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
  - $\frac{1}{2} \times 20 \text{kA} \times 400 \text{ohms}$ (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
  - \[ V_{\text{max}} = 38.8 \times (I_0 \times h_a) / y \]
    - Where: \( I_0 \) 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

\[ r_s = 10 \cdot I_0^{0.65} \] the striking distance
\[ r_g = 0.9 \cdot r_s \]
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
  - \( CFO_{add\_sec} = 0.45 \times CFO \)
  - \( CFO_{add\_third} = 0.20 \times CFO \)
CFO Explained

- **CFO₁**: Insulator
  - 105 kV (Value from Table 2 IEEE 1410)

- **CFO₂**: X-Arm
  - 250 kV/m (Table 3)

- **CFO₃**: Brace or Insulator
  - Brace: 0.2*360 kV/m
  - Insulator: 0.2*105 kV
  - From equation 11 – IEEE 1410
EMG & Striking Distance
Natural Shielding

* 25 kA will occur after contact with object.
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: