	=50Hz
	No. of poles (P)	=4
	Synchronous speed (Ns)	=120f/P=1500 RPM
	Actual speed (Nm)	=1440 RPM

	A.	Slip(s)	= (Ns – Nm)/ Ns = **0.04pu**	

B.   Motor output   =10817W
                  Stator Cu loss   =1060W
                  Friction & windage   =375W

Motor Output= Rotor Input – Rotor Copper loss – Friction & windage loss -- **Eq. (1)**

We know
     Rotor Input   = Rotor Copper loss/ slip
     Substituting in **Eq. (1)**
     Rotor Copper Loss = (Motor output + Friction & windage loss) x slip/ (1- slip)
     Therefore,
     Rotor Copper loss= (10817+375) x 0.04/ (1-0.04)
     Rotor Copper loss= **466.33W**

C.   Motor input = Rotor input + Stator loss
                  Rotor input = Rotor Copper loss/slip = 466.33/0.04 = 11658W
                  Motor input = 11658 + 1060 = 12718W
                  V= 415 Volts; Cos ϕ = 0.88lag;

                  Line Current   =Motor input/ (1.732 x V x Cos ϕ)
                                           = **20.11A**

D.   Efficiency   = (Motor Output/Motor input) x 100%
                                 = (10817/12718) x 100
                                 = **85%**

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15. Give short note on the features of a Synchronous motor?

AC power is fed to the stator of the synchronous motor. The rotor is fed by DC from a separate source. The rotor magnetic field locks onto the stator rotating magnetic field and rotates at the same speed. The speed of the rotor is a function of the supply frequency and the number of magnetic poles in the stator. While induction motors with a slip, i.e., rpm is less than the synchronous speed, the synchronous motor rotate with no slip i.e., the rpm is same as the synchronous speed governed by supply frequency and number of poles. The slip energy is provided by DC excitation power.

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16. Write a short note on a 'multi-speed motor'?

Motors can be wound such that two speeds, in the ratio of 2:1, can be obtained. Motors can also be wound with two separate windings, each giving 2 operating speeds, for a total of four speeds. Multi-speed motors can be designed for applications involving constant torque, variable torque, or for constant output power. Multi-speed motors are suitable for applications which require limited speed control (two or three fixed speeds instead of continuously variable speed), in which cases they tend to be very economical.

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17. Why 'induction motors' are so popular over all types of motors?

Low cost (compared with DC) and Wide availability

Low maintenance - no brushes or commutator

Rugged design - can be used in harsh environments

Low inertia rotor designs

High electrical efficiency

Wide speed ranges

No separately-powered field windings

18.	How do you size the capacitor rating required for an induction motor?
	The size of capacitor required for a particular motor depends upon the no-load reactive kVA (kVAR) drawn by the motor, which can be determined only from no-load testing of the motor. In general, for full loading operating motor, the capacitor selected to not exceed 90 % of the no-load kVAR of the motor. (Higher capacities could result in over-voltages and motor burn-outs).
19.	Write some strategies for correcting poor power factor in motors?
	The following are strategies for correcting power factor in motors:
	1. Minimise operation of idling or lightly loaded motors
	2. Ensuring correct supply of rated voltage and phase balance
	3. Installing capacitors to decrease reactive power loads
20.	List down some ill suited applications for 'energy efficient motors'?
	Because the favourable economics of energy-efficient motors are based on savings in operating costs, there may be certain cases which are generally economically ill-suited to energy-efficient motors. These include highly intermittent duty or special torque applications such as hoists and cranes, traction drives, punch presses, machine tools, and centrifuges.

Part – III: Long type questions and answers

1.	What are the losses in the 'induction motor' and briefly explain them?
	Losses are the source of inefficiency in motors, i. e. energy that goes into a motor but does not produce useful work. Losses in induction motors are classified into two types:
	1. No-load Losses: These losses are independent of load and incurred even when the motor is idling.
	2. Load dependent Losses: Vary as function of motor loading
	The losses in a motor are of two types such as fixed i.e. independent of load on the motor and the other variable i.e. dependent on the load.
	Fixed losses consist of Iron loss and mechanical loss (friction and windage loss). The iron loss vary with the material and geometry and with input voltage whereas friction and windage losses are caused by friction in the bearings of the motor and aerodynamic losses associated with the ventilation fan and other rotating parts.
	Variable losses consist of resistance losses in the stator and in the rotor and other stray losses. Resistance to current flow in the stator and rotor result in heat generation that is proportional to the resistance of the material and square of the current. Stray losses arise from a variety of sources and are difficult to measure directly or to calculate and are generally considered proportional to the square of the rotor current.
2.	What are the factors to be considered while selecting a motor?
	A. *Torque Requirement*
	The primary consideration defining the motor choice for any particular application is the torque required by the load. The relationship between the maximum torque generated by the motor (break-down torque) and the torque requirements for start-up (locked rotor torque) and during acceleration periods is very important. The thermal loading on the motor is determined by the duty/load cycle. One important consideration with totally enclosed fan cooled (TEFC) motors is that the cooling may be insufficient when the motor is operated at speeds lower than its rated speed.
	B. Sizing to Variable Load
	Industrial motors frequently operate under varying load conditions due to process requirements.

	A common practice in cases where such variable loads are found is to select a motor based on the highest anticipated load. In many instances, an alternative approach is typically less costly, more efficient and provides equally satisfactory operation. With this approach, the optimum rating for the motor is selected on the basis of the load duration curve for the particular application. Thus, rather than selecting a motor of high rating that would operate at full capacity for only a short period, a motor would be selected with a rating slightly lower than the peak anticipated load and would operate at overload for a short period of time. Since operating within the thermal capacity of the motor insulation is of greatest concern in a motor operating at higher than its rated load, the motor rating is selected as that which would result in the same temperature rise under continuous full-load operation as the weighted average temperature rise over the actual operating cycle.
3.	Write the checklist of good maintenance practices for proper motor operation? – A checklist of good maintenance practices to help insure proper motor operation would include. ❑ Inspecting motors regularly for wear in bearings and housings (to reduce frictional losses) and for dirt/dust in motor ventilating ducts (to ensure proper heat dissipation). ❑ Checking load conditions to ensure that the motor is not over or under loaded. A change in motor load from the last test indicates a change in the driven load, the cause of which should be understood. ❑ Lubricating appropriately. Manufacturers generally give recommendations for how and when to lubricate their motors. Inadequate lubrication can cause problems, as noted above. Over-lubrication can also create problems, e.g. excess oil or grease from the motor bearings can enter the motor and saturate the motor insulation, causing premature failure or creating a fire risk. ❑ Checking periodically for proper alignment of the motor and the driven equipment. Improper alignment can cause shafts and bearings to wear quickly, resulting in damage to both the motor and the driven equipment. ❑ Ensuring that supply wiring and terminal box are properly sized and installed. Inspect regularly the connections at the motor and starter to be sure that they are clean and tight.
4.	What are the effects of harmonics on motor operation and performance? Harmonics increase motor losses, and can adversely affect the operation of sensitive auxiliary equipment. The non-sinusoidal supply results in harmonic currents in the stator which increases the total current drawn. In addition, the rotor resistance (or more precisely, impedance) increases significantly at harmonic frequencies, leading to less efficient operation. Also, stray load losses can increase significantly at harmonic frequencies. Overall motor losses increase by about 20% with a six-step voltage waveform compared to operation with a sinusoidal supply. In some cases the motor may have to be de-rated as a result of the losses. Alternatively, additional circuitry and switching devices can be employed to minimize losses. Instability can also occur due to the interaction between the motor and the converter. This is especially true of motors of low rating, which have low inertia. Harmonics can also contribute to low power factor.
5	Calculate the annual energy savings and simple payback from replacing an existing standard motor with a premium efficiency Motor versus repairing a standard efficiency motor with a sample example. Energy Cost Savings (Rs./year) = HP x LF x 0.746 kW/HP x hrs x [$100/\eta_{std}$ - $100/\eta_{premium}$] x Rs./kWh Simple Payback (years) = Price premium / Annual cost savings (in (Rs) Energy cost savings $\quad = HP \times LF \times 0.746 \times \left[\dfrac{100}{\eta_{s\,\tan dard}} - \dfrac{100}{\eta_{\,premium}} \right]$ Example: Simple Payback Analysis for an average 20 HP, 1800 RPM, TEFC Motor Repair or

Replacement:

	Average Efficiency	Average Cost, Rs.
Rewind of Standard Efficiency Motor	88.3%	5000
Pr Premium Efficiency Motor	93.5%	40,000
Operating Hours	8,000	
Load Factor (LF)	75%	
Utility Rate	Rs. 4.0/kWh	

Energy Cost Savings = 20 HP x 0.75 x 0.746 x 8,000 hrs x [100/88.3 - 100/93.5] x Rs. 4/kWh

  = Rs. 21,485/year

Simple Payback = (Rs. 40000 – Rs.5000) / Rs. 21485

  = 1.6 years