

Power Supply Systems

EE 334 Power Systems
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Safety
Three-Phase Neutral and Earthing Connections
Equipment Classes
Switches

Earthing

- What is Earthing ?
- Can the earth be used as a return path?
- Is the earth an equipotential surface?

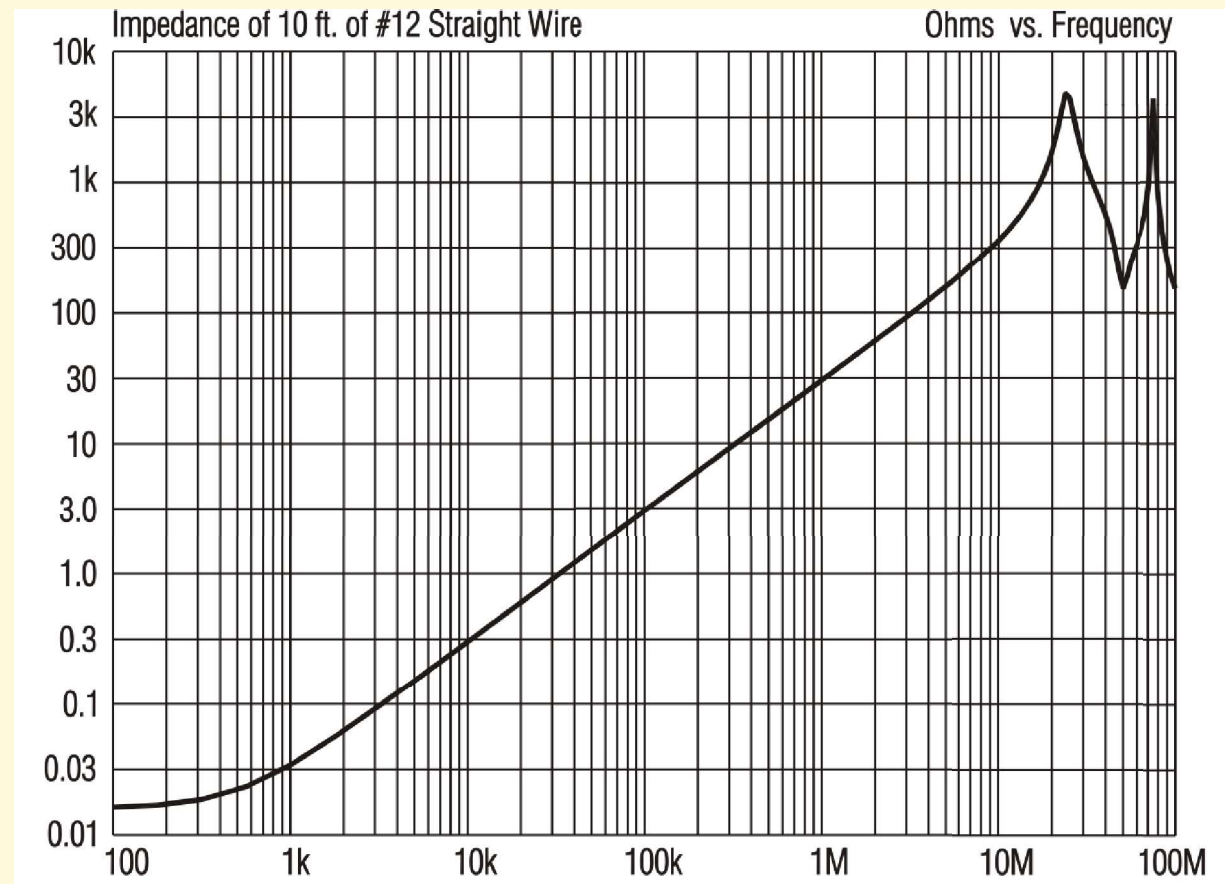
Ground Path (Earthing)

- A **ground** is a return path for current
 - Path can be **intended** or
 - **unintended** (parasitic branches).
- A **ground** is also a point to which circuits may be referenced
 - No **guarantee** that any two points will stay at the same voltage.

Ref: Daryl Gerke, “MYSTERIES OF GROUNDING”, Rocky Mountain Chapter EMC Society, September 2002.

