ATME COLLEGE OF ENGINEERING

13th KM Stone, Bannur Road, Mysore - 570 028

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

NOTES

COURSE TITLE: ELETRICAL POWER GENERATION AND ECONOMICS

COURSE CODE: BEE405A

SEMESTER: IV

MODULE-5: ECONOMICS ASPECTS

Prepared by

Department of EEE,
ATME College of Engineering

INSTITUTIONAL VISION AND MISSION

VISION:

- Development of academically excellent, culturally vibrant, socially responsible and globally competent human resources.

MISSION:

- To keep pace with advancements in knowledge and make the students competitive and capable at the global level.
- To create an environment for the students to acquire the right physical, intellectual, emotional and moral foundations and shine as torchbearers of tomorrow's society.
- To strive to attain ever-higher benchmarks of educational excellence.

Department Vision and Mission

Vision:

To create Electrical & Electronics Engineers who excel to be technically competent and fulfill the cultural and social aspirations of the society.

Mission:

- To provide knowledge to students that builds a strong foundation in the basic principles of electrical engineering, problem solving abilities, analytical skills, soft skills and communication skills for their overall development.
- To offer outcome based technical education.
- To encourage faculty in training & development and to offer consultancy through research & industry interaction.

Program Educational Objectives (PEOs)

PEO1: To produce competent and ethical Electrical and Electronics Engineers who will exhibit the necessary technical and managerial skills to perform their duties in society.

PEO2: To make Graduates continuously acquire and enhance their technical and socio-economic skills.

PEO3: To aspire Graduates on R&D activities leading to offering solutions and excel in various career paths.

PEO4: To produce quality engineers who have the capability to work in teams and contribute to real time projects.

Program Outcomes (POs)

Engineering Graduates will be able to:

PO1: Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems.

PO2: Problem Analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3: Design / Development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: Individual and team work: Function effectively as an individual and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11: Project management and finance: Demonstrate knowledge and understanding of the engineering management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12: Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change.

Program Specific Outcomes (PSOs)

The students will develop an ability to produce the following engineering traits:

PSO1: Apply the concepts of Electrical & Electronics Engineering to evaluate the performance of power systems and also to control industrial drives using power electronics

PSO2: Demonstrate the concepts of process control for Industrial Automation, design models for environmental and social concerns and also exhibit continuous self- learning

Module- 5 Economic Aspects

Structure

5.0. Introduction

A power station is required to deliver power to a large number of consumers to meet their requirements. While designing and building a power station, efforts should be made to achieve overall economy so that the per unit cost of production is as low as possible.

This will enable the electric supply company to sell electrical energy at a profit and ensure reliable service.

The problem of determining the cost of production of electrical energy is highly complex and poses a challenge to power engineers.

There are several factors which influence the production cost such as cost of land and equipment, depreciation of equipment, interest on capital investment etc. Therefore, a careful study has to be made to calculate the cost of production.

5.1 Objective

Explain the economics of power generation and importance of power factor.

5.1.1 Importance of Economic Aspects

- Interest

The cost of use of money is known as Interest. A power station is constructed by investing a huge capital. This money is generally borrowed from banks or other financial institutions and the supply company has to pay the annual interest on this amount.

Even if company has spent out of its reserve funds, the interest must be still allowed for, since this amount could have earned interest if deposited in a bank.

- **Depreciation**

The decrease in the value of the power plant equipment and building due to constant use is known as Depreciation.

From the time the power station is installed, its equipment steadily deteriorates due to wear and tear so that there is a gradual reduction in the value of the plant.

This reduction in the value of plant every year is known as annual depreciation.

Due to depreciation, the plant has to be replaced by the new one after its useful life. Therefore, suitable amount must be set aside every year so that by the time the plant retires, the collected amount by way of depreciation equals the cost of replacement.

5. 2. Cost of Electrical Energy

The total cost of electrical energy generated can be divided into three parts, namely:

1. Fixed cost 2. Semi-fixed cost 3. Running or operating cost

5. 2.1 Fixed cost: It is the cost which is independent of maximum demand and units generated.

The fixed cost is due to the annual cost of central organization, interest on capital cost of land and salaries of high officials.

The annual expenditure on the central organization and salaries of high officials is fixed since it has to be met whether the plant has high or low maximum demand or it generates less or more units.

