Sri Vidya College of Engineering And Technology
Virudhunagar – 626 005
Department of Electrical and Electronics Engineering

SHORT QUESTIONS AND ANSWERS

Year/ Semester/ Class : III/ V/ EEE Academic Year: 2017-2018

Subject Code/ Name: EE6501/ Power System Analysis

UNIT III FAULT ANALYSIS – BALANCED FAULTS

1. Write the relative frequency of occurrence of various types of faults.

S.No.	Type of fault	Relative frequency of occurrence
1.	Three phase fault	5%
2.	Double line-to-ground fault	10%
3.	Line- to-line fault	15%
4.	Single line-to-ground fault	70%

2. Find the fault current in Fig.2, if the pre-fault voltage at the fault point is 0.97 p.u.?

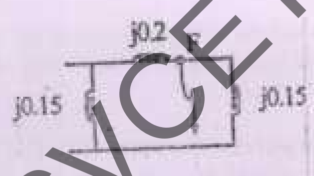


Fig.2

3. What are the assumptions made in short circuit studies of a large power system network?

- Representing each machine by a constant voltage source behind proper reactances which may be X'', X' or X.
- Pre fault load currents are neglected.
- Transformer taps are assumed to be nominal.
- Shunt elements in the transformer model that account for magnetizing current and core loss are neglected.
- A symmetric three phase power system is considered.
- Shunt capacitance of the transmission line is ignored.
- Series resistances of transmission lines are neglected.
- The negative sequence impedance of alternators are assumed to be the same as their positive sequence impedance. $Z_1=Z_2$

4. What are the reactances used in the analysis of symmetrical faults on the synchronous machines as its equivalent reactance?

1. Sub transient reactance X_d''
2. Transient reactance X_d'
3. Synchronous reactance X_d

5. What is the reason for transients during short circuits?

The faults or short circuits are associated with sudden change in currents. Most of the components of the power system have inductive property which opposes any sudden change in currents so the faults (short circuit) are associated with transients.

6. **Define short circuit interrupting MVA of a circuit breaker.**
The short circuit interrupting MVA of a circuit breaker is the volt-amperes (power) flowing through it at the moment of opening its contacts due to a fault.
It is estimated by the following equations
Short circuit interrupting MVA = $\sqrt{3}|V_{pf.}||I_{fl.}|$
Short circuit interrupting MVA = $|V_{pf.,p.u}||I_{fl.,p.u}|$ MVA_b
Where,
$|I_{fl.}|$ **=Magnitude of line value of short circuit interrupting current at the fault in kA.**
$|V_{pf.}|$ **= Magnitude of line voltage at the fault point in kV.**
$|I_{fl.,p.u}|$ **= Magnitude of short circuit interrupting current at the fault in p.u.**
$|V_{pf.,p.u}|$ **= Magnitude of prefault voltage at the fault point in p.u..**

7. **Define short circuit capacity of power system (or) fault level.**
Short circuit capacity or short circuit MVA or fault level at a bus is defined as the product of the magnitudes of the pre fault bus voltage and the post fault current.

8. **What is meant by doubling effect?**
If a symmetrical fault occurs when the voltage wave is going through zero then the maximum momentary short circuit current will be double the value of maximum symmetrical short circuit current. This effect is called doubling effect.

9. **What is momentary current rating of circuit breaker? How it is estimated.**
The momentary current rating is the maximum current that may flow through a circuit breaker for a short duration. It is estimated by multiplying the symmetrical sub transient fault current by a factor of 1.6.

10. **What is interrupting short circuit current rating of circuit breaker? How it is estimated.**
The interrupting short circuit current rating of the circuit breaker is the maximum current that may flow through it when its contact open due to fault. It is estimated by multiplying the transient short circuit current by a factor of 1.0 to 1.5.The value of the factor depends on the speed of the breaker.

