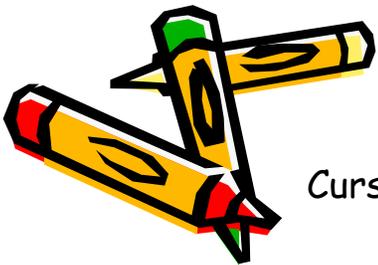
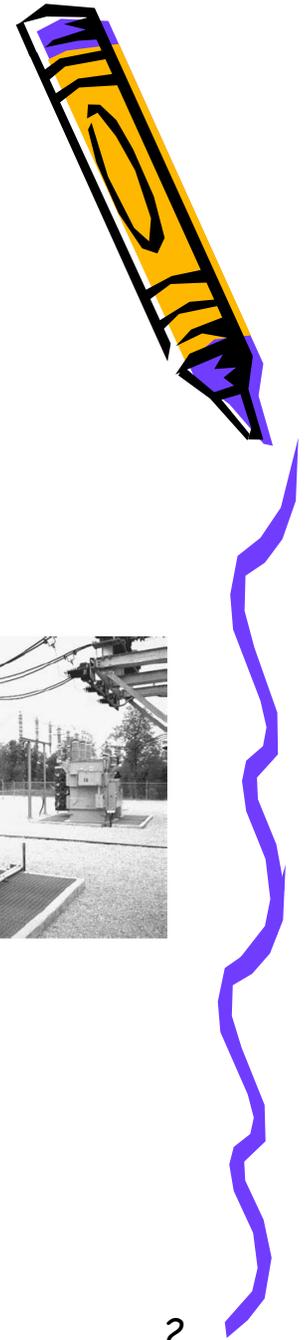
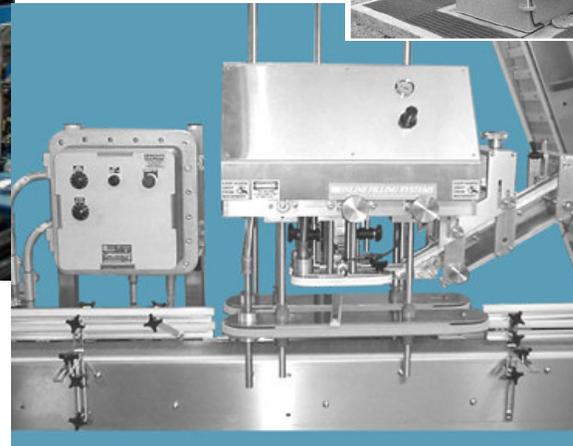
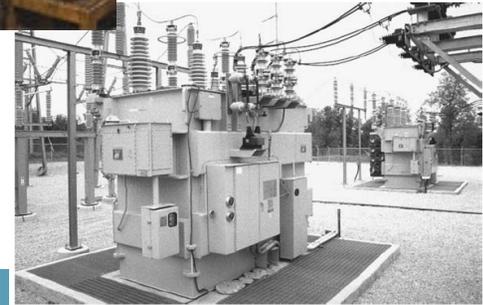


# MENTENANTA SI TESTAREA SISTEMELOR ELECTRICE



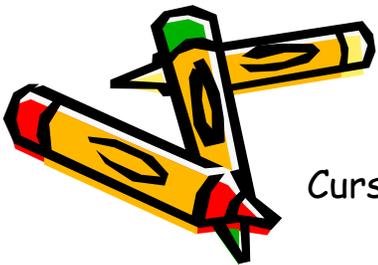
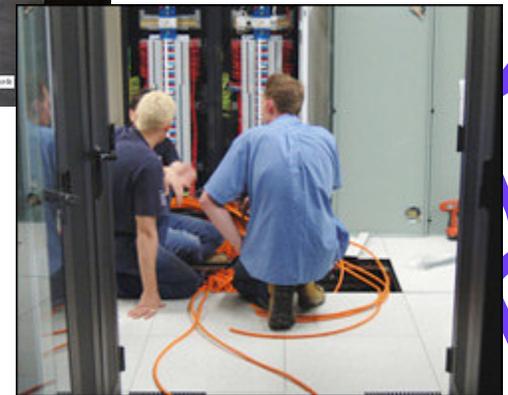
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# CABLURI SI ACCESORII