Further, the capital investment on the land is fixed and hence the amount of interest is also fixed.

5.2.2 Semi-fixed cost:

It is the cost which depends upon maximum demand but is independent of units generated. The semi-fixed cost is directly proportional to the maximum demand on power station and is on account of annual interest and depreciation on capital investment of building and equipment, taxes, salaries of management and clerical staff.

The maximum demand on the power station determines its size and cost of installation. The greater the maximum demand on a power station, the greater is its size and cost of installation.

Further, the taxes and clerical staff depend upon the size of the plant and hence upon maximum demand.

5.2.3 Running cost:

It is the cost which depends only upon the number of units generated. The running cost is on account of annual cost of fuel, lubricating oil, maintenance, repairs and salaries of operating staff.

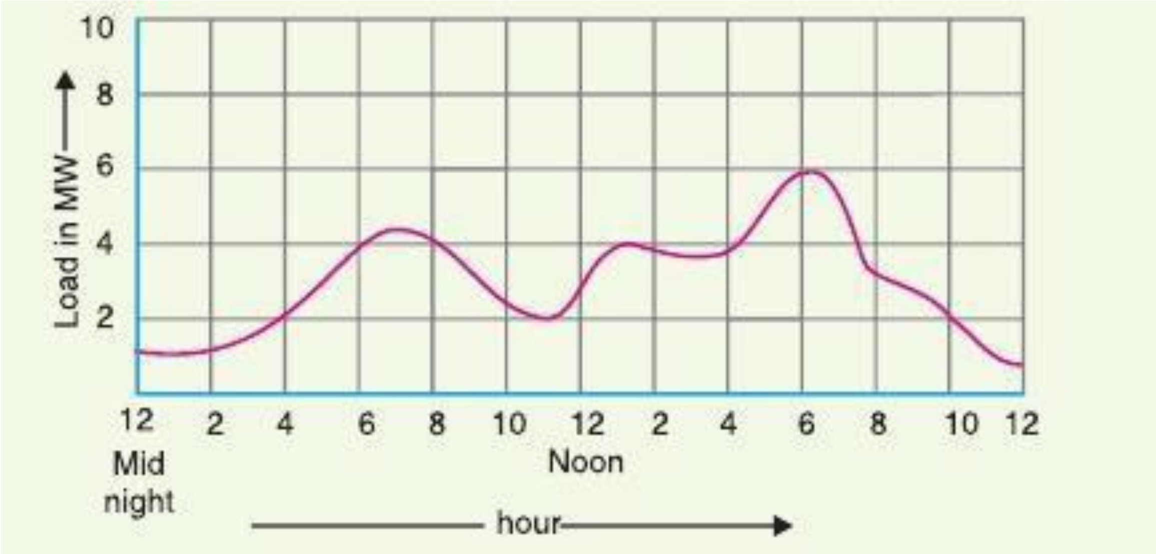
Since these charges depend upon the energy output, the running cost is directly proportional to the number of units generated by the station.

In other words, if the power station generates more units, it will have higher running cost and vice-versa.

5.3. Load Curves

The curve showing the variation of load on the power station with respect to time is known as a load curve.

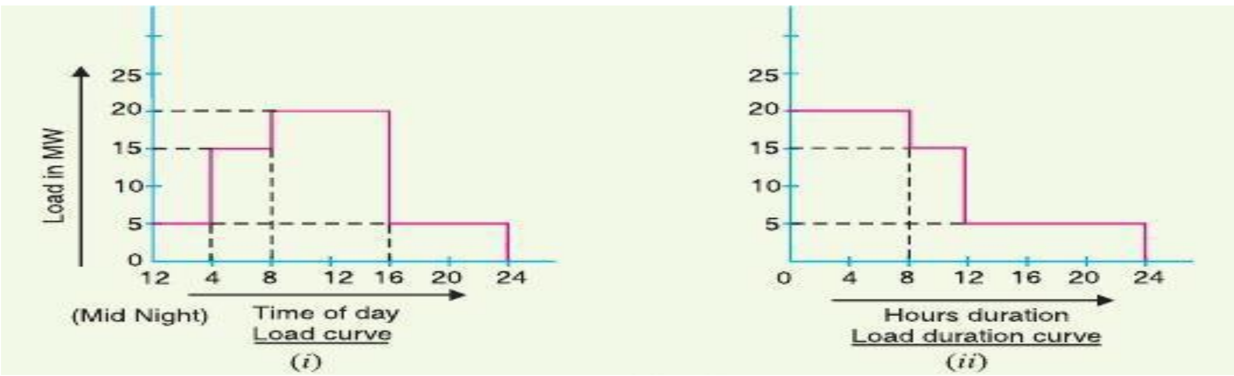
The load on a power station is never constant; it varies from time to time. These load variations during the whole day (i.e., 24 hours) are recorded half-hourly or hourly and are plotted against time on the graph. The curve thus obtained is known as daily load curve as it shows the variations of load w.r.t. time during the day.



