Q1

Saturday, March 23, 2024 3:18 PM

Bus #	Type	Rating	Details
1	Slack	400 MW	13.8 kV
2	Load	13.8 kV	$S_2 = 150 + j30$ MVA
3	Load	13.8 kV	$S_3 = 200 + j50$ MVA, p.f = 22 MVA

Power base of system $S_{base} = 100$ MVA

Voltage base of system $V_{base} = 13.8$ kV

$$Z_{Base} = \frac{(V_{Base})^2}{S_{Base}} = \frac{(13.8\,kV)^2}{100\,MVA} = 1.90\,\Omega$$

Bus 1 – 3 Voltages 1.0 p.u

$$P_1 = \frac{400\,MW}{100\,MVA} = 4\ p.u$$

$$P_2 = \frac{150\,MW}{100\,MVA} = 1.5\ p.u \qquad Q_2 = \frac{30\,MVAR}{100\,MVA} = 0.3\ p.u$$

$$P_3 = \frac{200\,MW}{100\,MVA} = 0.2\ p.u$$

$$Q_{3\text{-final}} = Q_3 - Q_{3\,(pf\ correction)}$$

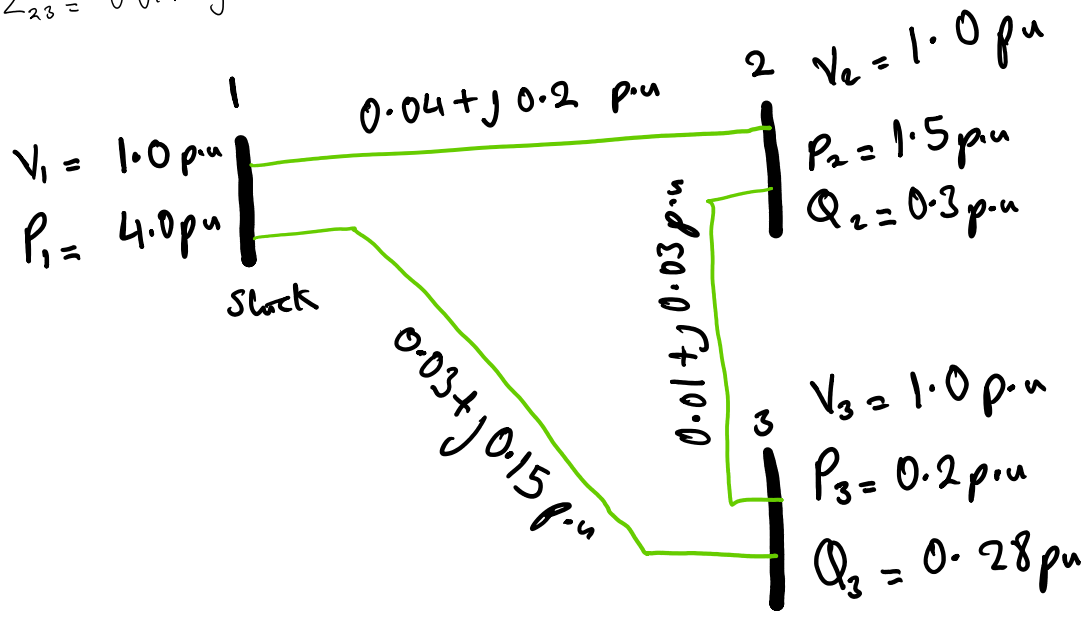
$$Q_{3\text{-final}} = 50 - 22\ [MVAR] = 28\,MVAR$$

$$Q_3 = \frac{28\,MVAR}{100\,MVA} = 0.28\ p.u$$

$$Z_{12} = 0.076 + j0.38\ \Omega = 0.04 + j0.2\ p.u$$

$$Z_{13} = 0.057 + j0.285\ \Omega = 0.03 + j0.15\ p.u$$

$$Z_{23} = 0.019 + j0.057\ \Omega = 0.01 + j0.03\ p.u$$



(1b) 3x3 Admittance Matrix

$$Y = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} \\ Y_{21} & Y_{22} & Y_{23} \\ Y_{31} & Y_{32} & Y_{33} \end{bmatrix}$$

