GROUNDING IN ELECTRICAL DISTRIBUTION

GROUNDING

- acc. to ČSN 33 2000-5-54 ed2 (09/2007)
- grounding purpose:
  - people and animals protection against injury (lower touch and step voltage to a safe value)
  - to keep an electrical circuit part on the ground potential
  - to enable function of electrical machines, apparatuses and devices or to help it
  - to protect electrical machines and devices from overvoltages and high currents
  - to divert atmosph. currents and reduce overvoltage

TERMINOLOGY

- **Grounding**
  - conductive connection between a point and the local ground
  - grounded points: generators and transformers neutral points, conductive parts, construction elements
- **Grounding system**
  - all electrical connections and objects which are parts of electrical system, installation and device grounding

TERMINOLOGY

- **Grounding mesh**
  - grounding system part which includes only ground electrodes and their mutual connection
- **Ground electrode**
  - conductive part which can be placed in a given conductive environment (e.g. concrete) with an electrical contact with the ground

TERMINOLOGY

- **Accidental ground electrode**
  - conductive object permanently placed in the ground (water, concrete,…) which was constructed for a different purpose than grounding but can be used as a gr. electrode
- **Artificial ground electrode**
  - gr. electrode intentionally constructed for grounding

GROUND ELECTRODES

- gr. electrode efficiency depends on local soil conditions
- parameters choice:
  - required ground resistance
  - allowed voltage on ground systém
  - allowed touch and step voltage
  - current carrying capacity
  - mechanical strength
  - corrosion endurance
- ground resistance depends on gr. electrode dimensions, placement and ground resistivity

