Chapter 3.10: Energy Efficient Technologies in Electrical Systems

Part-I: Objective type questions and answers

1.	Maximum demand controller is used to _____. a) switch off essential loads in a logical sequence b) exceed the demand of the plant c) switch off non-essential loads in a logical sequence d) controls the power factor of the plant
2.	Capacitors with automatic power factor controller when installed in a plant: a) reduces active power drawn from grid b) reduces the reactive power drawn from grid c) reduces the voltage of the plant d) increases the load current of the plant
3.	_____ controls the power factor of the installation by giving signals to switch on or off power factor correction capacitors. a) KILOVAR b) Automatic power factor control relay c) Intelligent power factor controller d) Maximum demand controller
4.	_____ determines the rating of capacitance connected in each step during the first hour of its operation and stores them in memory. a) Maximum demand controller b) Intelligent power factor controller c) Automatic power factor controller d) KILOVAR
5.	The following function can not be achieved with automatic power factor controllers. a) Voltage control b) KILOVAR control c) kW control d) PF control
6.	The following features apply to energy efficient motors by design: a) Energy efficient motors last longer b) Starting torque for efficient motors may be lower than for standard motors State whether the two statements are True or False?
7.	Eddy current drive can be a retrofit for _____. a) constant speed system requirement b) variable speed system requirement c) dual speed system requirement only d) none of the above
8.	Electronic variable frequency drive (VFD) connected to motors: a) provide variable speed with high efficiency b) induces eddy-current in the secondary member of the clutch mechanism c) is not suitable for variable torque load d) does not provide variable speed and has low-efficiency
9.	Variable speed can not be obtained with ____. a) DC motors controller b) AC motor controller c) soft starter controller d) AC & DC controllers

10.	Energy savings potential of variable torque applications compared to constant torque application is: a) higher b) lower c) equal d) none of the above
11.	As an energy efficient application, slip power recovery system fits well for _____. a) Squirrel cage and slip ring motors b) DC motor c) Slip ring motors only d) None of the above
12.	Energy efficient transformer core is made up of _____. a) silicon alloyed iron (grain oriented) b) copper c) amorphous core - metallic glass alloy d) none of the above
13.	The basic functions of electronic ballast excludes one of the following: a) to ignite the lamp b) to stabilize the gas discharge c) to reduce lumen output of the lamp d) to supply power to the lamp
14.	Select the application of fluid coupling fitting from the following: a) acts as a voltage limiter b) enables no-load start-up of prime-mover c) works on the principle of eddy current d) none of the above
15.	The characteristic of conventional ballast in lighting application is one among the following: a) They have low operational losses than electronic ballasts. b) They have tuned circuit to deliver power at 25 Hz c) They do not require a mechanical switch (starter) d) They have high operational losses and high temperature rise
16.	Application of occupancy sensors is well suited for ___. a) day light based controllers b) night based controllers c) motor controllers d) movement or noise detector in room space
17.	Find the odd retrofit group from the following: a) Occupancy sensors b) timer based control c) photo sensors d) capacitor based control
18.	Application of timers as a retrofit will assist in saving energy in areas of _____. a) Lighting & motors b) Transformers c) HV- Feeder Panels d) All the above
19.	Electronic soft starters are used for motors to: a) achieve variable speed b) provide smooth start and stop c) improve the loading c) none of the above
20.	Energy efficient lighting can be planned by using the following retrofits. – State True or False a) photo-sensor b) timer c) occupancy sensor d) localized switching