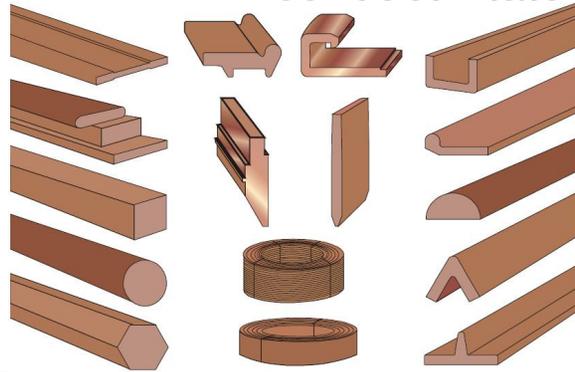
Cabluri de medie/inalta tensiune

Cabluri de joasa tensiune



# Materiale

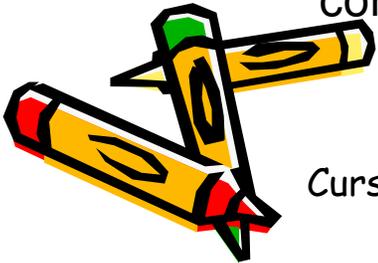
Cupru electrolitic, 100% conductivitate



Elemente de conectare cupru-aluminiu



Aluminiu aliaj, 61% conductivitate



Curs 7

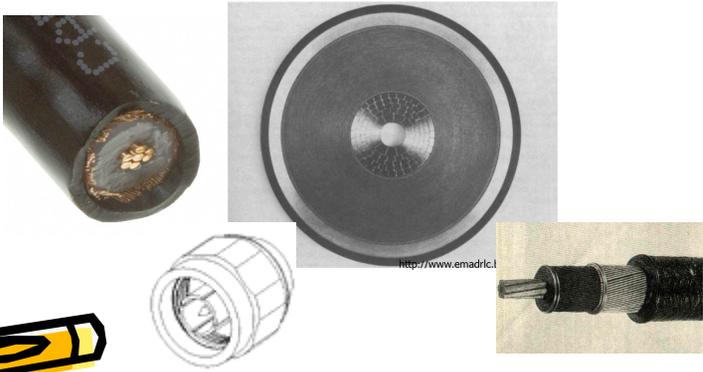
# Tipuri de conductoare

## Cabluri de putere

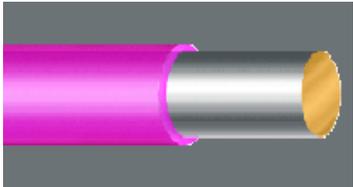


Cabluri aeriene (bronz, alama, otel-aluminiu)

## Cabluri pentru aplicatii speciale



## Conductor masiv

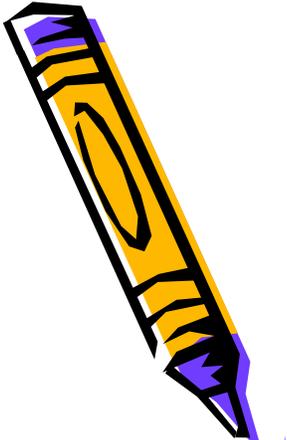


## Torsadat

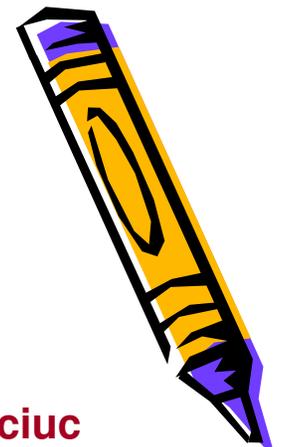
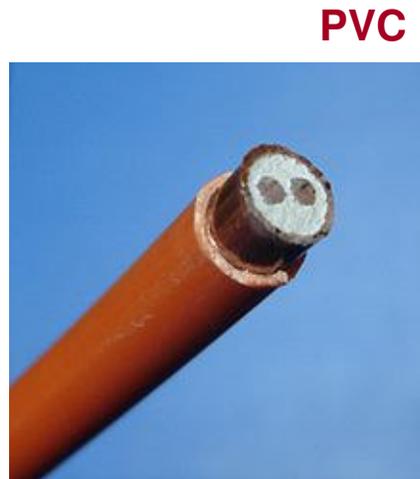
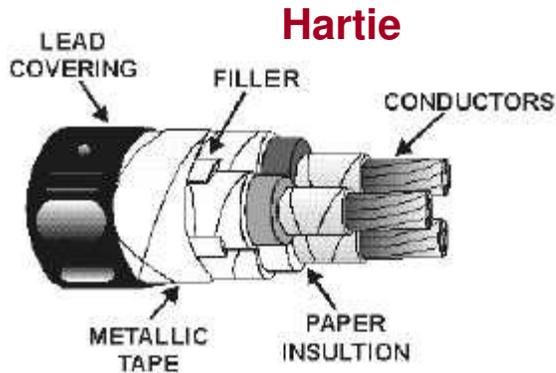
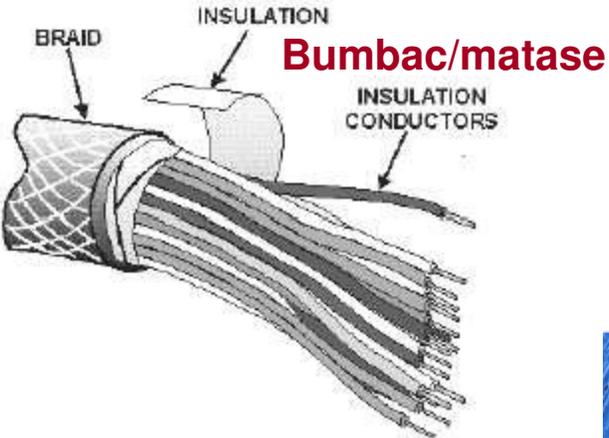


Concentric

Manunchi



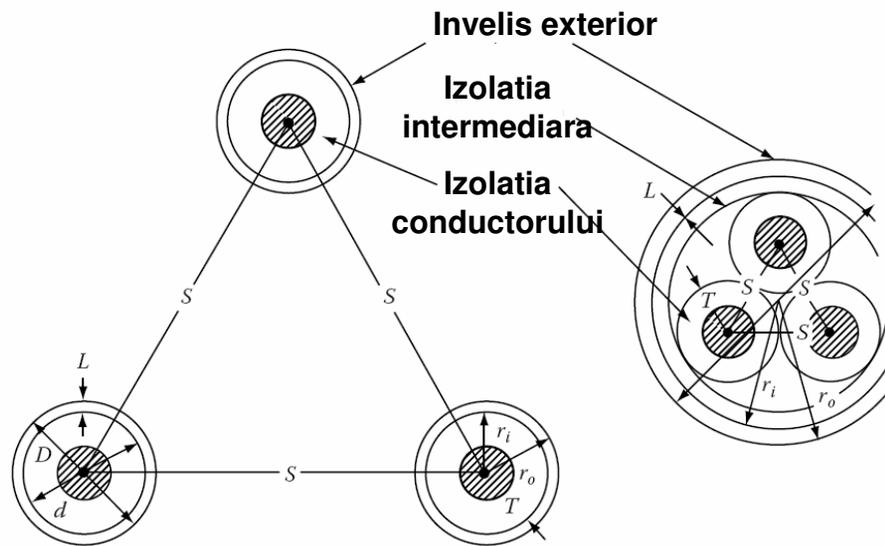
# Tipuri de izolatie



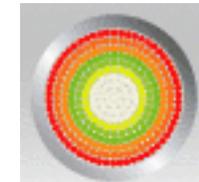
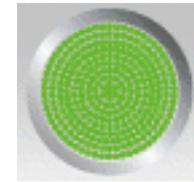
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# Caracteristicile cablurilor

