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UNIT4:SHORTCIRCUITANALYSIS

Possible2markquestions:

1. What is meant by a fault?

A fault in a circuit is any failure which interrupts with the normal flow of current. The faults are associated with abnormal change in current, voltage and frequency of the power system. The faults may cause damage to the equipments, if it is allowed to persist for a long time.

2. Give the reason for faults in power system?

Faults occur in a power system due to insulation failure of equipments, flashover of lines initiated by a lightening stroke, permanent damage to conductors and towers or accidental faulty operations.

3. List the various types of symmetrical and unsymmetrical faults. (MAY/JUNE 2006)

Symmetrical fault:

5. Three phase fault

Unsymmetrical faults:

6. Single line-to-ground fault
7. Line-to-line fault
8. Double line-to-ground fault

4. For a fault at a given location, rank the various faults in the order of severity.

In a power system, the most severe fault is three phase fault and less severe fault is open conductor fault. The various faults in the order of decreasing severity are,

6) 3 phase fault
7) Double line-to-ground fault
8) Line-to-line fault
9) Single line-to-ground fault
10) Open conductor fault

5. What is meant by fault calculations?

The fault condition of a power system can be divided into subtransient, transient, and steady state periods. The currents in the various parts of the system and in the fault locations are different in these periods. The estimation of these currents for various types of faults at various locations in the system is commonly referred to as fault calculations.

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6. What is synchronous reactance?

The synchronous reactance is the ratio of induced emf and the steady state rms current (i.e., it is the reactance of a synchronous machine under steady state condition). It is the sum of leakage reactance and the reactance representing armature reaction. It is given by,

$$X_s = X_l + X_a$$

Where,

X_s = Synchronous reactance
X_l = Leakage reactance
X_a = Armature reaction reactance.

7. Define subtransient reactance.(APR/MAY 2004)

The subtransient reactance is the ratio of induced emf on no-load and the subtransient symmetrical rms current, (i.e., it is the reactance of a synchronous machine under subtransient condition). It is given by,

Subtransient reactance, $$X_d'' = \frac{E_g}{I''} = X_l + \frac{1}{\frac{1}{X_a} + \frac{1}{X_f} + \frac{1}{X_{dw}}}$$

Where

X_l = Leakage reactance
X_a = Armature reaction reactance
X_f = Field winding reactance
X_{dw} = Damper winding reactance.

8. Define transient reactance.

The transient reactance is the ratio of induced emf on no-load and the transient symmetrical rms current. (i.e.,it is the reactance of synchronous machine under transient condition). It is given by,

Transient reactance, $$X_d' = \frac{E_g}{I'} = X_l + \frac{1}{\frac{1}{X_a} + \frac{1}{X_f}}$$

Where X_l = Leakage reactance X_a = Armature reaction reactance
X_f = Field winding reactance

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9.What is the significance of subtransient reactance and transient reactance in short circuit studies?

The subtransient reactance can be used to estimate the initial value of fault current immediately on the occurrence of the fault. The maximum momentary short circuit current rating of the circuit breaker used for protection or fault clearing should be less than this initial fault current.

The transient reactance is used to estimate the transient state fault current. Most of the circuit breakers open their contacts only during this period. Therefore for a circuit breaker used for fault clearing (or protection), its interrupting short circuit current rating should be less than the transient fault current.

10. Write down the equation determining fault current in a generator when its reactance is known.

The equation is,

$$|I| = \frac{|E_g|}{X_d} \quad , \quad |I'| = \frac{|E_g|}{X_d'}$$

where

$|I|$ = Steady state symmetrical fault current

$|I'|$ = Transient symmetrical fault current

X_d = Direct axis synchronous reactance

X_d' = Direct axis transient reactance

$|E_g|$ = RMS voltage from one terminal to neutral at no load.

11.Write the equation for subtransient and transient internal voltage of the generator.

The equation for subtransient internal voltage is,

$$E_g'' = V_t + jI_L X_d''$$

Transient internal voltage is,

$$E_g' = V_t + jI_L X_d'$$

where

E_g'' = Subtransient internal voltage of generator

E_g' = Transient internal voltage of generator

V_t = Terminal voltage

I_L = Load current

X_d'' =Direct axis subtransient reactance

X_d' =Direct axis transient reactance

12.Write the equation for subtransient and transient internal voltage of the motor.

