CHAPTER

5

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 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 public 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.

5.1 Tariff

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 same for all types of consumers. It is because the cost of producing electrical energy 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 it 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.

5.2 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 words, the total receipts from the consumers must be equal to 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 so that consumers can pay easily.

5.3 Types of Tariff

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

1. Simple tariff. *When there is a fixed rate per unit of energy consumed, it is called a* **simple tariff** *or* **uniform rate tariff.**

In this type of tariff, the price charged per unit is constant *i.e.*, it does not vary with increase or decrease in number of units consumed. The consumption 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.

2. Flat rate tariff. *When different types of consumers are charged at different uniform per unit rates, it is called a* **flat rate tariff**.

In this type of tariff, the consumers are grouped into different classes and each class of consumers is charged at a different uniform rate. For instance, the flat rate per kWh for lighting load may be 60 paise, whereas it may be slightly less† (say 55 paise per kWh) for 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 more fair to different 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 are reduced.

3. Block rate tariff. *When a given block 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 per 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 blocks 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.

4. Two-part tariff. *When the rate of electrical energy is charged on the basis of maximum demand of 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 split 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 consumed, the 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 rateable value of the premises or on the number of rooms or on the connected load.

$$\text{Total charges} = \text{Rs}\,(b \times \text{kW} + c \times \text{kWh})$$

where, b = charge per kW of maximum demand

c = charge per kWh of energy consumed

This type of tariff is mostly applicable to industrial consumers who have appreciable maximum 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 but 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 not consumed the electrical energy.

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

5. 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 rateable 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 separate maximum demand meter is required.

6. Power factor tariff. *The tariff in which power factor of the consumer's load is taken into consideration is 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 penalised. The following are the important types of power factor tariff :

(*i*) *k VA maximum demand tariff* : It is a modified form of 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.

(*ii*) *Sliding scale tariff* : This is also know as average power factor tariff. In this case, an average power factor, say 0·8 lagging, is taken as the reference. If the power factor of the consumer falls below this factor, suitable additional charges are made. On the other hand, if the power factor is above the reference, a discount is allowed to the consumer.

(*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.

7. 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.*,

$$\text{Total charge} = \text{Rs}\,(a + b \times \text{kW} + c \times \text{kWh})$$

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.

* See chapter on power factor improvement.

It may be seen that by adding fixed charge or consumer's charge (*i.e.*, *a*) to two-part tariff, it becomes three-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.

Power Factor Improvement

Example 5.1. *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.*

Solution.

$$\text{Units consumed/year} = \text{Max. demand} \times \text{L.F.} \times \text{Hours in a year}$$
$$= (200) \times (0{\cdot}4) \times 8760 = 7{,}00{,}800 \text{ kWh}$$
$$\text{Annual charges} = \text{Annual M.D. charges + Annual energy charges}$$
$$= \text{Rs } (100 \times 200 + 0{\cdot}1 \times 7{,}00{,}800)$$
$$= \text{Rs } 90{,}080$$
$$\therefore \quad \text{Overall cost/kWh} = \text{Rs } \frac{90{,}080}{7{,}00{,}800} = \text{Re } 0{\cdot}1285 = \mathbf{12{\cdot}85 \text{ paise}}$$

Example 5.2. *The maximum demand of a consumer is 20 A at 220 V and his total energy consumption is 8760 kWh. If the energy is charged at the rate of 20 paise 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.

Assume the load factor and power factor to be unity.

$$\therefore \quad \text{Maximum demand} = \frac{220 \times 20 \times 1}{1000} = 4 \cdot 4 \text{ kW}$$

(*i*) $\text{Units consumed in 500 hrs} = 4{\cdot}4 \times 500 = 2200 \text{ kWh}$

$$\text{Charges for 2200 kWh} = \text{Rs } 0{\cdot}2 \times 2200 = \text{Rs } 440$$
$$\text{Remaining units} = 8760 - 2200 = 6560 \text{ kWh}$$

$$\text{Charges for 6560 kWh} = \text{Rs } 0{\cdot}1 \times 6560 = \text{Rs } 656$$

$$\therefore \quad \text{Total annual bill} = \text{Rs } (440 + 656) = \textbf{Rs. 1096}$$

(*ii*) $$\text{Equivalent flat rate} = \text{Rs } \frac{1096}{8760} = \text{Re } 0{\cdot}125 = \textbf{12.5 paise}$$

Example 5.3. *The following two tariffs are offered :*

(*a*) *Rs 100 plus 15 paise per unit ;*

(*b*) *A flat rate of 30 paise per unit ;*

At what consumption is first tariff economical ?