Myths of Earthing

- **Earth grounds are all at zero volts** - 'presumably with respect to each other and to some "mystical absolute" reference point'.
- **Wires have zero impedance.**



Ref: Bill Whitlock, "**UNDERSTANDING, FINDING, & ELIMINATING GROUND LOOPS**", CEDIA Class EST016.

Material Characteristics (20°C)

Material	Resistivity ($\Omega \text{ m}$)	Temp. Coeff. ($^{\circ}\text{K}^{-1}$)
Copper	1.7×10^{-8}	0.004
Aluminium	2.65×10^{-8}	0.0039
Iron	9.7×10^{-8}	0.005
Nichrome	1.1×10^{-6}	0.0004
Sea Water	2×10^{-1}	
Drinking Water	2×10^1 to 2×10^3	
Deionized Water	1.8×10^7	
Alluvial Soil	5	
Granite	1000	
Wood (damp)	10^3 to 10^4	
Wood (oven dry)	10^{14} to 10^{16}	
Air	10^9 to 10^{15}	
Silicon	6.4×10^2	-0.075

Soil resistivity

Types of Soil	Climatic Condition			
	Normal and high rainfall (eg: > 500 mm an year)	Low rainfall and desert condition (eg: < 250 mm an year)		Underground waters (Saline)
	Probable value (Ωm)	Range of values encountered (Ωm)	Range of values encountered (Ωm)	Range of values encountered (Ωm)
(1)	(2)	(3)	(4)	(5)
Alluvium and lighter clays	5	*	*	1-5
Clays (excluding alluvium)	10	5-20	10-100	
Marls	20	10-30	50-300	
Porous limestone	50	30-100		
Porous sandstone	100	30-300		
Quartzites, compact and crystalline limestone	300	100-1000		
Clay slates and slatey shales	1000	300-3000	>1000	30-100
Granite	1000			
Fossile slates, igneous rocks	2000	>1000		

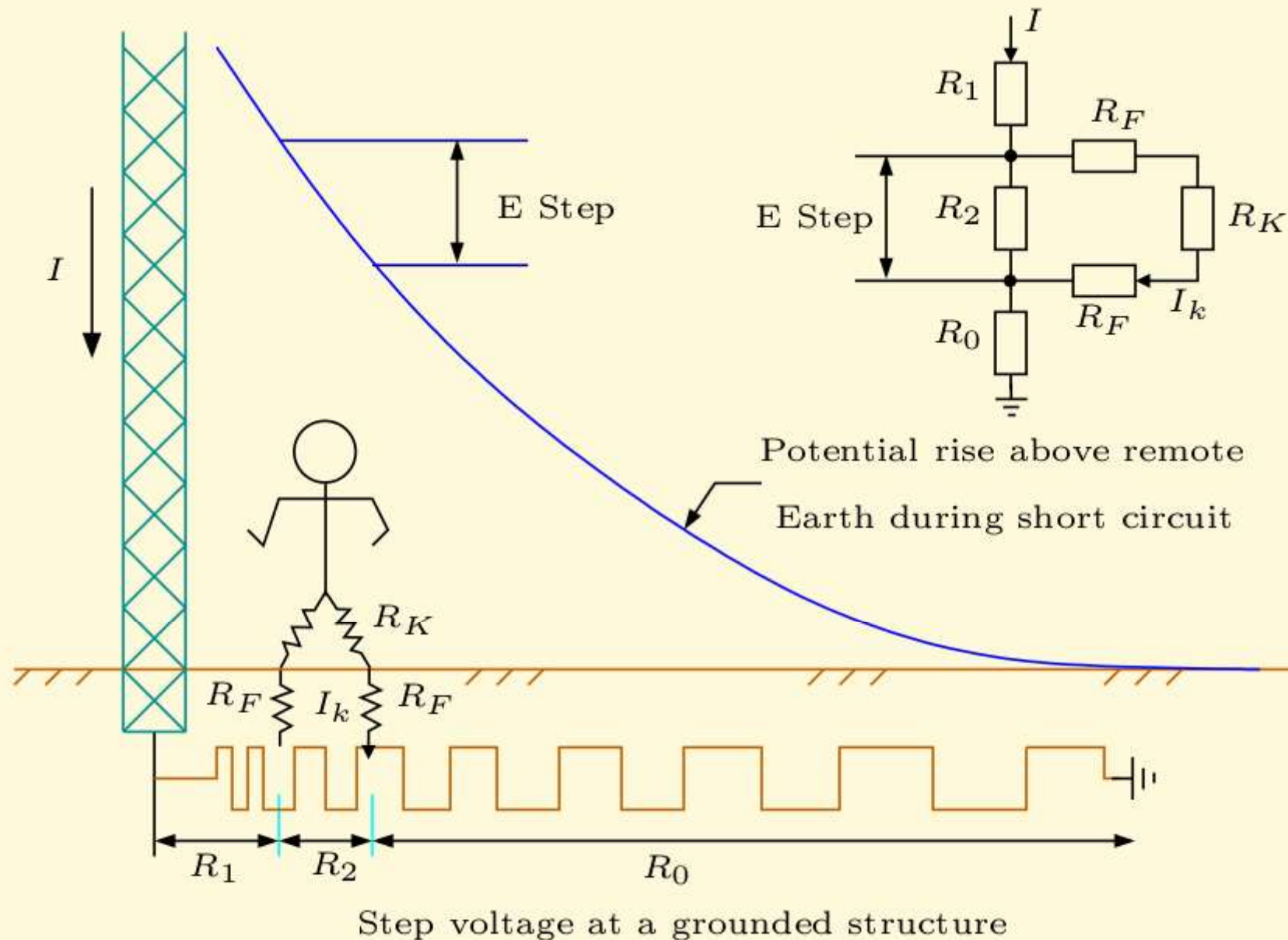
Adapted from: Indian Standard 3043 – 1987.

