MODULE - 4 10/4/2017

I. CORONA

When an alternating potential difference is applied a/c the two conductors whose spacing is large as compared to their diameters, there is no apperent change in the condition of atmos-pheric air sorrounding the wires, If the applied vtg is low.

However when the applied voltage exceeds certain value called critical disruptive voltage, the conditions are sorrounded by faint, ~~voi~~ voilet glow called (CORONA)

The pheonomenon of corona accompenied by hissing sound, production of ozone, Power loss and radio interference

The hiegher the voltage is raised the hiegher the luminous envolope and greater are the sound, power loss and radio noise

If the applied voltage is increased to breakdown value a flash over will occurs between the conductor due to the breakdown of air insulation.

" The pheonominon of voilet glow, hissing noise and product of ozone gas in an overhead transmission line is called CORONA"

If the conductors are poilished and smooth the corona glow will uniform throughout the length of the conductor, otherwise the rough points will be appear brighter ~~&~~ with the DC voltage difference the appearence of two wires, the positive wire has uniform glow about it, while the (-ve) cond" has spotty glow

Imp May-16 Dec-14

* Factors affecting the CORONA

The phenominon of corona affected by the physical state the atmospheare as well as by the conditions of the line. The foll° are the factors ~~e~~upon which the coron depends

i) Atmospheare

As corona is formed due to ionization of air sorrounding the conductors, their fore, it is affected by the physical state of atmospheare. In the stormy weather, the no.of ions is more than the normal and as such corona occurs at much less voltage as compared ~~to~~ with fair weather.

II) Conductor Size.

Corona effect depends upon the shape and conditions of the conductors. The rough and irregular surface will give rise to more corona, bcz of unevenness of the surface decreases the value of breakdown voltage. The stranded conductor has irregular surface and hence gives rise to more corona than a solid conductor

III) Spacing between Conductors

If the spacing between conducts is made very large compared to their diameters. There may not be corona effects; It is bcz larger distance between the conductor reduces the electrostatic stresses at the conductor surface, thus avoiding corona formation

IV) Line Voltage.

The line voltage greatly affects corona. If it is low their is no change is in the condition of air around the conductors & hence no corona is formed. However if line voltage has such a value that electrostatic stresses developed at the condr surface make the air around the condr the conducting. then corona is formed

11/4/17 May-16 Imp

Important Terms

The phenomenon of corona play an important role in the design an overhead T.L ∴ It is profitable to consider the folln terms much used in the analysis of corona effects

(I) Critical Dissruptive Voltage.

It is the minimum phase to neutral voltage at which corona occurs

Consider the two conductrs of radii 'r' cm and spaced 'd' cm apart. If 'V' is the phase to nutral voltage then potential gradiant at the condr surface is given as

$$g = \frac{V}{r \log_e\left(\frac{d}{r}\right)} \text{ volts/cm} \quad \text{--- (4.1)}$$

Inorder that coron is formed the value of g must be maid equal to the breakdown strength of the air. The breakdown strength of air at 76 cm pressure and 25°c temperature is 30 kV/cm (max) or 30k/$\sqrt{2}$ = 21.2 kV/cm (Rms value) and is denoted by g_o. if Vc is the phase to nutral potential required under thes condⁿ then

$$g_o = \frac{V_c}{r \log_e\left(\frac{d}{r}\right)} \quad (4.2)$$

where g_o = Breakdown strength of air 76 cm of mercury and 25°C

g_o = 30 kV/cm (max) or 21.2 kV/cm (rms)

∴ Critical disruptive voltage $V_c = g_o r \log_e\left(\frac{d}{r}\right)$ — (4.3)

The above expression for dissruptive voltage is under std condⁿ i.e at 76 cm of Hg and 25°c if there condⁿs vary. the air dencity also changes. Thus altering the value of g_o the value g_o is directly propotional to air dencity. Thus the breakdown strength of air at barrow matric pressure of b cm of Hg and t°c becomes δg_o where

$$\delta = \text{air dencity factor} = \frac{3.92b}{273+t} \quad (4.4)$$

Under std condⁿ the value of $\delta = 1$

Then critical dissructive vtg $V_c = g_o \delta r \log_e\left(\frac{d}{r}\right)$ — (4.5)

Correction must be also maid for the surface condⁿ of the condʳ this is accounted for by multiplying the above eqⁿ (4.5) by irregularity factor m_o