Part-II: Short type questions and answers

1.	How maximum demand control can be practiced in a plant? MD control is very important because the utility charges user not only for the energy consumed but also for the maximum demand made irrespective energy consumed (as per two part tariff). Hence in order to reduce the energy cost it is essential to control the maximum demand. MD can be controlled by ➢ Use of maximum demand controller, ➢ Staggering load during peak load period by sequencing of loads, operating in shifts etc. ➢ Maintaining very good pf at peak loads
2.	Briefly explain the benefits of employing a demand controller • Avoids excess maximum demand on the supply grid • Helps in improving the load factor by truncating the peaks and flattening the load curve. • Assists in meeting expansion plans • Leveling plant loads to avoid peak load on feeder and electrical equipment
3.	What is APFC? What are its advantages? APFC is an acronym for "automatic power factor controller". It is used to improve the system power factor by automatic sensing of PF correction and control. The advantages of APFC are ➢ Unmanned operation of pf control, ➢ Always maintains very good and accurate pf (as set), ➢ Results in decreased system current and hence reduced voltage drop and power loss automatically, ➢ Reduced energy bill and avoids penalties both pf penalty and maximum demand.
4.	Name watt loss areas for improvement by using energy efficient motors? • Iron loss • Stator I^2R loss • Rotor I^2R loss • Friction & windage • Stray load loss
5.	What are the technical aspects of energy efficient motors? Energy-efficient motors last longer, and may require less maintenance. At lower temperatures, bearing grease lasts longer; required time between re-greasing increases. Lower temperatures translate to long lasting insulation. Generally, motor life doubles for each 10°C reduction in operating temperature. Speed control is crucial in some applications. In polyphase induction motors, slip is a measure of motor winding losses. The lower the slip, the higher the efficiency. Less slippage in energy efficient motors results in speeds about 1% faster than in standard counterparts. Starting torque for efficient motors may be lower than for standard motors. Facility managers should be careful when applying efficient motors to high torque applications.

6.	Write brief notes on soft-starters Soft starter provides a reliable and economical solution to these problems by delivering a controlled release of power to the motor, thereby providing smooth, stepless acceleration and deceleration. Motor life will be extended as damage to windings and bearings is reduced. Soft Start & Soft Stop is built into 3 phase units, providing controlled starting and stopping with a selection of ramp times and current limit settings to suit all applications.
7.	Briefly explain the advantages of electronic soft-starters? • Less mechanical stress • Improved Power Factor • Lower maximum demand • Less mechanical maintenance
8.	Explain the affinity laws concerning variable torque loads. The following laws illustrate these relationships. • Flow is proportional to speed • Head is proportional to (speed)^2 • Torque is proportional to (speed)^2 • Power is proportional to (speed)^3
9.	Briefly describe the principle of variable frequency drive The VFD operates on a simple principle. The rotational speed of an AC induction motor depends on the number of poles in that stator and the frequency of the applied AC power. Although the number pole in an induction motor cannot be altered easily, variable speed can be achieved through a variation in frequency. The VFD rectifies standard 50 cycle AC line power to DC, then synthesis the DC to a variable frequency AC output.
10.	List the applications of variable frequency drive control for motors operating on pumps and fans. • For avoiding throttling with pumps & fans • To meet variable head requirement during cycle of operation • To meet intermittent variations in requirement of flow/head
11.	What are the means of varying speeds of induction motor? Speed can be varied by a) varying resistance of rotor circuit b) using multispeed windings c) using scherbius or Kramer drives d) using mechanical means such as gears & pulleys e) eddy current or fluid coupling f) variable frequency drive
12.	Explain the principle of Eddy current drive mechanism for motors. Eddy current drive mechanism employs an eddy current clutch to vary the output speed. The clutch consists of two parts, primary member and secondary member. The primary member is coupled to the motor shaft while the secondary member is a free revolving part coupled to the load shaft. The secondary member is separately excited using a DC field winding (rotating coil). The motor starts

