3.1 SYLLABUS

EE2303   TRANSMISSION AND DISTRIBUTION   **3 1 0 4**

1. INTRODUCTION   9

Structure of electric power system - different operating voltages of generation, transmission and distribution – advantage of higher operating voltage for AC transmission. An introduction to EHV AC transmission, HVDC transmission and FACTs. Mechanical design of transmission line between towers – sag and tension calculations using approximate equations taking into account the effect of ice and wind.

2. TRANSMISSION LINE PARAMETERS   9

Parameters of resistance, inductance and capacitance calculations - single and three phase transmission lines - single and double circuits - solid, stranded and bundled conductors - symmetrical and unsymmetrical spacing – transposition of lines - concepts of GMR and GMD - skin and proximity effects - interference with neighboring communication circuits. Corona discharge characteristics – critical voltage and loss. (Simple diagrams of typical towers and conductors for 400, 220 and 110 kV operations)

3. MODELLING AND PERFORMANCE OF TRANSMISSION LINES   9

Transmission line classification - short line, medium line and long line - equivalent circuits – Ferranti effect - surge impedance, attenuation constant and phase constant - voltage regulation and transmission efficiency - real and reactive power flow in lines – power circle diagrams – shunt and series compensation. an introduction to power angle diagram - surge-impedance loading, load ability limits based on thermal loading; angle and voltage stability considerations.

4. INSULATORS AND CABLES   9

Classification of insulators for transmission and distribution purpose – voltage distribution in insulator string and grading - improvement of string efficiency. Underground cables - constructional features of LT and HT cables – insulation resistance, capacitance, dielectric stress and grading – tan   and power loss - thermal characteristics.

5. SUBSTATION, GROUNDING SYSTEM AND DISTRIBUTION SYSTEM   9

Classification, functions and major components of substations.   Bus-bar arrangements - substation bus schemes - single bus, double bus with double breaker, double bus with single breaker, main and transfer bus, ring bus, breaker-and-a-half with two main buses, double bus-bar with bypass isolators. Importance of earthing in a substation. Qualitative treatment to neutral grounding and earthing practices in substations. Feeders, distributors and service mains. DC distributor – 2-wire and 3-wire, radial and ring main distribution. AC distribution – single phase and three phase 4-wire distribution. .

TOTAL : 45 PERIODS

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TEXT BOOKS

1. B.R.Gupta, 'Power System Analysis and Design', S. Chand, New Delhi, 2003.
2. S.N. Singh, 'Electric Power Generation, Transmission and Distribution', Prentice Hall of India Pvt. Ltd, New Delhi, 2002.

REFERENCE BOOKS

1. Luces M. Fualkenberry, Walter Coffer, 'Electrical Power Distribution and Transmission', Pearson Education, 1996.
2. Hadi Saadat, 'Power System Analysis,' Tata McGraw Hill Publishing Company', 2003.
3. Central Electricity Authority (CEA), 'Guidelines for Transmission System Planning', New Delhi.
4. 'Tamil Nadu Electricity Board Handbook', 2003.

3.2 SHORT QUESTIONS AND ANSWERS

UNIT 1
INTRODUCTION

1. **Why all transmission and distribution systems are 3 phase systems?**

A 3 phase a.c circuit using the same size conductors as the single phase circuit can carry three times the power which can be carried by a 1 phase circuit and uses 3 conductors for the 2 phases and one conductor for the neutral. Thus a 3 phase circuit is more economical than a 1 phase circuit in terms of initial cost as well as the losses. Therefore all transmission and distribution systems are 3 phase systems.

2. **Why the transmission systems are mostly overhead systems?**

Because of the cost consideration, the transmission systems are mostly overhead systems.

3. **Why all overhead lines use ACSR conductors?**

ACSR conductors comprises of hard drawn aluminium wires stranded around a core of single or multiple strand galvanized steel wire. They provides the , necessary conductivity while the steel provides the necessary mechanical strength. Has less corona loss. The breaking load is high and has less weight.

4. **Why transmission lines are 3 phase 3 wire circuits while distribution lines are 3 phase 4 wire circuits?**

A Balanced 3 phase circuit does not require the neutral conductor, as the instantaneous sum of the 3 line currents are zero. Therefore the transmission lines and feeders are 3 phase 3 wire circuits. The distributors are 3 phase 4 wire circuits because a neutral wire is necessary to supply the 1 phase loads of domestic and commercial consumers.