∴ Critical dissruptive vtg is

$$V_c = m_o g_o \delta r \log_e\left(\frac{d}{r}\right) \text{ kV/phase} \quad (4.6)$$

where $m_o = 1$ for polished condʳs

m_o = 0.98 to 0.92 for dirty condʳs

= 0.87 to 0.8 for stranded condʳs

(ii) Visual Critical voltage

"It is minimum phase to nutral voltage at which corona glow appears all along the line conductors"

It has been seen that in cas of ||el conductrs the corona glow doesnot begin at critical dissruptive voltage V_c but at higher voltage V_v called visual critical cal voltage. The phase to neutral effective value of visual critical vtg is given by foll^n formula

$$V_v = m_v g_0 \cdot \delta \cdot r \left(1 + \frac{0.3}{\sqrt{\delta r}}\right) \cdot \log_e \frac{d}{r} \quad kV \qquad (4.7)$$

where m_v is another irregularity factor having value of 1 for polished conductors & 0.72 to 0.82 for rough conductors

(iii) Power loss due to Corona

Formation of corona is alway acompanied by energy loss which is dissipated in the form of light heat, sound and chemical action.

When dissructive voltage is exceeded the power loss due to corona is given by

$$P = 242.2\left(\frac{f+25}{\delta}\right)\sqrt{\frac{r}{d}} \cdot (V - V_c)^2 \times 10^{-5} \ kW/km/phase \qquad (4.8)$$

Where f = Supply frequency in Hz

V = Phase to nutral voltage (rms)

V_c = Dissruptive voltave (rmp) per phase.

Advantages & Disadvantages of Corona

Corona has may advantages & dis advantage In the correct design of OHTL the balence should be struck their advantages and disadvantages

Advantages

1) Due to corona formation the air surrounding the cond^r becomes conducting and hence the vertual diameter of the cond^r is increased. The incresed diameter reduces the elertrostatic stresses betn the cond^r

2) Corona reduces the effects of transients produced by surges

Disadvantages

1) Corona is accompanied by loss of energy this affects the transmission efficiency of line

2) Ozone is produced by corona and may cause corrosion of the conductor due to chemical action

3) The current drawn by the line due to corona is non sinusoidal and hence non sinusoidal vtg drop occurs in the line. This may cause inductive interference with neighbouring communication line

17/4/17

*Methods of reducing Corona effect

It has been seen that intense corona effects are observed at a working voltage of 33kV or above ∴ careful design should be done to avoid corona on the substation or bus bar for 33kV and higher vtgs otherwise highly ionized air will be may cause flashover the insulator or betn the phases causing considerable damage to the equipment the corona effect can be reduced by foll^n method

(i) By Increasing Conductor Size

~~By~~ increasing the conductor size the vtg at which corona occurs is raised and hence corona effects are considerable reduce, this is this is one of that ACSR cond^r which has larger cross sectional ~~area are ACSR conductors which have a larger crosssectional~~ area are used in transmission lines

(ii) By Increasing Conductor Spacing

Imp-IA

$\log_e = \ln$
$\log_{10} = \log$

Problem-(4.1)

A 3ϕ line conductors 2cm in diameter spaced equilaterally 1m apart if the dielectric strength of air is 30kV/cm find the disruptive critical voltage for the line take air density factor $\delta = 0.952$ & irregularity factor is $m = 0.9$

Conductor radius $= r = \frac{2cm}{2} = 1cm$

$m_0 = 0.9$

$\delta = 0.952$

Conductor spacing $= 1m = 100cm = d$

Dielectric strength $= g_0 = 30kV/cm$ max $= \frac{30k}{\sqrt{2}} = 21.2kV(rms)/cm$ by (4.6)

Critical disruptive voltage $= m_0 g_0 \delta r \log\left(\frac{d}{r}\right)$

$= 0.9 \times 0.952 \; 1 \times \log_e\left(\frac{100cm}{1cm}\right)$

$V_c = 83.64 kV/phase$ (rms) value

Line voltage (rms.) $= \sqrt{3} \times 83.64kV/phase$

$= 144.8kV$

Problem (4.2)

A 132 kV line with 1.956 cm diameter conductors is built so that corona takes place if the line voltage exceeds to 210kV (rms). If the value of potential gradient at which ionization occurs can be taken as 30kV/cm Find the spacing betn the conductors

