MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC-27001-2005 Certified)

Summer – 2019 Examinations

Model Answer

Subject & Code: ENERGY CONSERVATION & AUDIT (17506)

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner should assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given importance (Not applicable for subject English and Communication Skills).
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner should give credit for any equivalent figure/figures drawn.
5) Credits to be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer (as long as the assumptions are not incorrect).
6) In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept

1 a) Attempt any THREE of the following: **12**

1 a) (i) State difference between commercial and non-commercial energy sources with examples.

Ans:

Difference Between Commercial and Non-Commercial Energy Source:

Sr. No.	Commercial Energy Source	Non-Commercial Energy Source
1	Commercial energy is energy which is available to the users at some price.	Non-commercial energy is energy which is available free of cost to the users.
2	It is used for commercial purposes in factories and farms.	It is used for domestic and consumption purposes.
3	This is a non-renewable form of energy.	It is a renewable form of energy.
4	Its utilization leads to more pollution of the environment.	These pollute the environment to lesser extent as their use is not as high as the commercial ones.
5	These types of energy are limited in nature.	These types of energy are abundant in nature.
6	High capital investment is required to for its utilization.	It can be used in raw form.
7	It is used in urban as well as rural areas.	It is dominantly used in rural areas.
8	Commercial Sources of Energy meet a major portion of our requirements.	Non-Commercial Sources of Energy meet our requirement on a limited scale.
9	**For example: coal, petroleum, natural gas and electricity.**	**For example: fire wood, agricultural waste, cow dung.**

Any 3 points except examples = 3 Marks

Examples 1 Mark

1 a) (ii) Define:

1) Luminous intensity
2) Luminous efficiency
3) CRI
4) Lux

Ans:

1) Luminous intensity: This is defined as the luminous flux emitted into a solid angle of space in a specific direction. Its unit is the candela.

OR

The luminous flux per unit solid angle (per steradian), as measured in the given direction relative to a light source. Its unit is the candela.

2) Luminous efficiency: This is the ratio of luminous flux (lumen) emitted by a lamp to the power (watts) consumed by the lamp. Unit is Lumens per watt.

3) CRI: It is a measure of the degree to which the colour of surfaces illuminated by a given source compares to those of the same surface under reference illuminant.

4) Lux: It is defined as luminous flux falling on unit surface area perpendicular

1 Mark for each definition = 4 Marks

to the flux. 1lux = 1 lumen/m^2.

1 a) (iii) How core loss and copper loss can be reduced in Conventional Induction Motor?

Ans:

Reduction of Core Loss and Copper Loss in Conventional Induction Motor:

Reduction of Core Loss:

1) Hysteresis loss is reduced by using low loss grade silicon steel
2) Increase in stator and rotor core length.
3) Eddy current loss is reduced by using thinner core laminations;
4) Thinner laminations for stator cores compared to rotor cores as the frequency of stator flux alternation is very high compared to rotor which is at slip frequency.

2 Marks for any 2 points

Reduction of Copper Loss:

1) Selection of proper size of winding conductors so as to reduce its resistance.
2) Winding conductors of purest copper.
3) Increasing the cross section of rotor bars and end rings so as to reduce rotor copper loss.
4) Operating motor near synchronous speed reduces I^2R loss.

2 Marks for any 2 points

1 a) (iv) State the periodical maintenance of transformer as a energy conservation techniques.

Ans:

Periodical Maintenance of Transformer as Energy Conservation Techniques:

Proper periodical maintenance leads to Energy conservation in transformers;

1) Measure the voltage, current and temperature.
2) Check for winding resistance including termination resistances:
3) Check oil level and dielectric strength of oil.
4) Check breather and silica gel.
5) Check cooling arrangement.
6) Check Insulation resistance.

1 Mark for each of any four = 4 Marks

1 b) **Attempt any <u>ONE</u> of the following:** **6**

1 b) (i) List any four causes for technical losses in transmission and distribution system. Also state the technique to reduce them.

Ans:

Causes of Technical losses in transmission and distribution system:

1) Leakage current
2) Open circuit loss
3) Dielectric loss
4) Corona loss
5) Heating due to current
6) Losses in contact resistance.

1 Mark for each of any four causes = 4 Marks

Techniques of Reducing Technical Losses:

1) Find out the weakest area of more technical loss in the distribution

system.

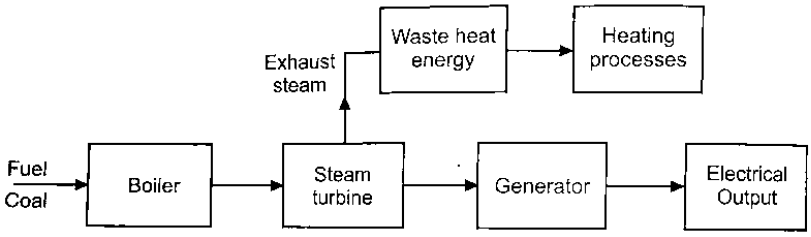
2) Locate distribution transformer near to the load center.
3) Use proper capacity distribution transformer.
4) Use energy efficient transformers.
5) Use shunt capacitors for reactive power management.
6) Use HVDC system for long distance bulk power transmission.
7) Use ACSR or bundled conductors instead of solid conductors.
8) Reduce overloads on distribution transformer.
9) Use reactive power compensation techniques.
10) Use power factor controlling devices or techniques.
11) Minimize I^2R losses.
12) Balance the load currents.
13) Regulate the system voltages..

1 Mark for each of any two techniques = 2 Marks

1 b) ii) Draw neat block diagram and explain:
1) Topping cycle
2) Bottoming cycle

Ans:

1)Topping cycle:



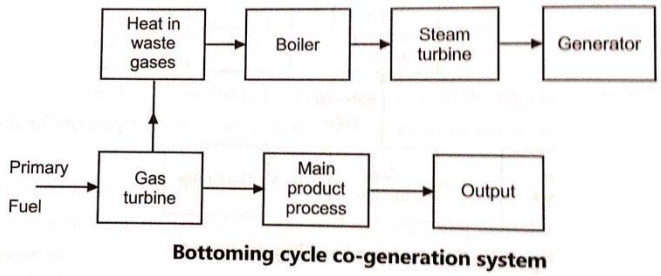
Topping cycle co-generation system

2 Marks for Figure

1) Topping cycle is that cycle in which fuel supplied is first used to produce power, and then it is used to generate thermal or heat energy i.e. heat energy is the byproduct of this cycle.
2) The heat energy available from this cycle is used for healing of various processes or it is used to meet the requirement of heat for different purposes.
3) In most of the systems topping cycle, co-generation is widely used, and it is the most popular method of co-generation.