5. **Why overhead line conductors are invariably stranded?**

They are stranded to make them flexible during erection and while in service.

6. **State the advantages of interconnected systems.**

Any area fed from one generating station during overload hours can be fed from another power station and thus reserved capacity required is reduced, reliability of supply is increased and efficiency is increased.

7. **What is a ring distributor?**

A ring distributor is a distributor which is arranged to form a closed circuit and is fed at one or more than one point.

8. **State any two advantages of ring main system**.

Less voltage fluctuations at consumer's terminals. Less copper is required as each part of the ring carries less current than in radial system.

9. Mention the disadvantages of a 3 wire system

In 3 wire system a third wire is required. The safety is partially reduced. A balancer is required and therefore cost is increased.

10. What are the advantages of a 3 wire dc distribution system over a 2 wire dc distribution system?

If 3 wire system is used to transmit the same amount of power over the same distance with same efficiency with same consumer voltage we require 0.3125 times copper as required in 2 wire system.

11. State kelvin's law.

The annual expenditure on the variable part of the transmission system should be equal to the annual cost of energy wasted in the conductor used in that system.

12. State any two limitations of kelvin's law.

It is difficult to estimate accurately the annual charge on the capital outlay. It does not give the exact economical size of the conductor.

13. Define resistance of the transmission line.

It is defined as the loop resistance per unit length of the line in a single phase system. In 3 phase system it is defined as the resistance per phase.

14. What are the advantages of high voltage ac transmission.

The power can be generated at high voltages.
The maintenance of ac substation is easy and cheaper.

15. Mention the disadvantages of high voltage ac transmission.

An ac line requires more copper than a dc line.
The construction of an ac line is more complicated than a dc transmission line.
Due to skin effect in the ac system the effective resistance of the line is increased.

16. Mention the limitations of using very high transmission voltage.

The increased cost of insulating the conductor.
The increased cost of transformers, switch gears and other terminal apparatus.

17. Mention the terminal equipments necessary in HVDC system.

Converters, mercury arc valves and thyristors.
Due to absence of charging currents.

18. **Mention the equipments that supply reactive power in HVDC converter stations ?**

> AC filters
> Static shunt capacitors
> Synchronous condensers
> StaticVAR compensators .

19. **Why dc transmission is economical and preferable over ac transmission for large distances only ?**

Because with larger distances ,the saving in cost of dc overhead lines become greater than the additional expenditure on terminal equipment .

UNIT 2
TRANSMISSION LINE PARAMETERS

1.Define inductance of a line.

It is defined as the loop inductance per unit length of the line .Its unit is henrys per meter.

2.Define capacitance of a line.

It is defined as shunt capacitance between the two wires per unit line length. Its unit is farads per meter.

3.What is skin effect?

The steady current when flowing through the conductor ,does not distribute uniformly, rather it has the tendency to concentrate near the surface of the conductor. This phenomenon is called skin effect.

4.Why skin effect is absent in dc system?

The steady current when flowing through a conductor distributes itself uniformly over the whole cross section of the conductor .That is why skin effect is absent in dc system.

5.What is the effect of skin effect on the resistance of the line?

Due to skin effect the effective area of cross section of the conductor through which current flow is reduced. Hence the resistance of the line is increased when ac current is flowing.

6.On what factors the skin effect depend?

Nature of the material, Diameter of the wire , Frequency and shape of the wire.

7.Define symmetrical spacing.

In 3 phase system when the line conductors are equidistant from each other then it is called symmetrical spacing.

8.What is the necessity for a double circuit line?

To reduce the inductance per phase and to increase the efficiency.

9.Mention the factors governing the inductance of a line.

Radius of the conductor and the spacing between the conductors.

10. Define a neutral plane.

It is a plane where electric field intensity and potential is zero.

11. Define proximity effect.

The alternating magnetic flux in a conductor caused by the current flowing in a neighbouring conductor gives rise to a circulating current which cause an apparent increase in the resistance of the conductor .This phenomenon is called as proximity effect

12. What is the effect of proximity effect?

It results in the non uniform distribution of current in the cross section, and the increase of resistance.

13. What is a composite conductor?

A conductor which operates at high voltages and composed of 2 or more sub conductors and run electrically in parallel are called composite conductors.