$$Y_{11} = \frac{1}{Z_{12}} + \frac{1}{Z_{13}} \qquad Y_{22} = \frac{1}{Z_{12}} + \frac{1}{Z_{23}}$$

$$Y_{33} = \frac{1}{Z_{23}} + \frac{1}{Z_{13}}$$

$$Y_{12} = Y_{21} = \frac{1}{Z_{12}}$$

$$Y_{13} = Y_{31} = \frac{1}{Z_{13}}$$

$$Y_{23} = Y_{32} = \frac{1}{Z_{23}}$$

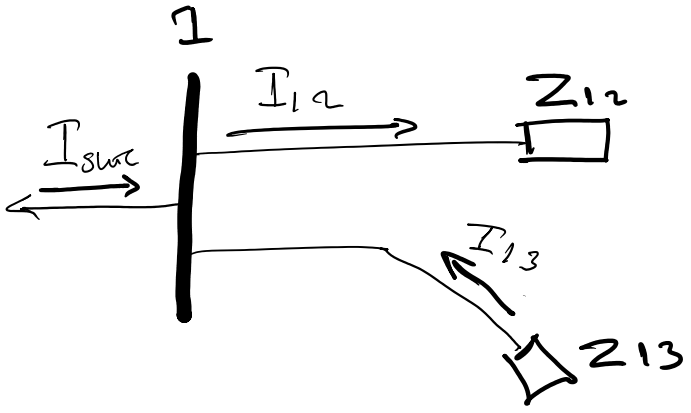
$$Y = \begin{bmatrix} 2.243 - j11.218 & -0.962 + j4.808 & -1.282 + j6.410 \\ -0.962 + j4.808 & 10.962 - j34.808 & -10.0 + j30.0 \\ -1.282 + j6.410 & -10.0 + j30.0 & 11.282 - j36.410 \end{bmatrix}$$

1c

$$V_k(i+1) = \frac{1}{Y_{kk}}\left[\frac{P_k - jQ_k}{V_k^*(i)} - \sum_{n=1}^{k-1} Y_{kn} V_n(i+1) - \sum_{n=k+1}^{N} Y_{kn} V_n(i)\right]$$

where $k = 1:3$ $n = 1:3$

Voltage at Bus 1



Sum of Current at a note is Zero

$$I_{slack} + I_{12} + I_{13} = 0$$

$$I_{slack} = \frac{S_{slack}}{V_1} = \frac{P - jQ}{V_1}$$

$$I_{12} = \frac{V_1 - V_2}{Z_{12}} = Y_{12}(V_1 - V_2)$$

$$I_{13} = \frac{V_1 - V_3}{Z_{13}} = Y_{13}(V_1 - V_3)$$

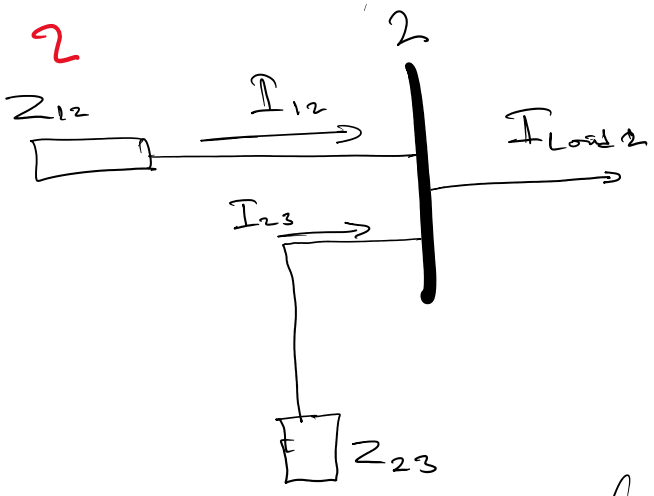
$$\frac{P - jQ}{V_1} = Y_{12}V_1 + Y_{13}V_1 - \left(Y_{12}V_2 + Y_{13}V_3\right)$$