The equation for subtransient internal voltage is,

$$E_m'' = V_t - jI_L X_d''$$

Transient internal voltage is,

$$E_m' = V_t - jI_L X_d's$$

where

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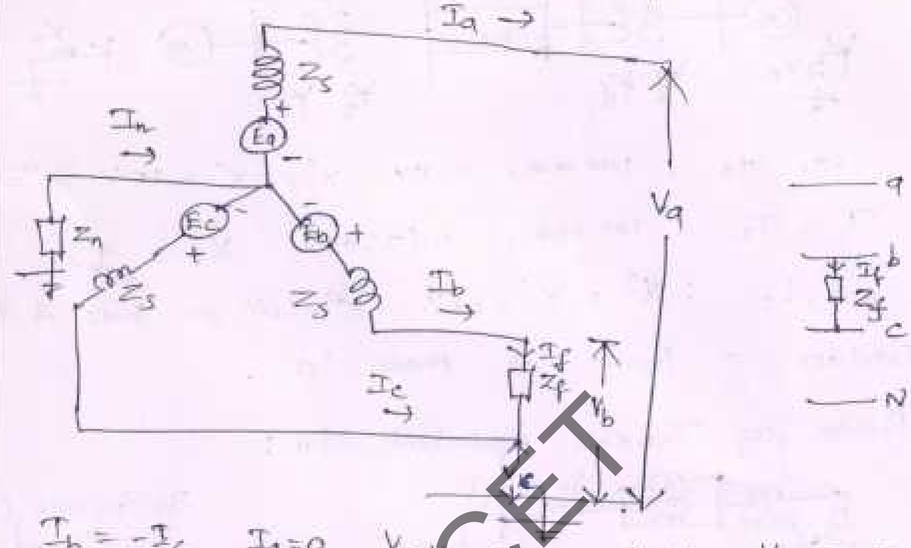
Part B

1. Derive the expression for fault current in line to line fault on an unloaded generator in terms of symmetrical components.



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$I_b = -I_c \quad I_a = 0 \quad V_b - V_c = Z_f I_b \Rightarrow V_c = V_b - Z_f I_b$

$$I_a^{+} = -I_a^{-} \ \& \ I_a^{0} = 0$$

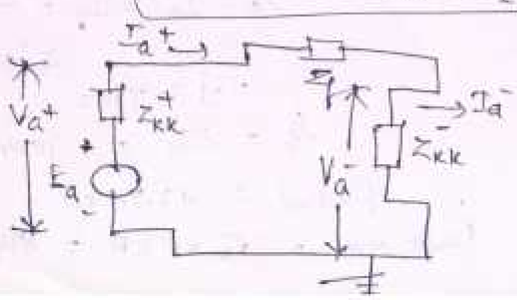
$V_a^{0} = 0 \ ; \ V_a = V_a^{+} + V_a^{-} \ ; V_b = a^2 V_a^{+} + a V_a^{-}$