14. What is a bundle conductor?

It is a conductor made up of 2 or more sub conductors and is used as one phase conductors.

15. Mention the advantages of using bundled conductors.

Reduced reactance, reduced voltage gradient , reduced corona loss .reduced Interference

16. What is meant by transposition of line conductors?

Transposition means changing the positions of the three phases on the line supports twice over the total length of the line .the line conductors in practice ,are so transposed that each of the three possible arrangements of conductors exit for one-third of the total length of the line .

17. Define bundled conductors?

The use of more than one conductor per phase is called bundled conductors.

18. What is skin effect?

The phenomenon of concentration of an ac current near the surface of the conductor is known as skin effect.

19. On what factors does the skin effect depends?

The skin effect depends upon the
1, type of the material
2, frequency of the current
3, diameter of conductor& shape of conductor.
It increases with the increase of cross-section, permeability and supply frequency.

20. Define voltage regulation.

Voltage regulation is defined as the change in voltage at the receiving (or load) end when the full-load is thrown off, the sending-end (or supply) voltage and supply frequency remaining unchanged..

% voltage regulation= ((Vs-Vr)/Vr)*100
where Vs is the voltage at the sending end
Vr is the receiving end voltage.

UNIT 3
MODELLING AND PERFORMANCE OF TRANSMISSION LINES

1.What is corona?

The phenomenon of violet glow, hissing noise and production o ozone gas in an overhead line is called corona.

2.Mention the factors affecting corona.

Atmosphere, conductor size, spacing between conductors and line voltage.

3.Define critical disruptive voltage.

It is defined as the minimum phase voltage at which corona occurs.

4.Define visual critical voltage.

It is the minimum phase voltage at which corona appears all along the line conductors.

5.State any two merits of corona.

Reduces the effects of transients produced by surges .System performance is improved.

6.Give the two demerits of corona.

The transmission efficiency is affected. Corrosion occurs.

7.Mention the methods of reducing corona effect.

By increasing the conductor size and conductor spacing.

8.Why ACSR conductors are used in lines?

If the size of the conductor is larger corona effects are reduced and reduces the proximity effect .Hence they are used in lines.

9.Define medium lines.

Lines having length between 60 and 150 km and line voltages between 20 and 100kv are called medium lines.

10. Define short lines.

Lines having lengths below 60km and voltages below 20kv are called short lines.

11. Mention the limitations of end condenser method.

This over estimates the effects of line capacitance .It is assumed to be lumped or concentrated.

12. Explain the term voltage stability.

The ability of the system to maintain the voltage level within its acceptable limits is called as voltage stability.

13. **Differentiate between voltage stability and rotor angle stability. Voltage stability:**

-It means load stability.
-It is mainly related to reactive power transfer.
-Here problems arise mainly in the event of faults.
Rotor angle stability:
-It means basically generator stability.
-It is mainly interlinked to real power transfer.
-Here problems arise during and after faults.

14. Mention the significance of Surge impedance loading.

--The voltage and current are equal and are in phase at all points along the line.
--No reactive power is generated or absorbed at the line ends.

15. What is shunt compensation ?

Shunt compensation is the use of shunt capacitors and shunt reactors is the line to avoid voltage instability.

16. Define a synchronous compensator (condenser)?

Synchronous compensator is a synchronous motor with no mechanical output. When it is under exited it operates at lagging p.f (ie it delivers vars) .Thus it operates both as a shunt capacitor and as a shunt reactor .

17. Mention any two advantages of series compensation

-improves system stability .
-are generally self regulatory and requires little or no control equipment

18. Mention any two advantages of SVS .(Static Var System)

Provides fast control over temporary over voltages.
Provides a better control of voltage profile .

19. State any two comparisons between series compensation and shunt compensation.

-Series compensation is cheaper than SVS .
-Losses are lower than in SVS .

20. Why series compensation is used in long series ?

-to increase transmission capacity
-to improve system stability .
-to obtain correct load division between parallel circuits .

UNIT 4
INSULATORS AND CABLES

1.Why cables are not used for long distance transmission?

Cables are not used for long distance transmissions due to their large charging currents.

2.Mention the 3 main parts of the cable?

Conductor ,dielectric ,sheath

3.What is the function of conductor?

