

### **Chapter 3.1: Electrical System**

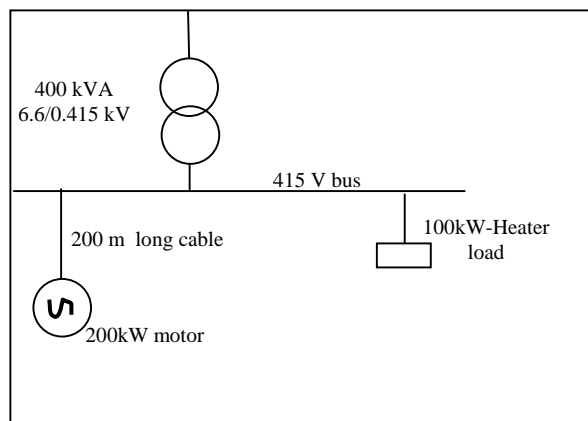
#### **Part-I: Objective type Questions and Answers**

1.	The heat input required for generating 'one' kilo watt-hour of electrical output is called as ____. a) Efficiency    b) <u>Heat Rate</u> c) Calorific Value    d) Heat value
2.	Which of the voltage is not available for Indian distribution system? a) 33 kV    b) 11 kV    c) <u>280 V</u> d) 433 V
3.	The power loss in transmission/distribution line depends on _____. a) Current in the line    b) Resistance of the line    c) Length of the line    d) <u>All</u>
4.	If distribution of power is raised from 11 kV to 66 kV, the voltage drop would lower by a factor a) 6 times    b) <u>1/6 times</u> c) 36 times    d) 1/36 times
5.	If the distribution voltage is raised from 11 kV to 33 kV, the line loss would be lower by a factor: a) <u>1/9</u> b) 9    c) 3    d) None
6.	The maximum demand of an industry, if trivector meter records 3600 KVA for 15 minutes and 3000 kVA for next 15 minutes over a recording cycle of 30 minutes is _____. a) 3600 kVA    b) 3000 kVA    c) <u>3300 kVA</u> d) 600 kVA
7.	Presenting the load demand of a consumer against time of the day is known as _____. a) Time Curve    b) <u>Load curve</u> c) Demand curve    d) Energy curve
8.	The vector sum of active power and reactive power required is _____. a) <u>Apparent Power</u> b) Power Factor    c) Load Factor    d) Maximum Demand
9.	Power factor is the ratio of _____ and apparent power. a) <u>Active power</u> b) Reactive power    c) Load Factor    d) Maximum Demand
10.	The kVAr rating required for improving the power factor of a load operating at 500 kW and 0.85 power factor to 0.95 is _____. a) <u>145 kVAr</u> b) 500 kVAr    c) 50 kVAr    d) 100 kVAr
11.	The rating of the capacitor at motor terminals should not be greater than _____. a) magnetizing kVAr of the motor at full load    b) <u>magnetizing kVAr of the motor at no load</u> c) magnetizing kVAr of the motor at half load    d) magnetizing kVAr of the motor at 75% load
12.	The percentage reduction in distribution losses when tail end power factor raised from 0.8 to 0.95 is _____. a) <u>29%</u> b) 15.8%    c) 71%    d) 84%
13.	If voltage applied to a 415 V rated capacitors drops by 10%, its VAR output drops by _____. a) 23%    b) 87%    c) <u>19%</u> d) 10%
14.	The ratio between the number of turns on the secondary to the turns on the primary of a transformer is know as: a) <u>turns ratio</u> b) efficiency    c) winding factor    d) power factor