$V_c = a V_a^{+} + a^2 V_a^{-} \qquad V_b - V_c = Z_f I_b$

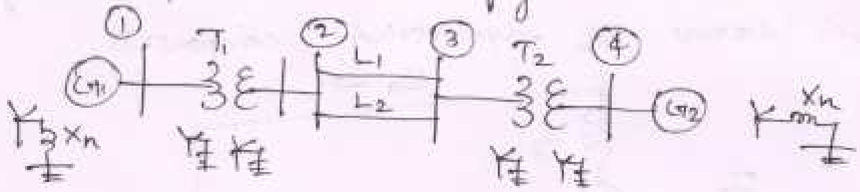
$I_a^{-} = -I_a^{+} \ ; \ I_a^{0} = 0$

$I_b = -I_c = (a^2 - a) I_a^{+}$

$$I_f = I_b = \frac{-j\sqrt{3}\,E_a}{Z_{kk}^{+} + Z_{kk}^{-} + Z_f}$$



2. Determine the fault current and MVA at faulted bus for a line to ground (solid) fault at bus 4 as shown in fig.



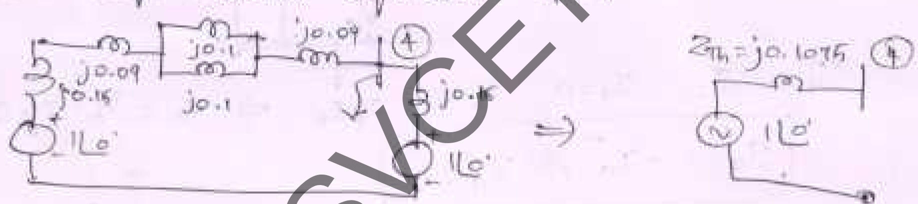
G_1, G_2 : 100 MVA, 11 kV $x^+, x^- = 15\%$ $x^0 = 5\%$ $X_n = 6\%$

T_1, T_2 : 100 MVA, 11/220 kV $X_1 = 9\%$

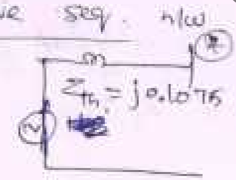
L_1, L_2 : $X^+ = X^- = 10\%$ $X^0 = 10\%$ on base of 100 MV

Consider a fault at phase 'a'.

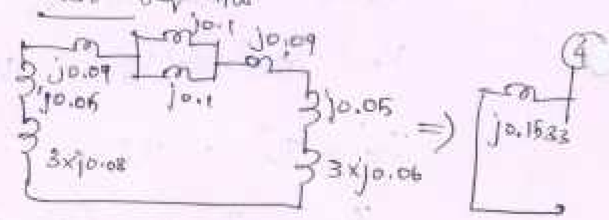
Positive seq. Thevenin equivalent n/w :



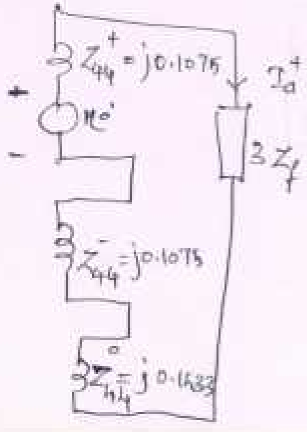
Negative seq. n/w



Zero seq n/w



Seq. n/w



$I_a^+ = I_a^- = I_a^0 = \frac{1}{3} I_f$

$E_a = V^0 = 1\angle 0$

$I_a^+ = I_a^- = I_a^0 = \frac{V^0}{Z_{44}^+ + Z_{44}^- + Z_{44}^0 + Z_f}$

$= -j\,2.7152$

$I_f = 3I_a^+ = -j8.1455$ pu

I_f actual $= 42.75$ kA

Fault MVA $= \sqrt{3}$ kV kA $= 814.55$,

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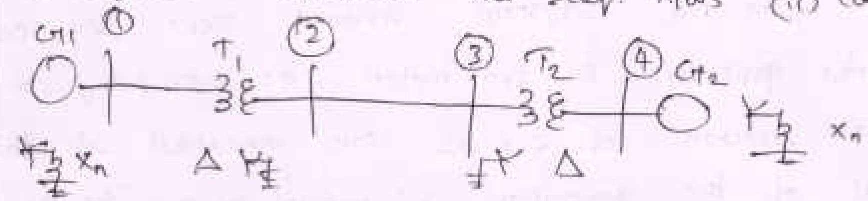
3. A single line to ground fault occurs on bus 4 of the system. (i) Draw the seq. n/ws (ii) Compute fault ct

