Power System Analysis
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Lecture - 46
Three phase fault studies (Contd.)

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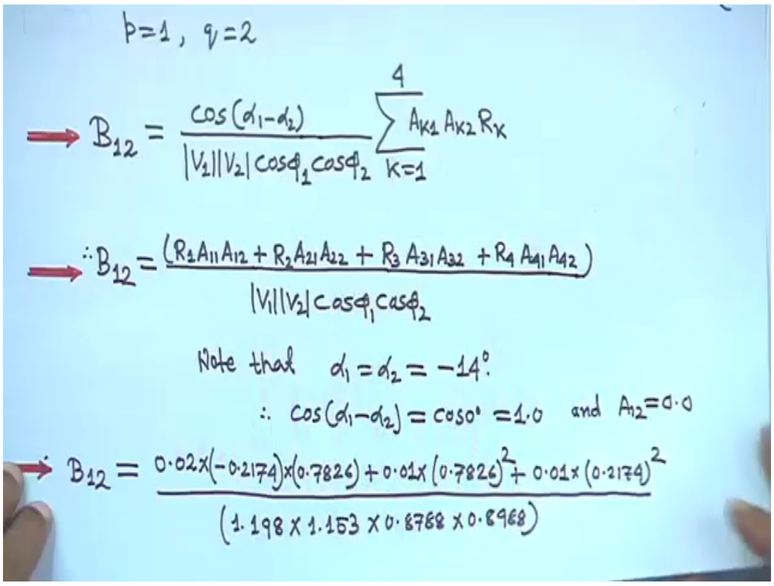

$p=1,\ q=2$

$$B_{12}=\frac{\cos(\alpha_1-\alpha_2)}{|V_1||V_2|\cos\phi_1\cos\phi_2}\sum_{K=1}^{4}A_{K1}A_{K2}R_K$$

$$\therefore B_{12}=\frac{(R_1A_{11}A_{12}+R_2A_{21}A_{22}+R_3A_{31}A_{32}+R_4A_{41}A_{42})}{|V_1||V_2|\cos\phi_1\cos\phi_2}$$

Note that $\alpha_1=\alpha_2=-14°$

$\therefore\ \cos(\alpha_1-\alpha_2)=\cos 0°=1.0$ and $A_{12}=0.0$

$$\therefore B_{12}=\frac{0.02\times(-0.2174)\times(0.7826)+0.01\times(0.7826)^2+0.01\times(0.2174)^2}{(1.198\times 1.153\times 0.8788\times 0.8968)}$$

Welcome back to these things, right when next is B12, when p is equal to 1, q is equal to 2. So, B12 will be cosine alpha 1 minus alpha 2 upon V1 V2 cos phi 1 cos phi 2, right and sigma k is equal to 1 to 4 with total number of branches 4 Ak1, Ak2, Rk. Expand this term, right and all the values are known, all this data you have, you substitute right and if you do so, you will get alpha 1 is equal to alpha 2 is equal to minus 14 degree. they are same. So, cos alpha 1 minus alpha 2 is equal to cos 0, that is one and A12 is equal to 0 that we have seen. So, all this data you put here.

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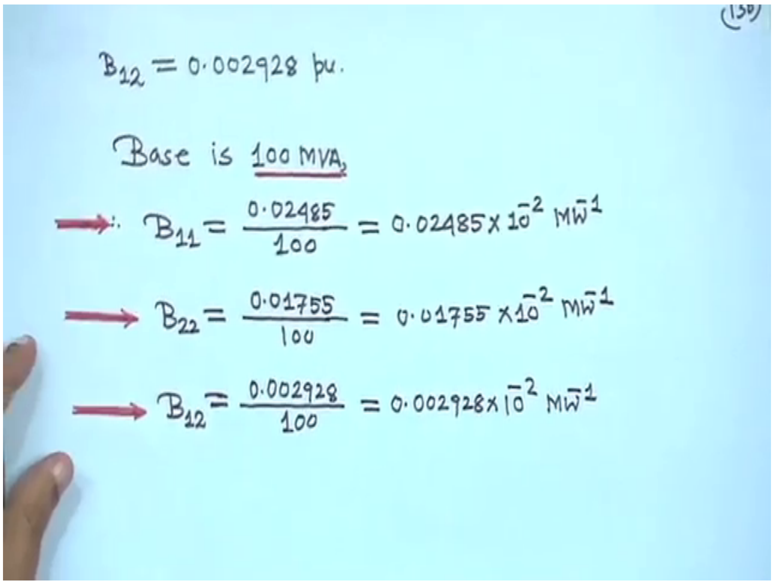

$B_{12} = 0.002928$ pu.

Base is 100 MVA,

$$\therefore B_{11} = \frac{0.02485}{100} = 0.02485 \times 10^{-2}\ MW^{-1}$$

$$B_{22} = \frac{0.01755}{100} = 0.01755 \times 10^{-2}\ MW^{-1}$$

$$B_{12} = \frac{0.002928}{100} = 0.002928 \times 10^{-2}\ MW^{-1}$$

If you put here, you will get your B12 is equal to 0.002928 per unit. So, all the values we got it in per unit, right. Now, because all current, then impedance everything it was given in per unit. So, this is unit, now per unit, right. Now, base MVA is given 100 MVA. So, you have to find out its correct value. In terms of real quantities, I told you that it is B coefficient dimension is megawatt inverse as it is per unit. This is all per unit. So, that is why this B11 whatever you have got, it has to be divided by 100 MVA base. Do not multiply, right. It has to be divided by this thing 100 m 100 thing and then only it will become the original unit megawatt inverse. So, per unit value of B coefficient must be divided by base MVA. That will give you megawatt inverse, right. So, B11 B22 and B3, your B12, these are the values, right in that real quantity or real unit megawatt inverse, right.

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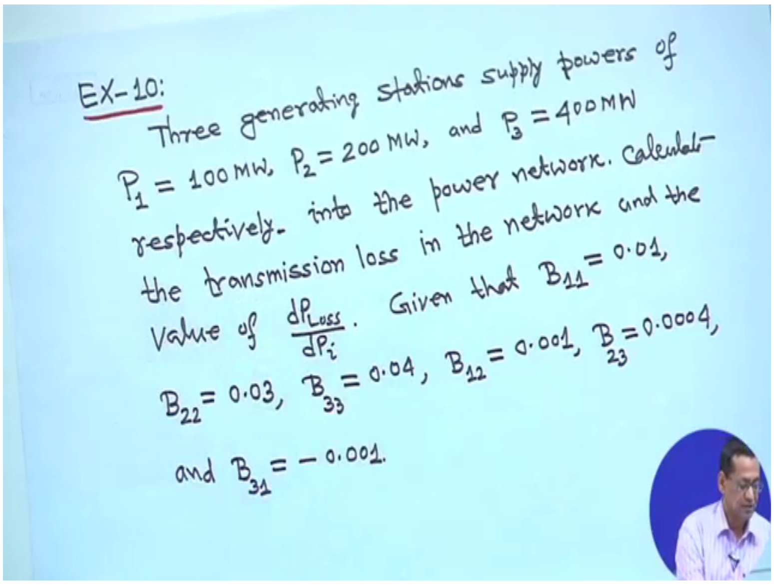

EX-10:

Three generating stations supply powers of $P_1 = 100$ MW, $P_2 = 200$ MW, and $P_3 = 400$ MW respectively. into the power network. Calculate the transmission loss in the network and the value of $\frac{dP_{Loss}}{dP_i}$. Given that $B_{11} = 0.01$, $B_{22} = 0.03$, $B_{33} = 0.04$, $B_{12} = 0.001$, $B_{23} = 0.0004$,

and $B_{31} = -0.001$.

So, that means for this topic, this is the last example, right. So, three generating stations supplying power P1 is equal to 100 megawatt, P2 is 100 megawatt and P3 say 400 megawatt respectively into the power network. Calculate the transmission loss in the network and the value of dP loss upon dP, given that this coefficient are given B11.01 B22.03 B33.04 B12.001 B23.0004 and B31 minus 0.001. B12 B21, they are same, B23 B32, they will be same and B31 and B13, they will be same, right. So, you have to find out your what you call that your P loss, this thing transmission loss and the value of dP loss upon dP i, right.

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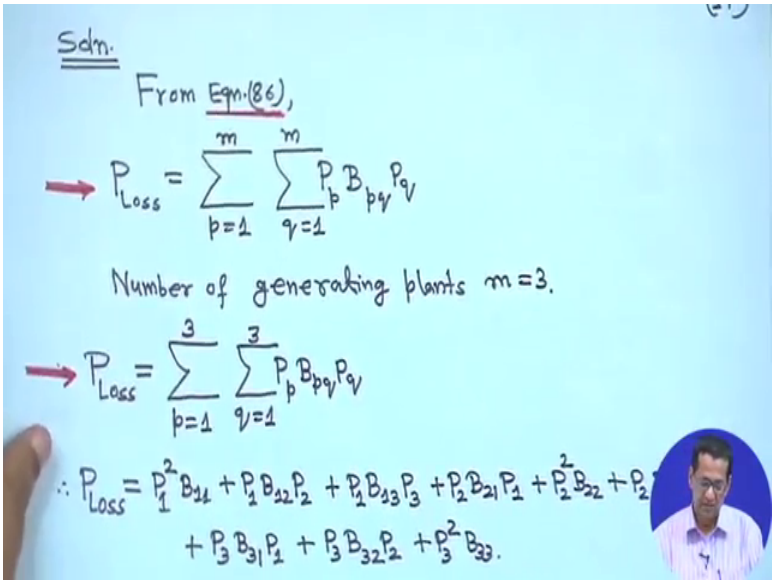

Soln.

