

**15<sup>th</sup> NATIONAL CERTIFICATION EXAMINATION  
FOR  
ENERGY MANAGERS & ENERGY AUDITORS– August, 2014**

**PAPER – 3: Energy Efficiency in Electrical Utilities**

Date: 24.04.2014 Timings: 0930-1230 HRS Duration: 3 HRS Max. Marks: 150

**Section – I: OBJECTIVE TYPE**

**Marks: 50 x 1 = 50**

- (i) Answer all 50 questions
- (ii) Each question carries one mark

|    |  |
|----|--|
| 1. | Which loss is considered the most unreliable or complicated to measure in electric motor efficiency testing?<br>a) stator Cu loss    b) rotor Cu loss    c) stator Iron loss    d) <u>stray loss</u>   |
| 2. | The intersection point of the centrifugal pump characteristic curve and the design system curve is the<br>a) pump efficiency point    b) <u>best efficiency point</u><br>c) system efficiency point    d) none of the above  |
| 3. | In case of increased suction lift from open wells, the pump delivered flow rate<br>a) increases    b) <u>decreases</u> c) remains same    d) none of the above   |
| 4. | In pumping systems where static head is a high proportion of the total, the appropriate solution is<br>a) install two or more pumps to operate in parallel<br>b) <u>install two or more pumps to operate in series</u><br>c) install two or more pumps to operate in independent operation<br>d) none of the above |
| 5. | A Plant wants to replace the existing 100 TR water cooled vapour compression refrigeration system with a waste heat driven vapour absorption chiller. The capacity of the existing cooling tower<br>a) needs no change    b) <u>is to be doubled</u><br>c) is to be raised to 1.2 times    d) none of the above    |
| 6. | Shaft power of the motor driving a pump is 30 kW. The motor efficiency is 0.92 and pump efficiency is 0.5. The power drawn by the motor will be<br>a) 65.2 kW    b) 15 kW    c) 30 kW    d) <u>32.6 kW</u>   |
| 7. | If water is flowing through a cooling tower at 120 m <sup>3</sup> /h with 5°C range, the load on cooling tower at an ambient wet bulb ambient temperature of 33°C is<br>a) <u>198.4 TR</u> b) 357 TR    c) 158 TR    d) none of the above  |
| 8. | In a plant, the loading on a transformer was 1000 kVA with the power factor of 0.88. The plant improved the power factor to 0.99 by adding capacitors on the load side. The release in transformer loading( kVA) will be   |

|     |   |
|-----|---|
|     | a) <u>111</u> b) 889                      c) 999                      d) none of the above  |
| 9.  | The wet bulb temperature normally chosen for designing of cooling tower is<br>a) average maximum wet bulb for rainy months<br>b) <u>average maximum wet bulb for summer months</u><br>c) average minimum wet bulb for summer months<br>d) average maximum wet bulb for winter months  |
| 10. | Which one from the following types of cooling towers consumes least power for the same operating conditions?<br>a) <u>counter flow film fill cooling tower</u> b) cross-flow splash fill cooling tow<br>c) counter flow splash fill cooling tower                      d) none of the above   |
| 11. | Lux is defined as<br>a) ratio of luminous flux emitted by a lamp to the power consumed by the lamp<br>b) <u>one lumen per square meter</u><br>c) one lumen per square feet<br>d) none of the above  |
| 12. | Which among the following is the most energy efficient lamp for the same wattage rating?<br>a) HPMV                      b) GLS                      c) CFL                      d) <u>Metal halide</u>   |
| 13. | _____ is a measure of effect of light on the perceived colour of objects<br>a) lux                      b) lumens                      c) <u>CRI</u> d) lamp circuit efficacy   |
| 14. | Which of the following is the best definition of illuminance?<br>a) <u>luminous flux incident on an object per unit area</u><br>b) flux density emitted from an object without regard for direction<br>c) time rate of flow of light energy<br>d) flux density emitted from an object in a given direction  |
| 15. | Two most important electrical parameters, which are to be monitored, among the following for safe operation of Diesel Generator set are:<br>a) voltage and ampere                      b) <u>kW and kVA</u><br>c) power factor and ampere                      d) kVA and ampere  |
| 16. | In a DG set, the generator capacity is 1000 kVA with a rated power factor 0.8. It is consuming 150 litre per hour diesel oil. If the specific fuel consumption of this DG set is 0.25 litres/ kWh at that load, then what is the kVA loading of the set at 0.88 PF?<br>a) <u>682 kVA</u> b) 800 kVA                      c) 750 kVA                      d) none of the above |
| 17. | The maximum unbalanced load between phases should not exceed _____ % of the capacity of the DG set<br>c) <u>10</u> b) 5                      c) 1                      d) none of the above   |
| 18. | The capacity of largest motor that can be started in the given DG set is..... of kVA rating of DG set<br>a) 25%                      b) <u>50%</u> c) 75%                      d) 100%  |

