Paper 3 Green

22^{nd} NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS – JULY, 2022

PAPER – 3 : ENERGY EFFICIENCY IN ELECTRICAL UTILITIES

Date : 31.07.2022 Timings : 09:30-12:30 HRS Duration : 3 HRS Max. Marks : 150

Section – I: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

1.	In BEE Star labelled distribution transformers, which of following losses are defined? **a) total loss at 50% and 100% loading** b) total loss at 75 % loading c) total loss at 75% and 100% loading d) total loss at 100% loading
2.	Friction losses in a pumping system is a) inversely proportional to flow b) inversely proportional to cube of flow **c) proportional to square of flow** d) inversely proportional square of flow
3.	If V_1 is actual supply voltage and V_2 is the rated voltage of a capacitor, the reactive kVAr produced would be in the ratio of a) V_2^2/V_1^2 **b) V_1^2/V_2^2** c) $1 - V_2^2/V_1^2$ d) $1 + V_2^2/V_1^2$
4.	The blow down loss in a cooling tower depends on a) TDS in circulating water b) TDS in make-up water c) evaporation loss **d) all the above**
5.	Energy Star Label Rating scheme for Fluorescent lamp is based on: **a) Lumens per Watt at 100, 2000 and 3500 hours of use** b) End of Lamp Life in terms of burring hours c) Lumen depreciation at 2000 hours d) Color Rendering Index
6.	Identify the wrong statement from the following regarding Vapor Compression Refrigeration system a) condenser rejects heat to atmosphere b) evaporator removes heat from process or space c) compressor sends superheated vapor to condenser **d) high pressure sub-cooled liquid refrigerant returns back to evaporator**
7.	The efficiency of a pump does not depend on a) suction head b) discharge head **c) motor efficiency** d) density of liquid
8.	Which of the following is a positive displacement compressor? a) Screw compressor b) Reciprocating compressor c) Centrifugal compressor **d) Both a & b**
9.	The most energy intensive dryer among the following a) refrigeration b) desiccant (heat of compression) **c) desiccant (heatless purge)** d) desiccant (blower reactivated)

10.	The ratings of the PF correction capacitors at motor terminals for a 37 kW induction motor at 3000 rpm synchronous speed will be ____________ in comparison to the same sized induction motor at 1500 rpm synchronous speed a) more **b) less** c) same d) dependent on the connected load
11.	In a vapor compression refrigeration system, the component across which the enthalpy remains constant a) compressor b) condenser **c) expansion valve** d) evaporator
12.	A pump discharge has to be reduced from 120 m^3/hr to 100 m^3/hr by trimming the impeller. What should be the percentage reduction in impeller size? a) 83.3% **b) 16.7%** c) 50.0% d) 33.3%
13.	In an engine room 15 m long, 10 m wide and 4 m high, ventilation requirement for 20 air changes/hr is___________m^3/hr a) 30 b) 3000 **c) 12000** d) none of the above
14.	Which of the following type of lamps is most suitable for color critical applications ? **a) halogen lamps** b) LED lamps c) CFLs d) Low pressure sodium vapour lamp
15.	Which of the following is not true regarding system characteristic curve in a pumping system with large dynamic head ? a) System curve represents a relationship between discharge and head loss in a system of pipes **b) System curve is dependent on the pump speed** c) The basic shape of a system curve is parabolic d) System curve will start at zero flow and zero head if there is no static lift
16.	The inexpensive way to improve energy efficiency of a motor which operates consistently at below 40% of rated capacity is by _____. a) **Operating in Star mode** b) Replacing with correct sized motor c) Operating in delta mode d) Operating in VFD mode
17.	Installing larger diameter pipe in pumping system results in reduction in-------- a) static head b) **frictional head** c) both a and b d) neither a nor b
18.	If the delivery valve of the pump is throttled such that it delivers 30% of the rated flow, one of the best options for improved energy efficiency would be a) Trimming of the impeller b) Replacing the motor c) **Replacing with a smaller pump** d) operating with VFD
19.	A cooling tower is said to be performing well when: a) **approach is closer to zero** b) range is closer to zero c) approach is larger than design d) range is larger than design
20.	Capacitors with automatic power factor controller when installed in a plant: a) reduces active power drawn from grid b) reduces the voltage of the plant **c) reduces the reactive power drawn from grid** d) increases the load current of the plant
21.	For an air compressor with displacement of 100 CFM and system leakage of 10%, free air delivery is ______. a) 111.11 CFM b) 90 CFM **c) 100 CFM** d) None of the above