From Eqn.(86),

$$P_{Loss} = \sum_{p=1}^{m} \sum_{q=1}^{m} P_p B_{pq} P_q$$

Number of generating plants $m = 3$.

$$P_{Loss} = \sum_{p=1}^{3} \sum_{q=1}^{3} P_p B_{pq} P_q$$

$$\therefore P_{Loss} = P_1^2 B_{11} + P_1 B_{12} P_2 + P_1 B_{13} P_3 + P_2 B_{21} P_1 + P_2^2 B_{22} + P_2$$

$$+ P_3 B_{31} P_1 + P_3 B_{32} P_2 + P_3^2 B_{33}.$$

So, from equation 86, loss formalized P loss is equal to P is equal to 1 to m q is equal to 1 to m P p B p q P q. This is the loss formula. We have given this general one. We have derived also, right and number of buss bar is 3. So, m is equal to 3 because total number of generating plants P1 P2 P3, three plans are there. So, m is equal to 3. So, you expand this, right.

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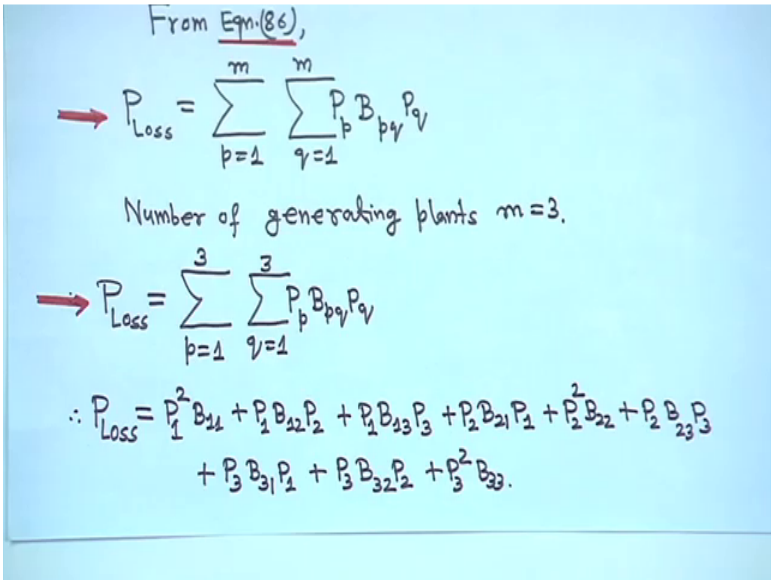

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Number of generating plants m = 3.

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$$\therefore P_{Loss} = P_1^2 B_{11} + P_1 B_{12} P_2 + P_1 B_{13} P_3 + P_2 B_{21} P_1 + P_2^2 B_{22} + P_2 B_{23} P_3 + P_3 B_{31} P_1 + P_3 B_{32} P_2 + P_3^2 B_{33}.$$

You expand this for p is equal to 1, q is equal to 1 2 3. Again for p is equal to 2, q is equal to 1 2 3 again. From p is equal to 3 vary q is equal to from q is equal to 1 2 3 and expand this, right. So, we will get altogether nine terms, right i.e. P1 P2 P3. Known all B coefficient are given and you substitute all these values, right.

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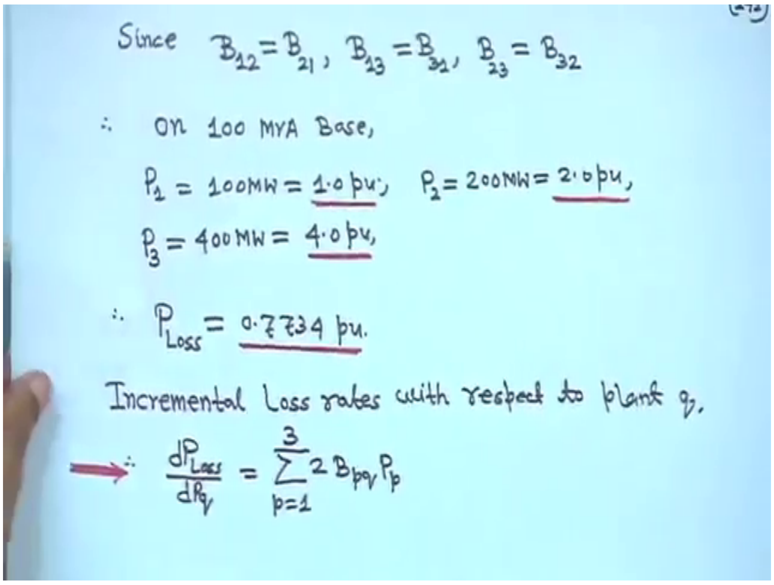

Since $B_{12}=B_{21}$, $B_{13}=B_{31}$, $B_{23}=B_{32}$

∴ on 100 MVA Base,

$P_1 = 100\,MW = \underline{1.0\,pu}$; $P_2 = 200\,MW = \underline{2.0\,pu}$,

$P_3 = 400\,MW = \underline{4.0\,pu}$,

∴ $P_{Loss} = \underline{0.7734\,pu}$.

Incremental Loss rates with respect to plant q.

$$\therefore \frac{dP_{Loss}}{dP_q} = \sum_{p=1}^{3} 2B_{pq}P_p$$

So, if you substitute all 100 MVA base P1 is 100 megawatt. So, 1 per unit P to 200 megawatt 2 per unit and P3, 400 megawatt 4 per unit, right.

So, substitute and compute, you will get P loss actually 0.7734 per unit. Now, incremental loss released with your incremental loss, right your this thing loss rate relates with respect to planned q dP loss upon dP q, that is p is equal to 1232 be P q P p. This also expression we have seen, right.

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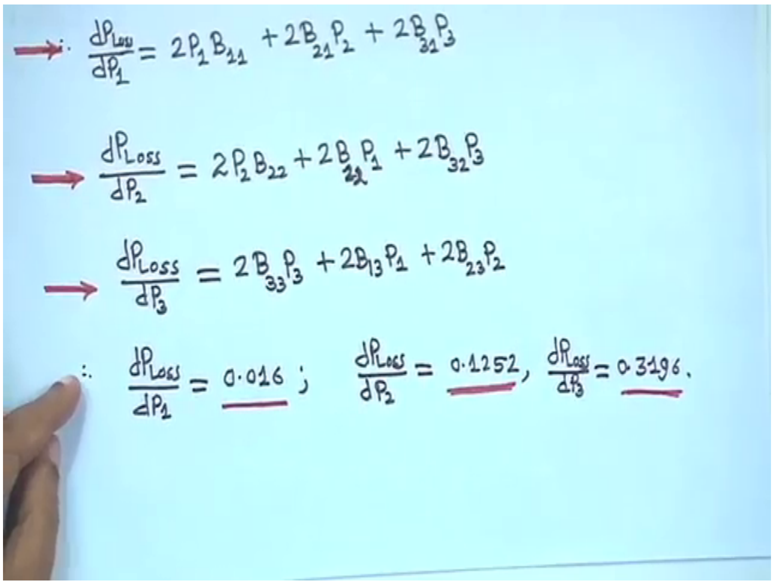

$$\therefore \frac{dP_{Loss}}{dP_1} = 2P_1B_{11} + 2B_{21}P_2 + 2B_{31}P_3$$

$$\frac{dP_{Loss}}{dP_2} = 2P_2B_{22} + 2B_{21}P_1 + 2B_{32}P_3$$

$$\frac{dP_{Loss}}{dP_3} = 2B_{33}P_3 + 2B_{13}P_1 + 2B_{23}P_2$$

$\therefore \frac{dP_{Loss}}{dP_1} = \underline{0.016}$; $\frac{dP_{Loss}}{dP_2} = \underline{0.1252}$, $\frac{dP_{Loss}}{dP_3} = \underline{0.3196}$.

Now, in that case, you put q is equal to 1 2 3 like this and you will get this expression dP loss upon dP1 is equal to this expression dP loss upon dP2. You will get this expression dP loss upon dP3, you will get this expression, right. For q is equal to 1, q is equal to 2, q is equal to 3, right. therefore, you will get this expression and all these values, your p and b values are there. So, all this thing you substitute and solve, you will get dP loss dP1 is equal to 0.016, dP loss dP2 will get 0.1252 and dp loss dP3 will get 0.3196, right. So, this is the last example for this economic load dispatch chapter. It s a long one, right but things are very simple, right. Only thing is that little bit practice if you make it, then things will be all right for you, right. Next one actually next will go for the fault studies, right.

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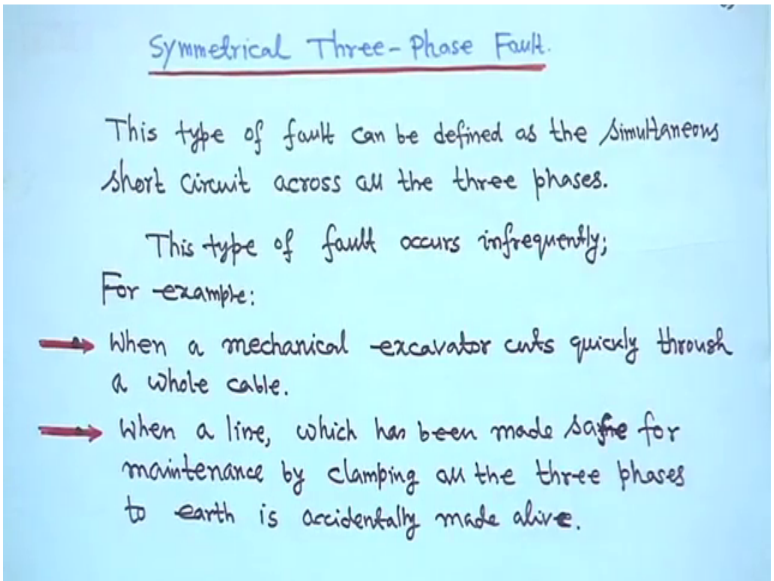

Symmetrical Three-Phase Fault.

