IEEE STANDARD 80 – 2000

IEEE SUBSTATIONS COMMITTEE ANNUAL MEETING – CIGRE COLLOQUIUM CHICAGO, IL MAY 19, 2011

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Purpose of IEEE-80

- **Establish as a basis for design, the safe limits of potential differences that can exist in a substation under fault conditions between points that can be contacted by a human body**
- **Review substation grounding practices with special reference to safety, and develop criteria for a safe design**

Purpose of IEEE-80

- **Develop analytical methods as an aid in the understanding and solution of typical gradient problems.**
- **Provide a procedure for the design of practical grounding systems, based on these criteria**

Objectives of a Grounding System

- **To provide means to carry electric currents into the earth under normal and fault conditions without exceeding any operating and equipment limits or adversely affecting continuity of service**
- **To assure that a person in the vicinity of grounded facilities is not exposed to the danger of critical electric shock**

Practical Approach Strives to Control the Interaction of Two Grounding Systems

- **The intentional ground, consisting of the ground electrodes buried at some depth below the earth's surface**
- **The accidental ground, temporarily established by a person exposed to a potential gradient in the vicinity of a grounded facility**

IEEE-80 DESIGN STEPS

- Determine Substation Size and Soil Resistivity
- Determine Fault Current and Clearing Time
- Calculate Tolerable Touch and Step Voltages
- Layout Out Substation Ground Grid

IEEE DESIGN (continued)

- Calculate the Resistance of the Substation
- Calculate the Grid Current
- Calculate the Actual Touch and Step Voltages
- Compare the Tolerable Touch and Step Voltages to the Actual Voltages
- Redesign if Needed

IEEE-80 DESIGN CRITERIA

- **Dalziel's Equation**
- **1000 Ω Body Resistance**
- **Resistance of Foot - 3ρ**
- **Touch Voltage**
- **Step Voltage**
- **Transferred Voltage**
- **Metal-Metal Voltage**

Dalziel's Findings

SS Current	Physiological Effects
1 mA	Perception
1 – 6 mA	Let-go
9 – 25 mA	Difficult or impossible to Let-go
60 – 100 mA	Ventricular Fibrillation

Dalziel's Equation

Current 99.5% of all persons can safely withstand without Ventricular Fibrillation