11. **List the various types of shunt faults.**
The various types of shunt faults are
- Line to ground fault
- Line to line fault
- Double Line to ground fault
- Three phase fault

12. **What is the need for short circuit analysis?**
The short circuit studies are essential in order to design or develop the protective schemes for various parts of the system. The protective scheme consists of current and voltage sensing devices, protective relays and circuit breakers. The selection of these devices mainly depends on various currents that may flow in the fault conditions.

13. List the various types of shunt and series faults.

The various types of shunt faults are

- Line to ground fault
- Line to line fault
- Double Line to ground fault
- Three phase fault

The various types of series faults are

- One open conductor fault
- Two open conductor fault

14. List the symmetrical and unsymmetrical faults.

The three phase fault is the only symmetrical fault. All other types of faults are unsymmetrical faults are unsymmetrical faults.

The various unsymmetrical faults are

- Line to ground fault
- Line to line fault
- Double Line to ground fault
- One or two open conductor fault.

15. Name any two methods of reducing short circuit current.

- By providing neutral reactance
- By introducing a large value of shunt reactance between buses.

17. Define DC off-set current.

The unidirectional transient component of short circuit current is called DC off-set current.

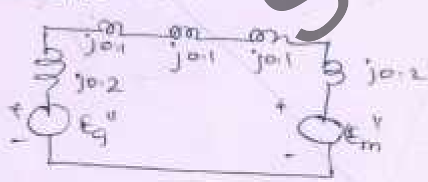
Part B

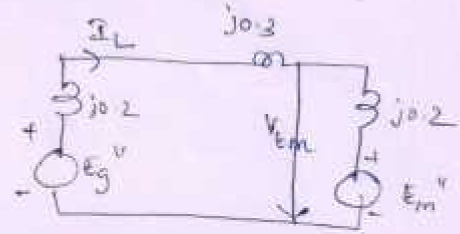
1. A synchronous generator and a syn. motor each rated 30 MVA, 11 kV having 20% sub transient reactance are connected through transformers and a line as shown in fig. The transformers are rated 30 MVA, 11/66 kV & 66/11 kV with a leakage reactance of 10% each. The line has a reactance of 10% on a base of 30 MVA, 66 kV. The motor is drawing 20 MW at 0.8 pf leading and a terminal voltage of 10.6 kV when a sym. fault occurs at the motor terminals. Find the sub. transient ct in the generator & motor.

Soln :

Base MVA = 30 Base kV = 11 kV

Reactance dia :





$V_{p.f} = \frac{10.6}{11} = 0.9636 \angle 0^\circ$ p.u

Prefault ct, $I^o = \frac{0.8333}{0.9636 \times 0.8}$ $\cos^{-1} 0.8$ $= 0.865 \angle 26.87^\circ$

$E_g'' = V^o + jI^o x_{dg}'' = 0.704 + j0.346$ pu

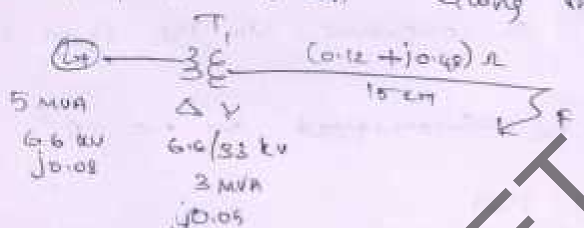
$I_g'' = E_g'' / Z_{pu} = 0.692 - j1.408$ pu