22.	If 30,000 kcal of heat is removed from a room every hour then the refrigeration tonnage will be nearly equal to a) 30 TR b) 15 TR **c) 10 TR** d) 100 TR
23.	A 500 cfm reciprocating compressor has a loading and unloading period of 5 seconds and 20 seconds respectively during a compressed air leakage test. The air leakage in the compressed air system would be a) 125 cfm **b) 100 cfm** c) 200 cfm d) none of the above
24.	The Solar Heat Gain Coefficient (SHGC) of window of a building is 0.30. This means that a) The window reflects back to exterior a minimum of 30 % of the sun's heat b) **The window allows 30 % of the sun's heat to pass through into the building interior** c) 70 % of the sun's heat is incident on the window d) The window allows 70 % of the sun's heat to pass through into interior of the buildings
25.	The illuminance is 20 lm/m² from a lamp at 1 meter distance. The illuminance at half the distance will be a) 401 lm/m² b) 10 lm/m² c) 20 lm/m² **d) 80 lm/m²**
26.	Use of soft starters for induction motors results in a) **Lower mechanical stress** b) Lower power factor c) Higher maximum demand d) All the above
27.	Energy performance index is calculated based on a) **total building annual energy consumption /built up area** b) total building annual energy consumption /carpet area c) total building annual energy consumption for HVAC and lighting /carpet area d) none of the above
28.	A 4 pole 50 Hz induction motor is running at 1470 rpm. What is the slip value? a) 20% b) **2%** c) 4% d) 40%
29.	Which of the following power plants has the highest efficiency? a) Open cycle Gas Turbine b) Diesel Engine c) **Combined cycle gas turbine** d) Conventional coal plants
30.	____________is used as refrigerant both in vapour compression and vapour absorption systems a) Lithium Bromide b) Water c) HFC 134A d) **Ammonia**
31.	Which of the following parameters is not required for evaluating volumetric efficiency of reciprocating air compressor? a) **Power input** b) FAD c) Cylinder Stroke d) Cylinder bore
32.	The gross efficiency of a coal based power generating unit with a gross heat rate of 2600 kcal / kWh is ________ a) 41.4% b) 38.7% **c) 33.1%** d) 30.8%

33\. The COP of a vapour compression refrigeration system is 3.3. If the motor draws power of 10 kW at an operating efficiency of 90%, the tonnage of refrigeration system is about:

a) 0.8
b) 8.5
c) 7.2
d) 9.6

34\. Increasing the suction pipe diameter in a pumping system will

a) Decrease NPSHA
b) Increase NPSHA
c) Decrease NPSHR
d) Increase NPSHR

35\. For a Cooling Tower, if evaporation loss is 15 m^3 / hour and Cycles of Concentration is 2.5, the blowdown is equal to

a) 6 m^3 / hour
b) 10 m^3 / hour
c) 22.5 m^3 / hour
d) 37.5 m^3 / hour

36\. In T-5 Fluorescent Lamp, "5" is indicative of:

a) 5 watt power rating
b) 5% Energy Saving with respect to T8
c) 5^{th} generation lamp
d) Tube diameter

37\. Which of the following is not likely to create harmonics in an electrical system?

a) soft starters
b) variable frequency drives
c) uninterrupted power supply source (UPS)
d) **electric heater**

38\. The performance of rewinding of an induction motor can be assessed by which of the following factors?