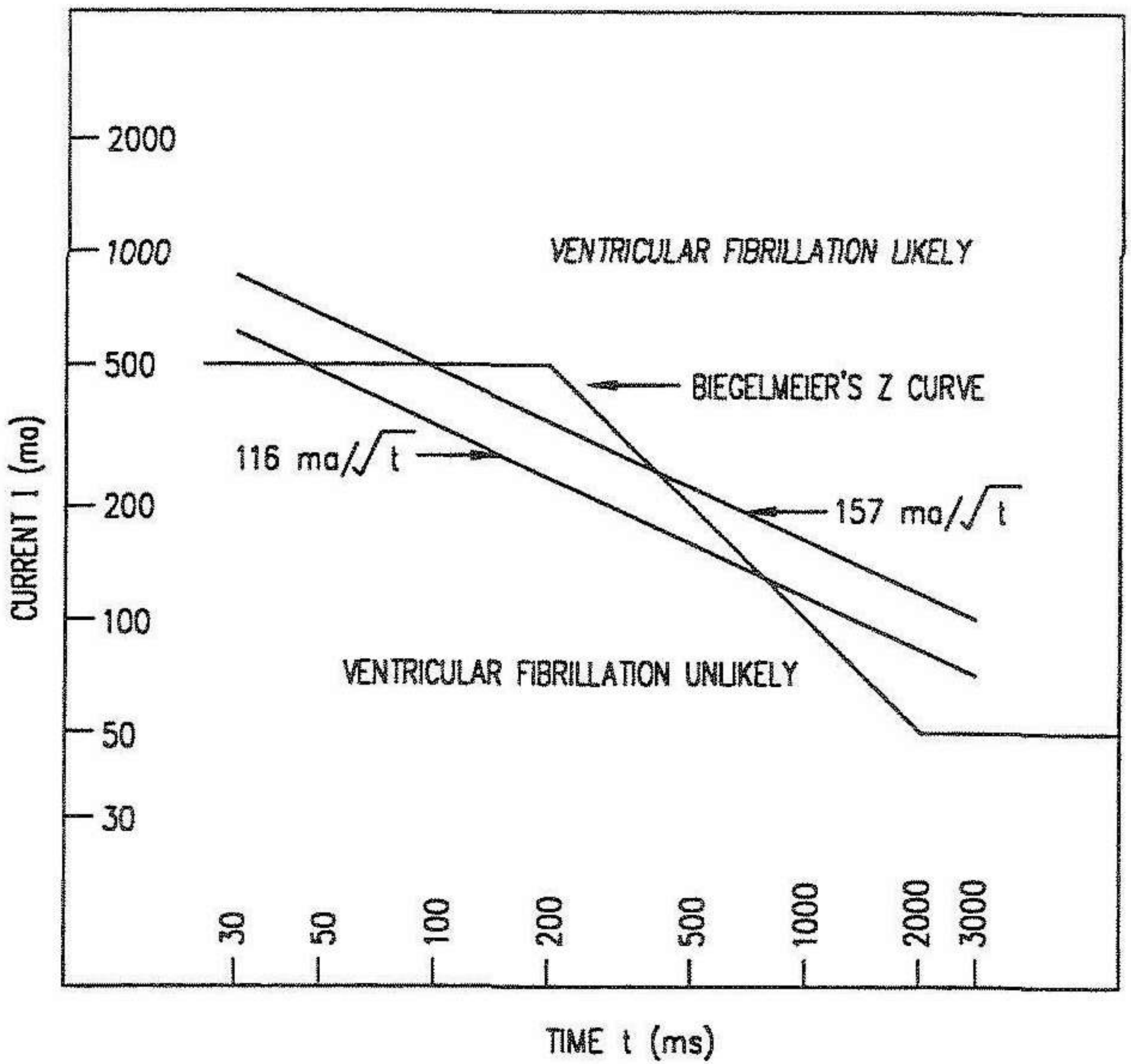
Tolerable Body Current Limits

$$I_B = \frac{0.116}{\sqrt{t_s}}$$ **for 50 kg body weight**

$$I_B = \frac{0.157}{\sqrt{t_s}}$$ **for 70 kg body weight**

t_s **time in seconds**

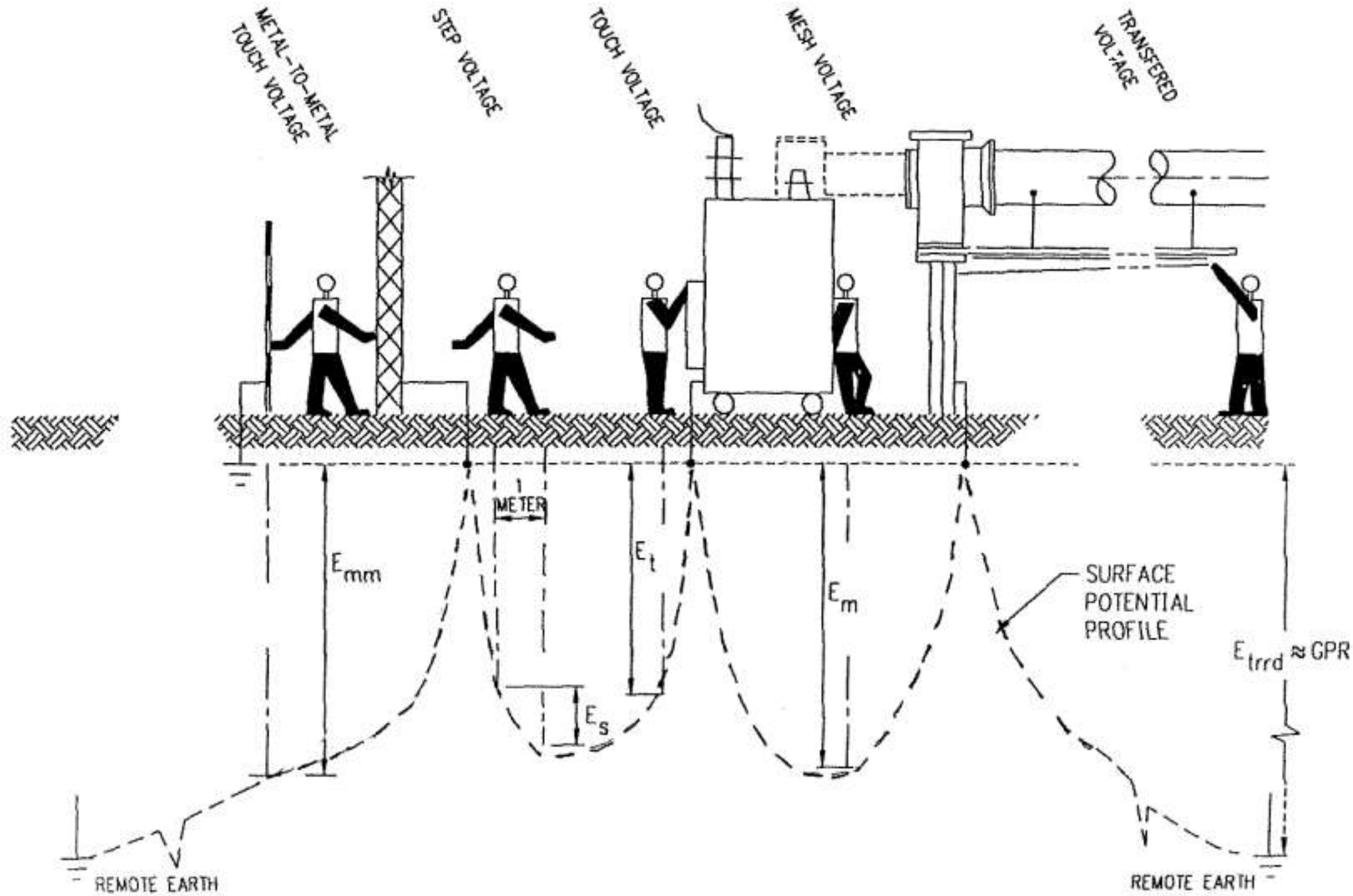
BODY CURRENT VERSUS TIME



KEY DEFINITIONS

GND POTENTIAL RISE (GPR):	**The maximum voltage that a substation grounding grid may attain relative to remote earth**
REMOTE EARTH:	**Theoretical grounding point located an infinite distance away from the substation at zero potential**
STEP VOLTAGE:	**The difference in surface potential that occurs between the feet of a person with feet spaced one meter apart**
TOUCH VOLTAGE:	**Voltage between objects within the substation site that may be bridged by direct hand-to-hand or hand-to-feet contact**
MESH VOLTAGE:	**The maximum touch voltage within a mesh of a ground grid**
TRANSFERRED VOLTAGE:	**Special case of touch voltage when a voltage is transferred to a remote location external to the substation**

BASIC SHOCK SITUATIONS



TOLERABLE VOLTAGES