Conductor provides the conducting path for the current.

4.What is the purpose of insulation in a cable?

The insulation or dielectric withstands the service voltage and isolates the conductor with other objects.

5.What is the function of sheath in a cables?

The sheath does not allow the moisture to enter and protects the cable from all external influences like chemical or electrochemical attack fire etc.

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6.Mention the conductor materials in cables?

Copper , Aluminium

7.What is the purpose of stranding of conductors?

Stranding increases the resistance of the cable .It has flexibility.

8.Define the segmental conductors.

The stranded wires which are compacted by the rollers to minimize the air spaces between the individual wires are called segmented conductors .Here the conductor size is reduced for a given conductance.

9.State the properties of insulating materials.

It should have high insulation resistance ,high dielectric strength ,good mechanical properties ,non-hygroscopic, capable of being operated at high temperatures ,low thermal resistance and low power factor.

10. Mention the commonly used power cables.

Impregnated paper, Polyvinyl chloride, polyethene

11. Mention the advantages of pvc over paper insulated cables.

Reduced cost and weight, Insulation is resistant to water, Simplified jointing, Increased flexibility No plumbing required.

12. State the merits of paper insulated cables.

High current carrying capacity ,long life and greater reliability

13. State the advantages of polythene insulators.

They are non-hygroscopic, light in weight, low dielectric constant, low loss factor and low thermal resistance.

14. By what materials cable sheaths are made?

Lead sheaths and Aluminium sheaths.

15. In what way Al sheaths are superior to lead sheaths?

Al sheaths are smaller in weight, high mechanical strength , greater conducyivity, cheap,easy to manufacture and install, withstand the required gas pressure without reinforcement.

16. Where CSA sheath is used in cables ?

Corrugated seamless aluminium sheath is used in high voltage oil filled cables and telephone lines.

17. Why it is used?

It is used because it is very flexible and easily by repeated bending the sheath is not distorted and it is not damaged. It has lesser weight and reduced thickness.

18. Why protective covering is done in cables?

To protect the cables from mechanical damage , corrosion and electrolytic action when laid direct in the ground the protective covering is made.

19. By what material protective covering is made?

Bitumen &Bituminized materials, pvc and layers of fibrous materials.

20. What is meant by serving of a cable?

Layers of fibrous material permitted with waterproof compound applied to the exterior of the cable is called serving of a cable. pressure cables.

UNIT 5
SUBSTATION, GROUNDING SYSTEM AND DISTRIBUTION SYSTEM

1. Define sag of a line.

The difference in level between the points of supports and the lowest point of the conductor is called as sag.

2.Mention the factors that affect sag in the transmission line.

Weight of the conductor, length of the span , working tensile strength and the temperature.

3. What is the reason for the sag in the transmission line?

While erecting the line , if the conductors are stretched too much between supports then there prevails an excessive tension on the line which may break the conductor. In order to have safe tension in the conductor a sag in the line is allowed.

4. How the capacitance effect is taken into account in a long line?

They have sufficient length and operate at voltage higher than 100 kv the effects of capacitance cannot be neglected. Therefore in order to obtain reasonable accuracy in long lines , the capacitance effects are taken.

5. Mention the limitations of nominal T and pi methods in the line problems.

Generally the capacitance is uniformly distributed over the entire length of the line. But for easy calculations the capacitance is concentrated at one or two points .Due to these effects there are error in the calculations.

6. What are limitations of end condenser method.

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There is considerable error in calculations because the distributed capacitance has been assumed to be lumped or concentrated. This method over estimates the effects of the line capacitance.

7. What is end condenser method?

It is a method used for obtaining the performance calculations of medium lines. Here the capacitance of the line is lumped or concentrated at the receiving end.

8. What is power circle diagram?

It is a diagram drawm for the transmission lines network involving the generalized circuit constants and the sending end and receiving end voltage.

9. What are the voltage regulating equipments used in transmission system?

Synchronous motors, tap changing transformers , series and shunt capacitors booster transformers , compound generators and induction regulator.

10. Mention the methods used for voltage control of lines

Tap changing auto- transformer, booster transformer , excitation control and induction regulator.

11. What is sending end power circle diagram?

The circle drawn with sending end true and reactive power as the horizontal and vertical co-ordinates are called sending end power circle diagram.

