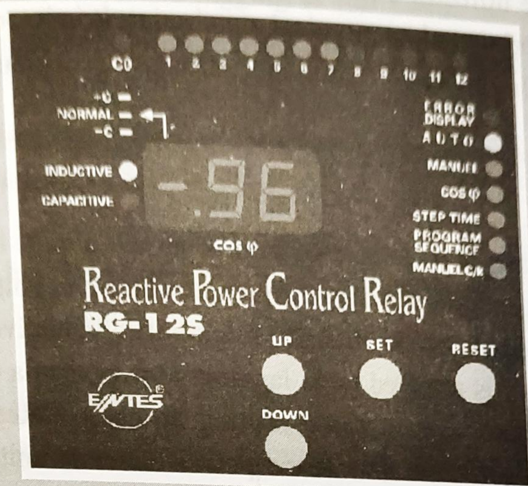
CHAPTER - 5

ELECTRICAL EQUIPMENT AND POWER FACTOR



OBJECTIVES

You will be able to:

- Define power factor and mention the causes of low power factor.
- Explain briefly the limitations of low power factor and the advantages of high power factor.
- Explain the calculation of power factor correction.
- Derive an Expression for most Economical Power factor considering constant active power with relevant vector diagram.
- Define Tariff and Explain different types of Tariff commonly Used.
- Explain the meaning of ABT and enumerate the broad features of ABT design.
- Give the comparison between existing tariff and availability based tariff.
- Write a note on Energy Efficient Motors.
- Explain What are the options available to meet the increased Demand on Power Station by justifing its installation.
- Write a note on Energy saving practices in street lighting.
- Explain briefly some good practices in lighting.
- Explain the location of capacitors with a power Distribution diagram
- Solve the numericals related to most economical power factor, tariff and meeting the increased demand on Power Station.

POWER FACTOR IMPROVEMENT

The electrical energy is almost exclusively Generated, Transmitted and Distributed in the form of alternation current. Therefore, the question of power factor immediately comes into picture. Most of the Loads (ex. induction Motors, arc lamps) are inductive in nature and hence have low lagging power factor. The low power factor is highly undesirable as it causes an increase in current, resulting in additional losses of active power in all the elements of power system from power station Generator down to the utilization devices. In order to ensure most favorable conditions for a supply system from engineering and economical standpoint. It is important to have power factor as close to unity as possible. In this chapter, we shall discuss the various methods of power factor improvement.

5.1 Power Factor:

The cosine of angle between voltage and current in an a.c circuit is known as power factor. In case of a.c. circuit, there is generally a phase difference ϕ between voltage and current. The term $\cos \phi$ is called the power factor of the circuits, If the circuit is inductive, the current lags behind the voltage and the power factor is referred to as lagging. However in a capacitive circuit, current leads the voltage and power factor is said to be leading. In case of Resistive circuit's current is in phase with applied voltage, ϕ is zero and hence power factor is unity.

Consider an inductive circuit drawing a lagging current from supply voltage V; the angle of lag being ϕ. The phosor diagram of the circuit is shown in Fig 5.1 The circuit current I can be resolved into two perpendicular components. Namely:

a) $I\cos \phi$ in phase with V

b) $I\sin \phi$, 90^0out of phase with V

The components $I\cos \phi$ is known as active or wattful components

Whereas components $I\sin\phi$ is called the reactive or wattless component. The reactive components are a measure of the power factor. If the reactive components are small .the phase angle ϕ is small and hence power factor $\cos\phi$ will be high. Therefore, a circuits having small reactive current (i.e. $I\sin\phi$) will have high power factor and vice versa. It may be noted that value of power factor can never be more than unity.

(i) It is a usual practice to attach the word 'lagging' or 'leading 'with the numerical value of power factor to signify whether the current legs or leads the voltage. Thus if the circuit has a pf of 0.5 and the current lags the voltage, we generally write p.f.as 0.5 lagging.

(ii) Some times power factor is expressed as a percentage. Thus 0.8 lagging power factor may be expressed as 80% lagging.

5.2 Causes of Low power Factor:

Low power factor is undesirable from economic point of view. Normally, the power factor of the whole Load on the supply system is less than 0.8; the following are the causes of low power factor:

(i) Most of the a.c Motors are of induction type (1 ϕ and 3 ϕ induction Motors) which have low lagging power factor. The 3 ϕ induction Motors work at a power factor which is extremely small on light Load (0.2 to 0.3) and rises to around 0.8 lagging at full Load and power factor of 1 ϕ induction Motors are about 0.6 lagging at full Load.

(ii) Transformers draw a magnetizing current from the line. This current lags the voltage at an angle 90°

(iii) Arc lamps, electric discharge lamps and industrial heating furnaces, welding equipment operate at low lagging power factor.

(iv) The Load on the power system is varying; being high during morning and evening and low at other times. During low Load period, supply voltages are increased which increases the magnetization current. This results in the decreased power factor.

5.3 Disadvantages of Low Power Factor:

The power factor plays and importance role in a.c circuits since power consumed depends upon this factor.

$P = V_L I_L \cos \phi$ (For single phase supply)

$$I_L = \frac{P}{V_L \cos \phi} \quad \text{Where } V_L \text{ is Line Voltage} \; \ldots\ldots\ldots\ldots (1)$$

$p = \sqrt{3} V_L I_L \cos\varnothing$ (For 3 phase supply)

$$I_L = \frac{P}{\sqrt{3} V_L \cos\varnothing} \quad \text{Where } V_L \text{ is Line Voltage} \; \ldots\ldots\ldots\ldots (2)$$

It is from above that for fixed power and voltage, the Load current is inversely proportional to the power factor. Lower the power factor, higher is the Load current and vice – versa.

A power factor less than unity result in the following disadvantages:

(i) **Large kVA rating of equipment:** The electrical machinery (e.g. Alternators, transformers and switchgear) is always rated in kVA, Now

$$KVA = \frac{KW}{\cos\varnothing}$$

It is clear that kVA rating of the equipment is inversely proportional to power factor. The smaller the power factor .the larger is the kVA rating Therefore, at low power factor, the kVA rating of the equipment (Size of the equipment) has to be made more, making the equipment larger and expensive.

(ii) **Greater conductor size**: To transmit or distribute a fixed amount of power at constant voltage, the conductor will have to carry more current at low power factor. This necessitates large conductor size. Cost the of conductor required for Transmission and Distribution will increases.

(iii) **Large copper losses**: The large current at low lagging power factor causes more I^2 R losses in all the elements of the supply system. This results in poor efficiency. Since

$$R \propto \frac{pl}{A}$$

Where *R = Resistance of the conductor*

P = Specific resistivity of conductor

l = Length of the conductor

A = Area of conductor

(iv) **Poor voltage regulation**: The large current at low lagging power factor causes greater voltage drops in alternators, transformers , transmission lined and distributors .This results in the decreased voltage available at the receiving end thus Voltage regulation is more , poor voltage at the receiving impairing the performance of utilization devices. In order to keep the receiving end voltage within permissible limits, extra equipments (i.e. voltage regulators) is required. According to bureau of Indian standards the voltage regulation should not vary + or – 5%

(v) **Reduced handling capacity of system**: The lagging power factor reduces the power handling capacity of all the elements of the power system .it is because the reactive component of current prevents the full utilization of installed capacity. There fore Active power supplied by alternators and transformers reduces. The above discussion leads to the conclusion that low power factor is an objectionable feature in the supply system

5.4 Advantages of High Power Factor:

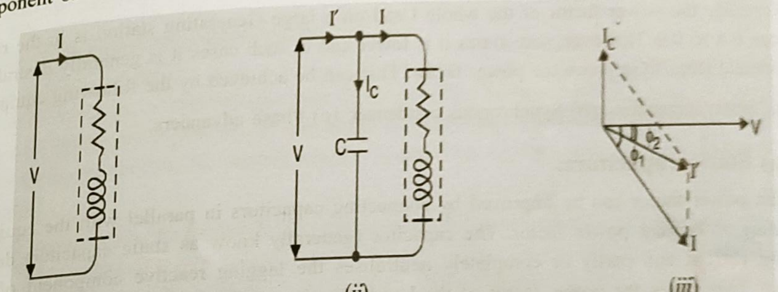
Installation of power factor improvement device, to raise the power factor, results in the following advantages:

- Reduces the transmission and Distribution line losses
- Improves the voltage regulation of the line
- Reduction in circuit current.
- Increases the voltage level at Load
- Cost required for power handling capacity decreases
- Improvement in power factor of the Generators
- Reduction in KVA Loading of the Generator and circuits. this reduction in KVA Loading may relieve an over Loaded condition
- Reduction in KVA demand charges for large consumers

- Avoids the Lpf penalty to the HT customers.
- Performance of devices connected to the supply will increase.

5.5 Power Factor Improvement:

The low power factor is mainly due to the fact that most of the power Loads are inductive and, therefore, take lagging currents. In order to improve the power factor, some device taking leading currents should be connected in parallel with the Load. One of such devices can be a capacitor. The capacitor draws a leading current and partly or completely neutralizes the lagging reactive component of Load current. This raises the power factor of the Load.



(i) (ii) (iii)

Figure 5.5

Illustration: To illustrate the power factor improvement by a capacitor, consider a single phase Load taking lagging current I at a power factor Cosϕ_1 as shown in Fig. 5.5

The capacitor C is connected in parallel with the Load. The capacitor draws current I_c which leads the supply voltage by 90^0. The resulting line current I is the phase sum of I and I_c and its angle of lag is ϕ_2 as shown in the phasor diagram of Fig 5.5 (iii). It is clear that ϕ_2 is less than 1 so that cosϕ_2 is greater than cos ϕ_1. Hence, the power factor of the Load is improved .The following points are worth nothing:

(i) The circuit current I' after pf .correction is less than the original circuit current *I*

(ii) The active or wattful component remains the same before and after pf because only the lagging reactive component is reduced by the capacitor.

$$I \cos\phi_1 = I' \cos \phi_2$$

(iii) The lagging reactive component is reduced after pf. improvement and is equal to the difference between lagging reactive component of Load ($I\sin\phi_1$) and capacitor current(I_c)i.e. I' sinϕ_2 = I sinϕ_1-Ic

(iv) As $\cos\phi_1 = I' \cos\phi_2$

$VI \cos\phi_1 = VI' \cos\phi_2$ (Multiplying by V)

Therefore, active power (kW) remains unchanged due to power factor improvement.

(v) $I' \sin\phi_2 = I \sin\phi_1 - I_c$ (Multiplying by V)

$VI \sin\phi_2 = VI \sin\phi_1 - V I_c$

Net kVAR after pf. correction = Lagging kVAR before pf correction – leading kVAR of Equipment.

5.6. Power Factor Improvements Equipment:

Normally the power factor of the whole Load on a large Generating station is in the region between 0.8 to 0.9. However, sometimes it is lower and in such cases it is generally desirable to take special steps to improve the power factor. This can be achieved by the following equipment.

(a) Static capacitors. (b) Synchronous condenser. (c) Phase advancers.

5.6(a) Static capacitors:

The power factor can be improved by connecting capacitors in parallel with the equipment operating at lagging power factor. The capacitor (generally know as static capacitor) draws a leading current and partly or completely neutralises the lagging reactive component of Load current. This raises the power factor of the Load. For three phase Loads the capacitors can be connected in delta or star shown in Fig 5.6 (a) static capacitors are invariably used for power factor improvement in factories.

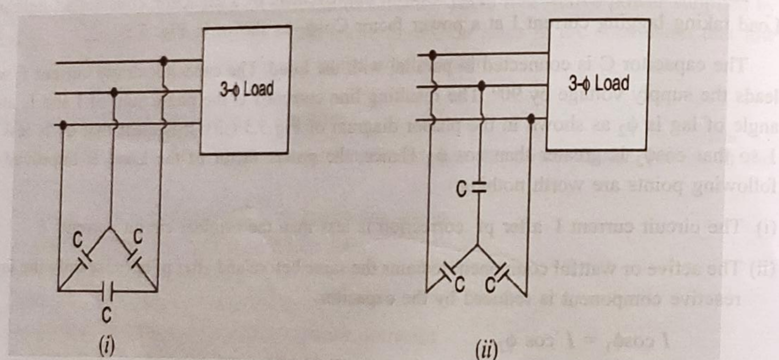


Figure 5.6(a)

Advantages

(i) They have low losses.

(ii) They require little maintenance as there are no rerating parts.

(iii) They can be easily installed as they are light and require no foundation.

(iv) They can work under ordinary atmospheric conditions.

Disadvantages

(i) They have short service life ranging from 8 to 10 years.

(ii) They are easily damages if the voltage exceeds the rated value.

(iii) Once the capacitors are damaged, their repair is uneconomical.

5.6(b) Synchronous condenser:

A synchronous Motor takes a leading current when over excited and therefore behave as a capacitor. An over excited synchronous Motor running on no Load is known as synchronous condenser. When such a machine is connected in parallel with the supply. It takes a leading current which partly neutralizes the lagging reactive component of the Load. Thus the power factor is improved.

Fig 5.6(b) shows the power factor improvement by synchronous condenser method. The 3ϕ Load takes current I_L at low lagging power factor cos ϕ_L . The synchronous condenser takes a current I_m which leads the voltage by an angle ϕ_m. The resultant current I is phasor sum of I_m and I_L which lags behind the voltage by an angle ô .It is clear that angle ϕ is less than ϕ_L so that cosϕ is greater than $\cos\phi_L$ .Thus the power factor is increased from $\cos\phi_L$ to cosϕ. Synchronous condensers are generally used at major bulk supply substation for power factor Improvement.

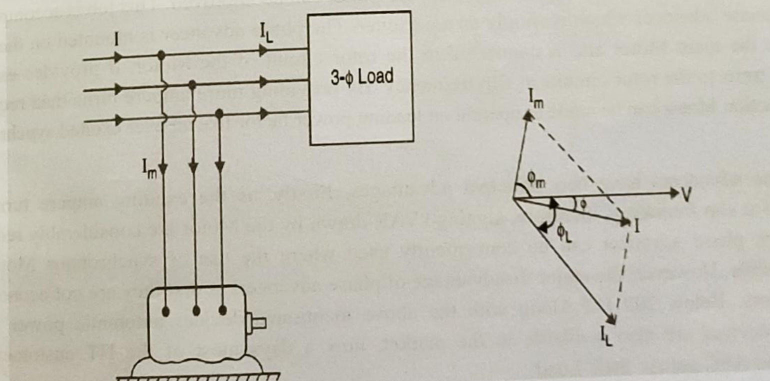


Figure 5.6(b). 3-ϕ Synchronous Motor

Advantages

(i) By varying the field excitation, the magnitude of current drawn by the Motor can be changed by any amount this helps in achieving steeples control of power factor.

(ii) The Motor windings have high thermal stability to short circuit currents.

(iii) The faults can be removed easily.

Disadvantages

(i) There are considerable losses in the Motor.

(ii) The maintenance cost is high.

(iii) It produces noise.

(iv) Except in sizes above 500 kVA, the cost is greater than of static capacitors of the same rating.

(v) As a synchronous Motor has no self starting torque, therefore, auxiliary equipment has to be provided for this purpose.

Note: The reactive power taken by a synchronous Motor depends upon two factors, the D.C. field excitation and the mechanical Load delivered by the Motor. Maximum leading power is taken by a synchronous Motor with maximum excitation and zero Loads.

5.6(c) Phase advancers:

Phase advancers are used to improve the power factor of induction Motors. The low power factors of an induction Motor are due to the fact that its stator winding draws exciting current which lags behind the supply voltage by 90^0. If the exciting ampere turns can be provided from some other a.c source, then the power factor of the Motor can be improved. This job is accomplished by the phase advancer which is simply an a.c exciter. The phase advancer is mounted on the same shaft as the main Motor and is connected in the rotor circuit of the Motor. It provides exciting ampere turns to the rotor circuits at slip frequency .By providing more ampere turns than required, the induction Motor can be made to operate on leading power factor like an over excited synchronous Motor.

Phase advancers have two principal advantages. Firstly, as the exciting ampere turns are supplied at slip frequency, therefore, lagging kVAR drawn by the Motor are considerably reduced. Secondly, phase advancer can be conveniently used where the use of synchronous Motors is inadmissible .However; the major disadvantage of phase advancers is that they are not economical for Motors. Below 200 H.P.Along with the above mentioned devices automatic power factor control devices are also available in the market, now a days most of the HT customers are connected AFC across their Load

5.7. Calculation of Power Factor Correction:

Consider an inductive Load taking a logging current *I* at a power factor $\phi 1$ in order to improve the power factor of this circuit, the remedy is to connect such an equipment in parallel with the Load which takes a leading reactive component and partly cancels the lagging reactive component of the Load Fig.5.5 (i) shows a capacitor connected across the Load. The capacitor takes a current I_c which leads the supply voltage V by 90^0. the current *Ic* partly cancels the lagging reactive component of the Load current as shown in the phasor diagram in Fig.5.5 (ii) the resultant circuit current becomes *I* and is angle of lag is ϕ_2 .It is clear that ϕ_2 is less than ϕ_1 so that new pf $\cos\phi_2$ is more than the previous pf $\cos\phi_1$.From the phasor diagram. It is clear that after pf correction, the legging reactive component of the Load is reduced to $I \sin\phi_2$

$$I \sin\phi_2 = I \sin\phi_1 - I_C$$

Obviously

$$I_c = I \sin\phi_1 - I \sin\phi_2$$

Capacitance of capacitor to improve pf from $\cos\phi_1$ to $\cos\phi_2$

The power factor correction can also be illustration from power triangle. Thus referring to Fig 5.8 the power triangle OAB is for the power factor $\cos\phi$ 1 whereas power triangle OAC is for the improved power factor $\cos\phi 2$ It may be seen that active power (OA) does not change with power factor improvement However the lagging kVAR of the Load is reduce by the pf correction equipment. Thus improving the power factor to $\cos\phi_2$

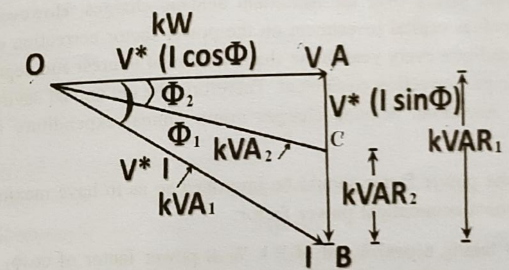


Fig 5.7 *Calculation of Power Factor Correction*

Leading kVAR supplied by pf correction equipment

$$\begin{aligned} BC &= AB - AC \\ &= kVAR_1 - kVAR_2 \\ &= OA\ (\tan\phi_1 - \tan\phi_2) \\ &= kW\ (\tan\phi_1 - \tan\phi_2) \end{aligned}$$

Knowing the leading kVAR supplied by the pf correction equipment, the desired results can be obtained.

5.8. Importance of Power Factor Improvement

The improvement of power factors is very important for both consumers and generating stations as discussed below:

(i) **For consumers**: A consumer has to pay electricity charges for his maximum demand in kVA plus the units consumed. If the consumer improves the power factor, then there is a reduction in his maximum kVA demand and also he has to pay LPF Penalty, consequently there will be annual saving due to maximum demand charges. Although power factor improvement involves extra annual expenditure on account of pf. correction equipment, yet improvement of pf. to a proper value results in the net annual saving for the consumer.

(ii) **For generating stations:** A generating station is as much concerned with power factor improvement as the consumer. The Generators in a power station are rated in kVA but the useful output depends upon kW output. As station output is kW = kVA x cosϕ, therefore, number of units supplied by it depends upon the power factor. The greater the power factor of the generating station, the higher is the kWh it delivers to the system. This leads to the conclusion that improved power factor increase the earning capacity of the power station.

5.9. Most Economical Power Factor:

If a company improves the power factor, there is reduction in his maximum kVA demand and hence there will be annual saving over the maximum demand charges. However, when power factor is improved, it involves capital investment on the power factor correction equipment. The consumer will incur expenditure every year in the shape of annual interest and depreciation on the investment made over the pf. correction equipment. Therefore, the net annual saving will be equal to the annual saving in maximum demand charges minus annual expenditure incurred on pf. correction equipment.

The value to which the power factor should be improved so as to have maximum net annual saving is known as the most economical power factor:

Consider a consumer taking a peak Load of P k W at power factor of cosϕ_1 and charged at a rate of Rs A per kVA of maximum demand per annum. Suppose the consumer improves the power factor to *Cos*ϕ_2 by installing pf correction equipment. Let expenditure incurred on the pf correction equipment be Rs. B per kVAR per annum. The power triangle at the original pf cosϕ_1 is OAB and for the improved pf cosϕ_2 it is OAC [see Fig.5.9]

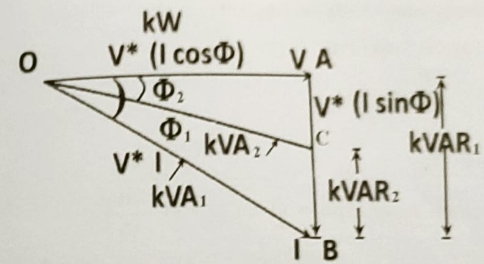


Fig 5.9. Most Economical Power Factor

KVA max demand at cosϕ_1, $kVA_1 = P\ sec\phi_1$

KVA max demand at cosϕ_2, $kVA_2 = P\ sec\phi_2$

Annual saving in maximum demand charges

$= Rs\ A\ (kVA_1 - kVA_2)$

$= Rs\ A\ (P\ sec\phi_1 - P\ sec\phi_2)$

$= Rs\ Ap\ (sec\phi_1 - sec\phi_2)$............. (i)

Reactive power at cos ϕ_1, $kVAR_1 = P\ tan\phi_1$

Reactive power at cosϕ_1, $kVAR_2 = P\ tan\phi_2$

Leading kVAR taken by p.*f* correction equipment

$= P\ (tan\phi_1 - tan\phi_2)$

Annual cost of pf correction equipment

$= Rs\ PB\ (tan\phi_1 - tan\phi_2)$........... (ii)

Net annual saving,S = exp, (i) – exp (ii)

$= AP\ (sec\phi_1 - sec\phi_2) - BP\ (tan\phi_1 - tan\phi_2)$

In this expression only ϕ_2 is variable while all other quantities are fixed. Therefore, the net annual saving will be maximum if differentiation of above expression with respect to ϕ_2 is zero.

$$\frac{d}{d\phi_2}(s) = 0$$

$$\frac{d}{d\phi_2}\{(Ap(sec\phi_1 - sec\phi_2) - Bp(tan\phi_1 - tan\phi_2))\} = 0$$

$$\frac{d}{d\phi_2}(Ap\ Sec\phi_1) - \frac{d}{d\phi_2}(Ap\ Sec\phi_2) - \frac{d}{d\phi_2}(Bp\ tan\phi_1) - \frac{d}{d\phi_2}(Bp\ tan\phi_2) = 0$$

$$0\text{-}AP \sec\phi_2 \tan\phi_2 - 0\text{-}Bp \sec^2 \phi_2 = 0$$

$$- A \tan\phi_2 - B \sec\phi_2 = 0$$

$$\tan \phi_2 = \frac{B}{A} \sec \phi_2$$

$$\sin \phi_2 = \frac{B}{A}$$

Most economical power factor, $\cos\phi_2 = \sqrt{1-\sin^2\phi_2} = \sqrt{1 - \left(\frac{B}{A}\right)^2}$

It may be noted that the most economical power factor $\cos\phi_2$ depends upon the relative costs of supply and pf. correction equipment but is independent of the original pf $\cos\phi_1$.

5.10 Meeting the Increased kW demand on power station:

The useful output of a power station is the kW output delivered by it to the supply system sometimes, a power station is required to deliver more kW to meet the increase in power demand this can be achieved by either of the following two methods:

(i) By useful output of a power station at the same power factor (say $\cos\phi_1$) obviously extra cost will be incurred to increase the kVA capacity of the station.

(ii) By improving the power factor of the station from $\cos\phi_1$ to $\cos\phi_2$ without increasing the kVA capacity of the station. This will also involve extra cost on account of power factor correction equipment.