Important Points

- The daily load curves have attained a great importance in generation as they supply the following information readily.
- The daily load curve shows the variations of load on the power station during different hours of the day.
- The area under the daily load curve gives the number of units generated in the day. Units generated/day = Area (in kWh) under daily load curve.
- The highest point on the daily load curve represents the maximum demand on the station on that day.
- The area under the daily load curve divided by the total number of hours gives the average load on the station in the day
- The ratio of the area under the load curve to the total area of rectangle in which it is contained gives the load factor.
- The load curve helps in preparing the operation schedule of the station.
- The load curve helps in selecting the size and number of generating units.
- The load curve helps in preparing the operation schedule of the station

5. 4. Load Duration curve



When the load elements of a load curve are arranged in the order of descending magnitudes, the curve thus obtained is called a load duration curve.

The load duration curve is obtained from the same data as the load curve but the ordinates are arranged in the order of descending magnitudes.

In other words, the maximum load is represented to the left and decreasing loads are represented to the right in the descending order.

Hence the area under the load duration curve and the area under the load curve are equal.

5. 5. Important terms and factors:

The variable load problem has introduced the following terms and factors in power plant engineering:

5.5.1. Connected load: It is the sum of continuous ratings of all the equipments connected to supply system. A power station supplies load to thousands of consumers. Each consumer has certain equipment installed in his premises. The sum of the continuous ratings of all the equipments in the consumer‛s premises is the ―connected load‖ of the consumer. For instance, if a consumer has connections of five100-watt lamps and a power point of 500 watts, then connected load of the consumer is 5×100 + 500= 1000 watts. The sum of the connected loads of all the consumers is the connected load to the power station.

5.5. **2. Maximum demand:**

It is the greatest demand of load on the power station during a given period. The load on the power station varies from time to time. The maximum of all the demands that have occurred during a given period (say a day) is the maximum demand.to the load curve of Fig. 3.2, the maximum demand on the power station during the day is 6 MW and it occurs at 6 P.M. Maximum demand is generally less than the connected load because all the consumers do not switch on their connected load to the system at a time.

5. 5.3. Demand factor: It is the ratio of maximum demand on the power station to its connected load i.e. Demand factor=Maximum demand /Connected load The value of demand factor is usually less than 1. It is expected because maximum demand on the power station is generally less than the connected load. If the maximum demand on the power station is 80 MW and the connected load is 100 MW, then demand factor = 80/100 = 0·8. The knowledge of demand factor is vital in determining the capacity of the plant equipment.

5. 5.4. Average load: The average of loads occurring on the power station in a given period (day or month or year) is known as average load or average demand

5. 5.**5. Load factor:** The ratio of average load to the maximum demand during a given period is known as Load factor. The load factor may be daily load factor, monthly load factor or

annual load factor if the time period considered is a day or month or year. Load factor is always less than 1 because average load is smaller than the maximum demand.

5. 5. **6. Diversity factor:** The ratio of the sum of individual maximum demands to the maximum demand on power station is known as diversity factor A power station supplies load to various types of consumers whose maximum demands generally do not occur at the same time.