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| 19. | The jacket cooling water in a diesel engine flows at 12.9 m <sup>3</sup> /hr with a range of 10°C and accounts for 30% of the engine input energy. What will be the hourly Diesel consumption in kg with a calorific value of 10,000 kcal/kg<br>a) <u>43</u> b) 12.9                      c) 17.3                      d) none of the above  |
| 20. | Select the incorrect statement:<br>a) harmonics occur as spikes at intervals which are multiples of the supply frequency<br>b) <u>harmonics are not multiples of the fundamental frequency</u><br>c) induction motors are not the major sources of harmonics<br>d) transformers operating near saturation level create harmonics   |
| 21. | If the speed of centrifugal fan is reduced to 80% of its rated speed then the power drawn will _____% of its rated power:<br>a) 80%                      b) <u>51.2 %</u> c) 40 %                      d) 64 %   |
| 22. | The order of movement of thermal energy in HVAC system is:<br>a) Indoor air - Condenser water - Chilled water - Cooling tower - Refrigerant<br>b) Chilled water - Indoor air - Refrigerant-Cooling tower - Condenser water<br>c) <u>Indoor air - Chilled water - Refrigerant-Condenser water- Cooling tower</u><br>d) Indoor air - Chilled water – Refrigerant - Cooling tower - Condenser water |
| 23. | Which one of the following device will help to eliminate the hunting problems normally associated with capacitor switching?<br>a) Maximum Demand Controller                      b) <u>Intelligent Power Factor Controller (IPFC)</u><br>c) Soft Starter                      d) Eddy Current Drives   |
| 24. | The occupancy sensors in a lighting installation are best suited for<br>a) <u>conference halls</u> b) large production shops/hangars<br>c) entrances of offices/buildings                      d) street lighting  |
| 25. | A pure resistive load in an alternating current (AC) circuit draws<br>a) lagging reactive power                      b) <u>active power</u><br>c) leading reactive power                      d) none of the above   |
| 26. | Select the incorrect statement: The advantage of PF improvement by capacitor addition in an electric network is<br>a) active power component of the network is not affected<br>b) <u>reactive power component of the network is not affected</u><br>c) I <sup>2</sup> R power losses are affected in the system<br>d) voltage level at the load end is affected                                  |
| 27. | “Heat Rate” of a thermal power station is the heat input in kilo Calories or kilo Joules, for generating<br>a) one kW of electrical output                      b) one kVAh of electrical output<br>c) <u>one kWh of electrical output</u> d) one kVA of electrical output   |
| 28. | Improving power factor at motor terminals in a plant will<br>a) increase active power drawn by motor                      b) <u>reduce system distribution losses</u><br>c) reduce contract demand with utility                      d) increase motor design power factor   |

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| 29. | For a 6 pole induction motor operating at 49.5 Hz, the percentage slip at a shaft speed of 950 RPM will be<br>a) <u>4.0 %</u> b) 5.0 %                      c) 0.04 %                      d) none of the above   |
| 30. | A plant had installed three phase shunt capacitors to improve power factor at Motor Control Circuit (MCC). Busbar three phase Voltages at the main electrical panel of a plant were balanced but at the Motor Control Circuit (MCC), receiving three phase power from busbars, the line voltages were found to be unbalanced. The main reason for this unbalanced voltage at MCC among the following could be<br>a) PF capacitors were operating at higher supply frequency<br>b) <u>PF improvement in all phase was not uniform due to blown fuse in one phase of the 3 phase PF capacitors</u><br>c) PF capacitors were operating at higher voltage then their rated values<br>d) PF capacitors were operating at lower voltage then their rated values |
| 31. | A 50 kVAr, 415 V rated power factor capacitor was found to be having terminal supply voltage of 430 V. The capacity of the power factor capacitor at the operating supply voltage would be approximately<br>a) <u>53.67 kVAr</u> b) 50 kVAr                      c) 46.57 kVAr                      d) none of the above  |
| 32. | A 75 kW rated squirrel cage induction motor installed with static PF correction capacitors across the motor terminals got damaged along with capacitors once supply was switched off due to power failure. The possible reason for the motor burn out among the following could be<br>a) motor was oversized<br>b) motor was undersized<br>c) <u>charging current of the capacitors was more than the magnetizing current of the motor</u><br>d) charging current of the capacitor was only 85% of the motor magnetizing current  |
| 33. | An induction motor rated for 75 kW and 94 % efficiency, operating at full load, will<br>a) deliver 70.5 kW    b) <u>deliver 75 kW</u> c) draw 75 kW    d) deliver 79.78 kW  |
| 34. | Higher chiller COP can be achieved with<br>a) higher evaporator temperature and higher condensing temperature<br>b) <u>higher evaporator temperature and lower condensing temperature</u><br>c) lower evaporator temperature and higher condensing temperature<br>d) lower evaporator temperature and lower condensing temperature  |
| 35. | Increase in the delivery pressure of a compressor by 1 bar would reduce the power consumption by<br>a) 1 to 5 %                      b) 6 to 10 %                      c) 11 to 15 %                      d) <u>none of the above</u>   |
| 36. | The FAD of a reciprocating compressor is directly proportional to<br>a) pressure                      b) volume                      c) <u>speed</u> d) all of the above  |
| 37. | Which of the following is not true of air receivers in a compressed air system?<br>a) smoothens pulsating air output<br>b) <u>increases the compressed air pressure</u>   |