15.	The sum of individual maximum demand of the plant to the sum of individual maximum demand of various equipments is _____. a) load factor    b) <u>diversity Factor</u> c) demand Factor    d) maximum demand
16.	Core losses in transformer are caused by _____. a) Hysteresis loss    b) Eddy current loss    c) <u>both a &amp; b</u> d) None
17.	The load losses in transformer vary according to _____. a) Loading of transformer    b) <u>Square of loading of transformer</u> c) Cube of loading of transformer    d) None
18.	The total losses in a transformer operating at 50% load with designed no load and load losses at 2 kW and 20 kW respectively are _____. a) <u>7 kW</u> b) 12 kW    c) 4.5 kW    d) 22 kW
19.	The total amount of harmonics present in the system is expressed using _____. a) Total Harmonic Factor    b) Total Harmonic Ratio c) <u>Total Harmonic Distortion</u> d) Crest Factor
20.	The 5 <sup>th</sup> and 7 <sup>th</sup> harmonic in a 50 Hz power environment will have: a) voltage and current distortions with 55 Hz & 57 Hz b) voltage and current distortions with 500 Hz & 700 Hz c) <u>voltage and current distortions with 250 Hz &amp; 350 Hz</u> d) no voltage and current distortion at all

### **Part II: Short type Questions and Answers**

1.	Define "Heat Rate" in the simplest form? "HEAT RATE" is a quantity of heat input in "kilo Calories" or "kilo Joules", for generating 'one' kilo Watt hour of electrical output.
2.	List all the important and useful parameters that a tri-vector meters records for industry/utility electricity billing. The important parameters that are read from "Trivector meters" for a billing cycle are: a) Maximum demand during the month (kW or kVA) b) Active energy (kWh) c) Reactive energy (kVARh) d) Apparent energy (kVAh) Apart from this it can also read other instantaneous values like, voltage & current, power factor, etc.
3.	The following single line diagram explain the location of 100 kW heater load and 200 kW motor, which is at 200 mtrs away from 415V, LT bus using suitable cable. The main incoming power factor of system is 0.85 lag. Calculate the rating of capacitors to improve pf of incomer to 0.9 lag.



Total Inductive load requiring PF compensation=200kW (since the other 100 kW is a resistive load)

Operating PF  $\cos \phi_1 = 0.85$  lag.

Desired PF  $\cos \phi_2 = 0.90$  lag

$$\begin{aligned} \text{kVAr required} &= \text{kW}((\tan(\cos^{-1}\phi_1) - \tan(\cos^{-1}\phi_2))) \\ &= 200(\tan(\cos^{-1}0.85) - \tan(\cos^{-1}0.90)) \\ &= 200(\tan(31.78) - \tan(25.84)) \\ &= 200(0.619 - 0.484) \\ &= 200(0.135) \\ &= 27 \text{ kVAr} \end{aligned}$$

4. During April-2003, the plant has recorded a maximum demand of 600 kVA and average PF is observed to be 0.82 lag, The minimum average PF to be maintained is 0.92 lag as per the independent utility supplier and every one % dip in PF attracts a penalty of Rs 10,000/in each month.

- a) Calculate the improvement in PF for May-2003 by installing 100kVAr capacitors.
- b) Calculate penalty to be paid if any during May-2003.

Ans. Recorded Maximum Demand = 600kVA @ 0.82 lag

a. (i) From power triangle, operating kW = kVA x PF = 600 x 0.82 = 492 kW

(ii) kVAr required at 0.82 PF =  $\sqrt{(600^2 - 492^2)}$  = 343 kVAr

(iii) Since 100 kVAr compensation is proposed, the new load kVAr would be :243 kVAr

New kVA after 100kVAr compensation:  $\sqrt{\text{kW}^2 + (\text{kVAr})_{new}^2} = \sqrt{(492)^2 + (243)^2} = 548 \text{ kVA}$

b. New pf with 100 kVAr =  $\frac{\text{kW}}{\text{kVA}} = \frac{492}{548} = 0.898 \approx 0.90$  lag.

The difference between tariff requirement and actual is less by 0.92-0.90 = 0.02 or 2%.