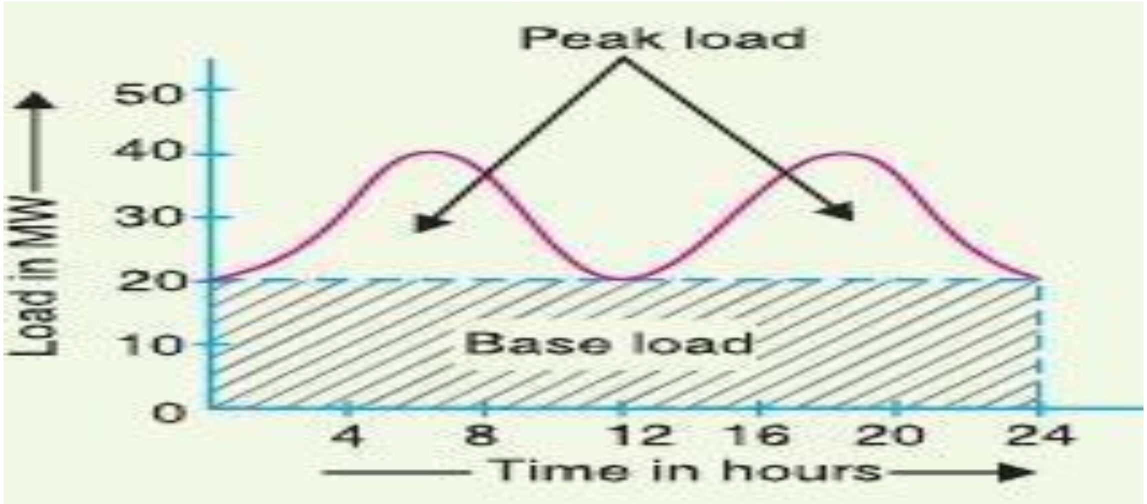
5. 5.7. Plant capacity factor: It is the ratio of actual energy produced to the maximum possible energy that could have been produced during a given period The plant capacity factor is an indication of the reserve capacity of the plant

5. 5.8. Plant use factor: It is ratio of kWh generated to the product of plant capacity and the number of hours for which the plant was in operation i.e. Plant use factor=Station output in kWh/Plant capacity X Hours fuse.

5. 6. Base Load and peak Load:

The changing load on the power station makes its load curve of variable nature. Figure shows the typical load curve of a power station. It is clear that load on the power station varies from time to time. However, a close look at the load curve reveals that load on the power station can be considered in two parts, namely;

1. Base load
2. Peak load



5.6.1 Base Load: The unvarying load which occurs almost the whole day on the station is known as Base load. Referring to the load curve of Figure, it is clear that 20 MW of load has to be supplied by the station at all times of day and night i.e. through out 24 hours. Therefore, 20 MW is the base load of the station. As base load on the station is almost of constant nature, therefore, it can be suitably supplied without facing the problems of variable load.

5. 6.2 Peak load: The various peak demands of load over and above the base load of the station is known as ***peak load***. Referring to the load curve of Figure. it is clear that there are peak demands of load excluding base load. These peak demands of the station generally form a small part of the total load and may occur throughout the day.

5.7 Power Factor Improvement & Tariffs

Introduction: The electrical energy is almost exclusively generated, transmitted and distributed in the form of alternating current. Therefore, the question of power factor immediately comes into picture. Most of the loads (e.g. 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 sys-tem from power station generator down to the utilization devices.

Power Factor:

The cosine of angle between voltage and current in an a.c. circuit is known as power factor.

In an a.c. circuit, there is generally a phase difference φ between voltage and current. The term cosφ is called the power factor of the circuit. 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 volt-age and power factor is said to be leading. Consider an inductive circuit taking a lagging current I from supply voltage V, the angle of lag being φ. The phasor diagram of the circuit is shown in Fig.1. The circuit current I can be resolved into two perpendicular components, namely:

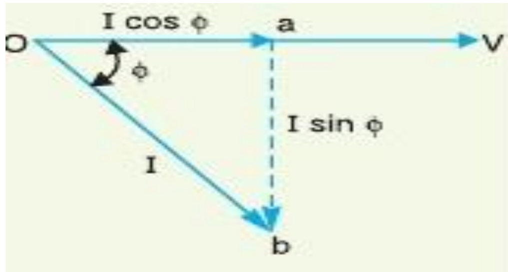


Fig.1

1. I cosφ in phase with V.

2. I sinφ90oout of phase with V.

The component I cosφ is known as active or wattful component, whereas component I sinφ is called the reactive or watt less component. The reactive component is a measure of the power factor. If the reactive component is small, the phase angle φ is small and hence power factor cosφ will be high. Therefore, a circuit having small reactive current (i.e., Isinφ) 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 lags or leads the voltage. Thus if the circuit has a p.f. of 0·5 and the current lags the voltage, we generally write p.f. as 0·5 lagging.
ii) Sometimes power factor is expressed as a percentage. Thus 0·8 lagging power factor maybe expressed as 80% lagging.

