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

Lecture- 51
Symmetrical Components (Contd.)

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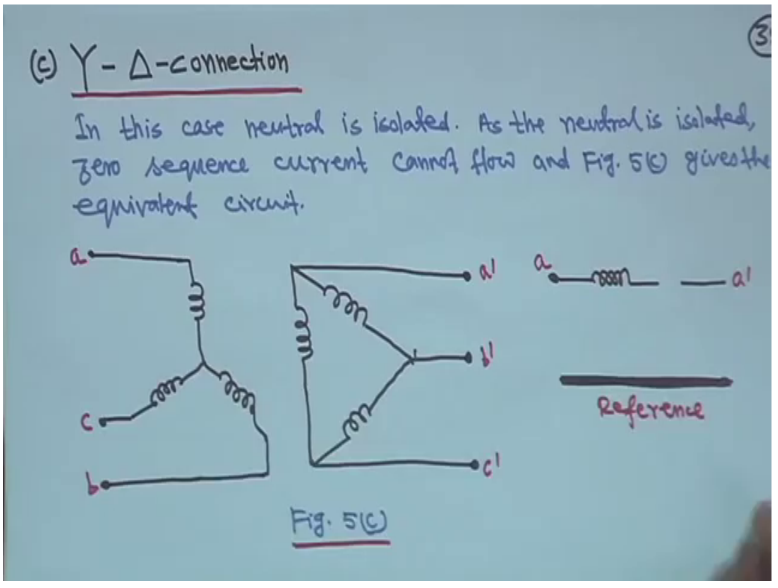

Then next is that star delta connection, in this case the neutral is isolated for star there is no neutral here right as the neutral is isolated. So, zero sequence current cannot flow as and this side is delta, and later will see about next diagram will see delta. So, it is star is that star side is your ungrounded no ground. So, no zero sequence current flow and for delta you know there is no neutral right. So, this will remain open and this is your reference one; that means, this two diagram this one that star grounded and other side secondary side is ungrounded, and this side and this one their your they have the same negative sequence diagram this kind of connection, this one as well as this one. So, this will remain open because no negative sequence current can flow. When you will take the numerical for unbalanced fault at that time will see how things are connected.

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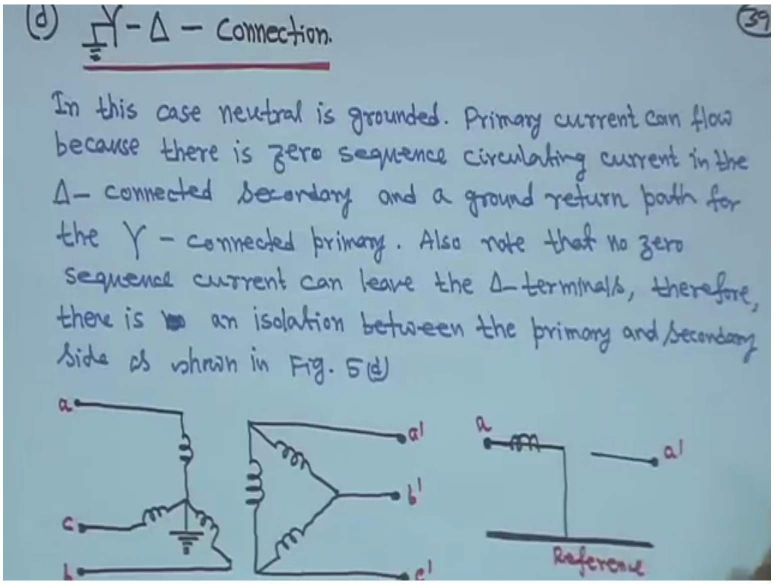

Now another one is next one is that star grounded, but delta connection in this case what will happen that neutral is grounded; that means, primary current can flow because there is a zero sequence circulation current in the delta connected secondary; that means, in this case a zero sequence your zero sequence that your what you call circulating current can flow in the delta, but it will not leave it right it cannot leave the your terminal. So, in this case I mean. So, it will circulate it will be a circulating your zero sequence current. So, in this case what will happen that that is a zero sequence circulating in the delta connected secondary, and a ground return path for the star connected primary.

That means your neutral is grounded is primary side means its current can flow because there will be a your what you call that circulating current inside the delta right; that means, but in this case what will happen that also note that no zero sequence current can leave the delta terminals. So, it cannot it cannot leave that delta terminal because it is a circulating current; that means, this zero sequence current can flow the neutral is grounded primary side it can flow, because the circulating zero sequence current is there in delta. So, in that case what will happen this is your zero sequence reactance of the transformer, then you ground it connect it, but as from delta as it cannot leave the terminal zero sequence current it is a circulating one. So, this will remain open and this is your a dash and this is your reference one. So, this little bit thing you have to understand this one. So, this side is grounded. So, primary circulating current will flow in delta because in delta also zero sequence circulating current will be there, but it cannot leave the delta terminal, but it will be inside it will be in circulating one that is why, but primary current can flow because this side is grounded and this side is your 0 sequence current can flow in primary side, that is why and delta a it is a circulating zero sequence current, but cannot leave the terminal therefore, that this your zero sequence diagram for this connection will be make the transformer reactance connect it to the reference right because at the beginning I said primary current can flow because there is zero sequence circulating current in the delta connector. So, connect it, but after that this you leave open because this side delta that zero sequence cannot leave the delta terminal.