	with load at rest and a DC excitation is provided to the secondary member. This induces eddy current in the primary member. The interaction of the fluxes produces by the two currents gives rise to a torque at the load shaft. By varying the DC excitation the output speed can be varied to match the load requirements. The major disadvantage of this system is relatively power efficiency particularly at low speeds.
13.	Explain slip power recovery system as a speed control mechanism of motors? Slip power recovery system is a more efficient alternative speed control mechanism for use with slip ring motors. In essence, a slip power recovery system varies the rotor voltage to control speed, but instead of dissipating power through resistors, this excess power is collected from the slip rings and returned as mechanical power to the shaft or as electrical power back to the supply line. Because of the relatively sophisticated equipment needed, slip power recovery tends to the economical only in relatively high power applications and where the motor speed range is 1:5 or less.
14.	Name any 4 retrofit actions at a facility having more than 100 standard efficiency motors in operation? • Replace with high Efficiency motors based on good running hours • Install variable speed drive controls for variable load cycle applications • Install two speed drives having specific application • Install flat belts drives at specific areas having V belt drives
15.	Indicate where this retrofit can play a role in an industrial facility A. Install High Efficiency motors B. Install Adjustable Speed Drives Motors A. As replacement to standard efficiency motors B. For damper controlled Fans and pumps
16.	Write a brief note on energy efficient transformers? The energy efficient transformers use amorphous material-a metallic glass alloy material for the core. The expected reduction in energy loss over conventional transformers is roughly around 70%, which is quite significant. By using an amorphous core with unique physical and magnetic properties – these new types of transformers have increased efficiencies even at low loads – 98.5% efficiency at 35% load.
17.	Briefly explain the functions of electronic ballast. The high frequency electronic ballast overcomes the above drawbacks. The basic functions of electronic ballast are: 1. To ignite the lamp 2. To stabilize the gas discharge 3. To supply the power to the lamp The electronic ballasts make use of modern power semi-conductor devices for their operation. The circuit components form a tuned circuit to deliver power to the lamp at a high resonant frequency (in the vicinity of 25 kHz) and voltage is regulated through an in-built feedback mechanism.
18.	At least name two applications each for “Photo-sensors” and “Timer-controls”? Applications of “photo-sensors”” • Controlling motor operation in carding machine in a textile industry

	• Unmanned area light/lux level control • Operation of water taps, etc. Applications of "timer-controls" • Street light control, • motor control during starting (star-delta) and for sequencing the line operation such as conveyors etc.
19.	List various energy efficient lighting controls. The following are various energy efficient lighting controls. a) use of occupancy sensors b) time based control c) photoelectric sensor control d) localized switching Using the above combinations, savings in lighting energy can be realized.
20.	Few actions on retrofitting a lighting installation are given below; briefly indicate areas where this retrofit can play a role in facility. A. Install High Efficiency Lighting with Electronic Ballasts B. Install Occupancy Sensors C. Install Light Sensors (Photocells) D. Install Skylights and Delamp E. Delamp in Overlit Areas A. In Large production shops/hangars B. At Conference halls C. For street-lighting/building lighting and areas having day-lighting D. Entrances of offices/buildings, passages E. Warehouses, passages, corridors and less occupied areas

Part-III: Long type questions and answers

1.	Explain the functions and benefits of a demand controller High-tension (HT) consumers have to pay a maximum demand charge in addition to the usual charge for the number of units consumed. This charge is usually based on the highest amount of power used during some period (say 30 minutes) during the metering month. The maximum demand charge often represents a large proportion of the total bill and may be based on only one isolated 30 minute episode of high power use. Maximum Demand Controller is a device designed to meet the need of industries conscious of the value of load management. Alarm is sounded when demand approaches a preset value. If corrective action is not taken, the controller switches off non-essential loads in a logical sequence. This sequence is predetermined by the user and is programmed jointly by the user and the supplier of the device. The plant equipments selected for the load management are stopped and restarted as per the desired load profile. Demand control scheme is implemented by using suitable control contactors. Audio and visual annunciations could also be used. *Benefits of Maximum demand controller:*