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|-----|---|
|     | c) stores large volumes of compressed air<br>d) facilitates draining of moisture  |
| 38. | Typical acceptable pressure drop in mains header at the farthest point of an industrial compressed air network is<br>a) 1.0 bar                      b) 0.7 bar                      c) 0.5 bar                      d) <u>0.3 bar</u>  |
| 39. | All other conditions remaining the same in a refrigeration system, at which of the following condenser temperatures, the power consumption will be the least:<br>a) <u>32.6 °C</u> b) 35.9 °C                      c) 40.8 °C                      d) 43.4 °C   |
| 40. | The pressure of refrigerant in vapour compression system changes in<br><b>a) compressor</b> b) expansion valve    c) <u>both (a) &amp; (b)</u> d) evaporator  |
| 41. | A 1.5 ton air conditioner installed in a room and working continuously for one hour will remove heat of<br>a) 3024 kcals                      b) <u>4536 kcals</u> c) 3000 kcals                      d) 6048 kcals   |
| 42. | If the power consumed by a 1.5 TR refrigeration compressor is 2.5 kW , what is the energy efficiency ratio?<br>a) <u>2.1</u> b) 1.5                      c) 0.6                      d) 1.66  |
| 43. | In the performance assessment of a refrigeration system, which performance ratio (energy efficiency) does not follow the trend “a higher ratio means a more efficient refrigeration system”?<br>a) Coefficient of performance(COP)                      b) Energy Efficiency Ratio (EER)<br>c) <u>kW per ton</u> d) none of the above       |
| 44. | 2 ton of refrigeration (TR) is equivalent to about<br>a) 100.8 kcal/min                      b) 7032 W                      c) 428.7 BTU/min                      d) <u>all of the above</u>  |
| 45. | A fan with 25 cm pulley diameter is driven by a 2940 rpm motor through a V-belt system. If the motor pulley is reduced from 20 cm to 15 cm keeping the motor rpm and fan pulley diameter the same, the fan speed will reduce by<br>a) 1176 rpm                      b) 1764 rpm                      c) <u>588 rpm</u> d) none of the above |
| 46. | In series operation of identical centrifugal fans, ideally<br>a) flow doubles                      b) <u>static pressure doubles</u><br>c) static pressure goes up by four times                      d) flow goes up by four times   |
| 47. | The hydraulic power of a motor pump set is 8 kW. If the power drawn by the motor is 16 kW at 90% efficiency, the pump efficiency will be<br>a) <u>55.5%</u> b) 50%                      c) 45%                      d) none of the above  |
| 48. | The energy saving with variable speed drives in a pumping system will be maximum for systems with<br>a) pure static head                      b) <u>pure friction head</u><br>c) high static head and low friction head                      d) high static head with high friction head  |
| 49. | A process fluid at 50 m <sup>3</sup> /hr, with a density of 0.96, is flowing in a heat exchanger and is to be cooled from 36°C to 29°C. The fluid specific heat is 0.78 kcal/kg. If the chilled water   |

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|     | range across the heat exchanger is 5°C, the chilled water flow rate is<br>a) 67.2 m <sup>3</sup> /hr      b) <u>52.42</u> m <sup>3</sup> /hr      c) 50 m <sup>3</sup> /hr      d) none of the above |
| 50. | The inner tube of an L-type pitot tube is used to measure ..... in the air duct<br>a) <u>total pressure</u> b) static pressure      b) velocity pressure      d) dynamic pressure                    |

..... End of Section – I .....

