Lightning Protection of Distribution Lines

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Chair – WG on Lightning Performance of Distribution Lines

Flashover Mechanisms

- What are we trying to protect against
  - Direct Strike to line
  - Induced from nearby strike
    - Most typical flashover on distribution
  - Back flash from strike to shield wire

Direct Stroke

- Lightning hits phase conductor
  - Current splits in both directions
- Average current of 20 kA will cause a voltage of 4 MV on line
  - ½ * 20 kA * 400 ohms (typical surge impedance)
- Most difficult to protect against

Number of Strikes to a Line

- Eriksson's equation:

$$N = N_g \left(\frac{28h^{0.6} + b}{10} \right)$$

- Where:
  - h is pole height
  - b is structure width (negligible for distribution)
  - N_g is GFD
- Assumes that the line is in open ground

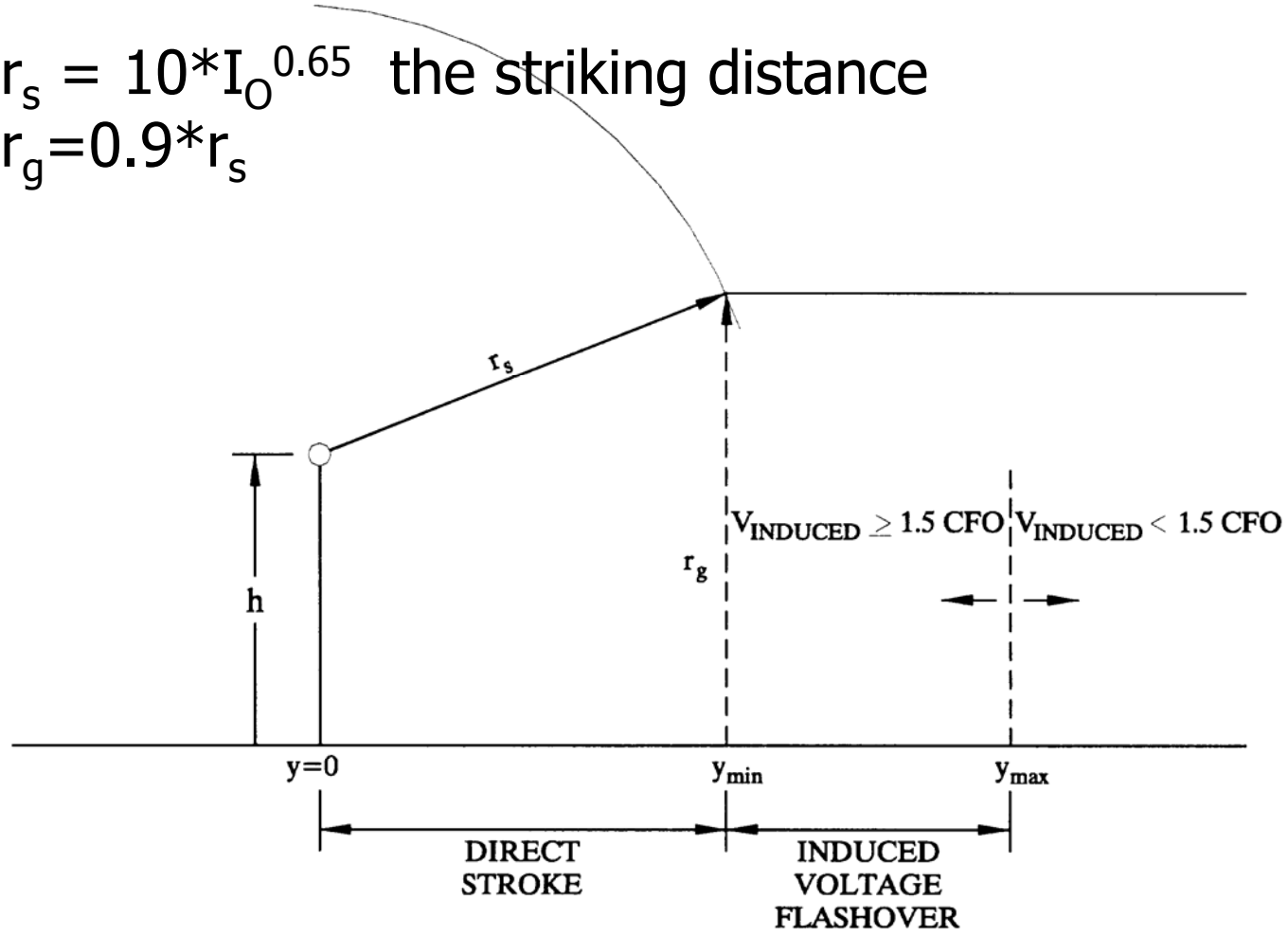
Induced Flashover

- Lightning strikes near line and induces a voltage on it
  - $V_{max} = 38.8*(I_O*h_a)/y$
    - Where: I_O is peak lightning current
      h_a is average height of line
      y is the distance from line of lightning stroke
- Most typical of lightning fashovers on a distribution line
- Much less energy than a direct strike

Lightning Strike in Open Ground No Natural Shielding

$r_s = 10*I_O^{0.65}$ the striking distance

$r_g = 0.9*r_s$



Back Flashover

- Lightning hits shield wire
- Surge divert to ground thru ground wire off of shield
- Voltage is dependant on ground resistance and lightning current

Protection of Lines

- Shielding
  - Shield Wire
  - Natural
- Arresters
- Added insulation

Shielding

- Shield wire used to prevent direct strike to line
  - Need good ground resistance
  - Dependant on shield angle
- Nearby objects can act as a shield
  - Trees, buildings, fences….