1 Mark for description = (3 Marks)

2)Bottoming cycle:



Bottoming cycle co-generation system

2 Marks for Figure

1) Bottoming cycle of co-generation system is that in which high temperature heat energy is produced using primary fuels.
2) This heat produced is mainly used for other processes except generation of

1 Mark for description = (3 Marks)

electricity.
3) Rejected heat from process is utilized to generate electricity.
4) The rejected heat is taken from recovery boiler and it is then applied to the turbine connected to the generator to produce electricity.
5) From manufacturing process of some products heat at high temperature is required in furnaces and kilns.
6) After the manufacturing process, the heat rejected or not utilized is also at significantly high temperature which cannot be neglected.And if neglected it will reduce the overall efficiency of the system greatly.
7) Bottoming cycles are suitable for cement industries, ceramic factories etc.

2	**Attempt any <u>FOUR</u> of the following:**	**16**
2 a)	Explain following energy conservation techniques in lighting system: (i) By using energy efficient luminaries (ii) By using light control gears.	

Ans:

Energy Conservation Technique in Lighting System:

(i) By Using Energy Efficient Luminaries :

- Optimum energy conservation can be obtained by using effective installation of luminaries along with lamps at proper height for achieving effective illumination.
- System layout and fixing of the luminaries play a major role in achieving energy efficiency. This also varies according to applications. For example, luminaries fitted with lamp should ensure that discomfort glare and viewing reflections are minimized.
- All incandescent lamps should be replaced by fluorescent/ CFL/LED lamps as per the application.
- All fluorescent lamps should be replaced by CFL/LED lamps as per the application.
- Better optical design of mirrors and quality of materials should be used for manufacturing of luminaries.

2 Marks for any two points

(ii) By Using Light controlled gears :

- By proper grouping of lighting system, use of timer control, grouping of switch control etc. minimizes manual errors leading to energy conservation. Such types of controllers are used in corridor lighting, go-downs etc.
- Advanced lighting control system uses movement detectors, photo sensors, audio sensors, occupancy-linked control, built-in time delay etc. Which feed signals to main ON / OFF controller which makes lighting ON and OFF as per requirements. e.g.: Building lighting, garden lighting, workshops, street lighting etc.
- Nowadays in commercial buildings, malls, offices, more no. of lights are to be controlled and operational hours are also definite. In such type of applications, microprocessor based controllers are used which switch ON/OFF as per the working schedule. System can also be programmed month wise, year wise and even season wise.
- By using dimmers, the intensity of light can be controlled as per requirement e.g Museums, Art galleries, Banks etc.

2 Marks for any two points

- If daylight alone is able to meet the illumination requirements, then the electric lighting can be turned OFF by using daylight linked control.

2 b) State any four advantages of energy efficient motors.

Ans:

Advantages of Energy Efficient Motors:

1) They are manufactured with higher quality conducting, electromagnetic & insulating material & techniques.
2) They usually have higher service factors & bearing lives, less waste heat output, all of which increase reliability.
3) They are having more length of core with higher quality and thinner steel laminations.
4) Optimized and uniform air gap between stator and rotor.
5) Smooth speed over a required range & less vibrations.
6) Negligible maintenance, longer warranties, low failure rates.
7) Can withstand high temperature without any problem.
8) Voltage fluctuations in input supply side have less effect on energy efficient motor.
9) Their operation is almost noise free.
10) They are having high acceleration and high retardation capabilities.
11) Low cost of operation due to less consumption of electricity.
12) Less heating of motor due to the efficiency factor being high. These can run for long periods of time.
13) Low maintenance because of the higher quality materials used. The chances of breakdown are very less.

1 Mark for each of any four advantages = 4 Marks

2 c) What is VFD? State the benefits of it**.**

Ans:

VFD: A Variable Frequency Drive (VFD) is a type of motor controller that drives an electric motor by varying the frequency and voltage supplied to the electric motor.

1 Mark for definition

Benefits of VFD:

1) Smooth starting.
2) Smooth acceleration & deceleration
3) Quick stopping.
4) Quick reversal of motor.
5) Reduces harmonics.
6) Increases power factor.
7) Saves energy.
8) Smooth speed control.
9) Better process control.
10) Lower maintenance cost.
11) Higher life span.
12) Very low losses.
13) Improved power quality of system
14) Jerk and vibration free operation.
15) Highly efficient.
16) Energy conservation

1 Mark for each of any three benefits = 3 Marks

2 d) Compare conventional transformer and energy efficient transformer on the basis

of: (i) Construction
(ii) Material used
(iii) Losses
(iv) Application

Ans:

Conventional Transformer and Energy Efficient Transformer:

Parameter	Conventional Transformer	Energy Efficient Transformer
Construction	Conventional transformer uses the core of silicon steel laminations (CRGO). They are generally oil cooled.	Energy efficient Transformer employ core of amorphous steel which has lower hysteresis losses. They are generally of dry type (no oil is used).
Material used	They are manufactured with higher quality conducting, electromagnetic & insulating materials & techniques.	They are manufactured with lower quality conducting, electromagnetic & insulating materials & techniques
Losses	They usually have higher service factors & less waste heat output all of which increase reliability with less losses.	More losses.
Application	1. In Generation, Transmission, Distribution networks. 2. For step-up and step-down voltage applications.	1. The main application of AMTs are the grid distribution transformers rated at about 50–1000 kVA. 2. Used in energy efficient application areas.

1 Mark for each of any four points = 4 Marks

2 e) Explain:
(i) Electricity duty
(ii) Energy cost

Ans:

(i) Electricity duty: In some states duty is applied on the supply of electricity. This duty is charged as additional cost per unit or it may also be in percentage. This amount is received to the state government and not to the utility. Since utility companies are utilizing land, infrastructure etc of state government hence they are imparting some charges as electricity duties on every consumer which is collected by state government. 2 Marks

(ii)Energy cost: Expense for generating, distributing, and using energy. Include monetary and non-monetary expenses. Example is environmental impact. 2 Marks

Monetary and non-monetary costs (such as the environmental impact) associated with the production, transmission, and consumption of energy.

The electrical energy is produced by utility company and delivered to large number of consumers. The cost of generation, transmission and distribution is incurred from the consumers as energy cost.

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2 f) Explain energy conservation by improving load factor and power factor.

Ans:

Energy Conservation by Improving Load Factor:

1) System capacity is properly utilized.
2) This increases production efficiency as even consumption over large time span.
3) This distributes load on proper rating supply system components.
4) This lowers power losses which give higher system efficiency.

So better is the load factor, lower is the cost of electric service & ultimately conservation of energy.