## Geometria



## Raza medie



Pentru a fi echivalent din punct de vedere al inductivitatii echivalente raza unui cablu tubular trebuie sa fie mai mica decat cea a unui conductor masiv:

$$\frac{d}{2} \quad K \frac{d}{2}, 0 < k < 1$$

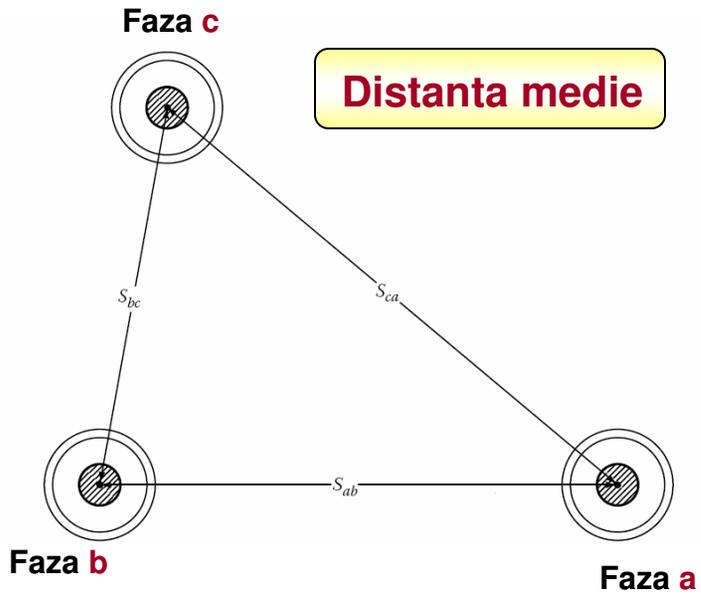
Cupru solid

Cupru tubular

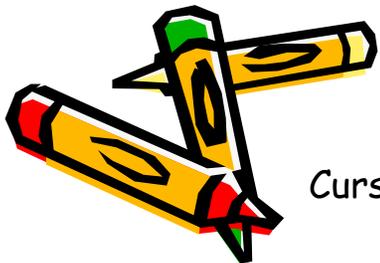
$$\frac{d}{2} \sim 0.779 \frac{d}{2}$$



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$$D_{med} = \sqrt[3]{S_{ab} S_{bc} S_{ca}}$$



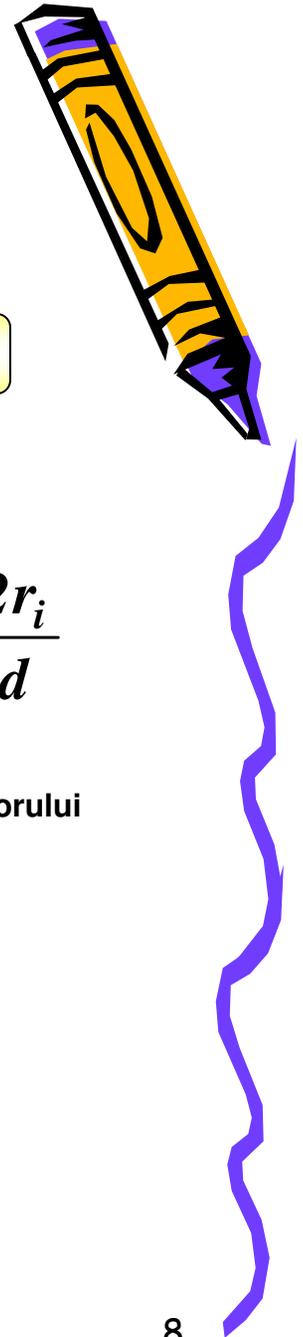
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Factor geometric

$$G = 2.303 \log_{10} \frac{2r_i}{d}$$

$r_i$  - raza interioara a izolatiei

$d$  - diametrul exterior al conductorului



## Constante electrice

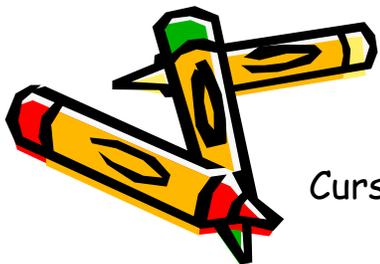
**Rezistenta de secventa directa/inversa**  
depinde de:

- Efectul pelicular
- Efectul de proximitate
- Curentii din invelisul conductorului

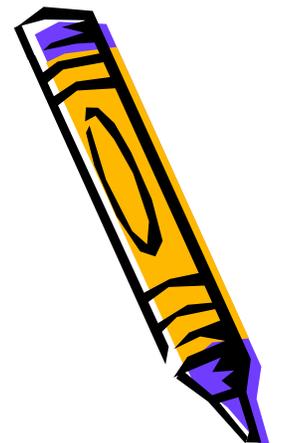
**Rezistenta izolatiei**

$$r_1 = r_2 = r_0 = \frac{0.597G * 10^6}{fK \cos \theta}$$

$\cos \theta$  – factor de putere al izolatiei per unit



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## Constante electrice

### Reactanta de secventa directa/inversa:

$$X_1 = X_2 = 0.4 * \pi * f * 10^{-3} \left( \ln \frac{D_{med}}{R_{med}} + K \right) \quad [\Omega / km]$$