Economical comparison of two methods: It is clear that each method of increasing kw capacity of the station involve extra cost. It is, therefore desirable to make economical comparison of the two methods, Suppose a power station of rating P kVA is supplying Load at pf of $\cos \phi_1$. Let us suppose that the new power demand can be met either by increasing the pf to $\cos\phi_2$ at P kVA or by increasing the kVA rating of the station at the original pf $\cos\phi_1$. The power triangle whole situation are shown in Fig 5.10

(i) **Cost of increasing kVA capacity of station :** referring to Fid. 5.10 The increase in kVA capacity of the station at $\cos\phi_1$, to meet the new demand is given by:

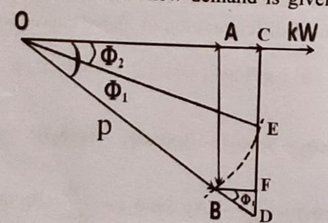


Fig 5.10 *Meeting the increased demand*

Increase in kVA capacity

$$BD = \frac{BF}{\cos\phi_1} = \frac{AC}{\cos\phi_1} = \therefore (BF = AC)$$

$$= \frac{OC\text{-}OA}{\cos\phi_1}$$

$$= \frac{OE\cos\phi_2 - OB\cos\phi_1}{\cos\phi_1}$$

If Rs A is the annual cost per kVA of the station, then Annual cost due to increase in kVA capacity

$$= \text{Rs.} \frac{AP(\cos\phi_2 - \cos\phi_1)}{\cos\phi_1} \quad \text{.....................} \quad (i)$$

(i) **Cost of pf correction equipment :** Refering to Fig 5.10 the new demand in kW can be met by increasing the pf from $\cos\phi_1$ to $\cos\phi_2$ at the original kVA of the station, The leading kVAR to be taken by pf correction equipment

$$= ED = CD - CE$$

$$= OD \sin\phi_1 - CE \sin\phi_2$$

$$= \frac{OC}{\cos\phi_1} \sin\phi_1 - CE \sin\phi_2$$

$$= CE(\tan\phi_1 \cos\phi_2 - \sin\phi_2)$$

$$= P (\tan\phi_1 \cos\phi_2 - \sin\phi_2)$$

If Rs. B is the annual cost per kVAR of the pf correction equipment, then Annual cost of an pf correction equipment is

$$= \text{Rs. } Py (\tan\phi_1 \cos\phi_2 - \sin\phi_2) \quad \text{....................} \quad (ii)$$

Different cases

(a) The pf correction equipment will be cheaper if

Exp (ii) < exp (i)

$$\text{Or } BP (\tan \phi_1 \cos \phi_2 - \sin\phi_2) < \frac{AP(\cos\phi_2 - \cos\phi_1)}{\cos\phi_1}$$

$$\text{Or } B (\tan \phi_1 \cos \phi_2 - \sin\phi_2) < \frac{A(\cos\phi_2 - \cos\phi_1)}{\cos\phi_1}$$

(b) The maximum annual cost per kVAR (i.e.) of pf correction equipment that would justify its installation is when

Exp (i) = exp (ii)

$$BP(\tan\phi_1 \cos\phi_2 - \sin\phi_2) = \frac{AP(\cos\phi_2 - \cos\phi_1)}{\cos\phi_1}$$

$$B\left(\frac{\sin\phi_1}{\cos\phi_1}\cos\phi_2 - \sin\phi_2\right) = \frac{A(\cos\phi_2 - \cos\phi_1)}{\cos\phi_1}$$

$$B\left(\frac{\sin\phi_1\cos\phi_2 - \sin\phi_2\cos\phi_1}{\cos\phi_1}\right) = \frac{A(\cos\phi_2 - \cos\phi_1)}{\cos\phi_1}$$

$$B\sin(\phi_1 - \phi_2) = A(\cos\phi_2 - \cos\phi_1)$$

$$\boxed{\therefore B = \frac{A(\cos\phi_2 - \cos\phi_1)}{\sin(\phi_1 - \phi_2)}}$$

5.11 worked Examples on Power factor correction and Tariff

Example 5.11.1 An alternator is supplying a Load of 300 kW at 0.6 pf lagging. If the power factor is raised to unity. How many more kilowatts can alternator supply for the same kVA Loading? Comment on the result obtained.

VTU/Dec.09/Jan.10/06 Marks

Solution:

$$kVA = \frac{kw}{\text{cost } \phi} = \frac{300}{0.6} = 500 \text{ kVA}$$

KW at 0.6 pf = 300 kW

KW at 1 pf = 500 x 1 = 500 kW

Increased power supplied by the alternator

= (500 – 300) = 200 kW

Note the importance of power factor improvement. When the pf of the alternator is unity. The 500 kVA is also 500 kW and the engine driving the alternator has to be capable of developing this power together with the losses in the alternator. But when the power factor of the Load is 0.6 lagging the power delivered by alternator is only 300kW Therefore, the engine is developing only 300kW through the alternator is supplying its rated output of 500 kVA

Example 5.11.2 A single phase Motor connected to 400 V 50 Hz supply takes 31.7A at a power factor of 0.7 lagging Calculate the capacitance required parallel with the Motor to raise the power factor to 0.9 lagging.

VTU/December2010/10 Marks

The circuit and phasor diagrams are shown in Fig 5.11.2(a) and Fig 5.11.2(b)

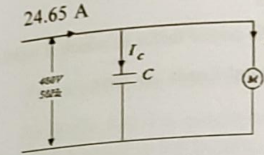


Fig 5.11.2(a)

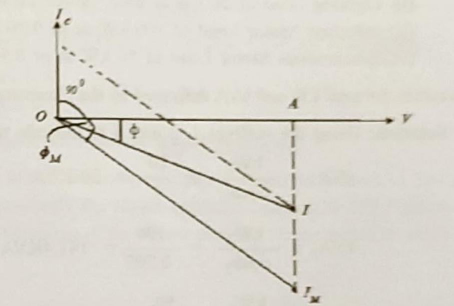


Fig 5.11.2(b)

Active component of I_M $= I_M \cos\phi_M = 31.7 \times 07 = 22.19A$

Active component of $I = I\cos\phi = 1 \times 0.9 = 0.9$

These components are resented by OA in Fig 5.11.2(b)

$$I = \frac{22.19}{0.9} = 24.65 \text{ A}$$

Reactive components I_M $= I_M \sin\phi_M = 31.7 \times 0.714 = 22.6A$

Reactive component of I $= I\sin\phi = 24.65$

$= 24.65 \times \sqrt{(1\text{-}0.9)^2}$ (Since $\sin\phi = \sqrt{1-\cos^2\phi}$)

= 10.75A

It is clear from Fig 5.11.2 (b) that $I_c = 22.6\text{-}10.75 = 11.85A$ ($I_C = I_M \sin\phi_M - I\sin\phi$)

$$I_c = \frac{V}{Xc} = V \times 2\pi fc$$

$\therefore 11.85 = 400 \times 2\pi \times 50C$

C= 94.3 x 10^{-6} F = 94.3 μF

Note the effect connecting a 94.3 μF capacitor in parallel with the Motor. The current taken from the supply is reduced from 30.7 A to 24.65 A without altering the current or power taken by the Motor. This enables an economy to be affected in the size of Generating plant and in cross-sectional area of conductor.

Example 5.11.3 A single phase a.c Generator supplies the following Load;

(i) Lighting Load of 20 kW at unity power factor.
(ii) Induction Motor Load of 100 kW at pf 0.707 lagging.
(iii)Synchronous Motor Load of 50 kW at pf 0.9 leading

Calculate the total kW and kVA delivered by the Generator and the power factor at which it works

Solution: Using the suffixes 1, 2 and 3 to indicate the different Loads we have

$$kVA_1 = \frac{kW_1}{\cos\phi_1} = \frac{20}{1} = 20 \text{ KVA}$$

$$kVA_2 = \frac{kW_2}{\cos\phi_2} = \frac{100}{0.707} = 141.4\text{KVA}$$

$$kVA_3 = \frac{kW_3}{\cos\phi_3} = \frac{50}{0.9} = 55.6\text{KVA}$$

There Loads are represented In Fig 5.11.3 the three kVA are not in phase In order to find the total kVA. We resolve each kVA into rectangular components kW and kVA as shown in Fig 5.11.3 The total kW and kVAR may then be combined to obtained it obtain total kVA.

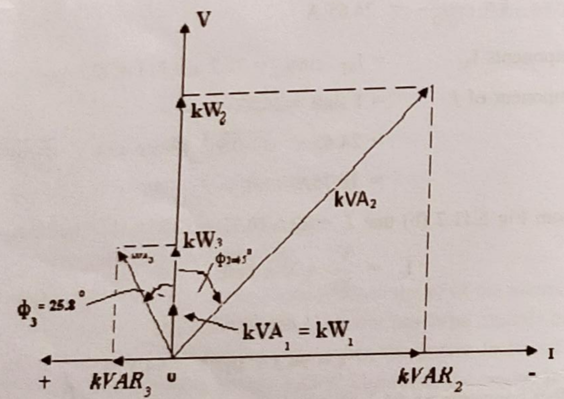


Fig. 5.11.3

$kVAR_1 = kVA_1 \sin\phi_1 = 20 \times 0 = 0$

$kVAR_2 = kVA_2 \sin\phi_2 = - 141.4 \times 0.707 = - 100$ kVAR

$kVAR_3 = kVA_3 \sin\phi_3 = +55.6 \times 0.436 = + 24.3$ kVAR

Note that $kVAR_2$ and $kVAR_3$ are in opposite direction: $kVAR_2$ being a lagging while $kVAR_3$ being a leading kVAR.

Total kVA = 20 + 100 + 50 = 170 kW

Total kVAR = 0-100 + 24.3 = - 75.7 kVAR

Total kVA = $\sqrt{(KW)^2 + (KVAR)^2} = \sqrt{(170)^2 + (75.7)^2} = 186$KVA

$$\text{Power factor} = \frac{\text{Total KW}}{\text{Total KVA}} = 0.914 \text{ lagging}$$

The power factor must be lagging since the resultant kVAR is lagging.

Example 5.11.4 A synchronous the Motor improves the power factor of a Load of 300 kW from 0.7 lagging to 0.9 lagging. Simultaneously the Motor carries a Load of 80 kW Find (i) the leading kVAR taken by the Motor (ii) kVA rating of the Motor and (iii) Power factor at which the Motor operates.

Solution:

Load, P_1 = 300KW; Motor Load P_2 = 80KW

P.F of Load $\cos\phi_1$= 0.7 Lag

P.F of Load (Combined Load) $\cos\phi_2$= 0.9 Lag

Combined Load P= $P_1 + P_2$ = 300+80 = 380KW

$\phi_1 = \cos^{-1}(0.7) = 45.57^0$; $\phi_2 = \cos^{-1}(0.9) = 25.84^0$

(i) Leading KVAR taken by the Motor

CE = DE-DC

= AB-DC[∴ DE = AB]

= $(P_1 \tan\phi_1) - (P \tan\phi_1)$

= $(300 \text{ X } \tan(45.57^0)) - (380 \text{ X } \tan(25.84^0))$

= 121.986 KVAR

(ii) KVA rating of the Motor BC $= \sqrt{(BE)^2 + (CE)^2}$

$= \sqrt{(P_2)^2 + (CE)^2}$

$= \sqrt{(80)^2 + (121.986)^2}$

= 145.878KVA

(iii) P.F of Motor, $\cos\phi_m = \frac{\text{Motor KW}}{\text{Motor KVA}} = \frac{80}{145.878}$

= 0.548Leading

Example 5.11.5 A 3- phase , 50 Hz 400 V Motor develops 200 H.P (149.2 kW) the power factor being 0.75 lagging and efficiency 90% A bank of capacitors is connected in delta across the supply terminals and power factor raised to 0.95 lagging . Each of the capacitance units is built of 4 similar 100 V capacitors; determine the capacitance of each capacitor.

Solution:

Original P.F $\cos\phi_1$ = 0.75 Lagging

Final P.F $\cos\phi_2$ = 0.95 Lagging

Motor input, $P = \frac{Output}{\eta} = \frac{149.2 \times 10^3}{0.9}$

$= 165.77KW$

$\phi_1 = \cos^{-1}(0.75) = 41.41^0$

$\tan\phi_1 = 0.8819$

$\phi_2 = \cos^{-1}(0.95) = 18.19^0$

$\tan\phi_2 = 0.3286$

Leading KVAR taken by condenser bank

$= (P \tan\phi_1) - (P \tan\phi_2)$

$= P(\tan\phi_1 - \tan\phi_2)$

$= 165.77\ (0.8819 - 0.3286)$

$= 91.72KVAR$

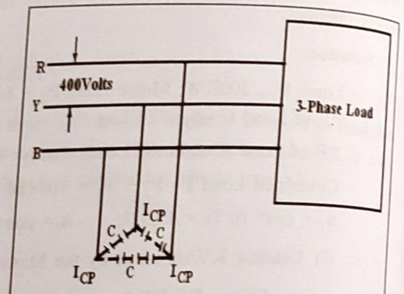


Fig 5.11.4

Leading KVAR taken by each of three sets

$= \frac{91.72}{3}$

$= 30.57KVAR$ ....(i)

Fig 5.11.4 shows the delta connected condenser bank let c farad be capacitance of 4 capacitors in each phase

Phase current of capacitor is

$I_{CP} = \frac{V_{ph}}{X_c} = 2\pi fc\, V_{ph}$

$I_{CP} = 2\pi c \times 50 \times 400$

$I_{CP} = 1{,}25{,}663.7.0$ C amperes

KVAR /Phase $= \frac{V_{ph} \times I_{cp}}{1000} = 50265.48C$..........(ii)

Equating (i) and (ii)

$30.57 = 50265.48C$

$C = 608.17 \times 10^{-6}$ farad

$C = 608.17\mu F$

Since it is combined capacitance of four equal capacitors joined in series

$\therefore$ Capacitance of each capacitor $= 4 \times 608.17\mu F$

$= 2432.68\mu F$

Example 5.11.6 An Educational institute takes a Load of 400 kW at 0.80 p.f lagging for 2300 hours per annum the tariff is Rs 150 / kVA plus 50 paise / kWh consumed. If the p.f is improved to 0.95 lagging by means of capacitors costing Rs 520 / kVAR and having a power loss of 50 Watts power / kVA, calculate the annul saving effected by their use Allow 10% per annum for Interest and depreciation.

Solution:

Load $P_1 = 400KW$

$\cos\phi_1 = 0.8$ lagging

$\phi_1 = \cos^{-1}(0.8) = 36.86^0$; $\tan\phi_1 = 0.075$

$\cos\phi_2 = 0.95$ lagging

$\phi_2 = \cos^{-1}(0.95) = 18.19^0$

$\tan\phi_2 = 0.3286$

Let the leading KVAR taken by the capacitor is 'x'

$\therefore$ Capacitor loss $= \frac{50x}{1000} = 0.05x$ KW

Total power, $P_2 = (400 + 0.05x)$ KW

Leading KVAR taken by the Capacitor is

$x = P_1 \tan\phi_1 - P_2 \tan\phi_2$

$x = [(400 \times 0.075) - ((400 + 0.05x)(0.3286)]$

$x = (300) - [(131.44) + 0.01643x]$

$1.01643x = 168.56$

$x = \frac{168.56}{1.01643} = 165.835\ KVAR$

Annual cost before P.F. Correction

Max KVA demand $= \frac{400}{0.8} = 500KVA$

Max KVA demand charges = Rs.150x500 = Rs. 75000

Units consumed/year = (400 x 2300) = 9, 20,000 KWh

Energy charges/year = Rs. (0.5 x 9, 20,000) = Rs. 4, 60,000

Total annual cost = Rs. (75,000 + 4, 60,000)= Rs. 5, 35,000

Annual cost after P.F. correction

Max KVA demand $= \frac{400}{0.95} = 421.052KVA$

Max KVA demand charges = Rs.150 x 421.0520 = Rs. 63,157.8

Units consumed/year = (400 x 2300) = 9, 20,000KWh

Energy charges/year = Rs. (0.5 x 9, 20,000) = Rs. 4, 60,000

Capital cost of capacitors = Rs. 520 x 168.56 = 87,651.2

Annual interest and depreciation = 0.1 x 87651.2 = 8,765.12

Annual Energy loss in capacitor = 0.05x x 2300

= 0.05x168.56 x 2300 = 19,384.4KWh

Annual cost of lossess occurring in capacitors

= Rs. 0.5 x 19,384.4 = Rs. 9,692.2

∴ Total annual cost = Rs. (63,157.8 + 4, 60,000+8767.12+9692.2)

= Rs. 5, 41,615.12

Annual saving = Rs. (5, 41,615.12 – 5, 35,000) = Rs. 6,615.12

Example 5.11.7 An Industrial Load operates at 0.75 p.f lagging and has a monthly demand of 750 kVA the monthly power rate is Rs 8.50 per kVA. To improve the power factor 200 kVAR. Capacitors are installed, in which there is negligible power loss. The installed cost of equipment is Rs 20,000 and fixed charges are estimated at 10% per year .Calculate the annual saving effected by the use of capacitors.

Solution:

Monthly Demand = 750KVA

Cosϕ = 0.75

ϕ = $\cos^{-1}(0.75)$

ϕ = 41.409^0

Sinϕ = 0.6614

KW component of MD = (750 x 0.75); since [KVA x cosϕ]

KW = 562.5

KVAR component of Max Demand = (750 x 0.6614)

= 496.05 KVAR

Leading KVAR taken by the capacitor is 200 KVAR

Net KVAR after improvement = (496.05 – 200)

= 296.05 KVAR

KVA after P.F. improvement = $\sqrt{(562.5)^2 + (296.05)^2}$ = 635.65

Reduction in KVA = 750 - 635.65 = 114.35

Monthly saving on KVA charges = Rs.(8.5 x 114.35) = Rs.971.975

Yearly saving on KVA charges = Rs. (971.975 x 12) = Rs. 11663.7

Fixed charges/year = Rs.(0.1 x 20,000) = Rs. 2,000

Net annural savings = Rs. (11663.7 – 2000) = Rs. 9663.07

Example 5.11.8. A Factory Load consists of the following.

(i) An induction Motor of 100 H.P with 0.75 p.f lagging and efficiency 80%

(ii) A synchronous Motor of 50 H.P with 0.9 leading and efficiency 90%

(iii)Lighting Load of 100 kW at unity p.f

Find the annual electrical charges if the tariff is Rs 100 per kVA of maximum demand per annum plus 50paise per kWh; assuming the Load to be steady for 2000 hours in a year.

Solution:

Input power to induction Motor $= \frac{100 \times 735.5}{80}$

= 919.37KW

Lagging KAVR taken by induction Motor

= 919.375 x tan $(\cos^{-1}(0.75))$

= 81.0812KVAR

Input power to synchronous Motor $= \frac{50 \times 735.5}{90}$

= 408.33KW

Leading KVAR taken by synchronous Motor

= 408.33 x tan $(\cos^{-1}(0.9))$

= 19.789KVAR

Since lighting Load works at unity power factor its lagging KVAR is 0

$\therefore$ Total Lagging KVAR = (81.0812 – 19.789)

= 61.2922KVAR

Total active power = 91.9375 + 40.8611

= 132.7986KW

Total KVA = $\sqrt{(132.7986)^2 + (61.2922)^2}$

= 146.26KVA

Annual KVA demand charges = Rs. 100 x 146.26

= Rs. 14,626.07

Energy consumed/year = 132.7986 x 2000

= 2,65,597.2 KWh

Annual energy charges = Rs. 0.5 x 2, 65,597.2

= Rs. 1, 32,798.6

Total annual bill = KVA demand charges + Energy charges

= 14,626.07 + 1, 32,798.6

= Rs. 1,47,424.67

Example 5.11.9 A supply system feeds the following Loads (i) a lighting Load of 1500 kW (ii) a Load of 400 kW at a p.f of 0.8 lagging (iii) a Load of 800 kW at a p.f of 0.8 leading (iv) a Load of 1500 kW at a p.f 0.6 lagging (v) a synchronous Motor driving a 540 kW D.C Generator and having an overall efficiency of 90%. Calculate the power factor of synchronous Motor so that the station power factor may become unity.

Solution:

The lighting Load works at unity power factor and

$\therefore$ it's lagging KVAR is 0

The lagging KVAR are taken by the Loads 2nd and 4th

Whereas Loads 3rd and 5th take the leading KVAR for station power factor to be unity and total lagging KVAR must be neutralized by the total leading KVAR

$\therefore$ Total lagging KVAR taken by Load 2nd and 4th

= [(400 tan $(\cos^{-1}(0.8))$] + [(1500 x tan $(\cos^{-1}(0.6))$]

= 2300KVAR

Leading KVAR taken by Load = [800 x tan $(\cos^{-1}(0.6))$]

= 600

Leading KVAR taken by synchronous Motor

= 2300 – 600

= 1700KVAR

Motor input = out/(= 540/0.9 = 600 KW

If Ø is the phase angle of synchronous Motor then tanØ

$$= \frac{KVAR}{KW} = \frac{1700}{600} = 2.833$$

Ø = $\tan^{-1}(0.833)$

= 70.55^0

In order that station power factor may become unity the synchronous Motor should operated at a power factor 0.332 leading.

Example 5.11.10 A factory which has a maximum demand of 175 kW at a power factor of 0.75 lagging is charged at Rs 100 per kVA per annum. If the phase advancing equipment costs Rs 100 per kVAR, find the most economical power factor at which the factor should operate. Interest and depreciation total 10% of the capital investment on the phase advancing equipment.

Solution:

Power factor of the factory cos ϕ_1 = 0.75 lagging.

Maximum Demand charges, x = Rs 100/KVA/annum.

Expenditure on pahse advancing plant y = Rs 100x0.1

= Rs 10/KVAR/annum

Most economical power factor at which factory should operate

$$\text{Cos } \phi_2 = \sqrt{1 - \left(\frac{y}{x}\right)^2}$$

$$= \sqrt{1 - \left(\frac{10}{100}\right)^2}$$

$\text{Cos}\phi_2$= 0.9486 lagging

Example 5.11.11 A factory has an average demand of 50kW and an annual Load factor of 0.6 The power factor is 0.75 lagging The tariff is Rs 150 per kVA of maximum demand per annum plus 50 paise per kWh If loss free capacitors costing Rs 600 per kVAR are to be utilized find the value of power factor at which maximum saving will result The interest and depreciation together amount to 10% also determine the annual saving effected by improving the p.f to this value. Power factor is improved to 0.96 lagging by installing phase advancing equipment.

Solution:

Max KW demand $P = \frac{50}{0.6} = 83.33KW$

Original P.F $\cos Ø_1$ = 0.75 lagging

$Ø_1 = \cos^{-1}(0.75)$

$= 41.41^0$

$\tan Ø_1 = 0.8819$

Final P.F $\cos Ø_2$ = 0.96

$Ø_2 = 16.26^0$

$\tan Ø_2 = 0.2916$

(i) Leading KVAR taken by phase advancing equipment

$= P(\tan Ø_1 - \tan Ø_2)$

$= 83.33(0.8819 - 0.2916)$

$= 49.1896KVAR$

∴ Capacity of phase advancing equipment should be 49.1896KVAR

(ii) Max demand charges

x = *Rs.*150/KVA/annum

Expediture on phase advancing equipment

y = Rs. 0.1 x 600

= Rs. 60/KVAR/annum

Max demand at 0.75 P.F. lagging $= \frac{83.33}{0.75} = 111.106KVA$

Max demand at 0.96 P.F lagging $= \frac{83.33}{0.96} = 86.802KVA$

Annual saving in maximum demand charges

= Rs.(150x86.802)

= Rs.13020.3125

Annual expenditure on phase advancing equipment

= Rs. (Y x capacity of equipment)

= Rs. (60 x 49.1896)

= Rs. 2951.376

Net annual savings = Rs.(13020.3125 – 2951.376)

= Rs. 10068.9365

Example 5.11.12 An industrial Load takes 100,000 units in a year, the average power factor being 0.8 lagging. The recorded maximum demand is 500 kVA. The tariff is Rs 120 per kVA of maximum demand plus 2.5 paise per kWh Calculate the annual cost of supply and find out the annual saving in cost by installing phase advancing plant costing Rs 50 per kVAR which raises the p.f from 0.8 to 0.95 lagging. Allow 10% per year on the cost of phase advancing plant to cover all additional costs.

Solution:

Energy consumed/year = 100000KWh

Max demand = 500KVA

Annual cost of supply = Max demand charges Energy charges

= Rs.(120 x 500)+(0.025 x 100000)

= Rs.62500

$\cos Ø_1$ = 0.8 lagging

$\cos Ø_2$ = 0.95 lagging

Max KW demand at 0.8 P.F lagging P, = 500 x 0.8

= 400KW

Leading KVAR taken by phase advancing equipment

$= P(\tan Ø_1 - \tan Ø_2)$

$= [(400 \tan(\cos^{-1}(0.8)] - [(\tan(\cos^{-1}(0.95)]$

$= 168.52KVAR$

Annual cost of phase advancing equipment

= Rs.168.52 x 50 x 0.1

= Rs. 842.6

When P.F. is raised from 0.8 to 0.95 lagging

The new maximum KVA demand is $= \frac{400}{0.95} = 444.44KVA$

Reduction in KVA demand = 500 – 444.44

= 55.55KVA

Annual savings in KVA charges = Rs. 120 x 55.55

= Rs. 6666.67

As units consumed remains the same, therefore saving will be equal to saving of max demand charges – annual cost of phase advancing plant

∴ Annual savings = Rs. (6666.67 – 842.6)

= Rs.5824.06

Example 5.11.13 A Captive power plants is working at its maximum kVA capacity with a lagging p.f 0.75 It is now required to increase its kW capacity to meet the demand of Additional Load this can be done:

(a) By increasing the p.f to 0.85 lagging by p.f correction equipment

(b) By installing additional generation plant costing Rs 800 per kVA

What is the maximum cost per kVA of p.f. correction equipment to make its use more economical than the additional plant?