a) load current
b) stator resistance
c) no load current
d) both b and c

39\. In a DG set, a 3-phase alternator is supplying on an average 100 A at 420 V and 0.9 pf to a load. If the specific fuel consumption of this DG set is 0.30 lts/ kWh at that load, then how much fuel is consumed while delivering generated power for one hour?

a) 11.34 litre
b) 19.64 litre
c) 21.82 litre
d) 1964.088 litre

40\. The total loss for a transformer loading at 60% with no load and full load losses of 3 kW and 25 kW respectively, is

a) 3 kW
b) 12 kW
c) 18 kW
d) 25 kW

41\. A process fluid at 40 m^3/hr, with a density of 0.95, is flowing in a heat exchanger and is to be cooled from 35 ^oC to 29 ^oC. The fluid specific heat is 0.78 kCal/kg. If the chilled water range across the heat exchanger is 4 ^oC, the chilled water flow rate is

a) 44.46 m^3/hr
b) 40.41 m^3/hr
c) 35.37 m^3/hr
d) none of the above

42.	In which of the following fans the air does not change flow direction from suction to discharge? a) tube axial fan b) vane axial fan c) propeller fan **d) all the above**
43.	What is window to wall ratio________ **a) Vertical fenestration area / gross exterior wall area** b) Vertical fenestration area / Net exterior wall area c) gross exterior wall area/ Vertical fenestration area d) Net exterior wall area/ Vertical fenestration area
44.	The maximum thermal efficiency of a diesel engine power plant is in the range of _____ **a) 43-45 %** b) 53-55% c) 63-65 % d) 73-75%
45.	The advantage of multi-staging compression over single stage compression is a) Lower power consumption per unit of air delivered b) High volumetric efficiency c) Decreased discharge temperature **d) All of above**
46.	The specific ratio as defined by ASME and used in differentiating fans, blowers and compressors, is given by **a) discharge pressure/suction pressure** b) suction pressure/discharge pressure c) discharge pressure/ (suction pressure + discharge pressure) d) suction pressure/ (suction pressure + discharge pressure)
47.	A device that distributes filters or transforms the light emitted from one or more lamps is a) Control gear **b) Luminaire** c) Lamp d) Starter
48.	For the same quantity of power handled by a distribution line, lower the voltage a) lower the current drawn and lower the distribution loss b) lower the voltage drop and lower the distribution loss c) **higher the current drawn and higher the distribution loss** d) higher the voltage drop and lower the distribution loss
49.	The power drawn by a centrifugal fan is **a) inversely proportional to fan efficiency** b) directly proportional to fan efficiency c) inversely proportional to static pressure d) inversely proportional to flow rate
50.	In a transformer on load, if the secondary voltage is one-fourth the primary voltage, then the secondary current will be **a) four times the primary current** b) sixteen times the primary current c) one-fourth the primary current d) two times the primary current

-------- **End of Section - I** --------

Section – II: SHORT DESCRIPTIVE QUESTIONS **Marks: 8 x 5 = 40**

<table>
<tr><td>S-1</td><td>a) A plant has installed a refrigerant dryer for supplying dry air for their process applications and dryer coil is maintained at 5 ^{0}C & 100% RH. The average air flow through the dryer is 100 kg/min. The air properties are given below 3 Marks

Parameter	Enthalpy (kJ/kg of dry air)	Absolute Humidity (grams/kg of dry air)
Inlet air 35 ^{0}C & 50% RH	81	18
Dryer coil 5 ^{0}C & 100% RH	19	5.5

Calculate the following:
i) Moisture removed per hour.
ii) Cooling capacity of coil in TR.