Touch Voltage

$$E_{touch50} = \left(1000 + 1.5C_s \cdot \rho_s\right)\frac{0.116}{\sqrt{t_s}}$$

$$E_{touch70} = \left(1000 + 1.5C_s \cdot \rho_s\right)\frac{0.157}{\sqrt{t_s}}$$

Step Voltage

$$E_{step50} = \left(1000 + 6C_s \cdot \rho_s\right)\frac{0.116}{\sqrt{t_s}}$$

$$E_{step70} = \left(1000 + 6C_s \cdot \rho_s\right)\frac{0.157}{\sqrt{t_s}}$$

Where

E_{step}	**is the step voltage in V**
E_{touch}	**is the touch voltage in V**
C_s	**is determined from figure or equation**
ρs	**is the resistivity of the surface material in Ω-m**
ts	**is the duration of shock current in seconds**

If no protective surface layer is used, then C_s =1 and $\rho_s = \rho$.

C-FACTOR

Determined by

- **Resistivity of Surface Material**
- **Depth of Surface Material**
- **Resistivity of Upper Layer Soil**
- **Reflection Factor Based on Surface Material and Soil**

REFLECTION FACTOR

$$k = \frac{\rho - \rho_s}{\rho + \rho_s}$$

where

ρ_s	**surface material resistivity in Ω-m**
ρ	**resistivity of the earth beneath the surface material in Ω-m**