Solution:

Let the initial capacity of the plant be OB KAV AT P.F $\cos\text{Ø}_1$

Referring the figure the new KW demand (OC)

Can be met by increasing the P.F from 0.75($\cos\text{Ø}_1$) to 0.85($\cos\text{Ø}_2$) lagging at OB KVA or increasing the capacity of the station to OD KVA at $\cos\text{Ø}_1$

Cost of increasing plant capacity referring figure the increase in KVA capacity is BD

Now OE $\cos\text{Ø}_2$ = OD $\cos\text{Ø}_1$

OB $\cos\text{Ø}_2$ = OD $\cos\text{Ø}_1$

$$OD = \frac{OB \cos\text{Ø}_2}{\cos\text{Ø}_1}$$

$$OD = OB\,\frac{0.85}{0.75}$$

$$= OB \times 1.133$$

Increase in KVA capacity of the plant is

BD = OD – OB

= 1.133 OB – OB

= 0.133 OB

∴ Total cost of increasing the plant capacity

= Rs. 800 x 0.133 OB

= Rs. 106.667 OB.........(i)

Cost of P.F correction equipment

$\cos\text{Ø}_1$ = 0.75 lagging ? $\sin\text{Ø}_1$ = 0.6614

$\cos\text{Ø}_2$ = 0.85 lagging ? $\sin\text{Ø}_2$ = 0.5267

Leading KVAR taken by P.F. Correction equipment

ED = CD – CE

= OD - $\sin\text{Ø}_1$. OE $\sin\text{Ø}_2$

= (1.133 OB $\sin\text{Ø}_1$) – (OB $\sin\text{Ø}_2$)

= OB (1.133 x 0.6614 – 0.5267)

= OB (0.2225)

Let the cost per KVAR of the equipment be Rs. Y

∴ Total cost of P.F. correction equipment

= Rs, (0.2225 x OB x Y)..............(ii)

The cost per KVAR of the equipment that would justify

Its installation is when exp. (i) = exp. (ii)

106.667 OB = 0.225 x OB x Y

Y = 479.22/KVAR

If the losses in P.F. correction equipment are neglected then it's KVAR = KVA.

Therefore, the maximum cost per KVA OF P.F. correction equipment that can be paid is Rs. 479.22

Example 5.11.14. A consumer has a maximum demand of 400 kW at 50% Load factors. If the tariff is Rs. 100 per kW of maximum demand plus 15 paise per kWh. Find the overall cost per kWh. The maximum demand of a consumer is 20 V and his total energy consumption is 8760 kWh. If the energy is charged at the rate 0f 20 per unit for 500 hours use of the maximum demand per annum plus 10 paise per unit for additional units, calculate : (i) Annual bill (ii) Equivalent flat rate

Solution:

Units consumed/year = (M.D x L.F x hours in a year)

= (400 x 0.5 x 8760)

= 1752000KWh

Overall cost per KWh = Rs. (0.15 x 1752000)

= Rs. (262800)

Assume the Load factor and power to be unity

∴ Maximum demand = 4.4KW

(i) Units consume in 500 hrs. = 4.4 x 500

= 2200KWh

Charges for 2200KWh = Rs. 0.2 x 2200

= Rs. 440

Remaining units $= 8760 - 2200$

$= 6560$KWh

Charges for 6560KWh $=$ Rs. 0.1×6560

$=$ Rs. 656

$\therefore$ Total annual bill $=$ Rs.(440+656)

$=$ Rs.1096

(ii) Equivalent flat rate $= \text{Rs.}\ \dfrac{1096}{8786}$

$=$ Rs. 0.125

$=$ 12.5Phase

Example 5.11.15 A supply is offered on the rate of 60 paise per unit for the first 400 units per annum and 50 paise per unit for all the additional units. Find the number of units taken per annum for which the cost under the two tariffs becomes the same.

Solution:

Let no. of units be x (>400)

Annual charges due to first tariff $=$ Rs.(0.6×400)

$=$ Rs. 240

Annual charges due 2nd tariff $= 0.5 \times (x - 400)$

$=$ Rs. $(0.5x - 200)$

As the charges in both cases are equal

$0.5x - 200 = 240$

$0.5x = 440$

$x = \dfrac{440}{0.5} = 880$KWh

Example 5.11.16. An electric supply company having a maximum Load of 500 MW generates 180×10^7 units per annum and the supply consumers have an aggregate demand of 75 MW. The annual expenses including capital charges are: For fuel =Rs90lakhs Fixed charges concerning generation = Rs 28 lakhs Fixed charges concerning transmission = Rs 32 lakhs And distribution Assuming 90% of the fuel cost is essentials to running charges and the loss in transmission and distribution as 15% of kWh generated, deduce a two part tariff to the actual cost of supply to the consumers.

Solution:

Annual fixed charges for generation $=$ Rs.0.25×10^5

for transmission and distribution $= 32 \times 10^5$

For fuel (10% only) $=$ Rs. $0.1 \times 90 \times 10^5$

$=$ Rs. 9×10^5

Total annual fixed charge $=$ Rs. $(28 + 32 + 9) \times 10^5$

$= 69 \times 10^5$

This cost has to be spread over the aggregate maximum demand of all consumers i.e. 750MW

$\therefore$ Cost per KW of maximum demand $= \text{Rs.}\ \dfrac{69 \times 10^5}{75 \times 10^3}$

$=$ Rs. 92

Annual running charge cost of fuel (90%) $=$ Rs. $0.9 \times 90 \times 10^5$

$=$ Rs. 81×10^5

Units delivered to consumers $=$ 85% of units generated

$= 0.85 \times 180 \times 10^7$

$= 1.53 \times 10^9$KWh

This cost is to be spread over the units delivered to the consumers

Cost/KWh $= \text{Rs.}\ \dfrac{69 \times 10^5}{75 \times 10^3}$

$=$ Rs. 0.0052

$=$ Rs. 0.52paise

$\therefore$ Tariff of Rs.92 per KW of maximum demand plus 0.52 paise per KWh

Example 5.11.17A generating station has a maximum demand of 75 MW and a yearly Load factor of 50% generating cost inclusive of station capital cost are Rs.60 per annum per kW demand plus 4 paise Per kWh transmitted. The annual capital charges for transmission system are Rs. 20, 00,000 and for distribution system Rs 15, 00,000 the respective diversity factors being 1.2 and 1.25. The efficiency of transmission system is 90% and that of the distribution system inclusive of substation losses is 85%. Find the yearly cost per kW demand and cost per kWh supplied; i) At the substation (ii) at the consumer's premises

Maximum demand=75MW=75×10^3KW

Annual Load factor=50%=0.5

Solution:

(i) **Cost of substation**

The cost per KW of maximum demand is to be determined from the total annual fixed charges associated with the suppy of energy at the substation. The cost per KWh shall be determined from the running charges

a. **Annual fixed charges :**

Generation cost = Rs. $60 \times 75 \times 10^3$

= Rs. 4.5×10^6

Transmission cost = Rs. 2×10^6

Total annual fixed charges at the substation

= Rs. $(4.5 + 2) \times 10^6$

= 6.5×10^6

Aggregate of all maximum demands by the various substations

= Maximum demand on generating station x Diversity factor

= $75 \times 10^3 \times (1.2)$

= 90×10^3KW

The total annual fixed charges have to be spread over the aggregate maximum demand by various substations i.e. 90×10^3KW

Annual cost per KW of maximum demand

= Rs.

= Rs. 72.22

b. **Running charges:**

It is given that cost of 1KWh transmitted to substations is 4paise. As the transmission efficiency is 90% therefore for every KWh transmitted 0.9KWh reaches the substation.

Therefore cost per KWh at substation = = 4.45paise

Hence at substation, the cost is Rs.72.22 / annum / KW maximum demand + 4.45 paise per KWh

(ii) Cost at consumer premises

The total annual fixed charges at consumers premises is the some of annual fixed charges at substation (i.e. Rs. 6.5×10^6) and annual charge for distribution i.e. Rs. 1.5×10^6

∴ Total annual fixed charges at consumer premises

= Rs. $(6.5 \times 10^6 + 1.5 \times 10^6)$

= Rs.8×10^6

Aggregate of maximum demands for all consumers = Maximum demand on substation x Diversity factor

= $(90 \times 10^3) \times 1.25$

= 112.5×10^3KW

∴Annual cost per KW of Maximum demand

= Rs. $\dfrac{8 \times 10^6}{112.5 \times 10^3}$

= Rs. 71.11

As the distribution efficiency is 85%, therefore for each KWh delivered from substation 0.85KWh reaches the consumer's premises

∴Cost per KWh at consumers premises

= $\dfrac{\text{cost per KWh at Substation}}{0}$. 85

= $\dfrac{4.45}{0.85}$

= 5.23 paise

Hence at consumer's premises the cost is 71.11 per annum per KW maximum demand 5.23 paise per KWh

Example 5.11.18. Calculate annual bill of a consumer whose maximum demand is 1000 KW, p.f. = 0.8 lagging and Load factor = 69% the tariff used is Rs 75 per kVA of maximum demand plus 15 paise per kWh consumed.

Solution:

Units consumed/year = Max. Demand XL. FX hours in a year

= $(1000 \times 0.69 \times 8760)$

= 6044400 KWh

Annual charges = Annual M.D charges + Annual energy charges

Annual M.D charges = Rs. (75 x)

= Rs. 93750

Annual energy charges = Rs. (0.15×6044400)

= Rs. 906660

Annual charges = Rs $(93750 + 906660)$

= Rs. 1000410

Example 5.11.19 A factory has a maximum Load of 240 kW at 0.7 p.f lagging with an annual consumption of 50.000 units the tariff is Rs 50 per kVA of maximum demand plus 10 paise per unit calculate the flat rate of energy consumption. What will be annual saving if p.f is raised to unity?

Solution:

Maximum demand in KVA at a P.F of 0.8

$$= \frac{240}{0.7}$$

$$= 342.857\text{KVA}$$

$\therefore$ Annual bill = Demand charges + energy charges

$$= \text{Rs. } (50 \times 342.857) + (0.1 \times 50{,}000)$$

$$= \text{Rs. } 22412.85$$

$$\therefore \text{ Flat rate/unit} = \text{Rs. } \frac{22142.85}{50{,}000}$$

$$= \text{Rs. } 0.4428$$

$$= 44.28\text{paise}$$

When P.F. raised to unity the maximum demand in KVA

$$= \frac{240}{1} = 240\text{KVA}$$

$$\text{Annual bill} = \text{Rs.}(50 \times 240) + (0.1 \times 50{,}000)$$

$$= \text{Rs. } 17{,}000$$

$$\text{Annual saving} = \text{Rs. } (22142.85 - 17000)$$

$$= \text{Rs. } 5142.85$$

Example 5.11.20 The monthly readings of a costumer's meter are as follows:

Maximum demand = 50kWh
Energy consumed = 36.000 kWh
Reactive energy = 23,400 kVAR

If the tariff is Rs 100 per kW of maximum demand plus 6 paise per unit plus 0.5 paise per units for each 1% of power factor below 86%, calculate the monthly bill of the consumer.

Solution:

$$\text{Average Load} = \frac{36{,}000}{24 \times 30} = 50\text{KW}$$

$$\text{Average reactive power} = \frac{23400}{24 \times 30} = 32.5 \text{ KVAR}$$

Suppose Ø is the power factor angle

$$\therefore \tan Ø = \frac{\text{KVAR}}{\text{Active power}} = \frac{32.5}{50} = 0.65$$

$$Ø = \tan^{-1}(0.65) = 33.02^0$$

$$\therefore \text{ Power factor } \cos Ø = \cos(33.02^0) = 0.8384$$

$$\text{Power factor surcharge} = \text{Rs. } \frac{36000 \times 0.5}{100}(86 - 83.84)$$

$$= \text{Rs. } 388.8$$

$$\text{Monthly bill} = \text{Rs. } (100 \times 50 + 0.06 \times 36000 + 388.8)$$

$$= \text{Rs } (7548.8)$$

5.12 Location of Capacitors:

The primary purpose of capacitors is to reduce the power consumption. Additional benefits are derived by capacitor location. The Figure 5.12 indicates typical capacitor locations. Maximum benefit of capacitors is derived by locating them as close as possible to the Load. At this location, its kVAR are confined to the smallest possible segment, decreasing the Load current. This, in turn, will reduce power losses of the system substantially. Power losses are proportional to the square of the current. When power losses are reduced, voltage at the Motor increases; thus, Motor performance also increases. Locations C1A, C1B and C1C of Figure 5.12 indicate three different arrangements at the Load. Note that in all three locations extra switches are not required, since the capacitor is either switched with the Motor starter or the breaker before the starter. Case C1A is recommended for new installation, since the maximum benefit is derived and the size of the Motor thermal protector is reduced. In Case C1B, as in Case C1A, the capacitor is energized only when the Motor is in operation Case C1B is recommended in cases where the installation is existing and the thermal protector does not need to be resized. In position C1C, the capacitor is permanently connected to the circuit, but does not require a separate switch, since it can be disconnected by the breaker before the starter.

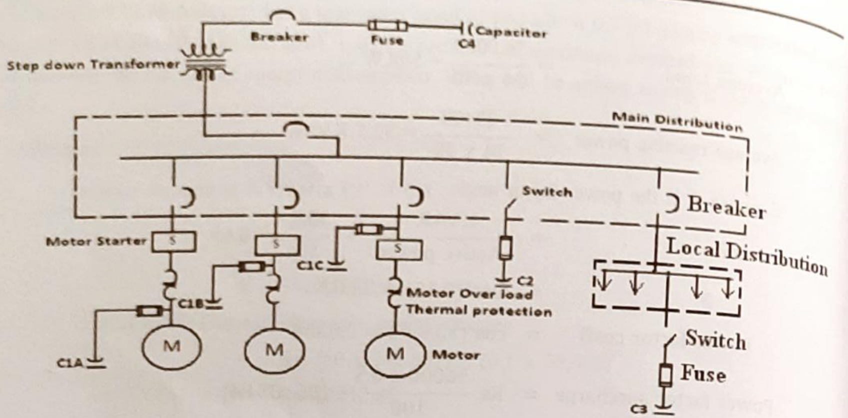


Fig 5.12 Illustrating Location of Capacitors

It should be noted that the rating of the capacitor should not be greater than the no-Load Magnetizing KVAR of the Motor. If this condition exists, damaging over voltage or transient Torques can occur. This is why most Motor manufacturers specify maximum capacitor ratings to be applied to specific Motors.

The next preference for capacitor locations as illustrated by Figure 5.12 is at locations C2 and C3. In these locations, a breaker or switch will be required. Location C4 requires a high voltage breaker. The advantage of locating capacitors at power centers or feeders is that they can be grouped together. When several Motors are running intermittently, the capacitors are permitted to be on line all the time, reducing the total power regardless of Load.

Capacitors for Other Loads

The other types of Load requiring capacitor application include induction furnaces, induction heaters and arc welding transformers etc. The capacitors are normally supplied with control gear for the application of induction furnaces and induction heating furnaces. The PF of arc furnaces experiences a wide variation over melting cycle as it changes from 0.7 at starting to 0.9 at the end of the cycle. Power factor for welding transformers is corrected by connecting capacitors across the primary winding of the transformers, as the normal PF would be in the range of 0.35.

5.13 Performance Assessment of Power Factor Capacitors Voltage effects:

Ideally capacitor voltage rating is to match the supply voltage. If the supply voltage is lower, the reactive kVAR produced will be the ratio ($V1^2$_$V2^2$) where V_1 is the actual supply voltage, V_2 is

the rated voltage. On the other hand, if the supply voltage exceeds rated voltage, the life of the capacitor is adversely affected.

Material of capacitors:

Power factor capacitors are available in various types by dielectric material used as; paper/ polypropylene etc. The watt loss per kVAr as well as life vary with respect to the choice of the dielectric material and hence is a factor to be considered while selection.

Connections: Shunt capacitor connections are adopted for almost all industry/ end user applications, while series capacitors are adopted for voltage boosting in distribution networks.

Operational performance of capacitors:

This can be made by monitoring capacitor charging current via the rated charging current. Capacity of fused elements can be replenished as per requirements. Portable analyzers can be used for measuring kVAr delivered as well as charging current. Capacitors consume 0.2 to 6.0 Watt per kVAr, which is negligible in comparison to benefits.

Some checks that need to be adopted in use of capacitors are:

i) Nameplates can be misleading with respect to ratings. It is good to check by charging currents.

a. Capacitor boxes may contain only insulated compound and insulated terminals with no capacitor elements inside.

b. Capacitors for single phase Motor starting and those used for lighting circuits for voltage boost, are not power factor capacitor units and these cannot withstand power system conditions.

5.14. Energy Efficient Motors:

Standard efficiency Motors are remain popular because they generally cost less than energy efficient Motors, Losses in induction Motors consist of losses which vary with Load and those that are constant whatever the Load. The split is about 70% and 30% respectively of full Load losses that is when a Motor is running at full Load .the Load losses include the rotor resistance loss, the stator resistance losses and stray losses usually regarded as losses in or near rotor conductor slots. when the Motor is running with no Load these losses are nill.how ever once a Load is applied ,these losses will increase as the square of the Motor output ,being I^2R losses and therefore function of the current .the constant losses consists of the components-the mechanical and electrical. The mechanical component is that of friction in bearing, turbulence around the rotor as it rotates and the windings of the cooling fan Motors designed to minimize these losses are termed as energy efficient Motors. Another factor which may be taken into account in the design, it is consideration of "normal"Loading.it can be shown that the application of a Motor while requiring full power at some times normally run at 60% full Load .the Motor could be designed so that highest efficiency is at this Load rather than at full Load output designed to minimize electrical losses will mean increased cost in terms of better material as I^2R losses (heat losses), how ever total cost will be higher than for a standard Motor .the economics of replacement of standard Motor with energy efficient Motor must be considered.

Modern Technology and research in material science have helped a great deal in Designing and manufacturing energy efficient Motors. Energy efficient Motors are generally made to higher manufacturing standards and tighter quality controls than the standard efficiency Motors .they are meant to replace this cost is about 30% more than equivalent standard Motors. The new Motors run cooler because they generate less I^2R heat producing less stress on windings. This is generally taken to be an indication that life of energy efficient Motors is more than standard Motors and operating or repair cost is less than standard Motors. Its installation is justified based on its operating hours, when ever its operating hours is more than 2000 hrs/year it is economical. Power factor of energy efficient Motor is better than standard Motors for different Load conditions

The following are the new features of energy efficient Motors

1. Use of superior steel laminations with higher densities results in reduction in core length and consequently length of the copper wire. Thus iron and copper losses are optimised.
2. Use of thinner but better quality insulation in slots and increased cross section of Copper results in decreased copper losses in stator.
3. Use of copper instead of aluminum enables the slot size to be reduced and improvement in magnetic flux with reduction in core losses
4. Use of unidirectional fan (instead if bidirectional as of now),which consumes less power, especially in pumps and compressors
5. Internal grinding and stator bore and better machining tolerances reduces the air gap between stator and rotor and improves the power factor of the Motor.

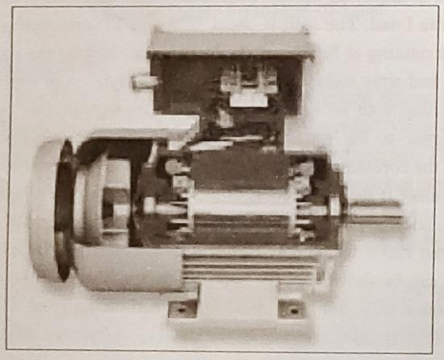


Fig: 5.14(a)

Though there are several other innovative features of modern Motors, only a few are mentioned above, the cost however is more but it pays back within reasonable time due to saving in consumption of power. Typical energy efficient Motor and standard Motor efficiency curves showing the reduction in losses are shown in fig-5.14.(b)

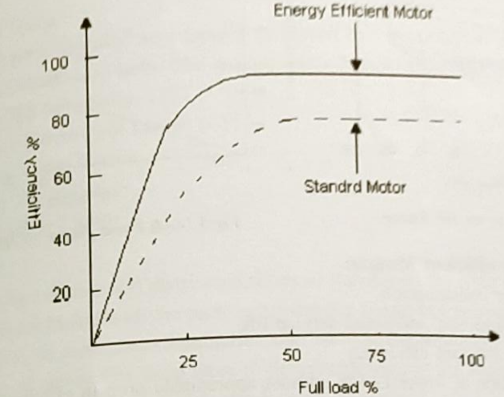


Fig-5.14.(b) efficiency v/s % of full Load

It will be seen that with the energy efficient Motor loss reduction is particularly good at light Loads. This obviously improves performance in such cases where long period of the operating time are on very light Loads. For example an air compressor Motor can be running off Loaded for greater part of the day. If the use of compressor air is neither heavy nor continuous. Typical cases of Motor replacement by energy efficient Motors have shown payback period between 6 Months to 2 ½ years depending on whether the Motor is being run continuously over the year or in single shift

Factors to be taken into account when looking at the energy efficient Motors are:

- Load in terms of maximum Load and how the Load fluctuates from the correct size of Motor can be established and are hopefully some idea of average Loading.
- How the standard Motor of the required capacity compares with the average Load With the energy efficient Motor
- Times and hours of operation during the year
- Electricity tariff including Kwh rates and maximum demand charges

Typical energy efficient Motor and standard Motor characteristics i.e. Efficiency v/s HP Rating and Power factor v/s HP Rating are shown in Fig-5.14(c) and Fig-5.14(d) respectively.

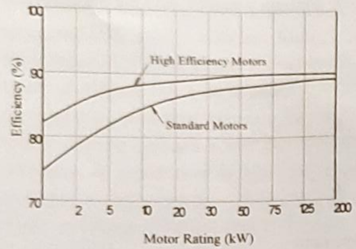


Fig-5.14.(c) Efficiency v/s HP Rating

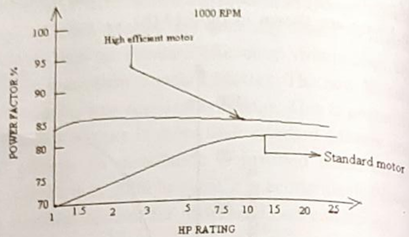


Fig-5.14.(d) Power factor v/s HP Rating

Advantages of energy efficient Motors:

- Reducing power consumption
- Lower temperature rise ,increased service life
- Broad band of constant efficiency
- Enabling operation at lower Loads without appreciable drop in efficiency
- Improved power factor of operation even at light Loads
- Less noise level
- Ability to accelerate higher inertia Loads than standard Motors

5.15. LIGHTING BASICS:

Introduction:

Lighting is an essential service in all the industries. The power consumption by the industrial Lighting varies between 2 to 10% of the total power depending on the type of industry. Innovation and continuous improvement in the field of lighting, has given rise to tremendous Energy saving opportunities in this area. Lighting is an area, which provides a major scope to achieve energy efficiency at the design Stage, by incorporation of modern energy efficient lamps, luminaries and gears, apart from good Operational practices.

Basic Terms in Lighting System and Features Lamps:

Lamp is equipment, which produces light. The most commonly used lamps are described briefly as follows:

Incandescent lamps:

Incandescent lamps produce light by means of a filament heated to incandescence by the flow of electric current through it. The principal parts of an incandescent lamp, also known as GLS (General Lighting Service) lamp include the filament, the bulb, the fill gas and the cap.

Reflector lamps:

Reflector lamps are basically incandescent, provided with a high quality internal mirror, which follows exactly the parabolic shape of the lamp. The reflector is resistant to corrosion, thus making the lamp maintenance free and output efficient.

Gas discharge lamps:

The light from a gas discharge lamp is produced by the excitation of gas contained in either a tubular or elliptical outer bulb. The most commonly used discharge lamps are as follows:

- Fluorescent tube lamps (FTL)
- Compact Fluorescent Lamps (CFL)
- Mercury Vapor Lamps
- Sodium Vapor Lamps
- Metal Halide Lamps

Luminaries:

Luminaries is a device that distributes filters or transforms the light emitted from one or more lamps the luminary includes all the parts necessary for fixing and protecting the lamps, accept the lamps themselves in some cases luminaries also include the necessary circuit axillaries together with the means of connecting them from to the electric supply the basic physical principles used in optical luminary are reflection absorption transmission and refraction.

Control Gear:

The gears used in the following equipment are as follows:

Ballast:

A current limiting device, to counter negative resistance characteristics of any discharge lamps in case of florescent lamps it aids the initial voltage buildup required for starting.

Igniters:

These are used for starting high intensity metal halide and sodium vapor lamps.

Luminance:

This is the quotient of the luminous flux incident on an element of the surface at a point of surface containing the point, by the area of that element.

The light level produced by a lighting installation is usually qualified by the luminance produced on a specified plane. In most cases this plane is the major plane of the tasks in the interior and is commonly called the working plane. The luminance provided by an installation affects both the performance of the tasks. Appearance of the space.

Lux (lx)

This is the luminance produced by a luminous flux of one lumen uniformly distributed over a surface of one square metered. One lux is equal to one lumen per square metere.

Luminous efficiency (lm/W)

This is the ratio of luminous flux emitted by a lamp to the power consumed by the lamp. It is a reflection of efficiency of energy conversion from electricity to light form.

Colour Rendering Index (RI)

It is a measure of the degree to which the colour of surface illuminated by a given light source conform to those of the same surfaces under a reference illuminant; suitable allowance having been made for the chromatic adaptation.

5.15. (a) Lamp types and their features:

The Table 5.15 shows the various types of lamp available along with their features.