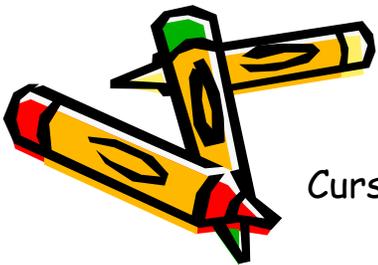
### Reactanta de secventa homopolara

Earth wire	Overhead line	$X_0/X_1$
–	Single circuit	3.5
–	Double circuit	5.5
Galvanized steel	Single circuit	3.5
Galvanized steel	Double circuit	5.0
Non-magnetic	Single circuit	2.0
Non-magnetic	Double circuit	3.0

### Reactanta capacitiva

$$X_{1c} = X_{2c} = X_{0c} = \frac{1.11G}{fK} \quad [M\Omega / faza / km]$$

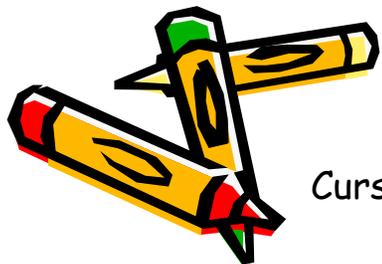
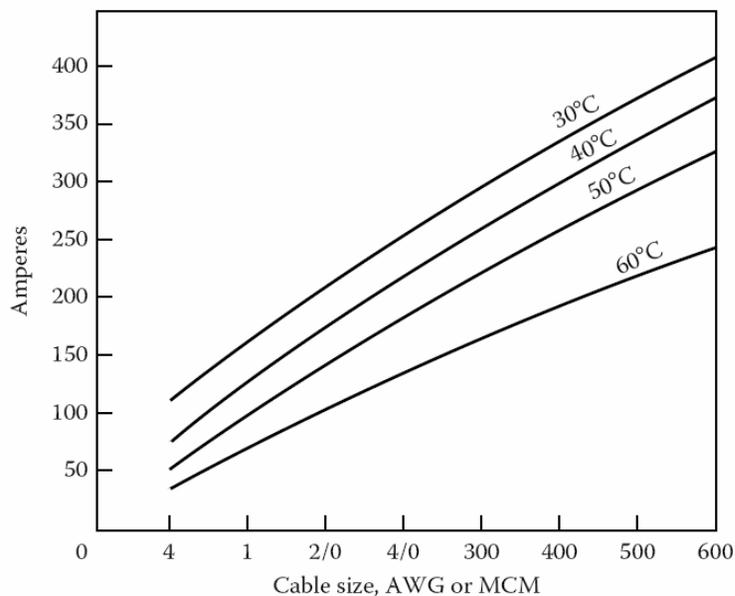
K – constanta dielectrica



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## Curentul nominal depinde de:

- Temperatura maxima admisa
- Pierderile totale
- Abilitatea de disipare a caldurii
- Temperatura mediului de lucru



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## Date nominale

### Curentul maxim

$$I_0 = I_c \sqrt{\frac{(t_0 - t_c) R_c}{(t_c - t_a) R_0}}$$

$I_c$  – curentul de regim permanent

$t_0$  – temperatura de varf

$t_a$  – temperatura mediului

$t_c$  – temperatura maxima de functionare

$R_c$  – rezistenta conductorului la temperatura maxima

$R_0$  – rezistenta conductorului la temperatura mediului

Emergency Overload Temperature of Rubber-Insulated Cables

Voltage Rating	Type of Cable	Maximum Operating Temperature (°C)	Emergency Overloading Temperature (°C)
600V	PVC	60	75
	Butyl	90	125
	Silicone	125	150
	Polyethylene	75	85
1-5kV	PVC	75	85
	Butyl	90	125
	Silicone	125	150
15kV	Butyl	85	105
	Silicone	125	150

### Tensiunea nominala:

- Este specificata ca si tensiune de linie
- Se bazeaza, totusi, pe tensiunea de faza

$$U_N = 15kV \longrightarrow U_f = \frac{15}{\sqrt{3}}kV = 8.66kV$$

Tensiunea pentru alegerea izolatiei conductorului:

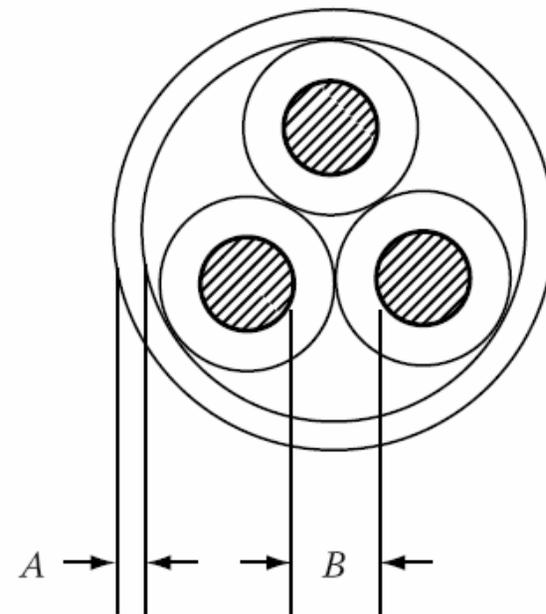
$$B = \frac{15}{2}kV = 7.5kV$$

Tensiunea pentru alegerea izolatiei exterioare:

$$A = 8.66kV - \frac{15}{2}kV = 1.16kV$$



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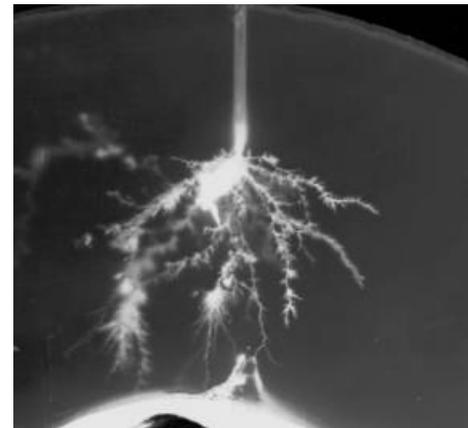
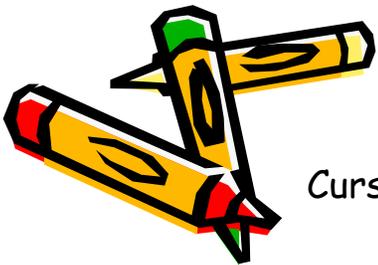
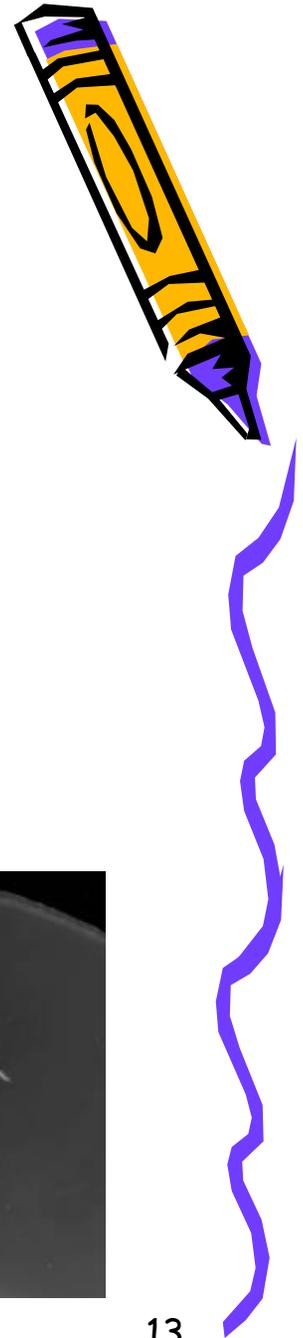


## TESTE ASUPRA CABLURILOR SI ACCESORIILOR

**Testarea izolatiei:** dupa instalare, dar inainte de instalarea accesoriilor

**Teste de acceptare:** dupa instalarea tuturor accesoriilor

**Teste de mentenanta:** pe durata timpului de viata

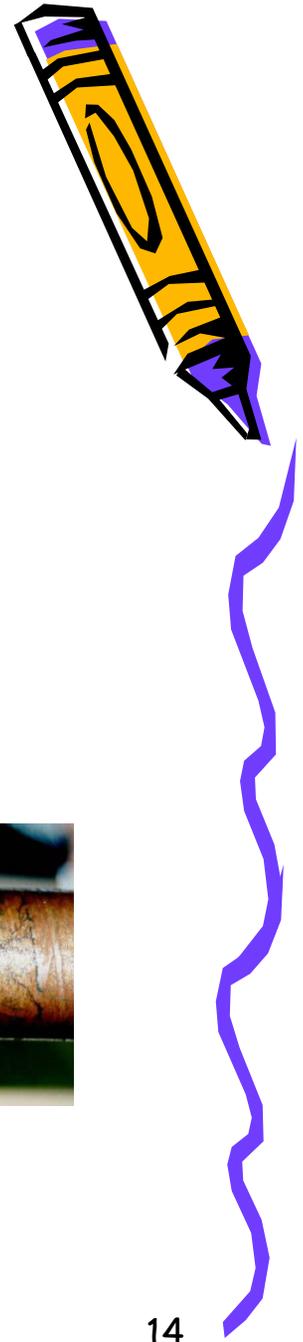


**Conform IEEE 400-2001:**

**Test tip 1:** functional/nefunctional, fara a pune in evidenta sursa defectului (se realizeaza la tensiuni inalte)

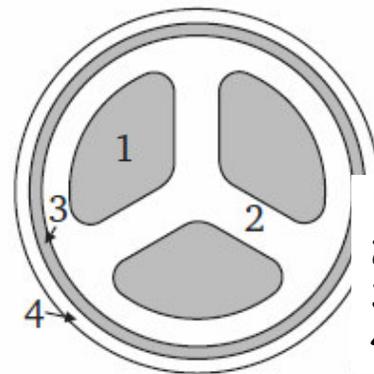
**Test tip 2:** stabilesc starea cablului (se lucreaza la tensiunile nominale sau la valori mai mici):

- Teste care evalueaza starea cablului
- Teste care detecteaza si localizeaza defectul





Cablu tip XLPE

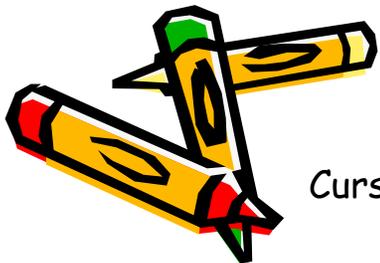


- 1 - Conductor
- 2 - Izolatie de hartie
- 3 - Ecran legat la pamant
- 4 - Invelisuri exterioare