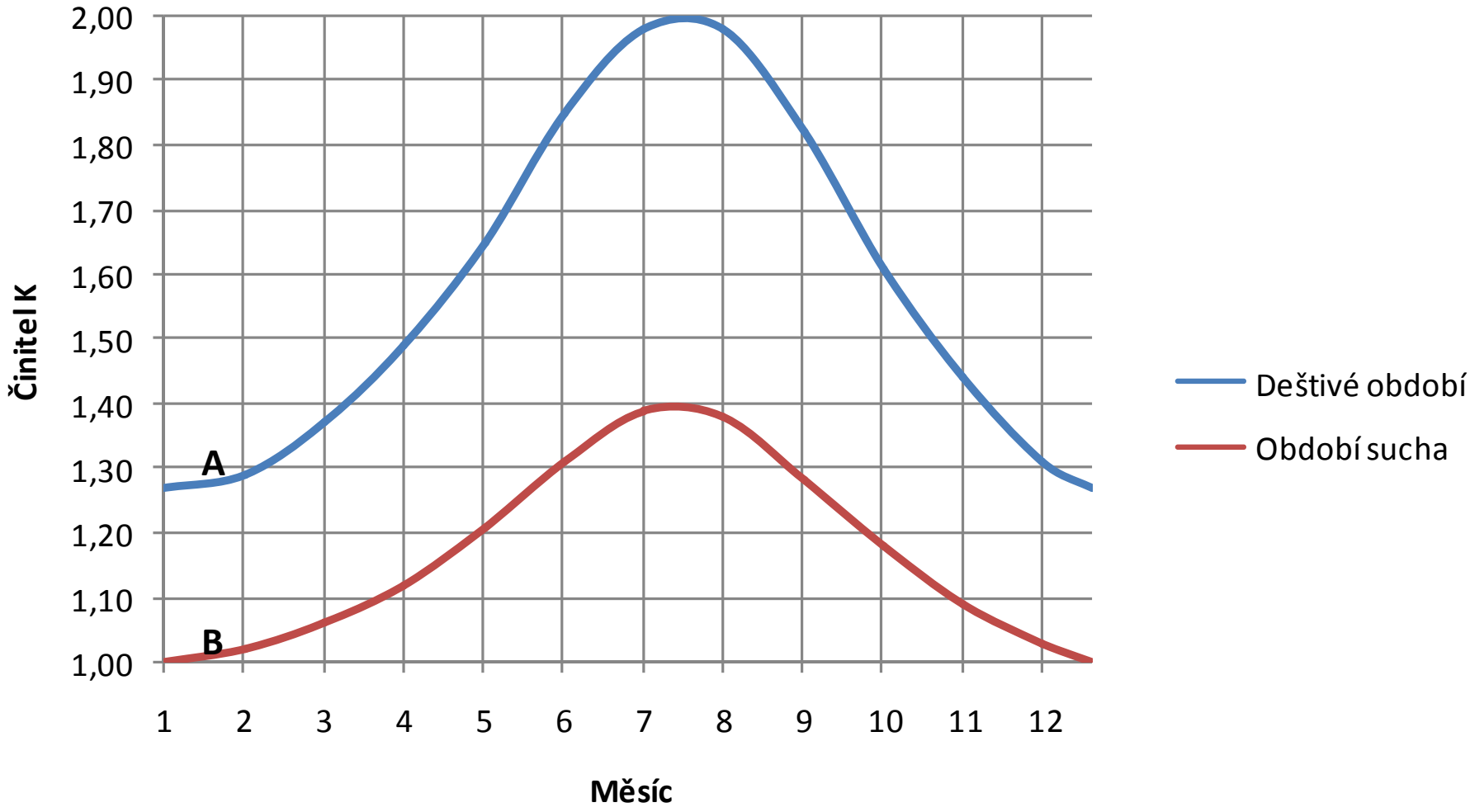
SOIL RESISTIVITY

– depends on soil structure, temperature and humidity

Charakter půdy	Rezistivita (Ωm)
Bažinatá půda	1 ÷ 300
Naplaveniny	20 ÷ 100
Humus, prsť	10 ÷ 150
Vlhká rašelina	5 ÷ 100
Vápenatý a kompaktní jíl	100 ÷ 200
Jílovité písky	50 ÷ 500
Křemenné písky	200 ÷ 3 000
Holé kamenité půdy	1 500 ÷ 3 000
Zatravněné kamenité půdy	300 ÷ 500
Měkký vápanec	100 ÷ 300
Kompaktní vápenec	1 000 ÷ 5 000
Břidlice	50 ÷ 300
Žula a pískovec	1 500 ÷ 10 000
Zvětralá žula nebo zvětralý vápenec	100 ÷ 600

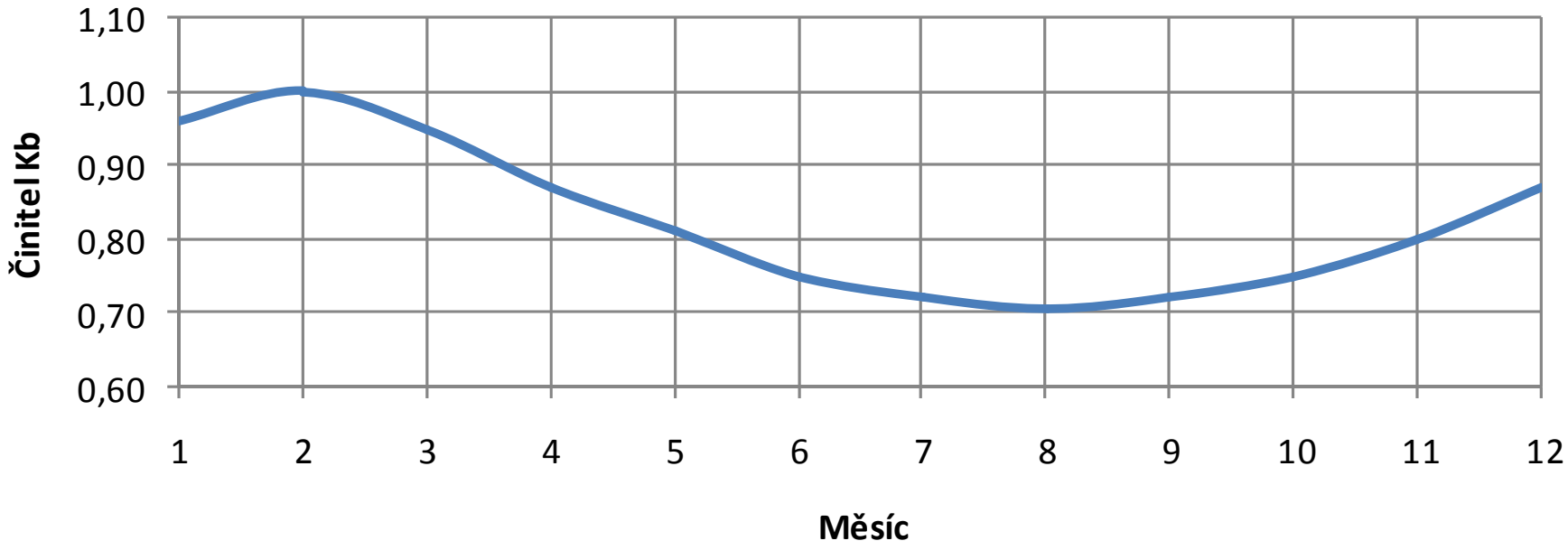
SOIL RESISTIVITY

– soil resistivity changes during the year (Wettstein curves):