Assume $m_0 = 1$ for smooth conductor &

$\delta = 1$ for standard condition

$V_c = \frac{210kV \text{ line}}{\sqrt{3}} = 121.25 kV$

Conductor radius $= r = \frac{1.956cm}{2} = 0.978 cm$

Dielectric strength $= g_0 = \frac{30kV}{\sqrt{2}} = 21.213kV/cm$

$V_c = m_0 g_0 \delta r \log_e\left(\frac{d}{r}\right)$

$\log_e\left(\frac{d}{r}\right) = \frac{V_c}{m_0 g_0 \delta r}$

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$$\log_e\left(\frac{d}{r}\right) = \frac{121.25k}{1 \times 21.213k \times 1 \times 0.978}$$

$$\log_e\left(\frac{d}{r}\right) = 5.848$$

For (d/r) antilog to agbove eq^n

$$2.3 \log\left(\frac{d}{r}\right) = 5.848$$

$$\log\left(\frac{d}{r}\right) = 2.5426$$

$$\left(\frac{d}{r}\right) = \text{Antilog}\,(2.5426) \qquad \text{shift}[\log(\text{Ans})]$$

$$d = 348.5 \times 0.978$$

$$d = 341\ \text{cm}$$

Problem (4.3) A 3ϕ 220kV, 50 Hz transmission line consist of 1.5cm radius conductor spaced 2m apart in equilateral trangular formation if the tempreture is 40°c and the atmospheric pressure 76cm calculate corona effect loss per km of the line Take $m_0 = 0.85$

Radius of conductor $= r = 1.5$ cm

Supply voltage $= V = 220$ kV line.

$$V_{phase} = \frac{220k}{\sqrt{3}} = 127\ \text{kV}$$

Supply frequency $= f = 50$ Hz

Tempreture $= t = 40°$C

Atmospheric pressure $= b = 76$ cm

we know that

$$P = \frac{224.2}{\delta}(f+25)\sqrt{\frac{r}{d}}\,(V-V_c)^2 \times 10^{-5}\ \text{KW/km/phase}$$

But $\delta = \frac{3.92b}{273+t} = \frac{3.92 \times 76}{273+40°} = 0.952$

Assuming $g_0 = 30$ KV ~~(max)~~ (avg)

$$g_0 = \frac{30\text{kV}}{\sqrt{2}} = 21.2\ \text{kV (rms)}$$

Given $m_o = 0.85$ $d = 2m = 200cm$

we have

$$V_c = m_o g_o \delta . r \log_e\left(\frac{d}{r}\right) kV$$

$$= 0.85 \times 21.2K \times 0.9252 \log_e\left(\frac{200cm}{1.5cm}\right) \times 1.5$$

$$= 125.90 kV$$

Now,

$$P = \frac{242.2}{0.952}(50+25)\sqrt{\frac{1.5}{200}} \times (127 - 125.9)^2 \times 10^{-5} \quad kW/ph/km$$

$$P = 0.01999 kW/phase/km$$

Problem (4.9) A certain equilateral transmission line has total corona loss of 53KW at 106 KV and a loss of 98KW at 110.9 KV what is the dissruptive critical voltage. what is the corona loss at 113 KV

The power loss due to corona in ad is given by

$$P = 3\frac{242.2}{\delta}(f+25)\sqrt{\frac{r}{d}}(V-V_c)^2 \times 10^{-5}$$

As f, δ, r and d are same for both the cases

$$P \propto (V-V_c)^2$$

For first case $P = 53KW$ at $V = \frac{106KV}{\sqrt{3}} = 61.2KV$

For second case $P = 98KW$ at $V = \frac{110.9}{\sqrt{3}} = 64KV$

$$\therefore \quad 53 \propto (61.2 - V_c)^2 \quad \text{and} \quad \text{--- (1)}$$

$$98 \propto (64 - V_c)^2 \quad \text{--- (2)}$$

Deviding (2) by (1) we get

$$\frac{98}{53} = \frac{(64-V_c)^2}{(61.2-V_c)^2}$$

$$V_c = 54 KV$$

Let 'W' KW be the power loss at 113KV

$$W \propto \left(\frac{113}{\sqrt{3}} - V_c\right)^2$$

$$W = (65.2 - 54)^2 \text{ —— (3)}$$

Deviding (3) by (1) $\frac{W}{53} = \frac{(65.2-54)^2}{(61.2-54)^2} \rightarrow W = (11.2/7.2)^2 = 128KW$

2. Under Ground Cables

Introduction.