List down any three energy saving measures in compressed air systems. 2 Marks</td></tr>
<tr><td>Ans</td><td>a)
i) Moisture removed = 100 x (18 - 5.5)
= 1250 grams/min = 1.25 kg/min = 75 kg/hr
ii) TR = 100 x (81 - 19)
= 6200 kJ/min = 6200/(4.186) = 1481.13 kcals/min
= 1481.13*60/3024
= 29.39 TR

b) Energy saving measures -for compressed air system

Refer Guide Book-3, Page no: 80-99</td></tr>
<tr><td>S-2</td><td>A DISCOM has taken initiatives to reduce Aggregate Technical & Commercial (AT & C) losses in their network. The energy supplied, received and revenue details are given below:

Input energy : 50 MU
Billed Energy (Metered) : 39 MU
Billed Energy (Un-metered) : 2 MU
Amount Billed : Rs. 470 Million
Arrears collected : Rs. 30 Million
Gross Amount collected : Rs. 390 Million
a) Estimate the AT & C losses (in %) 3 Marks

List any four strategies to reduce the commercial losses. 2 Marks</td></tr>
<tr><td>Ans</td><td>a)

Billing efficiency % = (Total Units billed, MU/ Total Input, MU) x 100

= [(39 + 2) / 50] x 100 = 82%

Collection efficiency, % = (Gross amount collected-Arrears, Rs. / Amount billed,Rs.) x 100

= [(390 - 30) / 470)] x 100 = 76.6%

AT & C Loss = [1 - (Billing efficiency x Collection Efficiency)] x 100

= [1 - (0.82 x 0.766)] x 100 = 37.19%

b) Strategies to reduce commercial losses.

Refer Guide Book-3, Page no: 27</td></tr>
</table>

S-3	The size of an air-conditioned office is 12 m X 7 m. Desired illuminance level is 200 Lux. An architect has suggested to install 24 no's of 20 W LED lights at a height of 3 m from ground level. The working plane is 0.75 m above the floor. The other details of 20W LED lamps are: • Output of LED Lamp : 2000 lumens • Utilization factor : 0.65 • Light Loss Factor (LLF) : 0.75 Calculate Room Index & number of LED lights required to get the desired illuminance. As an energy manager do you agree with the architect decision-why?
Ans	Mounting Height, $H_m = 3 – 0.75 = 2.25$ m Room Index (RI) = $[L \times W] / [H_m \times (L + W)]$ = [12 x 7] / [2.25 x (12 + 7)] = 1.97 Number of LED lights = $\frac{E \times A}{F \times UF \times LLF}$ = $\frac{200 \times (12 \times 7)}{2000 \times 0.65 \times 0.75}$ = 17.23 So total number of 20 W LED lights required is 18 nos No, I don't agree with architect decision as number of LED light required is only 18 against suggested of 24 nos which is an energy inefficient design.
S-4	A centrifugal fan drawing 54 kW and operating at 1440 RPM is delivering air at 30000 m^3/hr. The head developed by the fan is 400mmWC, If the speed is decreased by 200 rpm, calculate the following a) Air Flow in m^3/hr (1 mark) b) Static Pressure in mmWC (2 marks) c) Power drawn in kW (2 marks)
Ans	1. Air flow in m^3/hr = (1240/1440) *30000 = 25833.33 m^3/hr 2. Static Pressure in mmWC =$(1240/1440)^2$ *400 = 296.61 mmWC 3. Power drawn in kW =$(1240/1440)^3$ *54 =34.48 kW
S-5	State True or False. (1 Mark each)
Ans	1. An industrial electrical system is operating at unity power factor. Addition of further capacitors will reduce the maximum demand (kVA). **- False** 2. In a step-down transformer for a given load the current in the primary will be more than the current in the secondary. **- False** 3. For the same no of poles and kW rating, the RPM of an energy efficient motor is higher than that of a standard motor. **– True** 4. The advantage of evaporative cooling is that it is possible to obtain water temperatures below the wet bulb economically. **– False** 5. A fluid coupling changes the speed of the driven equipment without changing the speed of the motor. **– True**
S-6	The input parameter measured for a 15 kW, 3 phase, 415 V induction motor is 25 A and 12 kW at 410 V. Calculate the following a) Apparent Power drawn by the motor at the operating load (1 Mark) b) Reactive Power drawn by the motor at the operating load (3 Marks) c) Operating power factor (1 Mark)
Ans	Apparent power = 1.732 x 0.410 x 25 = 17.75 KVA Reactive power = sqrt (apparent power^2 - active power^2) Active power = 12 kW