This type of fault can be defined as the simultaneous short circuit across all the three phases.

This type of fault occurs infrequently;

For example:

→ When a mechanical excavator cuts quickly through a whole cable.

→ When a line, which has been made safe for maintenance by clamping all the three phases to earth is accidentally made alive.

So, actually there is symmetrical three phase fault. Now, general look in fault studies we have symmetrical three phase fault. Then, we have to study that your what you call that symmetrical components and then, unbalanced fault, right. Now, generally this symmetrical three phase fault will take one or two example. My objective here is to show you that how to construct the z bus algorithm, right and certain in this case that in a reality that symmetrical three phase fault, its probability of happening is very less, right compared to that your line to ground fault, your line to line fault or double line to ground fault, but more severe fault is symmetrical three phase fault, right.

So, whatever it is here, what we will do is, we will see something and one or couple of examples we will take on fault studies, right and as it is in general, many derivations may be available in the literature. So, first I will show you that how to compute for currents, right and then, directly we will go for what you call that z bus building algorithm, right and some of the things because this fault is very rare. So, more we will concentrate on symmetrical component and particularly positive negative and zero sequence network, right and how to make this thing and then, unbalanced what you call that thing with your unbalanced fault, right like line to ground double line to ground and then, your line to line fault, right.

So, here what we will do is, we will see that how this fault if there any bus there is a fault, how network can be solved, right and few examples. So, this type of fault can be defined as the simultaneous short circuit across all the three phases. This happening is very rare, but there is a chance that this can happen, right. This type of fault occurs infrequently and probability is very less, right. So, our concentration will be more on unbalanced fault and before that symmetrical component, right. For example, when a mechanical excavator cuts quickly through a whole cable, this can create a three phase fault, right and when a line which has been made safe for maintenance by clamping all the three phases to earth is accidentally made alive.

This also can happen, right. This in reality can happen that this will create also three phase fault, right.

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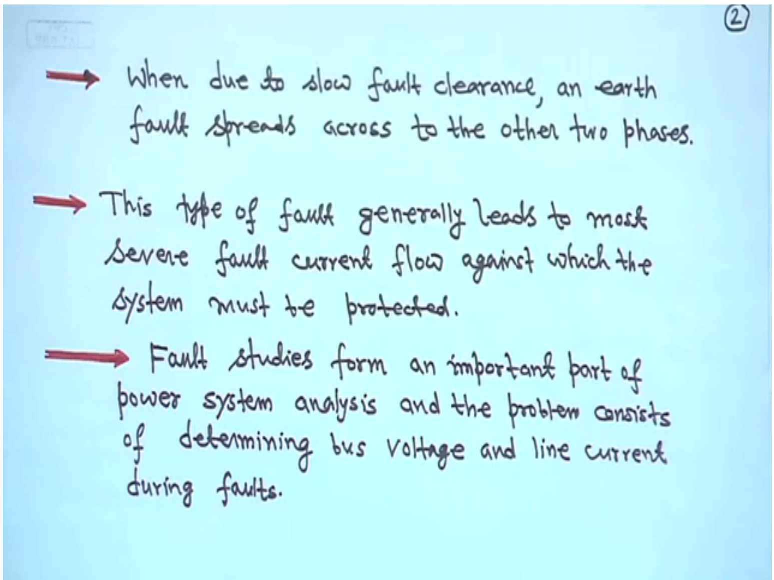

- When due to slow fault clearance, an earth fault spreads across to the other two phases.
- This type of fault generally leads to most severe fault current flow against which the system must be protected.
- Fault studies form an important part of power system analysis and the problem consists of determining bus voltage and line current during faults.

Another thing is that when due to slow fault clearance on earth, fault spread across to the other two phases. So, in that case also that three phase fault can happen, right. This type of fault actually generate leads to most severe fault current flow against which the system must be protected because three phase symmetrical fault means the fault current will be too high, right. So, fault study is actually an important part of power system analysis. You have to study this, right and the problem consists of determining bus voltage and line current during faults, right. So, that means what you call that these three phase fault is your what you call is a very severe type of fault, right.

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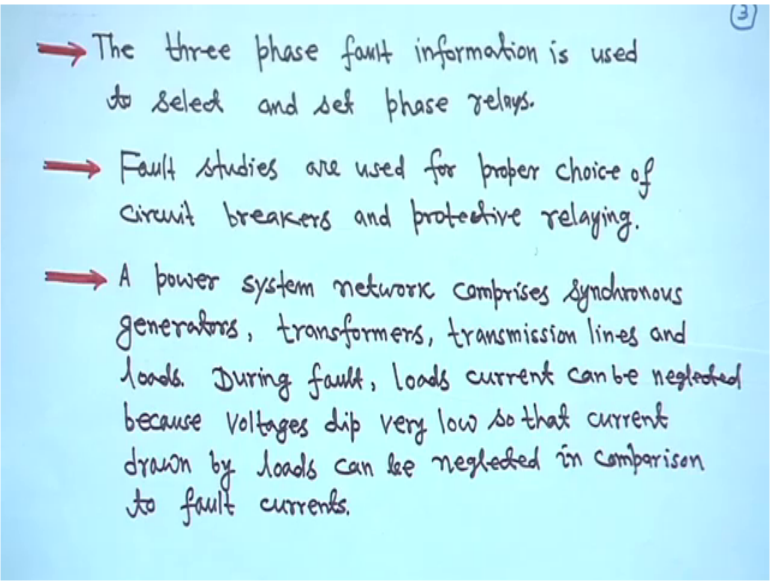

- The three phase fault information is used to select and set phase relays.
- Fault studies are used for proper choice of circuit breakers and protective relaying.
- A power system network comprises synchronous generators, transformers, transmission lines and loads. During fault, loads current can be neglected because voltages dip very low so that current drawn by loads can be neglected in comparison to fault currents.

This information is used to select your what you call as set face is used to select and set phase relays, right. So, fault studies are used for proper choice of circuit breakers and protective relaying that is true, right because based on your fault current thing, you have to go for choosing the circuit breaker rating, but here anyway we will not study relay, we will not study circuit breaker. Those are separate topics, right. So, a power system network actually comprises your synchronous generators, transformers, transmission lines and loads, right. So, during fault actually load currents can be neglected because voltage is deep, very low. So, the current drawn by loads can be neglected in comparison to fault current, right. So, actually fault current is very high, right. Therefore, load currents during fault one can neglect it, right.

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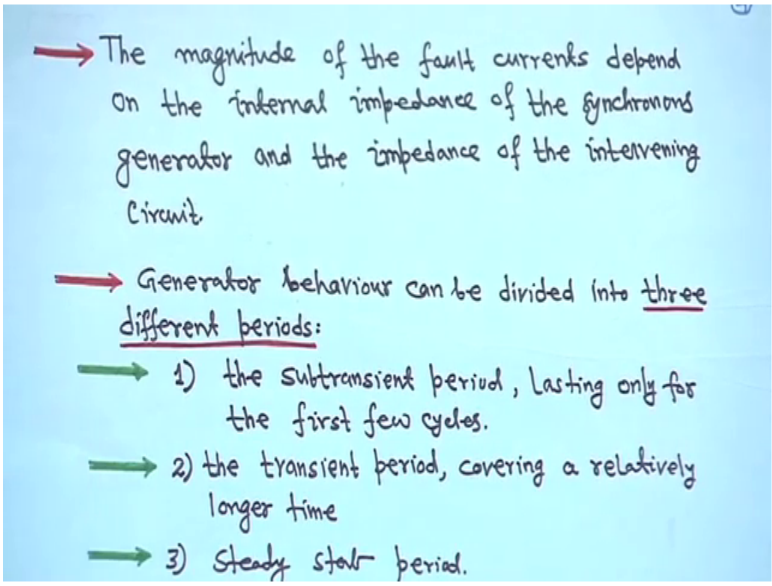

- The magnitude of the fault currents depend on the internal impedance of the synchronous generator and the impedance of the intervening circuit.
- Generator behaviour can be divided into three different periods:
  - 1) the subtransient period, lasting only for the first few cycles.
  - 2) the transient period, covering a relatively longer time
  - 3) Steady state period.

So, the magnitude of the fault current depends on the internal impedance of the synchronous generator. That is true and the impedance of the intervening circuit, right. I mean during fault if you have a fault impedance also, that you need to consider. So, generator behavior can be divided into three different periods. One is the sub transient lasting only for the first few cycles, right. The transient period covering a relatively longer time and then, steady-state period. So, three different what you call periods are there for generator behavior.

So, another important aspect is that you are just hold on. Another important aspect is that your circuit breakers is rated MVA. MVA braking capacity is based on three phase fault MVA because this is the severe one, right.