Electric power can be transmitted or distributed either by OH s/m or by Underground cables
The under ground cables have several advantages such as less liable to damage through storms or lightning, low maintenance cost, less chances of fault, smaller vtg drop and better general apperance. However their major drawback is that they have grater installation cost and introduced insulation problems at high voltages, compared with equivelent OH s/m For this reson under ground cables are employed where it is impracticle to use overhead lines such locations may be thickly populated areas where municiple authorities prohabits over head lines for reasons or safty or around plants and substations or where mantance conds do not use the permit of OH s/m construction

The cheif use of under-ground cables for many yers has been for distribution of electric power has conjusted urban areas at comparitivly low or moderate voltage. However recent improvements in design and manufacture have lead to the development of cables suitable at high vtgs this has maid it possible to employe under ground cables for transmission of electric power for short or madrate distances

Under Ground Cables

" An under ground cable essentially consist of one more conductors covered with insulation and surrounded by protencting cover"

Al though defferent types of cables are avialable, the type of cable to be used will depend upon the working voltage and service requirments

VVImp

Construction of Cables

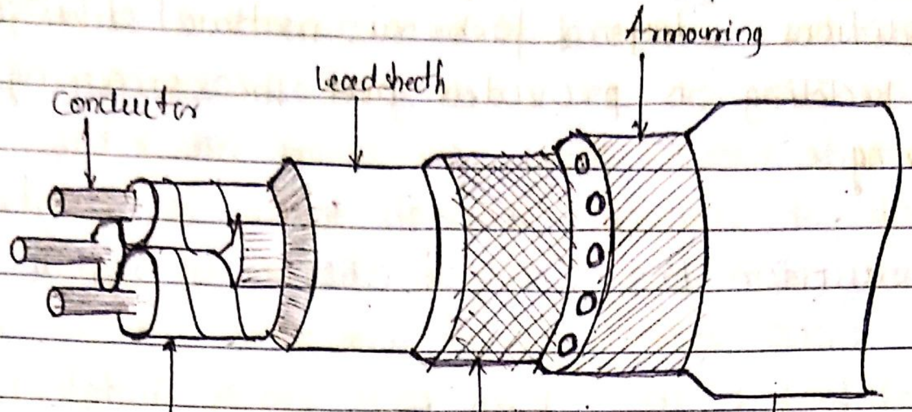


fig -

Fig shows a general constn of 3-conductor cable

(i) Cores of conductors : A cable may have one or more than 1 core (conductor) depending upon the type of service for which it is intended. For instance the 3-conductor cable shown in above fig they are maid of tinned copper or aluminium and are usually stranded

(ii) Insulation : Each core of or conductor is provided with a suitable thickness of insulation thickness of layer depending upon the voltage to be withstand by the cable the commonly used materials for insulation are impregneted papers, varnished cambric or rubber mineral compound

(iii) Metalic sheath : In order to protect the cable from moisture gases or other damaging liquids like (acids & alkalids) in soil and atmosphere a metalic sheath of lead or aluminium is provided over the insulation as shown in fig

(iv) Bedding : Over the metalic sheath is applied a layer of Bedding which consist of fibrous material like Jute or hassian tape. the perpouse of bedding is to protect the sheath against corrossion and from mechanical injury due to armouring

(v) Armouring : Over the bedding armouring is provided which consist two layers of galvenised steel wire or steel tape its purpose is to protect the cable from mechanical injury while laying it and during the cource of handling Armouring may not be done in this case of some cables

vi) serving : Inorder to protect the armouring from atmospheric conditions a layer of fibrous material like jute (similar to bedding) is provided over the armouring is known as serving

* Insulation Resistance of a single core Cable 23/5/17

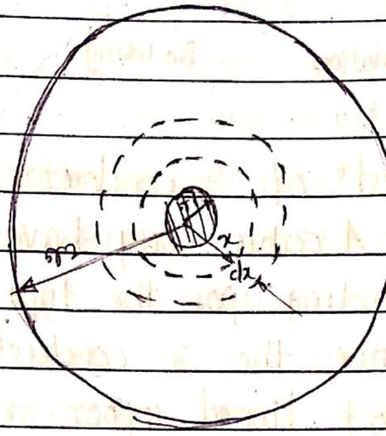


fig -

The cable conductor is provided with the suitable thickness of insulating material, in order to prevent leakage c/n. The path for leakage c/n is radial through the insulation. "The opposition offered by the insulation to the leakage c/n is known as insulation resistance of the cable"

For satisfactory operation the insulation resistance of cable should be very high

Consider a single core cable of conductor radius r_1 and internal sheath radius r_2 as shown in above fig

Let 'l' be the length of the cable & 'ρ' be the resistivity of the insulation

Consider a very small layer of insulation of thickness dx at a radius x. The length through which the leakage c/n tends to flow is dx and the area of crosssection offered to this flow $2\pi x l$