	Maximum demand helps in two ways: • Avoids excess maximum demand on the supply grid, and • Helps in improving the load factor by truncating the peaks and flattening the load curve. Electricity billing by any utility power supply to any facility is based on 'two-part tariff. One component of the tariff is based on the kWh of energy consumed and the other is based on the actual kVA (or some times kW) demand made/contracted. If the facility makes a demand more than the contracted value, then the excess demand is billed at higher rate (2 to 3 times) than the normal rate. Maximum demand controller helps in avoiding peaking of load by tripping and staggering such non-priority loads to 'off-peak' period as each industrial application has its own load profiles / load curves. It finds more usefulness in TOD (i.e. time of the day) control.
2.	Explain at least two automatic power factor control methods? Various types of automatic controls are available with relay / microprocessor logic. Two of the most common controls are: Voltage Control and KVAR Control Voltage Control: Voltage alone can be used as a source of intelligence when the switched capacitors are applied at point where the circuit voltage decreases as circuit load increases. Generally, where they are applied the voltage should decrease as circuit load increases and the drop in voltage should be around 4 – 5 % with increasing load. Voltage is the most common type of intelligence used in substation applications, when maintaining a particular voltage is of prime importance. This type of control is independent of load cycle. During light load time and low source voltage, this may give leading PF at the substation, which is to be taken note of. KILOVAR Control: Kilovar sensitive controls are used at locations where the voltage level is closely regulated and not available as a control variable. The capacitors can be switched to respond to a decreasing power factor as a result of change in system loading. This type of control can also be used to avoid penalty on low power factor by adding capacitors in steps as the system power factor begins to lag behind the desired value. Kilovar control requires two inputs - current and voltage from the incoming feeder, which are fed to the PF correction mechanism, either the microprocessor or the relay.
3.	List any 5 different types of energy efficient retrofits? Explain their application and benefits in 2-3 lines each. There are several energy efficient retrofits which are listed below: a. Energy efficient motors (EEM): Higher efficiency and flat efficiency characteristic between 50 to 100% load results in very good saving opportunities compared to standard motors. b. Variable speed drives (VSD): VSDs by virtue of electronic control can control the speed very accurately in closed looped system and thereby adjust the speed according to the process requirements. c. Electronic chokes: Electronic chokes consume 15% to 25% of power consumption of conventional chokes. d. Use of energy efficient lamps: Use of energy efficient lamps with higher luminous efficiency such as CFL, sodium vapour lamps, and metal halide lamps yields energy savings without affecting the light output. e. Maximum demand controllers: This is useful device which senses the occurrence of peak loads and their duration and accordingly automatically switches-off the non-priority loads, thereby reducing peak Maximum demand and MD cost.

4. Why variable torque loads offer greatest energy savings? Explain electronic methods of speed controllers?

In variable torque applications, Affinity law holds good which defines the relationships between speed, flow, torque, and horsepower illustrated below:

1. Flow is proportional to speed
2. Head is proportional to square of the speed
3. Torque is proportional to square of the speed
4. Power is proportional to cube of the speed

Variable torque loads include centrifugal pumps and fans which make up the majority of large plant loads.

Thus, theoretically, for 50% of full load requirement the power input needed would be less than 13% of full load power. In a centrifugal pump when the flow discharge is reduced to 70% of the rated discharge a savings of 65 percent in power is theoretically possible.

To achieve this savings, Solid state electronic VSDs are used to control the voltage and frequency delivered to the motor to change its speed. However, in practice the savings will depend upon the type and efficiency of variable speed drive employed and other system losses.

5. Write short notes on Energy Efficient Lighting Controls.

Compact Fluorescent Lamp

The new low energy and therefore highly cost effective compact fluorescent lamp is a recent addition to modern lighting technology and is an attractive alternative to incandescent lamps.

Development of very stable fluorescent powders that can handle strong ultra violet radiation has made it possible to reduce the internal diameter of tubular fluorescent lamps as much as 10 mm. These small bore tubes form the basis for various type of compact fluorescent. The compact fluorescent lamp basically is a low wattage, low-pressure gas discharge lamp.

Because of the small diameter of the lamp tube and consequent high wall loading, the surface temperature of this lamp is higher than that of a conventional fluorescent lamp. This results in increase in the vapour pressure inside the tube and consequently lower light output at normal ambient temperature within the luminaire. To counteract this either amalgam technique or principle of cool spot is employed. These measures reduce the vapour pressure and maintain the light output.

Energy Savings

It is self evident that price of such a complicated compact fluorescent lamp exceeds the price of a simple incandescent lamp many times. However, by virtue of much lower energy consumption of these lamps the higher initial cost is more than paid back. The energy cost comparison between incandescent and compact fluorescent lamp is shown in Table

Energy Cost Comparison

Lamp	Wattage, W	Efficacy, LM/W	Average Life, (Hrs)	Energy saving, %
Incandescent	60	12	1000	-
Compact Fluorescent	9	67	7500	80

The use of compact fluorescent lamp not only saves considerable amount of energy but also brings with it an overall reduction in operating cost. The above Table shows a comparison of these costs for a 60 W incandescent and a compact fluorescent lamp. The comparison is based on a burning time of 5000 hours and electricity tariff of Rs.1.50 per unit and normal lamp prices. As can be seen the energy savings is 65 to 80% at an operating cost of 50%.