**Section – II: SHORT DESCRIPTIVE QUESTIONS**

Marks: 10 x 5 = 50

- (i) Answer all Ten questions
- (ii) Each question carries Five marks

S-1 An energy audit of a fan was carried out. It was observed that the fan was delivering 18,500 Nm<sup>3</sup>/hr of air with static pressure rise of 62 mm WC. The power measurement of the 3-phase induction motor coupled with the fan recorded 3.1 kW/ phase on an average. The motor operating efficiency was assessed as 88% from the motor performance curves. What would be the fan static efficiency?

Ans:

$$Q = 18,500 \text{ Nm}^3 / \text{hr.} = 5.1388 \text{ m}^3/\text{sec}$$

$$SP = 62 \text{ mmWC}$$

$$\eta_{st} = ?$$

$$\text{Power input to motor} = 3.1 \times 3 = 9.3 \text{ kW}$$

$$\text{Power input to fan shaft} = 9.3 \times 0.88 = 8.184 \text{ kW}$$

$$\begin{aligned} \text{Fan static } \eta &= \frac{\text{Volume in m}^3/\text{sec} \times \Delta P_{st} \text{ in mmWc}}{102 \times \text{Power input to shaft}} \\ &= \frac{5.1388 \times 62}{102 \times 8.184} \\ &= 0.38 \\ &= 38\% \end{aligned}$$

S-2 A 37 kW, 3 phase, 415 V induction motor draws 56 A and 30 kW power at 410 V . What is the Apparent and Reactive Power drawn by the motor at the operating load?

Ans:

$$\begin{aligned} \text{Apparent power} &= 1.7321 \times 0.410 \times 56 = 39.769 \text{ kVA} \\ \text{Reactive power} &= \text{sqrt} (\text{apparent power}^2 - \text{active power}^2) \\ \text{Active power} &= 30 \text{ kW} \\ \text{Therefore reactive power} &= \text{sqrt} (1581.57 - 900) \\ &= 26.1 \text{ kVA} \end{aligned}$$

S-3 Define Range, approach and effectiveness in cooling tower operation

Ans:

- i) "Range" is the difference between the cooling tower water inlet and outlet temperature.
- ii) "Approach" is the difference between the cooling tower outlet cold water temperature and ambient wet bulb temperature. Although, both range and approach should be monitored, the 'Approach' is a better indicator of cooling tower performance.
- iii) Cooling tower effectiveness (in percentage) is the ratio of range, to the ideal range, i.e., difference between cooling water inlet temperature and ambient wet bulb temperature, or in other words it is =  $\text{Range} / (\text{Range} + \text{Approach})$ .

S-4 Compute AT & C (Aggregate Technical and Commercial) Losses for the following data:

| S. No. | Description   |                | Annual Data |
|--------|---|----------------|-------------|
| 1      | Input Energy = (Import-Export), MU                      | E <sub>i</sub> | 22          |
| 2a     | Energy Billed (Metered), MU                             | E <sub>1</sub> | 16          |
| 2b     | Energy Billed (Un-Metered), MU                          | E <sub>2</sub> | 1           |
| 2c     | Total Energy Billed ( E <sub>1</sub> + E <sub>2</sub> ) | E <sub>b</sub> | 17          |
| 3      | Amount Billed (Rs. lakhs )                              | A <sub>b</sub> | 800         |
| 4a     | Gross Amount Collected (Rs. lakhs)                      | A <sub>G</sub> | 820         |
| 4b     | Arrears Collected (Rs. lakhs)                           | A <sub>r</sub> | 40          |

Ans:

| Estimation of AT & C Losses |   |  |             |
|-----------------------------|---|--|-------------|
| S. No.                      | Description   |  | Annual Data |
| 1                           | Input Energy = (Import-Export), MU                      | E <sub>i</sub>                                 | 22          |
| 2a                          | Energy Billed (Metered), MU                             | E <sub>1</sub>                                 | 16          |
| 2b                          | Energy Billed (Un-Metered), MU                          | E <sub>2</sub>                                 | 1           |
| 2c                          | Total Energy Billed ( E <sub>1</sub> + E <sub>2</sub> ) | E <sub>b</sub>                                 | 17          |
| 3                           | Amount Billed (Rs. lakhs )                              | A <sub>b</sub>                                 | 800         |
| 4a                          | Gross Amount Collected (Rs. lakhs)                      | A <sub>G</sub>                                 | 820         |
| 4b                          | Arrears Collected (Rs. lakhs)                           | A <sub>r</sub>                                 | 40          |
| 4c                          | Amount Collected without Arrears (Rs. lakhs)            | A <sub>c</sub> =A <sub>G</sub> -A <sub>r</sub> | 780         |
| 5                           | Billing Efficiency (BE)                                 | = E <sub>b</sub> /E <sub>i</sub> *100%         | 77.27 %     |
| 6                           | Collection Efficiency(CE)                               | =A <sub>c</sub> /A <sub>b</sub> *100%          | 97.5%       |
| 7                           | AT& C Loss  | {1- (BE *CE ) *100%                            | 24.7 %      |