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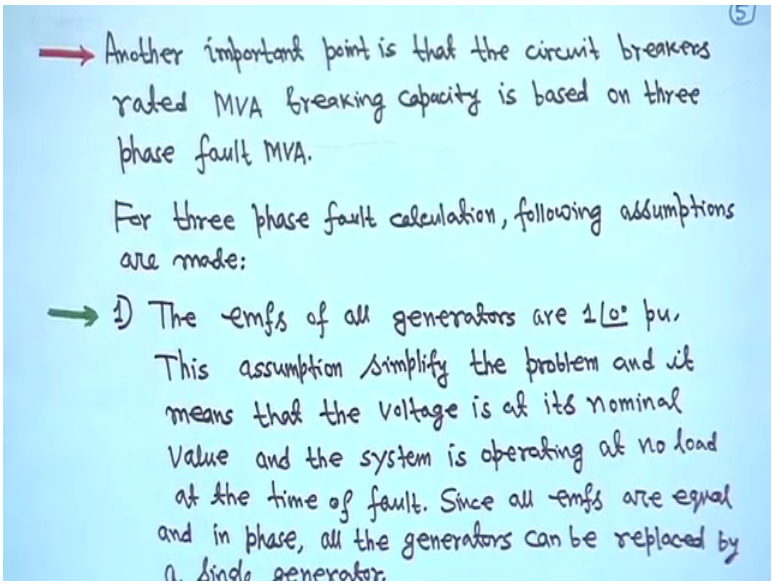

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Another important point is that the circuit breakers rated MVA breaking capacity is based on three phase fault MVA.

For three phase fault calculation, following assumptions are made:

1) The emfs of all generators are $1\angle 0^\circ$ pu. This assumption simplify the problem and it means that the voltage is at its nominal value and the system is operating at no load at the time of fault. Since all emfs are equal and in phase, all the generators can be replaced by a single generator.

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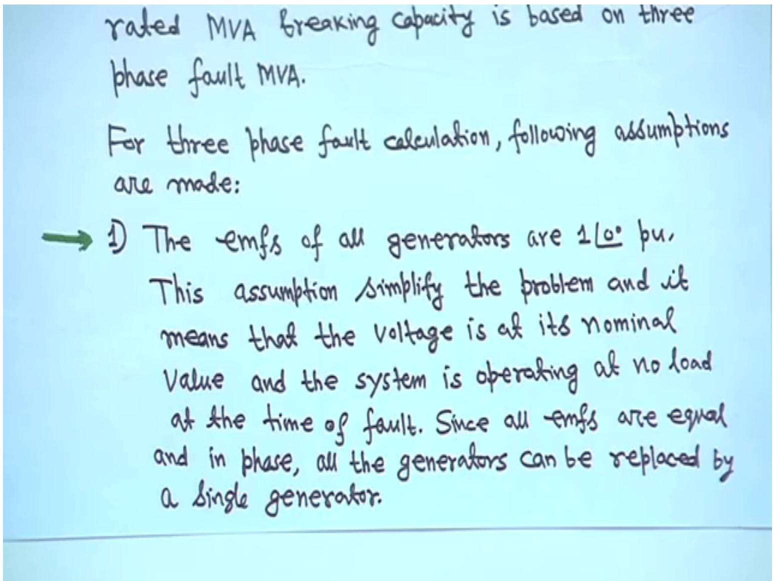

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So, for three phase fault calculation, following assumptions we have to make, right. First thing is the emf of all generators are one angle zero per unit. This assumption will make our analysis easy. These assumptions simplify the problem and it means that the voltage e that is at its nominal value and the system is operating at no load at the time of fault.

So, we are assuming that emfs of all generators are war angle, your one angle zero per unit, right and since all the emfs are equal and in phase all the generators can be replaced by a single generator, right. This is also possible because all voltages we are assuming one angle zero and the same phase angle, all can be represented by single generator. Another thing is your charging capacitance, right that we have studied in your load flow studies also, right and its capacitance chapter also.

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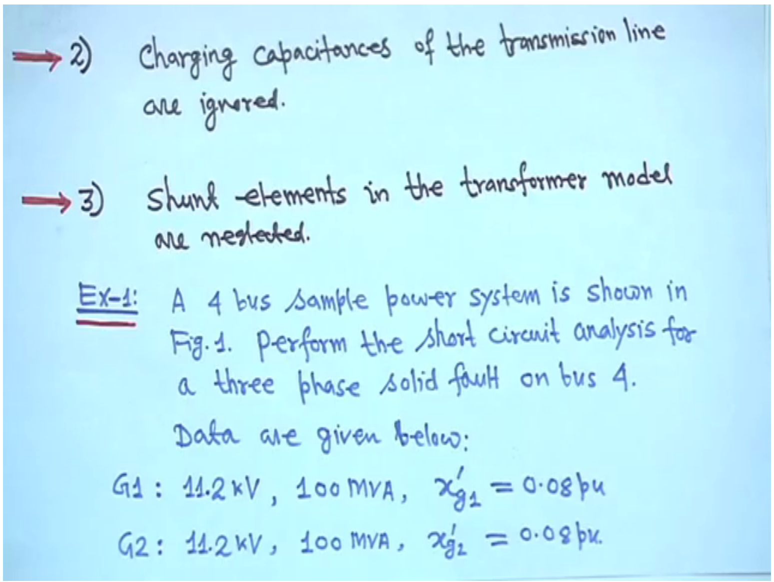

→ 2) Charging capacitances of the transmission line are ignored.

→ 3) Shunt elements in the transformer model are neglected.

Ex-1: A 4 bus sample power system is shown in Fig. 1. Perform the short circuit analysis for a three phase solid fault on bus 4.

Data are given below:

G1 : 11.2 kV, 100 MVA, $x'_{g1} = 0.08$ pu

G2 : 11.2 kV, 100 MVA, $x'_{g2} = 0.08$ pu.

So, charging capacitance of the transmission line are ignored. We have neglected and shunt elements in the transformer model are neglected transformer that pi model. We have also seen in that load flow studies that shunt model, the transformer model are neglected. So, based on this assumption, before going to that your what you call your z bus building algorithm, right and this numerical, how one can solve, right.

So, just one or two examples for you, right just fault study. For example, just hold on just hold on. For example, your figure that a four bus sample power system is shown in figure 1. I will show you perform the short circuit analysis for a three phase solid fault. This means we will assume the fault impedance is 0, right on bus 4. So, data are given below at generator 11.2 KV 100 MVA x. G1 dash is 0.08 per unit generator. G 2 is 11.2 KV, 100 MVA, right x. G 2 dash is equal to 0.08 per unit, right.

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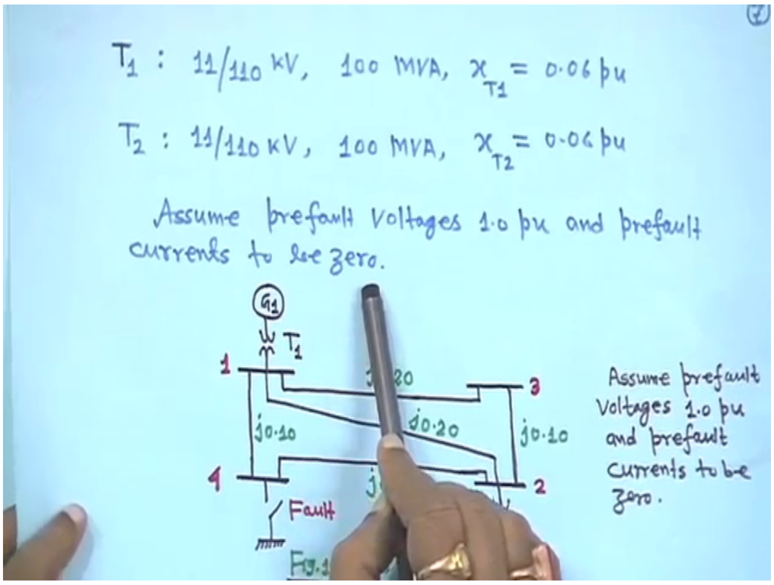

T_1 : 11/110 kV, 100 MVA, $x_{T1} = 0.06$ pu

T_2 : 11/110 kV, 100 MVA, $x_{T2} = 0.06$ pu

Assume prefault voltages 1.0 pu and prefault currents to be zero.

Assume prefault Voltages 1.0 pu and prefault currents to be zero.

Transformers, this is the diagram transformer T1 and transform at T2, it is there. So, T1 is 11 by 110 KV, 100 MVA x. T1 is given 0.06 per unit and T2 is 11 by 110 KV, 100 MVA x. T2 is 0.06 per unit. You assume pre-fault voltage 1 per unit and pre-fault currents to be your 0. So, this is the diagram, right. This is the same thing actually written here. Whatever is written here, same thing is written here.

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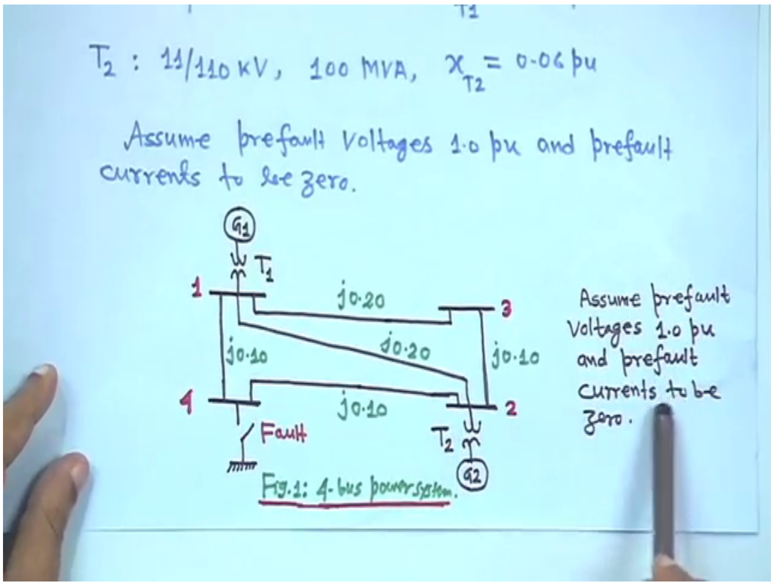

T_2 : 11/110 kV, 100 MVA, $x_{T2} = 0.06$ pu

Assume prefault voltages 1.0 pu and prefault currents to be zero.

