### Homework #4

#### System parameters

- \( V_{\text{source}} = \frac{\sqrt{2}}{\sqrt{3}} \times 115 \text{ kV} = 93.897 \text{ kV} \)

- \( Z_{\text{source}} = 0.658 + j 6.58 \ \Omega \) \((115 \text{kV} \text{L}, 100 \text{MVA} \text{L})\)

- Breaker bushing capacitance = 250 pF

- Bus inductance

<table>
<thead>
<tr>
<th>5&quot; Al (Ω)</th>
<th>1590 MCM (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( l = 40' )</td>
<td>0.00378</td>
</tr>
<tr>
<td>( l = 80' )</td>
<td>0.00757</td>
</tr>
<tr>
<td>( l = 120' )</td>
<td>0.01136</td>
</tr>
</tbody>
</table>

- Cap Banks

\[ Q = 40 \text{ MVAR} / 3 \] , \( C_{1,2} = 8.02 \mu \text{F} \) , \( R = 4.13 \mu \Omega \)

\[ Q = 14.4 \text{ MVAR} / 3 \] , \( C_{\text{distr}} = 8.03 \mu \text{F} \) , \( R = 3.31 \mu \Omega \)

- Transformer

\( Z_{\text{LV side}} = 0.0634 + j 1.903 \ \Omega \)
Case 1 - Inrush current (energizing @ Vp)

\[ I_p = 2kA @ 425Hz \]
\[ TRV = 180kV = 1.92 \text{ p.u. (At 115kV bus)} \]

- Can do a synchronized switching operation
  (switch-in the cap-bank @ V \text{ zero-crossing}) to reduce
  these peak values. Now,

\[ I_p = 546A @ 430Hz \]
\[ V_p = 108kV = 1.15 \text{ p.u.} \]

Case 2 - Back-to-back switching (Energize @ Vp)

I \text{ through breaker} = 21.8kA @ 9.2 \text{ kHz}

\[ I \times f = 20.3 \times 10^3 \text{ AH} \] (exceeds \(8.4 \times 10^3\text{ rating}\))
\[ TRV = 142kV = 1.51 \text{ p.u.} \]

- Use a current-limiting reactor (110\mu H)
  between \(C_1\) & \(C_2\)

\[ I_p = 14.2kA @ 5.81 \text{ kHz} \] (\(I \times f = 8.2 \times 10^3 \text{ AH} \))
\[ V_p = 162kV = 1.73 \text{ p.u.} \] (Could also do synchronized
  switching to reduce \(V_p\))
* Case 3 - After clearing a fault at point R

\[ TRV = 18.7 \text{ kV} @ 76.2 \text{ kHz} = 1.99 \text{ p.u.} \]

* Case 4 - Outrush current @ point o

\[ I_p = 46.7 \text{ kA} @ 4.78 \text{ kHz} \]
\[ I_{xf} = 22.3 \times 10^3 \text{ AH} \text{z} \text{ (exceeds } 2 \times 10^3 \text{ AH}z \text{ rating)} \]

Use a current limiting reactor (680 \mu\text{H}) in series (before the cap-banks) with the bus. Then,

\[ I_p = 14.3 \text{ kA} @ 1.42 \text{ kHz} \text{ (} I_{xf} = 2 \times 10^3 \text{ AH}z \text{)} \]

* Case 5 - Voltage magnification

- Single-bank energization, \( f = 425 \text{ Hz} \)
  - At 115 KV bus, \( V_p = 1.88 \text{ p.u.} \)
  - At 69 KV feeder, \( V_p = 2.34 \text{ p.u.} \)

Using synchronized switching
  - At 115 KV bus, \( V_p = 1.11 \text{ p.u.} \)
  - At 69 KV feeder, \( V_p = 1.15 \text{ p.u.} \)

- Back-to-back energization
  - At 115 KV bus, \( V_p = 1.46 \text{ p.u.}, V_p = 1.05 \text{ p.u.} \text{ (after s.s.)} \)
  - At 69 KV feeder, \( V_p = 1.65 \text{ p.u.}, V_p = 1.06 \text{ p.u.} \text{ (after synchronized sw.)} \)