S-5 State any three major differences between vapor compression refrigeration (VCR) and Vapour Absorption Refrigeration (VAR) system?

Ans:

- VCR uses electric power for the compressor as main input while VAR uses a source of heat
- VCR uses compounds of hydrogen, fluorine and carbon as refrigerants while VAR uses water

- VCR works under pressure while VAR works under vacuum
- VCR has a high COP while VAR has a low COP
- VAR requires cooling tower capacity double that of VCR
- *Any other relevant point.....*

S-6 As Energy Manager, what are all the factors you look into for energy saving in operating DG Sets.?

Ans:

- 1.Ensuring steady load conditions on the DG set & providing cold and dust free intake air
- 2.Improving air filtration
- 3.Ensuring fuel oil storage, handling and operation as per manufacturer's guidelines/oil company's data
4. Consideration of fuel oil additives
- 5.Calibration fuel injection pumps periodically
- 6.Ensuring compliance with maintenance check lists
- 7.Ensuring balanced electrical loading
- 8.In case of a base load operations, consideration of waste heat recovery system

S-7 A 180 kVA, 0.80 PF rated DG set has diesel engine rating of 210 BHP. What is the maximum power factor which can be maintained at full load on the alternator without overloading the DG set? (Assume alternator losses and exciter power requirement as 12.66 kW and there is no derating of DG set)

Ans:

$$\text{Engine rated Power} = 210 \times 0.746 = 156.66 \text{ kW}$$

$$\text{Rated power available for alternator} = 156.66 - 12.66 = 144 \text{ kW}$$

$$\text{Maximum power factor possible} = 144 / 180 = 0.8$$

S-8 An induced draft-cooling tower is designed for a range of 7° C. An energy manager finds the operating range as 4 °C. In your opinion what could be the reasons for this type of situation.

Ans:

1. There may be excess cooling water flow rate
2. There may be reduced heat load from the process
3. Some of the cooling tower cells fan is switched off
4. Approach may be poor because of high humid condition
5. Nozzles may be blocked

..... *End of Section - II* .....



Section – III: LONG DESCRIPTIVE QUESTIONS

Marks: 5 x 10 = 50

- (i) Answer all Five questions
- (ii) Each question carries Ten marks

L-1 (a) A 3 phase, 415 V, 75 kW induction motor is drawing 58 kW at a 0.7 PF.

Calculate the capacitor rating requirements at motor terminals for improving PF to 0.95. Also, calculate the reduction in current drawn and kVA reduction, from the point of installation back to the generating side due to the improved PF at operating voltage of 415 V.

(b) A process plant consumes of 2,00,000 kWh per month at 0.92 Power Factor (PF). What is the percentage reduction in distribution losses per month if PF is improved up to 0.96 at load end?

a)  $kVA_r \text{ Rating} = kW [\tan \phi_1 - \tan \phi_2]$

$\cos \phi_1 = 0.70, \phi_1 = \cos^{-1} 0.70 = 45.57, \tan \phi_1 = 1.02$

$\cos \phi_2 = 0.95, \phi_2 = \cos^{-1} 0.95 = 18.2, \tan \phi_2 = 0.329$

$kVA_r \text{ Rating} = 58 \text{ kW} (1.02 - 0.329)$   
 $= 40.1 \text{ kVA}_r$

Current drawn at 0.7 PF  $= 58 / \sqrt{3} \times 0.415 \times 0.7$   
 $= 115.27 \text{ A}$

Current drawn at 0.95 PF  $= 58 / \sqrt{3} \times 0.415 \times 0.95$   
 $= 84.94 \text{ A}$

Reduction in current drawn  $= 115.27 - 84.94$   
 $= 30.3 \text{ A}$

Initial kVA at 0.7 PF  $= 58 / 0.7$   
 $= 82.85 \text{ kVA}$

kVA at 0.95 PF  $= 58 / 0.95$   
 $= 61.05 \text{ kVA}$

Reduction in kVA  $= 82.85 - 61.05$   
 $= 21.8 \text{ kVA}$

(OR)