Shield Angle

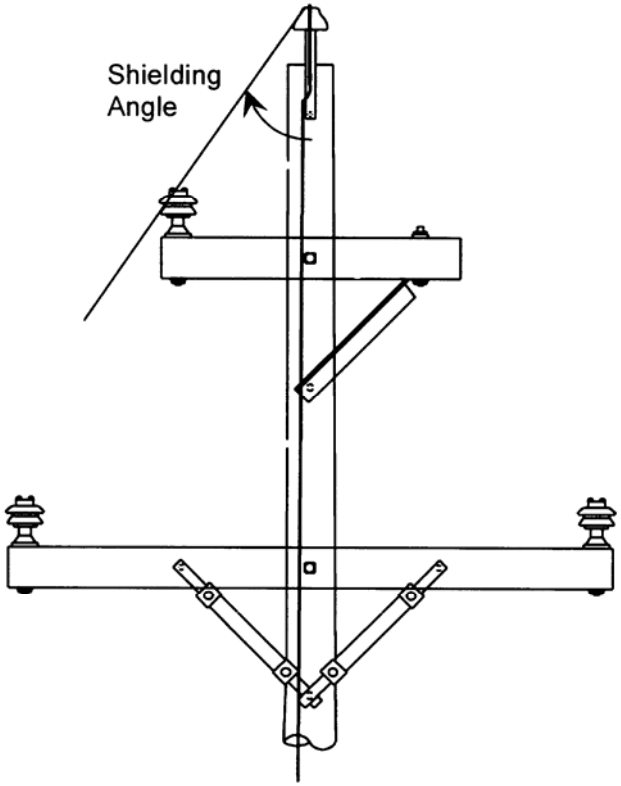


Figure 7 from IEEE Std. 1410-2004

Effect of ground resistance on shield-wire performance

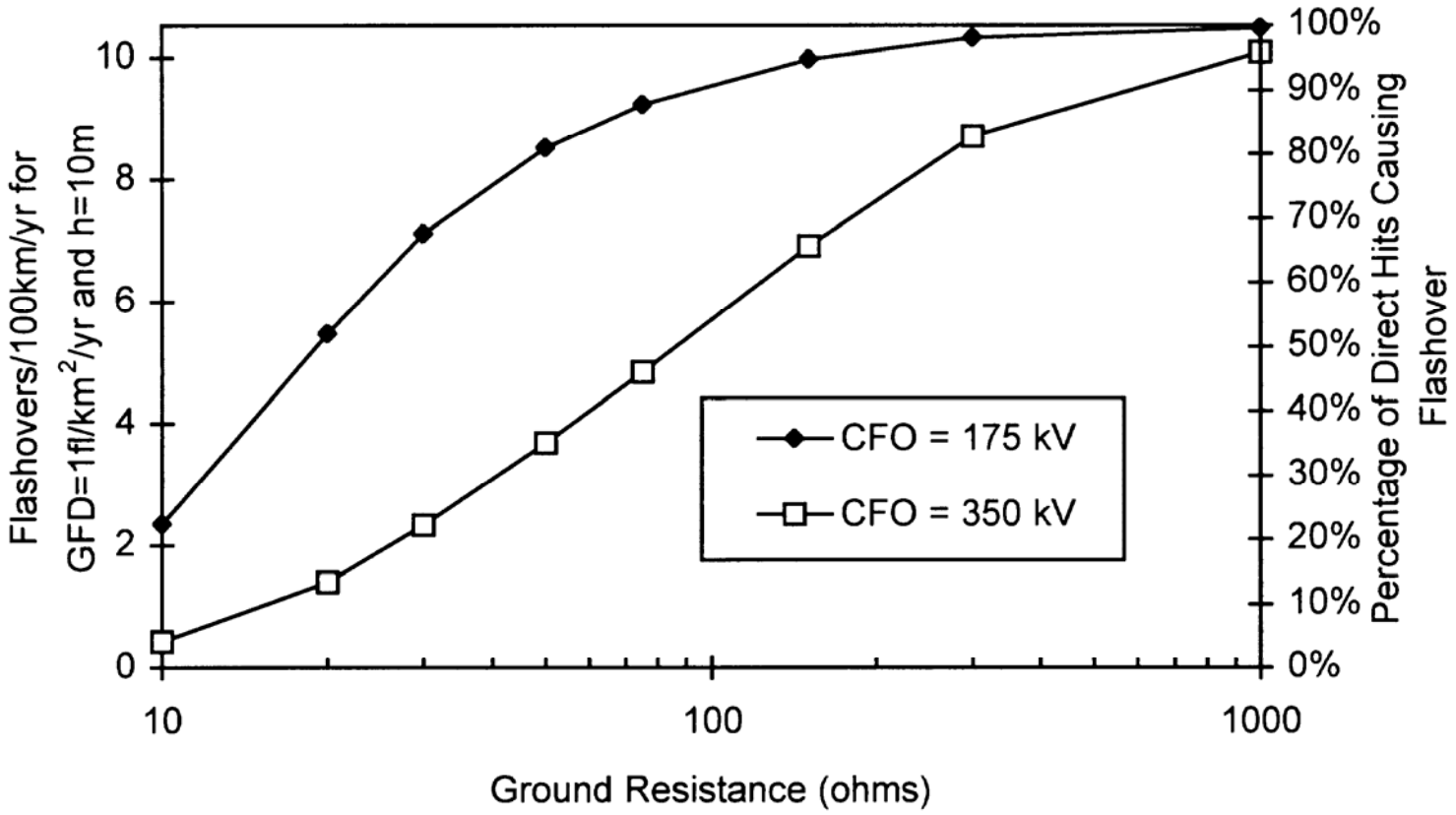


Figure 8 from IEEE Std. 1410-2004

CFO