2 Marks for any two Points

Energy Conservation by Improving Power Factor:

1) The KVA rating of equipment is reduced making equipment smaller and less costly.
2) Conductors carry less current, so no need of conductors having less cross section.(Saving created)
3) Less I^2R losses, higher efficiency of system.
4) Less voltage drop in alternator, transformer and transmission lines hence better voltage regulation.
5) It improves power handling capacity & efficiency of the system.

So better is the power factor, higher is the handling capacity of system ultimately conservation of energy.

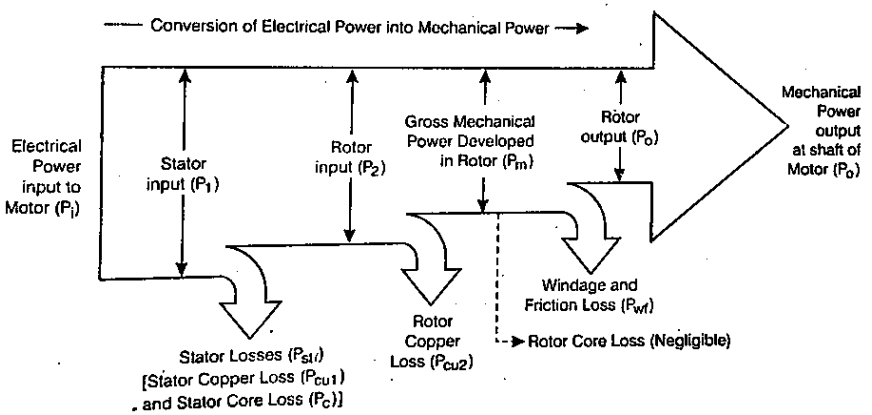
2 Marks for any two points

3 Attempt any <u>FOUR</u> of the following: **16**

3 a) Draw power flow diagram of induction motor and suggest methods of improving power quality in it.

Ans:

Power Flow Diagram of Induction Motor



Power flow diagram of induction motor

2 Marks for diagram

Methods of Improving Power Quality:

1) By applying rated input voltage.
2) By maintaning rated frequency of input voltage.
3) By maintenaing perfect sinusoidal waveshape of input voltage.

1)By Applying Rated Input Voltage: Applying andmaintaining the voltage at the rated value for motors results in the properly expected torque speed characteristics available to drive the load. Lower voltage leads to excessive current drawn due to which the line losses increase, machine copper losses

increase, line voltage drops increase, line voltage drop increase. Even if voltage is above required value higher flux density results in motors that leads to higher iron losses. These lead to decrease in efficiency. Hence proper voltage has to be maintained.

2)By Maintaning Rated Frequency of Input Voltage: It governs speed related losses and iron losses. If its value is more than rated then these losses increases as speed is directly propertional to the frequency alsot speed dependent friction & windage losses increase that will decrease the efficiency. Lower value of frequency leads to lower speed that affects the output power. Hence frequency has to be maintained at rated value.

3)By maintenaing perfect sinusoidal waveshape of input voltage: When the supply voltage waveform is purely sinusoidal the harmonics are absent which means no iron & copper losses due to harmonic voltages & currents. The harmonics even if very small, leads the production of unwanted harmonic torques which in turn waste of energy . Hence the supply voltage must be as near as possible to of sine wave shape in case of AC induction motors.

2 Marks for any two methods

3 b) Explain contract demand and billing demand with reference to tariff.

Ans:

Contract Demand: It is demand of power made by consumer and mutually agreed through written documents between the consumer and the supply authority in KW or KVA.

The supply utility company has to made arrangement to supply that particular consumer continuously up to his / her contract demand.

Billing Demand: The billing demand during unrestricted period shall be the maximum demand recorded during the month or the CD, whichever is higher. The electric utility company uses demand meters, which register the highest demand during a billing period. If the recorded demand is lower than contract demand then the demand charges are charged on contract demand. If the recorded demand is higher than contract demand then the demand charges are charged according to reading of demand meter.

2 Marks for explanation of each demand = 4 Marks

3 c) State at least eight industries suitable for co-generation.

Ans:

Industries suitable for co-generation of energy:

i) Sugar mills
ii) Rice mills
iii) Petrochemical Industry
iv) Distilleries
v) Cement Industry
vi) Pulp and paper industry
vii) Aluminum Industry
viii) National parks
ix) Wineries
x) Waste treatment plants

½ Mark each any eight = 4 Marks

(Any other valid industries may please be considered)

3 d) Which instruments are used for energy audit? Give function of any four.

Ans:

Instruments used for Energy Audit and there function:

Instruments	Functions in energy audit procedure
Lux meters	Measure illumination levels on working area.
Contact thermometer	These are thermocouples, which measures temperature, for example flue gas, hot air, and hot water temperatures by insertion of probe into the stream. For surface

	temperature, a leaf type probe is used with the same instrument.
Infrared thermometer	This instrument is useful for measuring hot spots in furnaces, surface temperatures etc.
Harmonic meter	Direct reading of %THD. Works with oscilloscopes as a harmonic and current transducer
Stroboscope / Tachometer	This is useful for speed measurements.
Load manager	This is used for measuring major electrical parameters such as kVA, kW, PF, hertz, kVAR, Amperes and Volts.
Fuel efficiency monitor	This measures oxygen and temperature of the flue gases.
Fyrite	Fyrite can be used for O_2 and CO_2 measurement in the flue gases.
Leak detector	This is Ultrasonic instrument used to detect leaks of compressed air / other gases.
Pitot tube & manometer	Air velocity in ducts can be measured using a pitot tube
Combustion analyzer	This instrument has in-built chemical cells which measure various gases such as O_2, CO, NO_X and SO_X

½ Mark for name and ½ Mark for function of each of any four instruments = 4 Marks

3 e) Explain stepwise procedure to study, assess and evaluate the existing lighting system.

