Power System Analysis
Prof. Debapriya Das
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 54
Symmetrical components (Contd.)

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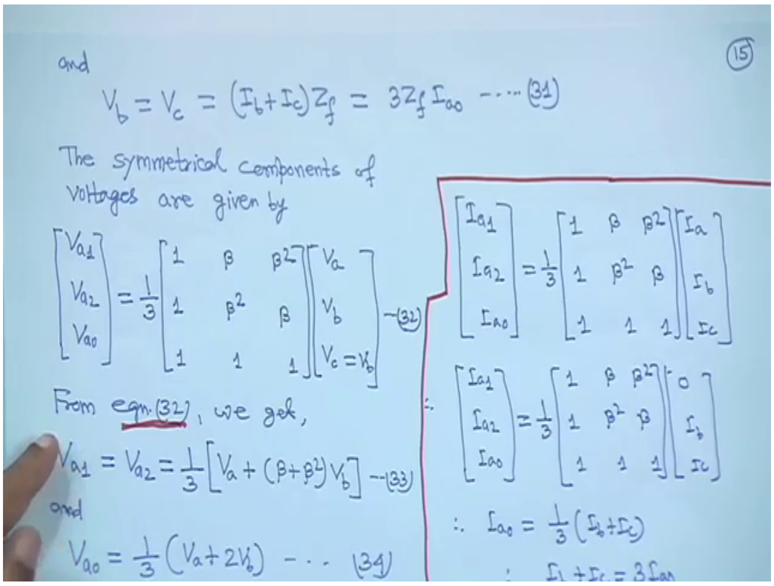

So, V b is equal to V c equal to I b plus I c in to Z f is equal to 3 Z f I a0. So, I in this case what you call that this one will come to that; this one why we are writing 3 Z f I a0. So, here if you see will see that I b plus I c is equal to 3 I a0; I am making it here on the right hand side here. I a1, I a2, I a0 you know one-third 1 beta beta square, 1 beta square beta and 1 1 1: I a I b I c this are known to us.

Therefore, I a1, I a2 I a0 is equal to one-third 1 beta beta square is the same you know matrix then I a is equal to 0 and this is I b and this is I c.

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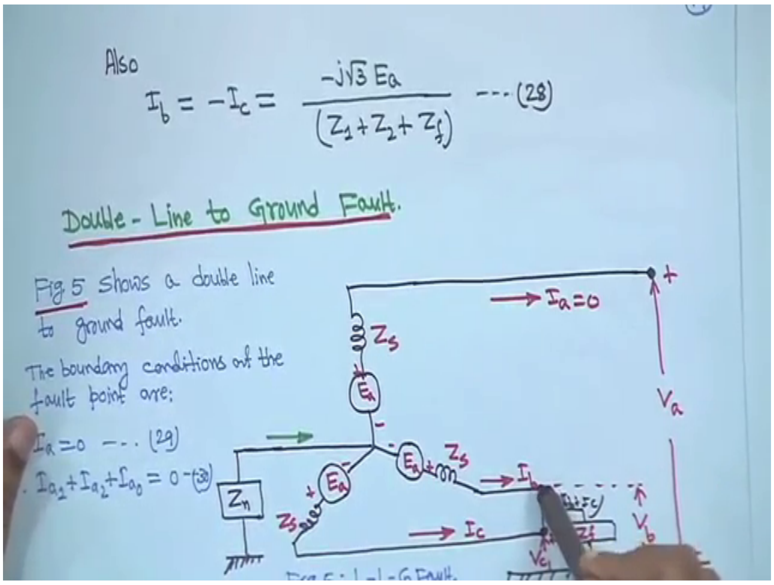

Because that this double line to ground fault, it has happen between phase b and c so I a is equal to 0. So, here if you put I a is equal to 0 then it is I b I c, therefore I a0 is equal to from this equation because I a0 is equal to one-third then your I b plus I c. That means, I b plus I c is equal to 3 I a0. Therefore, this one I b plus I c is replaced by 3 I a0. That is why V b is equal to V c is equal to 3 Z f I a0.

Now, the symmetrical components of voltages are given by. These are again known to us. So, V a1, V a2, V a0 is equal to one-third 1 beta beta square, 1 beta square beta, 1 1 1. And this is your V a V b and V c is equal to V b. Here we are writing V c is equal to V b this is equation say 32. Now from equation 32 you can write directly I am writing if you write V a1 for example if you write V a1 it will be V a plus beta V b plus beta square V b again, because V c is equal to V b.

If you write V a2 that is also one-third you will write V a plus beta square V b plus beta V b. That means, beta square plus beta both the equation is common. That means, directly we can write that V a1 is equal to V a2 is equal to one-third in bracket V a plus beta plus beta square V b. This is equation 33. And the V a0 the last one it is V a plus V b plus V c is equal to V b; that means V a0 is equal to one-third V a plus 2 V b. So, this is equation 34.

So, using equation 33 and 34; that means using this two equation you subtract equation 33 from equation 34.

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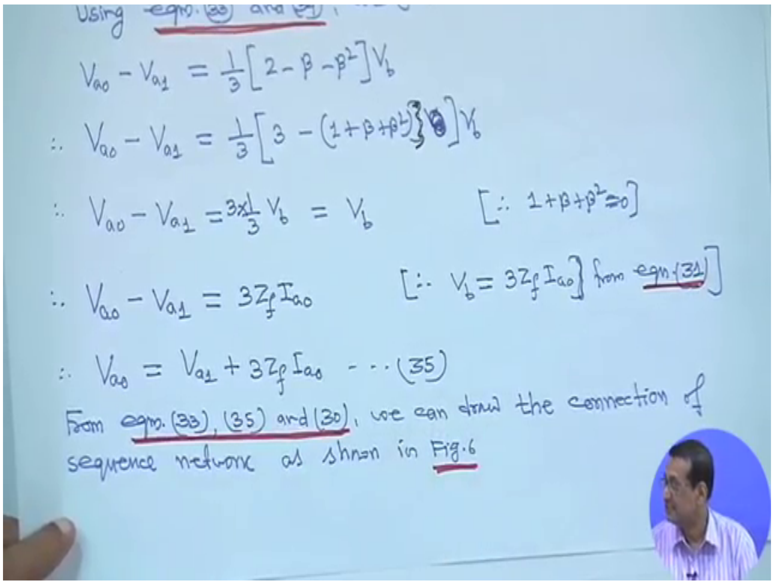

If you subtract you will get; we want V a0 minus V a1. So, subtract equation your 33 from equation 34. If you do so V a0 minus V a1 will come like this one-third 2 minus beta minus beta square in to V b. Now V a0 minus basically one-third add 1 subtract 1. If you add 1 2 plus 1- 3, then minus you take common it will be 1 plus beta plus beta square into your V b.