Solution.

Let x be the number of units at which charges due to both tariffs become equal. Then,

$$100 + 0{\cdot}15x = 0{\cdot}3x$$

or $$0{\cdot}15x = 100$$

$$\therefore \quad x = 100/0{\cdot}15 = \textbf{666·67 units}$$

Therefore, tariff (*a*) is economical if consumption is more than 666·67 units.

Example 5.4. *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.*

Solution. Let x (> 400) be the number of units taken per annum for which the annual charges due to both tariffs become equal.

$$\text{Annual charges due to first tariff} = \text{Rs } (30 + 0{\cdot}03x)$$

$$\text{Annual charges due to second tariff} = \text{Rs } [(0{\cdot}06 \times 400) + (x - 400) \times 0{\cdot}05]$$

$$= \text{Rs } (4 + 0{\cdot}05x)$$

As the charges in both cases are equal,

$$\therefore \quad 30 + 0{\cdot}03x = 4 + 0{\cdot}05x$$

or $$x = \frac{30 - 4}{0{\cdot}05 - 0{\cdot}03} = \textbf{1300 kWh}$$

Example 5.5. *An electric supply company having a maximum load of 50 MW generates 18×10^7 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 and distribution = Rs 32 lakhs

Assuming 90% of the fuel cost is essential to running charges and the loss in transmission and distribution as 15% of kWh generated, deduce a two part tariff to find the actual cost of supply to the consumers.

Solution.

Annual fixed charges

$$\text{For generation} = \text{Rs } 28 \times 10^5$$

$$\text{For transmission and distribution} = \text{Rs } 32 \times 10^5$$

$$\text{For fuel (10\% only)} = \text{Rs } 0{\cdot}1 \times 90 \times 10^5 = \text{Rs } 9 \times 10^5$$

$$\text{Total annual fixed charge} = \text{Rs } (28 + 32 + 9) \times 10^5 = \text{Rs } 69 \times 10^5$$

This cost has to be spread over the aggregate maximum demand of all the consumers *i.e.*, 75 MW.

$\therefore$ Cost per kW of maximum demand $= \text{Rs } \dfrac{69 \times 10^5}{75 \times 10^3} = $ **Rs. 92**

Annual running charges.

$$\text{Cost of fuel (90\%)} = \text{Rs } 0{\cdot}9 \times 90 \times 10^5 = \text{Rs } 81 \times 10^5$$

$$\begin{aligned}\text{Units delivered to consumers} &= 85\% \text{ of units generated} \\ &= 0{\cdot}85 \times 18 \times 10^7 = 15{\cdot}3 \times 10^7 \text{ kWh}\end{aligned}$$

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

$\therefore$ Cost/kWh $= \text{Rs } \dfrac{81 \times 10^5}{15 \cdot 3 \times 10^7} = \text{Re } 0 \cdot 053 = $ **5.3 paise**

$\therefore$ Tariff is Rs 92 per kW of maximum demand plus 5·3 paise per kWh.

Example 5.6. *A generating station has a maximum demand of 75 MW and a yearly load factor of 40%. Generating costs inclusive of station capital costs 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.*

Solution.

$$\text{Maximum demand} = 75 \text{ MW} = 75{,}000 \text{ kW}$$

$$\text{Annual load factor} = 40\% = 0{\cdot}4$$

(*i*) **Cost at substation.** The cost per kW of maximum demand is to be determined from the total annual fixed charges associated with the supply of energy at the substation. The cost per kWh shall be determined from the running charges.