	Reactive power = sqrt $(17.75^2 - 12^2)$ = sqrt (171.06) = 13.07 kVAr Operating power factor = Active power/Apparent power = 12/17.75 = 0.676
S-7	The total system resistance of a water supply piping system is 30 meters and the static head is 10 meters at designed water flow. Calculate the system resistance offered at 75%, 50% and 25% of water flow.
Ans	Total System Resistance of piping system: 30m Static Head :10 m **(Static head will remain same irrespective of the flow)** So, Dynamic Head at designed water flow: (30-10) =20m

No.	Flow %	Static Head (m)	Dynamic Head (m) = 20 x $(\%flow)^2$	Total System Resistance (m)
1	75%	10	11.25	21.25
2	50%	10	5.0	15.0
3	25%	10	1.25	11.25

S-8	An energy audit study of a central chiller system in a commercial building was conducted and measured parameters are given below. Chilled water inlet temperature :12 ^{0}C Chilled water Outlet temperature :7 ^{0}C Chilled water pump discharge pressure : 3.6 kg/cm^{2}g Pump suction is 5 meters above the pump center line Power drawn by the chilled water pump motor:70 kW Efficiency of pump motor : 93 % Pump efficiency: 60 % Find out the operating load of the Chiller system in TR.
Ans	Total head 36 –5 = 31 m Pump shaft power 70 x 0.93 = 65.1 kW Flow rate = (65.1 x 1000) X 0.6 / 31 x 1000 x 9.81 = 0.128 m^3/s or 460.8 m^3/hr Refrigeration load (460800 x 5) / 3024 = 761.9 TR

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

Section – III: LONG DESCRIPTIVE QUESTIONS **Marks: 6 x 10 = 60**

L-1	**Fill in the blanks for the following** 1. The main input energy used for refrigeration in vapor absorption refrigeration plants is____ 2. One ton of refrigeration is equivalent to ______kW 3. Stray losses in an induction motor generally are proportional to the square of the ________current 4. The unit of AAhEPI is ______ 5. If the pump impeller diameter is reduced by 10% then head reduces by ______% 6. A 4 pole,50Hz motor operating with slip of 3% will have a shaft speed of ______RPM 7. Effective Aperture Glazing (EA) = VLT x ______ 8. In an amorphous core distribution transformer, no-load loss is ______ than a conventional transformer 9. As the condensing temperature increases, kW/TR of refrigeration system will ______ 10. The extent of drying compressed air is expressed by the term ______