Reduction in kVA  $= (\sqrt{3} VI)_{old} - (\sqrt{3} VI)_{new}$

$$\begin{aligned}
 &= (\sqrt{3} \times 0.415 \times 115.27) - (\sqrt{3} \times 0.415 \times 84.94) \\
 &= 82.85 - 61.05 \\
 &= 21.8 \text{ kVA}
 \end{aligned}$$

$$\begin{aligned}
 \text{Reduction in kVA} &= \text{(OR)} \\
 &= 1.7321 \times 0.415 \times \text{reduction in current} \\
 &= 1.7321 \times 0.415 \times 30.3 \\
 &= 21.8 \text{ kVA}
 \end{aligned}$$

$$\begin{aligned}
 \text{b) \% Reduction in distribution losses} &= \left[ 1 - \frac{PF_1}{PF_2} \right] \\
 &= [1 - (0.92/0.96)^2] \\
 &= 0.0816 \\
 &= 8.16 \%
 \end{aligned}$$

L-2 The measured values of a 20 TR package air conditioning plant are given below:

Average air velocity across suction side filter: 2.5 m/s

Cross Sectional area of suction: 1.2 m<sup>2</sup>

Inlet air = Dry Bulb: 20°C, Wet Bulb: 14°C, Enthalpy: 9.37 kcal/kg

Outlet air = Dry Bulb: 12.7°C, Wet Bulb: 11.3°C; Enthalpy: 7.45 kcal/kg

Specific volume of air: 0.85 m<sup>3</sup>/kg

Power drawn: by compressor: 9.44 kW

by Pump: 4.86 kW

by Cooling tower fan: 0.87 kW

Calculate:

- i. Air Flow rate in m<sup>3</sup>/hr
- ii. Cooling effect delivered in kW
- iii. Specific power consumption of compressor in kW/TR
- iv. Overall kW/TR
- v. Energy Efficiency Ratio in kW/kW

Ans:

- i. Air flow rate = 2.5\*1.2 = 3 m<sup>3</sup>/sec = 10800 m<sup>3</sup>/hr
- ii. Cooling Effect delivered = [(9.37-7.45)\*10800]/(0.85\*3024) = 8.07 TR = 28.37 kW
- iii. Compressor kW/TR = 9.44/8.07 = 1.17
- iv. Overall kW/TR = (9.44+4.86+0.87)/8.07 = 1.88
- v. Energy Efficiency Ratio(EER) in kW/kW = 28.37/9.44 = 3

L-3 During an energy audit following data were obtained on a 3 phase induction motor:

Rated values: 37 kW, 415V, 66 A, 0.88 pf  
 Operating values: 410 V, 49A, 0.76 pf

Note: Motor efficiency in this particular case does not change between 50 –100 % loading.

The plant operates for 7000 hours per year with the electricity cost of Rs. 7.00 per unit.

It is proposed to replace the existing motor by a 30 kW energy efficient motor with 92% efficiency.

- Determine the rated efficiency and the loading of the existing motor.
- Calculate the loading with energy efficient motor.
- If replacing the existing motor with energy efficient motor which costs Rs.75,000, determine the pay back period for the investment required for the energy efficient motor over the existing motor. Consider the salvage value of the existing motor as Rs.10,000/.

Ans:

|                                      |   |
|--------------------------------------|---|
| <b>Rated input power</b>             | <b><math>1.732 \times 0.415 \times 66 \times 0.88</math></b>                |
|                                      | <b>41.746 kW</b>  |
| <b>Rated efficiency of the motor</b> | <b><math>37 / 41.746</math></b>   |
|                                      | <b>88.63%</b>   |
|                                      |   |
| <b>Actual input power drawn</b>      | <b><math>1.732 \times 0.410 \times 49 \times 0.76</math></b>                |
|                                      | <b>26.44 kW</b>   |
|                                      |   |
| <b>Loading of the motor</b>          | <b><math>26.44 / 41.746 = 0.633</math> or 63.3%</b>                         |
| <b>Shaft power or motor output</b>   | <b><math>37 \times 0.633 = 23.44</math> kW</b>                              |
|                                      |   |
| <b>Energy efficient motor rating</b> | <b>30 kW</b>  |
| <b>Actual output required</b>        | <b>23.44 kW</b>   |
| <b>% loading of the motor</b>        | <b><math>23.44 / 30</math></b>  |
|                                      | <b>78 %</b>   |
|                                      |   |
| <b>Annual energy savings</b>         | <b><math>23.44(1/0.8863 - 1/0.92) \times 7000 \times \text{Rs.}7</math></b> |
|                                      | <b>Rs.48020 /-</b>  |
|                                      |   |
| <b>Payback period</b>                | <b><math>(75,000 - 10,000) / 48020</math></b>                               |
|                                      | <b>1.35 years</b>   |