Ans:

Procedure for Lighting System Assessment:

1. **Room Index:**
   Calculate the room index in order to determine number of points and their positions where measurements are to be carried out.
   Let L_i – Length of interior, 1 Mark
   W_i – Width of interior.
   H_m – Height of the lighting fitting above the horizontal working plane.
   The room index is calculated as
   $$RI = \frac{L_i \times W_i}{H_m(L_i + W_i)}$$
2. **Finding out the Installed Load Efficacies:**
   Step 1: Measurement of the floor area of interior, Area = ---------- m^2
   Step 2: Determine room index
   Step 3: Measure the total circuit watts of the lighting installation using power meter
   Step 4: (Value obtained in step 3) / (Value obtained in step 1)
   Total circuit watts / floor area = ---------- w / m^2
   Step 5: Find out the average maintained illumination using Lux meter. 1 Mark
   Step 6: (Value obtained in step 5) / (Value obtained in step 4)
   Step 7: Get target Lux/w/m^2 according to the type of interior or application and RI obtained in step in step 2
   Target Lux/w/m^2 = ----------
   Step 8: Installed load efficacy ratio (ILER)

= (Value obtained in step 6) / (Value obtained in step 7)

ILER = ------

3. **Target Lux/w/m^2 for Various Premises:**
The amount of light required is an important factor to perform a particular task or to illuminate the workspace. The most effective lighting with respect to performance and cost needs to have detail knowledge of the premises or application for which it is to be installed. The primary requirement of lighting as well as quality and amount of illumination depend upon, 1 Mark
   a) Nature of industry
   b) Its ocular needs & personnel
4. **Assessment of ILER Using Indicators of Performances:**
Annual energy wastage is possible to calculate after deriving the actual ILER as:
Annual energy wastage (kwh) 1 Mark
= (1- ILER) × Total load (kW) × annual operating hours (h)
Efficiency of the new lighting installations or replacement can also be assessed by comparison of ILE with target value for RI and type. In this case if the calculated ILE is found less than the target value, it is suggested to diagnose the reasons.

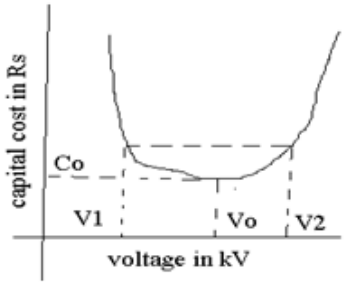
4 a) Attempt any <u>THREE</u> of the following: **12**

4 a) i) Explain voltage optimization and phase current balancing.

Ans:

Voltage Optimization:

In transmission system, rise in voltage level improves the power transmission capacity. If voltage is increased by 'n' times, then the size of conductor reduces by $1/n^2$ times. Higher voltage involves higher cost of the system (cost of insulation, cost of switch gear, terminal apparatus etc.



The relation between capital cost in Rs and standard line voltage in kV can be plotted and we get parabolic curve. The lowest point on the curve represents optimum voltage to be chosen. If capital cost does not differ appreciably, two voltages are selected (because higher V is easy to control than higher I). Optimum voltage for a system can be calculated by, 2 Marks

$V_L = 5.5\sqrt{((L/1.6) + (P\times1000/\cos\phi \times NC \times 150))}$

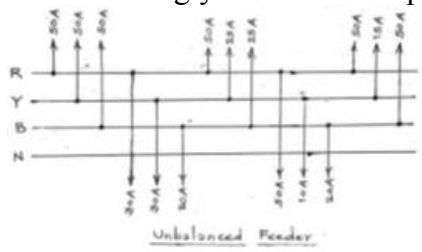
where, V_L = Transmission line voltage in kV

L = Length of line in km

P = Power to be transmitted
NC = Number of circuits
cosϕ =Power factor of load

Phase Current Balancing:

1) In India for distribution of electrical power, three-phase, 4 wire system is used.
2) By using this system, three phase as well as single phase loads are supplied.
3) Most of the three phase loads are of balanced type but single phase loads used by consumer will cause unbalance.
4) Due to which there is a need of balancing single phase loads and hence the system load is balanced accordingly. It is called as phase balancing system. 2 Marks



4 a) ii) State various energy conservation opportunities in transmission and distribution system.

Ans:

Energy Conservation Opportunities in Transmission and Distribution System:

1. **Mitigation of Power Theft:**
   Power theft being the most important issue for all supply utility companies. It necessitates strong steps towards mitigation of power theft. State government can contribute in this by forming strict rules, regulations and laws.
2. **Meter Seal:**
   CT/PT terminals at meter terminal box should be provided with proper seal management in order to prevent power theft / meter tampering. Severe penalties should be imposed for meter tampering.
3. **Vigilance Squad:**
   Areas of power theft should be identified and vigilance squad should be formed. They should have regular checking in order to speed up mitigation.
4. **Installation of MVD:**
   In areas sensitive to power theft, installation of medium voltage distribution is an option. Under this scheme each consumer can be directly connected to low voltage terminal of the supply transformer, immediate action should be taken to stop the unmetered supply.
5. **Faulty Meter Replacement :**
   a) Replacement: Distribution agency should pay full attention to faulty or sluggish meters. The faulty meters should be replaced by newer & advanced meters at the earliest.
   b) Checking: Meter should be checked periodically as per standard schedule for accuracy.
   c) Advanced Meters: Old inaccurate electromechanical meters should be

1 Mark for each of any four points = 4 Marks

replaced with latest microprocessor based digital meters so that energy consumption is measured accurately.

d) Prepaid Metering: Prepaid metering encourages efficient use of power especially for agricultural sector. Prepaid meters may prove effective measures against unauthorized abstraction of energy.

6. Bill Collection Facility:

a) Payment cells: Number of payment collection centers should be increased for paying electricity bill**.**

b) E-payment facility: Option of E-payment facility is suitable for both consumer as well as utility. It avoids long and time consuming queue for bill payment.

7. Reduce Debits:

Consumer having old debits should be legally communicated and necessary judicial action should be taken against them in order to recover debits. Police action may be taken to disconnect the supply if recovery is not being done.

8. Energy Audit Schemes:

Big industries and utilities should be mandated to carry out an energy audit as it identifies the areas of losses and measures to reduce them.

4 a) iii) Explain causes and effect of low power factor.

Ans:

Causes of Low Power Factor:

1) **Wide use of Induction Motors:** Most of single phase and three phase induction motors used works at lagging power factor (0.7 to 0.8) so resulting into low system power factor.
2) **Varying Load in Power System**: As we know that load on power system is varying. During low load period, supply voltage is increased which increase the magnetizing current which causes decreased power factor.
3) **Industrial Heating Furnaces:** Induction and arc furnaces used in steel manufacturing industry works at low power factor which reduces p.f. of the system.
4) **Arc / Discharge Lamps:** Electrical arc / discharge lamps operate at very low power factor which reduces p.f. of the system.
5) **Transformers**: At light / low loads transformers works on low p.f. which causes decreased power factor.
6) **Harmonic Currents:** Because of nonlinear electrical loads, harmonic currents are generated in the system which causes low power factor.
7) **Welding Transformers:** Welding transformers generally operates at very low p.f. which reduces p.f. of the system.
8) **Equipment Operating at Light Load:** When any electrical equipment operates at light load then its p.f. falls so power factor of system reduces.
9) **Inductance of Transmission and Distribution Line:** The transmission and distribution line possess inductance of their own hence reducing the system power factor.
10) **Series Reactors:** Series reactors (Highly inductive coils) are used in substation etc for maintaining fault current hence use of them reduces system power factor.