(*a*) Annual fixed charges

$$\text{Generation cost} = \text{Rs } 60 \times 75 \times 10^3 = \text{Rs } 4{\cdot}5 \times 10^6$$

$$\text{Transmission cost} = \text{Rs } 2 \times 10^6$$

Total annual fixed charges at the substation

$$= \text{Rs } (4{\cdot}5 + 2) \times 10^6 = \text{Rs } 6{\cdot}5 \times 10^6$$

Aggregate of all maximum demands by the various substations

$$\begin{aligned} &= \text{Max. demand on generating station} \times \text{Diversity factor} \\ &= (75 \times 10^3) \times 1{\cdot}2 = 90 \times 10^3 \text{ kW}\end{aligned}$$

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

Annual cost per kW of maximum demand

$= \text{Rs } \dfrac{6 \cdot 5 \times 10^6}{90 \times 10^3} = $ **Rs. 72.22**

(*b*) Running Charges. It is given that cost of 1 kWh transmitted to substation is 4 paise. As the transmission efficiency is 90%, therefore, for every kWh transmitted, 0·9 kWh reaches the substation.

$\therefore$ Cost/kWh at substation $= 4/0{\cdot}9 = $ **4·45 paise**

Hence at sub-station, the cost is **Rs 72·22** per annum per kW maximum demand plus **4·45 paise** per kWh.

***(ii)* Cost at consumer's premises.** The total annual fixed charges at consumer's premises is the sum of annual fixed charges at substation (*i.e*. Rs $6{\cdot}5 \times 10^6$) and annual fixed charge for distribution (*i.e.*, Rs $1{\cdot}5 \times 10^6$).

∴ Total annual fixed charges at consumer's premises

$$= \text{Rs}\ (6{\cdot}5 + 1{\cdot}5) \times 10^6 = \text{Rs}\ 8 \times 10^6$$

Aggregate of maximum demands of all consumers

$$= \text{Max. demand on Substation} \times \text{Diversity factor}$$

$$= (90 \times 10^3) \times 1{\cdot}25 = 112{\cdot}5 \times 10^3 \text{ kW}$$

∴ Annual cost per kW of maximum demand

$$= \text{Rs}\ \frac{8 \times 10^6}{112 \cdot 5 \times 10^3} = \textbf{Rs. 71.11}$$

As the distribution efficiency is 85%, therefore, for each kWh delivered from substation, only 0·85 kWh reaches the consumer's premises.

∴ Cost per kWh at consumer's premises

$$= \frac{\text{Cost per kWh at substation}}{0 \cdot 85} = \frac{4 \cdot 45}{0 \cdot 85} = \textbf{5.23 paise}$$

Hence at consumer's premises, the cost is **Rs. 71·11** per annum per kW maximum demand plus **5·23 paise** per kWh.

Example 5.7. *Determine the load factor at which the cost of supplying a unit of electricity from a Diesel and from a steam station is the same if the annual fixed and running charges are as follows :*

Station	*Fixed charges*	*Running charges*
Diesel	*Rs 300 per kW*	*25 paise/kWh*
Steam	*Rs 1200 per kW*	*6·25 paise/kWh*

Solution. Suppose energy supplied in one year is 100 units *i.e.*, 100 kWh. Let L be the load factor at which the cost of supplying a unit of electricity is the same for diesel and steam station.

Diesel Station.

$$\text{Average power} = \frac{100 \text{ kWh}}{8760 \text{ hrs}} = 0{\cdot}0114 \text{ kW}$$

$$\text{Maximum demand} = \frac{0 \cdot 0114}{L} \text{ kW}$$

$$\text{Fixed charges} = \text{Rs}\ 300 \times \frac{0 \cdot 0114}{L} = \text{Rs}\ \frac{3 \cdot 42}{L}$$

$$\text{Running charges} = \text{Rs}\ 100 \times 0{\cdot}25 = \text{Rs}\ 25$$

∴ Fixed and running charges for 100 kWh

$$= \text{Rs}\left(\frac{3 \cdot 42}{L} + 25\right) \quad \text{...}(i)$$

Steam station.

