I. NORMAL

$$c_4 = 0.5(c_{45} + c_{46}) \tag{1}$$
$$c_5 = 0.5(c_{45} + c_{57}) \tag{2}$$
$$c_6 = 0.5(c_{69} + c_{46}) \tag{3}$$
$$c_7 = 0.5(c_{57} + c_{78}) \tag{4}$$
$$c_8 = 0.5(c_{78} + c_{89}) \tag{5}$$
$$c_9 = 0.5(c_{69} + c_{89}) \tag{6}$$

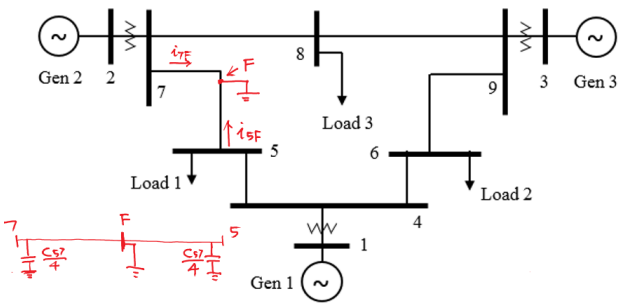
A. State Equations

$$c_4 v_4' = -i_{41} - i_{45} - i_{46} \tag{1}$$
$$c_5 v_5' = -i_{5A} + i_{75} + i_{45} \tag{2}$$
$$c_6 v_6' = -i_{6B} + i_{96} + i_{46} \tag{3}$$
$$c_7 v_7' = -i_{72} - i_{78} - i_{75} \tag{4}$$
$$c_8 v_8' = -i_{8C} + i_{78} + i_{98} \tag{5}$$
$$c_9 v_9' = -i_{93} - i_{98} - i_{96} \tag{6}$$
$$L_A i_{5A}' = v_5 - R_A i_{5A} \tag{7}$$
$$L_B i_{6B}' = v_6 - R_B i_{6B} \tag{8}$$
$$L_C i_{8C}' = v_8 - R_C i_{8C} \tag{9}$$
$$L_1 i_{41}' = v_4 - e_1 \tag{10}$$
$$L_{45} i_{45}' = v_4 - v_5 - R_{45} i_{45} \tag{11}$$
$$L_{46} i_{46}' = v_4 - v_6 - R_{46} i_{46} \tag{12}$$
$$L_2 i_{72}' = v_7 - e_2 \tag{13}$$
$$L_{57} i_{75}' = v_7 - v_5 - R_{57} i_{75} \tag{14}$$
$$L_{78} i_{78}' = v_7 - v_8 - R_{78} i_{78} \tag{15}$$
$$L_3 i_{93}' = v_9 - e_3 \tag{16}$$
$$L_{96} i_{96}' = v_9 - v_6 - R_{96} i_{96} \tag{17}$$
$$L_{89} i_{98}' = v_9 - v_8 - R_{89} i_{98} \tag{18}$$

B. Output Equations

$$y_1 = v_4 \tag{1}$$
$$y_2 = i_{41} \tag{2}$$
$$y_3 = i_{45} + \frac{c_{45}}{2c_4}(-i_{41} - i_{45} - i_{46}) \tag{3}$$
$$y_4 = i_{46} + \frac{c_{46}}{2c_4}(-i_{41} - i_{45} - i_{46}) \tag{4}$$
$$y_5 = v_7 \tag{5}$$
$$y_6 = i_{75} + \frac{c_{57}}{2c_7}(-i_{72} - i_{75} - i_{78}) \tag{6}$$
$$y_7 = i_{72} \tag{7}$$
$$y_8 = i_{78} + \frac{c_{78}}{2c_7}(-i_{72} - i_{75} - i_{78}) \tag{8}$$
$$y_9 = v_9 \tag{9}$$
$$y_{10} = i_{96} + \frac{c_{69}}{2c_9}(-i_{93} - i_{96} - i_{98}) \tag{10}$$
$$y_{11} = i_{98} + \frac{c_{89}}{2c_9}(-i_{93} - i_{96} - i_{98}) \tag{11}$$
$$y_{12} = i_{93} \tag{12}$$

II. Line 5-7 Midpoint Short to Ground



$$c_4 = 0.5(c_{45} + c_{46}) \tag{13}$$
$$c_5 = 0.5c_{45} + 0.25c_{57} \tag{14}$$
$$c_6 = 0.5(c_{69} + c_{46}) \tag{15}$$
$$c_7 = 0.25c_{57} + 0.5c_{78} \tag{16}$$
$$c_8 = 0.5(c_{78} + c_{89}) \tag{17}$$
$$c_9 = 0.5(c_{69} + c_{89}) \tag{18}$$

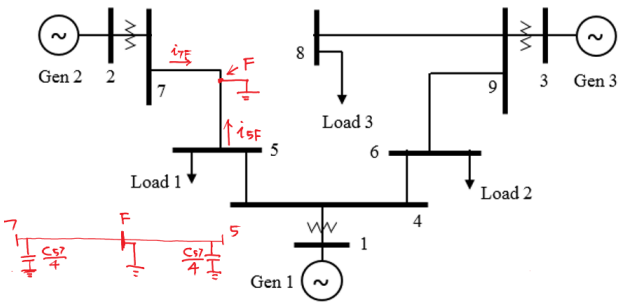
A. State Equations

$$c_4 v_4' = -i_{41} - i_{45} - i_{46} \tag{1}$$
$$c_5 v_5' = -i_{5A} - i_{5F} + i_{45} \tag{2}$$
$$c_6 v_6' = -i_{6B} + i_{96} + i_{46} \tag{3}$$
$$c_7 v_7' = -i_{72} - i_{78} - i_{7F} \tag{4}$$
$$c_8 v_8' = -i_{8C} + i_{78} + i_{98} \tag{5}$$
$$c_9 v_9' = -i_{93} - i_{98} - i_{96} \tag{6}$$
$$L_A i_{5A}' = v_5 - R_A i_{5A} \tag{7}$$
$$L_B i_{6B}' = v_6 - R_B i_{6B} \tag{8}$$
$$L_C i_{8C}' = v_8 - R_C i_{8C} \tag{9}$$
$$L_1 i_{41}' = v_4 - e_1 \tag{10}$$
$$L_{45} i_{45}' = v_4 - v_5 - R_{45} i_{45} \tag{11}$$
$$L_{46} i_{46}' = v_4 - v_6 - R_{46} i_{46} \tag{12}$$
$$L_2 i_{72}' = v_7 - e_2 \tag{13}$$
$$0.5L_{57} i_{7F}' = v_7 - 0.5R_{57} i_{7F} \tag{14}$$
$$L_{78} i_{78}' = v_7 - v_8 - R_{78} i_{78} \tag{15}$$
$$L_3 i_{93}' = v_9 - e_3 \tag{16}$$
$$L_{69} i_{69}' = v_9 - v_6 - R_{69} i_{69} \tag{17}$$
$$L_{89} i_{98}' = v_9 - v_8 - R_{89} i_{98} \tag{18}$$
$$0.5L_{57} i_{5F}' = v_5 - 0.5R_{57} i_{5F} \tag{19}$$

B. Output Equations

$$y_1 = v_4 \tag{1}$$
$$y_2 = i_{41} \tag{2}$$
$$y_3 = i_{45} + \frac{c_{45}}{2c_4}(-i_{41} - i_{45} - i_{46}) \tag{3}$$
$$y_4 = i_{46} + \frac{c_{46}}{2c_4}(-i_{41} - i_{45} - i_{46}) \tag{4}$$
$$y_5 = v_7 \tag{5}$$
$$y_6 = i_{7F} + \frac{c_{57}}{4c_7}(-i_{72} - i_{7F} - i_{78}) \tag{6}$$
$$y_7 = i_{72} \tag{7}$$
$$y_8 = i_{78} + \frac{c_{78}}{2c_7}(-i_{72} - i_{7F} - i_{78}) \tag{8}$$
$$y_9 = v_9 \tag{9}$$
$$y_{10} = i_{96} + \frac{c_{69}}{2c_9}(-i_{93} - i_{96} - i_{98}) \tag{10}$$
$$y_{11} = i_{98} + \frac{c_{89}}{2c_9}(-i_{93} - i_{96} - i_{98}) \tag{11}$$
$$y_{12} = i_{93} \tag{12}$$

III. Line 5-7 Midpoint Short to Ground, Line 7-8 Removed



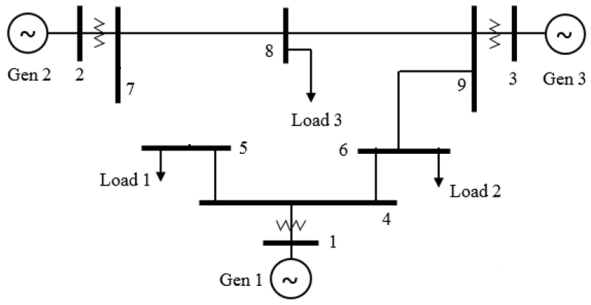
A. State Equations

$$c_4 v_4' = -i_{41} - i_{45} - i_{46} \quad (1)$$
$$c_5 v_5' = -i_{5A} + i_{5F} + i_{45} \quad (2)$$
$$c_6 v_6' = -i_{6B} + i_{96} + i_{46} \quad (3)$$
$$c_7 v_7' = -i_{72} - i_{7F} \quad (4)$$
$$c_8 v_8' = -i_{8C} + i_{98} \quad (5)$$
$$c_9 v_9' = -i_{93} - i_{98} - i_{96} \quad (6)$$
$$L_A i_{5A}' = v_5 - R_A i_{5A} \quad (7)$$
$$L_B i_{6B}' = v_6 - R_B i_{6B} \quad (8)$$
$$L_C i_{8C}' = v_8 - R_C i_{8C} \quad (9)$$
$$L_1 i_{41}' = v_4 - e_1 \quad (10)$$
$$L_{45} i_{45}' = v_4 - v_5 - R_{45} i_{45} \quad (11)$$
$$L_{46} i_{46}' = v_4 - v_6 - R_{46} i_{46} \quad (12)$$
$$L_2 i_{72}' = v_7 - e_2 \quad (13)$$
$$0.5 L_{57} i_{7F}' = v_7 - 0.5 R_{57} i_{7F} \quad (14)$$
$$\cancel{L_{78} i_{78}'} = \cancel{v_7 - v_8 - R_{78} i_{78}} \quad (15)$$
$$L_3 i_{93}' = v_9 - e_3 \quad (16)$$
$$L_{69} i_{69}' = v_9 - v_6 - R_{69} i_{69} \quad (17)$$
$$L_{89} i_{98}' = v_9 - v_8 - R_{89} i_{98} \quad (18)$$
$$0.5 L_{57} i_{5F}' = v_5 - 0.5 R_{57} i_{5F} \quad (19)$$

B. Output Equations

$$y_1 = v_4 \quad (1)$$
$$y_2 = i_{41} \quad (2)$$
$$y_3 = i_{45} + \frac{c_{45}}{2c_4}(-i_{41} - i_{45} - i_{46}) \quad (3)$$
$$y_4 = i_{46} + \frac{c_{46}}{2c_4}(-i_{41} - i_{45} - i_{46}) \quad (4)$$
$$y_5 = v_7 \quad (5)$$
$$y_6 = i_{7F} + \frac{c_{57}}{4c_7}(-i_{72} - i_{7F}) \quad (6)$$
$$y_7 = i_{72} \quad (7)$$
$$\cancel{y_8 = i_{78} + \frac{c_{78}}{2c_7}(-i_{72} - i_{7F} - i_{78})} \quad (8)$$
$$y_9 = v_9 \quad (9)$$
$$y_{10} = i_{96} + \frac{c_{69}}{2c_9}(-i_{93} - i_{96} - i_{98}) \quad (10)$$
$$y_{11} = i_{98} + \frac{c_{89}}{2c_9}(-i_{93} - i_{96} - i_{98}) \quad (11)$$
$$y_{12} = i_{93} \quad (12)$$