CONCRETE RESISTIVITY

– important data for design of e.g. tower base or foundations gr. electrodes:



CURRENT CARRYING CAPACITY

– allowed current densities related to gr. electrode surface:

Doba průchodu proudu	Proudová hustota (A/m2) plochy povrchu zemniče uloženého v půdě o rezistivitě (Ωm):			
	100	**500**	**1 000**	**3 000**
1 s	1 000,0	447,0	316,0	182,0
5 s	447,0	200,0	141,0	82,0
1 hod	16,6	7,5	5,2	3,0
2 hod	11,8	5,3	3,7	2,2
3 hod	9,6	4,3	3,0	1,8

CURRENT CARRYING CAPACITY

– allowed current densities for gr. electrodes placed in concrete:

Doba průchodu proudu	Střední hustota proudu (A/m2) z betonového zákrytu při rezistivitě půdy (Ωm), která jej obklopuje:			
	100	**500**	**1 000**	**3 000**
1 s	1 100,0			
5 s	490,0			
1 hod	26,5	10,8	7,0	2,6
2 hod	18,8	8,2	5,0	1,5
3 hod	15,4	6,8	3,9	0,9
> 3 hod	8,0	4,0	2,0	-

CURRENT CARRYING CAPACITY

– allowed currents for FeZn strips:

Doba průchodu proudu	Dovolený proud (A)		
	30x4 mm	40x4 mm	20x5 mm
0,1 s	26 700	35 600	22 200
0,2 s	18 900	25 200	15 700
0,3 s	15 400	20 500	12 800
0,4 s	13 300	17 800	11 100
0,5 s	11 900	15 900	9 960
0,6 s	10 900	14 500	9 090
0,7 s	10 100	13 400	8 420
0,8 s	9 450	12 600	7 870
0,9 s	8 910	11 800	7 420
1,0 s	8 450	11 200	7 040

Profil	Dovolený trvalý proud (A)
Pásek 30x4	420
Pásek 40x4	540
Pásek 20x5	330
Drát ∅10	220

GR. ELECTRODES REALIZATION

- Accidental:
  - their primary purpose different than grounding
  - metal object of large sizes (small contact ground resistance):
    - steel constructions (armatures, line constructions)
    - cable screens
    - rails
  - they should be used preferably – but they must satisfy all conditions as *artificial gr. electrodes*

GR. ELECTRODES REALIZATION

- Artificial:
  - they are constructed if:
    - accidental gr. electrodes don’t satisfy
    - their utilization is required by any regulation
  - type and shape are chosen according to:
    - soil levels resistivity
    - space available for their placement
  - usual shapes:
    - tubes, rods
    - strips, wires
    - plates

ROD GR. ELECTRODES

- small diameter in comparison with length
- suitable for places with lower gr. resistivity
- steel rods (tubes, alternatively L, I, U, T profiles) 2÷3 m long
- using more rods – distances min 2l (interconnected)
- top end 0,5 m under ground surface
- unpleasant potential distribution