So, in this case we know that this identity 1 plus beta plus beta square is equal to 0. During symmetrical component we have given this so put here it is 0. That means, V a0 minus V a1 is equal to 3, because of this 3 into one-third V b. That means, V a0 minus V 1 actually is equal to V b. And V b is equal to V c, so naturally it will be is equal to V c. So, V a0 minus V a1 is equal to 3 Z f I a0, because V b is equal to 3 Z f I a0. Here we have in equation 31 we have shown that V b is equal to V c is equal to 3 Z f I a0: all exercise has been done for you on the right hand side.

So in this case, that means your V a0 is equal to V a1 plus 3 Z f into I a0. This is actually equation 35. That means this equation, the equation 33 35 and 30 this three equation we can draw the connection of the sequence network as shown in figure 6: so 33 35 and 30.

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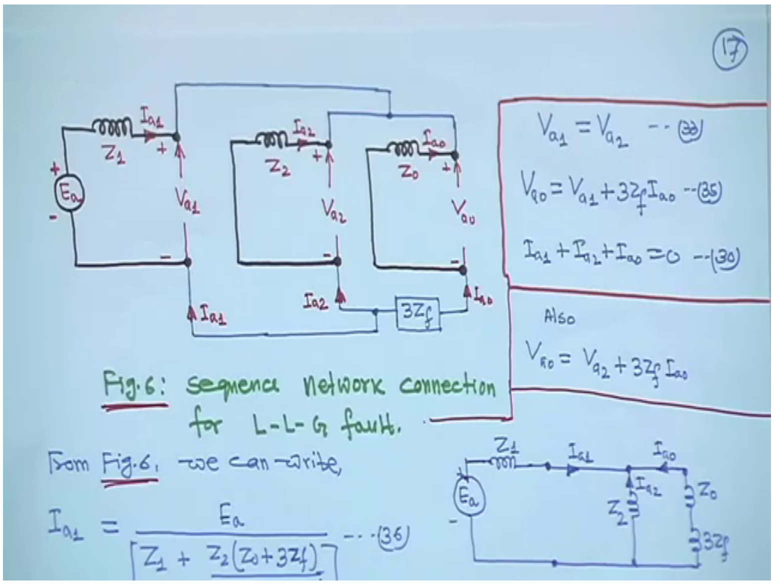

So, equation 33 it is actually V a1 is equal to V a2, this is the first thing. Then equation 35 I have written right hand side it is V a0 is equal to V a1 plus 3 Z f I a0. And equation 30 actually I am rewriting this equation just for drawing this diagram and it is given I a1 plus I a2 plus I a0 is equal to 0. That means, this three equations suppose this for example, suppose this three equations are given to you and you please draw the complete your sequence network connection. Suppose some fault has happen this equations are given to you.

For example, say after solving somebody has given that this are the positive negative and zero sequence connection you please make the circuit. So, 33 is V a1 is equal to V a2; that means we suggest that positive and negative your sequence it perhaps to be connected in parallel. And another is I a1 plus I a2 plus I a0 is equal to 0, this condition also you have to satisfy. And V a0 is equal to also you have to satisfy V a1 plus 3 Z f I a1 I a0; how one will make it.

So, the black color is my positive sequence network E a is there Z 1 I a1. This one is my negative sequence one, this is g Z 2, again by there is a black ink I have used right. And this is zero sequence Z 0. Now first thing is that my V a1 is equal to V a2 and all this connect connectors I a1 plus I a2 plus I a0 is equal to 0. So, in this case what you will do that this your V a0 this your this negative sequence network: this is I a2 is coming here and from zero sequence this I a0 is coming here and from positive sequence I a an come inverse you have to make a junction point such that I a1 plus I a2 plus I a is is equal to 0. That means, this I a1 is coming here, I a2 is coming here, I a0 also coming here, at this point you apply here (Refer Time: 17:17) of first law. So, I a1 plus I a2 plus I a0 is equal to 0

Similarly this is your plus plus connection, right. Similarly here also that you have to see first outgoing one here also as you have connected here means here also you have to connect, but question is that V a0 is equal to V a1 plus 3 Z f I a0. That means, this I a0 is this current is flowing to the fault impedance total is coming as a equivalent 3 Z f. That means, this is I a0; I a0 current is entered and going like this so this is I a0. So, leaving this terminal, but it will be 3 Z f I a0 will be there because V a0 is equal to V a1 plus 3 Z f I, so 3 Z f, this 3 Z f will come here. And here also I a2 this is the current path for I a2. So, from this I a2 also will leave, and this is the current path for I a1 it will also leave, but this 3 Z f will come. If Z f is equal to 0 then it will be same as before, only one is incoming and here it is all currents are outgoing.

And this is what you call this is V a1 is equal to V a2, because if you make a KVL here this loop will go like this, it will go like this, this is your plus V a2 it will come like this minus V a1 is equal to 0. Only it will go like this, it will go like this, go like this, it will go like this, it will go like this. So, that is why V a1 is equal to V a2. And if you make that V a0 is equal to V a1 plus 3 Z f I your I a0. That in this case if you make loop like this KVL you come here right, so it will be your plus your V a0 plus V a0 then this current is going so opposing. So, minus I a0 in to 3 Z f and then your minus V a1 is equal to 0. That means, V a0 will be is equal to V a1 plus 3 Z f I a0. And at this point or at this point I a1 plus I a2 plus I a0 is equal to 0.

