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Computer Simulations of Lightning Side Flashes from Grounding Wires to Humans

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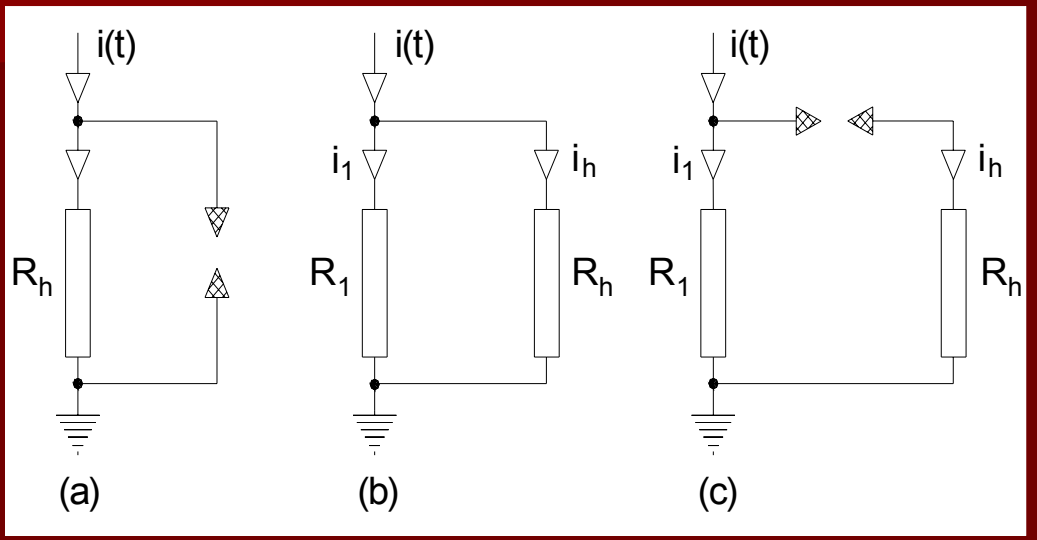
Basis and results

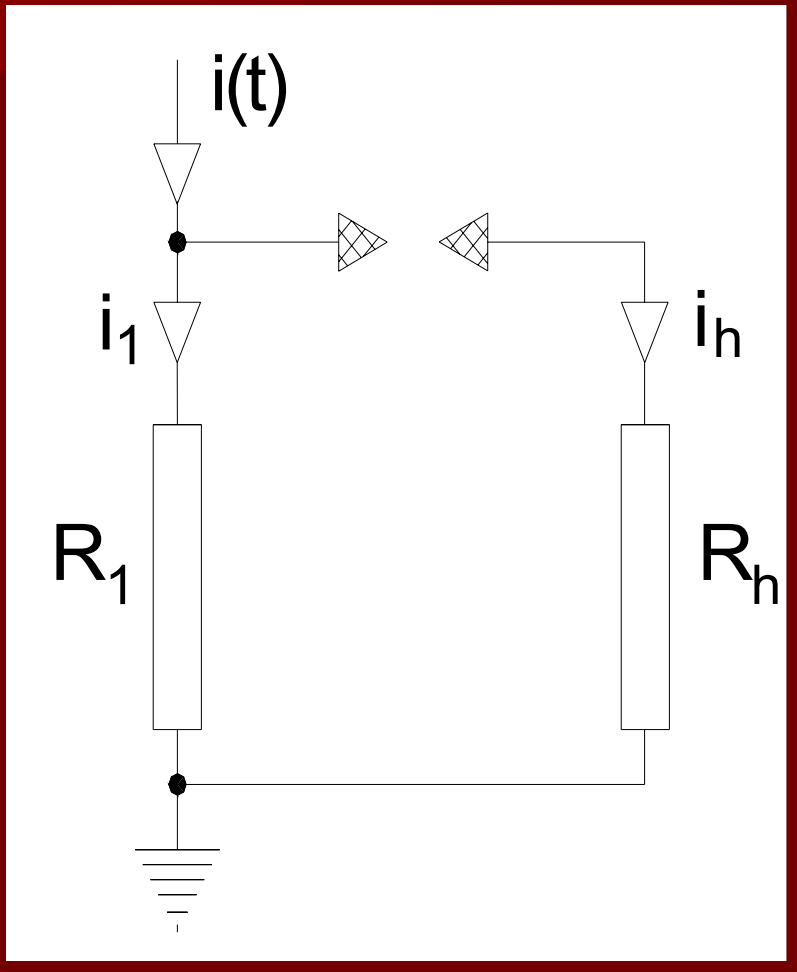
- Taking into account real circumstances, the authors worked up a computer program for calculation and simulation lightning side flash possibility when a human is close to the grounding wire. Critical parameters of the phenomena for mortal hazard may be also calculated.