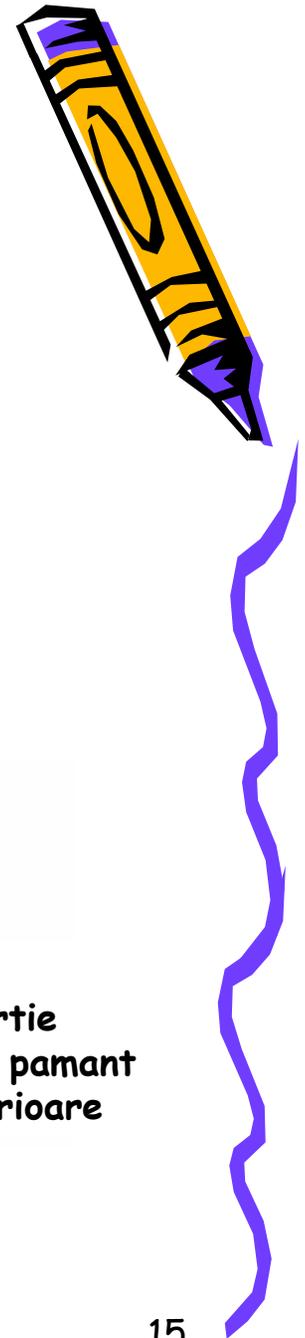
Cablu tip PILC

<http://www.youtube.com/watch?v=SWZc0l3zzZs>

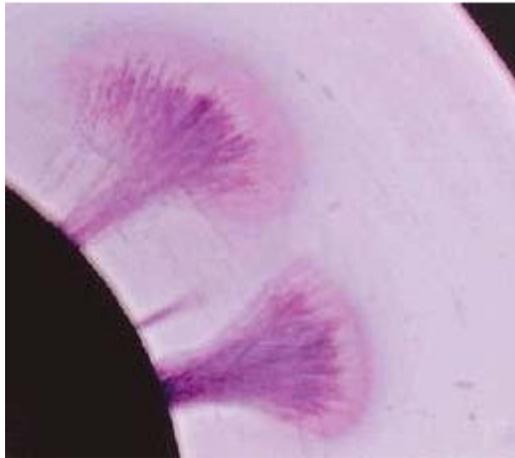
<http://www.youtube.com/watch?v=svgW0YYSSOA>



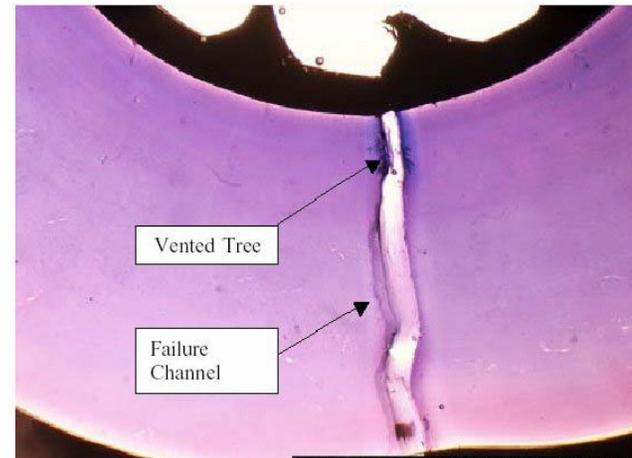
Curs 7



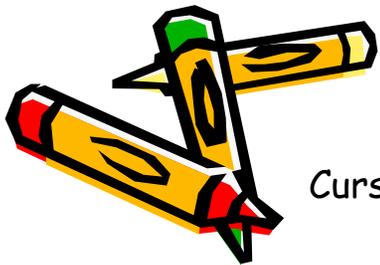
## Defecte si surse de defecte in cabluri cu izolatie din polietilena



Goluri in izolatia in care intra apa



Izolatie distrusa prin dezvoltarea golurilor in canale, sub influenta unei descarcari partiale sau a unui test de tensiune.



## Testarea in c.c. (DC Hi-pot Testing)

- Se utilizeaza atat ca test de tip 1, cat si ca test de tip 2.
- Este recomandat testarii cablurilor cu izolatie din hartie si pentru siguranta, inainte de conectare, a cablurilor cu izolatie extrudata
- Tensiunea aplicata este mai mare de 5kV.
- Se aplica cablurilor ecranate de medie tensiune.
- Trebuie respectate conditii de securitate, conform standardelor.
- Dupa testare, cablul trebuie legat la pamant pentru a asigura scurgerea sarcinilor.

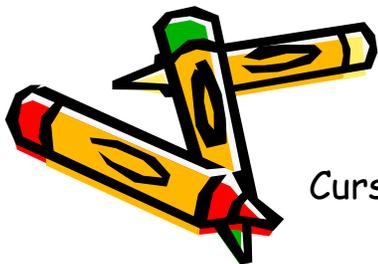


Curs 7



## PROCEDURA DE MASURARE

- Se desfasoara activitati preparatorii (pamantarea celorlalte cabluri, curatirea terminalelor conductorului testat, evitarea descarcarilor de tip Corona, etc)
- Se aduce tensiunea la cea prescrisa in cinci pasi, fiecare nivel de tensiune fiind mentinut pentru 60 de secunde.
- Se mentine tensiunea de testare nu mai putin de 10 min, dar nici mai mult de 15 minute.
- Se inregistreaza componenta rezistiva a curentului din 15 in 15 s in primele 2 minute, dupa care numai la un minut.
- Se aduce sursa de tensiune la zero.
- Se masoara tensiunea pe cablu la 30 de secunde, respectiv 60 secunde.
- Se conecteaza pamantarea si se indeparteaza setul de testare numai cand tensiunea pe cablu a ajuns la 0V.