IV. Post-Fault, Line 5-7 Removed



$$c_4 = 0.5(c_{45} + c_{46}) \quad (13)$$
$$c_5 = 0.5c_{45} \quad (14)$$
$$c_6 = 0.5(c_{69} + c_{46}) \quad (15)$$
$$c_7 = 0.5c_{78} \quad (16)$$
$$c_8 = 0.5(c_{78} + c_{89}) \quad (17)$$
$$c_9 = 0.5(c_{69} + c_{89}) \quad (18)$$

A. State Equations

$$c_4 v_4' = -i_{41} - i_{45} - i_{46} \quad (1)$$
$$c_5 v_5' = -i_{5A} + i_{45} \quad (2)$$
$$c_6 v_6' = -i_{6B} + i_{96} + i_{46} \quad (3)$$
$$c_7 v_7' = -i_{72} - i_{78} \quad (4)$$
$$c_8 v_8' = -i_{8C} + i_{78} + i_{98} \quad (5)$$
$$c_9 v_9' = -i_{93} - i_{98} - i_{96} \quad (6)$$
$$L_A i_{5A}' = v_5 - R_A i_{5A} \quad (7)$$
$$L_B i_{6B}' = v_6 - R_B i_{6B} \quad (8)$$
$$L_C i_{8C}' = v_8 - R_C i_{8C} \quad (9)$$
$$L_1 i_{41}' = v_4 - e_1 \quad (10)$$
$$L_{45} i_{45}' = v_4 - v_5 - R_{45} i_{45} \quad (11)$$
$$L_{46} i_{46}' = v_4 - v_6 - R_{46} i_{46} \quad (12)$$
$$L_2 i_{72}' = v_7 - e_2 \quad (13)$$
$$\cancel{L_{57} i_{75}' = v_7 - v_5 - R_{57} i_{75}} \quad (14)$$
$$L_{78} i_{78}' = v_7 - v_8 - R_{78} i_{78} \quad (15)$$
$$L_3 i_{93}' = v_9 - e_3 \quad (16)$$
$$L_{69} i_{69}' = v_9 - v_6 - R_{69} i_{69} \quad (17)$$
$$L_{89} i_{98}' = v_9 - v_8 - R_{89} i_{98} \quad (18)$$

B. Output Equations

$$y_1 = v_4 \quad (1)$$
$$y_2 = i_{41} \quad (2)$$
$$y_3 = i_{45} + \frac{c_{45}}{2c_4}(-i_{41} - i_{45} - i_{46}) \quad (3)$$
$$y_4 = i_{46} + \frac{c_{46}}{2c_4}(-i_{41} - i_{45} - i_{46}) \quad (4)$$
$$y_5 = v_7 \quad (5)$$
$$\cancel{y_6 = i_{75} + \frac{c_{57}}{2c_7}(-i_{72} - i_{75} - i_{78})} \quad (6)$$
$$y_7 = i_{72} \quad (7)$$
$$y_8 = i_{78} + \frac{c_{78}}{2c_7}(-i_{72} - i_{78}) \quad (8)$$
$$y_9 = v_9 \quad (9)$$
$$y_{10} = i_{96} + \frac{c_{69}}{2c_9}(-i_{93} - i_{96} - i_{98}) \quad (10)$$
$$y_{11} = i_{98} + \frac{c_{89}}{2c_9}(-i_{93} - i_{96} - i_{98}) \quad (11)$$
$$y_{12} = i_{93} \quad (12)$$