TABLE 5.1 LUMINOUS PERFORMANCE CHARACTERSTICS OF COMMONLY USED LUMINARIES

Type of lamps	Lumance per watt		Colour Rendering Index	Typical application	Typical Life (hours)
	Range	Average			
Incandescent	8-18	14	Excellent	Homes, restaurant, General lighting, Emergency lighting.	1000
Fluorescent lamps	46-60	50	Good w.r.t. coating	Offices, shops, hospitals, homes.	5000
Compact fluorescent lamps (CFL)	40-70	60	Very good	Hostels, shops, homes, offices.	8000-10000
High pressure mercury vapor lamp (HPMV)	44-57	50	Fair	General lighting in factories, garages, car parking, flood lighting	5000
Halogen lamps	18-24	20	Excellent	Display, flood lighting, stadium, exhibition, grounds, construction areas.	2000-4000
High pressure sodium vapor lamp (HPSV)	67-121	90	Fair	General lighting in factories, ware houses, street lighting.	6000-12000
Low pressure sodium vapor lamp (LPSV)	101-175	150	Poor	Road ways, tunnels, canals, street lightings.	6000-12000

5.15.(b) Recommended Luminance Levels for Various Tasks / Activities / Locations

Recommendations on Illuminance

Scale of Luminance:

The minimum luminance for all non-working interiors, has been Mentioned as 20 Lux (as per IS 3646). A factor of approximately 1.5 represents the smallest significant difference in subjective effect of Luminance. Therefore, the following scale of luminance is recommended.

20–30–50–75–100–150–200–300–500–750–1000–1500–2000.................. Lux

Luminance ranges:

Because circumstances may be significantly different for different Interiors used for the same application or for different conditions for the same kind of activity, a range of luminance is recommended for each type of interior or activity intended of a single value of luminance. Each range consists of three successive steps of the recommended scale of luminance. For working interiors the middle value (R) of each range represents the recommended service luminance that would be used unless one or more of the factors mentioned below apply.

The higher value: (H) of the range should be used at exceptional cases where low. Reflectance or contrasts are present in the task, errors are costly to rectify, visual work is critical, accuracy or higher productivity is of great importance and the visual capacity of the worker makes it necessary. Similarly, lower value (L) of the range may be used when reflectance or contrasts are unusually high, speed & accuracy is not important and the task is executed only occasionally.

Recommended Illumination

The following Table gives the recommended luminance range for different tasks and activities for chemical sector. The values are related to the visual requirements of the task, to user's Satisfaction, to practical experience and to the need for cost effective use of energy.

(Source IS 3646 (Part I): 1992). For recommended illumination in other sectors, reader may refer *Illuminating Engineers* Society Recommendations Handbook

Chemicals	
Petroleum, Chemical and Petrochemical works	
Exterior walkways, platforms, stairs and ladders	30-50-100
Exterior pump and valve areas	50-100-150
Pump and compressor houses	100-150-200
Process plant with remote control	30-50-100
Process plant requiring occasional manual intervention	50-100-150
Permanently occupied work stations in process plant	150-200-300
Control rooms for process plant	200-300-500

Chemicals	
Pharmaceuticals Manufacturer and Fine chemicals Manufacturer	
Pharmaceutical manufacturer	
Grinding, granulating, mixing, drying, tabulating, Sterilizing, washing, preparation of solutions, filling, Capping, wrapping, hardening	300-500-750
Fine chemical manufacturers	
Exterior walkways, platforms, stairs and ladders	30-50-100
Process plant	50-100-150
Fine chemical finishing	300-500-750
Inspection	300-500-750
Soap manufacture	
General area	200-300-500
Automatic processes	100-200-300
Control panels	200-300-500
Machines	200-300-500
Paint works	
General	200-300-500
Automatic processes	150-200-300
Control panels	200-300-500
Special batch mixing	500-750-1000
Colour matching	750-1000-1500

Methodology of lighting systems energy efficiency study:

A step-by-step approach for assessing energy efficiency of lighting system is given below:

Step–1: Inventories the Lighting System elements, & transformers in the facility as per Following typical format (Table – 5.19.1and 5.19.2).

TABLE 5.15.1 DEVICE RATING POPULATION AND USE PROFILE

Sl.No	Plant location	Lighting device and ballast type	Rating in watts lamp & ballast	Population numbers	No. of hors / Day

TABLE 5.15.2 LIGHTING TRANSFORMER RATING AND POPULATION PROFILE

Sl.No	Plant location	Lighting transformer rating (KVA)	Numbers installed	Meter provisions available Volts / Amps / kW / Energy

In case of distribution boards (instead of transformers) being available, fuse ratings may be inventorised along the above pattern in place of transformer kVA.

Step–2: With the aid of a lux meter, measure and document the lux levels at various plant locations at working level, as daytime lux and night time lux values alongside the number of Lamps "ON" during measurement.

Step–3: With the aid of portable Load analyzer, measure and document the voltage, current, Power factor and power consumption at various input points, namely the distribution boards or the lighting voltage transformers at the same as that of the lighting level audit.

Step–4: Compare the measured lux values with standard values as reference and identify Locations as under lit and over lit areas.

Step–5: Collect and analyse the failure rates of lamps, ballasts and the actual life expectancy levels from the past data.

Step–6: Based on careful assessment and evaluation, bring out improvement options, which could include:

i) Maximise sunlight use through use of transparent roof sheets, north light roof, etc.

ii) Examine scope for replacements of lamps by more energy efficient lamps, with due Consideration to luminaries, color rendering index, lux level as well as expected life Comparison.

iii) Replace conventional magnetic ballasts by more energy efficient ballasts, with due Consideration to life and power factor apart from watt loss.

iv) Select interior colours for light reflection.

v) Modify layout for optimum lighting.

vi) Providing individual / group controls for lighting for energy efficiency such as:

a. on / off type voltage regulation type (for luminance control)

b. Group control switches / units

c. Occupancy sensors
d. Photocell controls
e. Timer operated controls
f. Pager operated controls
g. Computerized lighting control programs

Vii) Install input voltage regulators / controllers for energy efficiency as well as longer life expectancy for lamps where higher voltages, fluctuations are expected.

viii) Replace energy efficient displays like LED's in place of lamp type displays in control Panels / instrumentation areas, etc.

5.16 Case Examples

5.16.(a). Energy Efficient Replacement Options

The lamp efficacy is the ratio of light output in lumens to power input to lamps in watts. Over the years development in lamp technology has led to improvements in efficacy of lamps. However, the low efficacy lamps, such as incandescent bulbs, still constitute a major share of the lighting Load. High efficacy gas discharge lamps suitable for different types of applications offer appreciable scope for energy conservation. Typical energy efficient replacement options, along with the per cent energy saving, are given in Table 5.19.

Table 5.13.1 SAVINGS BY USE OF HIGH EFFICIENCY LAMPS

Sector	Lamp type				Power saving	
	Existing		Proposed		Watts	%
Domestic / commercial	GLS	100W	CFL	25W	75	75
Industry	GLS	13W	CFL	9W	4	31
	GLS	200W	Blended	160 W	40	20
	TL	40 W	TLD	36 W	4	10
Industry / Commercial	HPMV	250W	HPSV	150W	100	37
	HPMV	400W	HPSV	250W	150	35

5.16. (b). Energy Saving Potential in Street Lighting:

The energy saving potential, in typical cases of replacement of inefficient lamps with efficient lamps in street lighting

TABLE 5.16(b) SAVAING POTENTIAL BY USE OF HIGH EFFICIENCY LAMPS FOR STREET LIGHTING

Existing lamp			Replaced units			Saving	
Type	W	Life	Type	W	life	W	%
GS	200	1000	ML	160	5000	40	7
SLS	300	1000	ML	250	5000	50	17
TL	2X40	5000	TL	2X 36	5000	8	6
HPMV	125	5000	PSV	70	12000	25	44
HPMV	250	5000	PSV	150	12000	100	40
HPMV	400	5000	PSV	50	12000	150	38

5.17. Some Good Practices in Lighting:

Installation of energy efficient fluorescent lamps in place of "Conventional" fluorescent lamps.

Energy efficient lamps are based on the highly sophisticated tri-phosphor fluorescent powder technology. They offer excellent colour rendering properties in addition to the very high luminous efficiency.

5.17(a). Installation of Compact Fluorescent Lamps (CFL's) in place of incandescent lamps.

Compact fluorescent lamps are generally considered best for replacement of lower wattage Incandescent lamps. These lamps have efficacy ranging from 55 to 65 lumens/Watt. The average rated lamp life is 10,000 hours, which is 10 times longer than that of normal incandescent lamps. CFL's are highly suitable for places such as Living rooms, Hotel lounges, Bars, Restaurants, Pathways, Building entrances, Corridors, etc.

5.17(b) Installation of metal halide lamps in place of mercury / sodium vapor lamps.

Metal halide lamps provide high color rendering index when compared with mercury & Sodium vapor lamps. These lamps offer efficient white light. Hence, metal halide is the choice for colour critical applications where, higher illumination levels are required. These lamps are highly suitable for applications such as assembly line, inspection areas, painting shops, etc. It is recommended to install metal halide lamps where colour rendering is more critical.

5.17(c). Installation of High Pressure Sodium Vapor (HPSV) lamps for applications where colour rendering is not critical.

High pressure sodium vapor (HPSV) lamps offer more efficacies. But the colour rendering property of HPSV is very low. Hence, it is recommended to install HPSV lamps for applications such street lighting, yard lighting, etc.

5.17(d). Installation of LED panel indicator lamps in place of filament lamps.

Panel indicator lamps are used widely in industries for monitoring, fault indication, signaling, etc. Conventionally filament lamps are used for the purpose, which has got the following disadvantages:

- High energy consumption (15 W/lamp)
- Failure of lamps is high (Operating life less than 1,000 hours)
- Very sensitive to the voltage fluctuations recently, the conventional filament lamps are being replaced with Light Emitting Diodes (LEDs).The LEDs have the following merits over the filament lamps.
- Lesser power consumption (Less than 1 W/lamp)
- Withstand high voltage fluctuation in the power supply.
- Longer operating life (more than 1, 00,000 hours)

It is recommended to install LEDs for panel indicator lamps at the design stage.

5.17(e). Light distribution

Energy efficiency cannot be obtained by mere selection of more efficient lamps alone. Efficient luminaries along with the lamp of high efficacy achieve the optimum efficiency. Mirror-optic luminaries with a high output ratio and bat-wing light distribution can save energy. For achieving better efficiency, luminaries that are having light distribution characteristics appropriate for the task interior should be selected. The luminaries fitted with a lamp should ensure that discomfort glare and veiling reflections are minimised. Installation of suitable luminaries depends upon the height - Low, Medium & High Bay. Luminaries for high intensity discharge lamp are classified as follows:

- Low bay, for heights less than 5 meters.
- Medium bay, for heights between 5 – 7 meters.
- High bay, for heights greater than 7 meters.

System layout and fixing of the luminaries play a major role in achieving energy efficiency. This also varies from application to application. Hence, fixing the luminaries at optimum Height and usage of mirror optic luminaries leads to energy efficiency.

5.17(f). Light Control

The simplest and the most widely used form of controlling a lighting installation is “On-Off” switch. The initial investment for this set up is extremely low, but the resulting operational costs may be high. This does not provide the flexibility to control the lighting, where it is not required.

Hence, a flexible lighting system has to be provided, which will offer switch-off or reduction in lighting level, when not needed. The following light control systems can be adopted at design stage:

5.17(g). Grouping of lighting system, to provide greater flexibility in lighting control

Grouping of lighting system, which can be controlled manually or by timer control.

5.17(h). Installation of microprocessor based controllers

Another modern method is usage of microprocessor / infrared controlled dimming or switching circuits. The lighting control can be obtained by using logic units located in the ceiling, which can take pre-programme commands and activate specified lighting circuits. Advanced lighting control system uses movement detectors or lighting sensors, to feed signals to the controllers.

5.17(i). Optimum usage of day lighting

Whenever the orientation of a building permits, day lighting can be used in combination with electric lighting. This should not introduce glare or a severe imbalance of brightness in visual environment. Usage of day lighting (in offices/air conditioned halls) will have to be very limited, because the air conditioning Load will increase on account of the increased solar heat dissipation into the area. In many cases, a switching method, to enable reduction of electric light in the window zones during certain hours, has to be designed.

5.17(j). Installation of “exclusive” transformer for lighting

In most of the industries, lighting Load varies between 2 to 10%. Most of the problems faced by the lighting equipment and the “gears” is due to the “voltage” fluctuations. Hence, the lighting equipment has to be isolated from the power feeders. This provides a better voltage regulation for the lighting. This will reduce the voltage related problems, which in turn increases the efficiency of the lighting system.

5.17(k). Installation of servo stabilizer for lighting feeder

Wherever, installation of exclusive transformer for lighting is not economically attractive, servo stabilizer can be installed for the lighting feeders. This will provide stabilized voltage for the lighting equipment. The performance of “gears” such as chokes, ballasts, will also improve due to the stabilized voltage. This set up also provides, the option to optimise the voltage level fed to the lighting feeder. In many plants, during the non-peaking hours, the voltage levels are on the higher side. During this period, voltage can be optimised, without any significant drop in the illumination level.

5.17(l). Installation of high frequency (HF) electronic ballasts in place of conventional ballasts

New high frequency (28–32 kHz) electronic ballasts have the following advantages over the Traditional magnetic ballasts: Energy savings up to 35% less heat dissipation; this reduces the air conditioning Load

- Lights instantly
- Improved power factor
- Operates in low voltage Load
- Less in weight
- Increases the life of lamp

The advantage of HF electronic ballasts, out weigh the initial investment (higher costs when compared with conventional ballast). In the past the failure rate of electronic ballast in Indian Industries was high. Recently, many manufacturers have improved the design of the ballast leading to drastic improvement in their reliability. The life of the electronic ballast is high especially when, used in a lighting circuit fitted with an automatic voltage stabilizer.

The Table 5.17 gives the type of luminaire, gear and controls used in different areas of industry.

TABLE 5.17 TYPE OF LUMINAIRE WITH THEIR GEAR AND CONTROLS USED IN DIFFERENT INDUSTRIAL LOCATION

Location	Source	Luminaire	Gear	Controls
Plant	HID/FT	Industrial rail reflector: High abay Medium bay Low bay	Conventional/low loss electronic ballast	Manual/electronic
Office	FTL/CFL	FTL/CFL	Electronic/low Loss	Manual/auto
Yard	HID	Flood light	Suitable	Manual
Road peripheral	HID/PL	Street light luminaire	Suitable	Manual

5.18. Tariff

Introduction

The electrical energy produced by a power station is delivered to a large number of consumers. The consumers can be persuaded to use electrical energy if it is sold at reasonable rates. The tariff i.e., the rate at which electrical energy is sold naturally becomes attention inviting for electric supply company. The supply company has to ensure that the tariff is such that it not only recovers the total cost of producing electrical energy but total cost of producing electrical energy but also earns profit on the capital investment. However, the profit must be marginal particularly for a country like India where electric supply companies come under sector and are always subject to criticism. . In this chapter, we shall deal with various types of tariff with special references to their advantages and disadvantages.

The rate at which electrical energy is supplied to a consumer is known as tariff. Although tariff should include the total cost of producing and supplying electrical energy plus the profit, yet it cannot be the cost of producing electrical depends to a considerable extent upon the magnitude of electrical energy consumed by the user and his Load conditions. Therefore, in all fairness, due consideration has to be given to different types of consumers (e.g., industrial, domestic and commercial) while fixing the tariff. This makes the problem of suitable rate making highly complicated.

Objectives of tariff. Like other commodities, electrical energy is also sold at such a rate so that is not only returns the cost but also earns reasonable profit. Therefore a tariff should include the following items:

(i) Recovery of cost of producing electrical energy at the Power Station.

(ii) Recovery of cost on the capital investment in transmission and Distribution systems.

(iii)Recovery of cost of operation and maintenance of supply of Electrical energy e.g. metering Equipment, billing etc.

(iv)A suitable profit on the capital investment.

5.19. Desirable Characteristics of a Tariff

A tariff must have the following desirable characteristics:

(i) **Proper return:** The tariff should be such that it ensures the proper return from each consumer. In other word, the total receipts from the consumers must be equal be or the cost of producing and supplying electrical energy plus reasonable profit. This will enable the electric supply company to ensure continuous and reliable service to the consumers.

(ii) **Fairness:** The tariff must be fair so that different types of consumers are satisfied with the rate of charge of electrical energy. Thus a big consumer should be charged at a lower rate than a small consumer. It is because increased energy consumption spreads the fixed charges over a greater number of units, thus reducing the overall cost of producing electrical energy. Similarly, a consumer whose Load conditions do not deviate much from the ideal (i.e., non variable) should be charged at a lower rate than the one whose Load conditions change appreciably from the ideal.

(iii) **Simplicity:** The tariff should be simple so that an ordinary consumer can easily understand it. A complicated tariff may cause an opposition from the public which is generally distrustful of supply companies.

(iv) **Reasonable profit:** The profit element in the tariff should be reasonable. An electric supply company is a public utility company and generally enjoys the benefits of monopoly. Therefore the investment is relatively safe due to non-competition in the market. This calls for the profit to be restricted to 8% or so per annum.

(v) **Attractive:** The tariff should be attractive so that a large number of consumers are encouraged to use electrical energy. Efforts should be made to fix the tariff in such a way is that consumers can pay easily.

5.20. Types of Tariff

There are several types of tariff. However, the following are the commonly used types of tariff:

5.20(a). Simple Tariff:

When there is a fixed rate per units of energy consumed. It is called a simple tariff of uniform Rae tariff. In this types of tariff, the price charged per unit is constant i.e. it does not very with increase or decrease in number of units consumed. The consumed of electrical energy at the consumer's terminals is recorded by means of an energy meter. This is the simplest of all tariffs and is readily understood by the consumers. The cost of producing electrical energy is not same for all consumers but increases with the increasing departure of consumer's Load conditions from the ideal (i.e. Constant Load).

Disadvantages

i. There is no discrimination between different types of consumers since every consumer has to pay equitably for the fixed charges.
ii. The cost per unit delivered is high.
iii. It does not encourage the use of electricity.

5.20(b). Flat Rate Tariff:

When different types of consumers are changed at different uniform per unit rates, it is called a flat rate tariff. In these types of tariff, the consumers are grouped into different classes and each class of consumers in charged at a different uniform rate. For instance, the flat rate per kWh for lighting Load may be 60paise, whereas it may be slightly less (say 55 paisa per kWh) fro power Load. The different classes of consumers are made taking into account their diversity and Load factors. The advantage of such a tariff is that it is fairer to difference types of consumers and is quite simple in calculations.

Disadvantages

i) Since the flat rate tariff varies according to the way the supply is used, separate meters are required for lighting Load, power Load etc, This makes the application of such a tariff expensive and complicated.

ii) A particular class of consumers is charged at the same rate irrespective of the magnitude of energy consumed. However, a big consumer should be charged at a lower rate as in his case the fixed charges per unit reduced.

5.20(c). Block Rate Tariff:

When a given of energy is charged at a specified rate and the succeeding blocks of energy are charged at progressively reduced rates, It is called a block rate tariff. In block rate tariff, the energy consumption is divided into blocks and the price unit is fixed in each block. The price per unit in the first block is the highest and it is progressively reduced for the succeeding block of energy.

For example, the first 30 units may be charged at the rate of 60 paise per unit; the next 25 units at the rate of 55 paise per unit and the remaining additional units may be charged at the rate of 30 paise per unit.The advantage of such a tariff is that the consumer gets an incentive to consume more electrical energy. This increases the Load factor of the system and hence the cost of generation is reduced however, its principal defect is that it lacks a measure of the consumer's demand. This type of tariff is being used for majority of residential and small commercial consumers.

5.20(d). Two Part Tariff:

When the rate of electrical energy is charged on the um demand if the consumer and the units consumed, it is called a two part tariff.

In two – part tariff, the total charge to be made from the consumer is spilt into two components viz., fixed charges and running charges. The fixed charges depend upon the maximum demand of the consumer while the running charges. Depend upon the number of units consumed by the consumer. Thus, the consumer is charged at a certain amount per kW of maximum demand plus a certain amount per kWh of energy consumed i.e.

- The total cost of electrical energy consists of fixed charges and running charges. The greater the number of units lesser the fixed charges per unit. Therefore, a consumer who consumes more units must pay less fixed charges per unit.
- The flat rate for power Load is always less than lighting Load. It is because power Load is much more than the lighting Load and, therefore, improves the Load factor of the system to a great extent.
- Generally fixed charges are merged into the running charges for the first and second blocks of energy so that price per unit for these blocks is high.
- The maximum demand of consumer is generally assessed on the basis of rate able value of the premises or on the number of rooms or on the connected Load.
- Total charges = Rs(b x kW + c x kWh)

  Where b = charge per kW of maximum demand

  c = charge per kWh of energy consumer

This type of tariff is mostly applicable to industrial consumers who appreciable demand.

Advantages

(i) It is easily understood by the consumers.

(ii) It recovers the fixed charges which depend upon the maximum demand of the consumer built are independent of the units consumed.

Disadvantages

(i) The consumer has to pay the fixed charges irrespective of the fact Whether he has consumed or nor consumed the electrical energy.

(ii) There is always error in assessing the maximum demand of the consumer.

5.20(e). Maximum Demand Tariff:

It is similar to two – part tariff with the only difference that the maximum demand is actually measured by installing maximum demand meter in the premises of the consumer. This removes the objection of two part tariff where the maximum demand is assessed merely on the basis of the ratable value. This type of tariff is mostly applied to big consumers; However, It is not suitable for a small consumer (e.g., residential consumer) as a separates maximum demand meter is required.

5.20(f). Power Factor Tariff:

The tariff in which power factor of the consumer's Load is taken into consideration known as power factor tariff. In an a.c. system, power factor plays an important role. A low power factor increases the rating of station equipment and line losses. Therefore, a consumer having low power factor must be penalized the following are the important type of power factor tariff.

5.20(f) (i) kVA maximum demand tariff:

It is a modified from two –part tariff. In this case, the fixed charges are made on the basis of maximum demand in kVA and not in kW. As kVA is inversely proportional to power factor, therefore, a consumer having low power factor has to contribute more towards the fixed charges. This type of tariff has the advantage that it encourages the consumers to operate their appliances and Machinery at improved power factor.

5.20(f) (ii) Sliding scale tariff:

This is also known as average power factor tariff. In this case, an average power factor, say 0-8 lagging, is taken as the references. If the power factor of the consumer falls below this factor, suitable additional charges are made. On the hand, if the power factor is above the references, a discount is allowed to the consumer.

5.20(f) (iii) kW and kVAR tariff:

In this type, both active power (kW) and reactive power (kVAR) supplied are charged separately. A consumer having low power factor will draw more reactive power and hence shall have to pay more charges.

5.20(h). Three-part tariff:

When the total charge to be made from the consumer is split into three parts viz. Fixed charge, semi-fixed charge and running charge, It is known as a three-part tariff.i.e.,

Total charge = Rs (a+bxkW+cxkWh)

Where a = fixed charge made during each billing period. It includes interest and Depreciation on the cost of secondary distribution and labour Cost of Collecting revenues.

b = charge per kW of maximum demand,

c = charge per kWh of energy consumed.

It may be seen that adding fixed charge or consumer's charge (i.e., a) to two –part tariff. It becomes that part tariff. The principal objection of this type of tariff is that the charges are split into three components. This type of tariff is generally applied to big consumers.

5.21. Concept of Availability based tariff (ABT):

- It is a performance based tariff for the supply of electricity by Generators owned and controlled by the central government. It is a frequency based tariff (drawls v/s frequency) and also reactive power based tariff (reactive power v/s voltage).
- It is also a new system of scheduling and dispatching, which requires both Generators and Beneficiaries to commit to day ahead schedules.
- It is a system of rewards and penalties seeking to enforce day ahead Pre-Committed schedules, though Variations are permitted if notified one to one half hours in advance.
- The order emphasizes prompt payment of dues. Nonpayment of prescribed Charges will be liable for appropriate action under section 44 and 45 of IER.

ABT has 3 parts:

1. A fixed charge (FC) payable every month by each beneficiary to the Generator for making capacity available for use .the FC is not same for each beneficiary .It varies with share of beneficiary in a Generator capacity. the FC payable from each beneficiary will also vary with level of availability achieved by a Generator .In case of thermal stations like those of NLC where the fixed charge has not been defined separately by GOI notifications, it will comprise interest on loan ,depreciation,O&M expenses,ROE,income tax and interest on working capital .In case of hydro stations it will be residual cost after deducing the variable cost calculated as being 90% of the lowest variable cost of thermal stations in a region .
2. An energy charge (defined as per the prevailing operational cost norms) per kWh of energy supplied as per the per a pre-committed schedule of supply drawn upon a daily basis.
3. A charge for unscheduled interchange (UI Charge) for the supply and consumption of energy in variation from the pre-committed daily schedule. This charge varies inversely with the system frequency prevailing at the time of supply/consumption. Hence it reflects the marginal value of energy at the time of supply

How is ABT different from normal proceedings to determine generation tariff?