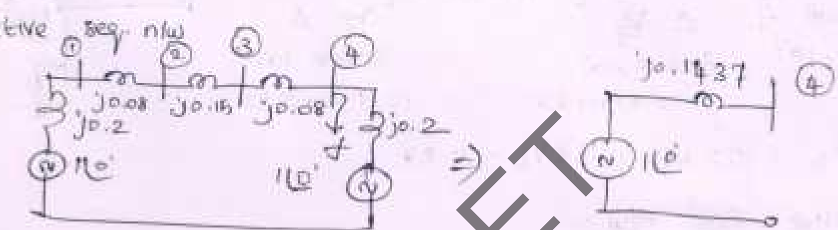


G_1 & G_2 : 100 MVA, 20 kV $X' = X'' = 20\%$ $X_0 = 4\%$ $X_n = 5\%$

T_1 & T_2 : 100 MVA, 20/345 kV $X_{leak} = 8\%$ on 100 MVA

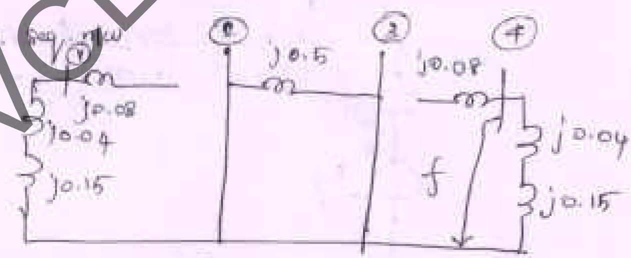
Tr. line : $X' = X'' = 15\%$ $X_0 = 50\%$ on a base of 100 MVA, 20 kV

Positive seq. n/w



Neg. seq n/w :

Zero seq. n/w



$Z_{44}^{0} = j0.19$

$$I_a^+ = I_a^- = I_a^0 = \frac{V^0}{Z_{44}^+ + Z_{44}^- + Z_{44}^0}$$

$$= -j\,2.094 \text{ p.u}$$

$$I_f = 3 I_a^+ = -j\,6.28 \text{ pu}$$

$$I_{f\,actual} = 18128.8 \text{ A}$$

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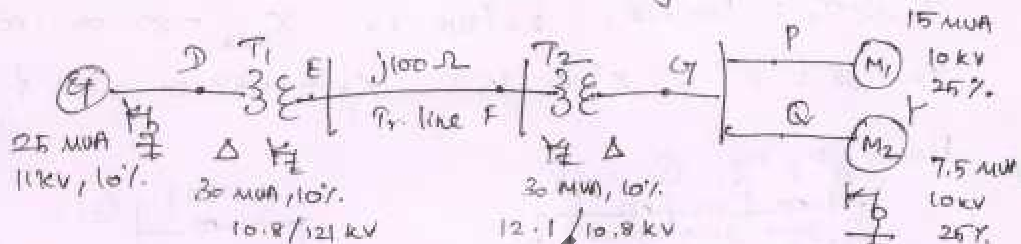
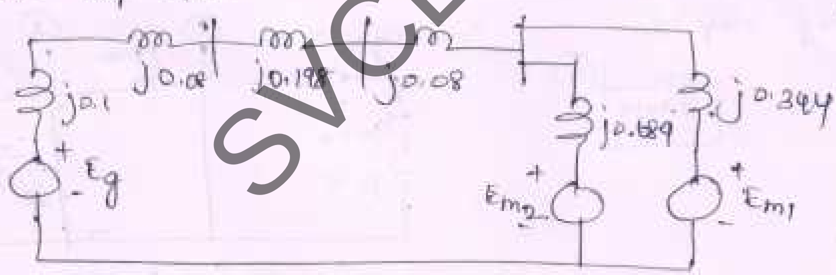
4. Determine the positive, negative & zero seq. n/ws for the system. Assume zero seq. reactance for the generator & syn. motors as 0.06 p.u, ct limiting reactors of 2.5 Ω are connected in the neutral of the generator & motor no 2. The zero seq. reactance of the tr. line is j300 Ω.



$MVA_b = 25$ MVA, $kV_b = 11$ kV

Positive Seq. n/w :