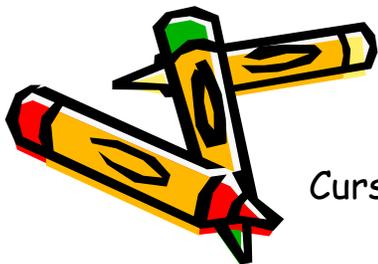


## INTERPRETAREA REZULTATELOR

- ❑ Componenta rezistiva a curentului trebuie sa aiba o variatie liniara pe perioada modificarii tensiunii pana la valoarea de testare.
- ❑ O instabilitate a curentului pe perioada de aplicare a tensiunii de test poate indica o problema. In aceste cazuri se recomanda extinderea perioadei de testare.
- ❑ Curentul trebuie sa scada. Daca nu se intampla acest lucru, sau daca acesta incepe sa creasca este semn al unei probleme grave. Se recomanda extinderea perioadei de testare.

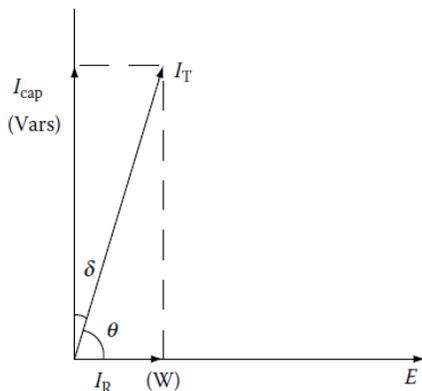


Rated Voltage Phase To Phase (kV)	Conductor Size (AWG or kcm)	Nominal Insulation Thickness (mils)		On-Reel Testing Maximum DC Hi-Pot Voltage (kV)		Installation Testing Maximum DC Hi-Pot Voltage (kV)		Maintenance Testing Maximum DC Hi-Pot Voltage (kV)*	
		100%	133%	100%	133%	100%	133%	100%	133%
5	8 - 1000	90	115	26	34	28	36	9	11
	1001 - 3000	140	140	26	34	28	36	9	11
8	6 - 1000	115	140	34	41	36	44	11	14
	1001 - 3000	175	175	34	41	36	44	11	14
15	2 - 1000	175	220	53	60	56	64	18	20
	1001 - 3000	220	220	53	60	56	64	18	20
25	1 - 3000	260	320	75	90	80	96	25	30
28	1 - 3000	280	345	79	94	84	100	26	31
35	1/0 - 3000	345	420	94	116	100	124	31	39
46	4/0 - 3000	445	580	124	161	132	172	41	54



## Testarea pe baza masurarii factorului de putere/factorului de disipare

- ❑ Furnizeaza informatii asupra starii generale a izolatiei.
- ❑ Nu solicita izolatiea.
- ❑ Prin aceasta metoda se masoara capacitatea electrica a izolatiei, pierderile in dielectric si raportul acestora.
- ❑ Trebuie facute corecturile datorate temperaturii si nivelului de umiditate la momentul masurarii.



$$I_{cap} = E \omega \epsilon_0 \epsilon_r \left( \frac{A}{d} \right)$$

$I_{cap}$  indica degradari la nivelul izolatiei de tipul umezelii, ingustarea stratului, modificari in geometria izolatei.

$I_R$  indica pierderile in dielectric.



## Testele la frecventa foarte joasa

- Se realizeaza utilizand curent alternativ la o frecventa foarte joasa (0.01 ...1Hz).
- Poate fi utilizat ca test de acceptare (la tensiune mai mare ca cea de lucru), dar si ca test in procedurile de mentenanta (la tensiune mai mica decat tensiunea de lucru).
- Formele de unda pentru testul de acceptare pot fi: cosinusoidala, rectangulara, sinusoidala, rectangulara bipolară, tensiune prag, pozitiva/negativa.
- Se masoara: factorul de disipare, curentul rezistiv, pierderile in dielectric.
- Testele pot dura de la 15 la 60 de minute. Valoarea medie e de 30 minute.

VLF Test Voltages for Cosine-Rectangular Waveform per IEEE 400-2004 (See Note 1)

Cable Rating Phase-to-Phase RMS Voltage (kV)	Installation Phase-to-Ground (See Note 2) RMS Voltage/Peak Voltage	Acceptance Phase-to-Ground (See Note 2) RMS Voltage/Peak Voltage	Maintenance Phase-to-Ground (See Note 3) RMS Voltage/Peak Voltage
5	12	14	10
8	16	18	14
15	25	28	22
25	38	44	33

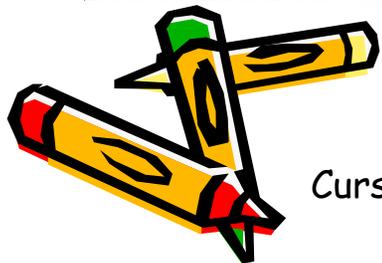
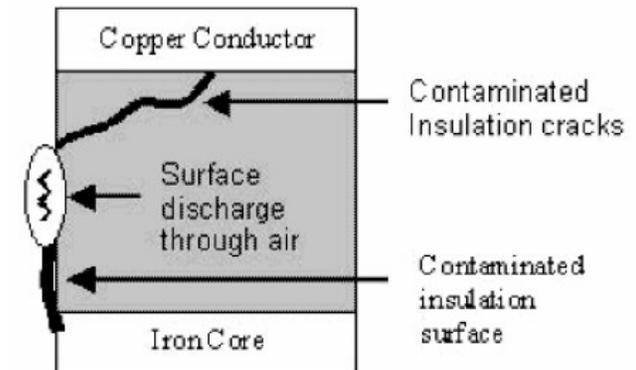
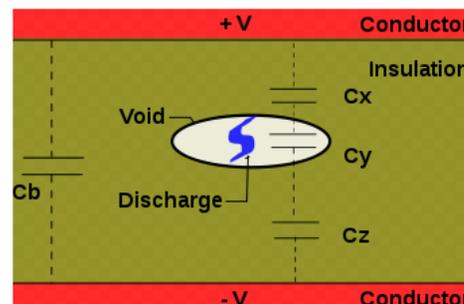
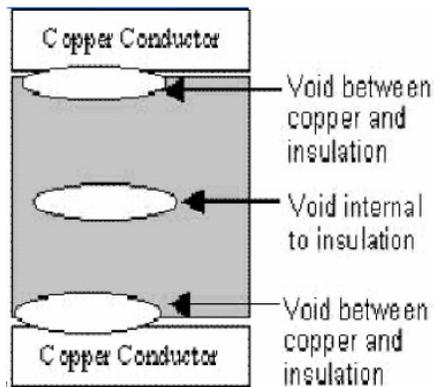
VLF Test Voltages for Sinusoidal Waveform (see Note 1) per IEEE 400.2