1. The ABT proceedings has not attempted to consider most of the cost drivers like ROE, operational costs, depreciation rate, composition of the rate base ,capital structure etc.proceedings tom redefine these norms are being held separately. Hence the ABT proceedings have been concerned more with tariff design rather than definition of tariff norms or determination of tariff levels,
2. Its incidence is a function not only of the behavior of a Generator but also of the behavior

of a beneficiary .disciplined beneficiaries and Generators stand to gain undisciplined beneficiaries and Generators stand to lose.

5.22. Broad features of ABT design

1. It implements the long held view that electricity tariffs should be two parts comprising of a fixed charge and a separate energy charge.
2. It increases the target availability level at which Generators will be able to recover their fixed costs and ROE from 62.79% deemed PLF at present to 80%(85% after one year)for all thermal stations ,85% for hydro in the first year and 77%(82% after one year) for NLC.
3. Misdeclaration of availability entails severe penalties.
4. It rationalizes the relationship between availability level and recovery of fixed cost. The draft notification provided for recovery of (annual fixed cost minus ROE) at 30% availability and recovery of ROE on prorate basis between 30% and 70% availability. This order provides for payment of capacity charges between 0% and target availability (as indicated in item 2 above) on pro-rate basis.
5. The draft notification had provided for payment of capacity charges for prolonged outages this order disallows such payments.
6. It delinks the earning of incentive from availability and links it instead to the actual achievement of generation. Hence incentives will be earned by Generators only. Where there is a genuine demand for additional generation unlike the prevailing situation, or the proposed draft received by the GOI, under which it is earned purely because the generation is available.
7. Draft notification linked incentives to equity. This order preserves the status quo of one paise /Kwh per each 1% increases in PLF above availability.
8. It increases the minimum performance criterion for earning of an incentive from 68.5% deemed PLF at present to 80 %(after one year) for all thermal stations, 85% for hydro and 77 %(82% after one year) for NLC.
9. It introduces severe financial penalties for grid indiscipline along with significant rewards for behavior, which enforces grid discipline for both Generators as well as beneficiaries
10. The order permits market pricing for the trading of surplus energy for beneficiaries and Generators.
11. The order urges the GOI to allocate the unallocated capacity a month in advance so that beneficiaries know their exact share in capacity in advance and can take steps to trade.
12. Surplus power it will be implemented in stages from April 1, 2000 starting from south. The new norms for incentive will how ever be applicable from this date for all central stations. in case of NPC; Government of India will decide the applicability of order.

5.23. Applicability and Tariff in ABT:

Constituent (i.e.) central generating station viz NTPC, NLC, and NHPC. It is also applied to all the constituents who draw power from central grid...Viz all SEB. (In SRLDC it is APTRANSCO, TNEB, KPTCL, and PONDY).

Availability Based Tariff comprises of 1) Capacity charge.2) Energy cost.3) UI Charges.

5.24 Comparison of existing tariff system and availability tariff

Sl. No.	Description of item	Existing system	Draft ABT proposal	ABT order
1	Capacity fixed charge	Annual fixed charge (AFC)include a) Interest on loan b) Depreciation c) O&M d) Return on equity e) Income tax f) Interest on working capital	Fixed charges excluding ROE i.e. all other 5 items of the existing system ROE treated separately	Capacity charge as per existing system
2	Basis of recovery	Recovery at 62.79% DeemedPLF.50% AFC at 0%PLF and full recovery at 8.49% deemed ELF	FC Excluding ROE recovered at 30% availability on pro rate basis between 0% and 30% availability.ROE recovered on pro rate availability between 30% and 70%	Pre rate recovery of capacity charge for 1)NTPC stations between 0 to 80% availability in the first year and 0 to 85% in the second year 2)NLC stations between 0 to 77% in the first year and 0 to 82% in the second year 3)NHPC stations between 0 to 85% availability in the first year and availability in the second tear announced by commission separately
3	Incentives	Above 68.49% deemed PLF,incentives at 1 paise/ kwh for each 1% increase in PLF	Incentives beyond target availability of 70% is as follows:70 to 85% —0.4% of equity for each 1% increase availability beyond	1 paise /kwh/each percentage increase in PLF of 80% /85% first and second year for NLC and 85% f in the first year for NHPC

5.25. UI Rate v/s Frequency Graph of ABT:

The Graph 5.25.Illustrates the variation of energy cost (UI Rate) with respect to frequency of supply. Cost per unit of energy consumption increases whenever the frequency of grid is less than 50 Hz, but cost per unit of energy consumption decreases when ever grid frequency is more than 50 Hz.

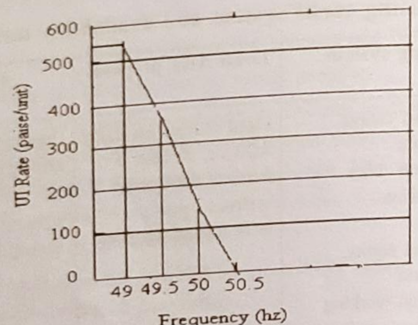


Fig.5.25 UI V/S Frequency Graph of ABT

5.26. Adverse conditions prior to introduction of ABT:

1. Low frequency during peak Load hours with frequency going down to 48 to 48.5 Hz for many hours every day.
2. High frequency during off peak hours, with frequency going unto 50.5 to 51 Hz for many hours every day.
3. Rapid and wide changes in frequency-1Hz change in 5 to 10 minutes. Frequent grid disturbance causing tripping of generating stations interruption of supply to large blocks of consumers, and disintegration of the regional grid.

TUTORIAL PROBLEMS

1. A synchronous the Motor improves the power factor of a Load of 200 kW from 0.8 lagging to 0.9 lagging. Simultaneously the Motor carries a Load of 80 kW Find (i) the leading kVAR taken by the Motor (ii) kVA rating of the Motor and (iii) Power factor at which the Motor operates.

   [Ans: 14.4 KVAR, 81.28KVA, 0.984leading]

2. A 3- phase, 50 Hz, 400 V Motor develops 100 H.P. (74.6 kW) the power factor being 0.75 lagging and efficiency 93%. A bank of capacitors is connected in delta across the supply terminals and power factor raised to 0.95 lagging. Each of the capacitance units is built of 4 similar 100 V capacitors; determine the capacitance of each capacitor.

   [Ans: Capacitance of each capacitor 1173.76μF]

3. An Industrial Load consists of (i) a Synchronous Motor of 100 metric H.P.(ii) Induction Motor aggregating 200 metric H.P, 0.707 power factor lagging and 82% efficiency and (iii) Lighting Load aggregating 30KW. The Tariff is Rs. 100 per annum Motor operates at 0.8 pf. leading 93% efficiency instead of 0.8 p.f. lagging at 93% efficiency.

   [Ans: When synchronous Motor runs at p.f. 0.8 leading, annual Savings = Rs. 6,200]

4. An Industrial Load on an installation in 800 kW 0.8 lagging p.f. which works for 3000 hours per annum, the tariff is Rs 100 per kVA plus 20 paise per kWh. If the Power factor is improved to 0.9 lagging by means of loss free capacitors costs Rs 60/KVAR.Calculate the annual saving effected. Allow 10% per annum for interest and depreciation on Capacitors.

   [Ans: Annual savings=Rs 9836]

5. A factory takes a Load of 200 kW at 0.85 p.f. lagging for 2500 hours per annum the tariff is Rs 150 per kVA plus 5 paise kWh consumed. If the p.f. is improved to 0.9 lagging by means of capacitors costing Rs 420 per KVAR and having a Power loss of 100 W per kVA, calculate the annul saving effected by their use .Allow 10% per annum for Interest and depreciation.

   [Ans: Annual savings=Rs 555]

6. A factory operates at 0.8 p.f. lagging and has a monthly demand of 750 kVA. The monthly power rate is Rs 8.50 per kVA. To improve the power factor 250 KVA capacitors are installed in which there is negligible power loss. The installed cost of equipment is Rs 20.000 and fixed charges are estimated at 10% per year. Calculate the annual saving effected by the use of capacitors.

   [Ans: Annual savings=Rs 9985]

7. A factor Load consists of the following.
   (iv) An induction Motor of 50 H.P (37.3kW) with 0.8 p.f. and Efficiency 0.85
   (v) A synchronous Motor of 25 H.P (18.65kW) with 0.9 p.f. leading and efficiency 0.9
   (vi) Lighting Load of 10 kW at unit p.f.

   Find the annual Electrical charges, if the tariff is Rs 60 per kVA of maximum demand per annum plus 5 paise per kWh; assuming the Load to be steady for 2000 hours in a year.

   [Ans: Total Annual bill=Rs 12,140]

8. A supply system feeds the following Loads (i) a lighting Load of 500 kW (ii) a Load of 400 kW at a p.f of 0.707 lagging (iii) a Load of 800 kW at a p.f. of 0.8 leading (iv) a Load of 500 kW at a p.f. 0.6 lagging (v) a synchronous Motor driving a 540 kW D.C. Generator and having an overall efficiency of 90%. Calculate the power factor of synchronous Motor so that the station power factor May become unity.

   [Ans: power factor of Synchronous Motor=0.79 leading]

   a) A factory which has a maximum demand of 175 kW at a Power factor of 0.75 lagging is charged at Rs 72 per kVA per annum. If the phase advancing equipment costs Rs 120 per kVAR. Find the most economical Power factor at which the factory should operate. Interest and depreciation total 10% of the capital investment on the Phase advancing equipment.

   [Ans: Most economical Power factor Cos $Ø_2$ =0.986 leading]

9. A factory has an average demand of 50kW and an annual Load factor of 0.5 .The power factor is 0.75 lagging, the tariff is Rs 100 per kVA of maximum demand per annum plus 5 paise per kWh .If loss free capacitors costing Rs 600 per kVAR are to be utilized. Find the value of Power factor at which maximum saving will result .The interest and depreciation together amount to 10%, also determine the annual saving effected by improving the p.f to this value. Power factor is improved to 0.95 lagging by installing phase advancing equipment.

   [Ans: most economical power factor Cos $Ø_2$ =0.8 lagging]

10. Factory takes a steady Load of 200 kW at a lagging power factor of 0.8 .The tariff is Rs 100 per KVA of maximum demand per annum plus 5 paise per kVAR and the annual interest and depreciation together amount to 10%. Find:
    i. The value to which the power factor be improved so that annual expenditure is minimum.
    ii. The capacity of the advancing plant
    iii. The new bill for energy assuming that the factory works for 5000 hours per annum.

    [Ans: i) Most economical power factor Cos $Ø_2$ =0.866 leading,

    ii) Capacity of phase advancing plant=34.52 KVAR

    ***iii)* Annual bill for energy=Rs 74820]**

11. An industrial Load takes 80,000 units in a year , the average power factor being 0.707 lagging. The recorded maximum demand is 500 kVA. The tariff is Rs 120 per kVA of maximum demand plus 2.5 paise per kWh. Calculate the annual cost of supply and find out the annual saving in cost by installing phase advancing plant Costing Rs 50 per kVAR which raises the p.f from 0.707 to 0.9 Lagging. Allow 10% per year on the cost of phase advancing plant to cover all additional costs.

    [Ans: Annual cost of supply = Rs 62000, annual savings=Rs 11,976]

12. power plants is working at its maximum kVA capacity with a agging p.f 0.7 It is now required to increase its kW capacity to Meet the demand of additional Load this can be done:
    a) By increasing the p.f to 0.85 lagging by p.f correction equipment
    b) By installing additional generation plant costing Rs 800 per kVA what is the maximum cost per kVA of p.f. correction equipment to Make its use more economical than the additional plant?

    [Ans : The maximum cost per KVA of power factor equipment that can be paid is Rs 502.4]

13. A system is working at its maximum kVA capacity with a lagging Power factor of Load can be met by one of the following two methods;
    i) By raising power factor of the system to 0.866 by installing phase Advancing equipment.
    ii) By installing extra generation plant .If the total cost of Generating Plant Rs 100 per kVA of phase advancing equipment to make its Use ore economical than the additional Generating plant, Interest and deprecation charge may be assumed 10% in each case.

    [Ans: The maximum cost per KVA of Power factor equipment that can be Paid is Rs 61.88]

14. A consumer has a maximum demand of 200 kW at 40% Load factor. If the tariff is Rs. 100 per kW of maximum demand plus 10 paise per kWh. Find the overall cost per kWh.

    [Ans: Overall cost per KWh=12.85 paise]

15. The maximum demand of a consumer is 20 V and his total energy Consumption is 8760 kWh. If the energy is charged at the rate 0f 20 per unit for 500 hours use of the maximum demand per annum plus 10 paise per unit for additional units, calculate : (i) Annual bill (ii) Equivalent flat rate

    [Ans: Total annual bill =Rs 1096, Equivalent flat rate=12.85 paise]

16. A supply is offered on the basis of fixed charges of Rs 30 per annum Plus 3 paise per unit or alternatively at the rate of 6 paise per unit for the first 400 units per annum and 5 paise per unit for all the additional units. Find the number of units taken per annum for which the cost under the two tariffs becomes the same.

    [Ans: x=1300 KWh]

17. An electric supply company having a maximum Load of 50 MW Generates 18 x 10^7 units per annum and the supply consumers have an Aggregate demand of 75 MW. The annual expenses including capital Charges are: For fuel = Rs 90 Lakhs Fixed charges concerning generation = Rs 28 Lakhs Fixed charges concerning transmission= Rs 32 Lakhs And distribution assuming 90% of the fuel cost is essentials to running charges in transmission and distribution as 15% of kWh generated, deduce a two part tariff to the actual cost of supply to the consumers.

[Ans: Cost /KW of Maximum Demand=Rs 92, Cost/KWh=5.3 Paise]

18. A generating station has a maximum demand of 75 MW and a yearly Load factor of 40% generating cost inclusive of station capital cost are Rs.60 per annum per kW demand plus 4 paise per kWh transmitted. The annual capital charges for transmission system are Rs 20, 00,000 and for distribution system Rs 15, 00,000 the respective diversity factors being 1.2 and 1.25. The efficiency of transmission system is 90% and that of the distribution system inclusive of substation losses is 85%. Find the yearly cost per kW demand and cost per kWh supplied; (i) At the substation (ii) at the consumers premises

[Ans: i) (a) Annual Cost /KW of Maximum Demand at substation=Rs 72.22,
(b) Cost /KWh at Substation = 5.3 Paise
ii) (a) Annual Cost /KW of Maximum Demand at consumer Premises = Rs 1096
(b) Cost /KWh at consumer Premises = 5.3 Paise.

19. Calculate annual bill of a consumer whose maximum demand is 100kW, p.f. = 0.8 lagging and Load factor = 69% the tariff used is Rs 75 per kVA of maximum demand plus 15 paise per kWh consumed.

[Ans: Annual bill=Rs 88,218]

20. A factory has a maximum Load of 240 kW at 0.8 p.f lagging with an Annual consumption of 50,000 units the tariff is Rs 50 per kVA of maximum demand plus 10 paise per unit Calculate the flat rate of energy consumption. What will be annual saving if p.f is raised to unity?

[Ans: Flat rate/unit= 40 Paise]

21. The monthly readings of a consumer's mater are as follows:

Maximum demand	=	50kWh
Energy consumed	=	36.000 kWh
Reactive energy	=	23,400 kVAR

If the tariff is Rs 80 per kW of maximum demand plus 8 paise per unit
Plus 0.5 paise per units for each 1% of power factor below 86%,
Calculate the monthly bill of the consumer.

[Ans: The monthly bill=Rs 7268.8]

REVIEW QUESTIONS

1. Define power factor mention the courses of low power factor.
2. What are the limitations of low power factor? Explain in brief.
3. Explain the Advantages of high power factor.
4. Explain the calculation of power factor correction.
5. Derive an Expression for most economical power factor considering Constant active power. Draw relevant vector diagram.
6. What is Tariff? Explain different types of Tariff commonly Used.
7. What is ABT? What are the broad features of ABT design?
8. Give the comparison between existing tariff and availability based tariff.
9. Write a note on Energy Efficient Motors.
10. What are the options available to meet the increased Demand on Power station? Justify its installation.
11. Write a note on energy saving practices in street lighting.
12. List some good practices in lighting explain in brief.
13. With a power distribution diagram explain the location of capacitors.

CHAPTER - 6

DEMAND SIDE MANAGEMENT

OBJECTIVES

You will be able to:

- Explain the meaning of Demand side management (DSM) and the scope of DSM
- Explain How did the DSM Evolve
- Enumerate the various steps in DSM planning and implementation.
- Explain peak clipping, valley filling and strategic Energy conservation.
- Discuss tariff options for DSM and mention the tariffs which promote DSM.
- Explain the management and organization of Energy conservation awareness programmes.
- With a flow chart explain DSM planning and implementation.
- Explain various DSM strategies from Load curve objectives view. Mention benefits of the strategies.
- Explain Energy conservation opportunities in Agriculture sector, illumination system and industrial sectors.
- Explain plant level organization with relevant diagram.
- Explain Load management as a DSM Strategy.
- Explain the basic ways of Load shape objectives of DSM.
- with a flow chart, explain corporate level organization of Energy conservation Programme.
- Describe the time of day pricing (TOD) With the help of suitable Example explain how this helps in an efficient DSM.

6.1. Introduction to DSM

Electricity has a Peculiar characteristic that it cannot be stored in large amounts. Moreover its supply is under the control of the Consumer. Power is drawn by the Consumer to the extent of his requirement and capacity of service mains.

Electric utilities have realized that Consumer demands cannot be met satisfactorily by adding new generating capacity alone. Due to increasing fuel prices and Energy costs, utilities have started thinking of Energy management/Demand side management. In addition to the classical approach of encouraging off peak Energy utilization, penalization for excessive use at peak time has also been considered. Differential charges for Energy used at different times of the day have been given due consideration.

The increased awareness of the potential problems of global Warming has led electric utilities to the thinking that, improved efficiency of Energy utilization is a cost effective method to reduce environmental damage. Demand side management means ***the approaches and actions which aim at augmenting the systems capacity by decreasing the Consumer's demand.*** It is widely recognised that DSM can be of great help in reducing Electricity shortages and increasing reliability of electric supply. DSM concepts, originated in USA, have now spread to almost all the countries of the world.

Energy demand management, also known as Demand side management (DSM), deals with actions that influence the quantity or patterns of use of Energy consumed by end users, such as actions targeting reduction of peak demand during periods when Energy supply systems are constrained. Peak demand management does not necessarily decrease total Energy consumption but could be expected to reduce the need or investments in networks and/or power plants. The term DSM was coined during the time of 1973 Energy crisis.

Demand side management programs consist of the planning, implementing and monitoring the activities of electric utilities that are designed to encourage Consumers to modify their level and pattern of Electricity usage.

In the past, the primary objective of most DSM programs was to provide cost effective Energy and capacity resources to help defer the need for new sources of power, including generating facilities, power purchases and transmission & distribution capacity additions. However, due to changes occurring within the industry, electric utilities are also using DSM to enhance customer service. DSM refers only to Energy and Load shape modifying activities undertaken in response to utility administered programs. It does not refer to Energy and Load shape changes arising from the normal operation of the market place or from government mandated Energy efficiency standards.

6.1.1 What is demand side management?

Demand side management is the process of managing the consumption of Energy, generally to optimize available and planned generation resources. Not all businesses are candidates for cogeneration or regeneration. However, the company may be a great candidate for other Energy saving solutions. One of these is demand side management (DSM). In the context of Power Sector DSM can be defined as "a set of measures to effectively manage the total demand on the integrated grid within its designed capacity to ensure acceptable quality of power supply to all Consumers". Management of voltage, frequency and stability. According to the Department of Energy, Demand side management refers to actions taken on the customer's side of the meter to change the amount or timing of Energy consumption. Utility DSM programs offer a variety of measures that can reduce Energy consumption and Consumer Energy expenses. DSM strategies have the goal of maximizing end use efficiency to avoid or postpone the construction of new generating plants.

6.1.2 Why DSM is required?

- It is an economic necessity; reduces overall cost of installed capacity
- It leads to efficient usage of overall power system
- Ensures quality and equity of supply
- Unlimited demand leads to instability of grid
- Essential during times of power/Energy shortage
- Reduces need for peaking stations (pumped storage Plant)

Reduces 25-35% of global CO_2 emissions to the atmosphere.

- Thinning of ozone layer, green house effect
- Global warming, sea level rise and acid rains
- Should be environmental friendly
- Increase in efficiency of production, transmission and end-use

6.1.3 Scope of demand side management

Demand side management involves all activities which involve actions on the customer's side of the Energy meter. These activities may be undertaken by customers themselves or stimulated by the utility. The scope of DSM includes Load management (shifting Loads form peak to off peak periods), Energy Conservation, increased electrification (replacement of non-electric devices be electric devices). In all the activities with customers for mutual benefit. It leads to the best use of capital and fuel resources.

6.2 Concept of DSM

The oil crises of 1973 had a profound effect on electric utilities and Electricity Consumers. Utilities had to face the problem of increased costs and shortage of fuel supply. The customers were squeezed by higher Electricity bills and shortages of electric supply. The higher prices and the problems associated with increased Energy use created a demand for more efficient technologies and services.

Thus the DSM concepts evolved due to the following.

1. Utility planning was plagued by the uncertainty of future Loads.
2. As Electricity tariffs rose, the Consumers felt greater attraction for Energy conservation.

3. Utilities realized that promoting DSM measures is less costly than increasing installed generating capacity.
4. Utilities sought methods to alleviate (lessen) customer dissatisfaction by providing service options that offered that opportunity to exercise control over Electricity bills.

It has been reported that between 1977 and 1983, DSM concepts and programs reached 40 million customers in USA and decreased the peak demand by 13,000 MW or 3%. Thus DSM came to be recognized as an important as an tool which can be integrated into long range utility planning.

6.3 Benefits of DSM:

Benefits for Supply Industry

- Reduction in customer's Energy bills.
- Reduction in the need for a new power plant, transmission and distribution network.
- Stimulating economic development.
- Creating long term jobs due to new innovations and technologies.
- Increasing the competitiveness of local enterprises.
- Reduction in air pollution.
- Reduced dependency on foreign Energy sources.
- Reduction in peak power prices for Electricity.
- Improved operating efficiency and flexibility.
- Improved Load factor.
- Increased efficiency of utilization of assets.

Customer benefits.

- Satisfy Electricity demands.
- Reduce / stabilize costs.
- Improve value of service.
- Maintain / improve lifestyle and productivity.

Societal benefits.

- Reduce environmental degradation.
- Conserve resources.
- Protect global environment.
- Maximize customer welfare.

6.3.1 DSM planning and implementation

DSM planning and implementation can be described in steps as shown in figure below. The steps shown are only representative. The actual process is dynamic and would vary from utility to utility.

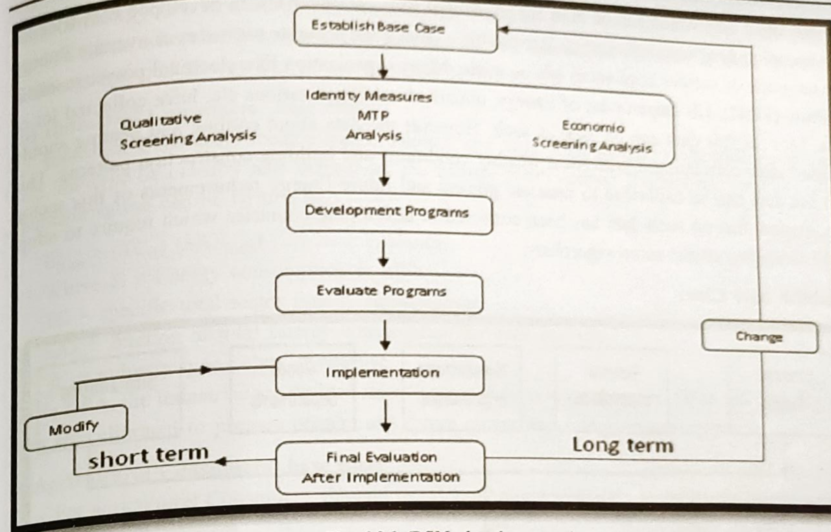


Fig. 6.3.1 (DSM planning stages)

Step 1: Establish base case:

The analyst determines a base case so that impact of DSM may be compared against it. The base case is determined for class of customers. Each segment is characterized using indicators such as total demand and Energy use, number of Consumers, consumption per Consumer. The creation of base case and its calibration with utility's demand and Energy forecasts helps in understanding the customer's usage pattern so that impacts DSM programs can be estimated. This step includes collection of data about end use efficiencies of various technologies.

(a)Domestic Consumer's Base Case:

In this base case domestic end uses of Electricity are found. These end uses include illumination, water heating, refrigeration, fans, cooking, room cooling, room heating etc. The end use Energy consumption is characterized and calibrated to forecast sales data.Domestic end use characteristics can be written as

$$E_{bc,eu} = (HH_{bc})\ (SAT_{bc,eu})\ (AEC_{bc,eu}) \ldots\ldots\ldots\ldots\ldots (1)$$

Where, E = Energy consumption, kWh;HH = number of households, SAT = fraction of households owning each end use;AEC = average Energy consumption in kWh per end use.'bc' means building category and 'eu' means end use .