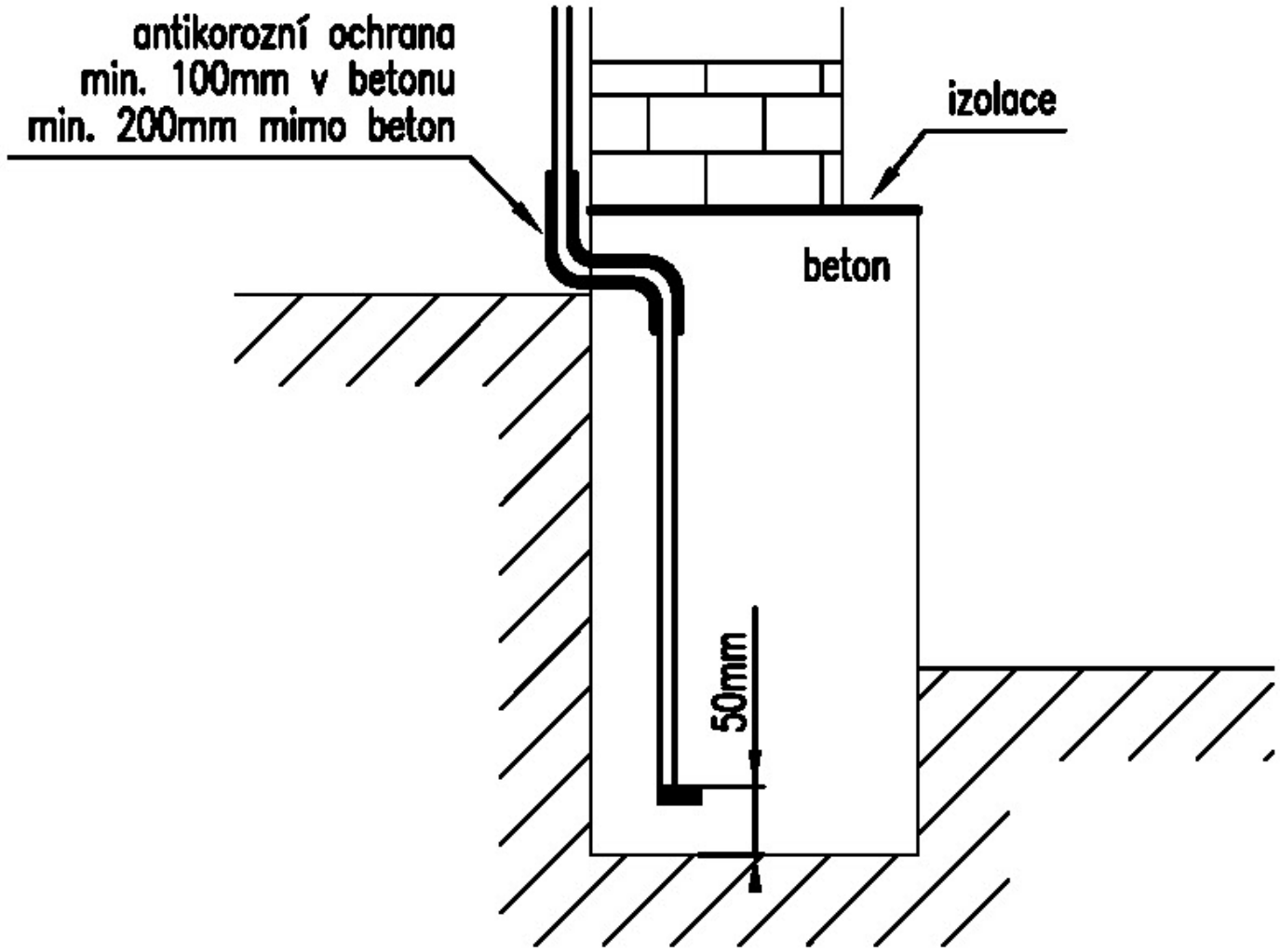
PLATE GR. ELECTRODES

- flat gr. electrode
  - thickness min 3 mm
  - area min 2 x 0,5 m^2
- using more plates – distances c. 3 m
- vertically placed square plates (0,5÷1 m under surface) were often used once
- today little used (higher resistance)

STRIP GR. ELECTRODES

- most often utilization
- strip dimensions: 30x4, 30x3, 40x4
  - thickness min 3 mm
  - cross-section min 80 mm^2
- strip length according to soil conditions and ground resistance requirement
- placed horizontally in depth 0,5÷1 m
- configuration: radiuses, rings, meshes