$E_m'' = V^o - jI^o \times x_{dm}'' = 1.0674 - j0.1384$ pu

$I_m'' = E_m'' / Z_{pu} = -0.692 - j5.337$ pu

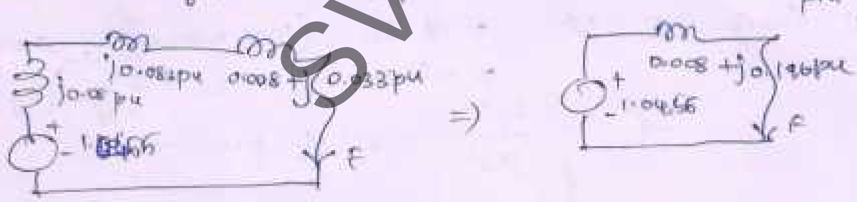
$I_f = I_g'' + I_m'' = -j6.745$ pu

3. A 3 ϕ, 5 MVA, 6.6 kV generator with a reactance of 8% is connected to a feeder of series impedance $(0.12 + j0.48)\ \Omega/\phi/km$ through a step up t/f. The t/f is rated at 3 MVA, 6.6 kV/33 kV & has a reactance of 5%. Determine the fault ck supplied by the generator operating under no load with a voltage of 6.9 kV, when a 3 ϕ sym. fault occurs at a point 15 km along the feeder.



$|E| = 1\ pu$ $\quad X_d'' = j0.08\ pu$ $\quad$ Base MVA = 5 $\quad kV_b = 6.6$

Reactance diagram $\quad V_{pf} = 6.9 \times 33/6.6 = 34.5 \quad V_{p.u} = \frac{34.5}{33} = 1.0455$



$$I_f(p.u) = \frac{E_{th}}{Z_{th}} = \frac{1.0455}{0.008 + j0.196} = 0.207 - j5.093\ pu$$

$$= 5.3197 \angle -87.6^\circ\ pu$$

$$\text{Base ck} = \frac{MVA \times 10^3}{\sqrt{3}\ kV_b} = \frac{5 \times 10^3}{\sqrt{3} \times 33} = 87.47\ A$$

$$I_{actual} = 5.3197 \times 87.47$$

$$= 465.2\ A$$

4. A generator is connected through a five cycle CB to a transformer, is rated at 100 MVA, 18 kV with reactances $X_d'' = 20\%$, $X_d' = 25\%$ & $X_d = 110\%$. It is operated on no load and at rated voltage. When a 3 φ fault occurs between the breaker and the t/f, find.

(a) Short ckt ct in CB

(b) Initial symmetrical rms ct in CB

(c) Max possible dc component of the short ckt ct in CB

(d) The ct to be interrupted by the CB

(e) Interrupting MVA.

Soln

$MVA_b = 100$ $kV_b = 18$ $I_b = 3207.5\ A$

(a) Short ckt ct $= 8\ I_b$ (max momentary short ckt ct $= 1.6\ |I_g''|$)

$= 25.66\ kA$

$$I_g'' = \frac{E_g''}{jX_d''} = 5 \angle -90^\circ \text{ pu}$$

(b) Initial Sym rms ct, $I_g'' = 5 \angle -90^\circ$ pu

$= 16.0375\ kA$

(c) Max possible dc component $= 25.66 - 16.0375$

$= 9.6225\ kA$

(d) Interrupting ct $=$ (p.u value of tr. fault ct) $\times 1.1$

$= \left(E_g'' / jX_d'\right) \times 1.1$

$= 4.4$ p.u $= 14.113\ kA$

(e) Interrupting MVA $=$ Prefault Voltage (p.u) $\times$ Int. ct (p.u) $\times$ Base MVA

$= 1 \times 4.4 \times 100 = 440$ MVA

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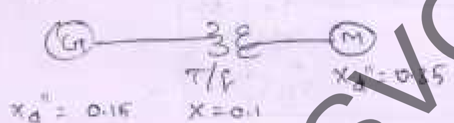
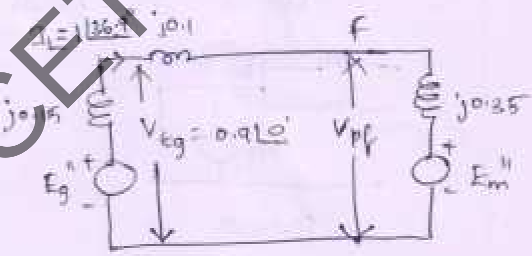
5. A generator is connected through a transformer to a syn. (m) the sub. tr. reactance of (g) & (m) are 0.15 p.u & 0.35 p.u. The leakage reactance of the t/f is 0.1 p.u. All the reactances are calculated on a common base. A 3 φ fault occurs at the terminals of the motor when the terminal voltage of the generator is 0.9 p.u. The output current of generator is 1 pu and 0.8 pf leading. Find the sub. tr. ct in p.u in the fault, generator and motor. Use the terminal voltage of generator as ref. vector.