Many utilities and task forces have carried out customer surveys which can be used. However, these available data have to be supplemented by utilities own efforts. Figure below shows the various input data which can be used for residential base case analysis. In developed countries lot of national and regional information is available so that quite accurate estimates of average Energy consumption of various appliances can be made. Many organization like electrical power research institute (EPRI), US Department of Energy, manufacturer organizations etc. have collected lot of data. Most of this data can be used as such. However the data about cooling and heating should be used after correlating it with local weather conditions and building construction patterns. This end use data can be calibrated to estimate present and future Energy requirements of this sector. It is ironical that no such data has been collected in developing countries which require to adopt DSM strategies all the more vigorously.

Establish base Case:

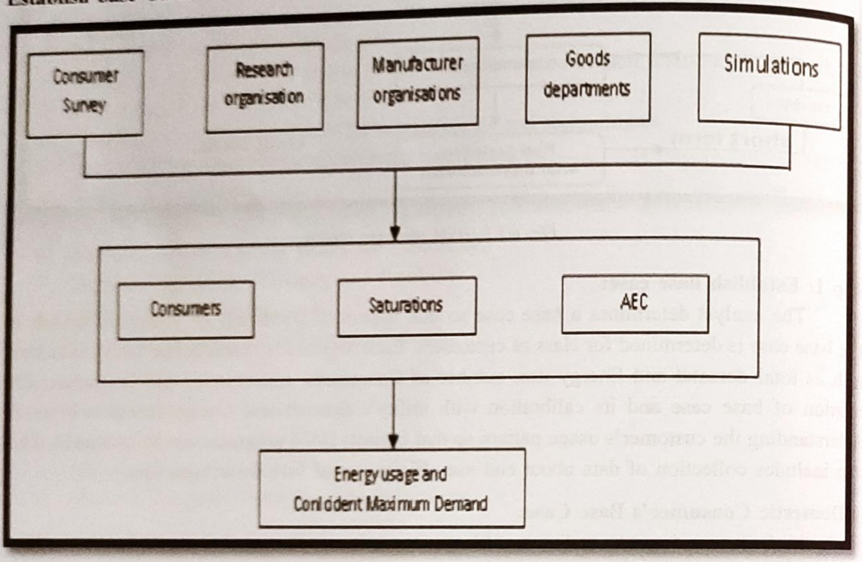


Fig: 6.3.2 (Domestic Consumers base case)

(a) Commercial Consumer's base case: Commercial Consumers include school and other Educational Institutions, Offices, Hotels, Restaurants, Hospitals, Lodging Houses, Shops, Departmental Stores etc. The end use Energy characterization in each year for each commercial building group can be written as $E_{bc,eu} = (SM_{bc})\ (SAT_{bc,eu})\ (EUI_{bc,eu})$ ....(2)

E = Energy consumption in kWh;SM = square metre of area.;SAT = fraction of total square metre of building for each end use.;EUI = average Energy use/m^2 for end use.'bc' and 'eu' stand for building category and end use respectively.

In USA, electrical power research institute (EPRI) and some other organization have collected

data of Energy use by various commercial organizations. This data can be used with suitable modifications wherever necessary. The commercial end use characterization is used to prepare estimates for total Energy and power demands of this sector.

(b) Industrial Consumers' base case:

Industrial Consumers include small, medium and large scale industries. In addition to the size, the type of industry also determines the Energy consumption. The end use characterization can be written as,

$E_{it,eu} = (TC_{it})\ (SAT_{it,eu})$ ....(3)

Where, E = Energy consumption in kWh

TC = specific total sector Energy consumption.

SAT = fraction of total Energy consumption for each end use.

'it' = industry type. 'eu' = end use.

In USA, the industries are divided into 40 categories. (Denoted by SIC 00 to SIC 39). The end uses are calibrated to prepare present and future power and Energy requirements.

(c)Agricultural Consumers' base case:

For agricultural Consumers, the end use Energy characterization in each year can be written as,

$E_{eu} = (A)\ (SAT_{eu})\ (EU)$ ....(4)

Where,E = Energy consumption, kWh.SAT = fraction of total agricultural area being irrigated through pump Sets, EU = Energy use per unit area, 'eu' = end use.Similar base case characterizations can be prepared for other categories of Consumers.

Step 2. Identify measures:

In this step, a comprehensive list of Energy conservation and demand management measures for each category of Consumers is prepared. The method of analysis available to determine the best measures to be incorporated by the utility into DSM program are,

(a) Qualitative screening analysis.

(b) Maximum technical potential (MTP) analysis.

(c) Economic screening analysis.

(a) Qualitative screening analysis:

In this step the best measures suited to the utility for inclusion in DSM option are identified. Simultaneously, the inappropriate measures are eliminated. The criteria to screen out inappropriate measures include poor customer acceptance (equipments which are difficult to install so that the customers would not accept these measures), poor utility match (equipments which have already reached their maximum saving potentials or equipments not suited to the climate of that area or equipments inappropriate to building patterns in that area etc.), Technological maturity (equipments not commercially available), savings variance (equipments or methods whose savings potential can not be estimated precisely), availability of better measures etc.After this qualitative screening, the next step i.e., maximum technical potential analysis (MTP) is taken up.

(b) MTP analysis:

In this step, the technical potential for measures suitable for that area is estimated. These measures have already been indentified in step 1, MTP is limited for Energy efficiency measures. This analysis is done in two steps.

The first step is purely Theoretical because it assumes that all inefficient equipments can be replaced by most efficient ones. This estimate ignores the fact that this would not be possible in most cases. Discarding old equipments (Geysers, Air Conditioners, Motors, Refrigerators etc.) and replacing them by new Energy efficient ones is not that easy.

The second analysis is done on the basis that only the customers purchasing new equipments or replacing old equipments (for reasons other than DSM) will adopt and purchase the efficient equipments. Finally all equipments are assumed to be replaced by more efficient ones so that the above estimates tend to converge over time. In this analysis also the unsuitable measures may be screened out.

(c) Economic screening analysis:

In this final step the cost effectiveness of each measure is evaluated and a cost benefit analysis is carried out. This analysis provides information about the financial savings of each measure. These financial savings become a base for deciding the incentives and rebates which can be given to the customers.

Step 3. Development of programs

The measures to be adopted have already been finalized in the previous step. In the third step, the programs to implement these measures are prepared and finalised.

The items in this step are, program description (i.e., preparation of brief overview of program concept, promotional strategy etc.), strategy for implementation (to overcome market barriers), incentives (loans, rebates etc.). to popularize the program, participation (target market size, penetration rates, participation level etc.), Load impacts (estimates of expected seasonal and time of day Energy and demand impacts per Consumer) on utility and participants costs (estimates of likely costs are for promotion of DSM, incentive, administration etc. and Consumers' costs are for replacement of equipment etc.).

Step 4. Initial evaluation of programs

This step involves exact cost benefit analysis of the proposed DSM programs. Generally the cost benefit analysis is carried out more than once. The repeated calculations ensure that only the best and most customer effective programs are adopted.

Step 5. Implementation

In this step, the details of implementation are worked out. The method of implementation is decided. The project to implement the program is identified. The rebates and incentives are decided. The program may be implemented either directly by the utility or through a contract. Many utilities in developed countries prefer implementation through contract so that the utility may not have to appoint extra permanent staff for this purpose.

Step 6. Final evaluation of program

In this step, the extent of the success of the program is evaluated. The evaluation involves process evaluation (to see how the implement is proceeding so that bottlenecks can be removed), impact evaluation (to find out the impact of program on the demand and Energy savings) and cost effective evaluation (to determine the extent of net benefits).

Many times at least a partial evaluation is done during the implementation so that the implementation process may be modified or adjusted to maximize the savings.

6.4. Different Techniques of DSM

1. Time of day pricing and metering,
2. Multi-utility power exchange model,
3. Load management,
4. Load priority technique,
5. Peak clipping,
6. Peak shifting,
7. Strategic conservation,
8. Energy efficiency improvement
9. Different time zones
10. Tariff interventions
11. Rain water harvesting

6.4.1 Time of day pricing and metering

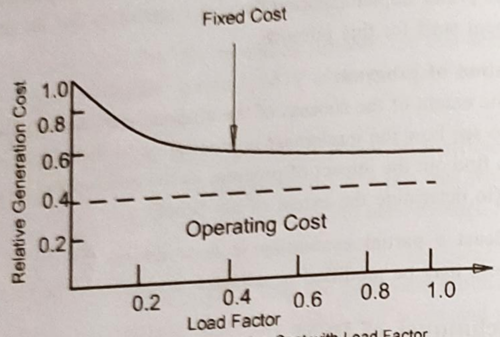
The rates which vary according to the time of the day is called time of day pricing, it is already being practiced in India For HV Installations / industries /large commercial installations .Should be extended to other installations in India; for all Loads above say, 10 kW, Much wider practice all over the world.

6.4.2 Multi-utility Power Exchange Model

Different utilities connected through the grid Shifting of Loads from one utility to the other Optimising the peak Load handling capacity < 10% difference between peak and average Load is desirable.

6.4.3 Load management as a DSM strategy

The total demand of an area keeps on varying depending on the time of the day and the season. The Load factor is the ratio of average power to peak power. A high Load factor means lower cost of generation (Refer to graph 6.4). Every utility tries to improve the Load factor to a value close to unity.



Variation of Generation Cost with Load Factor

Fig.6.4

Load management is the concept of changing the Consumer's Electricity use pattern. Load management has the purpose of improving the effective utilization of the generating capacity and encouraging the best use of Electricity by all Consumer categories.

Moreover, the forced outages are reduced and the service reliability is improved. By controlling the Load at Consumer's premises, the Load curve can be flattened. In this way, the power generation by low efficiency generation units can be minimized and some forced outages are avoided. The peak Load reduction can make it possible to postpone the building of new power stations. By this, considerable savings can be achieved. Moreover, addition of new transmission and distribution facilities can be postponed thus resulting in additional savings. The scope of Load management includes planning, development and implementation of programs whose objective is to actively shape the daily and seasonal Load profile of Consumers so as to result in better overall capacity utilization and lower the costs.

It is neither necessary nor feasible to alter the timings of operation of all devices at Consumer's premises. In residential areas the control of air conditioners, space heaters, water heaters and irrigation pumps can produce better results than control of illumination Loads. Industrial Loads should be controlled provided, the production does not suffer.

Load control can be achieved in different ways. Firstly, the Consumers may control their Loads voluntarily by altering the use of their equipments in response to tariff signals. Secondly, the utilities may control the Consumers' Loads using a signal activated either remotely or at the point of use. Both these methods have more or less the same impact on the Load shape. In India the only method used by electric utilities is to de-energise a feeder (or a section) during peak demand hours so as to reduce the peak demand.The control techniques for control of Load can be classified as direct Load control techniques, local Load control techniques and distributed Load control techniques.

Load management results

USA recognised the importance of Load management soon after the oil crises of 1973. Till 1990 more than 1750 Load control projects sponsored by more 500 utilities had been under taken. The total numbers of Loads involved were 13 million. The Loads involved were water heating systems, space heating systems and central air conditioning system. Since then more and more utilities have undertaken similar programs. All the three types of controls viz, direct, local and distributed have been used. It has been reported that because of Load control measures in USA, the average reduction in Load ranges from 1 kW/point for winter water heating to 28.7 kW/point for irrigation pumps. Utilities in Canada, especially Quebec and Ontario, have also undertaken Load management programs. Load management schemes have also been put into operation in Australia, New Zealand, Italy, France, England, Germany, Switzerland and many other countries. It has also been reported that Load control measures have led to considerable off peak Energy utilization in some countries.

6.4.4 Load priority technique

Load shedding widely used practice in India through 11 kV & 33 kV feeder control not very scientific and cannot differentiate between Consumers not a smooth way of managing the Load. Giving priority to important Loads by listing of important Loads.

(a) Direct Load control technique: The utility control the Consumer' Load without any interaction with Consumers. One example of this technique is the power line carrier or ripple control system as used in Europe. This ripple causes the shedding of Consumers' space heating and water heating Loads. After this technique was evolved and implemented, these ripples were also used to implement time of use (TOU) Rates. In some cases ripple control is used to send signals to industrial Consumers who have agreed to adopt DSM.

(b) Local Load control technique: In this technique, the Consumers control the Loads. One method to implement this technique is to have a circuit breaker at the Consumers' premises. When Load exceeds a certain value (as per circuit breaker setting), the supply is switched off. Generally the Consumer can identify the appliances which he can use simultaneously without exceeding the Load limit. Another way is to have interlocking devices which do not allow connection of several major power consuming devices at the same time.

(c) Distributed control technique: In this technique the Consumers control their Loads in communication with utilities. This technique is used mainly for large industrial Consumer with whom the utilities have special contracts such as interruptible Loads.

6.4.5. Peak clipping:

Peak clipping is defined as the reduction of utility Load primarily during peak demand Other terms for peak demand control is the Ripple control through identified Loads. Shifting Electricity consumption from peak to non peak hours, appeal to large Consumers for relief during peak hours.

Peak clipping or peak Load reduction is one of the classical forms of Load management. Here, some of the Consumers' appliances are switched off by direct Load control for some time. Evidently, these appliances are those which consume large power and whose disconnection for some time can be tolerated without much inconvenience. It can be more beneficial in case of large industrial Consumers. The relative peak clipping potential will be different in different industries. The ceiling demand required to be imposed in every case should be worked out in consultation with the participating industry and the time period required for this, when arithmetically summed up, should not exceed the power availability forecast for the cluster during that period. Figure below shows peak clipping.

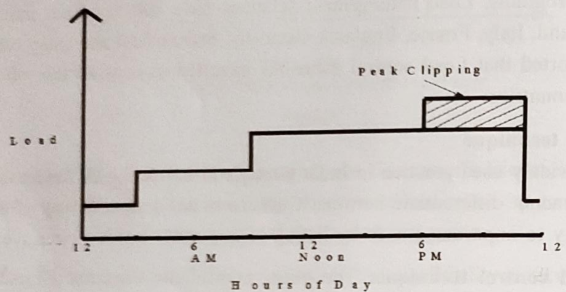


Fig: 6.4.5(a)Peak clipping

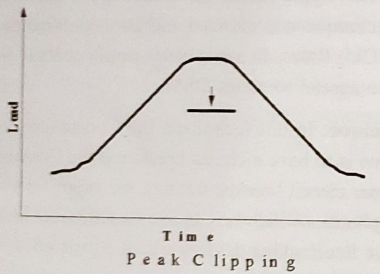


Fig: 6.4.5(b)

6.4.6. Load shifting

Load shifting is the reduction of utility Loads during periods of peak demand, while at the same time building Load in off peak periods. Load shifting typically does not substantially alter total Electricity sales. During the periods of power shortage some dispensable appliances are switched off. The appliances are such that their switching off causes only minor inconvenience to Consumers. Load shedding can be done on the entire system simultaneously or on different parts of the network turn by turn.

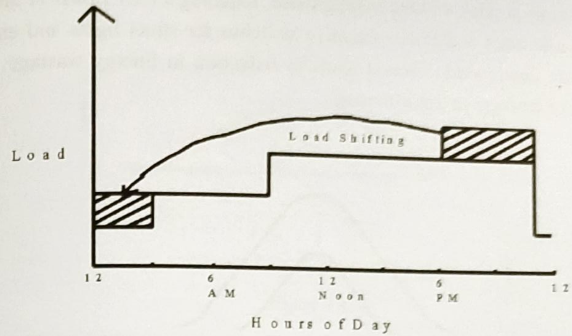


Fig: 6.4.6(a) Load Shifting

6.4.7 Valley filling:

Valley filling is the improvement in system Load factor by building Load in off peak periods.Incremental costs during off peak (generally night) hours are less the average costs of Electricity. In such case building up Loads during off peak hours may be advantageous. During nights there is surplus of generating capacity. By using this capacity economy of the utility can be improved. A part of these savings can be passed on to Consumers as incentive. Some heavy power appliances (irrigation pumps, water heaters etc.) are switched off during peak hours and switched on during off peak hours. This is known as valley filling and is shown in the Figure 6.4.7(a) and (b)

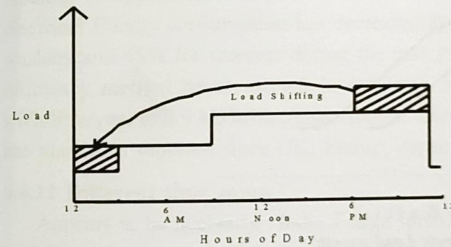


Figure 6.4.7(a)

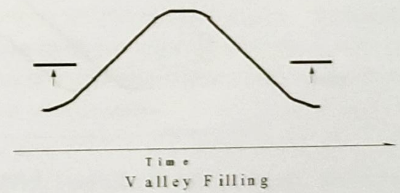


Figure 6.4.7(b)

6.4.8 Strategic Energy conservation:

Strategic Energy conservation is the reduction of utility Loads, more or less equally, during all or most hours of the day. Conservation of power in strategic locations aims at peak voltage management, reducing kVAR Loads at tail ends appeal to Energy intensive industries

Photo sensitive switches for street lights. Strategic Energy conservation is the reduction of utility Loads, more or less equally, during all or most hours of the day. Conservation of power in strategic locations aims at peak voltage management, reducing kVAR Loads at tail ends, appeal to Energy intensive industries and Photo sensitive switches for street lights and encouraging the use of high efficiency equipments. Thus it leads to reduction in Energy wastage. This leads to lower costs and lesser damage to environment.

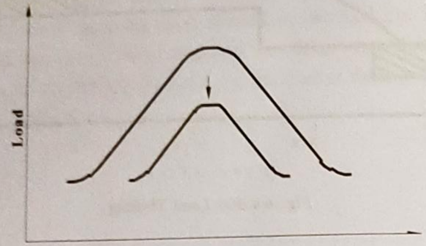


Figure 6.4.8. Strategic Energy Conservation

6.4.9 Strategic Load growth:

Load building is the increase of utility Loads, more or less equally, during all or most hours of the day. These Loads are the ones which produce a general increase in sales beyond any increase from valley filling. It may be achieved by increasing the market share of Loads or can be served by other fuels as well as general development.

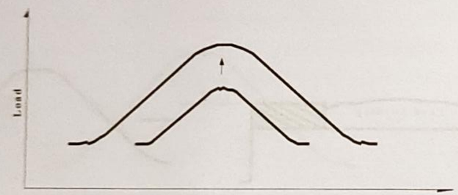


Figure 6.4.9 Strategic Load growth

6.4.10 Flexible Load shape:

The utility is allowed to adjust the Load shape to meet the reliability constraints. The Consumers are given incentives for reduced levels of service. The most common reduced levels of service are interruptible or curtailable service. Devices as available which can limit the power and Energy that individual Consumer can draw.

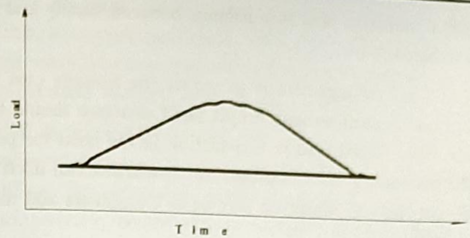


Figure 6.4.10

6.4.11 Energy efficiency improvement:

T&D loss reduction is the biggest source of DSM, Efficiency improvement in end use applications Improvement in agricultural pumping sets, Usage of CFLs/LEDs in place of bulbs, BEE's estimation of savings: 10,000 MW, Prayas Energy's study: 30 % savings in households; Corresponds to about 25,000 MW of avoided generating capacity.Education programs to educate Consumers about use of Energy efficient devices have been undertaken in many countries. Many new technologies for Energy saving have been developed in USA, Germany, Japan and some other countries. It has been reported that due to the use of most efficient devices, in USA, the average consumption in refrigerators fell from 950 kWh/year and in deep freezers from 1100 kWh/year to 835 kWh/year. These figures pertain to the period 1990-93.Many end use efficiency programs including cogeneration, promotion and sale of Energy efficient devices, Energy audit, Energy labeling of appliances etc. have been initiated and implemented in Australia. In Germany the electrical Energy consumption has decreased by about 20% for washing machines, 30% for dish washers and 45% for freezers during the past 15years.In Sweden an improvement in the end use efficiency method have resulted in reduction in Energy consumption of refrigerators from 1.4 kWh/litre/year to 0.9 kWh/litre/year. Similar decrease in Energy consumption of various appliances has also been reported from UK, France, Japan and other countries.

6.4.12 Different time zones

Appears to be necessity, India's large spread across longitude; 80 Minute spread, Shifting of peak Load from one to other time zone, Needs adequate transmission capacity, HV DC lines and UHV systems are required for this purpose.

6.4.13 Tariff options for DSM

To discriminate between legitimate use and luxuries/ wastages, Should discourage wastage and encourage efficiency, Very high tariff for higher usage in commercial and domestic usage, much higher demand charges for higher connected Loads, early introduction of feed-in tariff for renewable Energy sources. The function of a tariff structure should be to have an efficient use of resources. To achieve this goal, Consumers should receive correct information about the costs involved in delivering power. Tariff should also lead to a balance between supply and demand so that Load shedding etc., can be avoided.

The ultimate aim of Load management is to reduce the average cost of electric power. To achieve this objective, Load control through proper tariff structure should be applied to improve the system Load factor. This would lead to a reduction in the need for peaking capacity and a higher utilization of the generating units. A proper tariff structure can itself lead to peak clipping and valley filling. This can lead to improved service to Consumers and measures such as Load shedding may not be required.

The guiding principle for tariff design should be that each Consumer category should be charged equitably for its contribution to the total costs for generation, transmission and distribution of electric power. The subsidised Electricity tariff for some sections of economy always leads to wastage of Energy. Tariff structure can be used as a means for achieving DSM objectives because Consumers respond to Electricity bills by changing their level and pattern of usage. It has been found that Consumers respond in a predictable way to alternate rate structure.

Through appropriate price signals, Consumers can be encouraged to recognize that Electricity is not easily stored and that generating costs may vary considerably across the Load curve as increasing demand is met by relatively expensive peak duty generating plant. A properly designed pricing policy can defer investments in new generating capacity be creating incentives for the customers to shift Load from peak hours to off peak hours as well as induce customers to invest in Energy conservation measures.

The cost per unit of Energy varies with time of the day and season. Generally Consumers are charged per unit of Energy at all times of the day at the same flat rate. The variation in the cost of generation over a time period is not reflected in the rate charged for the customer.

Marginal cost based tariffs send the right price signal to Consumers, which helps them to make appropriate decisions when deciding on the purchase and use of Electricity. Marginal cost of power supply is defined as the change in cost of service resulting from small changes in demand. This cost may change according to the place and time of use (TOU). Marginal costs are a reflection of the costs incurred by utility to meet additional demand of Energy. These types of tariffs not only cover the historical costs but also provide a revenue that is high enough to cover the incremental costs arising from new investments (in generation, transmission and distribution) needed to meet the extra demand. Marginal cost based tariffs provide the utility with some leverage to control future Load growth and Load shape and can therefore, be used as a management tool in DSM programs. The tariff structures which can promote DSM activities are as under.

(a) Time of day tariff (TOD tariff): It is also known as time of use (TOU) tariff. The technical development of metering equipment has made it possible to measure Energy consumptions during different times of day, days of week and periods of year, economically. TOD rates make Electricity, more expensive when it costs more to generate additional Electricity during peak hours and cheaper during off peak hours. Such a tariff structure encourages Consumers to shift their Load, whenever possible, from peak to off peak hours thus flattening the Load curve. This would be favorable to the customers who find their bills reduced and also favorable to the electric utility who would gain by a decrease in peak Load.

(b) Seasonal Tariff: In this tariff structure, the rates change across the season. This type of tariff is an economical way of managing demand. Since the peak consumption months are more or less fixed, the tariff can be adjusted to reflect seasonal demand variations. Thus, the cost of Electricity is more during certain months of the year than that during other. This tariff system does not require the special Electricity meters needed for (TOD) tariff. Evidently the Electricity billing frequency has to be synchronising with the times when seasonal rates come into effect.

(c) Curtailable / interruptible (C/I) rates: C/I rates offer incentives to those Consumers who reduce demand to a predetermined level, when they receive a notice to this effect from success of this tariff system depends on reliable communication system.

It is an accepted fact that offering incentives and pricing options to Consumers is the best way to promote DSM. In USA, bill credits range from $1 to $5 per month for water heaters, $1.25 to $12per month for air conditioners and $1.5 to $29 per HP / year for irrigation. In addition 7% to 50% rate reduction per kW demand, 8% to 20% rate reduction per kWh and $0.003 to $0.061 per kWh discounts are offered by many utilities. Some utilities offer inconvenience payments of $25 to $150 per year. In UK, a tariff known as 'Economy' offers Electricity during night time at less than half the day time rate. In Ontario (Canada) DSM programs have resulted in annual savings of $27 to $48 per month. In France a 4 time period per day tariff structure has been proposed for small industrial Consumers. Similar incentives and multiple pricing options exist in a large number of countries in Europe and else where.

6.14 End use Energy Conservation

End use Energy conservation programs form a very important aspect of DSM. These programs reduce the customers' consumption of Energy thereby reducing their Electricity bills. Cost effective conservation options reduce overall requirement of the utility and serve to reduce Electricity tariff for all Consumers. The utilities and governments in all countries have undertaken a number of programs to improve efficiency of various appliances and to promote the use of such Energy efficient appliances. These programs include help to industries in manufacturing high efficiency equipments, information and education programs, Energy audit schemes, subsidies for equipment finance; equipment efficiency programs have limited effect unless supplemented by financial benefits. The various aspects of end use Energy conservation are as under.