$$\frac{P - jQ}{V_1} = V_1\left(Y_{12} + Y_{13}\right)$$

$$\frac{P - jQ}{V_1} = V_1\left(Y_{11}\right) - \left(Y_{12}V_2 + Y_{13}V_3\right)$$

$$V_1 = \frac{1}{Y_{11}}\left[\frac{P_1 - jQ_1}{V_1^*} - \left(Y_{12}V_2 + Y_{13}V_3\right)\right]$$

At Bus 2

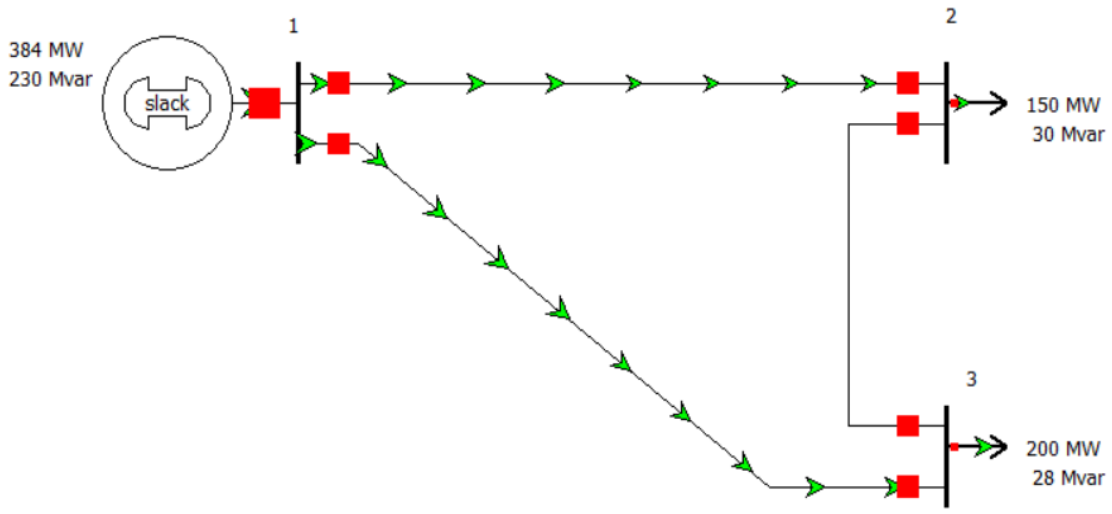


$$V_2 = \frac{1}{Y_{22}}\left[\frac{P_2 - jQ_2}{V_2^*} - \left(Y_{21}V_1 + Y_{23}V_3\right)\right]$$

At Bus 3

$$V_3 = \frac{1}{Y_{33}}\left[\frac{P_3 - jQ_3}{V_3^*} - \left(Y_{31}V_1 + Y_{32}V_2\right)\right]$$

Bus Data From Power World Simulation										
Number	Name	Area Name	Nom kV	PU Volt	Volt (kV)	Angle (Deg)	Load MW	Load Mvar	Gen MW	Gen Mvar
1	1	1	13.8	1	13.8	0			384.27	229.78
2	2	1	13.8	0.79114	10.918	-21.45	150	30		
3	3	1	13.8	0.79293	10.942	-21.49	200	28		



_____Lamin Jammeh EE488 SP2024_____

_____Y Admittance Matrix_____

```
   2.2436 -11.2179i  -0.9615 + 4.8077i  -1.2821 + 6.4103i
  -0.9615 + 4.8077i  10.9615 -34.8077i -10.0000 +30.0000i
  -1.2821 + 6.4103i -10.0000 +30.0000i  11.2821 -36.4103i
```