5.8 Power Triangle:

The analysis of power factor can also be made in terms of power drawn by the a.c. circuit. If each side of the current triangle oab of Fig. 6.1 is multiplied by voltage V, then we get the power triangle OAB shown in Fig. 1
where OA=VI cosφ and represents the active power in watts or
kW. AB =VI sinφ and represents the reactive power.
OB=VI and represents the apparent power.

The following points may be noted form the power triangle.

1. The apparent power in an a.c. circuit has two components viz., active and reactive power at right angles to each other. $OB^2=OA^2+AB^2$

2. Power factor, $\cos\varphi=OA/OB=$ active power/apparent power=kW/kVA.

3. The lagging reactive power is responsible for the low power factor. It is clear from the power triangle that smaller the reactive power component, the higher is the power factor of the circuit. $KVAR=KW\tan\varphi$

4. The power factor of a circuit can be defined in one of the following three ways:
   a) Power factor= R/Z= Resistance/ Impedance.
   b) Power factor= $VI\cos\varphi/VI$= Active power/ Apparent power

The reactive power is neither consumed in the circuit nor it does any useful work. It merely flows back and forth in both directions in the circuit. A wattmeter does not measure reactive power.

5.9 Disadvantages of Low Power Factor:

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

$$P=V_L \quad I_L \quad \cos\varphi$$

$$I_L=P/ V_L \cos\varphi$$

$$P=\sqrt{3}\, V_L I_L \cos\varphi$$

$$I_L=P/\sqrt{3}\, V_L \cos\varphi$$

It is clear 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 results in the following disadvantages:

a) Large kVA rating of equipment:

The electrical machinery (e.g., alternators, transformers, switchgear) is always rated in kVA. Now, kVA= kW/Cosφ 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 thee equipment has to be made more, making the equipment larger and expensive.

b) 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.

For example: take the case of a single phase a.c. motor having an input of 10 kW on full load, the

terminal voltage being 250 V. At unity p.f., the input full load current would be 10,000/250 = 40 A. At 0·8 p.f; the kVA input would be 10/0·8 = 12·5 and the current input 12,500/250 = 50 A. If the motor is worked at a low power factor of 0·8, the cross-sectional area of the supply cables and motor conductors would have to be based upon a current of 50 A instead of 40 A which would be required at unity power factor.

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

d) Poor voltage regulation: The large current at low lagging power factor causes greater voltage drops in alternators, transformers, transmission lines and distributors. This results in the decreased voltage available at the supply end, thus impairing the performance of utilization devices. In order to keep the receiving end voltage within permissible limits, extra equipment (i.e., voltage regulators) is required.

e) Reduced handling capacity of system: The lagging power factor reduces the handling capacity of all the elements of the system. It is because the reactive component of current prevents the full utilization of installed capacity.

5.9.1 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 in lower than 0·8. The following are the causes of low power factor.

a) Most of the a.c. motors are of induction type (1φand 3φinduction motors) which have low lagging power factor. These motors work at a power factor which is extremely small on light load (0·2 to 0·3) and rises to 0·8 or 0·9 at full load.

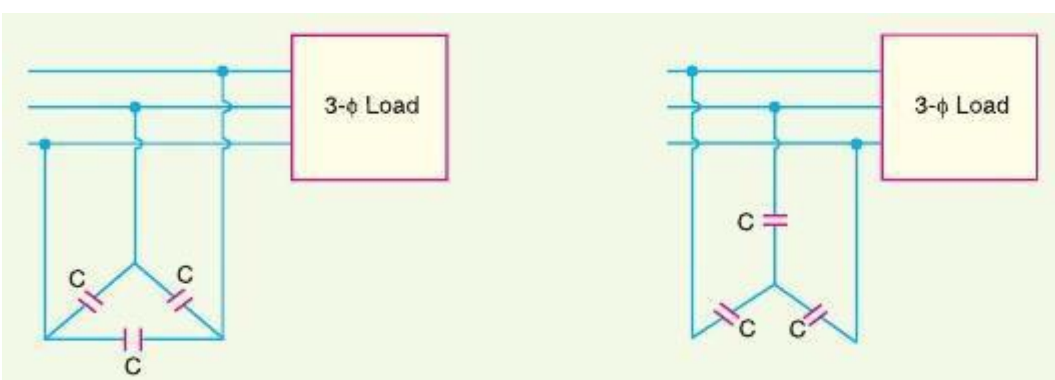
b) Arc lamps, electric discharge lamps and industrial heating furnaces operate at low lagging power factor.