So, this is the equivalent circuit connection for what you call that your double lines to ground fault. So I mean here, from your intuition only you have to make the circuit connection correct. So from this condition different type of faults will be there, so accordingly you have to make it. Suppose all the conditions you have to make and accordingly you have to this thing. Different places, different way this diagram is given, but I prefer always this way. Make positive negative 0, after that look in to the equation and accordingly you try to make it.

So therefore, this is the sequence network connection for double line to ground fault. I hope this much you have understood. Now this circuit if you make equivalent I mean equivalent is there. Suppose this is this is for you only I have made it figure 6 a, this is figure 6 a this is E a and this is Z 1. So, this current is going I a1, now this is Z 2 the current is going here because all the summation of all this current is 0. So, this is Z 2 and this is your and this is I a0 and this is Z 0 and 3 Z f they are in series. So, Z 0 3 Z f this current is there. That means, your this two are in parallel that your what you call that negative sequence and zero sequence, but here Z 0 plus 3 Z f these two are in parallel.

We suggest also that V a0 is equal to your this thing what you call that your this positive sorry this negative sequence and this zero sequence this two are in parallel. So, that means from here this two are in parallel. So, their equivalent will be Z 2 in to Z 0 plus 3 Z f divided by Z 2 plus Z 0 plus 3 Z f. That means, your this equation also I have written that is why that V a0 is equal to V a2 plus 3 Z f I a0, this is because V a earlier this we have we have made it that V a1 is equal to your V a1 is equal to V a2; this one we have made it.

That means, V a0 instead of V a1 we can write also V a2 plus 3 Z f I a0. That means, this suggest that your negative sequence and your zero sequence they are in parallel, but here fault impedance will be there. If Z f is 0 then 3 Z f (Refer Time: 11:54) will not be there. So, here they referring to your equation 33. That means, my I a1 is equal to your E a divided by this Z 1 plus the parallel combination of this Z 2 into Z 0 plus 3 Z f divided by Z 2 plus Z 0 plus 3 Z f. This is equation 36.

Similarly if you apply KVL in this loop this circuit is the simplest version of this one right; equivalent version of this one same circuit but drawn. If you apply KVL in this loop so it will be Z 1 I a1 minus your Z 2 I a2 minus E a is equal to 0. That means, I am writing this from this circuit only here for such that you can understand easily.

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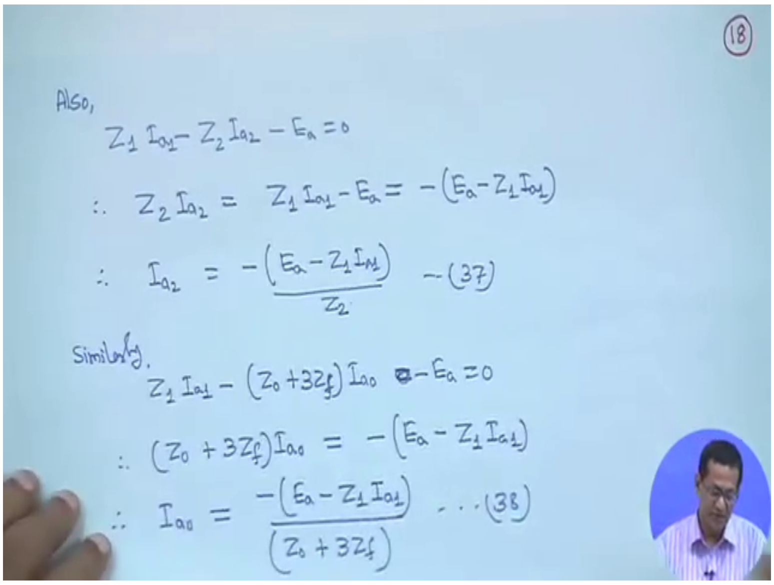

That means your Z 1 I a1 minus Z 2 I a2 minus E a is equal to 0. That means, from simply the simplification I a2 is equal to minus in bracket E a minus Z 1 I a1 by Z 2 this is equation 37. Similarly, in this circuit again here in this you made this. That means, KVL this second one. Z 1 I a1 right minus I a0 in bracket in to Z 0 plus 3 Z f minus E a is equal to 0. If you do so then same I am writing Z 1 I a1 minus Z 0 plus 3 Z f in to I a0 minus E a is equal to 0. That means, open simplification I a0 will be minus in bracket E a minus Z 1 I a1 divided by Z 0 plus 3 Z f. This is equation 38.

So, this way one has to solve, when data will be given and how things can be solved that through numericals we will see. But only before moving to that I would like to tell that particularly the positive sequence negative sequence and zero sequence component when you consider for a problem and fault has occurred this problems are little bit of; I will say that little bit of complexity is involved and little bit of long I mean lengthy. But will take few examples and will show you how things can be solved.

That means so far we have studied line to line fault, line to ground fault, and what you call double line to ground fault and all the expression. I hope you have understood this, but only if different fault is I mean some different type of fault is created so you have to generate those equations; I mean and accordingly you have to draw the sequence network.