$\therefore$ Insulation resistance of considered layer is equal

$$= \rho \frac{dx}{2\pi x l}$$

∴ The insulation resistance of whole cable is

$$R = \int_{r_1}^{r_2} \frac{\rho \, dx}{2\pi x l}$$

$$= \frac{\rho}{2\pi l} \int_{r_1}^{r_2} \frac{1}{x} \, dx$$

$$= \frac{\rho}{2\pi l} \left[\log x \right]_{r_1}^{r_2}$$

$$\boxed{R = \frac{\rho}{2\pi l} \log_e \left(\frac{r_2}{r_1} \right)}$$

This shows that insulation resistance of of cable is inversly propotional to its Length. In other words if the cable Length increases the insulation resistance disreases and vice. versa

Problem

① A sigle core cable has cond" diameter of 1cm & insulation resis thickness of 0.4cm if the specific resistance of insulation is 5×10^{14} Ω cm calculate the insulation resistance for 2km length of cable.

diameter = d = 1cm

$r = 0.5cm = 0.005m$

$l = 2km$

$\rho = 5 \times 10^{14}$ Ω cm

$r_2 = 0.4cm + r_1 = 0.4 + 0.5 = 0.9cm$

$$R = \frac{\rho}{2\pi l} \log_e \left(\frac{r_2}{r_1} \right)$$

$$= \frac{5 \times 10^{14} \times 10^{-2}}{2\pi \times 2 \times 10^3} \times \log_e \left(\frac{0.4}{0.5} \right)$$

$R = 233.87 \times 10^6$ Ω

26/05/

Thermal Rating / Thermal Feild

* The heat generated in the cable due to various losses raises the tempreture of cable
* Heat is dessipated to soil through dielectric, sheath armour & Serving
* The dielectric serving and soil has termal resistance through which the heat flows
* The maximum permissable tempreture rise in the cable depends on the type of cable, no of cores, sheath mete methoed of installation & presence armouring
* The specified maximum tempreture rise is known for a verity of above factors
* The heat generated can be expressed as a function of c/n in a cable

Charging Current

A cable has high capacitance which results in charging c/n and reactive power if 'V' is line to line voltage, The charging c/n

$$I_C = 2\pi f C \times \frac{V}{\sqrt{3}}$$

The 3-ϕ reactive power is $\sqrt{3}\, V I_C$

Reactive power $\sqrt{3} \cdot V I_C = \sqrt{3} V \, 2\pi f C \frac{V}{\sqrt{3}}$

$$= \sqrt{3} V \left(2\pi f C \frac{V}{\sqrt{3}}\right) \times \left[2\pi \varepsilon_0 \varepsilon_r / \ln\left(\frac{R}{r}\right)\right]$$

$$\because \; C = \frac{Q}{V} = \frac{2\pi \varepsilon_0 \varepsilon_r}{\ln\left(\frac{R}{r}\right)}$$

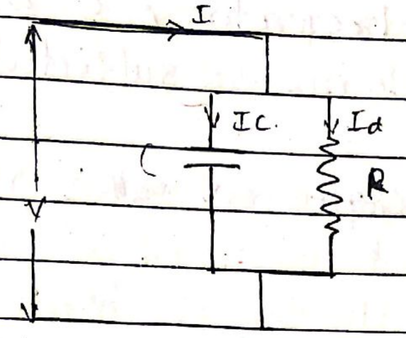
$$\therefore \text{Reactive Power} = \frac{4\pi^2 f V^2 \varepsilon_0 \varepsilon_r}{\ln\left(\frac{R}{r}\right)} \quad \text{VAR/meter}$$

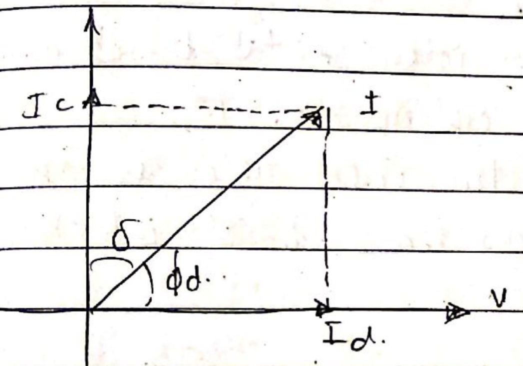
A 33 kV UG feeder using 3 single core cables each having cond^r diameter of 2.5cm & 0.6cm as the radial thickness of 0.6cm (with $\varepsilon_r = 3.1$) has a KVAR requirement of 148 KVAR/KM and charging c/n of 2.6A/km