c) The load on the power system is varying being high during morning and evening and low at other times. During low load period, supply voltage is increased which increases the magnetization current. This results in the decreased power factor.

5.9.2 Power Factor Improvement Equipment:

Normally, the power factor of the whole load on a large generating station is in the region of 0·8 to0·9. 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:

1. Static capacitors.
2. Synchronous condenser.
3. Phase advancers



1. Static capacitor: The power factor can be improved by connecting capacitors in parallel with the equipment operating at lagging power factor. The capacitor (generally known as static 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. For three-phase loads, the capacitors can be connected in delta or star as shown in Fig. 6.4. Static capacitors are invariably used for power factor improvement in factories.

Advantages:

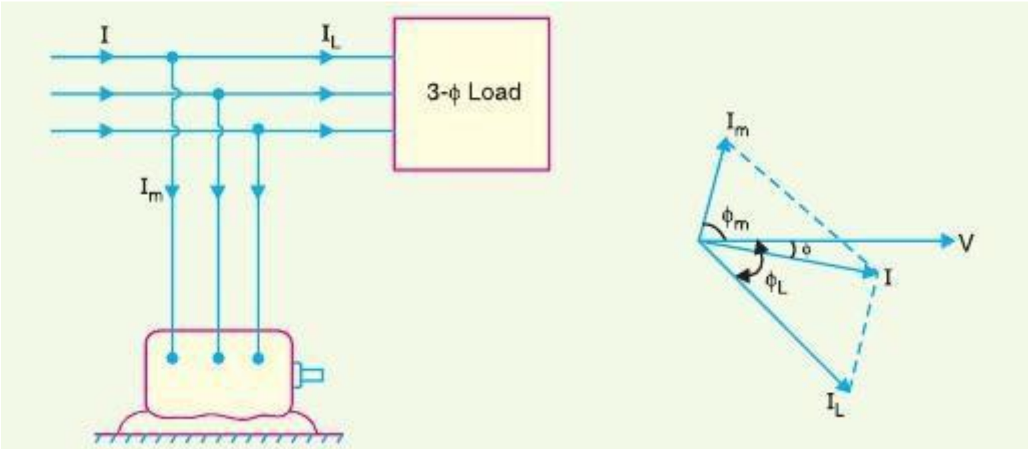
1. They have low losses.
2. They require little maintenance as there are no rotating parts.
3. They can be easily installed as they are light and require no foundation.
4. They can work under ordinary atmospheric conditions.

Disadvantages:

1. They have short service life ranging from 8 to 10 years.
2. They are easily damaged if the voltage exceeds the rated value.
3. Once the capacitors are damaged, their repair is uneconomical.

2. Synchronous condenser: A synchronous motor takes a leading current when over-excited and, therefore, behaves 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 shows the power factor improvement by synchronous condenser method. The 3φload takes current I_L at low lagging power factor $\cos\varphi_L$. The synchronous condenser takes a current I_m which leads the voltage by an angle φ_m. The resultant current I is the phasor sum of I_m and I_L and lags behind the voltage by an angle φ. It is clear that φ is less than φ_L so that cosφ is greater than $\cos\varphi_L$. Thus the power factor is increased from $\cos\varphi_L$ to cosφ. Synchronous condensers are generally used at major bulk supply substations for power factor improvement.