$$\text{Fixed charges} = \text{Rs}\ 1200 \times \frac{0 \cdot 0114}{L} = \text{Rs}\ \frac{13 \cdot 68}{L}$$

$$\text{Running charges} = \text{Rs}\ 100 \times 0{\cdot}0625 = \text{Rs}\ 6{\cdot}25$$

∴ Fixed and running charges for 100 kWh

$$= \text{Rs}\left(\frac{13 \cdot 68}{L} + 6 \cdot 25\right) \quad \text{...}(ii)$$

As the two charges are same, therefore, equating exps. (*i*) and (*ii*), we get,

$$\frac{3\cdot42}{L} + 25 = \frac{13\cdot68}{L} + 6\cdot25$$

or
$$\frac{10\cdot26}{L} = 18\cdot75$$

$\therefore$
$$L = 10\cdot26/18\cdot75 = 0\cdot5472 = \mathbf{54\cdot72\%}$$

TUTORIAL PROBLEMS

1. A consumer has a maximum demand of 100 MW at 60% load factor. If the tariff is Rs 20 per kW of maximum demand plus 1 paise per kWh, find the overall cost per kWh. **[1·38 paise]**
2. The maximum demand of a consumer is 25A at 220 V and his total energy consumption is 9750 kWh. If energy is charged at the rate of 20 paise per kWh for 500 hours use of maximum demand plus 5 paise per unit for all additional units, estimate his annual bill and the equivalent flat rate. **[Rs 900 ; 9·2 paise]**
3. A consumer has an annual consumption of 2×10^5 units. The tariff is Rs 50 per kW of maximum demand plus 10 paise per kWh.

   (*i*) Find the annual bill and the overall cost per kWh if the load factor is 35%.

   (*ii*) What is the overall cost per kWh if the consumption were reduced by 25% with the same load factor ?

   (*iii*) What is the overall cost per kWh if the load factor were 25% with the same consumption as in (*i*) ?
   [(*i*) Rs 23,400 ; 11·7 paise (*ii*) 11·7 paise (*iii*) 12·28 paise]
4. Daily load of an industry is 200 kW for first one hour, 150 kW for next seven hours, 50 kW for next eight hours and 1 kW for remaining time. If tariff in force is Rs. 100 per kW of maximum demand per annum plus 5 paise per kWh, find the annual bill. **[Rs 50,258·5]**
5. A consumer requires one million units per year and his annual load factor is 50%. The tariff in force is Rs. 120 per kW per annum plus 5 paise per unit consumed. Estimate the saving in his energy costs if he improves the load factor to 100%. **[Rs 13,692]**
6. An industrial undertaking has a connected load of 100 kW. The maximum demand is 80 kW. On an average, each machine works for 60 per cent time. Find the yearly expenditure on the electricity if the tariff is

   Rs 10,000 + Rs 1000 per kW of maximum demand per year + Re 1 per kWh. **[Rs 615600]**

Example 5.8. *Calculate annual bill of a consumer whose maximum demand is 100 kW, p. f. = 0·8 lagging and load factor = 60%. The tariff used is Rs 75 per kVA of maximum demand plus 15 paise per kWh consumed.*

Solution.

$$\begin{aligned}
\text{Units consumed/year} &= \text{Max. demand} \times \text{L.F.} \times \text{Hours in a year}\\
&= (100) \times (0\cdot6) \times (8760)\ \text{kWh}\\
&= 5\cdot256 \times 10^5\ \text{kWh}\\
\text{Max. demand in kVA} &= 100/\text{p.f.} = 100/0\cdot8 = 125\\
\text{Annual bill} &= \text{Max. demand charges} + \text{Energy charges}\\
&= \text{Rs } 75 \times 125 + \text{Rs } 0\cdot15 \times 5\cdot256 \times 10^5\\
&= \text{Rs } 9375 + \text{Rs } 78{,}840 = \textbf{Rs 88,215}
\end{aligned}$$

Example 5.9. *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?*

Solution.