L 4 : a) The suction head of a pump is 3 m below the pump centerline. The discharge pressure is 2.8 kg/cm<sup>2</sup>. The flow rate of water is 120 m<sup>3</sup>/hr. Find out the pump efficiency if the actual power input of the connected motor is 17.0 kW with an operating efficiency of 0.90.

b) A V-belt driven reciprocating instrument air compressor was found to be maintaining a distribution system pressure of 7 kg/cm<sup>2</sup>g. 20% of the instrument air was used for control valves installed in a boiler house and requiring 6.5 kg/cm<sup>2</sup>g, whereas balance 80% of the instrument air was used for other application requiring 2 kg/cm<sup>2</sup>g. What would you like to advice in this situation?

Ans:

a)

Discharge Head : 2.8 kg/cm<sup>2</sup> equals 28 metre head.  
Suction Head : - 3 metre.  
Total Head : 28 – (-3) = 31 metre.

Hydraulic power  $P_h = Q \text{ (m}^3\text{/s)} \times \text{Total head, } h_d - h_s \text{ (m)} \times \rho \text{ (kg/m}^3\text{)} \times g \text{ (m/s}^2\text{)} / 1000$

Hydraulic Power :  $(120/3600) \times 1000 \times 9.81 \times 31/1000 = 10.137 \text{ kW}$

Pump Efficiency :  $100 \times 10.137/17 \times 0.9 = \underline{66.2 \%}$

b)

**It is advisable to**

- 1) **Provide a separate small air compressor operating at 7 kg/cm<sup>2</sup> g near the control valves and reduce the existing distribution system pressure from 7 kg/cm<sup>2</sup>g to 2 kg/cm<sup>2</sup>g for pneumatic instrument**
- 2) **Since there will be reduced leakage loss due to reduced system pressure, the compressor unloading may begin due to reduced demand. Reduce appropriately the motor pulley size in order to match the capacity**

L-5 Fill in the blanks for the following:

1. One ton of refrigeration (TR) is equal to 3.516 kW.
2. A four pole 15kW induction motor operating at 50 Hz, with 1% slip will have rotor input power of 15.15 kW
3. A Pitot tube is used to measure total pressure and static pressure to determine velocity pressure of the fluid
4. In case of centrifugal pumps, impeller diameter changes are generally limited to reducing the diameter to about 75% of maximum size.
5. The value, by which the pressure in the pump suction exceeds the liquid vapour pressure, is expressed as Net Positive Suction Head Available (NPSHA).
6. The parameter used by ASME to define fans, blowers and compressors is Specific ratio.
7. It is possible to run pumps in parallel provided their closed valve heads are similar.
8. If the evaporation loss is 16 cubic meters per cell and Cycles of Concentration is 3, the blow down requirement per cell of a cooling tower is 8 cubic meters per cell
9. A centrifugal pump raises water to a height of 12 metre . If the same pump handles brine with specific gravity of 1.2, the height the brine will be raised to is 12 metres or the same height
10. Installing the capacitor near motor terminals will increase the design power factor of the motor  
- True / False (False)

L-6 List five energy conservation measures each for any two of the following

- a) Energy use in buildings
- b) Compressed air system
- c) Pumps and pumping systems
- d) Lighting systems

Ans:

**a) Energy use in buildings**

Air-Conditioning System:

- *Weather-stripping of Windows and Doors* : Minimise exfiltration of cool air and infiltration of warm air through leaky windows and doors by incorporating effective means of weather stripping. Self-closing doors should also be provided where heavy traffic of people is anticipated.
- *Temperature and Humidity Setting*: Ensure human comfort by setting the temperature to between 23°C and 25°C and the relative humidity between 55% to 65%.
- *Chilled Water Leaving Temperature*: Ensure higher chiller energy efficiency by maintaining the chilled water leaving temperature at or above 7° C. As a rule of thumb, the efficiency of a centrifugal chiller increases by about 2¼ % for every 1° C rise in the chilled water leaving temperature.
- *Chilled Water Pipes and Air Ducts*: Ensure that the insulation of the chilled water pipes and ducting system is maintained in good condition. This helps to prevent heat gain from the surroundings.
- *Chiller Condenser Tubes* : Ensure that mechanical cleaning of the tubes is carried out at least once every six months. Fouling in the condenser tubes in the form of slime and scales reduces the heat transfer of the condenser tubes and thereby reducing the energy efficiency of the chiller.
- *Cooling Towers* : Ensure that the cooling towers are clean to allow for maximum heat transfer so that the temperature of the water returning to the condenser is less than or equal to the ambient temperature.
- *Air Handling Unit Fan Speed* : Install devices such as frequency converters to vary the fan speed. This will reduce the energy consumption of the fan motor by as much as 15%.
- *Air Filter Condition* : Maintain the filter in a clean condition. This will improve the heat transfer between air and chilled water and correspondingly reduce the energy consumption.