Iteration	V1	V2	V3
1	1+0i	0.97981-0.036736i	0.96136-0.078769i
2	1+0i	0.94568-0.10548i	0.92945-0.13607i
3	1+0i	0.91548-0.15493i	0.90149-0.17702i
4	1+0i	0.88916-0.19018i	0.87729-0.20617i
5	1+0i	0.8665-0.21527i	0.85654-0.22697i
6	1+0i	0.84712-0.2332i	0.83886-0.2419i
7	1+0i	0.83063-0.24613i	0.82384-0.25274i
8	1+0i	0.81663-0.25556i	0.81109-0.26072i
9	1+0i	0.80475-0.26255i	0.80027-0.26668i
10	1+0i	0.79467-0.26781i	0.7911-0.27122i
11	1+0i	0.78611-0.27183i	0.7833-0.27472i
12	1+0i	0.77884-0.27496i	0.77668-0.27747i
13	1+0i	0.77266-0.27744i	0.77104-0.27967i
14	1+0i	0.76739-0.27942i	0.76623-0.28144i
15	1+0i	0.7629-0.28103i	0.76213-0.28289i
16	1+0i	0.75907-0.28235i	0.75863-0.28408i
17	1+0i	0.7558-0.28344i	0.75564-0.28506i
18	1+0i	0.753-0.28435i	0.75308-0.28589i
19	1+0i	0.7506-0.28511i	0.75088-0.28658i
20	1+0i	0.74855-0.28574i	0.74901-0.28716i
21	1+0i	0.74679-0.28628i	0.7474-0.28766i
22	1+0i	0.74528-0.28674i	0.74602-0.28808i
23	1+0i	0.74399-0.28712i	0.74483-0.28843i
24	1+0i	0.74288-0.28745i	0.74381-0.28874i
25	1+0i	0.74192-0.28773i	0.74294-0.28899i
26	1+0i	0.7411-0.28797i	0.74219-0.28921i
27	1+0i	0.7404-0.28818i	0.74154-0.2894i
28	1+0i	0.7398-0.28835i	0.74099-0.28956i
29	1+0i	0.73928-0.2885i	0.74051-0.2897i
30	1+0i	0.73883-0.28863i	0.7401-0.28982i
31	1+0i	0.73845-0.28874i	0.73975-0.28992i
32	1+0i	0.73812-0.28883i	0.73945-0.29001i
33	1+0i	0.73783-0.28892i	0.73919-0.29009i
34	1+0i	0.73759-0.28898i	0.73897-0.29015i
35	1+0i	0.73738-0.28904i	0.73877-0.2902i
36	1+0i	0.7372-0.2891i	0.73861-0.29025i
37	1+0i	0.73704-0.28914i	0.73846-0.29029i
38	1+0i	0.73691-0.28918i	0.73834-0.29033i
39	1+0i	0.73679-0.28921i	0.73824-0.29036i
40	1+0i	0.73669-0.28924i	0.73815-0.29038i

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41                1+0i          0.73661-0.28926i          0.73807-0.29041i
42                1+0i          0.73654-0.28928i            0.738-0.29043i
43                1+0i           0.73647-0.2893i          0.73794-0.29044i
44                1+0i          0.73642-0.28932i          0.73789-0.29046i
45                1+0i          0.73637-0.28933i          0.73785-0.29047i
46                1+0i          0.73633-0.28934i          0.73781-0.29048i
47                1+0i           0.7363-0.28935i          0.73778-0.29049i
48                1+0i          0.73627-0.28936i           0.73775-0.2905i

______Real Power, Reactive Power and Voltage at each Bus________
V(1) = 1;       P1) = 3.8;       Q(1) = 2.3
V(2) = 0.74-0.29i;       P2) = -1.5;       Q(2) = -0.3
V(3) = 0.74-0.29i;       P3) = -2;       Q(3) = -0.28