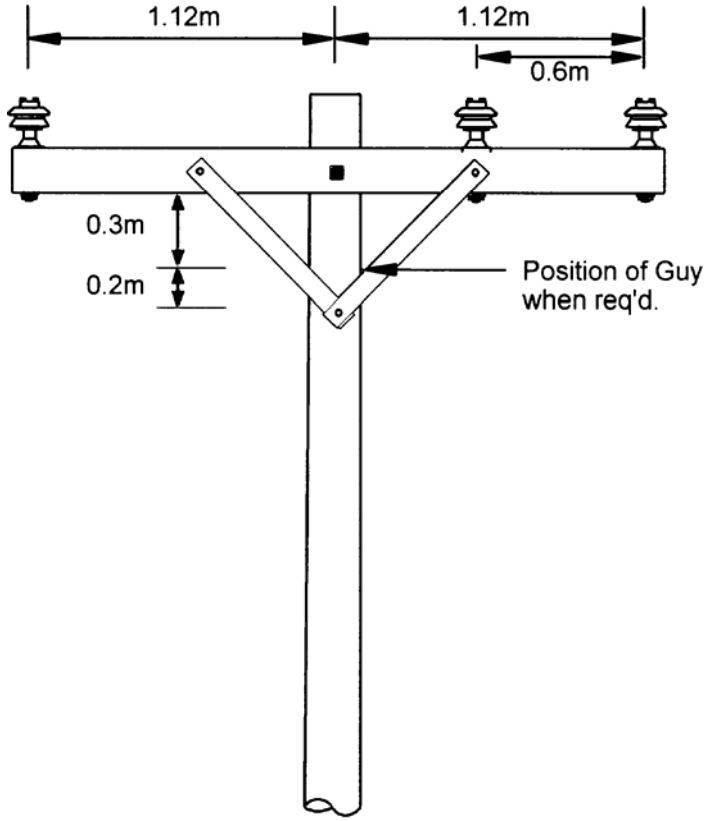
- CFO is Critical Flashover
  - The voltage level where 50% chance of flashover
- Combination of the components on pole

$$CFO_T = CFO_{ins} + CFO_{add.\sec} + CFO_{add.third} + \ldots + CFO_{add.nth}$$