Cable Rating Phase-to-Phase RMS Voltage (kV)	Installation Phase-to-Ground (See Note 2) RMS/Peak Voltage	Acceptance Phase-to-Ground (See Note 2) RMS/ Peak Voltage	Maintenance Phase-to-Ground (See Note 3) RMS/ Peak Voltage
5	9/13	10/14	7/10
8	11/16	13/18	10/14
15	18/25	20/28	16/22
25	27/38	31/44	23/33
35	39(55)	44(62)	33(47)



## Testarea de descarcare partiala

- ❑ Descarcarea partiala este o descarcare care apare intr-un gol creat fie de deformari ale ecranului, fie ale izolatiei, sau in izolatiile cu probleme de tip “water tree”, la tensiuni inalte (<http://www.youtube.com/watch?v=GRmOyUGAODA>).
- ❑ Forma de unda este o reprezentata de o serie de pulsuri de cate o jumatate de ciclu a unei unde de curent alternativ.
- ❑ Se aplica atat ca si test de acceptare, cat si va test de mentenanta.
- ❑ Masuratorile se pot face atat on-line, cat si off-line

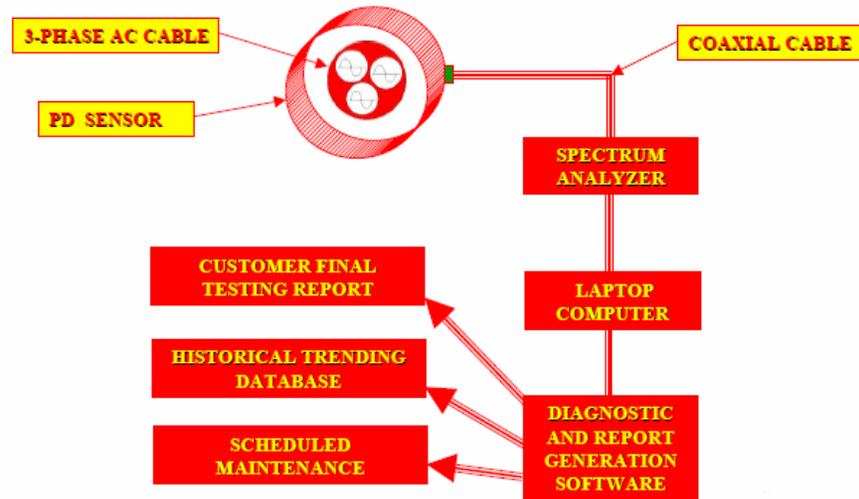


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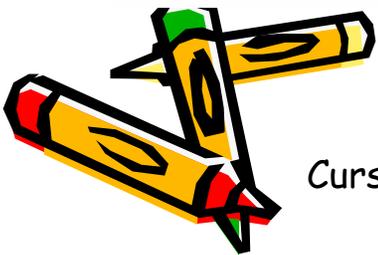
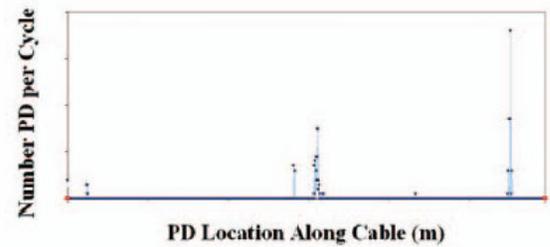
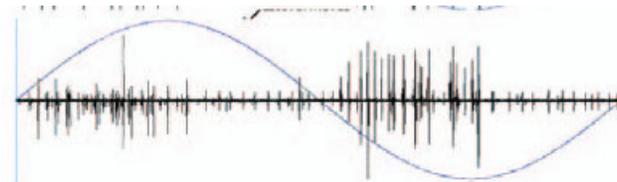
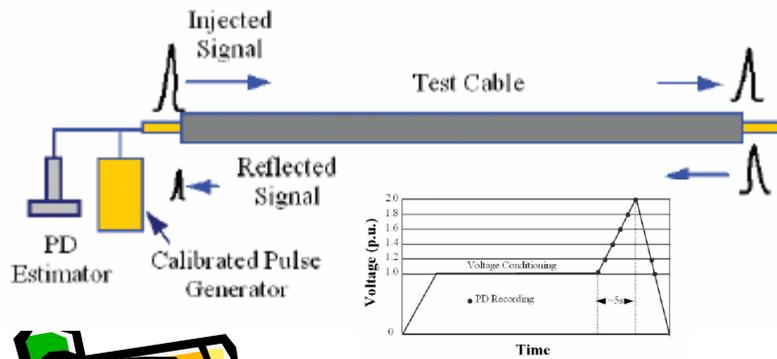
<http://www.youtube.com/watch?v=9wZZmte6VgA>



## Echipment pentru testare on-line



## Echipment pentru testare off-line



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Testarea liniilor de inalta tensiune :

<http://www.youtube.com/watch?v=9tzga6qAaBA>