Maximum demand in kVA at a p.f. of 0·8

$$= 240/0\cdot8 = 300$$

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

$= \text{Rs } 50 \times 300 + \text{Rs } 0{\cdot}1 \times 50{,}000$

$= \text{Rs } 15{,}000 + \text{Rs } 5000 = \text{Rs } 20{,}000$

$\therefore$ Flat rate/unit $= \text{Rs } \dfrac{20{,}000}{50{,}000} = \text{Rs } 0{\cdot}40 =$ **40 paise**

When p.f. is raised to unity, the maximum demand in kVA

$= 240/1 = 240$

Annual bill $= \text{Rs } 50 \times 240 + \text{Rs } 0{\cdot}1 \times 50{,}000$

$= \text{Rs } 12{,}000 + \text{Rs } 5{,}000 = \text{Rs } 17{,}000$

Annual saving $= \text{Rs } (20{,}000 - 17{,}000) =$ **Rs 3000**

Example 5.10. *The monthly readings of a consumer's meter are as follows :*

Maximum demand = 50 kW

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 unit for each 1% of power factor below 86%, calculate the monthly bill of the consumer.

Solution.

Average load $= \dfrac{36{,}000}{24 \times 30} = 50 \text{ kW}$

Average reactive power $= \dfrac{23{,}400}{24 \times 30} = 32{\cdot}5 \text{ kVAR}$

Suppose ϕ is the power factor angle.

$\therefore$ $\tan\phi = \dfrac{\text{kVAR}}{\text{Active power}} = \dfrac{32{\cdot}5}{50} = 0{\cdot}65$

or $\phi = \tan^{-1}(0{\cdot}65) = 33{\cdot}02^\circ$

$\therefore$ Power factor, $\cos\phi = \cos 33{\cdot}02^\circ = 0{\cdot}8384$

Power factor surcharge $= \text{Rs } \dfrac{36{,}000 \times 0{\cdot}5}{100}(86 - 83{\cdot}84) = \text{Rs } 388{\cdot}8$

Monthly bill $= \text{Rs } (80 \times 50 + 0{\cdot}08 \times 36{,}000 + 388{\cdot}8)$

$= \text{Rs } (4000 + 2880 + 388{\cdot}8) =$ **Rs 7268·8**

Example 5.11. *The tariff in force is Rs 150 per kVA of maximum demand and 8 paise per unit consumed. If the load factor is 30%, find the overall cost per unit at* (*i*) *unity p. f. and* (*ii*) *0·7 p. f.*

Solution. Suppose the maximum demand is 1 kVA.

(*i*) *When p.f. is unity*

Max. demand charge/unit $= \dfrac{150 \times 100}{8760 \times 0{\cdot}30} = 5{\cdot}7$ paise

Energy charge/unit = 8 paise

Overall cost/unit $= 5{\cdot}7 + 8 =$ **13·7 paise**

(*ii*) *When p.f. is 0·7*

Max. demand charge/unit $= \dfrac{150 \times 100}{8760 \times 0{\cdot}30 \times 0{\cdot}7} = 8{\cdot}15$ paise

Energy charge/unit = 8 paise

Overall cost/unit $= 8{\cdot}15 + 8 =$ **16·15 paise**

Example 5.12. *Two systems of tariff are available for a factory working 8 hours a day for 300 working days in a year.*

(*i*) *High-voltage supply at 5 paise per unit plus Rs 4·50 per month per kVA of maximum demand.*

(*ii*) *Low-voltage supply at Rs 5 per month per kVA of maximum demand plus 5·5 paise per unit.*

The factory has an average load of 200 kW at 0·8 p.f. and a maximum demand of 250 kW at the same p.f. The high voltage equipment costs Rs 50 per kVA and the losses can be taken as 4%. Interest and depreciation charges are 12%. Calculate the difference in the annual costs between the two systems.

Solution.