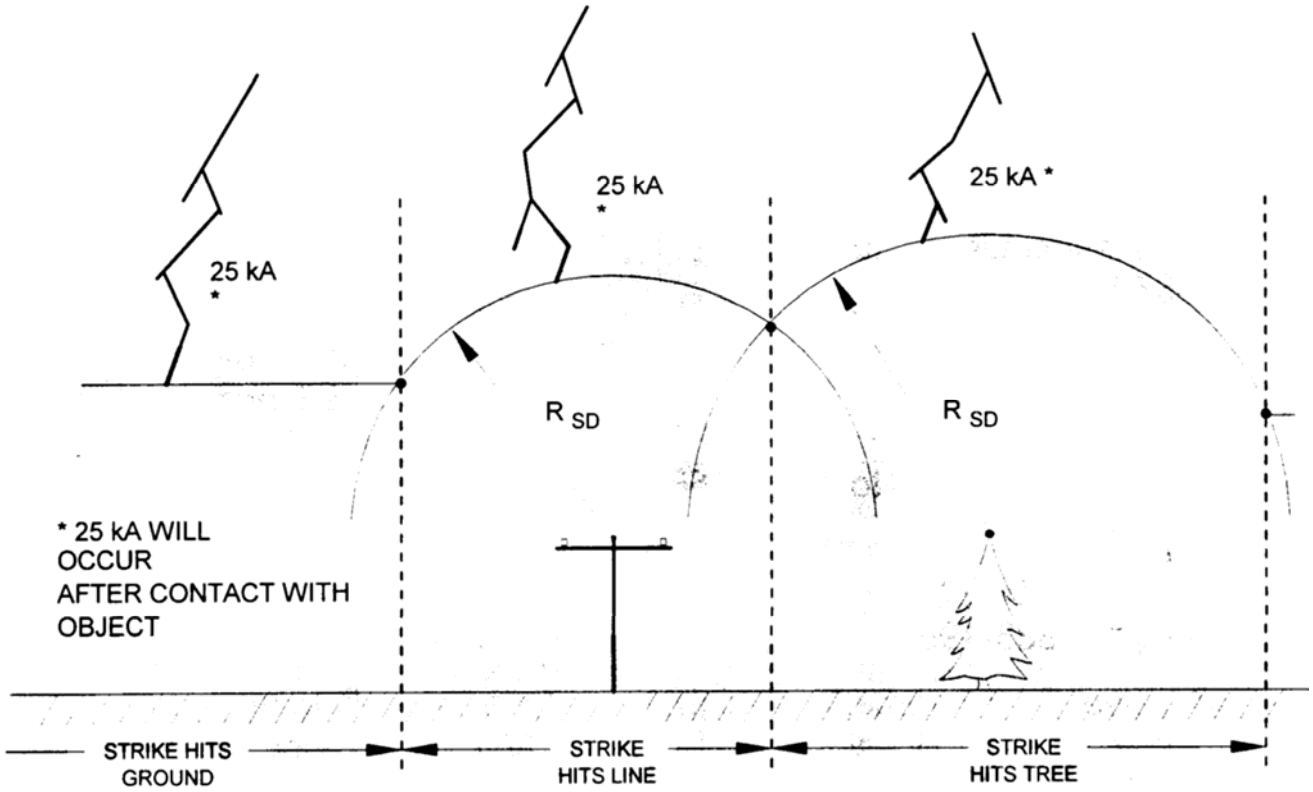
- Tables 2 – 4 in IEEE Std. 1410 contain the values for the CFO's
- If value not in tables 3 or 4, use equation 11 In IEEE Std. 1410
  - $CFO_{add.sec}$ = 0.45*CFO
  - $CFO_{add.third}$ = 0.20*CFO

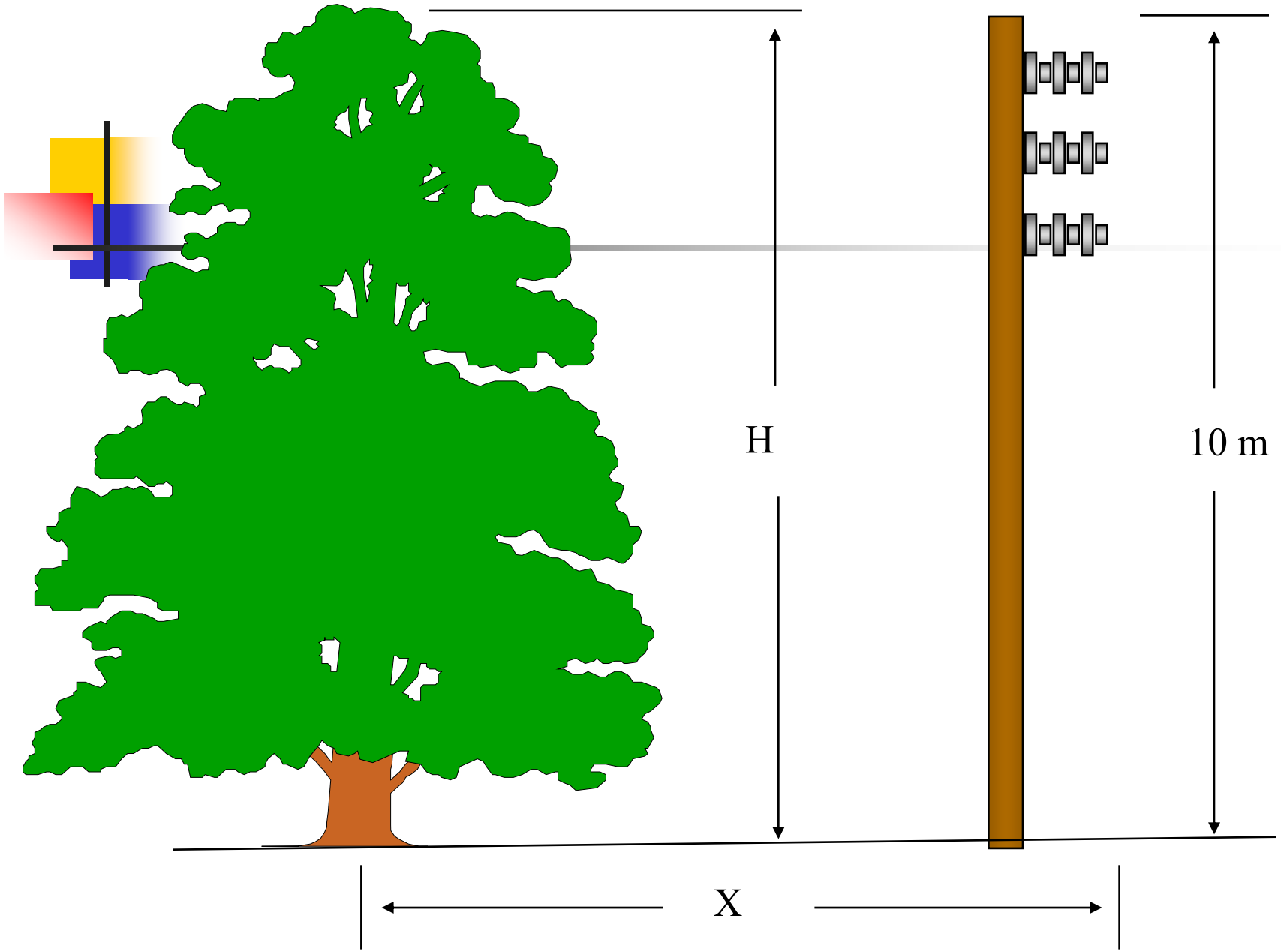
CFO Explained

- CFO_1: Insulator
  - 105 kV (Value from Table 2 IEEE 1410)
- CFO_2:X-Arm
  - 250 kV/m (Table 3)
- CFO_3:Brace or Insulator
  - Brace: 0.2*360 kV/m
  - Insulator: 0.2*105 kV
  - From equation 11 – IEEE 1410