Penalty to be paid=Rs. 10,000 x 2 = Rs. 20,000 for May-2003

5.	<p>Compute the MD recorded for a plant where the recorded load is as mentioned below in the recording cycle of 30 minutes.</p> <ul style="list-style-type: none"> <li>- 1000 kVA for 5 minutes</li> <li>- 200 kVA for 5 minutes</li> <li>- 500 kVA for 10 minutes</li> <li>- 800 kVA for 8 minutes</li> <li>- 1500 kVA for 2 minutes</li> </ul> <p>The MD recorder will be computing MD as:</p> $\frac{(1000 \times 5) + (200 \times 5) + (500 \times 10) + (800 \times 8) + (1500 \times 2)}{30} = 680kVA$
6.	<p>What are the different reactive power compensation options available in an electrical system? Following are the possible reactive power compensations methods:</p> <ul style="list-style-type: none"> <li>a) Use of HT capacitors</li> <li>b) Use of LT capacitors</li> <li>c) Use of synchronous motors</li> <li>d) Proper sizing of motors based on loads and use of energy efficient motors.</li> </ul>
7.	<p>Explain tariff based on “two part” basis which is generally applicable for most of medium and large type of industrial enterprises in India?</p> <p>The two part tariff has one part for capacity (or demand) drawn and the second part for actual energy drawn during the billing cycle. Capacity or demand is in kVA (apparent power) or kW terms. The reactive energy (i.e.) kVArh drawn by the service is also recorded and billed for in some utilities, because this would affect the load on the utility. In addition, other fixed expenses are also levied like tax, meter rent etc.</p>
8.	<p>What are the benefits of power factor improvement?</p> <p>The following are the benefits of PF improvement:</p> <ul style="list-style-type: none"> <li>(i) Reduced KVA (Maximum demand) charges in utility bill</li> <li>(ii) Avoidance of penalty on PF if relevant.</li> <li>(iii) Option of availing any incentives the utility offers on high power factor.</li> <li>(iv) Better voltage at load ends (improved voltage regulation)</li> <li>(v) Reduced distribution losses (kWh) within the plant network</li> </ul>
9.	<p>Which is the best location for capacitor banks for power factor improvement from energy conservation point of view?</p> <p>Locating capacitors at tail or load end will help to reduce losses within the plants distribution network. Further the voltage at tail end will also improve, thus the performance of equipment will improve.</p>
10.	<p>What are the important conditions one should consider before transformers are connected in parallel?</p> <p>Satisfactory parallel operations of two transformers depend on the following key factors. Both transformers should have the same:</p> <ul style="list-style-type: none"> <li>a) voltage ratio</li> <li>b) polarity</li> </ul>

	<p>c) phase sequence</p> <p>d) percentage impedance</p> <p>e) phase angle between primary and secondary terminals.</p>
11.	<p>Calculate the transformer total losses for a transformer loading at 60% and with no load and full load losses of 3 kW and 25 kW respectively?</p> <p>Transformer losses = No load losses + (% loading)<sup>2</sup> x Full load losses</p> <p>= 2 + (0.6)<sup>2</sup> x 25</p> <p>= 11 kW</p>
12.	<p>What are the likely affects on plant's electricity bill if Power Factor is found to be low say 0.7?</p> <ul style="list-style-type: none"> <li>* It would have attracted penalty towards low PF as per utility tariff stipulations</li> <li>* It might have lead to recording excess demand (kVA or kW) and in turn high fixed charges.</li> </ul>
13.	<p>Define load factor. Calculate annual load factor (%) in a facility having an annual consumption of 150.0 lakh kWh, maximum demand of 2421 kVA at 0.95 PF lag.</p> <p>Load factor is a ratio of the average demand (kVA or kW) to the peak demand for a power system.</p> <p>Average yearly consumption = 150.0 lakh kWh</p> <p>Load Factor = 150,00, 000/(8760 hr x 2421 x 0.95)</p> <p>LF = 74.45%</p>
14.	<p>Refer the sketch below:</p> <p>In the above facility, determine the best option to reduce transformer losses even considering long-term options. Indicate other system benefits if any.</p> <p>Instead of two step transformation in power supply, one new transformer of voltage ratio 11/0.433kV can be installed and losses can be minimized.</p> <p>In addition cost of maintaining two transformers, cables, switchgears etc. can be minimized.</p> <div style="border: 1px solid black; padding: 10px; margin: 10px auto; width: fit-content;"> </div>
15.	<p>What do you mean by better 'load management' from the point of view of electric supply utility?</p> <p>The popular measures for better load management by supply utilities include the issues relating to:</p> <ul style="list-style-type: none"> <li>• time of day tariff (ToD)</li> <li>• penalties on exceeding allowed maximum demand</li> </ul>