_____________Dispaly number of Iteration__________
iterations = 48
>>
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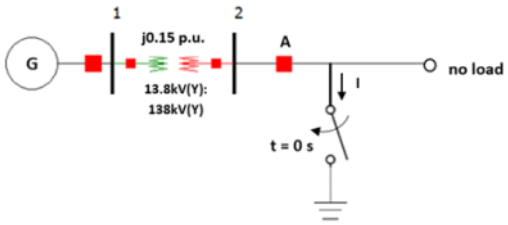
Q2

Friday, March 29, 2024 6:35 AM

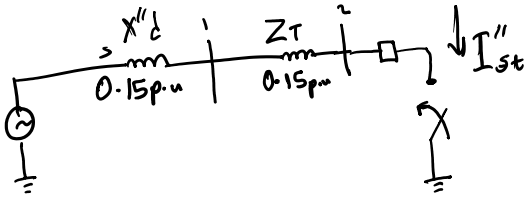


$S_{Base} = 100\,MVA$

$V_{Base} = 138\,kV$

$$I_{Base(sec)} = \frac{S_{Base}}{V_{Base}} = \frac{100\,MVA}{138\,kV} = 724.64\,A$$

$$Z_{Base} = \frac{(V_{base})^2}{S_{base}} = \frac{(138\,kV)^2}{100\,MVA} = 190.44\,\Omega$$



2a

$$I_{-stf} = \frac{\sqrt{2}\,(1.0)}{X''_d + Z_T} = \frac{\sqrt{2}\,(1.0)}{0.15 + 0.15}\ p.u \qquad (V_m = 1.0)$$

$$I_{-stf} = 4.714\ p.u$$

$$I_{-stf}[A] = I_{Base} \times I_{-stf} = 724.64A \times 4.714\ p.u$$

$$I_{-stf}[A] = 3.415\,kA$$

2b

$$I_{-DC} = I_{-stf} \times e^{\frac{-t}{T_A}}$$

$$t@\ 3\,cycles = \frac{3}{f} = \frac{3}{60} = 5\,m\,sec$$

$$I_{-DC} = 4.714 \times e^{\frac{-5}{0.15}}$$

$$I_{-DC} = 3.378\ p.u$$

$$I_{-DC[A]} = I_{-Base} \times I_{-DC} = 724.64A \times 3.378\ p.u$$

$$I_{-DC[A]} = 2.448\ [kA]$$

$$I_{-AC}(t) = \sqrt{2}\,(1.0)\left[\left(\frac{1}{x''_d + z_T} - \frac{1}{x'_d + z_T}\right)e^{\frac{-t}{T''_d}} + \left(\frac{1}{x'_d + z_T} - \frac{1}{x_d + z_T}\right)e^{\frac{-t}{T'_d}} + \frac{1}{x_d + z_T}\right)$$

$$I_{-AC}(0.05) = \sqrt{2}\left[\left(\frac{1}{0.15+0.15} - \frac{1}{0.25+0.15}\right)e^{\frac{-0.05}{0.038}} + \left(\frac{1}{0.25+0.15} - \frac{1}{1.2+0.15}\right)e^{\frac{-0.05}{1.50}} + \frac{1}{1.20+0.15}\right)$$