(*i*) High voltage supply

Max. demand in kVA $= 250/0{\cdot}8 = 312{\cdot}5$

As the losses in *h.v*. equipment are 4%, therefore, capacity of *h.v*. equipment

$= 312{\cdot}5/0{\cdot}96 = 325{\cdot}5$ kVA

Capital investment on *h.v*. equipment

$=$ Rs $50 \times 325{\cdot}5 =$ Rs 16,275

Annual interest and depreciation $=$ Rs $16{,}275 \times 0{\cdot}12 =$ Rs 1953

Annual charge due to maximum kVA demand

$=$ Rs $325{\cdot}5 \times 4{\cdot}5 \times 12 =$ Rs 17,577

Units consumed/year $= \dfrac{200 \times 8 \times 300}{0 \cdot 96} = 5 \times 10^5$ kWh

Annual charge due to kWh consumption

$=$ Rs $0{\cdot}05 \times 5 \times 10^5 =$ Rs 25,000

Total annual cost $=$ Rs $(1953 + 17{,}577 + 25{,}000) =$ Rs 44,530

(*ii*) Low voltage supply. There is no loss of energy as no equipment is used.

Max. demand in kVA $= 250/0{\cdot}8 = 312{\cdot}5$

Annual charge due to maximum kVA demand

$=$ Rs $312{\cdot}5 \times 5 \times 12 =$ Rs 18,750

Units consumed/year $= 200 \times 8 \times 300 = 48 \times 10^4$ kWh

Annual charge due to kWh consumption

$=$ Rs $0{\cdot}055 \times 48 \times 10^4 =$ Rs 26,400

Total annual cost $=$ Rs $(18{,}750 + 26{,}400) =$ Rs 45,150

Difference in the annual costs of two systems

$=$ Rs $(45{,}150 - 44{,}530) =$ **Rs 620**

Hence, high-voltage supply is cheaper than low-voltage supply by Rs 620.

Example 5.13. *A generating station has two 1000 kW diesel-generator sets. The load is estimated to reach a maximum demand of 2500 kW after two years with an increase of 5.5×10^6 units over the present value. To meet this demand, the following two alternatives are available :*

(*i*) *Purchasing one more set of 1000 kW at Rs 400 per kW. The annual interest and depreciation of the new set are 10% of the capital investment. The cost of generation for the station is Rs 75 per kW maximum demand plus 5 paise per kWh.*

(*ii*) *Purchasing bulk power from a grid supply at Rs 120 per kW maximum demand plus 3 paise per kWh.*

Find which alternative in cheaper and by how much ?

Solution.

In order to determine the cheaper alternative, we shall find the annual cost in each case.

(*i*) Purchasing diesel set

Capital cost of set $=$ Rs $400 \times 1000 =$ Rs 4,00,000

Annual interest and depreciation on capital investment

$=$ Rs $4{,}00{,}000 \times 0{\cdot}1 =$ Rs 40,000

The present capacity of the station is 2000 kW and the expected maximum demand after two years is 2500 kW. Therefore, extra power to be generated is

$= 2500 - 2000 = 500$ kW

Annual charge due to extra kW max. demand

$=$ Rs $500 \times 75 =$ Rs 37,500

Annual charge due to extra kWh consumption

$=$ Rs $0{\cdot}05 \times 5{\cdot}5 \times 10^6 =$ Rs 2,75,000

Total annual cost $=$ Rs (40,000 + 37,500 + 2,75,000)

$=$ Rs 3,52,500

(*ii*) Purchasing from grid supply

Annual charge due to extra kW max. demand

$=$ Rs $500 \times 120 =$ Rs 60,000

Annual charge due to extra kWh consumption

$=$ Rs $0{\cdot}03 \times 5{\cdot}5 \times 10^6 =$ Rs 1,65,000

Total annual cost $=$ Rs (60,000 + 1,65,000) = Rs 2,25,000

Hence alternative (*ii*) is cheaper by 3,52,500 – 2,25,000 = **Rs 1,27,500 per annum**

Example 5.14. *A supply company offers the following alternate tariffs for supply to a factory :*

(*i*) *H.V. supply at Rs 70 per kVA per annum plus 3 paise per kWh.*

(*ii*) *L.V. supply at Rs 65 per kVA per annum plus 4 paise per kWh.*

The cost of transformers and switchgears for H.V. supply is Rs 50 per kVA and full transformation losses are 2%. The annual fixed charges on the capital cost of H.V. plant are 15%. If the factory runs for 6 hours a day, find the number of days above which the factory should be run so that the H.V. supply is cheaper.