16.	<p>Name two types of transformer losses and write a brief note on this.</p> <p>Transformer losses consist of two parts: No-load loss and Load loss</p> <ol style="list-style-type: none"> <li>1. No-load loss (also called core loss) is the power consumed to sustain the magnetic field in the transformer's steel core. Core loss occurs whenever the transformer is energized; core loss does not vary with load. Core losses are caused by two factors: hysteresis and eddy current losses. Hysteresis loss is that energy lost by reversing the magnetic field in the core as the magnetizing AC rises and falls and reverses direction. Eddy current loss is a result of induced currents circulating in the core.</li> <li>2. Load loss (also called copper loss) is associated with full-load current flow in the transformer windings. Copper loss is power lost in the primary and secondary windings of a transformer due to the ohmic resistance of the windings. Copper loss varies with the square of the load current. (<math>P=I^2R</math>).</li> </ol>
17.	<p>Explain what you have understood by 'total harmonic distortion or THD'</p> <p>In case of harmonics, the 'magnitude' and 'order' of harmonics is governed by the nature of device being used and the impact is expressed as "total harmonic distortion" or THD</p>
18.	<p>List any five problems that can arise due to harmonics in a system.</p> <p>The problems that arise due to harmonics in a system are:</p> <ol style="list-style-type: none"> <li>1. Blinking of Incandescent Lights - Transformer Saturation</li> <li>2. Capacitor Failure - Harmonic Resonance</li> <li>3. Circuit Breakers Tripping - Inductive Heating and Overload</li> <li>4. Conductor Failure - Inductive Heating</li> <li>5. Electronic Equipment Shutting down - Voltage Distortion</li> </ol>
19.	<p>List down any three common type of devices which cause harmonics in the system?</p> <ol style="list-style-type: none"> <li>1. Electronic switching power converters</li> <li>2. Arcing devices</li> <li>3. Ferromagnetic devices</li> </ol>
20.	<p>What are the likely affects of voltage deviations from rated voltages in an electrical system?</p> <p>The likely affects of voltage deviations from rated voltages are</p> <ol style="list-style-type: none"> <li>1. Over voltages for motors</li> <li>2. reduce efficiency, power actor and equipment life</li> <li>3. increased temperature</li> </ol>