$$I_{-AC}(0.05) = 3.7701\ p.u \quad \text{from matlab}$$

$$I_{-rms} = \sqrt{I_{-AC}^2 + I_{-DC}^2}$$

$$I_{-rms} = \sqrt{(3.7701)^2 + (3.378)^2}$$

$$I_{-rms} = 5.062\ p.u$$

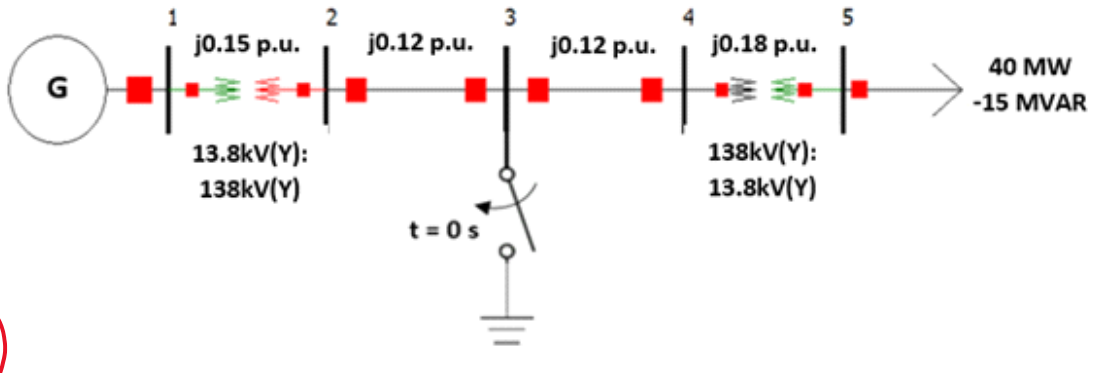
$$I_{-rms[A]} = I_{Base} \times I_{-rms}$$

