#Q	Mark	
1	31	31
2	14	14
3	5	11
4	19	21
5	13	13
Sum	82	90

27/30

University of Jordan

Electrical Eng. Dept

EE 0933481 Power Systems (1) **Second Exam.**

Time: 75 minutes **29-11-2017**

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31/31

Q1) The Z_{bus} matrix of a given network with values in PU is as follows:

$$Z_{bus} = j\begin{bmatrix} 0.69 & 0.61 & 0.55 & 0.60 \\ 0.61 & 0.73 & 0.63 & 0.69 \\ 0.55 & 0.63 & 0.69 & 0.64 \\ 0.60 & 0.69 & 0.64 & 0.71 \end{bmatrix}$$

a-Evaluate Z_{th} between buses 3 and 4. **[6]**

6/6

$Z_{th_{34}} = Z_{33} + Z_{44} - 2Z_{34} = j0.69 + j0.71 - 2(j0.64)$

$\Rightarrow Z_{th_{3,4}} = j0.12$

b-If a balanced 3-ph fault occur on Bus 1, evaluate the amount of fault current which would flow in the line between buses 2 and 4 if the line admittance is –j4 pu. **[8]**

8/8

$\boxed{I_{24} = \frac{V_2 - V_4}{Z_b}}$ --- ① ; where $Z_b \equiv$ impedance of the branch $= \frac{1}{-j4} = j0.25$ PU

$\boxed{Z_b = j0.25}$ --- ②

$V_2 = V_f\left(1 - \frac{Z_{21}}{Z_{11}}\right)$

$= 1\angle 0°\left(1 - \frac{j0.61}{j0.69}\right) \Rightarrow \boxed{V_2 = 0.1159}$ PU --- ③

$V_4 = V_f\left(1 - \frac{Z_{41}}{Z_{11}}\right)$

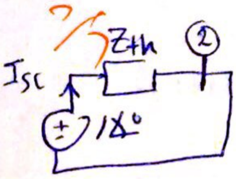
$= 1\angle 0°\left(1 - \frac{j0.6}{j0.69}\right) \Rightarrow \boxed{V_4 = 0.1304}$ PU --- ④

Now sub. ②, ③ & ④ into ① & solving:

$I_{24} = 0.058\angle 90°$ PU #

c-If an industrial consumer is to be connected to bus 2, what would be the S/C MVA supplied by the power company to the consumer. **[5]**

5/5



$I_{sc(PU)} = \frac{1}{Z_{th}}$; $I_{sc(PU)} = S/C\,MVA_{(PU)}$ | so $S/C\,MVA = \frac{1}{|Z_{th}|}$; $Z_{th} = Z_{22} = j0.73$

$\Rightarrow S/C\,MVA = -j1.37$

$\Rightarrow |S/C\,MVA| = 1.37$ PU.

d-If a 25 MVA, 13.8 kV generator is the only source in the network and connected to bus 1 through a circuit breaker and the Z_{bus} includes the generator reactance. The circuit breaker at its maximum voltage of 16 kv has rated s/c interrupting current of 10 kA and K=1.3, is this breaker suitable when a balanced 3-ph fault occur on bus 1. **[12]**

12/12

Max V = 16 KV → I_{sc} = 10 KA

K = 1.3

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Q1 (d)

This CB To be selected it must satisfy the followings:

(i) voltage of the system must be within the range of operating voltage of the CB.

$K = 1.3 = \frac{V_{max}}{V_{min}}$ so $V_{min} = \frac{16K}{1.3} \Rightarrow \boxed{V_{min} = 12.31 \text{ Kvolt}}$

so the range as follows: 12.31 Kvolt − 16 Kvolt.

⇒ and we were given that the voltage of the system is 13.8 Kvolt which is within the range.

* Condition (i) satisfied.

(ii) The calculated fault current $\leq$ 0.8 rated s/c current @ that voltage (i.e 13.8K volt.)

$I_f = \frac{V_f}{Z_{11}}$ (since it is on Bus (1)).

$\Rightarrow I_f = \frac{1\angle 0}{j0.69} = \underline{1.4493 \angle -90^\circ}$ PU.

The base current @ bus (1) given by: $I_B = \frac{25 * 10^6}{\sqrt{3} * 13.8 * 10^3} \Rightarrow \boxed{I_B \simeq 1046 \text{ A}}$

so $|I|_{calculated} = (1.4493)(1046) \Rightarrow I_{cal.} \simeq 1516 \text{ A}$

Now the rated s/c current can be found as follows:

$I_{s/c} * \text{voltage} = \text{Constant}$

so $I_{s/c} * 13.8K = 16K * 10K \Rightarrow I_{s/c} \simeq 11594 \text{ A}$ @13.8Kv

Now $0.8 * 11594 = 9275.2$

so $I_{calc.} = 1516 \leq 9275.2$

so condition (ii) satisfied.

** This CB is suitable to be used. #

for each Km

$$L_{aa} = \frac{0.002\,mH \times 1000}{1000\,m} = 2\,mH/Km$$

Q2) A 60 Hz transmission line has the following parameters:

L_{aa} =0.002 mH/m, Z_1 = j 0.524 Ω/km, Z_0 = j 1.847 Ω/km, Z_{an} =0.0

a-Evaluate the self inductance of the Neutral line. [7]

b-Evaluate the mutual inductance between phase conductors. [7]

14/14

a) $Z_0 = Z_s + 2Z_m$; $Z_s = Z_{aa} + 2Z_{an} + Z_{nn}$ & $Z_m = Z_{ab} - 2Z_{an} + Z_{nn}$

so $Z_0 = Z_{aa} + 2Z_{ab} - 6\overset{0}{Z_{an}} + 3Z_{nn} = j1.847$

b) ---

$Z_1 = Z_s - Z_m = Z_{aa} - Z_{ab} = j0.524 = j(120\pi)(2m) - Z_{ab}$

$\Rightarrow Z_{ab} = j0.23 = j\omega L \Rightarrow L_{ab} = \frac{0.23}{2\pi \times 60} \Rightarrow L_{ab} = 0.61\,mH/Km$

mutual between phase conductors.

Back to part ⓐ:

$j1.847 = j(120\pi)(2m) + 2(j0.23) + 3Z_{nn}$

$\Rightarrow 3Z_{nn} = j0.633$ so $j\omega L_{nn} = j\left(\frac{0.633}{3}\right) \Rightarrow L_{nn} = \frac{0.633}{2\pi \times 60\ (3)}$

$L_{nn} = 0.56\,mH/Km \Rightarrow$ ~~$L_{nn} = 1.679\,mH/Km$~~ $\Rightarrow$ mutual of Neutral line.

5/11

Q3) Derive the expression of Complex Power in terms of Symmetrical Components. [11]

~~$S_{3\phi} = 3V_{an}I_{an}^* + V_{bn}I_{bn}^* + V_{cn}I_{cn}^*$~~ ; ~~$V_{an} = V_{an}^{(0)} + V_{an}^{(1)} + V_{an}^{(2)}$~~

~~$I_{an}^* = I_a^{(0)} + I_a^{(1)} + I_a^{(2)}$~~

$S_{3\phi} = 3V_{an}I_{an}^*$

~~S could be written as follows: S = 3 [~~

$3\,I_a^{(0)*}V_a^{(0)}$

$3\,[V_a^{(0)}\ V_a^{(1)}\ V_{an}$

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Q3 The Complex Power in 3ϕ system is given by:

$$S_{3\phi} = V_{an} I_{an}^{*} + V_{bn} I_{bn}^{*} + V_{cn} I_{cn}^{*}$$

$$= \begin{bmatrix} V_{an} & V_{bn} & V_{cn} \end{bmatrix} \cdot \begin{bmatrix} I_{an}^{*} \\ I_{bn}^{*} \\ I_{cn}^{*} \end{bmatrix}$$

$$= \begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix}^{T} \begin{bmatrix} I_{an} \\ I_{bn} \\ I_{cn} \end{bmatrix}^{*}$$ ⇒ Now Converting To Symmetrical Components.