2 Marks for any two points

11) **Use of Faulty Capacitors:** Sometimes capacitors connected for improvement of p.f. are faulty causing low power factor.

Effects of Low Power Factor:

1) **Large Line Losses (Copper Losses):**
The large current at low power factor causes more I^2R loss.
2) **Large kVA rating and Size of Electrical Equipment's:**
As almost all electrical machinery (Transformer, Alternator, and Switchgears etc.) rated in kVA.
And, kVA = kW /CosΦ
The lower the power factor, the larger the kVA rating of machine required, so for larger the size of machines, the larger is the cost.
3) **Greater Conductor Size and Cost:**
In case of low power factor, current will be increased thus to transmit this high current, we need the larger size of conductor. Also, the cost of large size of conductor will be increased.
4) **Poor Voltage Regulation and Large Voltage Drop:**
As Voltage drop = IZ. Now in case of low power factor, current will be increased. So for large current, the large is the voltage drop and poor is the voltage regulation.
5) **Low Efficiency:**
In case of low power factor, there would be large voltage drop and large line losses and this will cause the system or equipment efficiency low.
6) **Penalty from Electric Power Supply Company on Low Pf:**
Electrical power supply company imposes a penalty of power factor below 0.95 lagging p.f. in electricity power bill.
7) **Design of Supporting Structure:**
As the power factor reduces, cross-section of conductor increases and ultimately its weight increases. To handle this increased weight, the design of supporting structure becomes heavier so its cost increases.

2 Marks for any two points

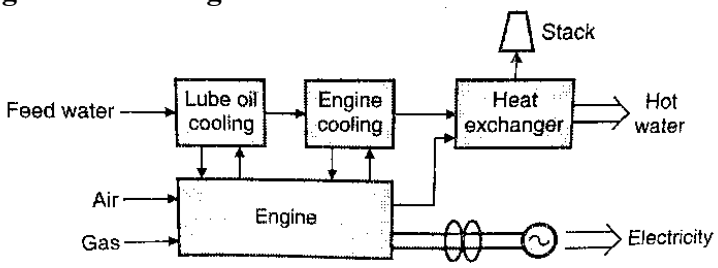
4 a) iv) With neat diagram explain working of any one reciprocating engine and state area of application.

Ans:

Working of Reciprocating Engine Cogeneration System:

There are two types of reciprocating engine cogeneration system as:

1. Spark Ignition Gas Engine:



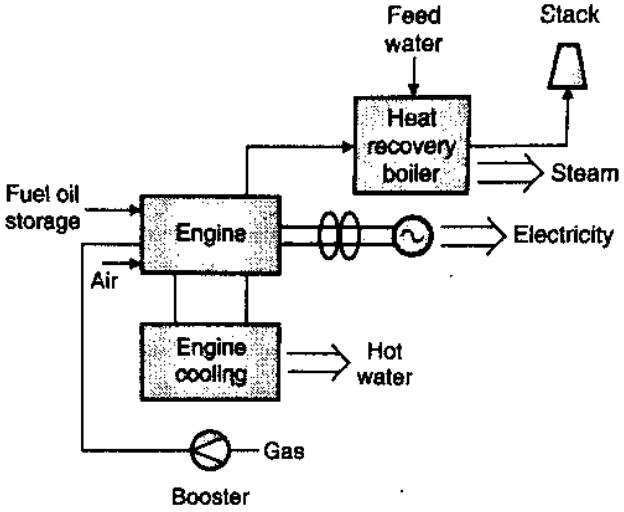
Spark ignition gas system

These engines have shaft efficiency near about 35% but low capital cost / kW comparing to compression idnition engine. Temperature range of 70-80° C can be obtained at engine cooling system which is possible to increase upto 110° C. Sizes of the engine may range upto 4 MW. Spark idnition engines are used to

3 Marks for explanation of any one method & 1 Mark for application =4 Marks

extract low pressure steam or medium or low temperature hot water on site.
Area of application: Small capacity cogeneration plants.

2. Compression Ignition Engine:



Compressor ignition engine

These are suitable for large co-generation plants. Shaft efficiency is in the range of 35-40%. These are direct injection engines which may employ turbochargers, intercoolers on fittings. This system offfers flexibility to make use of an alternative fuel that is oil. Full output can be derived using the same which proves useful for curtailing the cost of gas tariff. Compression ignition engines require complex cooling system as compared to spark ignition gas engine.
Area of application: Large capacity cogeneration plants.

4 b) **Attempt any <u>ONE</u> of the following.** **6**

4 b) i) Explain maximum demand controller and KVAR controller for distribution system.

Ans:

Maximum Demand Controller for Distribution System:

High –Tension (HT) users 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 energy demand used during billing period during the metering month. The maximum demand charges are often represents a large portion of the total bill. Considerable saving can be realized by controlling maximum demand used and turning off or reducing non- essential loads during periods 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 a controller switches off non-essential load. 3 Marks

kVAR Controller for Distribution System:

The power factor controller is used to maintain the system power factor at unity using capacitor banks across the line. It is controlled through microcontroller and contactor arrangement. Power factor of load is sensed and capacitors are connected /disconnected on the basis of KVAR demand. Maintaining the p.f. at unity leads to reduction in the current through the lines as Real power = apparent power x pf. The apparent power decides the MD for which the 3 Marks

consumer is billed.
The supply main terminals are connected to input of kVAR controller panel. Power factor is sensed by the CT & PT. As per the requirement the capacitor banks are operated to achieve the required power factor by microprocessor based relay automatically.

4 b) ii) Calculate annual bill of consumer whose maximum demand is 100kW at 0.8 p.f. lagging and at 60% load factor. Tariff used is Rs. 100/KVA of maximum demand and Rs. 2/kwh consumed.

Ans:

Data Given: M.D. = 100kW, p.f.= 0.8 Lag, L.F.= 60%= 0.6,
Tariff is Rs. 100 / kVA of MD, and rate p.u. = 2 Rupees /kWh

Units consumed / year: Max. Demand x L.F. x Hrs in years
= (100) x (0.6) x (365 x 24) — 2 Marks
= 525600kWh

Max. Demand in kVA = MD in kW/ p.f. — 1 Mark
= 100 / 0.8 = 125 kVA

Annual Bill = Annual Max. Demand charges + Annual Energy charges — 2 Marks
= (100 x 125) x 12 + (2) x 525600
= 12500 x 12 + 1051200 — 1 Mark
= Rs. 1201200/-

(assuming that MD charges given are on per month basis)

5 Attempt any <u>FOUR</u> of the following: **16**

5 a) State various techniques for energy conservation in 3 phase induction motor in industries. Explain any one in detail.