$$I_{-rms[A]} = 724.64A \times 5.062\ p.u$$

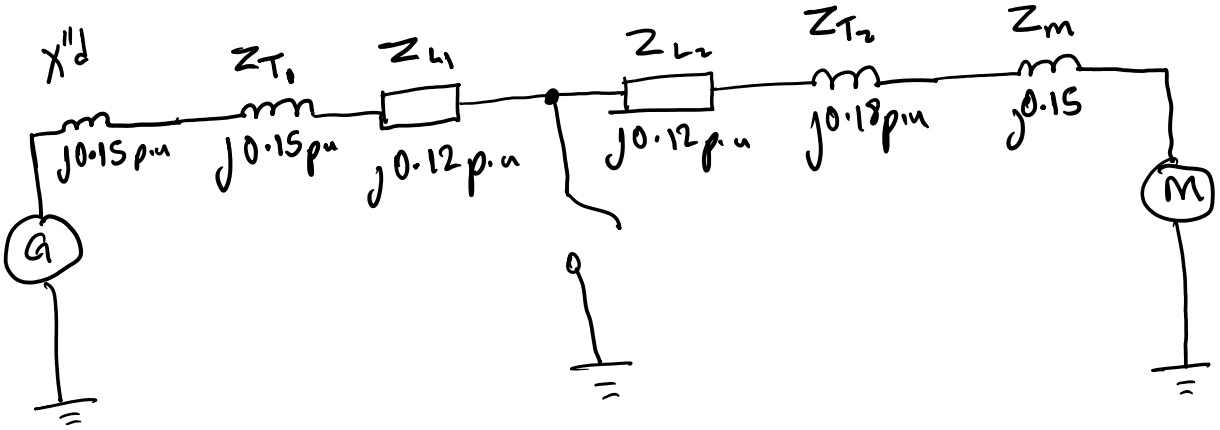
$$I_{-rms[A]} = 3.668\ [kA]$$

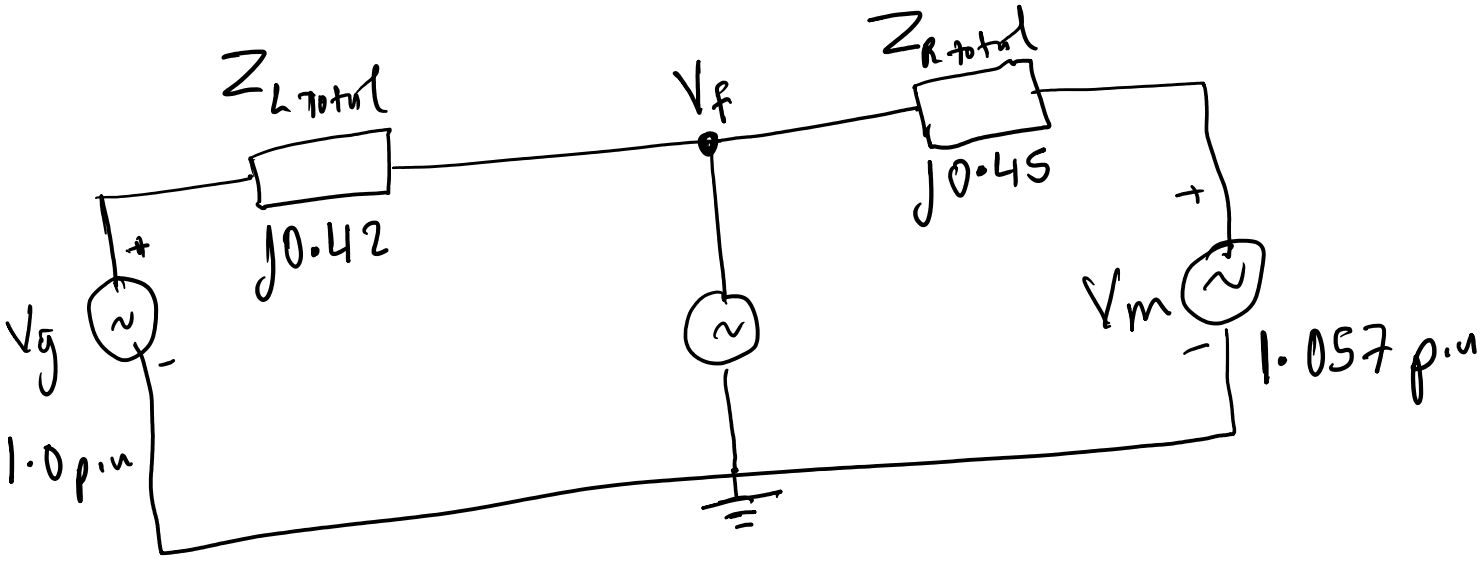
Q3

Friday, March 29, 2024 8:33 AM



3a





$$\frac{V_f - V_{1(LV)}}{Z_{L\,Total}} + \frac{V_f - V_m}{Z_{R\,Total}} = 0$$

$$\frac{V_f - 1.0}{0.42} + \frac{V_f - 1.057\angle -12.45^\circ}{0.45}$$

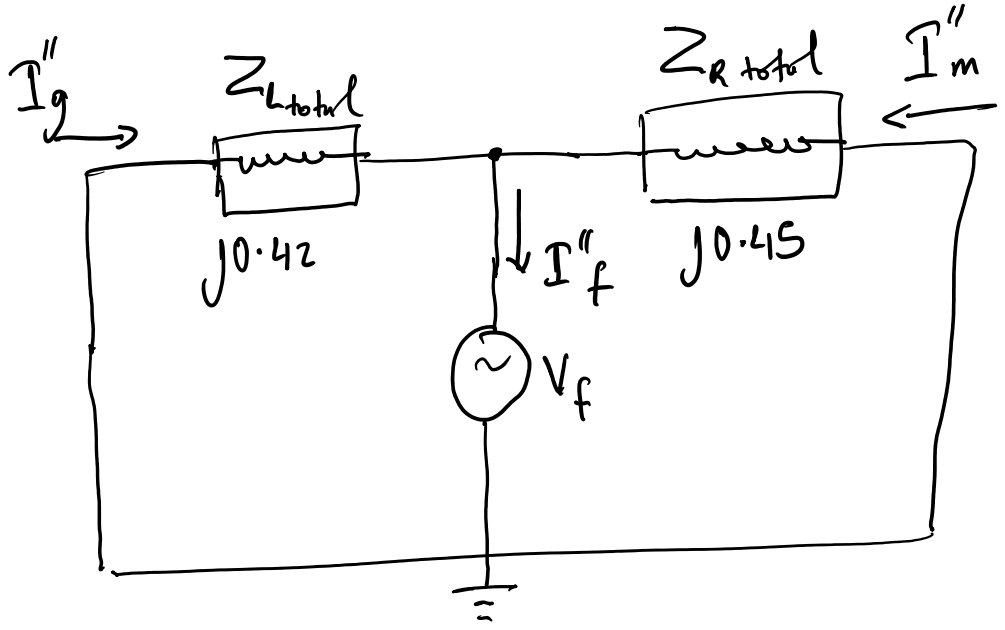
$$V_f\left(\frac{1}{0.42} + \frac{1}{0.45}\right) = \frac{1.0}{0.42} + \frac{1.057\angle -12.45^\circ}{0.45}$$

