ECE 526 (Spring 2019)

Lecture 20
Handwritten Notes
Topics to cover in the next few weeks:

1. Power Swing Blocking
2. Fault Location
3. Synchronous Generator Protection
   - Phase to ground fault
   - Phase to phase fault
   - Turn to turn fault
   - Loss of field protection
4. Wind Farm, Impact of DERs
5. Induction Motor Protection
What is Power Swing?

\[ E_s \angle 0 \]
\[ Z_s \]
\[ Z_L \]
\[ Z_R \]
\[ E_R \angle 0^\circ \]

\[ I_1 = \frac{E_s \angle 0 - E_R}{Z_T} \]

\[ Z_i = \frac{V_{is}}{I_1} = \frac{E_s \angle 0}{E_s \angle 0 - E_R} \cdot Z_T - Z_s \]

\[ V_{is} = E_s \angle 0 - Z_s \]
\[ I_1 = E_s \angle 0 - Z_s \cdot \frac{E_s \angle 0 - E_R}{Z_T} \]

If \( E_s = E_R \)

\[ Z_i = \frac{Z_T}{2} \left( 1 - j \cot \frac{\Theta}{2} \right) - Z_s \]
\[ Z_1 = \frac{V_{is}}{Z_1} = \frac{Z_T}{2} \left(1 - j \cot \frac{\theta}{2}\right) - Z_s \quad (\text{If} \ E_s = E_R) \]

\[ Z_T = Z_s + Z_L + Z_R \]
\[ Z_i = \frac{Z_T}{2} \left( 1 - j\cot\frac{\Theta}{2} \right) - Z_s \] (If \( E_s = E_R \))
\[ n = \frac{E_s}{E_R} \]

\[ n > 1 \]

\[ n = 1 \]

\[ n < 1 \]

\[ \frac{d\theta}{dt} = \omega \]

\[ Z_1 = \frac{V_{is}}{I_1} = \frac{E_s}{E_r} \frac{\cos \theta}{E_s \cos \theta - E_R} - Z_s \]

\[ \frac{\frac{dZ_1}{dt}}{\frac{d\theta}{dt}} = -jZ_T \frac{e^{-j\theta}}{1 - e^{-j\theta}^2} \frac{d\theta}{dt} \]

\[ \left| \frac{\frac{dZ_1}{dt}}{\frac{d\theta}{dt}} \right| = \frac{|Z_T|}{4 \sin^2 \frac{\theta}{2}} |\omega| \]
Rate of change of $Z_i$

\[
\left| \frac{dZ_i}{dt} \right| = \frac{1}{4} \frac{l_i^2 l_w}{\sin^2 \theta}
\]

Rate of change

\[
x \frac{l_i l_w}{4}
\]
Impact of power swing on Line protection:
Distance, phase overcurrent, directional overcurrent
Phase overvoltage and undervoltage

Zone 1 elements and directional comparison tripping schemes are particularly sensitive to power swing.