FOUNDATIONS GR. ELECTRODE



FOUNDATIONS GR. ELECTRODE

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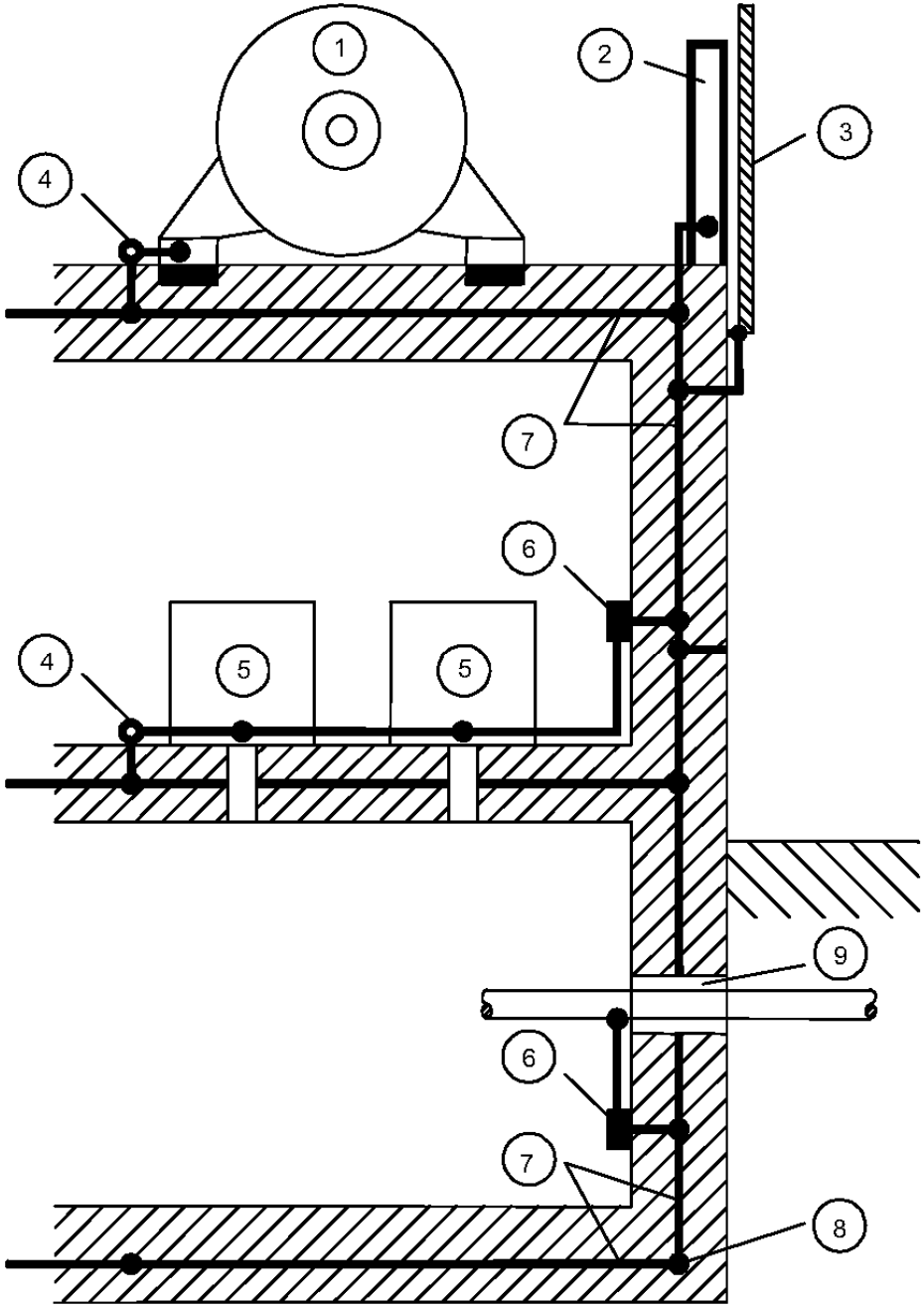


GROUND RESISTANCE

- max. allowed value (from touch voltage allowed value)
- up to 1kV (generally):

$$R \leq \frac{U_d}{I_V} \ (\Omega; V, A)$$

R – allowed resistance

U_d – allowed touch voltage

I_V – protection relay switching-off current

- required values (LV):
  - $R \leq 10\ \Omega$ – one lead grounding LPS
  - $R \leq 5\ \Omega$ – machine neutral point grounding
  - $R \leq 2\ \Omega$ – all protective conductors and source neutral point resistance

PRACTICAL DESIGN

- approximate relation for determination of gr. electrodes number and dimensions:

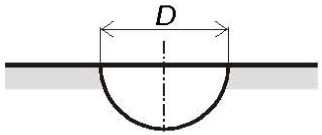
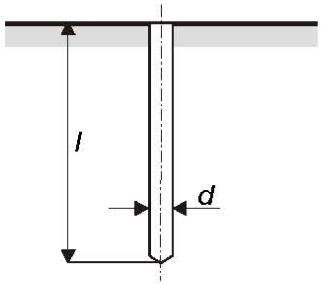
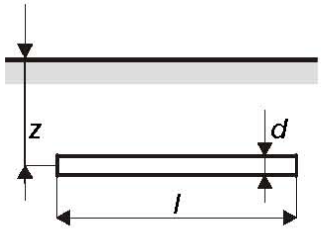
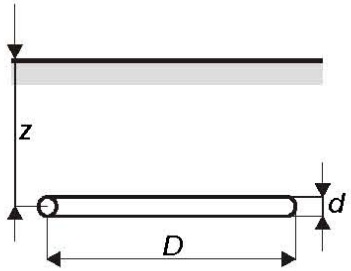
$$R = k\frac{\rho}{l}\ (\Omega; -, \Omega m, m)$$

l – gr. electrode max. dimension

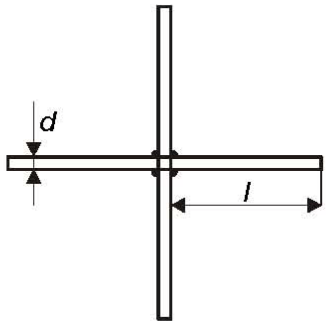
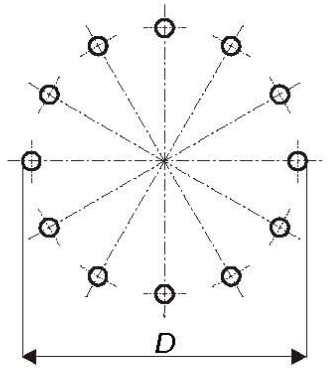
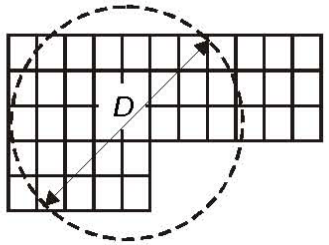
k – gr. electrode shape and placement coefficient (rod: 0,9; pásek: 2,0)

- exact calculation:
  - complicated
  - current field, voltage distribution (QuickField, FEMlab, Opera3D, …)
  - often simplifications: point source (half-sphere)

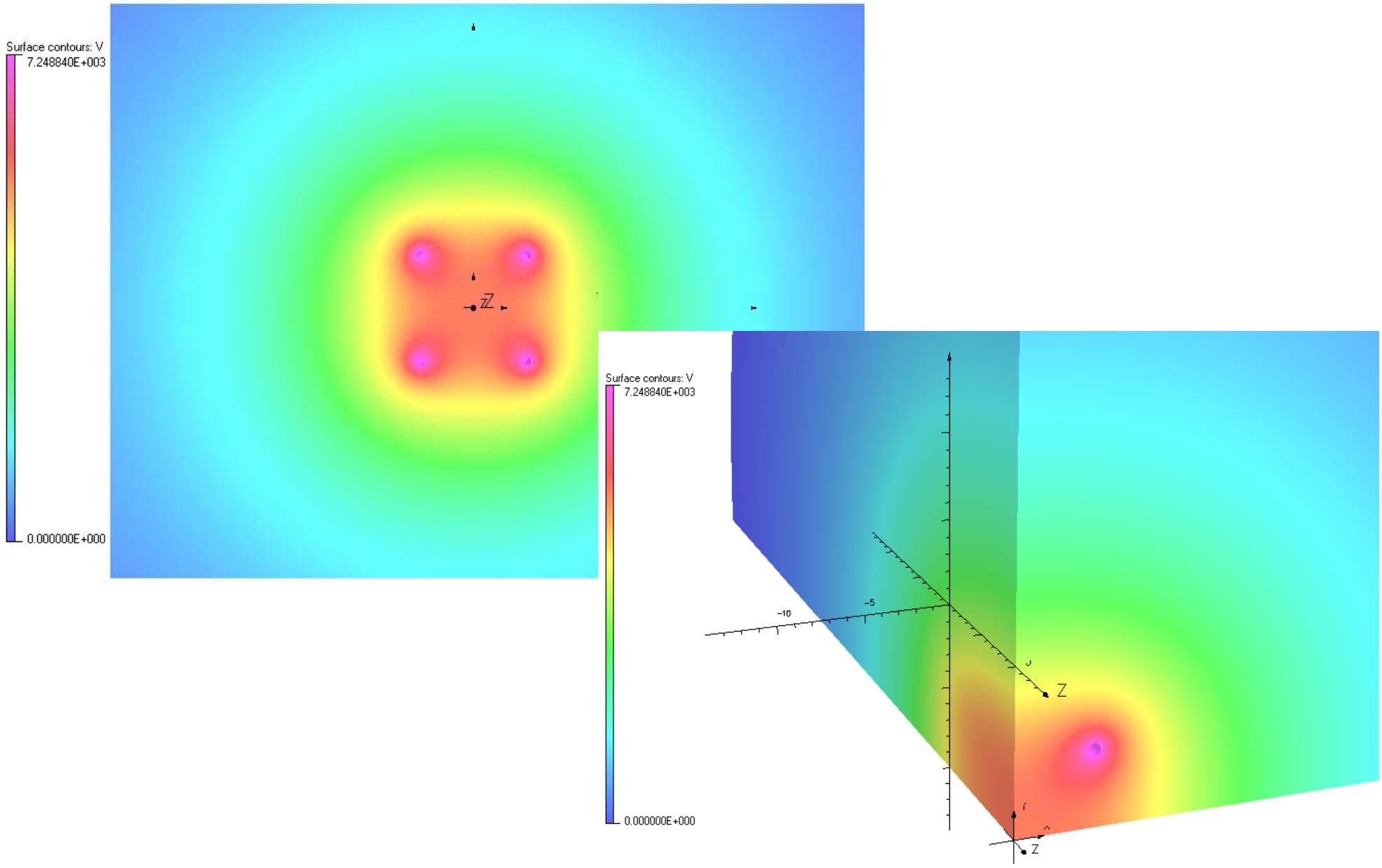
GROUND ELECTRODES

Typ zemniče *parametry*	Uložení	Exaktní vztah	Podmínky použití	Zjednodušený vztah	Podmínky použití
Polokoule		$R = \frac{\rho}{\pi \cdot D}$	–	–	–
Tyč (trubka)		$R = \frac{\rho}{2\pi l} \ln \frac{4l}{d}$	$l \gg \frac{d}{2}$	$R = 0,9 \frac{\rho}{l}$	$l \gg \frac{d}{2}$ $l = 1 \div 3m$
Pásek (drát)		$R = \frac{\rho}{2\pi l}\left(\ln \frac{2l}{d} + \ln \frac{l}{2z}\right)$	$l \gg d$ $z \ll \frac{l}{4}$	$R = 2 \cdot \frac{\rho}{l}$	$l \gg d$ $z \ll \frac{l}{4}$ $l = 10 \div 50m$
Prstencový zemnič		$R = \frac{\rho}{2\pi^2 D}\left(\ln \frac{8D}{d} + \ln \frac{\pi D}{2z}\right)$	$D \gg d$ $z \ll \frac{D}{2}$	$R = 2,1 \cdot \frac{\rho}{l}$	$D \gg d$ $z \ll \frac{D}{2}$ $\frac{D}{z} \gg 10$

GROUND ELECTRODES

Typ zemniče *parametry*	Uložení	Exaktní vztah	Podmínky použití	Zjednodušený vztah	Podmínky použití
Paprskový zemnič		$R = \frac{\rho}{4\pi l}\left(\ln\frac{2l}{d}+1\right)$	$l \gg d$	$R = 0,7\cdot\frac{\rho}{l}$	$\frac{l}{4} \gg d$ $l \ll 30m$
Tyče v obvodu		$R = \frac{R_0}{n}+\frac{\rho}{2\pi D}\cdot\frac{1}{n}\sum_{k=1}^{n-1}\frac{1}{\sin\frac{\pi}{n}k}$	$D \gg d$ $l \gg d$	–	–
Mřížová síť		–	–	$R = \frac{\rho}{2D}+\frac{\rho}{l}$	–

MV TOWER GROUNDING



STEP VOLTAGE

- potential field in gr. el. surroundings (also surface)
- potential:
  - the highest on the ground surface
  - proportional to gr. resistance and flowing current (kA)
- step voltage – potential difference on the ground surface on a human step length (0,75÷1 m)
- step voltage size control:
  - gr. electrode placement depth
  - modifications of gr. system edges
  - soil conditions modification
  - barrier (transformer station fence)

STEP VOLTAGE