using Matlab

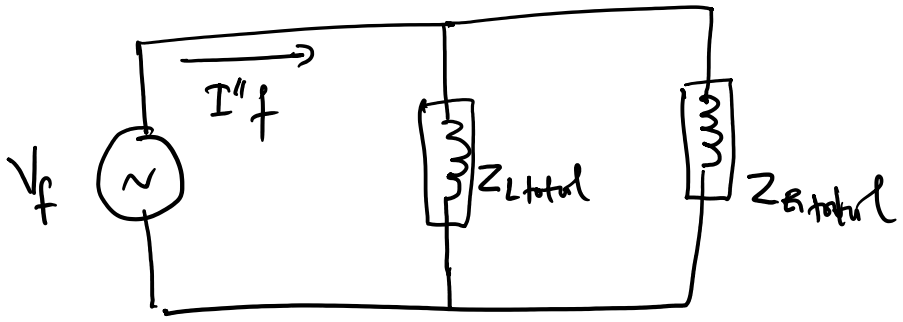
$$V_f = 1.0154 - j0.110$$

$$V_f = 1.02\angle -6.19^\circ \text{ p.u}$$

(35)



$$I''_f = I''_g + I''_m$$



$$I''_f = \frac{V_f}{Z_{L\,total} \,//\, Z_{R\,total}}$$

$$Z_{L\,total} \,//\, Z_{R\,total} = j\left(\frac{0.42 \times 0.45}{0.42 + 0.45}\right)$$

$$= j\,0.2172 \text{ p.u}$$

$$I''_f = \frac{1.02 \angle -6.8^\circ \text{ p.u}}{j\,0.2172} = -0.5067 - j4.6743 \text{ [p.u]}$$

$$I''_f = 4.70 \text{ p.u}$$

$$I_{Base\,(High\,Voltage)} = \frac{S_{Base}}{V_{Base\,(High\,Voltage}} = \frac{100MVA}{138KV}$$

$I_{base} = 724.64[A]$

$I''_{f[A]} = I''_f \times I_{base} = -j4.70\ p.u \times 724.64A$

$I''_{f[A]} = 3.4072$ [KA] from matlab

3d I''_f in Q_3 is greater than I''_f in Q_2

Because of the Synchronous load

When a synchronous Motor comes to an abrupt stop a back Electro Motive force (EMF) is generated, thus changes the motor from load to a Voltage source this Voltage contributes current in the system. In Robotics a Tvs diode is normally used to protect the circuit from Back, EMF of the motor

Q4

Friday, March 29, 2024 12:52 PM

Characteristic	Value
Normal operating voltage	161 kV
Maximum operating voltage	165 kV
Continuous current rating	1.8 kA
Maximum calculated symmetrical fault current (at max operating voltage)	35 kA

4part1

selecting line 24 from the top of table 7.10 pg 456

$I_{max} = 50\,kA \quad V_{max} = 169\,kV \quad V_{nominal} = 161\,kV$

Symetric Interupting Capability$(I_{fcap}) = I_{max}\left(\frac{V_{max}}{V_{normal}}\right) = 50\,kA\left(\frac{169\,kV}{161\,kV}\right)$

$I_{fcap} = 52.48[kA]$

80% $I_{fcap} \geq I_f$ of the system @ operating voltage

$0.8 \times 52.48[kA] \geq 35[kA]$

$41.98[kA] \geq 35[kA]$

4part2

In order to select the next circuit Breaker up the list the calculated symmetrical fault current (at max operating Kv (stage 5) will have to change from 35kA to 40kA