ELEC-E8422 An Introduction to Electric Energy

Exercise Session 7: Electric Safety

**EX1**

A big man gets in contact with a conductor having voltage 230 V. What is the current flowing through his body. Body resistance is 1000 Ω and soil resistivity is a) ρ=100 Ωm, b) ρ=2300 Ωm. c) How long it takes until he gets heart fibrillation.

**EX2**

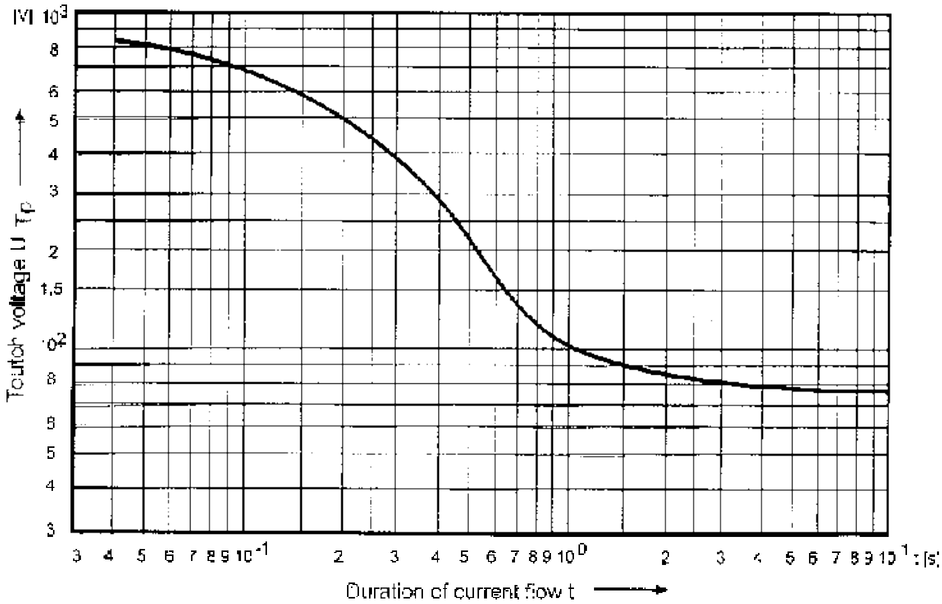
A man climbs 10 m high wood pole having total resistance 1 MΩ. On the top of the pole, the insulator is broken and the cross arm is in 20 kV voltage (line voltage, i.e. phase-phase). Man is carrying a grounding wire, the other part of which is in contact to soil (assume 10 kΩ contact resistance). Assume that the body resistance is 1000 Ω and that the man can stand 20 mA current until he can't control his muscles any more. How high can he climb? (in this kind of situation, if he does not fall down, he will die in about 20 seconds because of respiratory tetanus ….).

**EX3**

A man is running on soil of 2300 Ωm resistivity. In close by network happens a single phase to ground fault of 100 A. How large a current flows through the man, if body resistance is 1000 Ω and we assume one foot being 5 m from the fault point and the other 6 m. Use Thevenin's method.

**EX4**

At a distribution transformer takes place a single phase to ground fault, which causes 50 A current to flow to a 20 Ω grounding resistance. How quickly must the fault current be interrupted in a) base case, b) if potential grading is in use?



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**EX1**

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Part a)

Let us use for one foot grounding resistance the approximated value Rg ~ 3ρ, which gives for 100 Ωm soil resistance 300 Ω per leg (note: two legs ...).

Current will be $I = \frac{U}{R} = \frac{230\ V}{1000+\frac{1}{2}300\ ohm}$ = 200 mA

Part b)

For soil resistivity 2300 Ωm one foot ground resistance is 6900 Ω.

Current will be $I = \frac{U}{R} = \frac{230\ V}{1000+\frac{1}{2}6900\ ohm}$ = 52 mA

Part c)

Time to heart fibrillation is obtained from: t $= \frac{K}{\sqrt{t}}$ where K = 157 mA (> 70 kg)

Let us solve the time: $t = (157mA/I)^2$

200 mA ⇔ 0,6 s

52 mA ⇔ 9 s

**EX2**

A man climbs 10 m high wood pole having total resistance 1 MΩ. On the top of the pole, the insulator is broken and the cross arm is in 20 kV voltage (line voltage, i.e. phase-phase). Man is carrying a grounding wire, the other part of which is in contact to soil (assume 10 kΩ contact resistance). Assume that the body resistance is 1000 Ω and that the man can stand 20 mA current until he can't control his muscles any more. How high can he climb?

Total resistance:

$R = (1 - x/10)\ \mathrm{M\Omega} + (x/10\ \mathrm{M\Omega})\ ||\ (1\ \mathrm{k\Omega} + 10\ \mathrm{k\Omega})$

Total current = phase voltage / R = 11,5 kV / R (phase voltage is line voltage 20 kV / sqrt(3))

Total current is divided inversely between resistances (x/10 MΩ) and (1 kΩ + 10 kΩ).

Which results to x = 4.3 meters.

(above || means parallel connection of resistances)

**EX3**

A man is running on soil of 2300 Ωm resistivity. In close by network happens a single phase to ground fault of 100 A. How large a current flows through the man, if body resistance is 1000 Ω and we assume one foot being 5 m from the fault point and the other 6 m. Use Thevenin's method.

The voltage between feet is:

$$V_{ab} = \frac{\rho I}{2\pi}\left[\frac{1}{ra} - \frac{1}{rb}\right]$$

where Ra = 5m ja Rb = 6m, ρ = 2300 Ωm and I = 100 A ⇔ Vab = 1220 V (Thevenin´s voltage source)

Thevenin'n impedance is the resistance that can be "measured" between the contact points (feet). This 2 times one foot grounding resistance = 2 * 6900 Ω = 13800 Ω = Rth.

Current is now:

I = Vab / (Rth + Rman) = 1220 V / (13800 Ω + 1000 Ω) = 82 mA

**EX4**

At a distribution transformer takes place a single phase to ground fault, which causes 50 A current to flow to a 20 Ω grounding resistance. How quickly must the fault current be interrupted in a) base case, b) if potential grading is in use?

Ue = Ie Re = 50 * 20 V = 1000 V (grounding voltage)

a) Base case: Grounding voltage can be 2Utp, where Utp is touch voltage. This gives Utp = 500 V. The graph below gives accepted time 500 V ⇔ t = 0.2 s.
b) Potential grading: Grounding voltage can be 4Utp. This gives Utp = 250 V. The graph below gives accepted time 250 V ⇔ t = 0.45 s.