Soln ;



Single line dia



Ckt model to compute sub. transient fault ct

Prefault condition

$$E_g'' = j0.15\, I_L + V_{tg}$$
$$= 0.8187 \angle 8.4° \text{ p.u}$$
$$E_m'' = V_{tg} - 0.j0.35\, I_L - j0.1\, I_L$$
$$= 1.2243 \angle -17.1° \text{ p.u}$$

Fault condition

$$I_f'' = I_g'' + I_m''$$
$$I_g''\, j0.15 + I_g''\, 0.1 = E_g'' \Rightarrow E_g'' = 3.2748 \angle -81.6° \text{ p.u}$$
$$\& \quad j0.35\, I_m'' = E_m''$$
$$I_m'' = 3.498 \angle -107.1° \text{ p.u}$$
$$I_f'' = 6.606 \angle -94.8° \text{ p.u}$$

6. Explain the step by step procedure for symmetric fault analysis using bus impedance matrix.

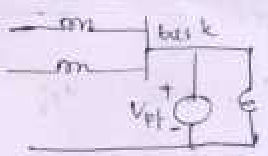
$$Z_{bus} I = V$$

$$\begin{bmatrix} Z_{11} & Z_{12} & \cdots & Z_{1k} & \cdots & Z_{1n} \\ Z_{21} & Z_{22} & \cdots & Z_{2k} & \cdots & Z_{2n} \\ \vdots & \vdots & & \vdots & & \vdots \\ Z_{k1} & Z_{k2} & \cdots & Z_{kk} & \cdots & Z_{kn} \\ \vdots & \vdots & & & & \\ Z_{n1} & Z_{n2} & \cdots & Z_{nk} & \cdots & Z_{nn} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ I_k \\ \vdots \\ I_n \end{bmatrix} = \begin{bmatrix} V_1 \\ V_2 \\ \vdots \\ V_k \\ \vdots \\ V_n \end{bmatrix}$$

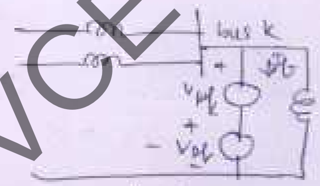
$I_1, I_2 \ldots I_n \Rightarrow$ cts injected to buses

$V_1, V_2 \ldots V_n \Rightarrow$ voltages at buses

Let a 3ϕ fault occur at bus k.



Prefault



fault

* $\Delta V_1 = -I_f Z_{1k}$; $\Delta V_2 = -I_f Z_{2k} \ldots -V_{pf} = -I_f Z_{kk}$

$\ldots \Delta V_n = -I_f Z_{nn}$; * $I_f = \dfrac{V_{pf}}{Z_{kk}}$

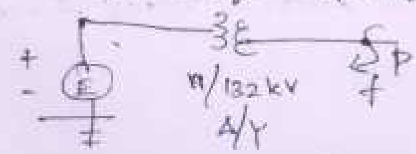
* $\Delta V_q = -I_f Z_{qk}$

* $V_1 = V_{pf} - I_f Z_{1k}$ $\quad V_2 = V_{pf} - I_f Z_{2k}$

$\ldots\ldots V_k = V_{pf} - V_{pf} = 0 \ldots V_n = V_{pf} - I_f Z_{nk}$

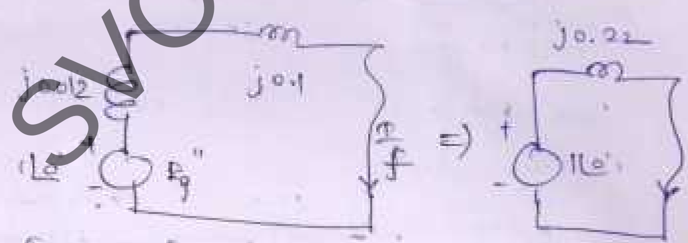
* $I_{qr} = \dfrac{V_q - V_r}{Z_{qr}}$.