Ans:

Techniques Used for Energy Conservation in 3 Phase Induction Motor in Industries:

i) Minimizing idle and redundant running of motor
ii) Matching motor rating with required load
iii) Improving power quality
iv) Motor survey
v) Operating motor in star mode
vi) Rewinding of motor
vii) Improving mechanical power and transmission efficiency

2 Marks for any four techniques

i)Minimizing Idle and Redundant Running of Load:

1) Loss of energy as the no load power drawn is approximately about 12% to 16% of rated power output in most of motors. Therefore, idle running should be avoided.
2) Unnecessary heat production at friction points such as bearings, leading to wearing of bearing.
3) Motor being highly inductive load under idle running as no real power (mechanical load) on it, the p.f. of such no-load running is low, leading to unnecessary line losses.
4) Reduction in overall system energy efficiency over period of time.

ii)Matching Motor Rating with Required Load:

Every motor is designed to perform efficiently at certain load. If total load

on the motor and the output rating of motor are identical, then this condition is called as the best matching of motor & load on it. If the load is much low or high as compared to the output rating of motor, then the motor works at lower efficiency and energy is unnecessarily wasted. Therefore, the rating of motor is chosen according to the probable load on it.

iii)Improving Power Quality:

1) Voltage**:** Maintaining the voltage at the rated value for motors results in the properly expected torque speed characteristics available to drive the load. Lower voltage leads to excessive current drawn due to which the line losses increase, machine copper losses increase and line voltage drops increase. Even if voltage is above required value higher fluxdensity results in motors that leads to higher iron losses. These lead to decrease inefficiency. Hence proper voltage has to be maintained.

2) Frequency**:** It governs the speed related losses and iron losses. If its value is more than rated these losses increase as speed is directly proportional to the frequency the speed dependent friction &windage losses increase that will decrease the efficiency. Lower value of frequency leads to lower speed that affects the output power. Hence frequency has to be maintained at rated value.

3) When the supply waveform is purely sinusoidal then harmonics are absent which means no iron & copper losses due to harmonic voltage & currents. The harmonics causes production of unwanted harmonic torques in motors which is waste of energy. Hence the supply voltage must be asnear as possible to sine wave in case of AC motors.

iv) Motor survey: Large industries have a massive population of LT motors. Load survey of LT motors can be taken-up methodically to identify improvement options.

2 Marks for explanation of any one technique

1)Sampling Criteria:

Towards the objective of selecting representative LT motor drives among the motor population, for analysis, the criteria considered are:

Utilization factor: Hours of operation with preference given to continuously operated drive motors.

Sample representative: Where one drive motor analysis can be reasoned as representative for the population. e.g. Cooling Tower Fans, Air Washer Units, etc.

Conservation potential: Here drive motors with inefficient capacity controls on machine side; fluctuating load drive systems, etc. are looked into.

2) Measurements:

Studies on selected LT motors involve measurement of electrical load parameters namely volts, amperes, power factor, kW drawn.

Observations on machine side parameters such as speed, load, pressure, temperature, etc., (as relevant) are also taken. Availability of online instruments for routine measurements, availability of tail-end capacitors for PF correction, energy meters for monitoring is also looked into for each case.

3) Analysis:

Analysis of observations on representative LT motors and connected drives is carried out towards following outputs:

- Motor load on kW basis and estimated energy consumption.
- Scope for improving monitoring systems to enable sustenance of a regular in-house Energy Audit function.
- Scope areas for energy conservation with related cost benefits and source information.

The observations are to indicate:
% loading on kW, % voltage unbalance if any, voltage, current, frequency, power factor, machine side conditions like load / unload condition, pressure, flow, temperature, damper / throttle operation, whether it is a rewound motor, idle operations, metering provisions, etc.

The findings / recommendations may include:

- Identified motors with less than 50 % loading, 50 – 75 % loading, 75 – 100 % loading, over 100 % loading.
- Identified motors with low voltage / power factor / voltage imbalance for needed improvement measures.
- Identified motors with machine side losses / inefficiencies like idle operations, throttling / damper operations for avenues like automatic controls / interlocks, variable speed drives, etc.

By proper loading / replacing / repairing the motors withload survey would help to bring out savings in driven machines / systems, which can give 30 – 40 % energy savings.

v)Operating Motor in Star Mode:

i) Lesser than 30% load means torque required by load is less than 30%. Hence current requirement is reduced.

ii) When connected in star, the phase voltage reduces to $(1/\sqrt{3})$ times that in delta mode. As the torque generated by motor is directly proportional to the (applied voltage per phase)^2 the torque produced falls to 1/3compared to delta mode.

iii) Due to decreased phase voltage, the iron losses decrease to nearly 1/3, as total iron losses are proportional to (applied voltage per phase)^2 before saturation.

iv) Due to reduction in phase voltage the current drawn in the lines also reduces leading to lower copper losses in motor and decrease line losses.

vi)Rewinding of Motor:

i) During rewinding by preserving the original winding characteristics (material quality, design and structure). It is possible to maintain the original operating characteristics.

ii) Using larger cross section area of conductors and better insulation the copper losses can be minimized.

iii) Rewinding for the required torque and power or speed results in lowering of the losses(better efficiency and hence energy savings)

iv) Extension of coils beyond the slot insulation must be minimized to reduce the amount of copper used that leads to lowering of the copper losses.

vii)Improving Mechanical Power and Transmission Efficiency:

To improve the mechanical power and transmission efficiency, proper selection of belt drives and gear drives suitable for particular application is

highly essential.

Belt Drives:

A well designed belt transmission offers:

- High efficiency
- Less noise
- Less maintenance
- No need of lubrication

Gear Drives:

A well designed gear transmission offers:

- Helical and bevel gear drives are more efficient (90 – 95%), hence mostly preferred.
- Helical gears are opted for larger loads.
- Spur gears are avoided in new systems due to their low efficiency.
- Worm gears are available with greatly reducing ratios but have inconsistent efficiency. However, proves economical upto 15HP.
- Energy conservation is achieved by using more efficient gears for particular applications.

5 b) State merits of dry type transformer and available maximum rating of it.

Ans:

Merits of Dry Type Transformer:

1) Amorphous core transformer is energy efficient transformer.
2) Better over load capacity.
3) Low partial discharge along with low loss. Hence efficiency is very good.
4) As it is with non-inflammable winding insulation, it offers zero risk to fire hazard. So it is suitable for indoor installation.
5) Can be fitted outdoor.
6) It is non-hygroscopic.
7) Dry type transformers pose no oil leak or pollution risk to the environment.
8) Highly reliable.
9) Require very less maintenance.
10) Produces less noise.
11) Compact in size
12) Almost vibration proof.
13) The magnetic core of dry type transformer is made up of amorphous metal. This core can be easily magnetized and demagnetized.
14) In dry type transformer core losses can be reduced up to 60-70% than conventional transformer.
15) The amorphous material is 9 times harder than CRGO steel. Hence the construction becomes more robust.
16) The amorphous material consists of low fieldmagnetization. Due to low field magnetization, hysteresis losses are low.

1 Mark for each of any three = 3 Marks

Available Maximum Rating of Dry Type Transformer:

In India dry type transformers in the range up to 2.5MVA, 11KV are manufactured / available. — 1 Mark

5 c) Explain power factor incentives and load factor incentives to HT-1 category of

consumer.

Ans:

Power Factor Incentives to HT-1 Category of Consumer:

Whenever the average power factor is more than 0.95, an incentive shall be given at the rate of the following percentages of the amount of the monthly bill including energy charges, reliability charges, FAC, and Fixed/Demand Charges, but excluding Taxes and Duties.

Range of Power Factor	Power Factor Level	Incentive
0.951 to 0.954	0.95	0 %
0.955 to 0.964	0.96	1 %
0.965 to 0.974	0.97	2%
0.975 to 0.984	0.98	3 %
0.985 to 0.994	0.99	5%
0.995 to 1	1	7 %

2 Marks

Load Factor Incentives to HT-1 Category of Consumer:

1) This incentive is applicable to the consumers where payment of arrears has been granted by the MSEDCL, & the same is being made as scheduled.
2) Consumers having load factor above 75% up to 85% : rebate of 0.5% on the energy charges for every 1% increase in the load factor.
3) Consumers having load factor over 85% will be entitled to rebate of 1% on the energy charges for 1% increase in the load factor from 85%.

2 Marks

5 d) State the advantages of soft starter over DOL starter.

Ans:

Advantages of Soft Starter Over DOL Starter:

1) Motor starts (without jerk) smoothly.
2) Severe spikes of starting currents are eliminated.
3) Loss of energy during starting is minimized to about 40 to 50%.
4) Severe wear and tear of mechanical parts such as bearing etc. during starting is eliminated.
5) Longer life of bearings and related components.
6) Very low mechanical stress.
7) Power factor improvement.
8) As current peaks are controlled the MD is reduced which may lead to lower MD billing.
9) Less mechanical maintenance.
10) Saving in operating costs.
11) Enhancement of motor starting duty by reducing the temperature rise in stator windings and supply transformer.

1 Mark for each of any four points = 4 Marks

5 e) State any four questionnaires in reference to energy audit.

Ans:

Questionnaires in Reference to Energy Audit:

1) What are details of the organization? OR
   List the different major energy drawing sections.
2) What is the demand? OR
   List the power demand parameters as contract demand, connected load etc.
3) How is the demand satisfied by the equipment / system? OR

List the different methods of meeting the energy demands of the different sections.

4) What are the equipment / system operating conditions to satisfy the demand? OR
List the different major energy system equipment to meet the energy demands of the different sections.
5) What is the equipment / system energy consumption at these conditions? OR List the working conditions of the different major energy supplying equipment.
6) What modifications in operating conditions are necessary to reduce / control energy consumptions? OR
Enlist the modifications in operating conditions needed to reduce or control the energies to different sections.
7) What is product wise capacity?
8) What is the expected energy saving areas? OR
List the different energy saving areas expected in the major energy drawing sections.
9) What are the costs incurring in undertaking energy conservation measures?
10) What are the production process details? OR
Prepare a chart showing the process details in terms of energy flow.
11) What is payback period?

1 Mark for each of any four Questions = 4 Marks

5 f) What is ABC analysis? How it helps in energy audit?

Ans:

ABC Analysis :

ABC analysis is used to identify components of project that have major and minor influence on the cost. The major and minor influential components are classified in to items of List A, B, C.

List A :- Contains the items that account for approximately 70% of total Cost
List B: - Contains the items that account for approximately 20-25% of total cost.
List C: - Contains items that account for approximately 5 to 10 % of total Cost.

2 Marks

ABC Analysis Helps in Energy Audit:

The ABC analysis works in a manner as to get prime attention to the important items or the critical few and not have unnecessary attention to be spent on the not so important items. This prioritization of attention and focus is vital to keep the costs in check and under control in the supply chain system. To get the best results, it is important that the items having a lot of costs are given the due management attention.

2 Marks

6 Attempt any <u>FOUR</u> of the following: **16**

6 a) List different lighting system. Explain two with examples, suggest energy efficient lighting system.

Ans:

List of Lighting System:

1) Direct lighting system
2) Semi-direct lighting system
3) Indirect lighting
4) Semi-indirect lighting system

1 Mark for any two types

5) General lighting

1) Direct lighting system: It is the most commonly used type of lighting system. Here more than 90% of total light flux is made to fall directly on the working plane with the help of deep reflectors.
Examples-Drawing rooms, Workshops, Kitchens, Flood lighting.
2) Semi-direct system: In this lighting system about 50% of total light flux is made to fall downloads directly with the help of semi-direct reflectors and about 30% is used to illuminate the ceiling and walls.
Examples-Rooms with high ceilings, Interior decoration purposes, Stair ways, Corridors.
3) Indirect lighting: Here more than 90% of total flux is thrown upwards to the ceiling for diffuse reflection by using inverted or bowl reflectors.
Examples-Hotels, Restaurants, Parking places, Theaters, Offices,
4) Semi-indirect lighting system: In this lighting system 60 to 90% of total light flux is thrown upwards to the ceiling for diffuse reflection and the rest reaches the working plane directly.
Examples-Indoor lighting decoration, Interior decorating purposes, Classrooms.
5) General lighting system: This is generally used in houses and industries where lights are hanged from ceiling. This gives equal light on the floor, ceiling walls etc.
Examples-House, Industries

2 Marks for any two explanation

Energy Efficient Lighting System:
The most energy efficient lighting system is the direct lighting system because in direct lighting system more than 90% of total light flux is made to fall directly on the working plane.

1 Mark

OR Equivalent Answer

(Such as lighting systems based on the types of lamps used such as induction lamp lighting systems, LED lamp systems, CFL lamp systems, fluorescent lamp systems, sodium vapor lamp lighting systems, mercury vapor lamp lighting systems, incandescent lamp systems, indoor lighting systems, outdoor lighting systems, flood lighting systems, garden lighting systems etc.)

6 b) Explain the concept of daylight saving as a means for energy conservation.

Ans:

Concept of Daylight Saving as a Means for Energy Conservation:

1) Whenever the orientation of a residential building permits, day lighting can be used in combination with electric lighting. Ultimately use of electrical lighting gets reduced resulting into energy conservation.
2) Usage of day lighting in offices, workshops, schools, factories, temples, hotels etc. Can be made so that burden on electrical lighting may reduce resulting into energy conservation.
3) In many cases, a switching OFF electric light in the window zones during certain daylight hours has to be designed resulting into energy conservation.
4) Maximum use of daylight for street / road lighting can be made with help of sensors.
5) Daily solar energy can be converted into electrical energy and stored in battery with help of PV module can be reused.