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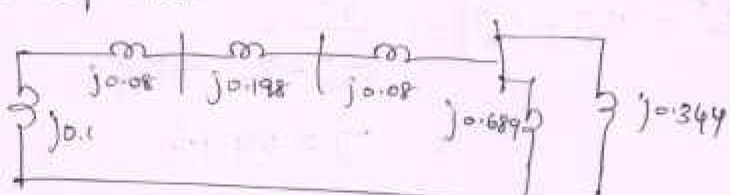
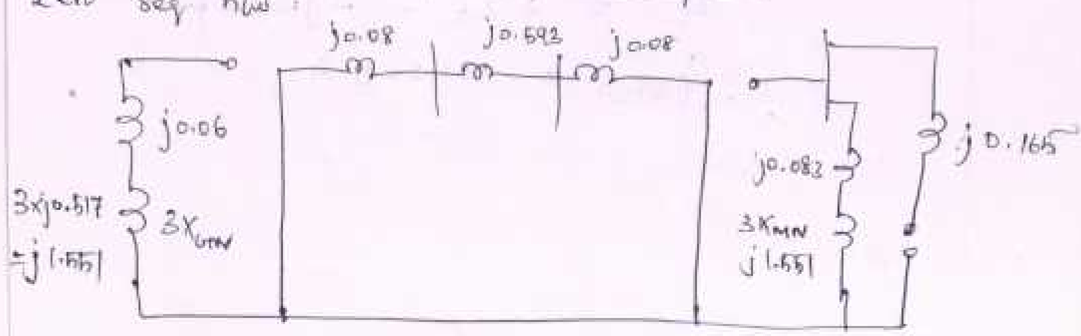
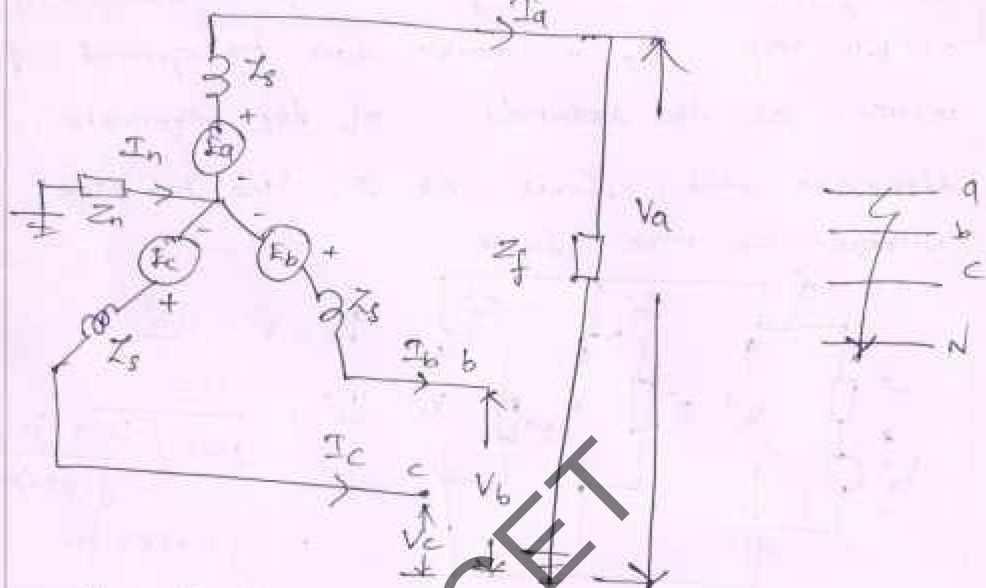
Negative Seq. n/w :



Zero Seq. n/w :



5. Develop the connection of seq. n/w when a line to ground fault occurs in a power n/w.



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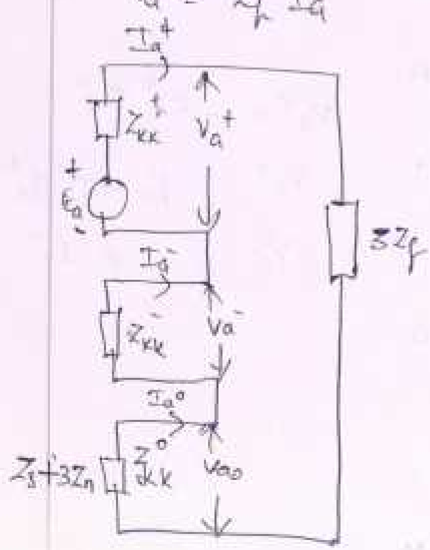
$V_a = Z_f I_a$; $I_b = I_c = 0$ $\quad I_f = I_a$