* depends on water level of locality

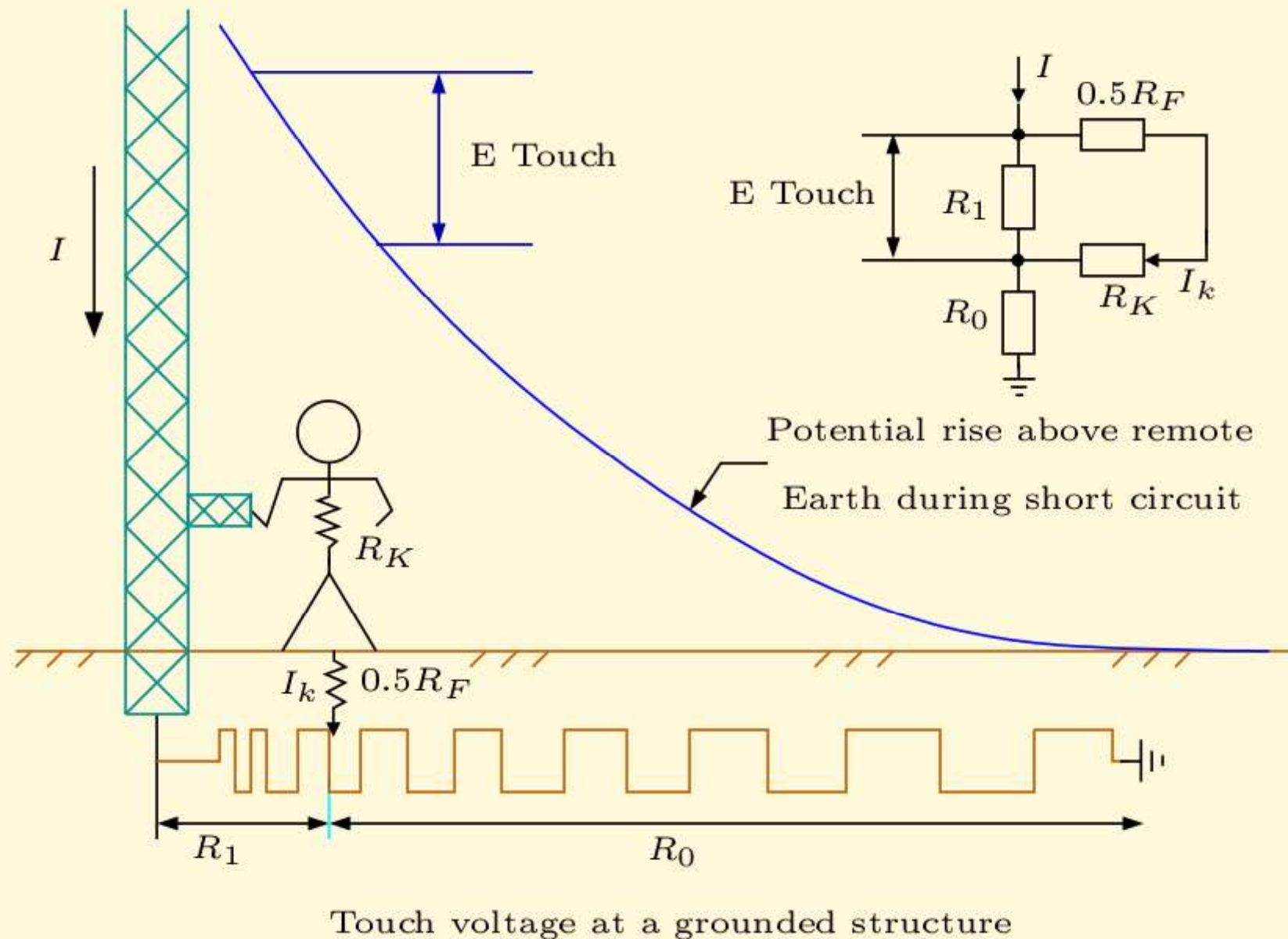
Can ground be a regular current path?