**Part III: Long Type Questions & Answers**

1.	<p>Define components of tariff structure? Explain in detail.</p> <p>The tariff structure generally includes the following components:</p> <p><i>a) Maximum demand Charges</i></p> <p>These charges relate to maximum demand registered during month/billing period and corresponding rate of utility.</p> <p><i>b) Energy Charges</i></p> <p>These charges relate to energy (kilowatt hours) consumed during month / billing period and corresponding rates, often levied in slabs of use rates. Some utilities now charge on the basis of apparent energy (kVAh), which is a vector sum of kWh and kVArh.</p> <p><i>c) Power factor penalty or bonus rates, as levied by most utilities, are to contain reactive power</i></p>
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	<p>drawl from grid.</p> <p><i>d) Fuel cost adjustment charges as levied by some utilities are to adjust the increasing fuel expenses over a base reference value.</i></p> <p><i>e) Electricity duty charges levied w.r.t units consumed.</i></p> <p><i>f) Meter rentals</i></p> <p><i>g) Lighting and fan power consumption is often at higher rates, levied sometimes on slab basis or on actual metering basis.</i></p> <p><i>h) Time Of Day (TOD) rates like peak and non-peak hours.</i></p> <p><i>i) Penalty for exceeding contract demand</i></p> <p><i>j) Surcharge if metering is at LT side in some of the utilities</i></p>																																																																		
2.	<p>Calculate the following from the data given below:</p> <p>a) kVAr required to improve PF to 0.95 lag</p> <p>b) reduction in kVA demand</p> <p>c) techno-economics of PF improvement option</p> <p><u>Data</u></p> <table border="0"> <tr> <td>Rating of transformer</td> <td>=</td> <td>1600 kVA</td> </tr> <tr> <td>Average loading on the transformer</td> <td>=</td> <td>1020 kVA</td> </tr> <tr> <td>Present power factor (old pf)</td> <td>=</td> <td>0.64 (lag)</td> </tr> <tr> <td>Demand charges/kVA</td> <td>=</td> <td>Rs 150/kVA</td> </tr> <tr> <td>Unit cost of Capacitor/kVAR</td> <td>=</td> <td>Rs. 300</td> </tr> <tr> <td>Transformer no-load loss/hour</td> <td>=</td> <td>2.4 kW</td> </tr> <tr> <td>Transformer Full -load loss/Hour</td> <td>=</td> <td>18.57 kW</td> </tr> </table> <p>Required rating of the capacitor banks to improve the pf from the present PF of 0.64 (lag) to 0.95 (lag). Take the unit price of capacitor as Rs.300 per kVAr.</p> <p><b><u>Calculation:</u></b></p> <table border="0"> <tr> <td>Present kW load</td> <td>=</td> <td>kVA x PF =</td> <td>1020 x 0.64</td> <td>=</td> <td>653 kW</td> </tr> <tr> <td>Present kW load</td> <td>=</td> <td>kVA x PF =</td> <td>1020 x 0.64</td> <td>=</td> <td>653 kW</td> </tr> <tr> <td>Present kVAr value</td> <td>=</td> <td><math>\sqrt{(\text{kVA})^2 - (\text{kW})^2}</math></td> <td>=</td> <td><math>\sqrt{(1020)^2 - (653)^2}</math></td> <td>= 784 kVAr</td> </tr> </table> <p>New value of kVA when pf is improved from old value of 0.64 (lag) to new pf of 0.95 (lag)</p> <table border="0"> <tr> <td>New kVA</td> <td>=</td> <td><math>\left(\frac{\text{Old pf}}{\text{New pf}}\right) \times \text{Old kVA}</math></td> <td>=</td> <td><math>\left(\frac{0.64}{0.95}\right) \times 1020 \text{ kVA}</math></td> <td>= 687 kVA</td> </tr> </table> <table border="0"> <tr> <td>New kVAr after pf improvement</td> <td>=</td> <td><math>\sqrt{(\text{kVA})^2 - (\text{kW})^2}</math></td> <td>=</td> <td><math>\sqrt{(687)^2 - (653)^2}</math></td> <td>= 213 kVAr</td> </tr> </table> <table border="0"> <tr> <td>Value of capacitor required</td> <td>=</td> <td>(New kVAr - Old kVAr)</td> <td>=</td> <td>784 kVAr - 213 kVAr</td> <td>= 570 kVAr</td> </tr> </table> <p><u>(Alternate method with formula for kVAr computation)</u></p> <table border="0"> <tr> <td>Capacitor value required</td> <td>=</td> <td>kW [tan (Cos<sup>-1</sup> (old pf) – tan (Cos<sup>-1</sup> (New pf))</td> </tr> <tr> <td></td> <td>=</td> <td>653 [ tan (Cos<sup>-1</sup> (0.64)) – tan (Cos<sup>-1</sup> (0.95))]</td> </tr> <tr> <td></td> <td>=</td> <td>653 x 0.8719 = 569.4 ≈ 570 kVAr</td> </tr> </table> <p><b>Reduction / release of kVA demand and cost savings</b></p>	Rating of transformer	=	1600 kVA	Average loading on the transformer	=	1020 kVA	Present power factor (old pf)	=	0.64 (lag)	Demand charges/kVA	=	Rs 150/kVA	Unit cost of Capacitor/kVAR	=	Rs. 300	Transformer no-load loss/hour	=	2.4 kW	Transformer Full -load loss/Hour	=	18.57 