Ans	1. Thermal energy (or steam or waste heat or gas or any energy related to thermal energy) 2. 3.51 3. Load current 4. Wh/sqm/hr 5. 19% 6. 1455 7. Window to wall ratio 8. Less 9. Increase 10. Atmospheric Dew point /Dew Point
L-2	In a steel industry, cooling water of 7500 m^3/hr and 4200 m^3/hr from two different sections with temperatures of 38 ^{0}C and 55 ^{0}C respectively, are fed to cooling tower after proper mixing. If the measured heat rejection by the cooling tower is 38,000 TR, calculate the effectiveness and evaporation loss of the cooling tower at 28 ^{0}C WBT.
Ans:	Mixed Hot Water Temp, ^{0}C = [(Flow1 x Temp1) + (Flow2 x Temp2)] / (Total Flow) = [(7500 x 38) + (4200 x 55)] / 11700 = 44.1 ^{0}C Range of Cooling Tower, ^{0}C = Heat Rejection / (Flow x Density x Sp. Heat) = (38000 x 3024) / (11700 x 1000 x 1) = 9.82 ^{0}C Cold Water Temp, ^{0}C = Mix Hot Water Temp – Range = 44.1 – 9.82 = 34.28 ^{0}C Approach, ^{0}C = Cold Water Temp – WBT of Air = 34.28 – 28 = 6.28 ^{0}C Effectiveness = Range / (Range + Approach) = 9.82 / (9.82 + 6.28) = 60.99% or 61% Evaporation Loss (m^3/hr) = 0.00085 x 1.8 x circulation rate (m^3/hr) x Range = 0.00085 x 1.8 x 11700 x 9.82 = 175.8 m^3/hr
L-3	Write short notes on the following : (each 2 Marks) a) Energy Performance Index (EPI) b) List any two Energy Efficiency measures in Building air conditioning system c) Building Envelop from an energy efficiency point of view. d) Difference between building area method and space function method for deriving Lighting Power density (LPD) e) Solar Heat Gain Coefficient (SHGC)
Ans	a) Refer Guide Book No 3, Chapter 10, Page No 287 b) Refer Guide Book No 3, Chapter 10, Page No 288 c) Refer Guide Book No 3, Chapter 10, Page No 270 d) Refer Guide Book No 3, Chapter 10, Page No 281 e) Refer Guide Book No 3, Chapter 10, Page No 272
L-4	a) During the performance evaluation of a DG set, the following parameters were noted

Capacity of DG set	750	kVA
Test duration	36	minutes
Units generated	250	kWh
Average Power factor	0.92	pf
Length of diesel tank	100	cm

Width of diesel tank	100	cm
Height of the diesel tank	90	cm
Initial tank dip level (from top)	63	cm
Final tank dip level (from top)	53	cm

Calculate the following:

1. Diesel consumption (Litres) **(1 Mark)**
2. Average load (kW) **(1 Mark)**
3. Percentage Loading (%) **(2 Marks)**
4. Specific power generation (kWh/Litre) **(1 Mark)**

b) A medium sized engineering industry has installed two 480 CFM screw compressors, A & B. Compressor-A is operating at full load and Compressor-B is running in load - unload condition. The load power of both the compressor is 74 kW and the unload power of the Compressor-B is 26 kW. Both the compressors are operated during working day.

The percentage loading of the Compressor-B during working day is 70 %. After arresting the leakage in the system the loading of the compressor was found to be 35 %. Estimate the energy savings per day. **5 Marks**

Ans

a)

1.	Diesel Consumption	=	(1x1x 0.1)x 1000	=100 Liters
2.	Average load (kW)	=	(250/36)x60	=416.67 kW
3.	Percentage Loading (%)	=	(416.6/.92)/750	=60.4 %
4.	Specific power generation (kWh/Litre)	=	(250/100)	=2.5 kWh/Litre

b)

<u>Existing Case:</u>

Energy consumed per hour by Compressor -A= 74 kWh

Energy consumed per hour by Compressor -B= 0.70 x 74 + 0.30 X 26 = 59.6 kwh

Total energy consumed (Compressor A& B) = 74 + 59.6 = 133.6 kWh/hr

Energy consumed per day= 133.6 X 24 hrs = 3206.4 kWh/day

<u>Leakage Calculation</u>

Energy consumed per hour by Compressor -B= 0.70 x 74 + 0.30 X 26 = 59.6 kwh

Energy consumed per hour by Compressor -B= 0.35 x 74 + 0.65 X 26 = 42.8 kWh

Difference in power consumption = 59.6 - 42.8 = 16.8 kWh/hr

Savings by arresting leakage per day= 16.8 X 24 = 403.2 kWh/day

L-5 The data for centrifugal chiller and vapour absorption chiller are given below

Parameter	Centrifugal chiller	VAM
Chilled water flow (m^3/h)	189	180
Condenser water flow (m^3/h)	238	340
Chiller inlet temp (°C)	13.0	14.6