- Not generally used in practice.
- Current can flow through ground during short-circuits.
- A **few** single-wire earth return systems are used in the world.
- For high voltage DC transmission, earth/sea are used as ground returns for short durations.

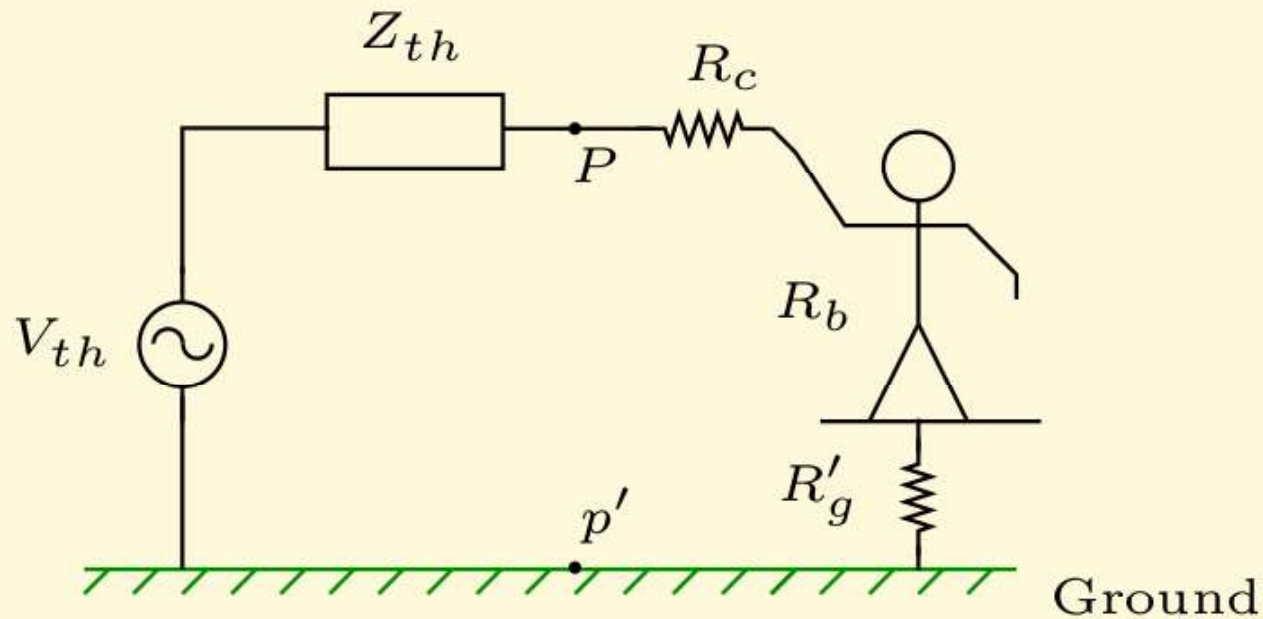
Step Voltage (under short circuit condition)



Touch Voltage (under short circuit condition)