- The calculated data are :
- *1. Resistance of grounding,*
- *2. Touch voltage*
- *3. Step voltage*
- *4. Critical distance for side flash phenomena,*
- *5. Energy absorbed by a man after side flash vs. the distance between him (her) and the grounding electrode,*
- *6.Energy absorbed by a man as a result of step voltage vs. the distance between him (her) and the grounding electrode*



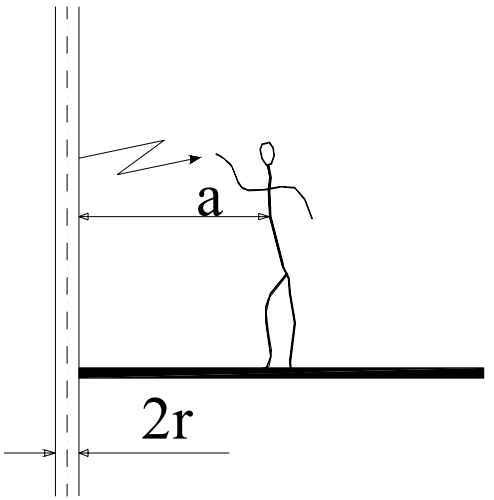
Equivalent circuits for a human in the lightning danger zone (a) direct flash with possibility of shunting flashover (b) contact voltage

