ECE 526 (Spring 2019)

Lecture 27
Handwritten Notes
Fault Location for transmission lines

2 types of decisions

1. Tripping related
   - Zone selection
     - Direction
     - Speed, sensitivity, security
   - Not precise location of fault
Fault Location for Line crews in some cases autoreclosing
- Some utilities will auto reclose for SLG, but not for DLG or 3#
  without inspection

→ for sending out crews prefer accurate location
down to a few towers
Challenges:

1. Fault challenge → remote infeed
2. Tapped line with remote infeed
3. Source impedance variation
4. Series compensation
5. Mutual coupling
6. Accuracy of line model → Earth (soil) resistivity → z₀
7. Tower configuration → mutual coupling
7. mixed overhead / underground

8. Time window for measurement
   - a few cycles before breaker opens

9. relay measurements
   CT/PT error - Transient response
Options for determining fault location

1. Nomographs
   - compare waveforms from event file with fault signature from offline

2. Impedance based schemes \(\Rightarrow\) Single ended (using \(V\) and \(I\) measurements)

3. Double ended (multi) impedance based (\(V, I\) phasors)
(4) Traveling wave schemes

(5) Signal injection methods

(more common for underground cables)
- Phasor based methods

1. Single ended "Impedance based"
   \[ V_A, V_B, V_C, I_A, I_B, I_C \]

2. Reactance method

\[ V_{B1} = I_s \cdot m Z_L + I_f R_f \]
$$Z_{eff} = \frac{V_{B1}}{I_s} = m \ Z_L + \left( \frac{I_f}{I_s} \right) R_f$$

↑ error term

$$m = \frac{I_m \left( \frac{V_{B1}}{I_s} \right) - R_f \cdot I_m \left( \frac{I_f}{I_s} \right)}{I_m \left( Z_L \right)}$$

If $\angle I_f = \angle I_s$ or $R_f = 0$ works well

- Also has problem if power flow during fault
Takagi Fault Location method

\[ I_s = I_{s_{\text{fault}}} - I_{s_{\text{prefault}}} \]

- Used in fault location calculation
- Reduces \( R_f \) effect on nonhomogeneous system
- Reduces sensitivity to load flow
\[ V_{B1} = m Z_L I_{s\text{fault}} + Rf I_f \]

- multiply both sides by \( I_s^* = (I_f - I_{pres})^* \)

\[ \text{Im} (V_{B1} I_s^*) = m \text{Im} (Z_L I_f I_s^*) + Rf \text{Im} (I_f I_s^*) \]

**complete equation for \( m \)**

\[ m = \frac{\text{Im} (V_{B1} I_s^*)}{\text{Im} (Z_L I_f I_s^*)} - Rf \frac{\text{Im} (I_f I_s^*)}{\text{Im} (Z_L I_f I_s^*)} \]

**what relay calculates**
Improved version: Modified Takagi method

2 versions

A) Instead of using $I_s$, use $3I_{os}$ measured
   - need to rotate with tilt angle like quad element if non-homogeneous

$$m = \frac{\text{Im} \left( V_{Bl} \cdot (3I_{os})^* e^{-j\theta} \right) - R_f \text{Im} \left[ I_f (3I_{os})^* e^{-j\theta} \right]}{\text{Im} \left[ Z_L I_{fs} (3I_{os})^* e^{-j\theta} \right]}$$
- Tilt angle requires info on source impedances
- good for SLG, DLG, not LL, 3φ
- zero sequence mutual effects...
B) Modified Takagi with $I_{2s}$
- $I_{2s}$ replaced by $I_{2s}$
- Use this for SLG, LL, DLG
- Use regular Takagi for $3\phi$
- Doesn't need a tilt angle

\[
m = \frac{\text{Im}(V_{B1} \cdot I_{2s}^*) - \Re \text{Im}(I_{2s}^*)}{\text{Im}(E_{2s} (I_{2s}^*))}
\]
what are $V_{BI}$ and $I_{fs}$?

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<tr>
<th>$m_{AG}$</th>
<th>$V_{AG}$</th>
<th>$I_{As} + k_0 3I_{os}$</th>
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<tbody>
<tr>
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<td>$V_{BG}$</td>
<td>$I_{Bs} + k_0 3I_{os}$</td>
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<td>$V_{CG}$</td>
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