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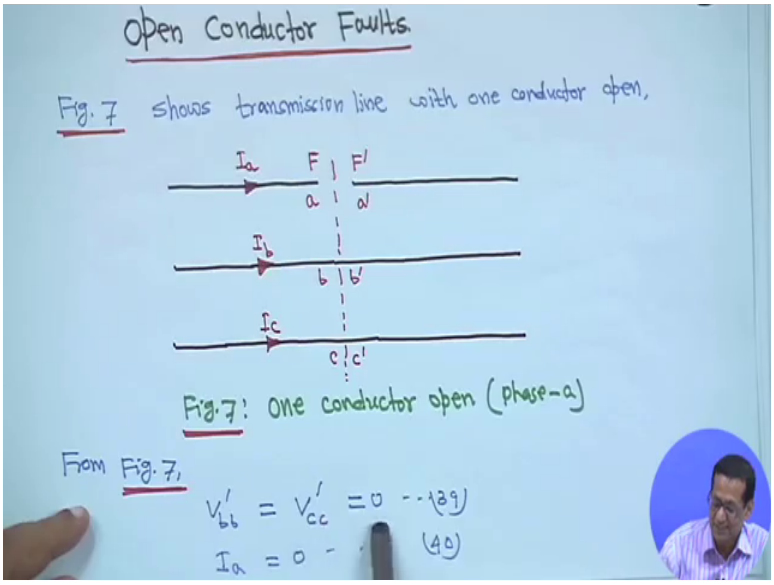

Next is that open conductor fault. This are although very very rare very rare, but suppose open conductor broken conductor; open conductor is broken conductor. Suppose this is the figure 7: you have a phase a b c, current flowing through this were I a I b I c, but suddenly in phase a suppose conductor is open. So, what we are doing is we are marking F F dash, then b b dash and c c dash. So, one conductor you open that is phase a conductor is open.

So in that case, as this is a continue as this is a there is no broken part here there be b and b dash point is common, c and c dash point common; that means, your V b b dash is equal to V c c dash is equal to 0. This is equation 39, because b and b dash actually common point c c dash common point, so no broken part here in phase b and c. So, V dash b b is equal to V dash c c is equal to 0 this is equation 39. And this phase a conductor is broken, so I a is equal to 0. So, I a is equal to 0 these are the boundary conditions.

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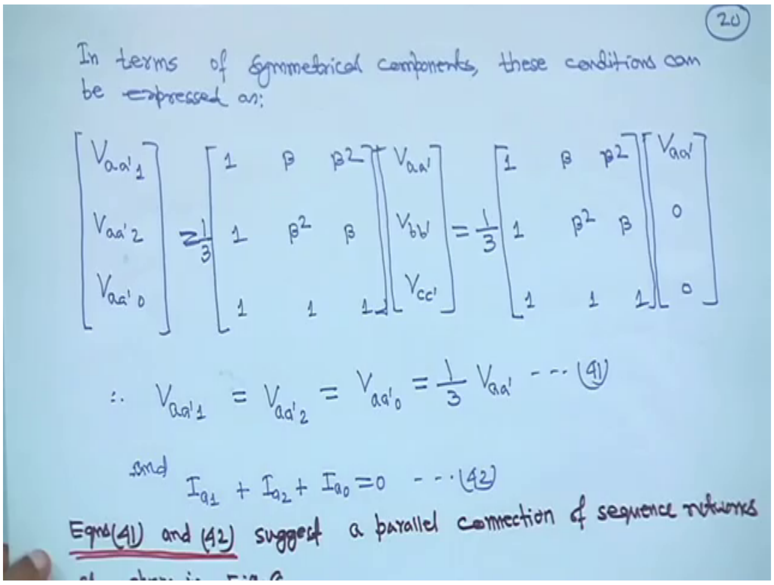

Now this one if you put in symmetrical component we can write like this in terms of this. This equation always known to you, we can write it write down V a a dash 1 positive sequence, V that is conductor open conductor cases. Then V a a a dash 2 then V a a dash 0 positive negative zero sequence component is equal to one-third, because we are we are taking the voltage V a a dash; V a a dash is equal to V a a dash 1 plus V a a dash 2 plus V a a dash 0.

That means, it is equal to one-third, 1 beta beta square, 1 beta square beta 111 this are known to you; into V a a dash V b b dash V c c dash. Now we are doing now V a1 V a2 V a0 is equal to this matrix into V a V b V c, here also because of open conductor that V a a dash V b b dash V c dash c c dash, but V b b dash and V c c dash is both are 0, here 0 because of this one V b b dash this two are zero from equation 39.

Therefore, we can write this is a zeros we can write then V a a dash 1 is equal to V a a dash 2 is equal to V a a dash 0 is equal to one-third V a a dash; this is equation 41. The reason is very simple: V a a dash 1 is equal to one-third V a a dash, V a a dash 2 is equal to one-third again V a a dash, and V a a dash a a dash 0 is equal to one-third again here as because this two are 0. So, this all are equal. This all are equal suggest it is a parallel connection. And I a1 plus I a2 plus I a0 is equal to 0 because phase conductor a has broken or open. That means, I a is equal to 0 I a is equal to 0 means your I a1 plus I a2 plus I a0 is equal to 0. This equation 42

From this you have to draw the; that means, this equation 41 and 42 this equation this two suggest a parallel connection of sequence network as shown in figure 8; that means next figure. That means, they are corrected parallel and some of this current positive negative and zero sequence is 0. That means, this is your say I make it.

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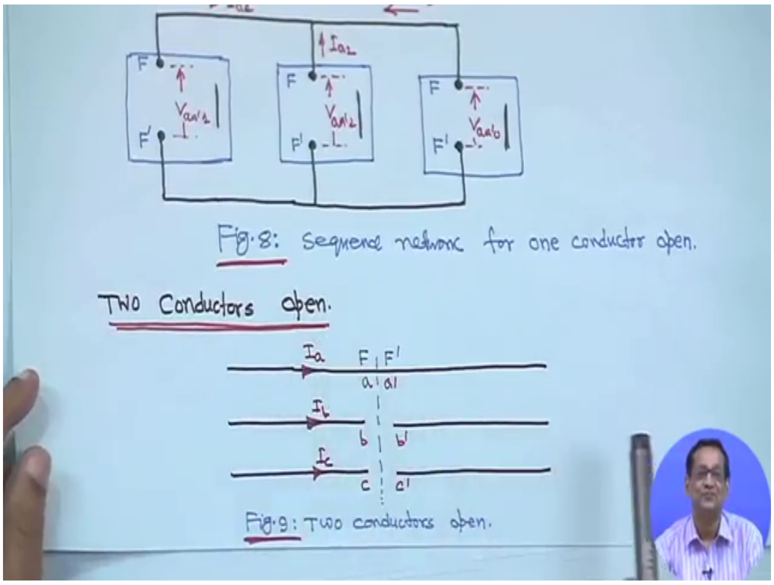