Safety



Z_{th} = Equivalent Impedance

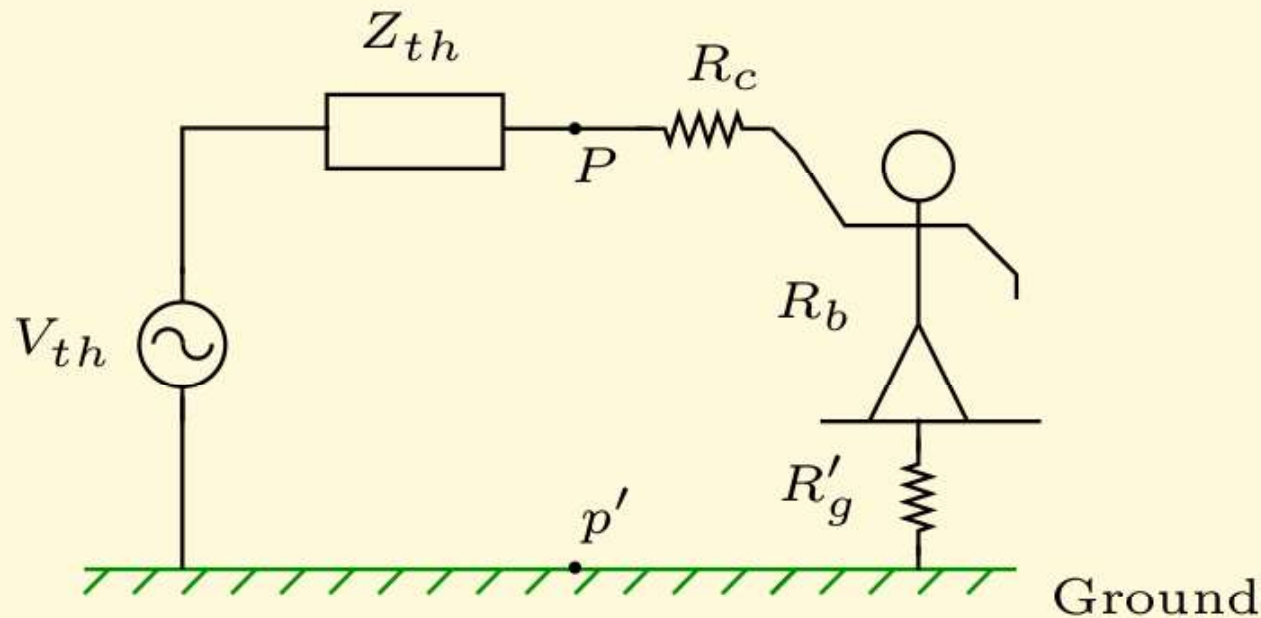
$V_{th} = V_{\text{open-circuit at } P p'}$

$R_c = R_{\text{contact}} \approx 500 \Omega$

$R_b = R_{\text{body}} \approx 1000 \Omega$

$R'_g = R_{\text{ground}} \approx 600 \Omega$

Safety



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Dalziel's electrocution formula

(fatal current for an average human at 60 Hz):

$$I = \frac{0.165}{\sqrt{t}}$$

' I ' is in ampere

' t ' is time in s

Source: Walter Weeks, *Transmission and Distribution of Electrical Energy*, Harper & Row Publishers 1980.

Source: C. F. Dalziel and W. R. Lece, "Lethal Electric Current", *IEEE Spectrum* 6, 44-51 (Feb.-1969).

Typical effects of currents on People

Sr No.	Effect	Current (mA)			
		Direct Current		60 Hz rms	
		Men	Women	Men	Women
1.	No sensation on hand	1	0.6	0.4	0.3
2.	Slight tingling. Perception threshold	5.2	3.5	1.1	0.7
3.	Shock- not painful but muscular control not lost	9	6	1.8	1.2
4.	Painful shock- painful but muscular control not lost	62	41	9	6
5.	Painful shock- let go threshold	76	51	16.0	10.5