4 Marks for any two points

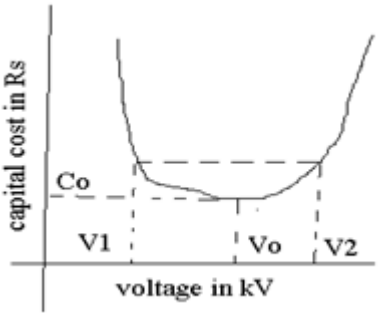
6 c) How the energy conservation can be achieved in distribution system by:
(i) Optimization of HT and LT lines
(ii) By balancing load in three phases

Ans:

(i)Optimization of HT and LT lines:

In transmission system, rise in voltage level improves the power transmission capacity. If voltage is increased by 'n' times, then the size of conductor reduces by $1/n^2$ times. Higher voltage involves higher cost of the system (cost of insulation, cost of switch gear, terminal apparatus etc.)In transmission system, rise in voltage level improves the power transmission capacity. If voltage is increased by 'n' times, then the size of conductor reduces by $1/n^2$ times. Higher voltage involves higher cost of the system (cost of insulation, cost of switch gear, terminal apparatus etc.) 2 Marks

The relation between capital cost in Rs and standard line voltage in kV can be plotted and we get parabolic curve. The lowest point on the curve represents optimum voltage to be chosen. If capital cost does not differ appreciably, two voltages are selected (because higher V is easy to control than higher I)



Optimum voltage for a system can be calculated by,

$V_L = 5.5\sqrt{((L/1.6) + (P\times1000/\cos\phi \times NC \times 150))}$

where, V_L = Transmission line voltage in kV
L = Length of line in km
P = Power to be transmitted
NC = Number of circuits
$\cos\phi$ =Power factor of load

(ii)By Balancing Load in Three Phases:

An unbalanced current produces 'Negative sequence' currents in the power system. This causes over heating of transformers, cables, conductors and motors. Negative phase sequence components create a rotating magnetic field in the stator which moves in the opposite direction. This causes a decrease in the resultant torque developed by the motor. The motor will thus have to draw a higher current for the same mechanical load. As a result losses are increased and unbalanced voltage condition is developed which leads to malfunctioning of motor. So it is necessary to keep the system negative phase sequence voltages within the limits. 2 Marks

As measure of energy conservation technique, the loads are distributed evenly among the phases. They can be separated as single phase loads and three phase loads by providing separate transformers. Similarly we can separate light loads and power loads with separate transformers. There is considerable amount of

saving in capital (saving the de-rating of equipment) as well as energy losses

6 d) State the factors governing selection of co-generation.

Ans:

Factors to be considered for selection of co-generation techniques:

1) Heat power ratio: It should match characteristics of cogeneration system.
2) Load pattern: For selection of cogeneration system, the type of load, its continuity is important aspect.
3) Type of fuel: Generally the type of fuel is selected according to cost. The cost of fuel should be less.
4) The quality of thermal energy: The quality of steam is decided by temperature & pressure of the steam.
5) Electricity buyback: Sometime the electrical energy generated in cogeneration system is sold out to supply company, after that whenever that factory is need of electrical power; it is purchased from Supply Company by common electricity buyback agreement.
6) Grid dependent & independent system technology: There are various technology systems applicable for grid.
7) Local environment regulations: In this regulation for cogeneration system we have to study all environmental conditions, politics & other regulation factors also.
8) Base electrical load matching: By cogeneration system the minimum electricity demand should be supplied.
9) Electricity load matching: It is the stand alone system or it is totally independent system in which the 100% electrical energy is achieved by the cogeneration system.
10) Base thermal load matching: The minimum thermal energy can be achieved by our cogeneration system & if required for additional thermal energy can be generated from purchased power of supply company or grid system.
11) Thermal load matching: In this system the 100% thermal energy is achieved by cogeneration system.

4 Marks for any four factors

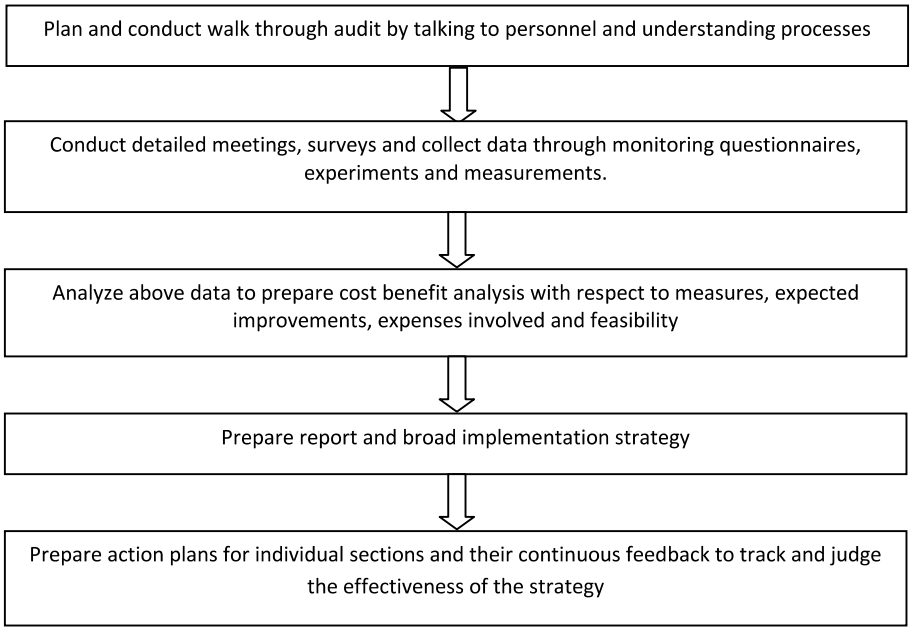
6 e) With the help of flow chart, explain procedure of energy audit.

Ans:

Energy Audit Procedure:

- The planning of energy audit is decided by conducting meeting with working personnel in the industry.
- The complete information about the processes in industry is collected.
- Preliminary audit is carried out with the help of available data.
- Some experimentation, measurements, data collection and detailed survey and meetings are carried out.
- Cost benefit analysis considering payback period is done.
- Accordingly broad report is prepared for implementation of the strategy.
- The action plans are prepared for individual section, approved by the authority.
- During implementation, the feedbacks are taken to judge the effectiveness of the strategy.

2 Marks for procedure



2 Marks for diagram