Assume prefault Voltages 1.0 pu and prefault currents to be zero.

Fig.1: 4-bus power system.

So, this is the diagram and these are your what you call r is neglected. So, all the branch reactances are given, but will tell that this is impedance, right. Now, fault has occurred here. This point the fault has occurred here. So, you have to this figure 4. If this fault has occurred here. So, you have to represent the equivalent diagram, right. So, your fault calculation, this generator, your generator reactance is given x G1 dash x G2 x dash, right

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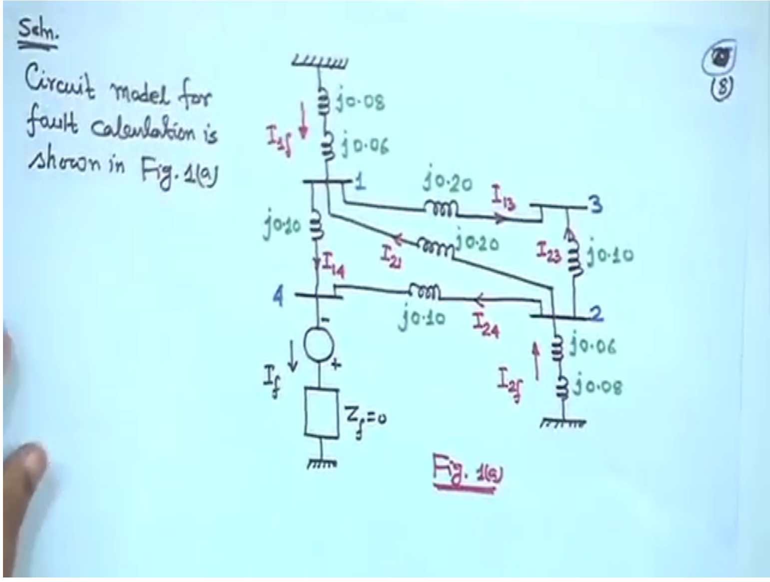

Soln.

Circuit model for fault calculation is shown in Fig. 1(a)

Transformer is given x T1 x T2, right. Therefore, this generator 1 when fault has occurred, this is grounded. So, j 0.08 generator transformer here also is generated and transformer, these reactants are taken, all these things are taken and fault has occurred at bus 4, right. So, this one, this fault impedance Z f is 0 and current going through this is I f, right and this actually this whole, all these your what you call this network that generator, your generator 1, generator 2, they are represented by their equivalent what you call that transformer and generator together their reactances and this voltage. This is V 40, right. This voltage actually it is one your what you call one angle zero not shown here.

Next figure it is shown, that is your pre-fault voltage, right and this is your Z f is equal to fault impedance. Z f is equal to 0, right. So, this whole network you have to simplify and then, what you have done during fault that all the generators represented by their reactances, transformer reactants also there that you have to make it and here fault has occurred, right. That means voltage at this was a pre fault voltage. That is what you call it is V 40 must be in series with that it fault impedance, right and here it is solid fault. So, Z f is equal to 0 there. So, later we will see that thevenin equivalent, right if this is your what you call that that equivalent diagram, right.

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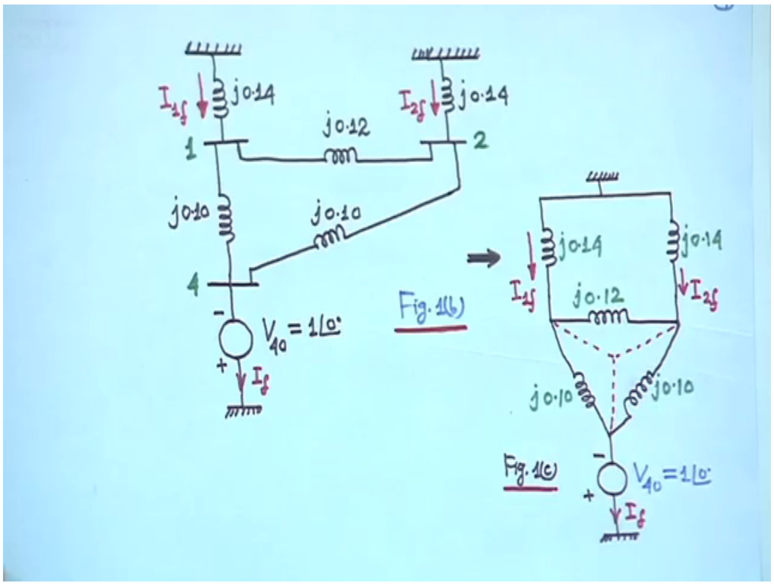

So, then this diagram actually this one if you look into that, these two actually are in series because nothing is here. So, this 0.2.10, these two are in series. So, if you add it, it will be 0.3, right.

It will be 0.3 and then, this 0.3 there is 0.2 plus 0.1, that is j 0.1 j 0.2 and 0.3 are in parallel with 0.2, this branch and if you take the equivalent 1, this will become actually j 0.12, right. So, what I have done these two are in series. You add this and it will become j 0.30.2.1 and sum it up. So, it will be j 0.3. With that j 0.2 are in parallel. So, these two parallel equivalent you take it will become actually j 0.12, right and then, this is your what you call bus 3 is eliminated. That means, from this network there is no bus 3 because you are added there. So, bus 3 is not there as it is eliminated, right. So, bus 2, so 4 2 2 is connected through 0.1 line impedance. So, j 0.1 is there and these two are added. So, j 0.14, these two are added 0.14.

So, here bus 2, it is connected here. So, j 0.14 j point, right and this is V40 actually one angle zero, right. So, once this is done, then you have this is actually delta corner. This first thing is these two generator grounded. That means, these two are in parallel. So, here it is current is I 1 f and here it is I 2 f say for during fault current flowing here is I 1 f and I 2 f and this is bus 4 and this is a delta connection make a common ground. So, j

0.14 j point, these two are in parallel and this delta connection first you convert it to star, right.

I do not tell you delta to star or star to delta. You know it, right. So, this voltage V40 actually one angle zero, the current going to the fault, right because fault impedance is 0.

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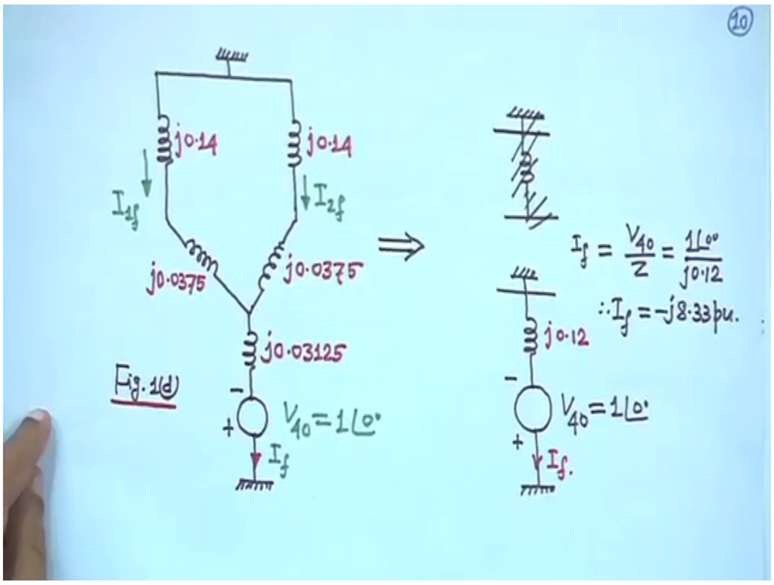

$$I_f = \frac{V_{40}}{Z} = \frac{1\angle 0°}{j0{\cdot}12}$$

$$\therefore I_f = -j8{\cdot}33\,pu.$$

So, it is not shown here not also, right. That means, if you simplify, make it delta to star. So, j 0.14 will be there and this branch will be j 0.0375. This is j 0.0375 and this is also j 0.03135, right. So, these two are in series and both this together these, they are in parallel make an equivalent of this one, right and your what you call add this one. So, you will get ultimately j 0.12. That means, j 0.14 and j 0.0375 we add it. You add these two are equal actually make it parallel. So, whatever will come, it will be half with that you add this one. So, total will come j 0.12, right. So, that means your I f will be is equal to V40 upon z that is V40 is the pre-fault voltage one angle zero upon that z is j 0.12, that is I f is equal to fault current minus z 8.33 per unit, right. So, that is the fault current now for every branch. Just hold on right.

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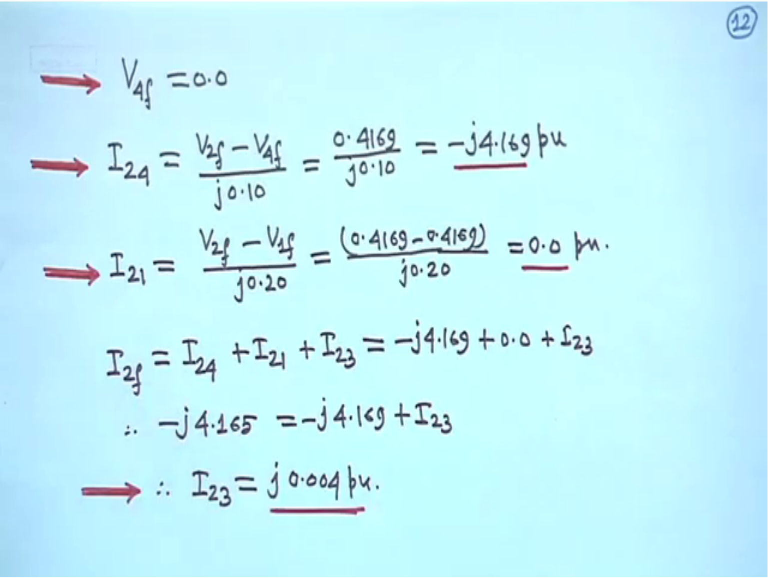

⑫

$$\rightarrow V_{4f} = 0.0$$

$$\rightarrow I_{24} = \frac{V_{2f} - V_{4f}}{j0.10} = \frac{0.4169}{j0.10} = \underline{-j4.169} \text{ pu}$$

$$\rightarrow I_{21} = \frac{V_{2f} - V_{1f}}{j0.20} = \frac{(0.4169 - 0.4169)}{j0.20} = \underline{0.0} \text{ pu.}$$

$$I_{2f} = I_{24} + I_{21} + I_{23} = -j4.169 + 0.0 + I_{23}$$

$$\therefore -j4.165 = -j4.169 + I_{23}$$

$$\rightarrow \therefore I_{23} = \underline{j0.004} \text{ pu.}$$

Now, for every branch I 24 that fault has actually occurred at bus 4. So, V 4 f is equal to 0 bus that voltage at faulted bus will be 0, right. Now, I 24 will be V 2 f minus V 4 f upon 0.01, right. So, in that case your v or just hold on, this is just hold on. Just hold on. Where it has gone? Just hold on just hold on just hold on. It has mixed up somewhere, all right.

Here it is, right. This is actually where we have come up to this one. Now, fault current, this is your fault current. Just hold on here, right.

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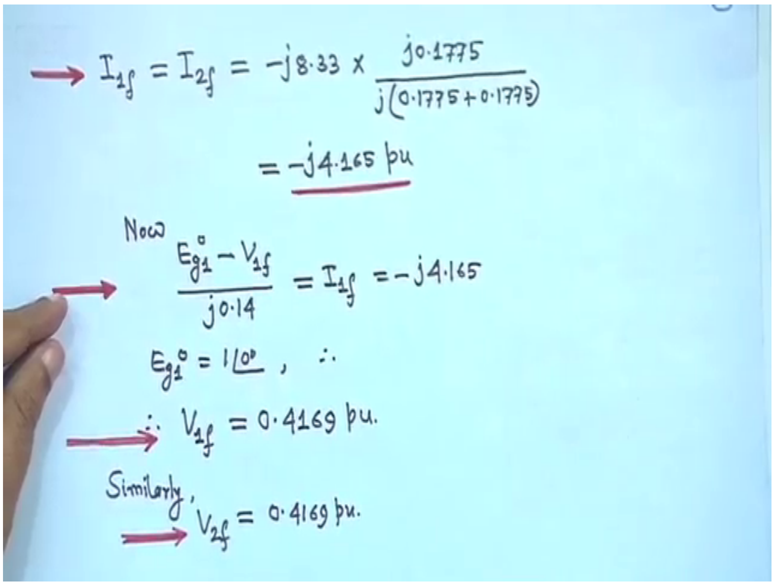

$$\rightarrow I_{1f} = I_{2f} = -j8.33 \times \frac{j0.1775}{j(0.1775 + 0.1775)}$$

$$= \underline{-j4.165 \text{ pu}}$$

Now

$$\rightarrow \frac{E_{g1}^{0} - V_{1f}}{j0.14} = I_{1f} = -j4.165$$

$$E_{g1}^{0} = 1\angle 0^{\circ}, \quad \therefore$$

$$\rightarrow \therefore V_{1f} = 0.4169 \text{ pu.}$$

Similarly,

$$\rightarrow V_{2f} = 0.4169 \text{ pu.}$$

Next your I 1 f is actually this I 1 f and I 2 f. I mean from this one, they both impedance are same, right. So, they are carrying your equal current, right I 1 f and I 2 f. So, is equal to minus j 8.43 and equal sharing. So, j 0.1775, right you add these two, divide by sum of these two. So, it is coming while it will be half actually minus j 4.165 per unit, right. therefore, that E g 10 minus V 1 f upon j 0.14 is equal to I 1 f. So, looking at this, look at this diagram, right. If you see this diagram, if you assume generator voltage is g 1, right then it will be E g 10. This thing pre fault voltage minus V 1 f divided by j 0.14 is equal to I 1 f is equal to this I 1 f is equal to I 2 f is equal to minus j 4.165. So, E g 10 is equal to one angle zero, right. So, put it here and you will get V 1 f will be 0.4169 per unit. Similarly if you go for your V 2 f, you calculate and will get 0.4169 per 69 per unit because in the case of V 2 f, it will be E g 20 minus v 2 f divided by again the same thing, right. You will get is equal to I 2 f I 1 f is equal to I 2 f. So, you will get the same value, right once this is done. Now, next is this one, right. So, next is your V 4 f. the faulted voltage is zero bus occurred at by your this thing what you call at fault occurred at bus 4.

So, V 4 f is equal to 0. That means, I 24 is equal to V 2 f minus V 4 f upon j 0.1 because impedance of that branch is j 0.1, right this diagram, right. So, your V 2 f minus V 4 f, right and this impedance is 0.1, j 0.1. Therefore, I 24 is equal to V 24 minus V 4 f upon j 0.1, so 0.4169 upon j, so that is minus j 4.169 per unit. Similarly, I 21 you compute V 2 f minus V 1 f upon j 0.20. So, this one will be 0, right. Similarly I 2 f is equal to I 24 plus I 21 plus I 23, right. If you come to this diagram, just hold on. If you come to this diagram that I 2 f, you can apply first law here. It will be I 24 plus I 21 plus I 23, right. So, that is why I 24 plus I 21 plus I 23 sum up all, you will get your minus j 4.165 because I 2 f is this one, I 24 is this one, right and your I 21 is 0 and plus I 23. So, you will get I 23 is equal to j 0.004 per unit, right. So, this is your what you call I 23.

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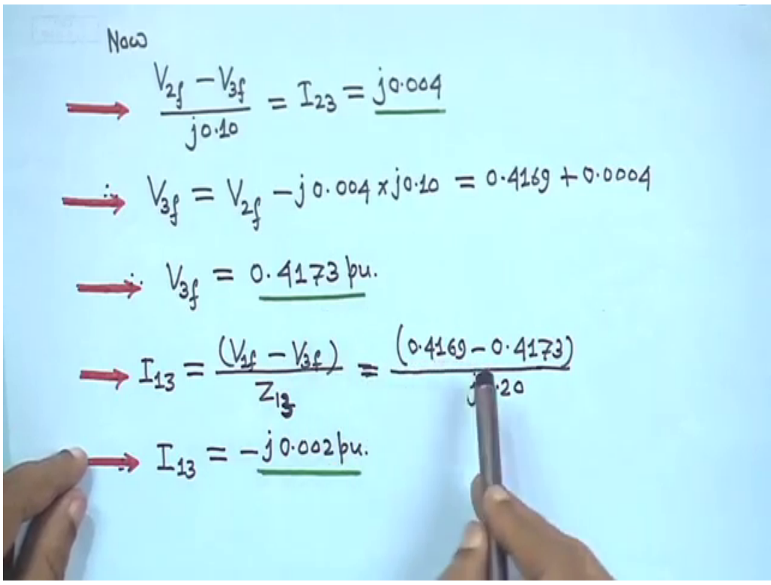

Now

$$\frac{V_{2f}-V_{3f}}{j0.10} = I_{23} = \underline{j0.004}$$

$$\therefore V_{3f} = V_{2f} - j0.004 \times j0.10 = 0.4169 + 0.0004$$

$$\therefore V_{3f} = \underline{0.4173\,pu.}$$

$$I_{13} = \frac{(V_{1f}-V_{3f})}{Z_{13}} = \frac{(0.4169-0.4173)}{j0.20}$$

$$I_{13} = -\underline{j0.002\,pu.}$$

Next is, similarly your V 2 f minus V 3 f upon j 0.10 is equal to I 23. Just we have computed I 23 j 0.004. Therefore, V 3 f is equal to V 2 f, right minus this one. So, you will get V 3 f is equal to 0.4174 per unit, right.

