Chapter 4.5: Electric Motors, Variable Speed Drives

Short type questions

1.	The resistance of a motor stator winding at 30°C is 0.264 ohms per phase. What will be the resistance of the stator winding per phase when the motor winding temperature is 100°C? Ans Stator resistance at 100°C = R1 x [(235 + t1] / (235 + t2)] = 0.264 x [(235 + 100) / (235 + 30)] = 0.334 ohms per phase
2.	Calculate the full load power factor of a motor with following operating details: Output power = 30 kW Efficiency = 85% Voltage (V) = 415 V Full load current (Ifl) = 58 A **Ans.** Full load power factor = [Input power / (1.732 x V x Ifl)] x 1000 Input power = output power / efficiency = 30/0.85 = 35.3 kW Full load power factor = [35.3 / (1.732 x 415 x 58)] x 1000 = 0.847
3.	Calculate the percentage loading of a motor using the following data: Synchronous speed in rpm = 1500 at 50 HZ operating frequency. Nameplate full load speed = 1440 Measured speed in rpm = 1475 Nameplate rated power = 11 kW **Ans.** $\% \, Loading = \frac{1500-1475}{1500-1440} * 100\% = 41.6\%$
4.	Calculate the rotor I^2 R losses using the following data:? Slip = 4% Stator input = 3000 W Stator I^2R losses = 100 W Core loss = 50 W **Ans.** Rotor I2R losses = Slip x (Stator input – stator I^2R losses - Core loss) = 0.04 x (3000 – 100 – 50) = 114 W
5.	What are the two main advantages of application of a variable frequency drive in an induction motor other than accurate speed regulation? **Ans.** Two of the main advantages are (i) High operating power factor (ii) Energy savings during part load operation for longer duration of time.
6.	Why the accuracy of the slip method is limited? The largest uncertainty relates to the accuracy with which manufacturers report the nameplate full-load speed. Manufacturers generally round their reported full-load speed values to some multiple of 5 rpm. While 5 rpm is but a small percent of the full-load speed and may be considered as insignificant, the slip method relies on the difference between full-load nameplate and synchronous speeds. Given a 40 rpm “correct” slip, a seemingly minor 5 rpm disparity causes a 12% change in calculated load.

7.	The nameplate details of the motor shows the motor is rated at 22 kW with efficiency 91%. The actual power measured was 13 kW. Estimate the percentage loading of the motor? Input power at full rated power in kW, Pi = 22/0.91 = 24.2 kW Percentage loading = 13/24.2 = 53.77%
8.	List down important factors required for successful implementation of variable speed drives for any application **Ans.** The important factors required to be considered for successful implementation of VSD are: • Load type • Motor information • Efficiency and power factor • Protection and power quality
9.	List down various methods available for determination of percentage loading of an induction motor? **Ans.** The following methods are available for determination of percentage loading of induction motors with their own advantages and disadvantages: 1. By input power measurements 2. By line current measurements 3. Slip method
10.	Comment on estimation of efficiency of 3 phase induction motor at field? **Ans.** It must be clear that accurate determination of efficiency is very difficult. The same motor tested by different methods and by same methods by different manufacturers can give a difference of 2 %. Estimation of efficiency in the field can be done as follows: a) Measure stator resistance and correct to operating temperature. From rated current value, I^2R losses are calculated. b) From rated speed and output, rotor R losses are calculated c) From no load test, core and F & W losses are determined for stray loss.

Long type questions

1.	What are the points to be considered while evaluating the efficiency of motor? It must be clear that accurate determination of efficiency is very difficult. The same motor tested by different methods and by same methods by different manufacturers can give a difference of 2 %. In view of this, for selecting high efficiency motors, the following can be done : a) When purchasing large number of small motors or a large motor, ask for a detailed test certificate. If possible, try to remain present during the tests. This will entail extra costs. b) See that efficiency values are specified without any tolerance c) Check the actual input current and kW, if replacement is done d) For new motors, keep a record of no load input power and current e) Use values of efficiency for comparison and for confirming; rely on measured inputs for all calculations.

2.	What is the information needed to evaluate energy savings for variable speed application? 1. Method of flow control to which adjustable speed is compared: o output throttling (pump) or dampers (fan) o recirculation (pump) or unrestrained flow (fan) o adjustable-speed coupling (eddy current coupling) o inlet guide vanes or inlet dampers (fan only) o two-speed motor. 2. Pump or fan data: o head versus flow curve for every different type of liquid (pump) or gas (fan) that is handled o Pump efficiency curves. 3. Process information: o specific gravity (for pumps) or specific density of products (for fans) o system resistance head/flow curve o equipment duty cycle, i.e. flow levels and time duration. 4. Efficiency information on all relevant electrical system apparatus: o motors, constant and variable speed o variable speed drives o gears o transformers. If precise information is not available for all the above, one can make reasonable assumptions for points 2 and 4.