Because the conductor open, open conductor only, so this is suppose F F dash F F dash F F dash right, this is for phase a. Why you are making F F dash, because phase a conductor has open positive negative and zero sequence that is why F F dash. That is why it is your F F dash your. I mean if you want you can make a line like this that conductor open F F dash and here also right. So, in that case this F F dash for positive sequence negative sequence zero sequence all voltage are in all parallel, because all voltages are same right and all the sum. And from here current is I a1 from here current is I a2, from here current is I a0 because I a is equal to 0, so at this is the meeting point. So, I a1 plus I a2 plus I a0 is equal to 0 (Refer Time: 19:07) of first law. And this is the sequence network for one conductor open.

So, things are very simple only from that fault condition you have to write those equations boundary conditions. And then you easily you can mathematically you can manipulate and you can easily construct the positive negative and zero sequence cancel. Then one more: that two conductors open. Suppose phase b and phase c both conductors are open. So, it is a a dash, then b b dash and c c dash, but phase b and phase c conductors are open. That means, I b is equal to 0 I c is equal to 0 right and this is a continue this is your V a dash it will be 0, because there is no broken path here a and a dash common point, so V a a dash is equal to 0. And I b is equal to 0, I b is equal to 0; this are actually boundary condition.

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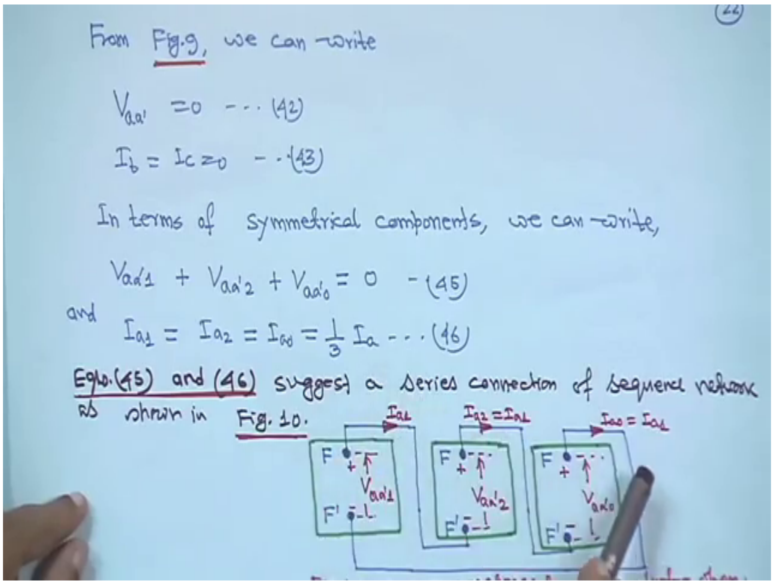

So, from this figure boundary condition we can write that V a dash is equal to 0 I b is equal to I c is equal to 0. So, in terms of symmetrical component you that V a a dash is equal to 0 means V a a dash 1 plus V a a dash 2 plus V a a dash is equal to 0: 45. This is positive negative and zero sequence components. And I b is equal to I c is equal to 0 and same way if you go for symmetrical component I am not putting it here now you have understand everything you will get I a1 is equal to I a2 is equal to I a0 is equal to one-third as it all I a1 I a2 I a0 is equal to one-third I a all are same.

That means this condition suggest actually a series connection because I a1 is equal to I a2 is equal to I a0, when currents are same it is suggested series connection. So, if it is a series connection this is your F F dash F F dash: F F dash I have told you earlier also. Series connection means this is your positive, positive to negative, than positive to negative, than positive to negative. And this is your positive sequence, this is your negative sequence, and this is your zero sequence connection. So, it is I a1 I a2 is equal to I a1 I a0 is equal to I a1 because all are same that is one-third I a1. This is equation 46.

So, this is actually sequence network for two conductors open. So, although this are very rare phenomena, but for the sake of completeness I took this one. And even simultaneous occurrence of I told you suppose line to ground fault that is same time double line to line to line fault very rare, but will see. I think we have taken one problem later on that will see.

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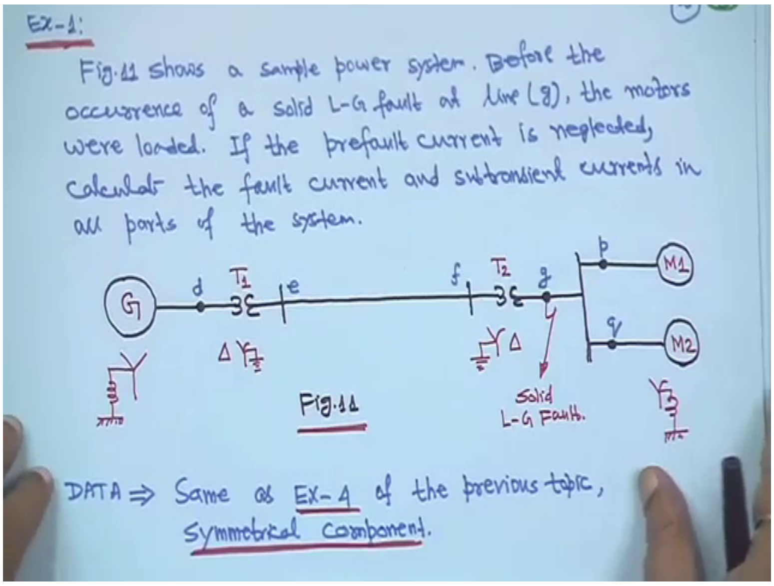

Now what will do that this example actually we have taken from your previous symmetrical component. Because then it will be easy for you to understand right.