7. A 60 MVA, Y connected 11 kV syn. G. is connected to a 60 MVA, 11/132 kV Δ/Y transformer. The sub transient reactance X_d'' of the generator is 0.12 p.u on a 60 MVA base, while the transformer reactance is 0.1 p.u on the same base. The g. is unloaded when a sym. fault is suddenly placed at point p as shown in fig. Find the sub. ct. fault ct in p.u and actual amperes on both side of the t/f. Phase to neutral voltage of the generator at no load is 1 p.v



Soln $|E| = 1$ pu $X_d'' = 0.12$ pu $MVA_b = 60$ $kV_b = 11$

Reactance dia



$$I_f\ (p.u) = \frac{E_{th}}{Z_{th}} = -j4.54\ p.u$$

Primary side of t/f

$$\text{Base ct } I_b = \frac{\text{Base MVA}}{\sqrt{3}\ kV_b} = 3.149\ kA$$

$$\therefore I_{f\,actual} = I_f\ (p.u) \times I_b = 14.297\ kA$$

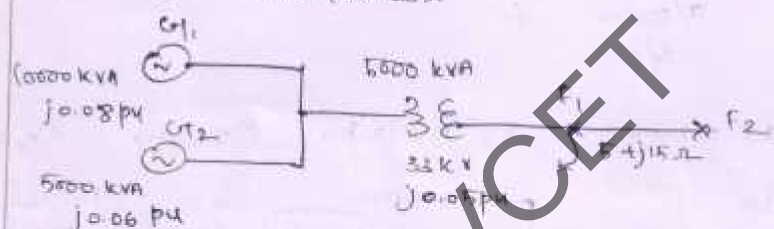
Secondary side of t/f

Base KV = 132 kV

Base ct = 0.262 kA

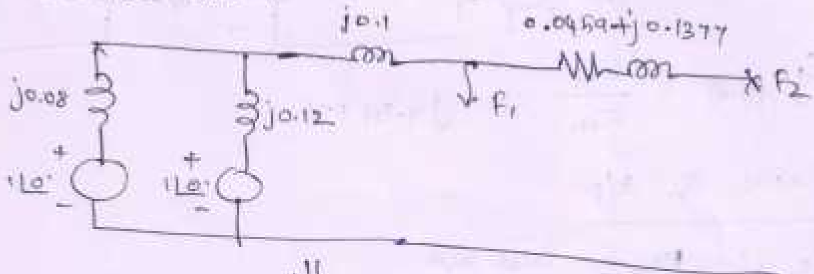
I_f (actual) = 1.189 kA

8. A 3φ tr. line operating at 33 kV and having resistance and reactance of 5 Ω & 15 Ω resp. is connected to the g. station bus bar through a 5000 kVA step up t/f which has a reactance of 0.05 p.u. Connected to the bus bars and two alternators are 10000 kVA having 0.08 p.u reactance and another 5000 kVA having 0.06 p.u reactance. Calculate the kVA at a short ckt fault between phases occuring at the high voltage terminals of the transformers.



Base MVA = 10 Base kV = 33

Reactance dia :