<u>Numerical type questions</u>

1.	Calculate the annual cost savings of a 25 HP motor operating at 90 % efficiency compared to 85 % efficiency. Consider 8000hours of operation and a tariff rate Rs 4 / kWh. At 85 % efficiency: Input electric power $= \frac{25 \times 0.746}{0.85}$ = 21.94 kW At 90 % efficiency Input electric power $= \frac{25 \times 0.746}{0.9}$ = 20.72 kW Power Input difference = 1.22 kW For 8000 hours of operation and Rs 4/ kWh the annual cost saving is = 1.22 x 8000 x 4 = Rs. 39,040/ annum

2. Estimate the percentage loading of the induction motor with following data using input power method, line current method and slip method.

Name plate details:

Rated kW of Motor = 30 kW
Rated Amps = 55 A
Rated voltage = 415 V
Name plate efficiency = 92%
Name plate speed = 1440 rpm
No. of poles = 4
Frequency = 50 Hz

Operating Data

Measured speed = 1460 rpm
Input load current = 45 A
Operating voltage = 425 V
Input power = 20 kW

Ans.
a) input Power method

Input power at full rated power in kW, Pi = 30/0.92 = 32.6 kW
Percentage loading = 20/32.6 = 61.3%

b) Line Current Method

% load = [input load current / Input rated current] x [Rated voltage/ operating voltage] x 100
= [45 / 55]x [415/425] x 100
= 79.9%

c)Slip Method

$$\%\text{Loading} = \frac{\text{Slip}}{(\text{Ss} - \text{Sr})\ \text{x}\ (\text{Vr} / \text{V})^2}\ \text{x}\ 100\%$$

Synchronous speed = 120 x 50 /4= 1500 rpm
Slip = Synchronous Speed – Measured speed in rpm,
= 1500 – 1460 = 40 rpm

$$\%\text{Loading} = \frac{40}{(1500 - 1440)\ \text{x}\ (415 / 425)^2}\ \text{x}\ \ 100\% = 69.9\%$$

3. Determine the actual output power of an induction motor using the following data?

No. of poles = 2
Frequency = 50 Hz
Rated voltage = 415 V
Name plate full speed = 2980 rpm
Measured speed at 423 V = 2990 rpm
Name plate rated power = 22 kW

Ans.

$$\%\text{Loading} = \frac{\text{Slip}}{(\text{Ss} - \text{Sr})\ \text{x}\ (\text{Vr} / \text{V})^2}\ \text{x}\ 100\%$$

Synchronous speed = 120 x 50 /2 = 3000 rpm
Slip = Synchronous Speed – Measured speed in rpm,

	$= 3000 - 2990 = 10$ rpm $\%\text{Loading} = \frac{10}{(3000-2980) \times (415/423)^2} \times 100\% \quad = \quad 51.9\%$ Actual output power = 51.9% x 22 = 11.418 kW
4.	Calculate the annual energy savings and simple payback from replacing an existing standard motor with premium efficiency Motor versus repairing a standard efficiency motor. The data given are: Motor : 15 kW, working hours: 8000 hr, $\eta_{standard}$ = 88.3, $\eta_{premium}$ = 93.5%, % Loading = 75 **Ans.** Energy cost savings (Rs./year) = kW x %loading x $\left[\frac{100}{\eta_{s\tan dard}} - \frac{100}{\eta_{\ premium}}\right]$ x hrs/annum x Rs./kWh Simple Payback (years) = Price premium / Annual cost savings (in (Rs) Simple Payback Analysis for an average 15 kW, 1500 RPM, TEFC Motor Repair or Replacement:

Description	Parameter
Efficiency after Rewound of Standard Motor	88.3%
Efficiency of Premium Efficiency Motor	93.5%
Operating Hours	8,000
% Loading of Motor	75%
Average cost of rewinding, Rs.	5,000
Cost of new premium efficiency motor, Rs.	40,000
Utility Rate	Rs. 4.0/kWh

Energy Cost Savings = 15 kW x 0.75 x 8,000 hrs x [100/88.3 - 100/93.5] x Rs. 4/kWh

= Rs. 22, 674.28/year

Simple Payback = (Rs. 40000 – Rs.5000) / Rs. 22,674.28 = 1.54 years