12. What is receiving end power circle diagram?

The circle drawn with receiving end values are called receiving end power circle diagram.

13. what is neutral grounding.

Connecting the neutral or star point of any electrical equipment(generator ,transformer etc) to earth.

14. define coefficient of earthing.

=(highest rms voltage of healthy line to earth)/(line to line rms voltage) *100 to the power frequency

15. mention 2 disadvantages of ungrounded neutral

occurance of insulation breakdown leading to the heavy phase to phase fault condition.
-system cannot be protected from earth fault.
-voltages due to lightning surges do not find path to earth.

16. Name the various types of grounding.

-solid grounding
-resistance grounding
-reactance grounding
-resonant grounding

17. give the response of resistance for earth driven rods.

R= ρ/2πl *ln(4l/d)
Where l – length of the rod
d – diameter of the rod
resistivity of the rod

18. **for the uniformly current carrying ground driven rod , give the resistance value**.

R= ρ/(2πl) *(ln(8l/d)-1)
Where ρ - resistivity
l – length
d – diameter

19. define screening coefficient.

Screening coefficient for 'n' electrodes in parallel is
= (resistance of one
electrode)/(resistance of n
electrodes in parallel * n)

20.what is a substation.

The assembly of apparatus used to change some characteristic (eg: voltage , A.C toD.C frequency power factor etc) of electric supply is called a substation.-frequency changer substation-converting substationS-industrial substation

PART B

UNIT-1

1. i, compare power transmission using over head line and under ground cable. [8 MARKS]
   ii, Draw a simple model of UPFC ? . [8 MARKS]
2. What are the advantages of high transmission voltage for the transmission of electrical power?
3. A50KM long transmission line supplies a load of 5 MVA at 0.8 power factor lagging at 33KV.The efficiency of transmission is 90% calculate the volune of Al conductor reqired for the   line when three phase 3 wire system is used .The specific resistance of AL IS $2.85*10^{-8}$ ohm-m. [16 MARKS]
4. Explain the detail types of FACTS controllers. [16 MARKS]
5. Derive expressions for sag and tension in a power conductor strung between to supports at equal highs taking into account the wind and ice loading also. [16 MARKS]

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6. i) Derive the expressions for sag and conductor length under bad weather conditions. Assume Shape of overhead line is a parabola. [8 MARKS]

ii) An overhead line has a span of 300m. The conductor diameter is 1.953cm and the conductor weight is 0.844kg/m. Calculate the vertical sag when a wind pressure is 736 N/sq.m of projected area acts on conductor. The breaking strength of conductor is 77990N and the conductor should not exceed half the breaking strength. [8 MARKS]

7. Draw and explain the structure of modern power systems with typical voltage levels. What is the highest VDH level available in India? [13 + 3 MARKS]

8. i) List out the main components of a HVDC system. [8 MARKS]

ii) Discuss various types of HVDC links. Mentions any one HDVC link available in Indian with rating ?[8 MARKS]

9. i) Explain the different types of HVDC links and state the advantages of HVDC transmission. . [8 MARKS]

ii) Explain why the transmission lines are 3 phase 3-wire circuits while distribution lines are 3 phase 4-wire circuits. . [8 MARKS]

UNIT-2

1. From the fundamentals derive an expression for inductance of a single phase transmission system.[16 MARKS]

2. Derive expression for the inductance of three phase line with conductors untransposed .What is the significance of imaginary term in the expression for inductance ?hence derive the expression for inductance for a completely transposed line.[16 MARKS]

3. Derive for expression for the capacitance of unsymmetrical and symmetrically spaced three Phase line compare the results

4. Derive an expression for capacitances of a single phase transmission system and discuss the effect of earth on capacitance with suitable equation. [16 MARKS]

5. Derive an expression for inductance

i) of a single-phase overhead line. . [8 MARKS]

ii) A conductor is composed of seven identical copper strands each having a radius r. Find the Self-GMD of the conductor. . [8 MARKS]

6. i Derive an expression for the capacitance between conductors of a single-phase overhead line.

[8 MARKS]

ii. Find the capacitance between the conductors of a single-phase 10 km long line. The diameter of each conductor is 1.213cm. The spacing between conductors is 1.25m.Also find

the capacitance of each conductor neutral. [8 MARKS]

7. Derive an expression for inductance of a 3-phase transmission line with unsymmetrical spacing? [16 MARKS]

8. Drive an expression for capacitance of a 3-phase transmission line with equilateral spacing?

[16 MARKS]

UNIT-3

1. Determine the efficiency and regulation of a 3phase, 100Km, 50 Hz transmission line delivering 20 MW at a power factor of 0.8 lagging and 66 kV to a balanced load. The conductors are of copper, each having resistance 0.1 O / Km, 1.5 cm outside dia, spaced equilaterally 2 metres between centres. Use nominal T method. [16 MARKS]

2. A three phase 5 km long transmission line, having resistance of 0.5 O / km and inductance of 1.76mH/km is delivering power at 0.8 pf lagging. The receiving end

voltage is 32kV. If the supply end Voltage is 33 kV, 50 Hz, find line current, regulation and efficiency of the transmission line. [16 MARKS]

3. i) Show that the real power transferred is dependent on the power angle and the reactive power transferred is dependent on the voltage drop in the line. [8 MARKS]

ii) The constants of a 3-phase lines are A=0.9 2? and B=140 70? O / phase. The lines delivers 60 MVA at 132 kV and 0.8 pf lagging. Draw circle diagrams and find.

4. Explain

   i. sending end voltage and power angle. [4 MARKS]

   ii. The maximum power, which the line can deliver with the above values of sending end and

      receiving end voltages. [4 MARKS]

   iii. Sending end power and power factor. [4 MARKS]

   iv. Line losses. [4 MARKS]

5. i) What is an equivalent ? circuit of long line? Derive expression for parameters of this circuit in terms of line parameters. [8 MARKS]

   ii) A 50Hz transmission line 300 km long total series impedance of 40+j25 O and total shunt admittance of 10-3 mho. The 220 Kv with 0.8 lagging power factor. Find the sending end voltage,current, power and power factor using nominal ? Method. [8 MARKS]

6. A short 3-phase transmission line has a series line impedance per phase of (20+j50) ohm. Them line delivers a load of 50 MW at 0.7 pf tag . Determine the regulation of the line and the A,B,C,D parameter of the line. If the same load is delivered at 0.7 pf load . determine the regulation of the line. system voltage 220KV? [16 MARKS]

7. The A,B,C,D constant of a 3- phase transmission line are A=D=0.963+j0.016,B=33.5+j138 ohm ,C=(-0.9280+j901.223) X 10^{-6} mho. The load at the receiving end is 40 MW at 220 KV with power factor of 0.86 lagging .Find the magnitude of the sending and voltage ,current, power line efficiency and the voltage regulation. Assume the magnitude of the sending and voltage remains constat ? [

UNIT-4

1 Discuss any two methods to increase the value of string efficiency, with suitable sketches.

2. Explain any two methods of grading of cables with necessary diagrams. [16 MARKS]

3. i) What are different methods to improve string efficiency of an insulator? [8 MARKS]

   ii) In a 3-unit insulator, the joint to tower capacitance is 20% of the capacitance of each unit. By how much should the capacitance of the lowest unit be increased to get a string efficiency of 90%. The remaining two units are left unchanged. [8 MARKS]

4. i) Derive the expression for insulator resistance, capacitance and electric stress in a single core cable.Where is the stress maximum and minimum? [8 MARKS]

   ii) A single core 66kv cable working on 3-phase system has a conductor diameter of 2cm and sheath of inside diameter 5.3cm. If two inner sheaths are introduced in a such a way that the stress varies between the same maximum and minimum in the three layers find:

      1.position of inner sheaths

      2.Voltage on the linear sheaths

      3.Maximum and minimum stress

5. Elaborate the various methods to improve the string efficiency? [16 MARKS]

6. What is grading of cable? Describe teo methods? [16 MARKS]

UNIT-5

1. With a neat sketch explain double bus with double breaker and double bus with single

breaker. State their advantages and disadvantages. [16 MARKS]

2. Explain the following:

    (i) Neutral grounding

    (ii) Resistance grounding. [16 MARKS]

4.i)Explain different types Tariff. [8 MARKS]

    ii) Why a consumer having low power factor is changed at high rates. [8 MARKS]

5. Describe any four type of substation bus schemes?6 Discribe and compare the radial and ring main distribution system. What is the role of interconnectors in distribution systems?

    [16 MARKS]