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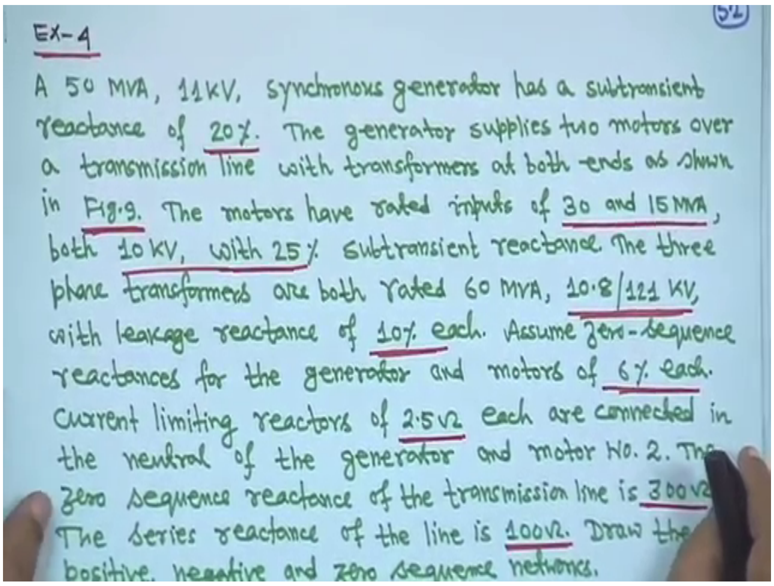

This example actually is the same example four of that your symmetrical component; details have been given there. This is the same problems same problem is taken.

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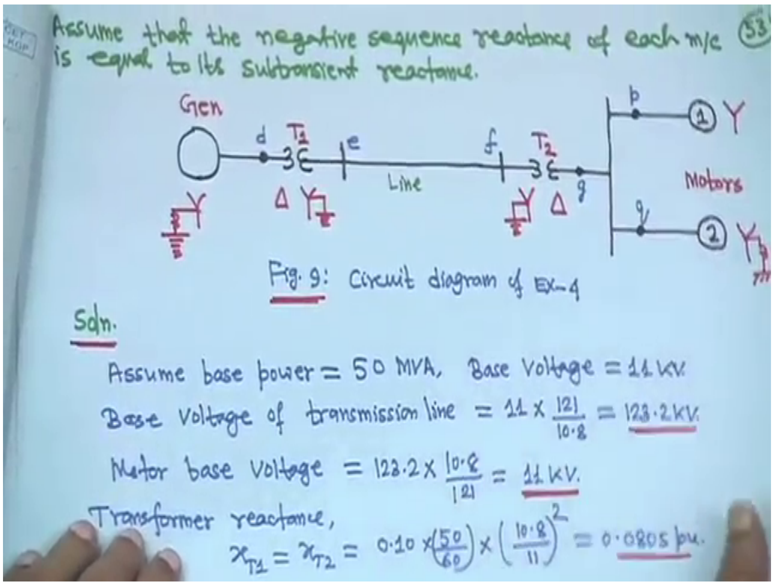

And same diagram and that same diagram everything all data are also same all the data are available in that in this problem all the data or whatever data we have made it.

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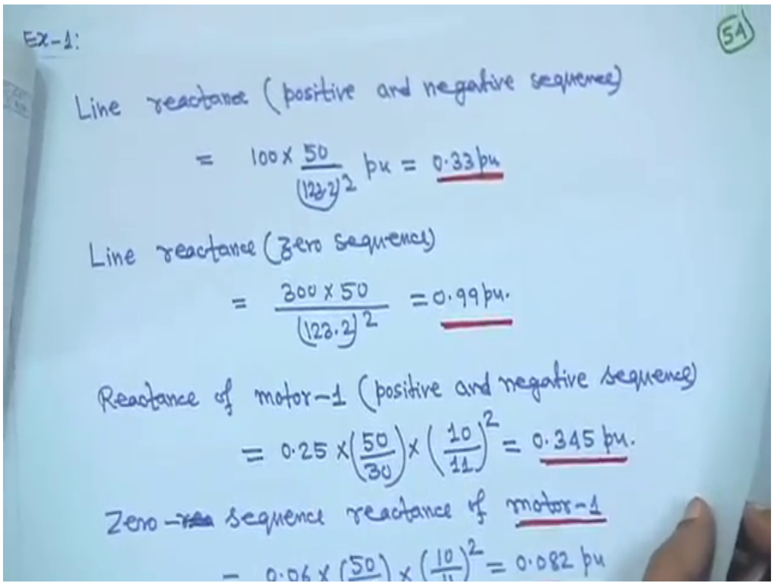

For example four of symmetrical component, I have taken the same data all data are same such that it will save time, it will help us to understand this. So, this same problem same diagram we have taken. So, all data remain same of example four of the symmetrical component. And there is a fault that point g that is solid line to ground fault, when it is telling solid line to ground fault means that fault impedance is 0. Now we have to find out that current supplied by the generator by the motor and how things will happen. So, all the parameters are same. Now when you will see that data of this problem, but still I have brought that previous one that motor terminal voltage was 10 kv.

Now fault actually has happened to the motor side; this motor side. And that is why here it is written data same as example four of the previous topic that is symmetrical component, you have all the data. Now if it is so and fault has occurred here fault has occurred at point g. Now if it is so first I will show you the diagram then the connection. So, this positive: just hold on this positive negative and zero sequence diagram for this network was given was shown to earlier.