$$= [A]^{T} \begin{bmatrix} V^{(0)} \\ V^{(1)} \\ V^{(2)} \end{bmatrix}^{T} \cdot [A]^{*} \begin{bmatrix} I^{(0)} \\ I^{(1)} \\ I^{(2)} \end{bmatrix}^{*}$$

Now we can note that: $[A]^{T} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}^{T} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} = [A]$

also $[A]^{*} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}^{*} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} = [A^{-1}] \times 3$ $\neq$

⇒ So Now: $S = [A]^{T} \begin{bmatrix} V^{(0)} \\ V^{(1)} \\ V^{(2)} \end{bmatrix}^{T} \cdot [A^{-1}] \begin{bmatrix} I^{(0)} \\ I^{(1)} \\ I^{(2)} \end{bmatrix}^{*}$

acc. to your $[A][A^{-1}] = 1$

$$\Rightarrow [A][A^{-1}] = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} = \begin{bmatrix} 3 & 0 & 0 \\ 0 & 3 & 0 \\ 0 & 0 & 3 \end{bmatrix} = 3 \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} = 3\, I_n$$

So, S becomes: $S = 3 \begin{bmatrix} V^{(0)} \\ V^{(1)} \\ V^{(2)} \end{bmatrix}^{T} \begin{bmatrix} I^{(0)} \\ I^{(1)} \\ I^{(2)} \end{bmatrix}^{*}$

$$\Rightarrow \boxed{S = 3 V^{(0)} I^{(0)*} + 3 V^{(1)} I^{(1)*} + 3 V^{(2)} I^{(2)*}} \quad (VA)$$

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19/21

Q4) **Fig. 1 shows a pu sequence network for a given power system.**

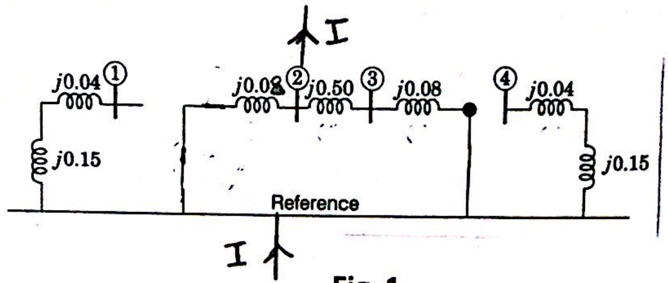


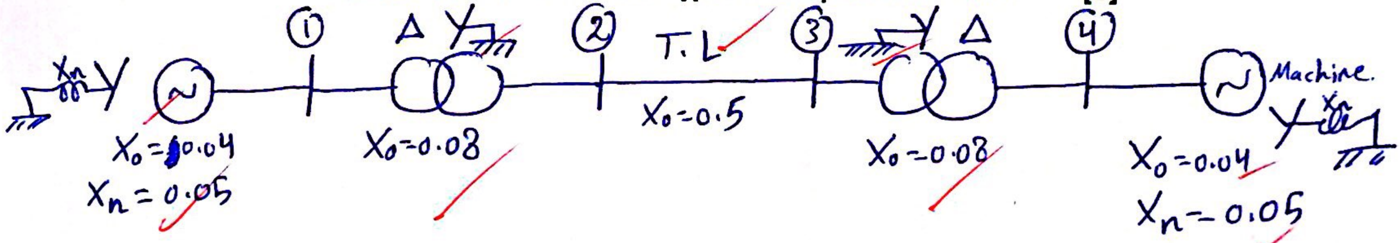
Fig. 1

a-What is the type of this sequence. **[2]**

2/2

Zero-seq-Network [since the Neutral impedance is shown & the connection of Transform Tells that].

b-Draw the corresponding single Line Diagram showing on each component its connection type and impedance value. **[8]**



8/8

c-If I= -j1.9 pu, find the value of the corresponding Sequence Voltage. **[11]**

The fault occur @ busbar ②.