Advantages:

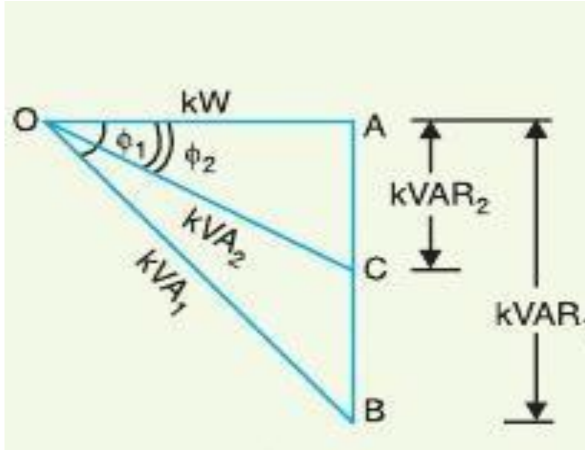
1. By varying the field excitation, the magnitude of current drawn by the motor can be changed by any amount. This helps in achieving step less control of power factor.
2. The motor windings have high thermal stability to short circuit currents.
3. The faults can be removed easily.

Disadvantages:

1. There are considerable losses in the motor.
2. The maintenance cost is high. 3. It produces noise.

4. Except in sizes above 500 kVA, the cost is greater than that of static capacitors of the same rating.

4. As a synchronous motor has no self-starting torque, therefore, auxiliary equipment has to be provided for this purpose.



5.9.3 Phase advancers:

Phase advancers are used to improve the power factor of induction motors. The low power factor of an induction motor is due to the fact that its stator winding draws exciting current which lags be-hind the supply voltage by 90o. If the exciting ampere turns can be provided from some other a.c. source, then the stator winding will be relieved of exciting current and 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 circuit 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 sup-plied 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.

5.9.4 Power Triangle:

The power factor correction can also be illustrated from power triangle. Thus referring to Fig.the power triangle OAB is for the power factor cosφ1, whereas power triangle OAC is for the improved power factor cosφ2. It may be seen that active power (OA) does not change with power factor improvement. However, the lagging kVAR of the load is reduced by the p.f. correction equipment, thus improving the p.f. to cosφ2.Leading kVAR supplied by p.f. correction equipment

$= BC = AB - AC$

$= kVAR_1 - kVAR_2$

$= OA (\tan\varphi_1 - \tan\varphi_2)$

$= kW (\tan\varphi_1 - \tan\varphi_2)$

Knowing the leading kVAR supplied by the p.f. correction equipment, the desired results can be obtained. The electrical energy produced by a power station is delivered to a large number of consumers.

5. 10. Tariff

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.

5.10.1 Objectives of tariff:

1.Recovery of cost of producing electrical energy at the power station.

2. Recovery of cost on the capital investment in transmission and distribution systems.

3. Recovery of cost of operation and maintenance of supply of electrical energy e.g., metering equipment, billing etc.

4. A suitable profit on the capital investment

5.10.2 Types of Tariff:

1. Simple tariff: When there is a fixed rate per unit of energy consumed, it is called a Simple tariff .In this type of tariff, the price charged per unit is constant i.e. it does not vary within crease or decrease in number of units consumed.

Disadvantages:

1. There is no discrimination between different types of consumers

2. The cost per unit delivered is high.

3. 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.. 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 fairer to different types of consumers and is quite simple in calculations.

Disadvantages:

1, separate meters are required for lighting load, power load etc. This makes the application of such a tariff expensive and complicated.

2. A particular class of consumers is charged at the same rate irrespective of the magnitude of energy consumed.

3. Block rate tariff:

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:

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 depen 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. Total charges=Rs($b \times$ kW + $c \times$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:

1. It is easily understood by the consumers.

2. It recovers the fixed charges which depend upon the maximum demand of the consumer

but are independent of the units consumed.

Disadvantages:

1. The consumer has to pay the fixed charges irrespective of the fact whether he has consumed or not consumed the electrical energy.
2. 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.

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.

1. **KVA 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.
2. **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 reference.
3. **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.
4. **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+b ×kW +c×kWh) Where, a=fixed charge made during each billing period. It includes interest and depreciation on the cost of secondary distribution and labor cost of collecting revenues, b=charge per kW of maximum demand, c=charge per kWh of energy consumed. It may be seen that by adding fixed charge or consumer‘s charge 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.

5.11. Outcome

- Understand the economic aspects of power system operation and its effects.
- Explain the importance of power factor improvement.

5.12. Further Readings

- http://www.nptel.ac.in/courses/Webcourse-contents/IIT-KANPUR/power system/nptel/module2/chap5.pdf