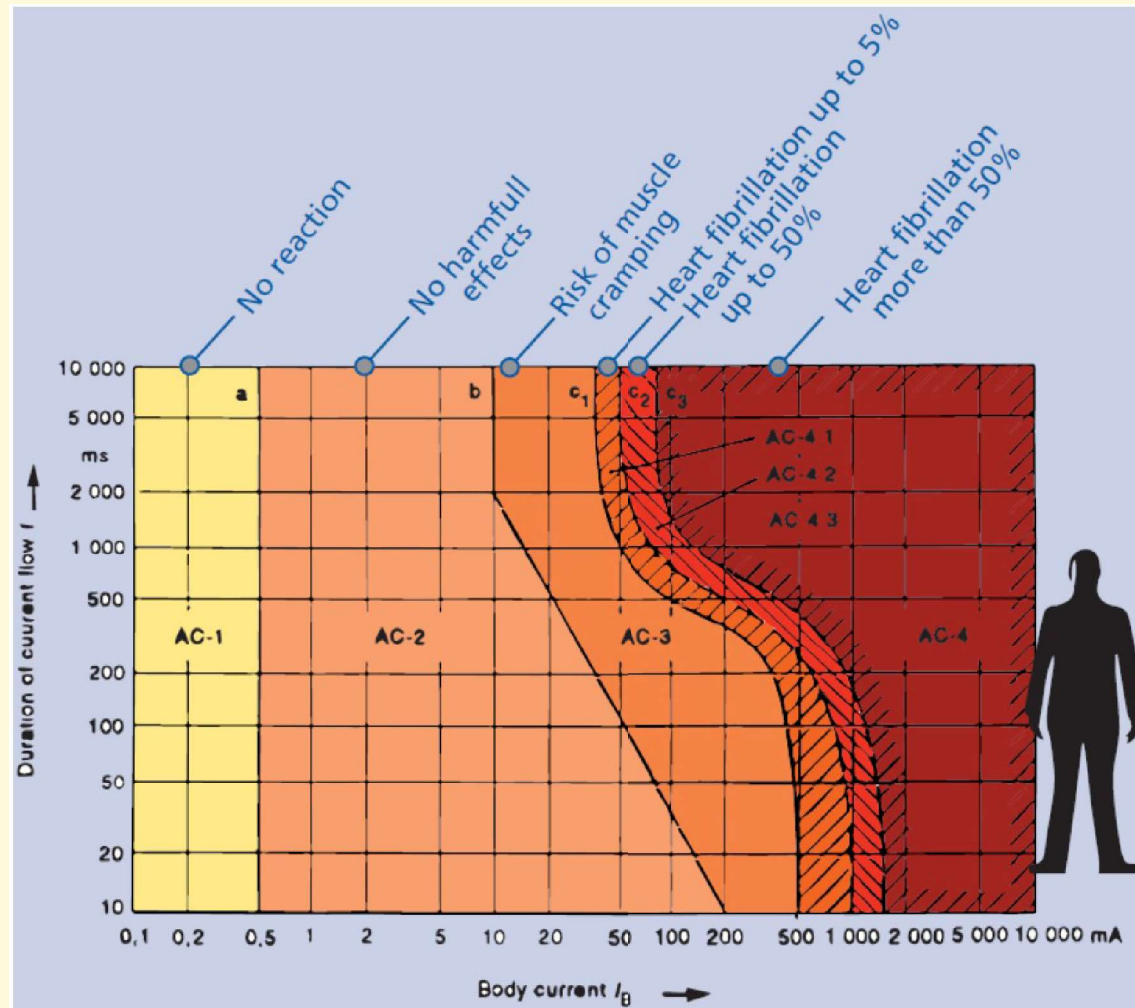
Threshold for 50% of males and females tested.

Typical effects of currents on People ...

Sr No.	Effect	Current (mA)			
		Direct Current		60 Hz rms	
		Men	Women	Men	Women
6.	Painful and severe shock, muscular contractions, breathing difficult	90	60	23	15
7.	Possible ventricular fibrillation from short shocks:				
(a)	Shock duration 0.03 s	1300	1300	1000	1000
(b)	Shock duration 3 s	500	500	100	100
(c)	Almost certain ventricular fibrillation (if shock duration is over one heart beat interval)	1375	1375	275	275

Threshold for 50% of males and females tested.

Effects of current



Source: IEC 60479-1 Technical Report - Effects of current on human beings and livestock

Factors which affect earthing scheme

- Safety
- Service Continuity
- Abnormal Voltage Hazards
- Multiple Faults to Ground
- Location of Faults
- Cost.