(c) side flash

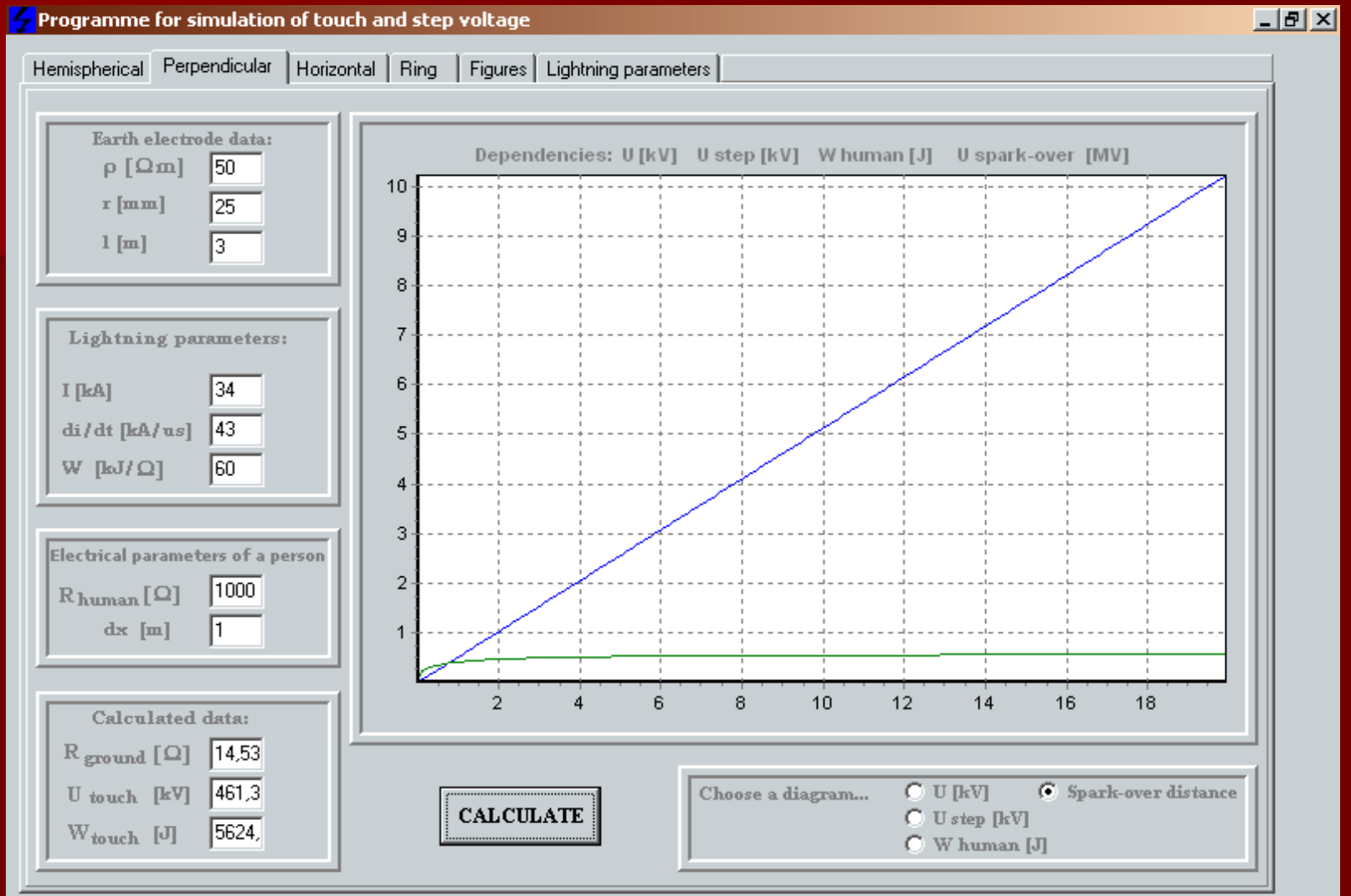

i(t)
i_1
i_h
R_1
R_h

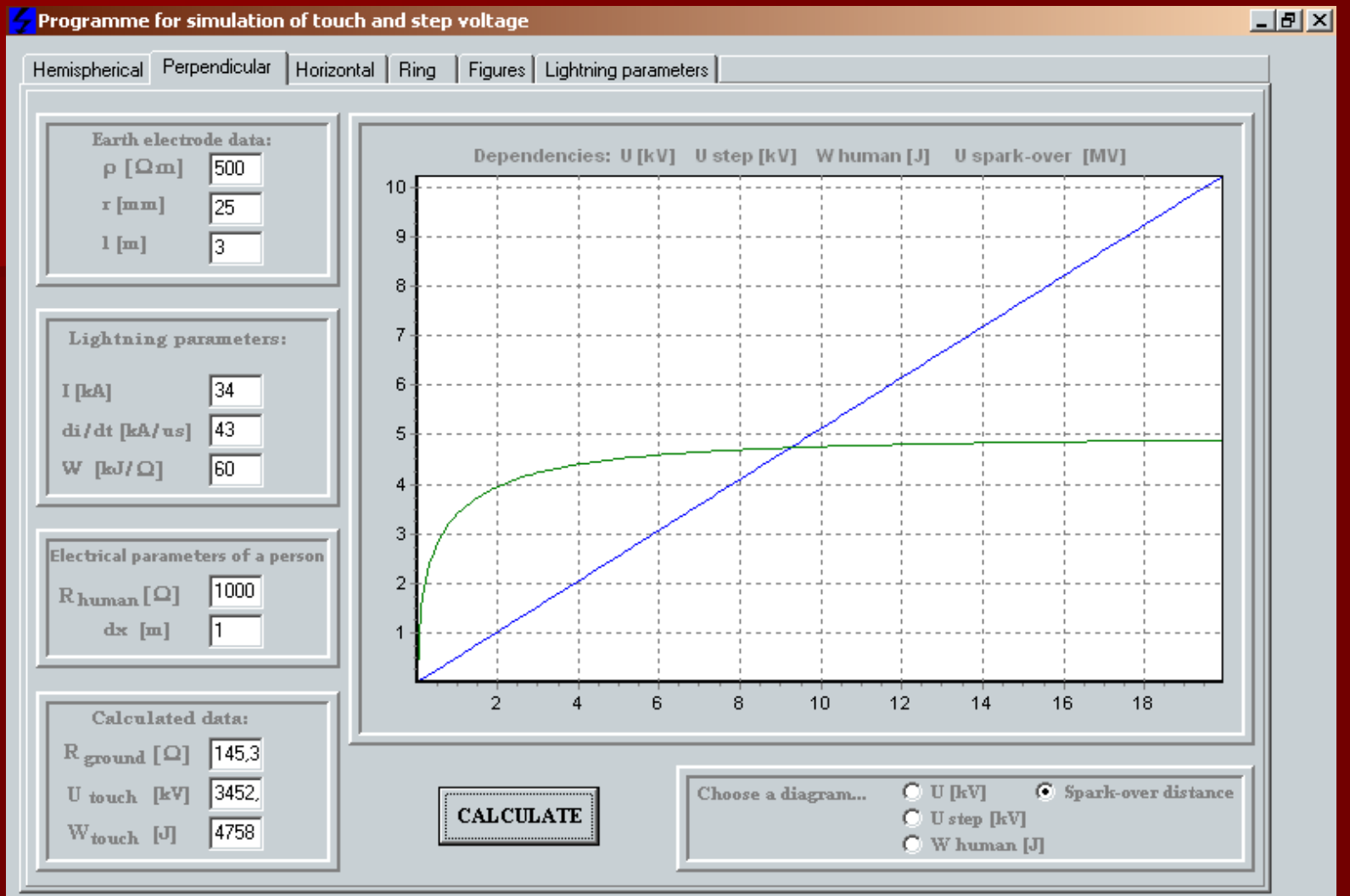
- In this case, the person stays next to an object that is struck by lightning. As the lightning current travels down the struck object, a spark jumps across to the person (side flash). The phenomenon of external flashover may take place if the voltage between the object and the human is high enough to start spark-over.