Solution.

Let $x =$ Factory load in kW

$y =$ No. of working days above which H.V. supply is cheaper

(*i*) H. V. Supply. Assume the power factor of the load to be unity. As the transformation losses are 2%,

∴ Rating of transformer and switchgear $= x/0{\cdot}98$ kVA

Energy consumed per annum $= (x/0{\cdot}98) \times y \times 6 = 6{\cdot}12\,xy$ kWh

Annual fixed charges of H. V. supply due to kVA demand

$=$ Rs $70 \times x/0{\cdot}98 =$ Rs. $71{\cdot}42x$

Cost of transformer and switchgear $=$ Rs $50 \times x/0{\cdot}98 =$ Rs $51x$

Annual fixed charges of transformer and switchgear

$=$ 15% cost of transformer and switchgear

$= 0{\cdot}15 \times 51\,x =$ Rs $7{\cdot}65x$

Total annual fixed charges of H. V. supply $=$ Rs $(71{\cdot}42x + 7{\cdot}65x) =$ Rs $79{\cdot}07x$

Total annual running charges of H. V. supply $=$ Rs $6{\cdot}12xy \times 0{\cdot}03 =$ Rs $0{\cdot}1836xy$

Total annual charges of H.V. supply $= \text{Rs}(79{\cdot}07x + 0{\cdot}1836xy)$ ... (*i*)

(*ii*) L. V. Supply

$$\text{Energy consumed per annum} = x \times y \times 6 = 6xy \text{ kWh}$$

$$\text{Annual fixed charges of L. V. supply} = \text{Rs } 65x$$

$$\text{Annual running charges of L. V. supply} = \text{Rs } 0{\cdot}04 \times 6xy = \text{Rs } 0{\cdot}24xy$$

$$\text{Total annual charges of L. V. supply} = \text{Rs}(65x + 0{\cdot}24xy) \qquad \text{... (ii)}$$

The two tariffs will give equal annual cost if the factory is run for y days. Therefore, equating exp. (*i*) and exp. (*ii*), we get,

$$79{\cdot}07x + 0{\cdot}1836xy = 65x + 0{\cdot}24xy$$

or $$14{\cdot}07x = 0{\cdot}057xy$$

or $$y = \frac{14{\cdot}07}{0{\cdot}057} = \mathbf{247 \text{ days}}$$

i.e., if the factory is run for more than 247 days, then H. V. supply will be cheaper.

TUTORIAL PROBLEMS

1. An industrial consumer has a maximum demand of 120 kW and maintains a load factor of 80%. The tariff in force is Rs. 60 per kVA of maximum demand plus 8 paise per unit. If the average p.f. is 0·8 lagging, calculate the total energy consumed per annum and the annual bill. **[8,40,960 kWh ; Rs 76,276·8]**

2. A customer is offered power at Rs 50 per annum per kVA of maximum demand plus 5 paise per unit. He proposes to install a motor to carry his estimated maximum demand of 300 b.h.p. (metric). The motor available has a power factor of 0·83 at full load. How many units will be required at 30% load factor and what will be the annual bill ? The motor efficiency is 90%. **[6,44,307 ; Rs 46,985·35]**

3. A factory has a maximum load of 300 kW at 0·72 p.f. lagging with an annual consumption of 40,000 units. The tariff in force is Rs 4·5 per kVA of maximum demand plus 2 paise per unit. Calculate the flat rate of energy consumption. What will be the annual saving if p.f. is raised to unity ? **[4·69 paise ; Rs 525]**

4. The monthly readings of a consumer's meter are under ;

Maximum demand = 60 kW

Energy consumed = 24,000 kWh

Reactive energy = 15,600 kVAR

If the tariff is Rs 20 per kW of maximum demand plus 3 paise per unit plus 0·1 paise per unit for each 1% power factor below 85%, calculate the monthly bill of the consumer. **[Rs 1960·4]**

5. Compare the annual cost of power supply to a factory having a maximum demand of 500 kW and a load factor of 40% by having the supply from :

(*i*) the factory's own diesel generating plant.