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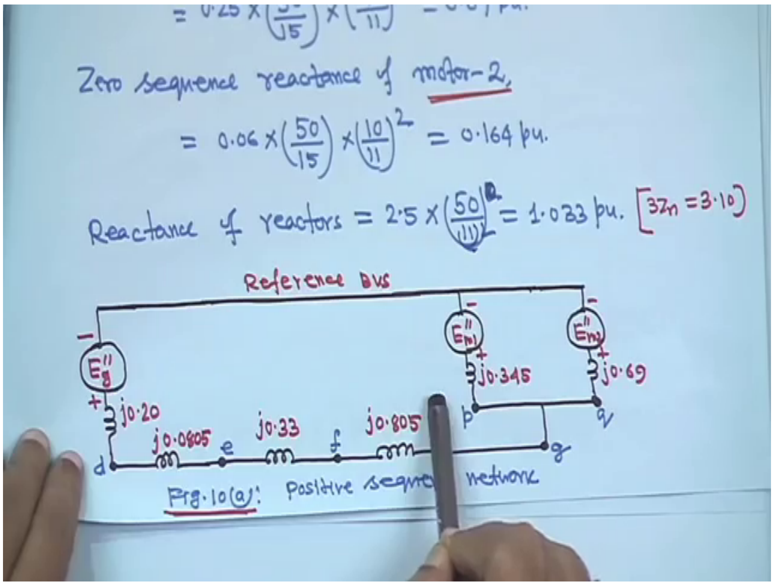

This is your positive sequence one, earlier I told you how to make it with all the voltage sources everything will be there positive it is by and all the positive sequence impedance.

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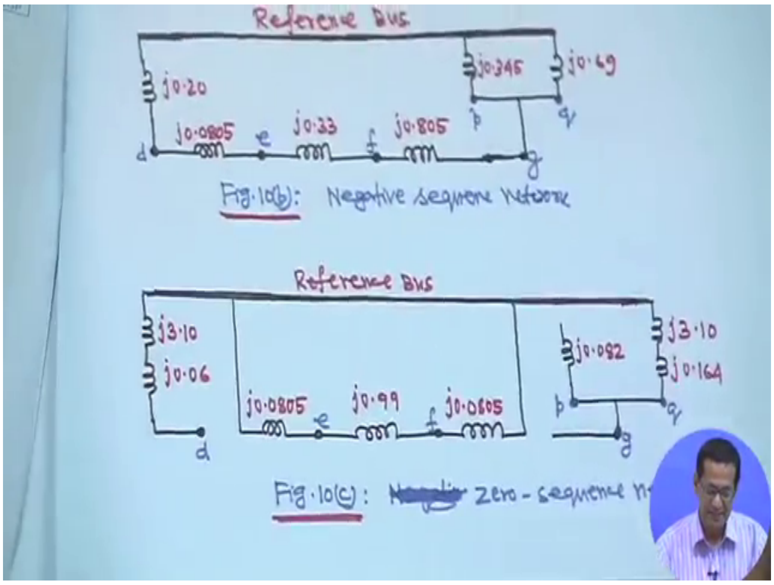

Negative sequence parameters are same, but only there is no voltage source. And all the zero sequence also this has been shown; that how it has been drawn has been explain in detail; so same network and same diagram. Now there is a point that fault has occurred. I mean there is a point here that is your near motor terminal this side there is a point here; suppose this is your g that means in this diagram that is p q and g things are there. So, in this diagram that is there is a point at g this is g at this point fault has occurred. So, in this case that this is the point g say that fault has your occurred fault has occurred line to ground fault solid line to ground fault has occurred.

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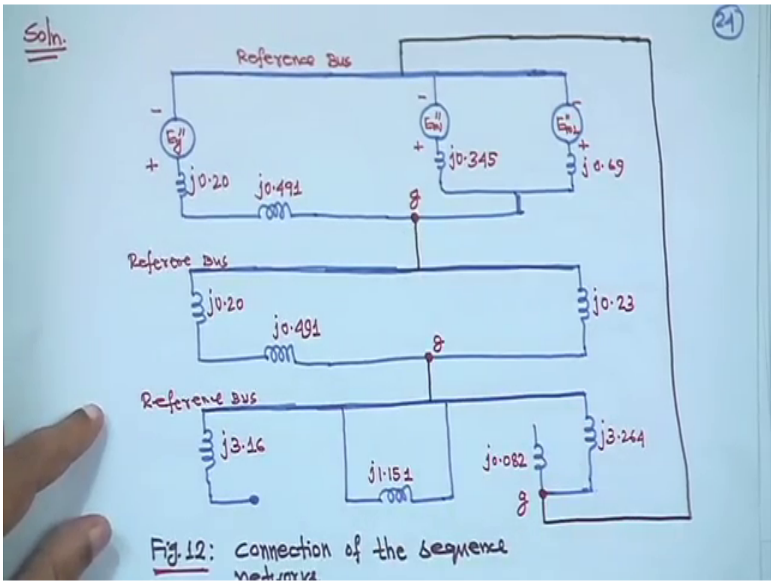

So, in this case what will happen that then how to connect. Now that this is your same positive sequence network of example four, same negative, same zero sequence. So, in this the fault has occurred here, this is reference bus, this is reference bus, this is reference bus. So, fault has occurred here, so make this ground to the reference bus of the that your negative sequence network and here also ground to reference network, and then here also this is this is your g point rather g point; g point to reference network and this is g point and it will go to the your reference bus.

So, this point is a g. That means, in this what you call this point is g; the fault has occurred here line to ground fault has occurred here. That means, this is my point g, they connected to the reference bus, then g connected to the reference bus, and this is also g connected to the reference bus. Before solving this problem that when you solve it using equation per three phase. For three phase fault we have made that pre fault voltage taken out and equivalent Thevenin representation. Three phase fault only our objective was to see that your Z bus will link algorithm, although little bit complicated and some problem few problems for solving this. But more emphasis we have given here symmetrical component and unbalanced fault.

So, in this case if you look at that that you have to find out what is the pre fault voltage because motor side fault has occurred. So, its voltage was 10 kv; that will see later. Now question is that if you look in to that that zero sequence network same network right that your zero sequence current actually will flow up from the motor side, because that this is your there are three motors: one is what you call ungrounded and another this one is your what you call this is better this one. If you take this one this one this is star connected this is star connected and this is through some impedance till grounded. So, here also I have missed that it is star connected, but ungrounded.