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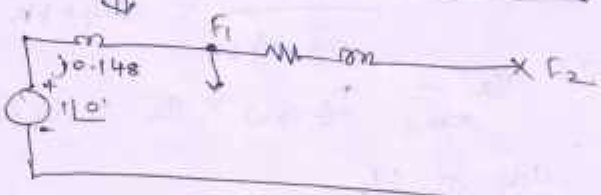
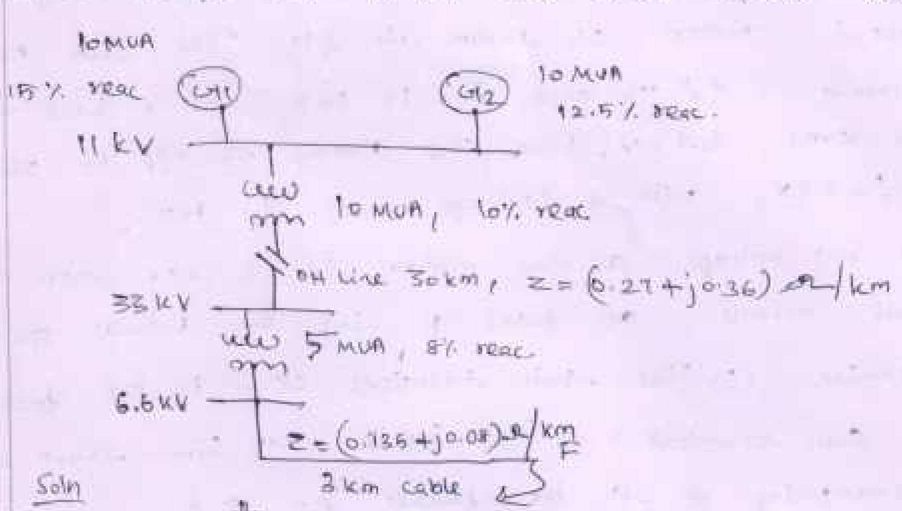


$$|KVA_{1\,s.c}| = \frac{KVA_b}{|Z_1 pu|} = \frac{10000}{0.148} = 67.568 \text{ MVA}$$

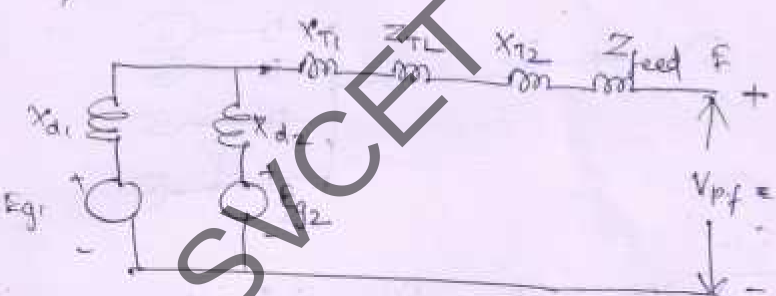
$$|KVA_{2.sc}| = \frac{KVA_b}{|Z_2 p.u|} = \frac{10000}{0.289} = 34.602 \text{ MVA}$$

9. For the radial n/w determine the fault ct & line voltage at 11 kV bus under fault conditions.



Soln

Imp. dia



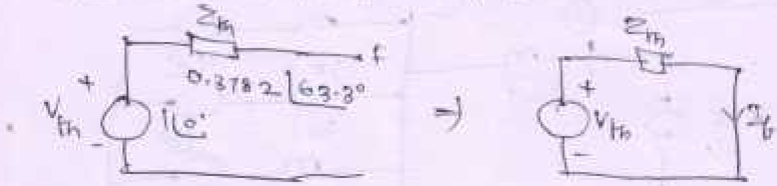
Base MVA = 10MVA ; Base kV = 11 kV

$V_{pf} = 1$ p.u

$X_{d1} = j0.2$ pu $\quad X_{d2} = j0.125$ pu

$X_{T1} = 0.1$ pu $\quad Z_{TL} = 0.0551 + j0.0918$ pu

$X_{T2} = 0.0348$ pu , $\quad Z_{feed} = 0.1148 + j0.0344$ p.u

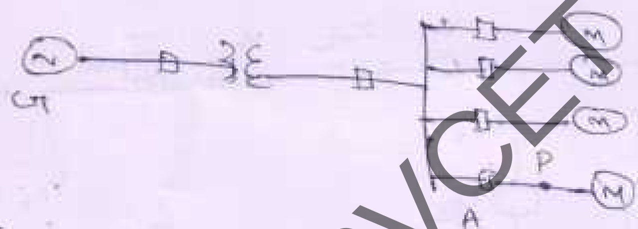


$Z_{th} = 0.3782\angle 63.3°$ $\quad I_f = \frac{V_{th}}{Z_{th}} = 2.6441\angle -63.3°$ p.u