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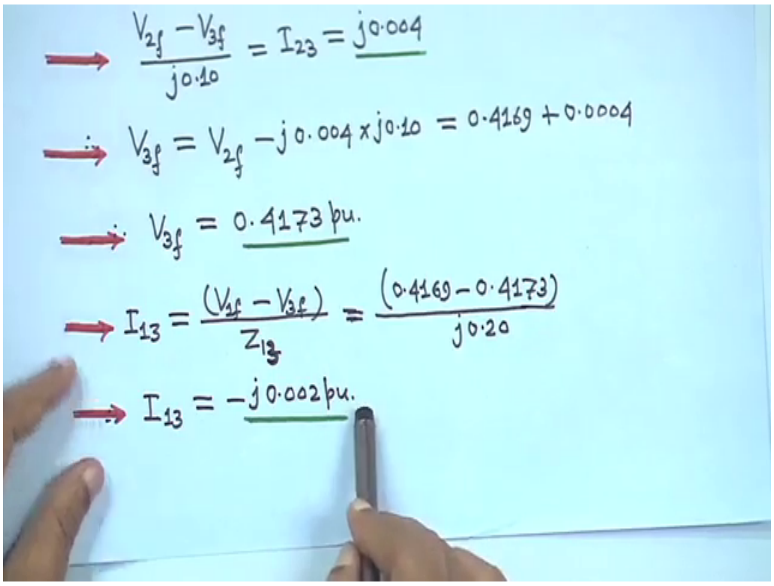

$$\frac{V_{2f}-V_{3f}}{j0.10} = I_{23} = \underline{j0.004}$$

$$\therefore V_{3f} = V_{2f} - j0.004 \times j0.10 = 0.4169 + 0.0004$$

$$\therefore V_{3f} = \underline{0.4173\,pu.}$$

$$I_{13} = \frac{(V_{1f}-V_{3f})}{Z_{13}} = \frac{(0.4169-0.4173)}{j0.20}$$

$$I_{13} = -\underline{j0.002\,pu.}$$

Similarly, I 13 is equal to V 1 f minus V 3 f upon z 13. Substitute all these and you will get I 13 is equal to 0.002 per unit, right.

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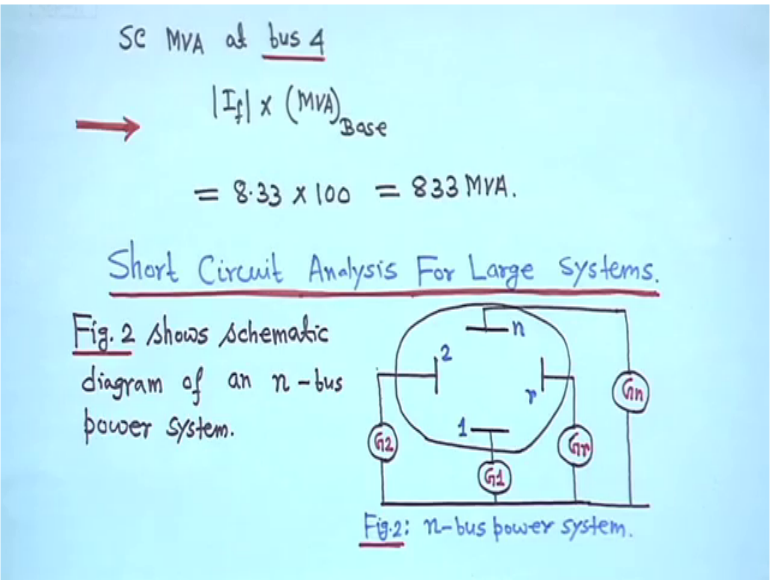
SC MVA at bus 4

→ $|I_f| \times (MVA)_{Base}$

$= 8.33 \times 100 = 833$ MVA.

Short Circuit Analysis For Large Systems.

Fig. 2 shows schematic diagram of an n-bus power system.

Fig. 2: n-bus power system.

So, your this thing what you call and your short circuit MVA at bus 4 fault current in to MVA bus fault current was 8.33 and base m is 100. So, it is 833 MVA, right.

So, this is one example before fault study for this one. Actually for three phase fault that will go for short circuit analysis for large system and your what you call that your z bus algorithm. So, this is your what you call that more important. So, rather many other small thing were was there for your three phase fault. So, that part I thought. I give more importance on symmetrical component and unbalanced fault, right particularly that positive negative and zero sequence diagram and their connection. Now, for short circuit analysis, suppose you have a in bus power system, you have a n bus power system that is bus 1, bus 2, bus n. This is r th bus, right. So, this is a schematic diagram of your what you call that your if this thing a power system and these are generator 1 generator 2 and it is rth generator and generator n, right.

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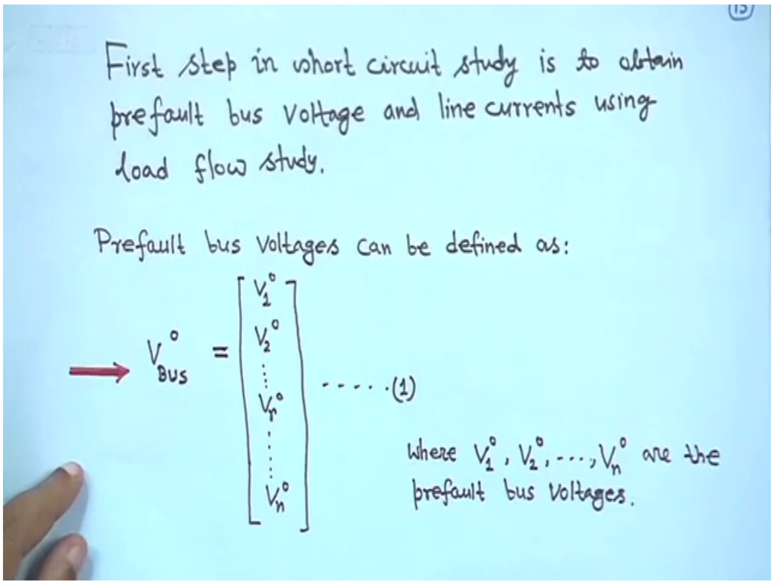

First step in short circuit study is to obtain prefault bus voltage and line currents using load flow study.

Prefault bus voltages can be defined as:

$$\longrightarrow \quad V_{BUS}^{0} = \begin{bmatrix} V_1^0 \\ V_2^0 \\ \vdots \\ V_r^0 \\ \vdots \\ V_n^0 \end{bmatrix} \quad \cdots\cdots (1)$$

where $V_1^0, V_2^0, \ldots, V_n^0$ are the prefault bus voltages.

Now, you assume first step for the short circuit studies actually to obtain the prefault bus voltage and line current using load flow studies. So, pre fault bus voltages, it can be defined as V bus superscript. It is 0 is equal to V 10 V 20 V r0 up to V n0. This is equation 1, where V n, V 10, V 20, V n 0 are the prefault bus voltages, right. So, these are the prefault bus voltages. Now, what will we do later is, your this bus r is a faulted bus. So, Z f is the fault impedance, right. You assume that Z f is the fault impedance.

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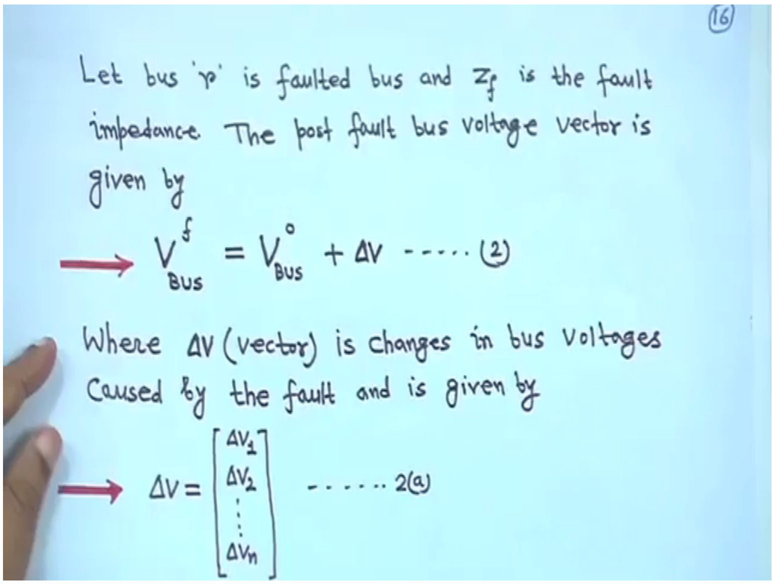

Let bus 'r' is faulted bus and Z_f is the fault impedance. The post fault bus voltage vector is given by

$$\longrightarrow \quad V_{BUS}^{f} = V_{BUS}^{0} + \Delta V \quad \cdots\cdots (2)$$

Where ΔV (vector) is changes in bus voltages caused by the fault and is given by

$$\longrightarrow \quad \Delta V = \begin{bmatrix} \Delta V_1 \\ \Delta V_2 \\ \vdots \\ \Delta V_n \end{bmatrix} \quad \cdots\cdots 2(a)$$

So, the post fault bus voltage vector is given as V bus, superscript is f, transfer fault is equal to that pre fault bus voltage V bus 0 plus delta V because when fault is there, voltage will change. So, you have to obtain what delta V is. This is equation 2, right. So, delta V vector changes in bus voltage caused by the fault and its given by delta V will be this is delta V 1, delta V 2, delta V n. This equation is given as 2, right. So, now we have to do is that thevenin network of the system, right. So, when we take the thevenin equivalent of this network, suppose fault has occurred at bus r and bus r is a faulted bus, right.