**b) Compressed Air Systems**

- Ensure air intake to compressor is not warm and humid by locating compressors in well-ventilated area or by drawing cold air from outside. Every 4°C rise in air inlet temperature will increase power consumption by 1 percent.
- Clean air-inlet filters regularly. Compressor efficiency will be reduced by 2 percent for every 250 mm WC pressure drop across the filter.

- Compressed air piping layout should be made preferably as a *ring main* to provide desired pressures for all users
- Compressed air leakage of 40- 50 percent is not uncommon. Carry out periodic leak tests to estimate the quantity of leakage.
- Install equipment interlocked solenoid cut-off valves in the air system so that air supply to a machine can be switched off when not in use.
- Present energy prices justify liberal designs of pipeline sizes to reduce pressure drops.
- If pressure requirements for processes are widely different (e.g. 3 bar to 7 bar), it is advisable to have two separate compressed air systems.
- Reduce compressor delivery pressure, wherever possible, to save energy.
- Retrofit with variable speed drives in big compressors, say over 100 kW, to eliminate the 'unloaded' running condition altogether.
- Keep the minimum possible range between load and unload pressure settings.
- Automatic timer controlled drain traps wastes compressed air every time the valve opens. So frequency of drainage should be optimized.
- A smaller dedicated compressor can be installed at load point, located far off from the central compressor house, instead of supplying air through lengthy pipelines.
- Misuse of compressed air such as for body cleaning, agitation, general floor cleaning, and other similar applications must be discouraged in order to save compressed air and energy
- Pneumatic transport can be replaced by mechanical system as the former consumed about 8 times more energy.

### c) Pumps & Pumping Systems

- Ensure adequate NPSH at site of installation
- Operate pumps near best efficiency point.
- Modify pumping system and pumps losses to minimize throttling.
- Adapt to wide load variation with variable speed drives or sequenced control of multiple units.
- Stop running multiple pumps - add an auto-start for an on-line spare or add a booster pump in the problem area.
- Use booster pumps for small loads requiring higher pressures.
- Increase fluid temperature differentials to reduce pumping rates in case of heat exchangers.
- Repair seals and packing to minimize water loss by dripping.
- Balance the system to minimize flows and reduce pump power requirements.
- Avoid pumping head with a free-fall return (gravity); use siphon effect to advantage.
- Conduct water balance to minimise water consumption

- In the case of over designed pump, provide variable speed drive, or downsize / replace impeller or replace with correct sized pump for efficient operation.
- Replace old pumps by energy efficient pumps
- Reduce system resistance by pressure drop assessment and pipe size optimisation

### d) Lighting System

- Switch off Lights When Not In Use
- Provision of Separate Switches for Peripheral Lighting : A flexible lighting system, which made use of natural lighting for the peripherals of the room.
- Install High Efficiency Lighting System : Use lamps with high luminous efficacy. For example, replacing incandescent bulbs with compact fluorescent lamps can reduce electricity consumption by 75% without any reduction in illumination levels.
- Fluorescent Tube Ballasts : The ballast losses of conventional ballast and electronic ballast are 12W and 2W respectively. Hence, consider the use of electronic ballast for substantial energy savings in the lighting system.
- Lamp Fixtures or Luminaires : Optical lamp luminaries made of aluminum, silver or multiple dielectric coatings have better light distribution characteristics. Use them to reduce electricity consumption by as much as 50% without compromising on illumination levels.
- Cleaning of Lights and Fixtures : Clean the lights and fixtures regularly. For best results, dust at least four times a year.
- Use Light Colors for Walls, Floors and Ceilings : The higher surface reflectance values of light colors will help to make the most of any existing lighting system.
- Lighting controls like timer controls, day light controls, voltage controllers, occupancy sensors, switching controls, PLC controls can be adopted.

..... End of Section - III .....