(*ii*) a public supply.

With regards to (*i*), the capital cost of factory's own generating plant is Rs 8 lakhs, cost of fuel oil is Rs 200 per ton, fuel consumption 0·65 lbs per kWh. Capital charges, cost of repairs and maintenance, interest and depreciation 15% of the total capital cost. Salaries and wages of the operating staff are Rs 15,000 per year.

With regards to (*ii*), the tariff is Rs 150 per kW per annum of maximum demand plus 2·5 paise per kWh.

Which of the two alternatives is favourable for the operation of the factory ?

[(*i*) 13·5 paise/unit (*ii*) 6·8 paise/unit]

6. An industrial load can be supplied from the following alternative tariffs :

(*i*) High voltage supply at Rs 65 per kW per annum plus 3 paise per kWh.

(*ii*) Low voltage supply at Rs 65 per kW per annum plus 3·3 paise per kWh.

The high voltage equipment costs Rs 50 per kW and the losses can be taken as 3%. Interest and depreciation charges are 15% per annum. If there are 40 working weeks in a year, find working hours per week above which high voltage supply is cheaper. **[55·42 hours/week]**

7. A supply company offers the following alternative tariffs :

(*i*) Standing charges of Rs 75 per annum plus 3 paise/kWh.

(*ii*) first 300 kWh at 20 paise/kWh ; and additional energy at 5 paise/kWh.

If the annual consumption is 1800 kWh, which tariff is more economical and by how much ?

[Tariff (*i*) is economical by Rs 6 per annum]

8. A factory has a maximum demand of 500 kW, the load factor being 60% during working hours. The following two tariffs are available :

(*i*) Rs 8 per kW of maximum demand plus 3 paise per kWh.

(*ii*) a flat rate of Re 0·1/kWh.

Determine the working hours per week above which tariff (*i*) will be cheaper. **[44 hours/week]**

SELF-TEST

1. Fill in the blanks by inserting appropriate words/figures :

(*i*) The flat rate for power load is generally .... than the lighting load.

(*ii*) In block rate tariff, the rate of energy in first one or two blocks is ...... because .... charges are merged into ...... charges.

(*iii*) The block rate tariff is mostly applicable to .... consumers.

(*iv*) A big consumer is charged at a lower rate than a small consumer because ......

(*v*) Maximum demand tariff is not applied to domestic consumers because ......

2. Pick up the correct words/figures from brackets and fill in the blanks :

(*i*) A consumer whose load conditions do not deviate from ideal one should be charged at ..... rate than the one whose load conditions change appreciably. (*lower, higher*)

(*ii*) A consumer who consumes more electrical energy should pay ...... fixed charges per unit. (*less, more*)

(*iii*) The ideal tariff for any type of consumer is .... tariff. (*two-part, three-part*)

(*iv*) The maximum kVA demand of the consumer is .... proportional to power factor. (*inversely, directly*)

ANSWERS TO SELF-TEST

1. (*i*) lower (*ii*) high, fixed, running (*iii*) domestic (*iv*) it improves the load factor (*v*) their maximum demand is small.

2. (*i*) lower (*ii*) less (*iii*) three-part (*iv*) inversely.

CHAPTER REVIEW TOPICS

1. What do you understand by tariff ? Discuss the objectives of tariff.

2. Describe the desirable characteristics of a tariff.

3. Describe some of the important types of tariff commonly used.

4. Write short notes on the following :

(*i*) Two-part tariff.

(*ii*) Power factor tariff.

(*iii*) Three-part tariff.

DISCUSSION QUESTIONS

1. Why is tariff for power load less than the lighting load ?

2. What is the effect of power factor on the cost of generation ?

3. Can the load factor of the system be 100% ?

4. What is the importance of power factor tariff ?

GO To FIRST