6.14.1 Least cost utility planning:

It is an established fact that investments in Energy conservation and Load management activities are less expensive per kW than addition of new generation facilities. In order to decide the best mix between capacity additions, conservation and Load management programs, many utilities in developed countries carry out least cost planning process. In this analysis the costs of new capacity additions, supply side efficiency improvements, end use efficiency measures are all examined critically. The mix of resources which can meet the future power & Energy needs at the lowest cost are selected. This planning process can lead to substantial savings because some expensive new projects can be substituted by low cost efficiency improvement methods.

6.14.2 Promotion of high efficiency technologies:

Many efficiency measures with good saving potential have been implemented in some countries. Examples are, improved efficiency refrigerators, air conditioners, evaporative coolers, fan Motors etc. Similarly electronic ballasts for fluorescent lights, variable speed drives using power electronics devices can also lead to substantial savings. The strategy should include Research and Development and demonstration projects with an emphasis on adopting technologies developed overseas to the Indian context.

1. Technical and financial assistance to the manufacturers so that high efficiency equipments are manufactured.
2. Selective reduction in import duties both for manufacturing equipments (needed to manufacture high efficiency devices indigeneously) as also the actual high efficiency devices.
3. Mandatory efficiency standards for equipments.
4. Preference for high efficiency devices by government and semi-government agencies.

6.14.3. Energy Conservation Opportunities in Agricultural Sector:

Agricultural sector account for about 30% of Electricity consumption in India. The current Energy consumption in this sector is about 93,000 million kWh and the total number of pump sets is 11,850,000. About Two lakh pump sets are added every year. It is evident that improved efficiency of agricultural pump sets can lead to enormous savings. The metering of Electricity to irrigation pump sets is necessary. In many states the agricultural pump sets are charged flatly per kW of the rating of the Motor. This practice leads to a lot of Energy wastage. Use of inefficient Motors and sub-standard accessories is leading to huge wastage of Energy. Use of drip irrigation keeping the pipe fitting losses to the minimum and the operation of pumps & threshers during off peak hours can also lead to saving in Energy and Energy costs.

6.14.4. Energy conservation opportunities in illumination systems:

A conventional incandescent lamp has a luminous efficiency of 12 lumens/watt. Fluorescent lamp has a luminous efficiency of about 60-70 lumens/watt. Compact fluorescent lamps (CFL) are all the more Energy efficient. Moreover CFL has long life and is environment friendly. CFL offer about 5% to 15% increase in efficiency (as compared to conventional fluorescent lamp), and provide good color rendering. Moreover replacement of 40W fluorescent lamps by 36W CFL leads to 10% savings for the same illumination level. A conventional choke consumes about 12-15 watts and operates at a very poor power factor. Electronic ballasts require only about 1-4 watts of power

and operate at good power factor. The only inhibiting factor is the higher cost (about Rs 300) of electronic ballast as compared to about Rs 80 for conventional magnetic ballast. High pressure sodium vapor lamps and high pressure mercury vapor lamps should be preferred for street lighting.

6.14.5. Energy conservation opportunities in Fans and Refrigerators:

Fans are used very extensively in summer months. Use of high efficiency fan Motor and use of electronic regulator (in place of conventional resistance regulator) can lead to about 20% saving in Energy. The fans with aerodynamic designs and improved impeller consume about 10% less Energy but are 30% costly as compared to conventional fans. However it is important to note that electronic ballasts introduce harmonics in the system.

The efficiency of refrigerators in India is rather poor. A typical 165 liter Indian refrigerator consumes about 540 kWh/year. On the other hand the 200 liter Korean model consumes about 240 kWh/year. High efficiency refrigerators are not manufactured in India. These refrigerators use a different compressor design which is very sensitive to voltage of electric supply. Unless quality of electric supply is improved these refrigerators cannot be introduced in India. Nevertheless use of better insulation technique can bring about some improvement.

6.14.6. Energy conservation opportunities in cooling and heating systems:

Air conditioners consume lot of Energy. Efficiency of air conditioner is expressed in Energy efficiency ratio (EER) which is BTU of cooling output divided by watts of input power. BIS calls for an EER of 6.6-7 whereas most of the air conditioners used in India have an EER ratio of 5.0 only.Efficiency of central AC systems can be improved by carefully designing the buildings to reduce heat gain into the buildings, improved thermostat and other controls. Slight reduction in thermostat setting can lead to considerable saving without loss of comfort. Reliable door closers can enhance the effectiveness of air conditioning by checking infiltration of outside air into the room. Desert coolers are widely used in India in summer months. A typical cooler consumes 20% more Energy than BIS standard.

The efficiency of a cooler can be increased by an improvement in efficiency of fan Motor and that of water circulating pump. It has been reported that extra cost of Rs 500/cooler can lead to 20% improvement in efficiency. Energy savings in water heating can be achieved by using better insulation techniques. Reduction in Energy use by the water heaters can be achieved by covering the tank with an insulating blanket made of fiber glass and backed with vinyl. These blankets can also be used to cover the sides of water heater.

6.14.7. Energy conservation opportunities in industrial sector:

Electric Motors are very widely used in industry. The most common Motors are squirrel cage induction Motor (up to a few kW rating) and wound rotor induction Motor (for large kW requirements). Use of high efficiency Motors can mean an Energy saving of 2-5%. However high efficiency Motors are about 25-35% more costly than the standard efficiency Motors. Moreover, the use of Motors made by standard manufacturers is also pretty common. These Motors are highly inefficient and operate at poor power factor. The rewinding of Motors reduces their efficiency because of poor rewinding, use of thinner conductor (than that required for the Motor size) and poor quality insulating materials.

Power electronic variable speed drives are Energy efficient but expensive. Their use can lead to Energy savings. Cogeneration should be encouraged in the industrial sector. Sugar, paper, textile, fertilizer, cement, chemical and pharmaceutical industries offer a good scope for cogeneration. The cogeneration systems are very Energy efficient. The use of non-fossil fuels in some industries like sugar can lead to enormous saving of fossil fuels.

6.15 Customer acceptance of DSM

The ultimate aim of electric utility before adopting DSM program should not be to manipulate Load, but to satisfy the customer. Customer satisfaction should be an index for measuring success of DSM program. The utility must put great emphasis on identifying and resolving the problems faced by customers.

Customer acceptance means willingness of customers to participate in an adopt the programme initiated by the utility. The choice of appropriate implementation strategies requires the utilities to have sufficient knowledge and understanding of a number of customer's characteristics. Although the utility may offer a wide range of incentives to encourage customer participation in a DSM activity, yet it is the customers' willing participation which determines the success of the activity. The factors which influence customer participation are,

a) **Incentives:** Some programs offer specific incentives to the customers to participate in DSM activities. In TOD tariff, the customers save on their bill by shifting Energy usage.

b) **Marketing:** Many approaches can be used to attract customer to DSM activities. Door to door campaigns, media campaigns can help a lot in this direction.

c) **Effect of Services:** Any program which affects the desired Energy service will have some effect on customer's decision to adopt the program or not. The DSM program should not affect the service dramatically. The aim should be to convince the customer that some little change in his life style, because of the program, would be economical and beneficial for him.

d) **Consumer Expenditure:** High efficiency equipments need more initial investment. Most of the customers are swayed by low initial cost devices irrespective of their high operation and maintenance costs. This is partly due to customer's inability to pay more initially and partly due to his ignorance about high O&M costs. The customers should be educated after life cycle costs.

e) **Attitude:** People's attitude towards the utility, Energy use and other basic issues strongly influence their acceptance of DSM programs. The Energy conservation programs are more readily accepted and adopted than valley filling programs. Customers' attitudes can be altered by changing the beliefs, feelings, self perceptions and social consciousness.

f) The decision making process for adoption of DSM programs is more complex in case of commercial and industrial Consumers as compared to that in case of domestic Consumers. The reasons are,

1. The industrial process required to be modified may be very complex and may require special design. An off the shelf solution may not be available.
2. The decision my require and hierarchy of individuals representing different functions in industrial and commercial organizations.
3. The decisions of management may not be acceptable to the work force.
4. A proper approach is to involve every individual in the ascending hierarchy in decision making process.

6.16 DSM implementation issues

DSM techniques have been successfully implemented in many developed countries. However their implementation in developing countries has been limited by a number of technical, institutional and other barriers. Early DSM programs tended to focus on audit, spread of information, direct Load control and rate making. More recently, utilities have begun to focus their attention on comprehensive programs incorporating a package of Energy efficient measures and multiple marketing and delivery techniques. DSM programs are now available for new markets as well as existing markets. The programs for new markets can result in high saving at modest cost to the utilities. The programs for existing markets range form information programs, audits to retrofit.

DSM programs do not necessarily mean advance technology or major process changes. Many changes require little investment. The need is to bring about awareness about Energy saving. The end user, the manufacturer of high efficiency equipment, financial institutions, testing laboratories, industrial associations, Consumer forums have to be involved in the process.

Most DSM programs achieve only partial success. The factors which restrain the Consumers to move towards Energy conservation are,

1. **Lack of information:** Information gap is one of the major constraints in the implementation of DSM programs. Consumers are generally unaware of the opportunities of improving Energy efficiency. Information on Energy efficiency of equipment is not available or available only partially. Educational efforts customized to each end user segment can be helpful. Energy labels on equipments, devices, Motors etc. can be helpful.
2. **Cost of Energy efficient equipment:** Most of the Consumers are not willing to purchase high efficiency equipments due to their high initial cost. Manufacturers have an important role to play in developing markets for high efficiency equipments. Incentives in the form of lower taxes and duties can help in making Energy efficient equipments more popular.
3. **Tariff:** In many developing countries the tariff for some categories of Consumers is very low, even lower than cost of Electricity generation. Such tariff structures need to be avoided.

4. **Poor power quality and reliability:** In many developing countries, electric power supply is characterized. Planned and forced outages are also very common. The poor power quality and reliability problems impede efficiency measures in many ways. Many types of equipments are very sensitive to low voltage and voltage fluctuations. Some equipment consumes more Energy at low voltages. The equipments designed to withstand voltage fluctuations are always less efficient. For successful implementation of DSM programs, power quality and reliability must be improved.
5. **Unavailability of efficient equipments:** Many types of efficient equipments are not available in developing countries. Efficient refrigerators, air conditioners. And evaporative coolers have not been marketed in developing countries. The manufacturers are reluctant to start production of such equipments due to unsure market conditions and demand. Moreover many raw materials and components to manufacture efficient equipments are also not available.
6. **Small scale sector:** Many devices like ballasts, lighting fixtures, small Motors, pumps, fans, coolers etc. are manufactured in small scale sector. Most of these devices are inefficient. The small scale industries do not invest in quality control measures and do not adhere to BIS. Moreover these manufacturers often produce low cost devices and to minimize the cost they ignore efficiency considerations.
7. **Retirement of inefficient and old equipments:** In developing countries, the equipments are repaired again and again and hardly thrown away. Most of the time the repair leads to increasing inefficiency because substandard materials and components are use in repair.
8. **Shortage of skilled staff:** There is shortage of skilled staff who can provide technical assistance in identifying, installing and maintaining efficiency measures.

6.17 DSM implementation strategies:

Some of the strategies which can lead to successful implementation of DSM are,

1. **Market transformation through voluntary retirement:** The utilities should engage in direct negotiations with manufacturers to ban manufacture of low efficiency devices. Moreover the utilities should take up market campaigns to promote Energy efficient devices. People should be educated about the replacement of poor efficient devices by new and more efficient devices.
2. **Energy efficiency labeling:** All participating brands of refrigerators, air conditioners, fans, coolers, pumps etc. should carry an efficiency label which indicates efficiency, annual kWh consumption etc. This would induce customers to go in for Energy efficient devices.
3. **Customer oriented program design:** Each customer has unique Energy requirement and financial position. Therefore DSM programs should be flexible that needs of every customer can be accommodated.

4. **Public privates sector partnership:** Design and development of Energy saving devices needs special knowledge and skill. Utilities should subsidize the manufacturers in the development of such devices, at least partly. Establishing a funding mechanism for DSM investments is essential for long term sustainability. Assurance of cost recovery for cost effective DSM investments is critical. It is difficult to convince utility managers to engage in DSM activities. DSM expenses, if prudently incurred, are automatically passed on to all Consumers through fuel adjustment charge.

6.18 International experience with DSM

All the DSM measures are being planned and implemented, at least to some extent, in most of the countries in the world.

DSM and Environment:

The areas of environmental concern attributable to electric power generation are, air quality, water quality, global climate change, worker and public safety, land use and solid waste. Protecting the environment has become a major concern for public and government. By devising methods to decrease the environmental effects of electric power generation, DSM programs help in reducing Electricity demand and therefore, the electric power generation. The financial incentives to encourage DSM and thereby avoid environmental damage include,

1. Performance incentive and bonus for well run DSM programs.
2. Decoupling revenues from sales through the use of fuel balancing account.
3. Share holder's incentives.
4. Shared savings mechanism.
5. Capitalizing DSM expenditures so that the utilities can earn a rate of return on the investment.

Many electro-technologies, if implemented can lead to Energy conservation as well as environmental protection. The table below is a sample list of such electro technologies. It is necessary that environmental protection and environmental costs are given due consideraion. If this aspect is taken into account, DSM grams become all the more tive.

Alternate DSM Technologies

Domestic	*Commercial*	*Industrial*
CFL'S	CFL'S	CFL'S
High efficiency Fluorescents	High efficiency Fluorescents	High efficiency Fluorescents
Day Lighting	Day Lighting	Day Lighting
Low Loss Ballasts	Low Loss Ballasts	Low Loss Ballasts
Efficient Fans	Delamping	Delamping
High Efficiency AC'S	High Efficiency AC'S	High Efficiency AC'S
High Efficiency Refrigerators	High Efficiency Refrigerators	High Efficiency Refrigerators

Domestic	*Commercial*	*Industrial*
Gas cooking	Air Conditioner Maintenance	Air Conditioner Maintenance
Efficient Rice Cookers	Air Conditioner Timers	Air Conditioner Timers
Orientation New Homes	Efficient Security Lighting	Efficient Security Lighting
Solar Hot water Systems	High efficiency Motors	High efficiency Motors
	TOD Tariff	TOD Tariff
	Interruptible Tariff	Interruptible Tariff
	EE Building code	EE Building code
	Solar Hot water system	Cogeneration
		Power factor Correction
		Variable speed drives

Energy conservation electro-technologies:

Industrial Process	*Conventional technology*	*Electro-technology*	*Energy saving in %*
Ferrous billet Heating	Gas/oil furnace	Induction furnace	20%
Drying	Forces air dryer	Microwave dryer	25%
Molten steel making	Blast oxygen Furnace	Electric furnace	60%
Aluminium welding	TIC Arc weld	Electron beam weld	90%

6.19 Summary of the discussions on DSM

1. Demand side management means the approaches and actions which aim at augmenting the system capacity by decreasing the Consumers demand.
2. DSM planning involves 6 steps viz., establishing base cases, (for domestic, commercial, industrial, agricultural and other Consumers), identification of measures, development of programs, and initial evaluation of programs, implementation and final evaluation.
3. One of the strategies of DSM is Load management. Applications of Load management include peak clipping, valley filling, Load shedding, strategic Energy conservation and flexible Load shape.
4. Least cost utility planning and promotion of high efficiency technologies are necessary for Energy conservation.
5. Energy conservation opportunities exist in almost all sectors of economy viz., industrial, agriculture, commercial, cooling and heating systems, illumination etc.

6. The Electricity tariff structure should be so as to promote demand side management. Time of day tariff, seasonal tariff and curtailable / interruptible rates are some types of tariff which promote DSM.
7. Customers should be given incentives so that they participate in DSM programs willingly.
8. Lack of information, cost of Energy efficient devices, poor power quality, reliability, unavailability of efficient equipments, substandard equipments manufactured in small scale sector, repeated use of repaired devices are some of the factors which restrain the Consumers to move towards Energy conservation.
9. Market transformation through voluntary retirement of equipments, Energy efficient labeling, and customer oriented designing of program and public private sector partnership are some DSM implementation strategies.
10. DSM programs have been successfully implemented in many countries and have led to considerable savings in Energy consumption.

6.20 Energy Efficient Technology in Electrical system

1. Maximum demand controllers
2. Automatic power factor controllers
3. Soft starters with Energy saver
4. Variable speed drives
5. Energy efficient transformers
6. Electronic ballast
7. Occupancy sensors
8. Energy saving potential of each technology.

6.20.1 Maximum Demand Controllers

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. Considerable savings can be realized by monitoring power use and turning off or reducing non-essential Loads during such periods of high power use. Maximum Demand Controller (See Figure) 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 Load in a logical sequence. This sequence is predetermined by the user and is pro-grammed 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.

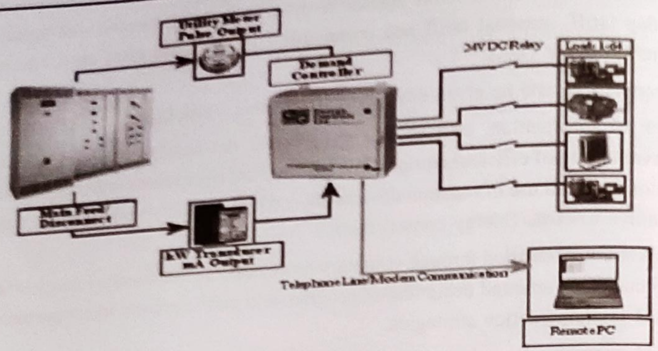


Figure 6.20.1 Maximum Demand Controllers

6.20.2Automatic power factor controller

Various types of automatic power factor controls are available with relay / microprocessor Logic. Two of the most common controls are: Voltage Control and kVAR Control

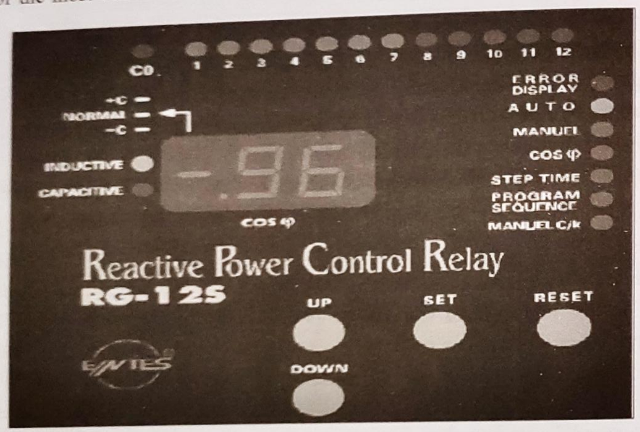


Figure 6.20.2 Automatic power factor controller

6.20.2(a) 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 sub Station, which is to be taken note of.

6.20.2(b) KILOVAR Control

Kilovar sensitive controls (see Figure) are used at locations where the voltage level is closely regulated and not avail-able 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.

6.20.2(c) Automatic Power Factor Control Relay

It controls the power factor of the installation by giving signals to switch on or off power factor correction capacitors. Relay is the brain of control circuit and needs contactors of appropriate rating for switching on/off the capacitors. There is a built-in power factor transducer, which measures the power factor of the installation and converts it to a DC voltage of appropriate polarity. This is compared with reference voltage, which can be set by means of a knob calibrated in terms of power factor.

When the power factor falls below setting, the capacitors are switched on in sequence. The relays are provided with First in First out (FIFO) and First in Last Out (FILO) sequence. The capacitors controlled by the relay must be of the same rating and they are switched on/off in line-ear sequence. To prevent over correction hunting, a dead band is provided. This setting deter-mines the range of phase angle over which the relay does not respond; only when the PF goes beyond this range, the relay acts. When the Load is low, the effect of the capacitors is more pronounced and may lead to hunting. Under current blocking (low current cut out) shuts off the relay, switching off all capacitors one by one in sequence, when Load current is below setting. Special timing sequences ensure that capacitors are fully discharged before they are switched in. This avoids dangerous over voltage transient. The solid state indicating lamps (LEDS) display various functions that the operator should know and also and indicate each capacitor switching stage.

6.20.2 (d) Intelligent power Factor Controller (IPFC)

Determines the rating of capacitance connected in each step during the first hour of its operation and stores them in memory. Based on this measurement, the IPFC switches on the most appropriate steps, thus eliminating the hunting problems normally associated with capacitor switching

6.20.3 Soft Starter with Energy saver

When starting, AC Induction Motor develops more torque than is required at full speed. This stress is transferred to the mechanical transmission system resulting in excessive wear and premature failure of Chains, belts, gears, mechanical seals, etc. Additionally, rapid acceleration also has a massive impact on Electricity supply charges with high inrush currents drawing +600% of the normal run current. The use of Star Delta only provides a partial solution to the problem. Should the Motor slow down during the transition period, the high peaks can be repeated and can even exceed direct on line Current.Soft starter. See Figure 6.20.3(a)

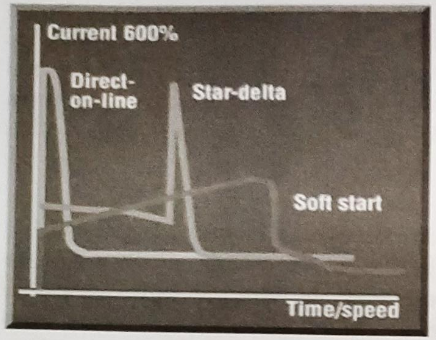


Figure 6.20.3(a)

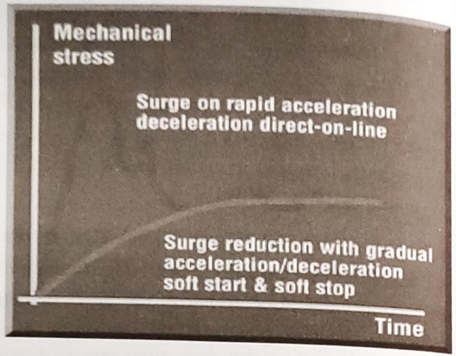


Figure6.20.3 (b)

(Starter starting current, Stress profile during starting)

Provides a reliable and economical solution to these problems by delivering a controlled release of power to the Motor, thereby providing smooth, steplessacceleration and deceleration. Motor life will be extended as damage to windings and bearingsis reduced.Soft Start & Soft Stop is built into 3 phase units, providing controlled starting and stoppingwith a selection of ramp times and current limit settings to suit all applications. see Figures 6.20.3(a), (b) and (c).

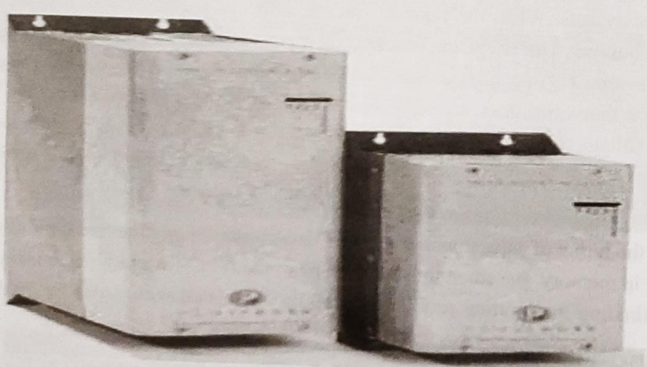


Figure 6.20.3(c)

Advantages of Soft Start

- Less mechanical stress
- Improved power factor.
- Lower maximum demand.
- Less mechanical maintenance

6.20.4 Variable Speed Drives:

6.20.4 (a) Speed Control of Induction Motors:

Induction Motor is the workhorse of the industry. It is cheap rugged and provides high power to weight ratio. On account of high cost-implications and limitations of D.C. System, induction Motors are preferred for variable speed application, the speed of which can be varied by changing the supply frequency. The speed can also be varied through a number of other means, including, varying the input voltage, varying the resistance of the rotor circuit, using multi speed windings, using Scherbius or Kramer drives, using mechanical means such as gears and pulleys and eddy current or fluid coupling, or by using rotary or static voltage and frequency converters.

6.20.4 (b)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 of poles 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 synthesizes the DC to a variable frequency AC output. Motors connected to VFD provide variable speed mechanical output with high efficiency. These devices are capable of up to a 9:1 speed reduction ratio (11 percent of full speed), and a 3:1 speed increase (300 percent of full speed). In recent years, the technology of AC variable frequency drives (VFD) has evolved into highly sophisticated digital microprocessor control, along with high switching frequency IGBTs (Insulated Gate Bi Polar Transistors) power devices. This has led to significantly advanced capabilities from the ease of programmability to expanded diagnostics. The two most significant benefits from the evolution in technology have been that of cost and reliability, in addition to the significant reduction in physical size.

6.20.4 (c) Variable Torque Vs. Constant Torque

Variable speed drives, and the Loads that are applied to, can generally be divided into two groups: constant torque and variable torque. The Energy savings potential of variable torque applications is much greater than that of constant torque applications. Constant torque Loads include vibrating conveyors, punch presses, rock crushers, machine tools, and other applications where the drive follows a constant V/Hz ratio. Variable torque Loads include centrifugal pumps and fans, which make up the majority of HVAC applications.