So, here that means this zero sequence diagram that it is connected to the reference if you see the circuit is computed, but if you look at the generator side right because of the isolation star is grounded but delta is here, so there is an isolation. That means, from the generator side there be no zero sequence current, but from the motor side there will be what you call there will be zero sequence current right. That means, when you will solve this all the zero sequence current by whatever it is it will flow from the motor side, because you see it is getting a path, it is getting a path, it is getting a path like this, but this side there is isolation. So, no current will flow from the generator side. This you have to judge looking at the zero sequence network.

That means if you make only your Thevenin equivalent from the for the positive sequence network.

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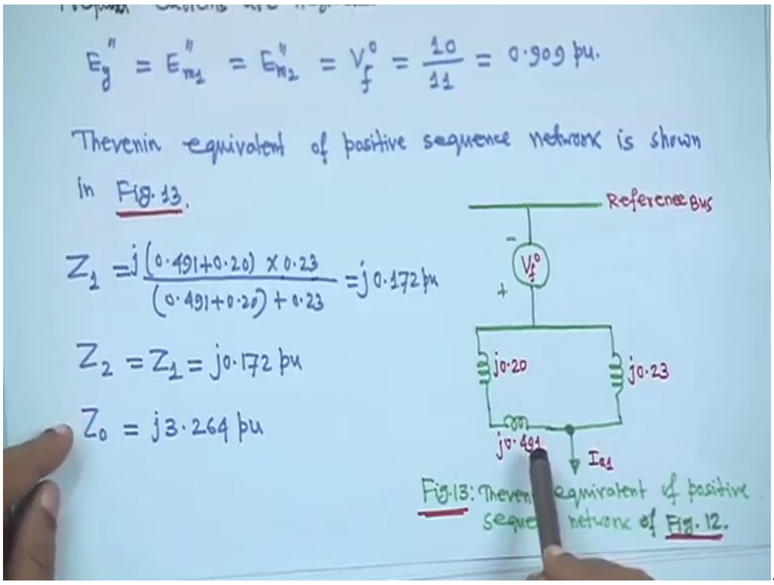

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So, motor side voltage was 10 kv, so pre fault currents are neglected. So, we can say E g double dash is equal to E m one double dash is equal to E m two double dash is equal to V f 0 is equal to 10 by 11 0.909 per unit. But motor side terminal voltage 10 kv base k V we have taken 11, so 0.909. So, this is my your V f 0 this thing.

And next is this all this thing sum of this two and take the equivalent of this parallel point 0.345 and 0.69 j take this equivalent, its equivalent will be actually j 0.23. And this side is point j 0.20 j 0.491 we have to add this two and take the equivalent. If you take then Z 1 will become j 0.172 per unit and Z 2 is equal to Z 1 will be j 0.172 per unit and Z 0 is equal to j 3.264 this is the j 3.2 this. All this parameters have been computed for example, four in symmetrical component. So, all parameters we are taking. Other this one, this one, this one, will not be equaled for that kind of fault where fault had occurred at your what you call point g. And this is the Thevenin equivalent.

Now that means, similarly this one also this two were and this are there make equivalent parallel and this one in this case only j 3.264 will come. So, if you make that equivalent circuit. So, this equivalent is coming your Z 2 is equal to Z 1 is equal to this one and this is this one.

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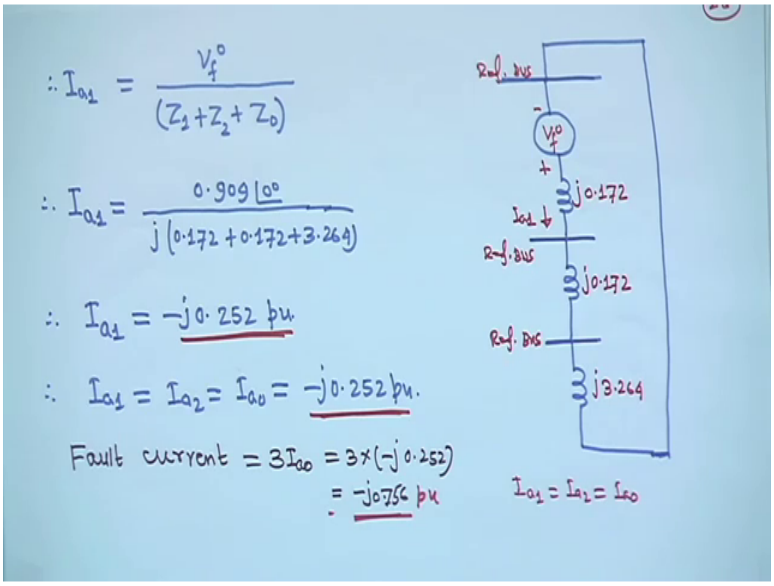

So, equivalent circuit will be this one. This is reference bus, reference bus, this is j 0.172 j 0.172 and j 3.264 and I a1 is equal to I a2 is equal to I a0. So, in that case I a1 will get V f 0 up on Z 1 plus Z 2 plus Z 0. So, substitute all these. If you substitute all this then you will get I a1 is equal to minus j 0.252 per unit.

And I a1 is equal to I a2 is equal to as all are same right; I have not shown here, but this is I a1, this is I a2, this is I a0 series circuit all are same; that means, your this will be minus j 0.252. Now fault current will be 3 I a0; that is your 3 into minus j your 0.252. That means, it is minus j 0. Ultimately is coming 75 here 6 per unit. So, this way this what you call this way you have to solve that zero sequence your positive sequence negative sequence at zero sequence you have to understand and then only you can apply that how are why fault has occurred. And accordingly you have to see that how all parameters are computed correctly. And then you can easily solve that what will be my fault current.

Thank you, again we will be back.