	Condenser water inlet temp (°C)	27.1	33.5
	Chiller outlet temp (°C)	7.7	9.0
	Condenser water outlet temp (°C)	35.7	39.1
	Power drawn by compressor (kW)	190	-
	Steam consumption (kg/h)	-	1570
	Chilled water pump (kW)	28	28
	Condenser water pump (kW)	22	33
	Cooling tower fan (kW)	6.0	15
	Cost of Steam (Rs/kg)	-	2.0
	Cost of electricity (Rs/kWh)	9.0	9.0

a) Evaluate the tonnes of refrigeration (TR) of both the systems? (4 Marks)
b) Operating Energy cost per hour for both the systems? (6 Marks)

Ans

a) Refrigeration load (TR) = Chilled water flow (m^3/hr.) x Spec. heat x Diff. in temp. / 3024

Centrifugal chiller TR = 189 x 1000x 1 x (13-7.7) / 3024 = 331.25 TR

VAM TR = 180 x 1000x 1 x (14.6-9.0) / 3024 = 333.33 TR

b) Auxiliary power consumption : Chilled water pump + condenser water pump + cooling tower fan

Auxiliary power (kW) : 28 + 22 + 6.0 = 56 kW

VAM auxiliary power (kW) : 28 + 33 + 15 = 76 kW

Energy cost of centrifugal chiller =(56+190)*9= Rs 2214/hr

Energy cost of VAM system = (76*9)+(1570*2)

= Rs 3824 /hr

L-6 A review of electricity bills of a process plant was conducted as a part of energy audit. The plant has a contract demand of 3000 kVA with the power supply company. The average maximum demand of the plant is 2000 kVA/month at a power factor of 0.95. The maximum demand is billed at the rate of Rs.350/kVA/month. The minimum billable maximum demand is 80% of the contract demand.

An incentive of 0.5 % reduction in energy charges component of electricity bill are provided for every 0.01 increase in power factor over and above 0.95. The average energy charge component of the electricity bill per month for the plant is Rs.80 lakhs.

Calculate the following

a) If the plant decides to improve the power factor to unity, determine the power factor capacitor kVAr required and the annual monetary benefits. **6 Marks**
b) What will be the simple payback period if the cost of power factor capacitors is Rs.1200/kVAr. **4 Marks**

Ans

kW drawn	= 2000 x 0.95 = 1900 kW
KVAr required to improve power factor from 0.95 to 1	= kW ($\tan \theta_1 - \tan \theta_2$)
	= kW ($\tan(\cos^{-1}\varphi_1) - \tan(\cos^{-1}\varphi_2)$)
	= 1900 ($\tan(\cos^{-1}0.95) - \tan(\cos^{-1}1)$)
	= 1900(0.329 - 0)
Power Factor Capacitor KVAr required	= 625.1 kVAr

		Cost of P.F. capacitors @Rs.1200/kVAr	= 625 KVAr x 1200 Rs. / kVAr	
			= Rs.7,50,120/-	
		Maximum Demand at unity power factor	= 1900/1 = 1900 kVA	
		80% of contract demand (3000 kVA)	= 3000x 0.8 =2400kVA	
		Reduction in Maximum Demand charges	(NIL) Though demand is reduced to 1900 KVA as per minimum billing requirement plant has to pay for 2400 KVA.	
		Percentage reduction in energy charge from 0.95 to 1 @ 0.5 % for every 0.01 increase	= ((1-0.95)/0.01) x (0.5%) = 5 x 0.5% = 2.5 %	
		Monthly energy cost component of the bill	= Rs.80,00,000	
		Reduction in energy cost component	= 80,00,000 x (2.5/100)	
			= Rs.2,00,000/month	
		Annual reduction in energy cost component owing to P.F. improvement	= Rs.2,00,000 x 12 = 24,00,000/- per year	
		Annual Savings in electricity bill	= Rs.0+ 24,00,000= Rs. 24,00,000/-	
		Investment	= Rs.7,50,000/-	
		Payback period	= (Investment / Annual Savings) X 12 = (Rs.7,50,000/ 24,00,000) X 12	
			= 3.75 months	

-------- **End of Section - III** --------