$I_a^+ = I_a^- = I_a^0 = \frac{I_a}{3} = I_f/3$

$V_a = V_a^0 + V_a^+ + V_a^-$

$V_a = Z_f I_a$

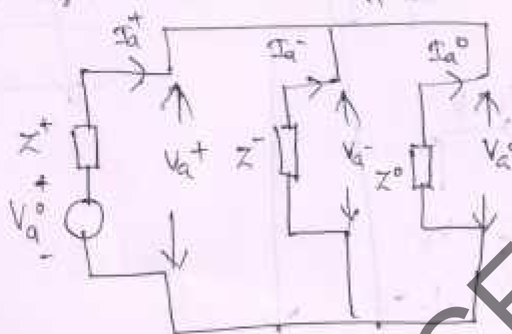


$$I_a^+ = \frac{E_a}{Z_{kk}^0 + Z_{kk}^+ + Z_{kk}^- + 3Z_f}$$

$I_f = I_a = 3 I_a^+$

$Z_{kk}^+ = Z_{kk}^-$

6. A 25 MVA, 13.2 kV alternator with solidly grounded neutral has a sub. transient reactance of 0.25 pu. The negative & zero seq. reactances are 0.35 p.u & 0.01 p.u resp. If a double line to ground fault occurs at the terminals of the alternator, determine the fault ct & line to line voltage at the fault.



$E_a = V^0 = 1\angle 0$

$$I_a^+ = \frac{1\angle 0}{j0.25 \left(\frac{j0.35 \times j0.1}{j0.35 + j0.1} \right)}$$

$= -j3.0508$ pu

$$I_a^- = -I_a^+ \times \frac{Z_0}{Z^- + Z^0} = j0.678 \text{ pu}$$

$$I_a^0 = -I_a^+ \frac{Z^-}{Z^- + Z^0} = j2.373 \text{ pu}$$

$I_f = 3 I_a^0 = j7.119$ pu

$I_{f\,(actual)} = I_f I_b = j7.784$ kA

$V_a^0 = -Z_a^0 I_a^0$

$V_a^+ = E_a - Z^+ I_a^+$

$V_a^- = -Z^- I_a^-$

$V_a = V_a^0 + V_a^+ + V_a^- = 0.7119$

$V_b = V_a^0 + a^2 V_a^+ + a V_a^- = 0$

$V_c = V_a^0 + a V_a^+ + a^2 V_a^- = 0$

$V_{ab} = V_a - V_b = 0.7119$ pu

$V_{bc} = V_b - V_c = 0$ pu

$V_{ac} = V_a - V_c = 0.7119$ pu

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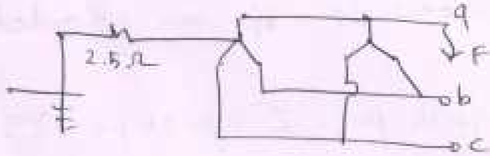
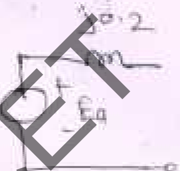
7. Two 13.2 kV, 25 MVA, 3ϕ Y connected g, operate in parallel the positive, negative & zero seq. reactance s are j0.4, j0.30 & j0.08 p.u. The star point of one of the g is isloted and that of the other is earthed through a 2.5 Ω recistor. A single line to gnd fault occure at the terminals of one of the generators. Estimate (i) I_f (ii) ct in the grounding recistor (iii) Voltage across the grounding recistor.



Positive seq n/w

$$Z^+ = \frac{j0.4 \times j0.4}{j0.4 + j0.4} = j0.2$$



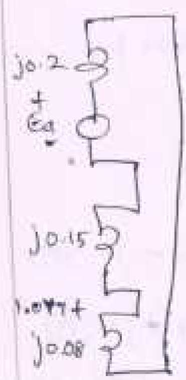
Negative seq. n/w

$$Z^- = \frac{j0.3 \times j0.3}{j0.3 + j0.3} = j0.15$$

Zero seq. n/w

$$Z^0 = Z_s + 3Z_n = j0.08 + 1.077$$

Seq. n/w



$$I_a^+ = I_a^- = I_a^0 = E_a / Z^+ + Z^- + Z^0 = 0.8 - j0.3194 \text{ p.u}$$

$$I_f = 3I_a^+ = 2.4025 - j0.959 \text{ pu}$$

$$I_f = 2828.69 \text{ A}$$

$$V_f = 7.07 \text{ kV}$$

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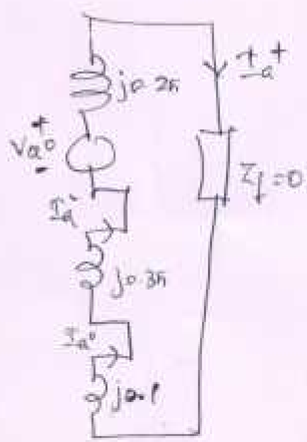
8. A salient pole generator with out damper is rated 25 MVA, 13.2 kV and has a direct axis sub. tr. reac. of 0.25 p.u. The negative & zero seq. reac. are 0.35 & 0.1 p.u. The neutral of the generator is solidly grounded. Determine the sub. tran. ct in the generator and line to line voltage for a sub. tr. conditions when a single line to ground fault occurs at the terminals of an unloaded g.