$I_b = 874.77$ A

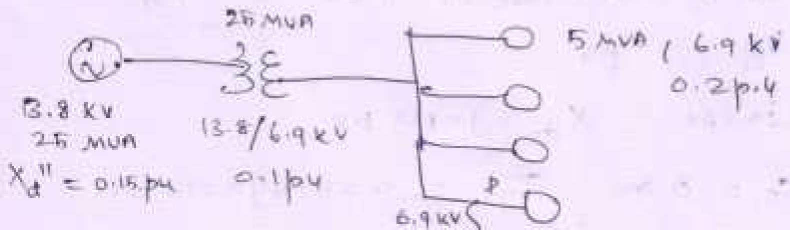
$I_{f\,(actual)} = 2.313\angle -63.3°$ kA

10. A 25000 KVA, 13.8 KV g. with $X_d'' = 15\%$ is connected through a t/f to a bus which supplies four identical motors as shown in fig. The sub. tr. reactance X_d'' of each (m) is 20% on a base of 5000 KVA, 6.9 kV. The 3φ rating of t/f is 25000 kVA, 13.8 / 6.9 kV, with a leakage reac. of 10%.
The bus voltage at the motor is 6.9 kV, when a 3φ fault occurs at point p. For the fault specified, determine (i) The sub. transient ct in the fault (ii) Sub. transient ct in CB A (iii) Sym. short ckt interrupting ct in the fault & CB A.

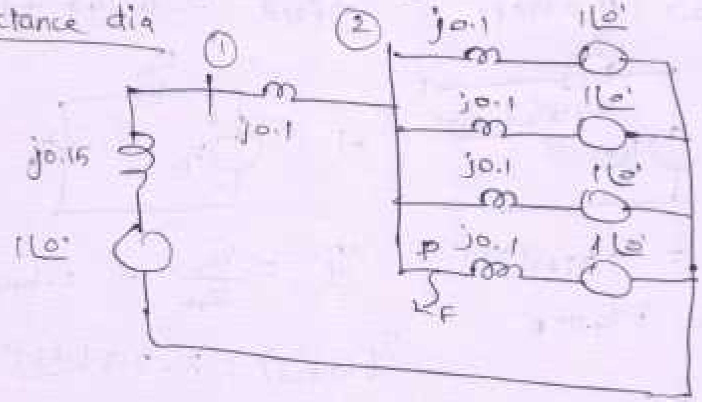


Soln

$MVA_b = 25$ $KV_b = 13.8$



Reactance dia



$$Z_{eq} = \frac{1}{j0.1} + \frac{1}{j0.1} + \frac{1}{j0.1} + \frac{1}{j0.1}$$

$$= j0.025$$

$$Z_{th} = \frac{j0.25 \times j0.025}{j0.25 + j0.025} = j0.023$$

$E_{th} = 1\angle 0°$ pu

(i) $I_f = \frac{E_{th}}{Z_{th}} = -j43.48$ pu

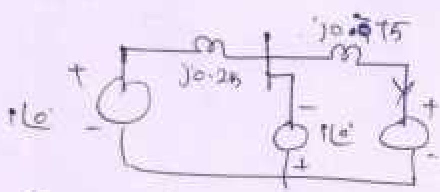
$I_{f\,(actual)} = 90.87$ kA

(ii) $I_{cr} = I_{f\,(p.u)} \times \frac{Z_{parallel}}{Z_{Total}} = -j4$

Sub. tr. ct in A $I'' = I_{cr} + 3 \times$ Motor ct

$= -j7$ p.u $= 14.63$ kA

(iii) Short ckt interrupting ct in the fault and CB A :



$Z_{th} = j0.15$ p.u

$I_f = -j6.667$ p.u

$I_{cr} = -j4$ p.u