The flow of charging c/n causes the heating of cable ∴ the load c/n capability of the cable is decreased a further reduction in c/n carrying capacitor occurs due to dielectric. this factors limit the length of cable, used in actual practice to less that 50km

• Dielectric loss

There excists the capacitance bet^n conductor and a sheath, with a dielectric bet^n the two, this represented as 'C' the lekeage resistance is denoted as 'R'. the eq^uivalent ckt of cable is the ||^el combination of R & C





phasor diagram

So they are two c/n

(i) ⊥^er to to voltage V. which is leading capacitive c/n Ic while other. with is in phase with voltage 'V' when is resistan current : Id representing dielectric loss. this shon in fig above the dielectric loss due to lekeage resistance. is given by.

$W = \frac{V^2}{R}$

$\tan\delta = \frac{I_d}{I_c} = \frac{V/R}{V/X_C} \Rightarrow \frac{V}{R} = V \cdot X_C \cdot \tan\delta \quad | \because \frac{1}{X_C} = \frac{1}{1/\omega C} = \omega C$

$\frac{V}{R} = V\omega C \cdot \tan\delta$

$$W = V^2 \omega C \tan\delta$$

where δ = dielectric loss angle in radians. Generally δ is very small angle. For low voltage cables dielectric losses can be neglected as these small but for voltage cables it must be considered.

The angle ϕ_d in the phasor diagram is the p.f angle of the power factor $\cos\phi_d = \cos(90-\delta)$

$= \sin\delta$

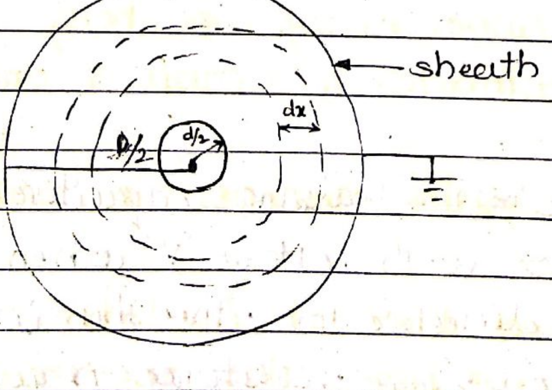
It depends on the the temperature and & vtg stresses to which ~~the~~ the dielectric is subjected

~~Dielectric Stress in a single cor cable~~
~~Under operating condn~~

- Capacitance of single core cable.

A single core cable can be considered to be equivalent two long coaxial ~~cables~~ cylinders.

- The condr or core ~~the~~ is the inner cylinder while the out sheet is represented as lead sheath which is at earth potential



Consider a single core cable with condr diameter d and inner sheath diameter 'D' as shown in above fig. Let the charge / axial length of the cable be Q cables and ε is the Permittivity of the insulation materiale beth core and lead sheath. where $\varepsilon = \varepsilon_r \varepsilon_0$

where ε_r = relative permittivity

If the cable has the length of L meters then the capacitance of cable is as follow

$$C = \frac{\varepsilon_r l}{41.4 \log\left(\frac{D}{d}\right)} \times 10^{-9} \ F$$

On solving

27/5/17

* Grading Cables

Defination: "The process of achieving uniform electrostatics stress in the dielectric of cables is known as grading of cables"

Electrostatic stress in a single core cable has a maximum value (g_{max}) at the conductor surface and goes on decreasing as we move towards sheath. The maximum voltage that can be safly applyied to the cable is dependent on g_{max} i.e electrostatic stress at conductor surface. for safe working of a cables having homogenous dielectric the strength of dielectric must be more than g_{max} if dielectric of high strength is used for cable it is useful only near the conductor where stress is maximum. But as we move away from the condr the electro static stress decreases, so the dielectric stress will be unneccessarily over strong

The unequal stress distribution in a cable is undesirable for two reg resons

1) Firstly insulation of grater thickness is requred which increases the cablesize

2) it may lead to break down of insulation

So inorder to overcome from this disadvantages it is neccessary to have uniform distribution of stress in cable

This can be achived by distributing the stress in such a way that its value is increased in outer layers of dielectric this is known as grading of Cables.

Imp
Following are the main methods of Grading of cables

1) Capacitance Grading (11.2) Pg:281, 282 associate Prob

2) Intersheath grading (11.13) Pg: 284, 285 assosicated Prob