C-CURVE

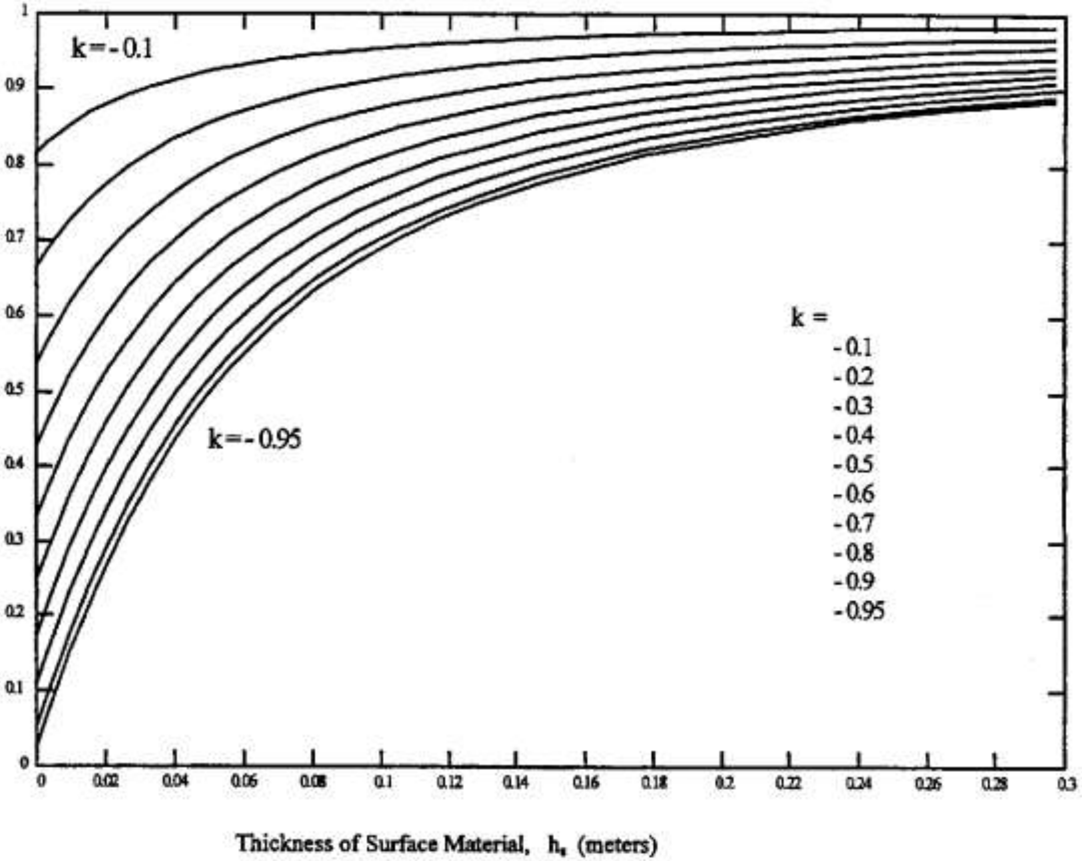


Figure 11—C_s versus h_s

$$C_s = 1 - \frac{0.09\left(1 - \frac{\rho}{\rho_s}\right)}{2h_s + 0.09}$$

ACTUAL TOUCH & STEP VOLTAGES BASED ON LAYOUT

Dependent on:

- **Substation Grounding Layout**
- **Soil Resistivity**
- **Grid Resistance**
- **Grid Current**

IEEE 80 Includes Approximate Equations or Methods for:

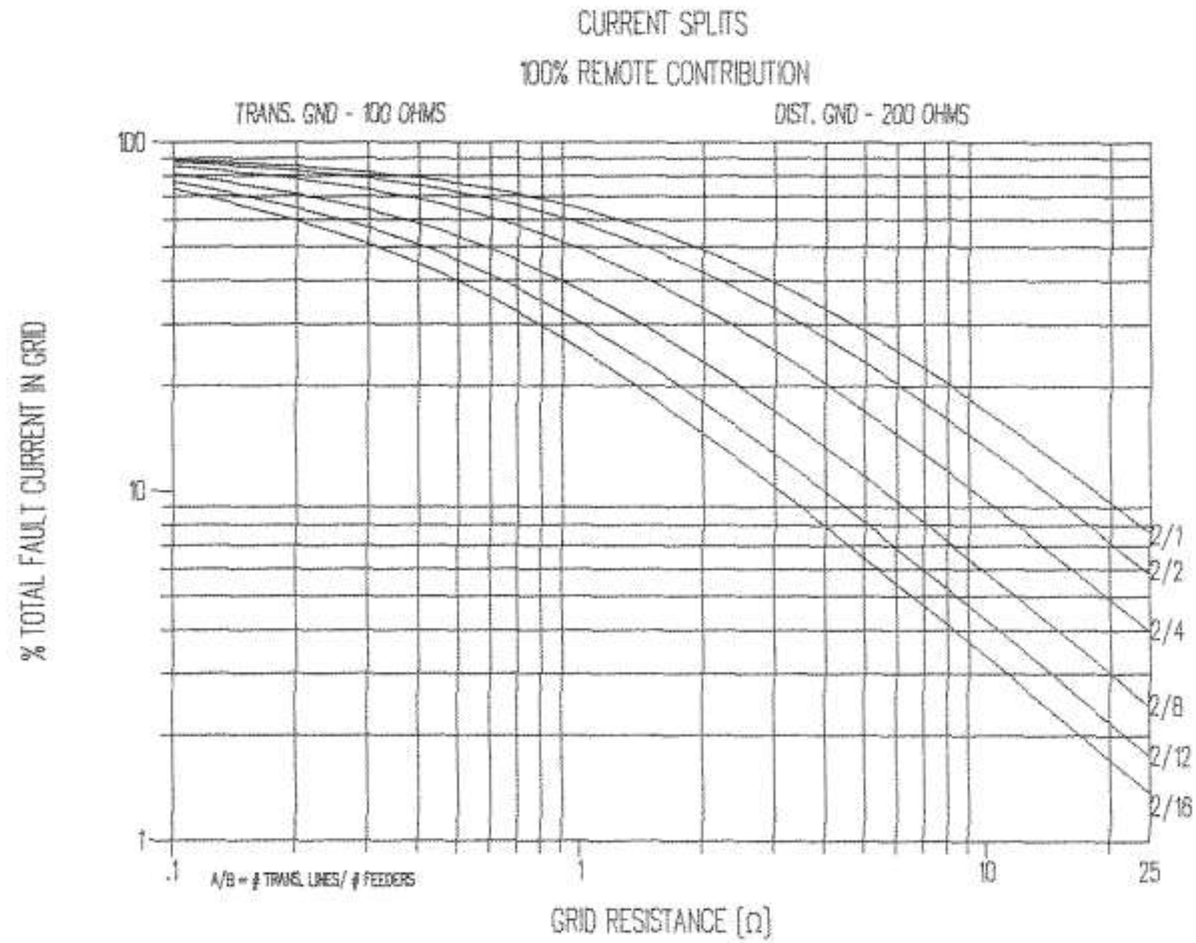
- Grid resistance
- Grid current (current division)
- Touch & Step Voltages
  - Geometric limitations
  - Uniform soil limitations

IEEE Resistance Equation

$$R_g = \rho\left[\frac{1}{L_T} + \frac{1}{\sqrt{20A}}\left(1 + \frac{1}{1 + h\sqrt{20/A}}\right)\right]$$

A	**Area of Grid in m^2**
h	**Depth of Grid in m**
L_T	**Total Length of Grounding System**

GRID CURRENT BASED ON TOTAL FAULT CURRENT AND SPLIT CURVES



Mesh Voltage Equation

$$E_m = \rho \frac{K_m K_i I_G}{L_m}$$

Spacing Factor for Mesh Voltage

$$K_m = \frac{1}{2 \cdot \pi} \cdot \left[\ln\left[\frac{D^2}{16 \cdot h \cdot d} + \frac{(D + 2 \cdot h)^2}{8 \cdot D \cdot d} - \frac{h}{4 \cdot d} \right] + \frac{K_{ii}}{K_h} \cdot \ln\left[\frac{8}{\pi (2 \cdot n - 1)} \right] \right]$$

where

K_m	**Spacing factor**
D	**spacing between parallel conductors, m**
d	**Diameter of grid conductor, m**
h	**Depth of ground grid conductor, m**

Step Voltage Equation

$$E_s = \frac{\rho \cdot K_s \cdot K_i \cdot I_G}{L_S}$$

Spacing Factor for Step Voltage

$$K_s = \frac{1}{\pi}\left[\frac{1}{2 \cdot h} + \frac{1}{D+h} + \frac{1}{D}\left(1 - 0.5^{n-2}\right)\right]$$

Safe Design Criteria
Actual Voltages less than Tolerable Voltages

Mesh Voltage

$$\boldsymbol{E_m < E_{touch50}}$$

Step Voltage

$$\boldsymbol{E_s < E_{step50}}$$

Major Changes in 2012 (?) Edition

- Clarify Some Information on Current Division (Curves)
- Correct Some Information on Conductors/Material Ampacity
- Benchmarks for Computer Software

Questions