6.20.4 (d) Why Variable Torque Loads Offer Greatest Energy Saving?

In variable torque applications, the torque required varies with the square of the speed, and the horsepower required varies with the cube of the speed, resulting in a large reduction of horse power for even a small reduction in speed. The Motor will consume only 25% as much Energy at 50% speed as it will at 100% speed. This is referred to as the Affinity Laws, which define the relationships between speed, flow, torque, and horsepower.

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}

6.20(d) tighter process control with variable speed drives:

No other AC Motor control method compares to variable speed drives when it comes to accurate process control. Full-voltage (across the line) starters can only run the Motor at full speed, soft starts reduced voltage soft starters can only gradually ramp the Motor up to full speed, and back down to shutdown. Variable speed drives, on the other hand, can be programmed to run the Motor at a precise speed, to stop at a precise position, or to apply a specific amount of torque. In fact, modern AC variable speed drives are very close to the DC drive in terms of fast torque response and speed accuracy. However, AC Motors are much more reliable and afford-able than DC Motors, making them far more prevalent. Most drives used in the field utilize Volts/Hertz type control, which means they provide open loop operation. These drives are unable to retrieve feedback from the process, but are sufficient for the majority of variable speed drive applications. Many open-loop variable speed drives do offer slip compensation though, which enables the drive to measure its out-put current and estimate the difference in actual speed and the set point (the programmed input value).

The drive will then automatically adjust itself towards the set point based on this estimation. Most variable torque drives have Proportional Integral Differential (PID) capability for fan and pump applications, which allow the drive to hold the set point based on actual feedback from the process, rather than relying on estimation. A transducer or transmitter is used to detect process variables such as pressure levels, liquid flow rate, air flow rate, or liquid level. Then the signal is sent to a PLC (Programmable Logic Controllers), which communicates the feedback from the process to the drive. The variable speed drive uses this continual feedback to adjust itself to hold the set point. High levels of accuracy for other applications can also be achieved through drives that offer closed-loop operation. Closed-loop operation can be accomplished with either afield-oriented vector drive, or a sensor less vector drive. The field-oriented vector drive obtains process feedback from an encoder, which measures and transmits to the drive the speed and/or rate of the process, such as a conveyor, machine tool, or extruder. The drive then adjusts itself accordingly to sustain the programmed speed, rate, torque, and/or position.

Extended equipment life and reduced maintenance

Single-speed starting methods start Motors abruptly, subjecting the Motor to a high starting torque and to current surges that are up to 10 times the full-Load current. Variable speed drives, on the other hand, gradually ramp the Motor up to operating speed to lessen mechanical and electrical stress, reducing maintenance and repair costs, and extending the life of the Motor and the driven equipment. Soft starts, or reduced-voltage soft starters (RVSS), are also able to step a Motor up gradually, but drives can be programmed to ramp up the Motor much more gradually and smoothly, and can operate the Motor at less than full speed to decrease wear and tear. Variable speed drives can also run a Motor in specialized patterns to further minimise mechanical and electrical stress. For example, an S-curve pattern can be applied to a conveyor application for smoother control, which reduces the backlash that can occur when a conveyor is accelerating or decelerating. Typical full-Load efficiencies are 95% and higher. High power units are still more efficient. The efficiency of VSDs generally decreases with speed but since the torque requirement also decreases with speed for many VSD applications, the absolute loss is often not very significant. The power factor of a VSD drops drastically with speed, but at low power requirement the Absolute kVAR requirement is low, so the loss is also generally not significant. In a suitable operating environment, frequency controllers are relatively reliable and need little maintenance. A disadvantage of static converters is the generation of harmonics in the supply, which reduces Motor efficiency and reduces Motor output - in some cases it may necessitate using a Motor with a higher rating.

Eddy Current Drives

This method employs an eddy-current clutch to vary the output speed. The clutch consists of a primary Member coupled to the shaft of the Motor and a freely revolving secondary member coupled to the Load Shaft. The secondary member is separately excited using a DC field winding. The Motor starts with the Load at rest and a DC excitation is provided to the secondary member, which induces eddy currents in the primary member. The interaction of the fluxes produced 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 poor efficiency particularly at low speeds. (see Figure)

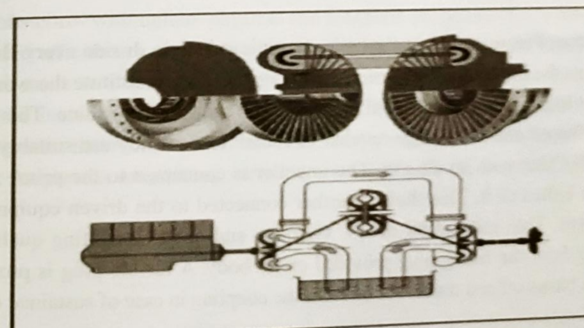


Figure Eddy Current Drive

Slip Power Recovery Systems

Slip power recovery is a more efficient alternative speed control mechanism for use with slipring Motors. In essence, a slip power recovery system varies the rotor voltage to control speed,but instead of dissipating power through resistors, the 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 be economical only in relatively high power applications and where the Motor speed range is 1:5or less.

Fluid Coupling

Fluid coupling is one way of applying varying speeds to the driven equipment, without changing the speed of the Motor.

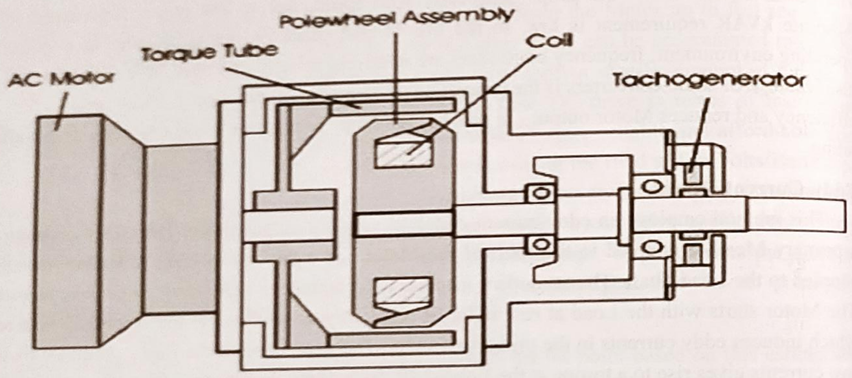


Figure. Fluid Coupling

Construction

Fluid couplings (see Figure) work on the hydrodynamic principle. Inside every fluid coupling are two basic elements the impeller and the runner and together they constitute the working circuit. One can imagine the Impeller as a centrifugal pump and the runner as a turbine. The impeller and the rotor are bowl Shaped and have large number of radial vanes. They are suitably enclosed in a casing, facing each Other with an air gap. The impeller is connected to the prime mover while the rotor has a shaft bolted to it. This shaft is further connected to the driven equipment through a suitable arrangement. Thin mineral oil of low viscosity and good-lubricating qualities is filled in the fluid coupling from the filling plug provided on its body. A fusible plug is provided on the fluid coupling which blows off and drains out oil from the coupling in case of sustained overLoading.

Operating principal:

There is no mechanical inter-connection between the impeller and the rotor and the power is transmitted by virtue of the fluid filled in the coupling. When the impeller is rotated by the prime mover, the fluid flows out radially and then axially under the action of centrifugal force. It then crosses the air gap to the runner and is directed towards the bowl axis and back to the impeller. To enable the fluid to flow from impeller to rotor it is essential that there is difference in head between the two and thus it is essential that there is difference in RPM known as slip between the two. Slip is an important and inherent characteristic of a fluid coupling resulting in several desired advantages. As the slip increases, more and more fluid can be transferred. However when the rotor is at a stand still, maximum fluid is transmitted from impeller to rotor and maximum torque is transmitted from the coupling. This maximum torque is the limiting torque. The fluid coupling also acts as a torque limiter.

Characteristics

Fluid coupling has a centrifugal characteristic during starting thus enabling no-Load start up ofprime mover, which is of great importance. The slipping characteristic of fluid coupling provides a wide range of choice of power transmission characteristics. By varying the quantity of oil filled in the fluid coupling, the normal torque transmitting capacity can be varied. The maximum torque or limiting torque of the fluid coupling can also be set to a pre-determined safe value by adjusting the oil filling. The fluid coupling has the same characteristics in both directions of rotation.

Energy Efficient Transformers

Most Energy loss in dry-type transformers occurs through heat or vibration from the core. The new high-efficiency transformers minimise these losses. The conventional transformer is made-up of a silicon alloyed iron (grain oriented) core. The iron loss of any transformer depends on the type of core used in the transformer. However the latest technology is to use amorphous material - a metallic glass alloy for the core (see Figure 10.9). The expected reduction in Energy loss over conventional (Si Fe core) transformers is roughly around70%, which is quite significant. By using an amorphous core- with unique physical and magnetic properties- these new type of transformers have increased efficiencies even at low Loads – 98.5% efficiency at35% Load. Electrical distribution transformers made with amorphous metal cores provide excellent opportunity to conserve Energy right from the installation. Though these transformers are a little costlier than conventional iron core transformers, the overall benefit towards Energy savings will compensate for the higher initial investment. At present amorphous metal core transformers are available up to1600 kVA.

Figure. 1600 kVA Amorphous Core Transformer

Electronic Ballast:Role of Ballast

In an electric circuit the ballast acts as a stabilizer. Fluorescent lamp is an electric discharge lamp. The two electrodes are separated inside a tube with no apparent connection between them. When sufficient voltage is impressed on these electrodes, electrons are driven from one electrode and attracted to the other. The current flow takes place through an atmosphere of low pressure mercury vapour.Since the fluorescent lamps cannot produce light by direct connection to the power source, they need an ancillary circuit and device to get started and remain illuminated. The auxiliary circuit housed in a casing is known as ballast.

Conventional Vs Electronic Ballasts

The conventional ballasts make use of the kick caused by sudden physical disruption of current in an inductive circuit to produce the high voltage required for starting the lamp and then rely on reactive voltage drop in the ballast to reduce the voltage applied across the lamp. On account of the mechanical switch (starter) and low resistance of filament when cold the uncontrolled filament current, generally tend to go beyond the limits specified by Indian standard specifications. With

high values of current and flux densities the operational losses and temperature rise are on the higher side in conventional choke.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 (see Figure) 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. It is now well established that the fluorescent lamp efficiency in the kHz range is higher than those attainable at low frequencies. At lower frequencies (50 or 60 Hz) the electron density in the lamp is proportional to the instantaneous value of the current because the ionization state in the tube is able to follow the instantaneous variations in the current. At higher Frequencies (kHz range), the ionization state cannot follow the instantaneous variations of the Current and hence the ionization density is approximately a constant, proportional to the RMS (Root Mean Square) value of the current. Another significant benefit resulting from this phenomenon is the absence of stroboscopic effect, thereby significantly improving the quality of light output. One of largest advantages of electronic ballast is the enormous Energy savings it provides. This is achieved in two ways. The first is its amazingly low internal core loss, quite unlike old fashioned magnetic ballasts. And second is increased light output due to the excitation of the lamp phosphors with high frequency. If the period of frequency of excitation is smaller than the light retention time constant for the gas in the lamp, the gas will stay ionized and, therefore, produce light continuously. This phenomenon along with continued persistence of the phosphors at high frequency will improve light output from 8–12 percent. This is possible only with high frequency electronic ballast.

Energy Efficient Lighting Controls:

Occupancy Sensors

Occupancy-linked control can be achieved using infra-red, acoustic, ultrasonic or microwave sensors, which detect either movement or noise in room spaces. These sensors switch lighting on when occupancy is detected, and off again after a set time period, when no occupancy movement detected. They are designed to override manual switches and to prevent a situation where lighting is left on in unoccupied spaces. With this type of system it is important to incorporate a built-in time delay, since occupants often remain still or quiet for short periods and do not appreciate being plunged into darkness if not constantly moving around.

Timed Based Control

Timed-turnoff switches are the least expensive type of automatic lighting control. In some cases, their lowcost and ease of installation makes it desirable to use them where more efficient controls would be too expensive (see Figure 10.11).

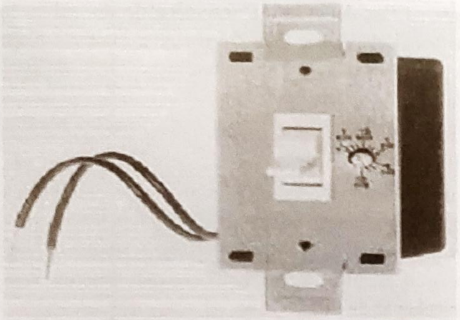


Figure Timed Turnoff Switch

Types and Features

The oldest and most common type of timed-turnoff switch is the "dial timer," a spring-wound mechanical Timer that is set by twisting the knob to the desired time. Typical units of this type are vulnerable to damage because the shaft is weak and the knob is not securely attached to the shaft. Some spring-wound units make an Annoying ticking sound as they operate. Newer types of timed-turnoff switches are completely electronic and silent. Electronic switches can be made much more rugged than the spring-wound dial timer. These units typically have a spring-Loaded toggle switch that turns on the circuit for a preset time interval. Some electronic models provide a choice of time intervals, which you select by adjusting a knob located behind the faceplate. Most models allow occupants to turn off the lights manually. Some models allow occupants to keep the lights on, overriding the timer. Timed-turnoff switches are available with a wide range of time spans. The choice of time span is a compromise. Shorter time spans waste less Energy but increase the probability that the lights will turn off while someone is in the space. Dial timers allow the occupant to set the time span, but this is not likely to be done with a view toward optimising efficiency. For most applications, the best choice is an electronic unit that allows the engineering staff to set a fixed time interval behind the cover plate.

Daylight Linked Control

Photoelectric cells can be used either simply to switch lighting on and off, or for dimming. They may be mounted either externally or internally. It is however important to incorporate time delays into the control system to avoid repeated rapid switching caused, for example, by fast moving clouds. By using an internally mounted photoelectric dimming control system, it is possible to ensure that the sum of daylight and electric lighting always reaches the design level by sensing the total light in the controlled area and adjusting the output of the electric lighting accordingly. If daylight alone is able to meet the design requirements, then the electric lighting can be turned off. The Energy saving potential of dimming control is greater than a simple photoelectric switching system. Dimming control is also more likely to be acceptable to room occupants.

Localized Switching

Localized switching should be used in applications which contain large spaces. Local switches give individual occupants control over their visual environment and also facilitate Energy savings. By using localized switching it is possible to turn off artificial lighting in specific areas, while still operating it in other areas where it is required, a situation which is impossible if the lighting for an entire space is controlled from a single switch.

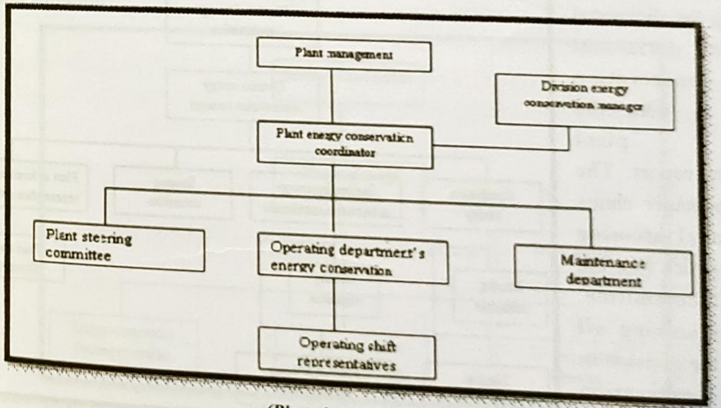
6.20 Organization of Energy Conservation Programs

Even in a relatively small plant, Energy management involves many people. The details of an Energy conservation program will depend on the size and nature of the manufacturing organization. In the decision making process, it is desirable to involve all segments of the production organization concerned. The general structure of a large corporate Energy management program has been discussed here, starting from the plant level organization. All elements of this typical organizational structure will not be pertainment to every situation. However, certain aspects can be adopted to Energy management even in a small company.

6.20.1 Plant Level Organisation

A typical plant level Energy conservation organization is shown in figure below. This organizational structure will be discussed in some detail as it should have broad applicability to both large and small plants. In general, the plant level organization has a relatively short term and technical focus. It is concerned primarily with directly affecting production operations on a day to day basis. The plant Energy conservation coordinator is the key person of the organization.

The coordinator is primarily responsible to the plant manager and in the case of a multi-plant corporation, he may report on Energy conservation progress to divisional or corporate management as well.

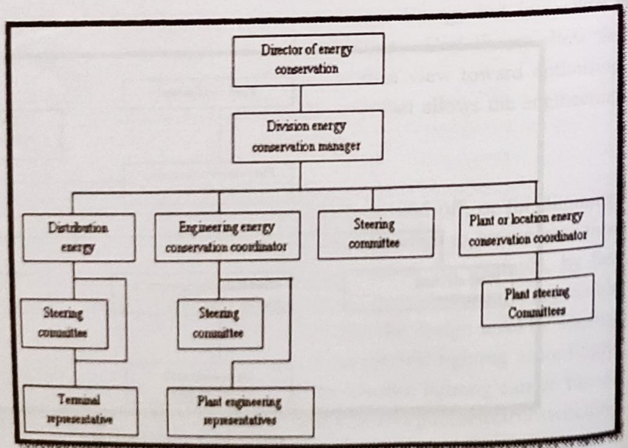


(Plant level organisation)

The plant coordinator chairs the plant Energy management committed, which in a small plants, may be compose of representatives such as production supervisors form individual operating units. This committee structure may become cumbersome in a large plant because of the large number of operating departments. In this case, the committee might be limited be perhaps five or six members by selecting representatives from such key areas as engineering, maintenance, production, labour relations and public relations. The program and provides a channel of communications to major areas of plant operation. In addition to the plant Energy management committee, each operating department should have a designated Energy conservation representative who has primary responsibility for progress in that department and who reports to the plant coordinator. In turn in a two or three shift operation, a representative from each operating shift should be designated to report to the department representative. It should be emphasized that in most plants, these various assignments are handled on a part time basis by regular operating personnel, such as shift maintenance foreman or unit operating engineers. Even the position of plant coordinator is a part time responsibility in all plants. The amount of time devoted to these responsibilities is largely determined by the importance of Energy as an element of overall manufacturing costs. In addition to the various operating unit representatives, a special maintenance department representative may be designated, since this department generally plays a pivotal role in the Energy conservation program.

6.20.2 Division level organization:

The division level organization shown in the figure below is concerned primarily with monitoring the Energy conservation progress of the several plants in a division and planning the overall division program on a medium term (quarterly) basis. It facilitates the transfer of useful information between geographically dispersed but operationally similar plants and can bring to bear division wide resources, such as central engineering and resource capabilities, in support of plant level efforts.



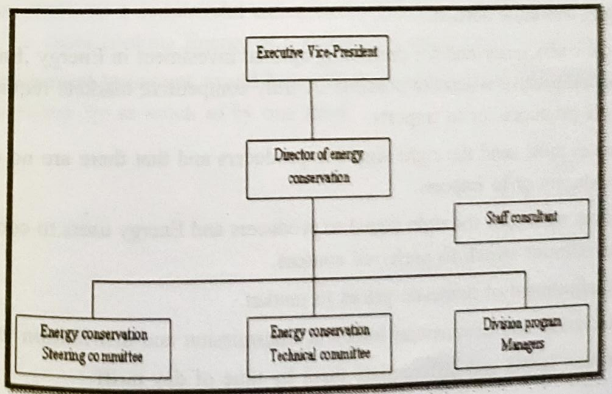
Heading the divisional level is the divisional Energy conservation manager, to who the individual plant coordinators report. The divisional manager chairs the divisional steering committee, which like the plant level committee, assists in involving all elements of the division in Energy conservation program planning and implementation. The steering committee generates ideas for employee awareness, technical projects, and improved operating procedures applicable on a broad basis throughout the division. The committee also acts as an impartial review body to assess annual Energy conservation program plans of the various plants and ensure uniformity of effort.

Division Level Energy management Organisation

Since engineering is often handled on a centralized basis in a corporation, a sub organization within the engineering department, headed by an engineering department Energy conservation coordinator reporting directly to the division manager, may be desirable. Also, since product distribution is a major Energy consuming function and normally handled on a division wise basis, similar organization might exist within the department, concentrating primarily on Energy conservation in the transportation area.

6.20.3 Corporate level organization

In a large multidivisional corporation, a corporate level Energy management organization is established reporting directly to top level management. This is shown in the figure below. This organization usually has responsibility for all systems of Energy supply as well as Energy conservation and is concerned with integration of the divisional Energy conservation programs into the overall business plans of the corporation. It also has primary responsibility for Energy related interactions with outside entities such as government level associations, and Energy suppliers. The focus is relatively long range with forecasting future Energy prices and planning for long term Energy supplies. Again, the organization is base around a steering committee, which at this level comprises or representatives from the major business planning segments of the corporate structure. In addition, there may be a technical committee primarily oriented toward research, development, engineering and operations, since Energy conservation, in the final analysis, requires careful technical and economic evaluation. The division program managers report directly to the corporate Energy conservation director.



(Corporate level organization)

6.21. Integrated Energy policy

India needs to sustain an economic growth of at least 9% over the next 25 years if it is to eradicate poverty and meet its larger human development goals. The primary supply including gathered non- commercial such as wood and dung must increase at the rate of 5.8% annually for fuelling the growth. Meeting this requirement is a challenging which needs to be addressed through an integrated Energy policy. The broad vision behind the integrated Energy policy is to reliably meet the demand for Energy services of all sectors including vulnerable households in all parts of the country with safe and clean Energy at the least cost.

Salient features of the policy:

- Provide appropriate fiscal policies.
- Both the tax structure and regulatory philosophy applied in each Energy sector should be consistent with the overall Energy policy should provide a level playing field to all players whether public or private.
- Subsidies must be transparent and targeted consideration should be given to alternative means of achieving the social objectives sought to be achieved by Energy subsidies.
- Promote Energy- efficiency by enforcing Energy standards effectively
- PSUs operating in the Energy sector must operate with autonomy and also full accountability to ensure incentives for adequate investment through their own resources and improvements in efficiency in Energy production and distribution.
- India will have to pursue all available fuel options and forms of Energy and must seek to acquire new Energy sources abroad.
- India must actively promote Technologies that maximize efficiency; demand side management, conservation and Energy security and this must be done by encouraging domestic research into such technologies and free access to suitable Energy related technologies available abroad.
- For economic efficiency and for promoting optimal investment in Energy ,Energy markets should be competitive wherever possible .A truly competitive markets requires that there are multiple producers or to imports.
- Energy prices must send the right signal to producers and that there are no entry barriers to new producers or to imports.
- Energy prices must send the right signal to producers and Energy users to conserve Energy and where relevant switch to preferred sources.
- A phased adjustment of domestic prices to market.
- Reduce Technical and commercial losses in transmission and distribution utilities.
- Set multi-year Tariffs and differentiate them by time of day tariff

- Incentives for promoting Renewables should be linked to outcomes (Energy generated) and not just outlays (capacity installed).
- Fuel wood plantations, biogas plants, wood gasifier based power plants, Bio-diesel and ethanol should be promoted.
- Set up a national Energy fund (NEF) to finance R&D in Energy sector.
- A number of technology missions including solar Energy mission should be mounted for developing near commercial technologies and rolling out in a time bound manner new technologies that emphasise nationally relevant sources of Energy.
- Ensure Energy security by,
- Lowering the requirement of Energy by Energy efficiency.
- Substituting imported fuels with alternatives.
- Expanding the domestic Energy resource base.
- Maintaining reserve equivalent to 90 days of oil imports.
- Building strategic stockpile of nuclear fuel to counter the risk of disruption of international fuel supply.
- Acquiring Energy assets abroad and setting up Energy using industries such fertilizer plants in Energy rich countries.
- Provide Electricity to all rural households through Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) and clean cooking Energy such as LPG, NG, BIOSGAS or KEROSENE to all within 10 years.
- Subsidy for Electricity and cleaner fuels, Kerosene or LPG to targeted households should be delivered through a system of Debit card in phased manner.
- A large scale socio-economic experiment should be financed to operate community sized biogas plants as a commercial entrepreneur; Bio-gas plants on this scale could meet the need for clean cooking Energy of a sizable segment of the rural population.
- Recommended initiatives would have effect on reducing the green house gas intensity of the economy by as much as by one third.

REVIEW QUESTIONS

1. What is demand side management (DSM)? What is the scope of DSM? How did the concept of DSM Evolve?
2. Explain the various steps in DSM planning and implementation.
3. Explain peak clipping, valley filling and strategic Energy conservation.
4. Discuss tariff options for DSM.Which tariffs promote DSM?
5. Explain the management and organization of Energy conservation awareness programmes.
6. With a flow Diagram explain DSM planning and implementation.
7. Explain various DSM strategies from Load curve objectives view. Mention benefits of the strategies.
8. Explain Energy conservation opportunities in Agriculture sector.
9. Explain Energy conservation opportunities in illumination system.
10. Explain plant level organization with relevant diagram.
11. Explain Load management as a DSM Strategy.
12. Explain the basic ways of Load shape objectives of DSM.
13. with a flow chart, explain corporate level organization of Energy conservation Programme.
14. What is time of day pricing (TOD)? With the help of suitable Example, explain how this helps in an efficient DSM.