EMG & Striking Distance
Natural Shielding





Courtesy of Progress Energy-Florida

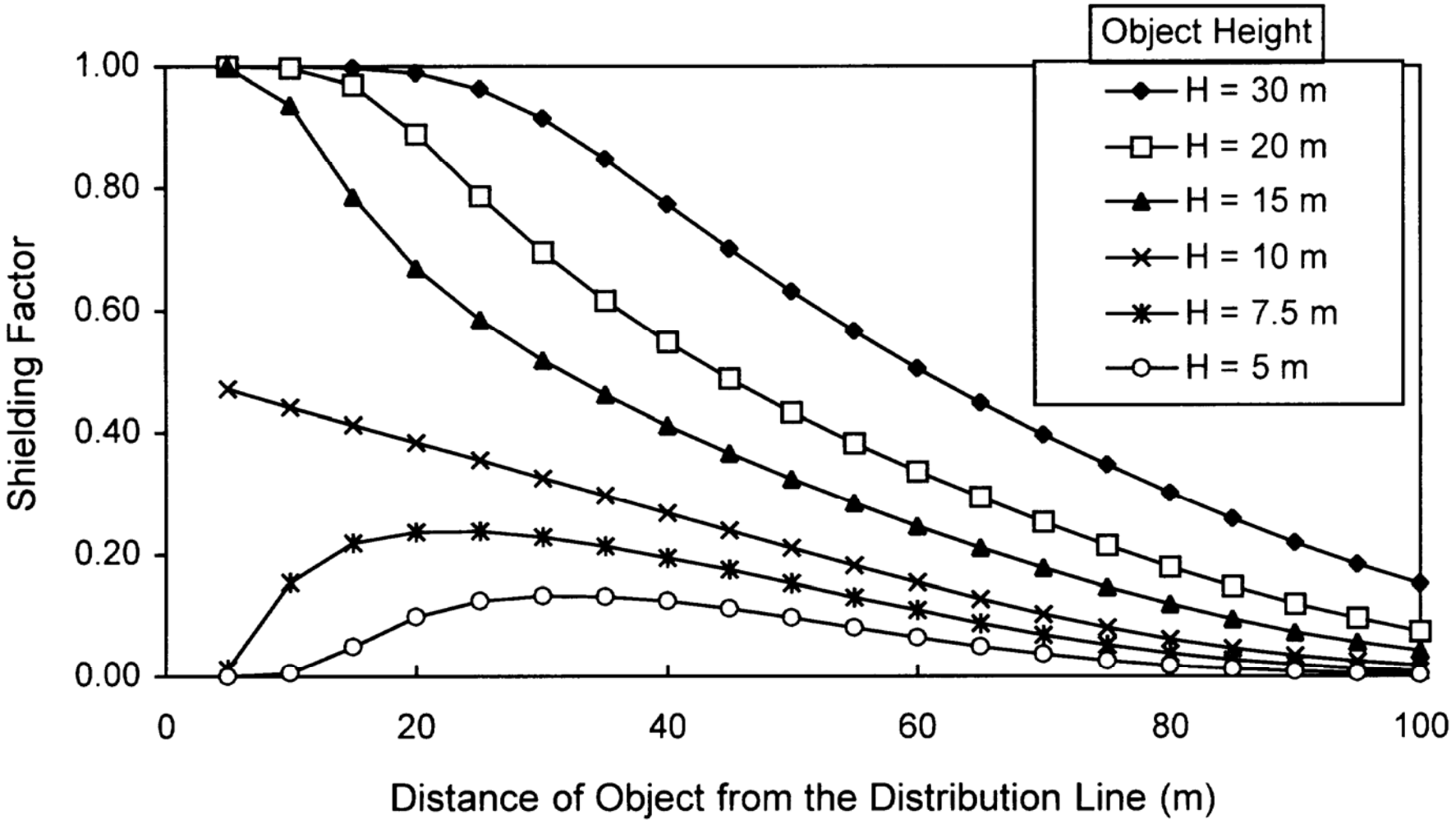
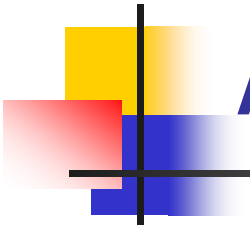


Figure 4 from IEEE Std. 1410-2004



Arresters

- Protection for both direct strokes and induced flashovers
- Limit voltage by shunting the lightning surge to ground
- Performance based on spacing of arresters and to some extent ground resistance

IEEE Std. 1410-2004

- Can be purchased from IEEE SA at:
- http://shop.ieee.org/ieeestore/Product.aspx?product_no=SH95218