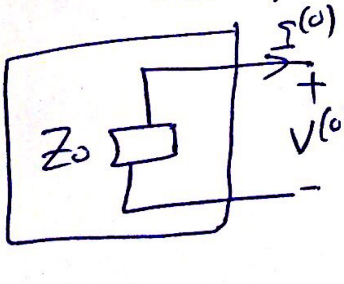
9/11

so Z_0 represent the thevenin equ. seen by bus② & Ref. as follows: $Z_0 = (j0.08) // (j0.5 + j0.08)$

$\Rightarrow \boxed{Z_0 = j0.0703}$ --①

$I = -j1.9 = 3I^{(0)} \Rightarrow$ so $\boxed{I^{(0)} = 0.633 \angle -90^\circ}$ --②

The equ. zero-seq-Network for a fault @ busbar② is given by:



so $\boxed{V^{(0)} = -I^{(0)} Z_0}$ --③

Now sub ①&② into ③ gives:

$V^{(0)} = -(0.633 \angle -90^\circ)(j0.0703) \Rightarrow \boxed{V^{(0)} = -0.0445}$ PU.

1.37

=1.37

PU.

Q5) Let the Z_{bus} in (Q1) represent $Z_{bus}^{(2)}$ of a given power system. If a line-to-line fault occur at Bus 4 with $Z_f = 0$. By drawing the corresponding connection between sequence networks, evaluate the phase fault currents. **[13]**

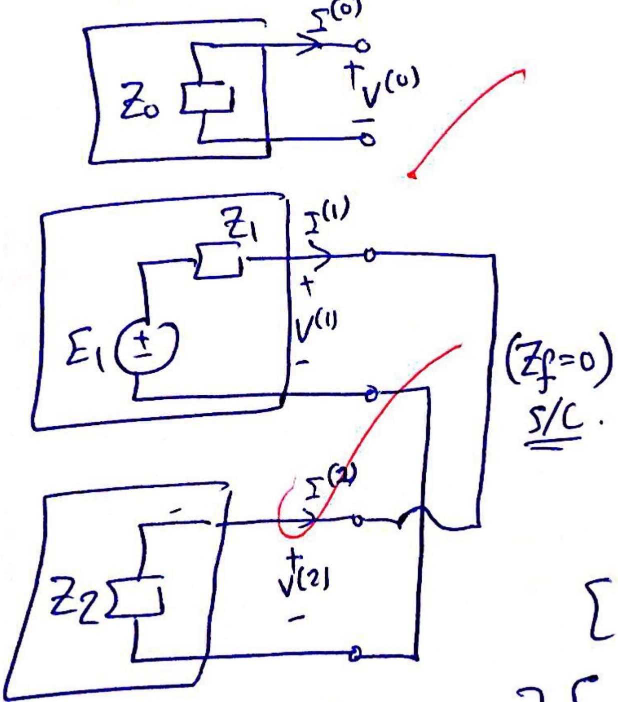
13/13

First we have to find Z_0, Z_1 & Z_2:

$Z_1 = Z_2 = Z_{44} = j0.71$ pu

Z_0 (we don't care to its value since it would be O/C).

Now the Connection would be as follows:



$$\boxed{I^{(0)} = V^{(0)} = 0}$$

$$I^{(1)} = \frac{E_1}{Z_1 + Z_2}$$

$$I^{(1)} = \frac{1\angle 0}{j0.71 + j0.71} \Rightarrow \boxed{I^{(1)} = 0.7042\angle -90^\circ}$$

$$I^{(2)} = -I^{(1)}$$

$$\Rightarrow \boxed{I^{(2)} = 0.7042\angle +90^\circ}$$

$$[I_{abc}] = [A][I_{012}]$$

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} 0 \\ 0.7042\angle -90 \\ 0.7042\angle 90 \end{bmatrix} = \begin{bmatrix} 0 \\ 1.2197\angle 180^\circ \\ 1.2197\angle 0^\circ \end{bmatrix}$$

so

$I_a = 0$ pu

$I_b = 1.2197\angle 180^\circ$ pu

$I_c = 1.2197\angle 0^\circ$ pu

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