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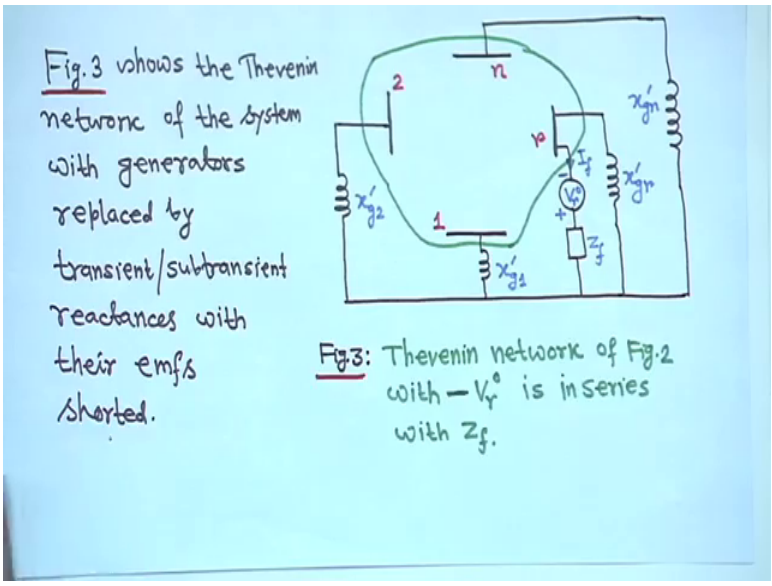

Fig.3 shows the Thevenin network of the system with generators replaced by transient/subtransient reactances with their emfs shorted.

Fig.3: Thevenin network of Fig.2 with $-V_r^0$ is in series with Z_f.

So, this is the figure 3. So, thevenin network of the system we generate is replaced by transient and sub transient reactants with their emfs shorted, the way we did the example 1, right. So, that you are what you call with their emf shorted and the way we did that for first problem. So, all things are only generator represent x g x g1 dash x g2 dash and x gn dash and x gr dash. All this thing and and fault has occurred at bus 4 r. So, this V r 0 is the prefault your voltage, right and when fault impedance is there Z f, so that V r f, this Z f is in series with V r and the fault current is I f, right. So, that means this is an thevenin equivalent, all right, whenever fault has occurred that particular faulted bus you consider that voltage V r 0 and if fault impedance, so basically we say that minus V r 0 because minus here, polarity plus here, minus here. Fault current is going down and that means, it is in series with Z f, right and all the generators you are what you call this thing replaced by transient or sub transient reactances with their emf short circuited.

So, generators emf is not coming here, right and only the fault where that bus r, this has happened. So, that V r 0, the pre fault voltage, right this way you represent your what you call thevenin network, right. Once this is done, that thevenin network and this I f is the current direction is taken here. That means, injected current to this bus r will be minus I f, right because fault current is going here, right. So, this is the figure 3.

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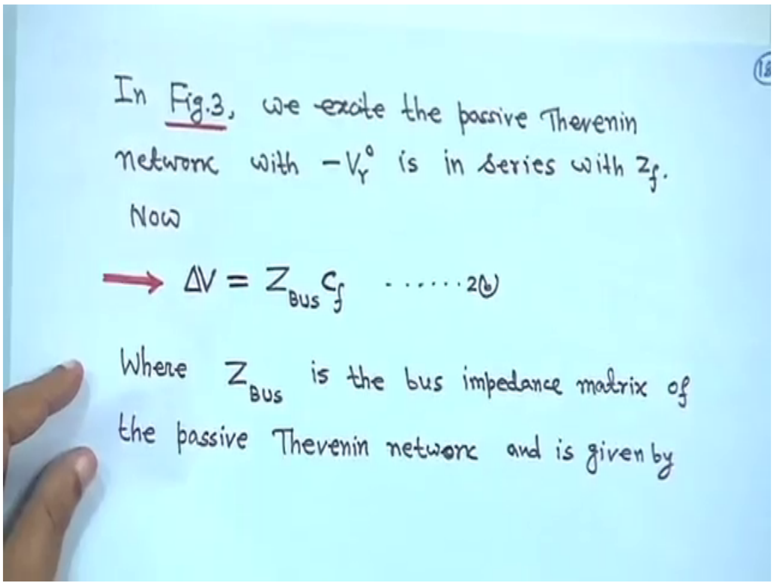

In Fig.3, we excite the passive Thevenin network with $-V_r^0$ is in series with z_f.

Now

→ $\Delta V = Z_{BUS} C_f$ ......2(b)

Where Z_{BUS} is the bus impedance matrix of the passive Thevenin network and is given by

So, that means for your understanding, little bit we have written that you excite the passive thevenin network with minus V r 0, that is in series with Z f, right. Therefore, you can write delta v. That voltage is equal to Z bus into C f. C f actually is the current, right. I will come to that, right where Z bus is the bus impedance matrix of the passive thevenin network. So, you need Z bus and this network, this is actually a bus impedance of this passive thevenin network for this one, right.

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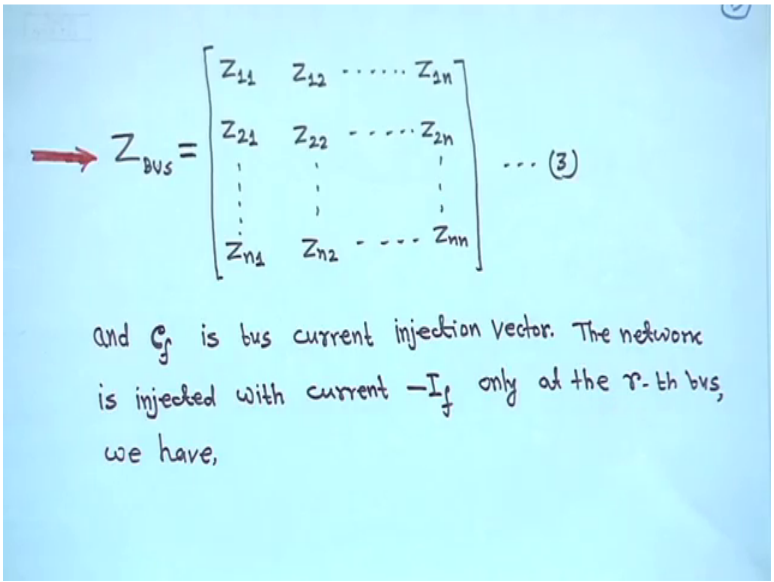

$$Z_{BUS} = \begin{bmatrix} Z_{11} & Z_{12} & \cdots & Z_{1n} \\ Z_{21} & Z_{22} & \cdots & Z_{2n} \\ \vdots & \vdots & & \vdots \\ Z_{n1} & Z_{n2} & \cdots & Z_{nn} \end{bmatrix} \quad \cdots (3)$$

and C_f is bus current injection vector. The network is injected with current $-I_f$ only at the r-th bus, we have,

That is actually given by just hold on. That is given by your Z bus is equal to this way you write y matrix Z 11, Z 12, Z 1 n, Z 21, Z 22 j n and Z n 1, Z n 2, Z n n. I mean inversion of y matrix will give the Z bus. So, this is the Z bus matrix and C f is bus current injection vector, right. So, the network actually is injected with current minus I f only at the r th bus. That means, when you take this equivalent network, only this current being injected all other currents are 0, right.

So that means, C f is your what you call bus current injection vector and injected current with minus If because it is fault current is going your distinct downwards, right. So, if it is three phase fault to the ground, the current that is going to your, this current is going to this, right. So, an injected current will be minus I f. So, that means, only at the r th bus therefore your what you call this equation, if you write this equation, this current vector, right that means your this current.

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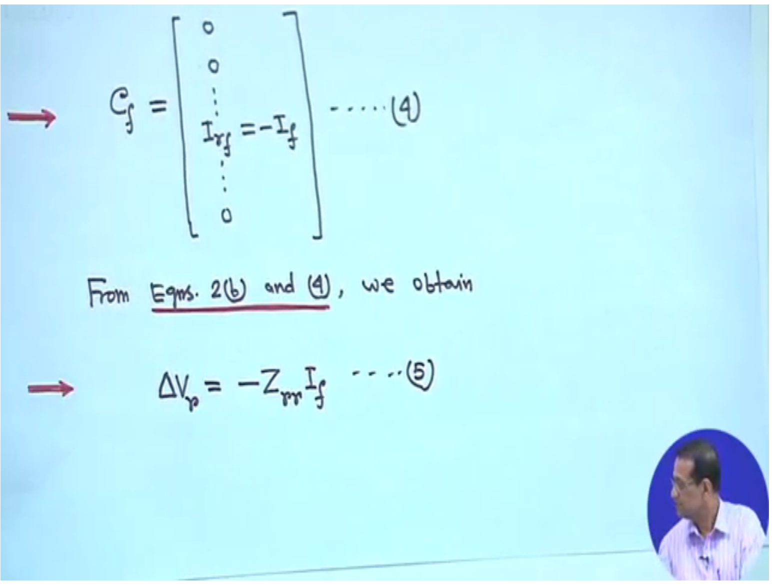

$$C_f = \begin{bmatrix} 0 \\ 0 \\ \vdots \\ I_{rf} = -I_f \\ \vdots \\ 0 \end{bmatrix} \cdots\cdots (4)$$

From Eqns. 2(b) and (4), we obtain

$$\Delta V_r = -Z_{rr} I_f \quad \cdots\cdots (5)$$

I have taken c instead of I c f, that is all. The current injection at that figure is 0 except rth bus, I r f is equal to minus I f. This is actually equation your what you call 4, right. All are 0 except r th bus fault current minus I f. therefore, from equation 2 b and 4 your what you call from 2b, that means this equation from this equation that is 2 b write this equation 2 b and this equation 4, you will get your del v r is equal to minus your Z r r into I f because all are 0. If you write from this equation delta v 1 delta V 2 up to delta V r, then again your del dot dot dot delta V n and put all Z f z down 1 Z 12, then C f is all 0 0 0 and except the minus your I f thing. So, this will come delta V r minus Z r r into I f, right.

Thank you again. We will come to this.