- The program does not take into account the second type of flashover which may occur outside the body (from head or hand to the earth) – shunting the victim. So, the energy absorbed by the victim may be overestimated.



Not only voltage drop on the resistance but also on inductance is taken into account


Programme for simulation of touch and step voltage
Hemispherical
Perpendicular
Horizontal
Ring
Figures
Lightning parameters
Earth electrode data:
ρ [Ωm] 50
r [mm] 25
l [m] 3
Lightning parameters:
I [kA] 34
di/dt [kA/us] 43
W [kJ/Ω] 60
Electrical parameters of a person
R human [Ω] 1000
dx [m] 1
Calculated data:
R ground [Ω] 14,53
U touch [kV] 461,3
W touch [J] 5624,
Dependencies: U [kV] U step [kV] W human [J] U spark-over [MV]
10
9
8
7
6
5
4
3
2
1
2
4
6
8
10
12
14
16
18
CALCULATE
Choose a diagram...
U [kV]
Spark-over distance
U step [kV]
W human [J]


Programme for simulation of touch and step voltage
Hemispherical
Perpendicular
Horizontal
Ring
Figures
Lightning parameters
Earth electrode data:
ρ [Ωm] 500
r [mm] 25
l [m] 3
Lightning parameters:
I [kA] 34
di/dt [kA/us] 43
W [kJ/Ω] 60
Electrical parameters of a person
R human [Ω] 1000
dx [m] 1
Calculated data:
R ground [Ω] 145,3
U touch [kV] 3452,
W touch [J] 4758
Dependencies: U [kV] U step [kV] W human [J] U spark-over [MV]
10
9
8
7
6
5
4
3
2
1
2
4
6
8
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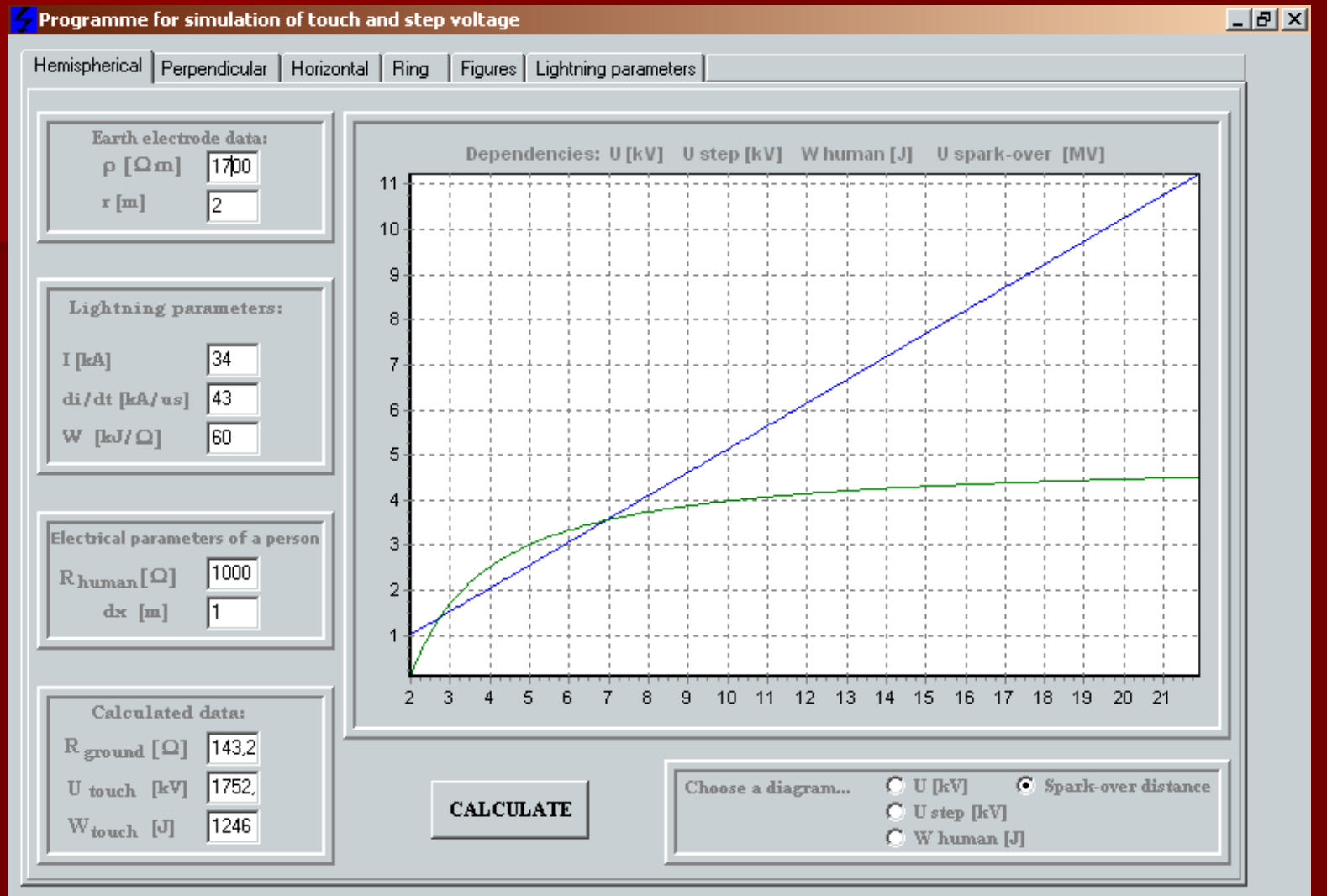
12
14
16
18
CALCULATE
Choose a diagram...
U [kV]
Spark-over distance
U step [kV]
W human [J]


Programme for simulation of touch and step voltage
Hemispherical
Perpendicular
Horizontal
Ring
Figures
Lightning parameters
Earth electrode data:
ρ [Ωm] 1700
r [m] 2
Lightning parameters:
I [kA] 34
di/dt [kA/us] 43
W [kJ/Ω] 60
Electrical parameters of a person
R human [Ω] 1000
dx [m] 1
Calculated data:
R ground [Ω] 143,2
U touch [kV] 1752,
W touch [J] 1246
Dependencies: U [kV] U step [kV] W human [J] U spark-over [MV]
CALCULATE
Choose a diagram...
U [kV]
Spark-over distance
U step [kV]
W human [J]

The energy absorbed by a victim:

When a human shunts the lightning current, the current distribution is as follows

$$\frac{i_h}{i_1} = \frac{R_1}{R_h}$$

and the distribution of energy

$$\frac{W_h}{W_1} = \frac{i_h^2 R_h}{i_1^2 R_1}$$

where:

$R_1\ [\Omega]$ – resistance shunted with a human (that is a part of the total grounding resistance)