kW	Present kW load	=	kVA x PF =	1020 x 0.64	=	653 kW	Present kW load	=	kVA x PF =	1020 x 0.64	=	653 kW	Present kVAr value	=	$\sqrt{(\text{kVA})^2 - (\text{kW})^2}$	=	$\sqrt{(1020)^2 - (653)^2}$	= 784 kVAr	New kVA	=	$\left(\frac{\text{Old pf}}{\text{New pf}}\right) \times \text{Old kVA}$	=	$\left(\frac{0.64}{0.95}\right) \times 1020 \text{ kVA}$	= 687 kVA	New kVAr after pf improvement	=	$\sqrt{(\text{kVA})^2 - (\text{kW})^2}$	=	$\sqrt{(687)^2 - (653)^2}$	= 213 kVAr	Value of capacitor required	=	(New kVAr - Old kVAr)	=	784 kVAr - 213 kVAr	= 570 kVAr	Capacitor value required	=	kW [tan (Cos <sup>-1</sup> (old pf) – tan (Cos <sup>-1</sup> (New pf))		=	653 [ tan (Cos <sup>-1</sup> (0.64)) – tan (Cos <sup>-1</sup> (0.95))]		=	653 x 0.8719 = 569.4 ≈ 570 kVAr
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	<p>Release or reduction in kVA = (Old kVA - New kVA) = (1020 - 687) = 333 kVA</p> <p>Annual cost savings due to reduction in kVA = kVA(savings) x Rs/ kVA x 12Months = 333 x 150 x 12 = Rs.5,99,400/-</p> <p><b>Cost of implementation</b></p> <p>Cost of 570 kVA capacitor bank, taking Rs.300/ kVA = Rs.300 x 570 kVA = Rs.1,71,000</p> <p>Simple Payback period = 171000/599400 = 0.29 years</p>															
4.	<p>The maximum demand approved by a utility is 5500 kVA and tariff provides for minimum billing demand of 80% of approved. Review of past 12 months records of bills reveals that the monthly maximum demand recorded is around 4200 kVA.</p> <p>Will there be any benefits in surrendering part of contract demand? If so what is the kVA that you recommend for surrendering?</p> <p>Give the costs savings by surrendering demand, if unit rate for kVA demand is Rs 200.</p> <p>Approved maximum demand : 5500 kVA Minimum billing demand (MBD) : 4400 kVA Maximum demand recorded : 4200 kVA</p> <p>The approved maximum demand is selected such a way that the gap between MD recorded and minimum billing demand are narrowed down.</p> <p>A different scenario is to be created.</p> <table border="1" data-bbox="256 1084 1139 1240"> <tr> <td>Contract demand</td> <td>5500</td> <td>5400</td> <td>5300</td> <td>5200</td> </tr> <tr> <td>(Minimum Billing Demand) 80% of contract demand</td> <td>4400</td> <td>4320</td> <td>4240</td> <td>4116</td> </tr> <tr> <td>Monthly demand recorded</td> <td>4200</td> <td>4200</td> <td>4200</td> <td>4200</td> </tr> </table> <p>From above, it would be advantage to surrender '300 kVA' demand and set new approved demand at 5200 kVA.</p> <p>The actual savings possible is calculated below:</p> <p>New contract (approved) demand : 5200 kVA New minimum billing demand : 4160kVA) Existing MD recorded : 4200kVA Present billing demand : 4200 (since recorded kVA is more than MBD) Original minimum billing demand : 4400kVA (Before surrendering demand) Reduction demand value taken for billing: 200 kVA Savings in demand charges/month Rs 200 * 200kVA = Rs40,000</p> <p><i>(Note: The pay back in above case will be 'immediate' as there is no investment.)</i></p>	Contract demand	5500	5400	5300	5200	(Minimum Billing Demand) 80% of contract demand	4400	4320	4240	4116	Monthly demand recorded	4200	4200	4200	4200
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5.	<p>Why maximum demand <b>need to</b> be controlled? What are the options for controlling maximum demand?</p> <p>MD control is very important because the utility charges user not only for the energy consumed but also for the maximum demand made (as per two part tariff). Hence in order to reduce the energy cost it is essential to control the maximum demand.</p> <p>MD control can be achieved by a step by step and a systematic approach as given below:</p> <p>i) Generate load curve &amp; analyze all electrical loads in the plant with respect to the demand drawn by the particular equipment/process/ department. Stagger operation of loads as far as possible.</p>															

	<ul style="list-style-type: none"><li>ii) Identification of electrical loads/process/department that can be rescheduled towards load factor improvement.</li><li>iii) Incorporation of automation such as demand controllers and maximum demand controllers.</li><li>iv) Adoption of alternative sources such as captive generation / co-generation for peak demand reduction</li><li>v) Reactive power demand compensation to maintain highest possible power factor so that maximum demand in KVA is optimized</li></ul>
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