$Z^+ = j0.25$ pu $Z^- = j0.35$ pu $Z^0 = 0.1j$ pu

$E_a = V^0 = 1\angle 0^\circ$

$I_a^+ = I_a^- = I_a^0 = \frac{V_0}{Z_1^+ + Z^- + Z^0} = -j1.4286$ pu

$I_f = 3 I_a^+ = -j4.2857$ pu

$I_{f\,actual} = 4686.28$ A

$I_a = I_a^0 + I_a^+ + I_a^- = -j4.2858$ pu

$I_b = I_a^0 + I_a^+ a^2 + a I_a^- = 0$ pu

$I_c = I_a^0 + a I_a^+ + a^2 I_a^- = 0$ pu

$V_a^0 = -Z_0 I_a^+ = -0.1429$ pu

$V_a^+ = V_0 - Z^+ I_a^+ = 0.6429$ pu

$V_a^- = -Z^- I_a^+ = -0.5$ pu

$V_a = V_a^0 + V_a^+ + V_a^- = 0$

$V_b = V_a^0 + a^2 V_a^+ + a V_a^- = -0.2144 - j0.9898$

$V_c = V_a^0 + a V_a^+ + a^2 V_a^- = -0.2144 + j0.9898$

$V_{ab} = 0.2144 + j0.9898$ pu $V_{bc} = -j1.9796$ pu $V_{ca} = -0.2144 - j0.9898$ pu

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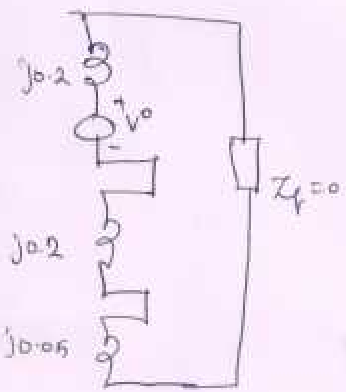
9. A 30 MVA, 11 kV generator has $Z_1 = Z_2 = j0.2$ pu $Z_0 = j0.05$ pu. A line to gnd fault occurs on the generator terminals. Find the fault ct & line to line voltages during fault conditions. Assume that the generator neutral is solidly grounded and that the generator is operating at no-load and at rated voltage at the occurence of fault.



$I_a^+ = I_a^- = I_a^0 = -j2.222$ pu

$I_f = 3I_a^+ = -j6.666$ pu

$I_{f(actual)} = 10496.2$ A

$V_a^0 = -0.111$ $\quad V_a^+ = 0.5555$

$V_a^- = -0.4444$

$V_a = 0$ $\quad V_b = -0.29 - j0.267$

$V_c = -0.29 + j0.267$

$V_{ab} = 0.29 + j0.267$ pu

$V_{bc} = -j0.534$ pu

$V_{ac} = 0.29 - j0.267$ "

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6. A 50 MVA, 11 kV, 3 ϕ alternator was subjected to different types of faults. The fault cts are 3ϕ fault 1870 A, line to line fault 2590 A, single line to gnd fault 4180 A. The alternator neutral is solidly grounded. Find the p.u values of the 3ϕ seq. reactance of the alternator.

$MVA_b = 50 \qquad kV_b = 11$

$I_b = \frac{MVA_b \times 10^3}{\sqrt{3}\, kV_b} = 2624.3 A$

$I_f(pu) = V^0/Z^+ = -j0.713$

$Z^+ = j1.4$ pu

$I_f(pu)LL = \frac{-j\sqrt{3}V^0}{Z^+ + Z^-} = -j0.99$

$Z^- = j0.36$

$I_{fpu}(L.G) = \frac{3V^0}{Z^+ + Z^- + Z^0} = -j1.57$

$Z^0 = j0.16$ p.u

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