$W_1\ [J]$ – Joule's energy dissipated in R_1

$R_h\ [\Omega]$ – resistance of a human

$W_h\ [\Omega]$ – Joule's energy dissipated in R_h

As a result

$$\frac{W_h}{W_1} = \frac{R_h}{R_1}$$

Total energy W_t, dissipated in the resistances R_1 and R_h, is given by the formula

$$W_t = W_1 + W_h = W_{1\Omega} R_{\Xi}$$

where

$$R_{\Xi} = \frac{R_1 R_h}{R_1 + R_h}$$

Assuming typical situation that $R_1 << R_h$, one obtains $W_1 >> W_h$, and as a consequence $W_1 \approx W_{1\Omega} \cdot R_1$. The equation takes the form

$$\frac{W_h}{W_{1\Omega} R_1} \approx \frac{R_1}{R_h}$$

Finally

$$W_h = \sqrt{\frac{W_{1\Omega} R_1}{R_h}}$$

Program do symulacji napięcia dotykowego i krokowego

Półkulowy | Pionowy | Poziomy | Otokowy | Rysunki | Parametry pioruna

Dane o uziomie:

ρ [Ωm]	50
r [m]	2

Parametry wyladowania piorunowego:

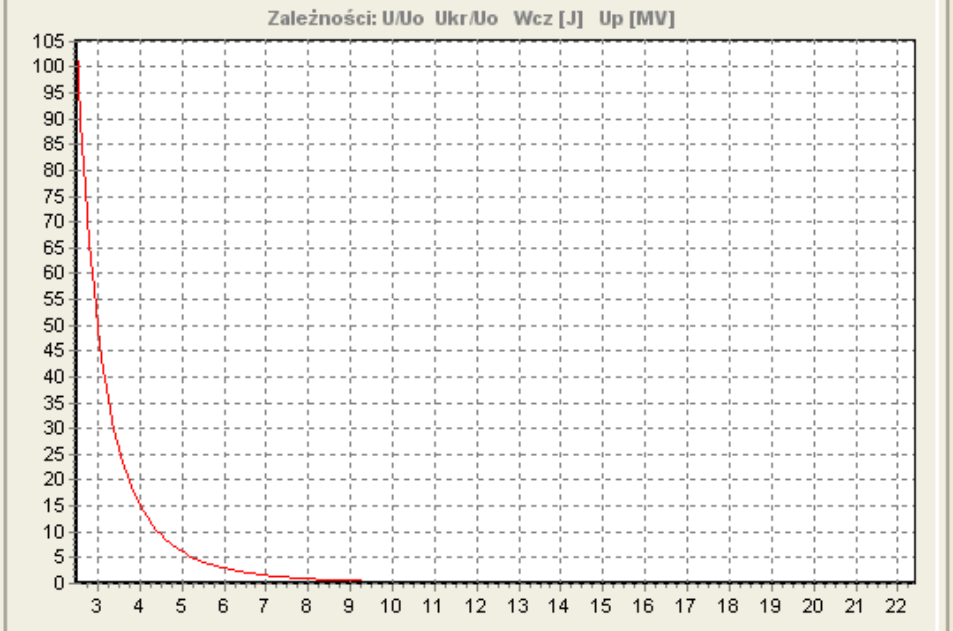
I [kA]	34
di/dt [kA/us]	43
W [kJ/Ω]	60

Dane o czlowieku:

Rcz [Ω]	1000
dx [x]	1

Wartosci obliczone:

Ru [Ω]	3,978
Ud [kV]	174,0
Wd [J]	105,2



Oblicz

Wybierz wykres:
- ○ U/Uo
- ○ Ukr/Uo
- ○ Odleglosc przeskoku
- ◉ Wcz [J]

Program do symulacji napięcia dotykowego i krokowego

Półkulowy | Pionowy | Poziomy | Otokowy | Rysunki | Parametry pioruna

Dane o uziomie:

ρ [Ωm]	50
rw [mm]	25
ro [m]	3
h [m]	0,5

Parametry wyladowania piorunowego:

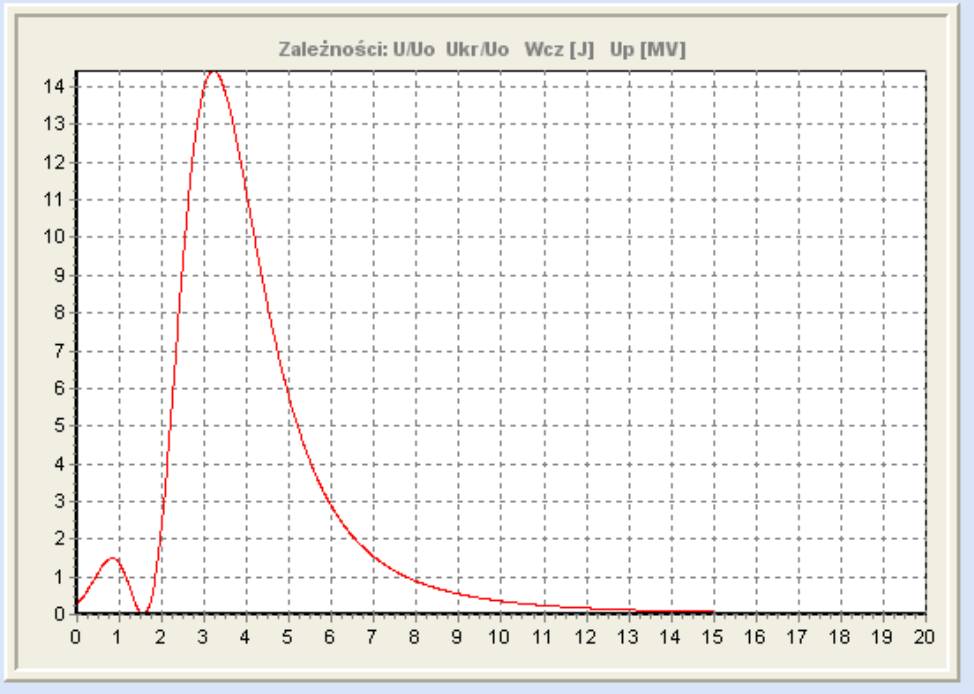
I [kA]	34
di/dt [kA/us]	43
W [kJ/Ω]	60

Dane o czlowieku:

Rcz [Ω]	1000
dx [x]	1

Wartosci obliczone:

Ru [Ω]	4,240
Ud [kV]	200,1
Wd [J]	261,7



Oblicz

Wybierz wykres:

- ○ U/Uo
- ○ Ukr/Uo
- ○ Odleglosc przeskoku
- ◉ Wcz [J]

Program do symulacji napięcia dotykowego i krokowego

Półkulowy | Pionowy | Poziomy | Otokowy | Rysunki | Parametry pioruna

Dane o uziomie:

ρ [Ωm]	50
r [mm]	25
l [m]	5
h [m]	0,5

Parametry wyladowania piorunowego:

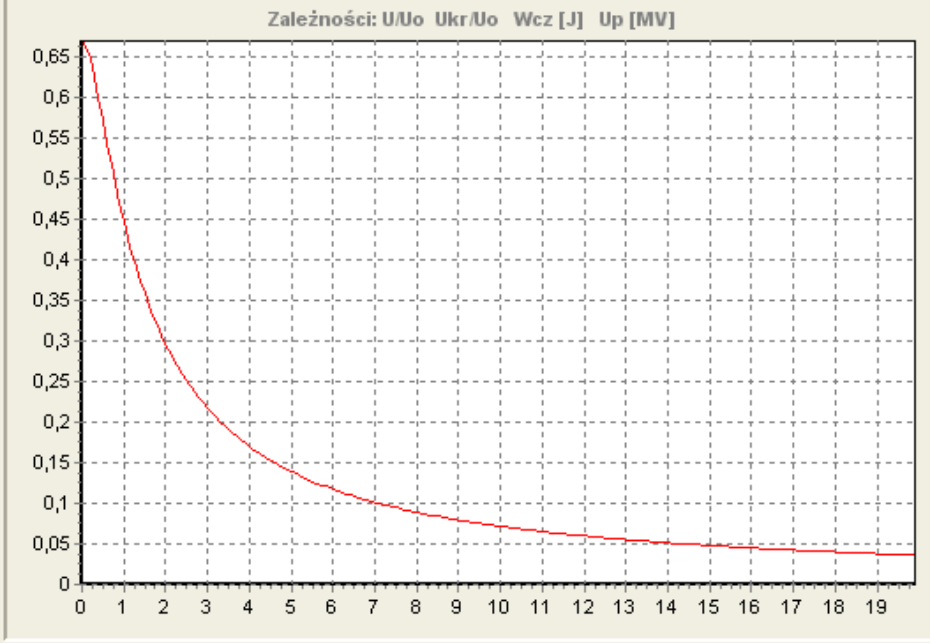
I [kA]	34
di/dt [kA/us]	43
W [kJ/Ω]	60

Dane o czlowieku:

Rcz [Ω]	1000
dx [x]	1

Wartosci obliczone:

Ru [Ω]	10,99	
	os x	os z
Ud [kV]	335,6	261,3
Wd [J]	2189,	901,6



Oblicz

Wybierz wykres:

os x	(•) U/Uo	( ) Ukr/Uo	( ) Wcz [J]	( ) Odleglosc prz.
os z	( ) U/Uo	( ) Ukr/Uo	( ) Wcz [J]	( ) Odleglosc prz.

Program do symulacji napięcia dotykowego i krokowego

Półkulowy | Pionowy | Poziomy | Otokowy | Rysunki | Parametry pioruna

Dane o uziomie:

ρ [Ωm]	50
r [mm]	25
l [m]	5
h [m]	0,5

Parametry wyladowania piorunowego:

I [kA]	34
di/dt [kA/us]	43
W [kJ/Ω]	60

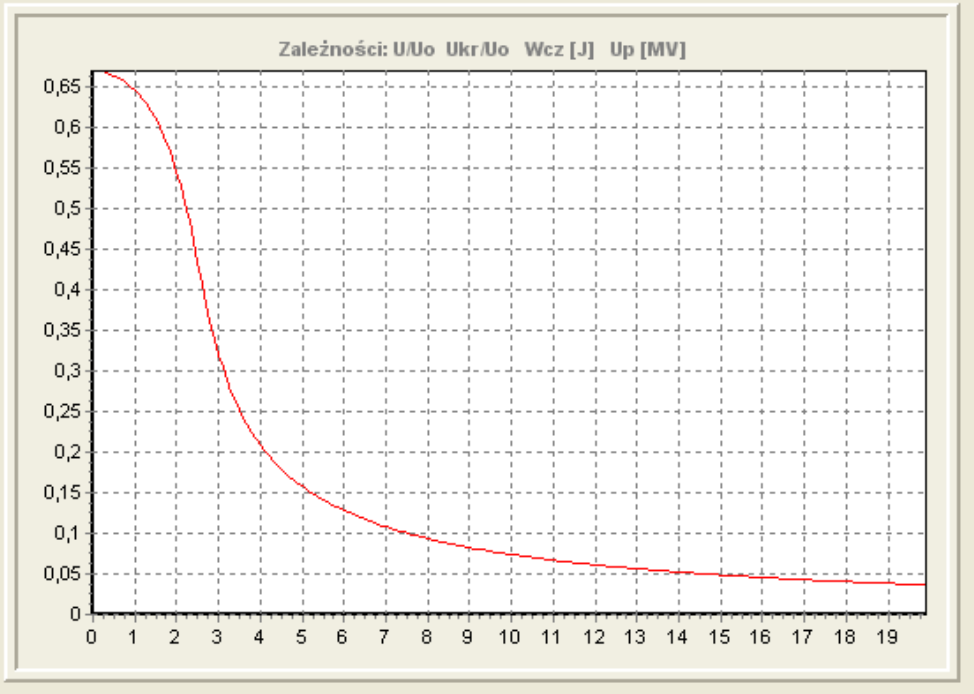
Dane o czlowieku:

Rcz [Ω]	1000
dx [x]	1

Wartosci obliczone:

Ru [Ω] 10,99

	os x	os z
Ud [kV]	335,6	261,3
Wd [J]	2189,	901,6



Oblicz

Wybierz wykres:

os x	○ U/Uo	○ Ukr/Uo	○ Wcz [J]	○ Odleglosc prz.
os z	◉ U/Uo	○ Ukr/Uo	○ Wcz [J]	○ Odleglosc prz.

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