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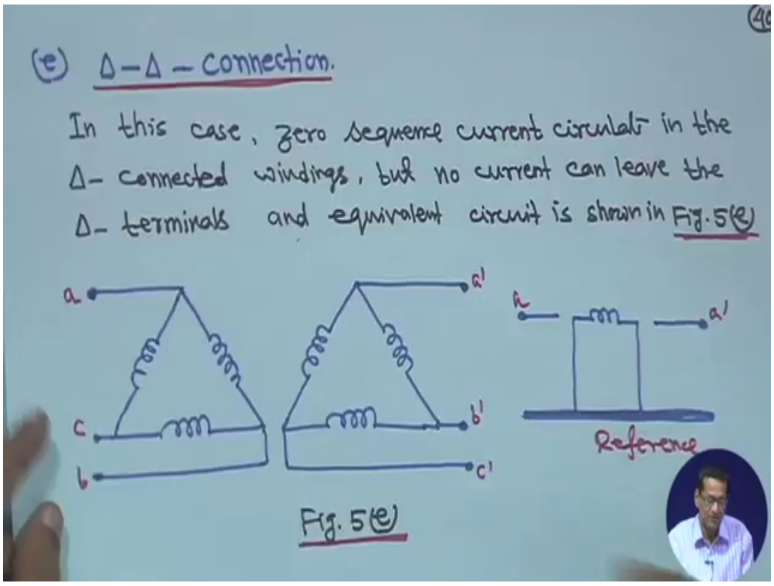

So, this is your zero sequence network diagram for this kind of connection.

And another last one for this one that another thing is that your delta delta connection this is also delta this is also delta. In this case what will happen zero sequence current will circulate in the delta, but it cannot leave the terminal. So, diagrams will be right. So, delta terminal and equivalent circuit that is a circulating current this is delta this is delta. So, this is line this side will remain open this side will remain open, but make a small loop make the transformer zero sequence your impedance and just close it like this. So, if you look this kind of diagram when you will I mean this kind of thing, this loop itself is isolated from this side or this side because it is a circulated your circulating current. So, for delta delta it will be a simply that you make it to the reference, make it to the reference, but this will remain open. So, this is that zero sequence diagram for delta

delta. So, there are 5 such connections for transformer, these are very important for solving for your what you call when fault at occurs and this kind of say your dia this zero sequence network is very important and it makes simple things very simple. So, that is your; that means, whatever we have said the symmetrical component positive negative and zero sequence right. So, all this things more or less we have discussed nothing has been left out actually. Now let us take yes an example it is example means something like this.

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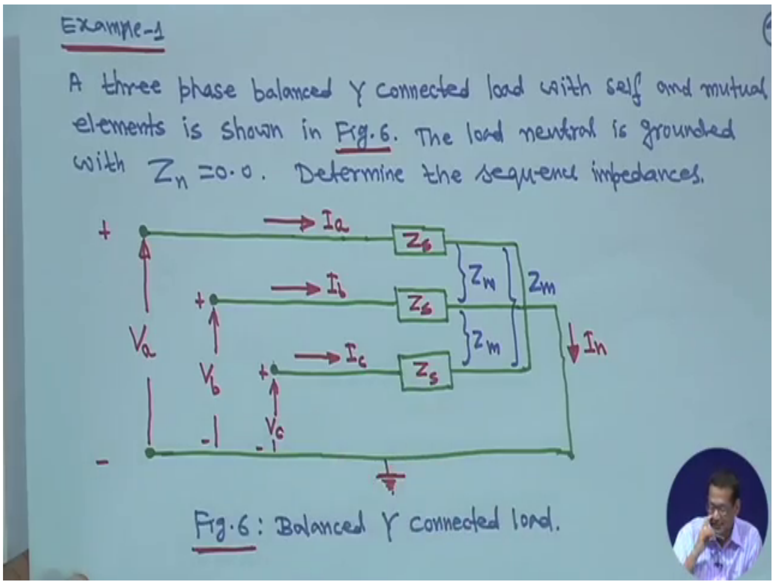

So, suppose you have a 3 phase balance star connected load with self and mutual elements as shown in figure 6, the load neutral is grounded with Z n is equal to 0; that means, your this Z n reactance that is taken as 0 you have to determine the sequence impedances. So, you 3 phase your what balance Y connected load right; that means, that is your phase a this is a this is b and this is c voltage is V a V b V c and current flowing through this I a I b I c and reactance is Z s, Z s, Z s, but they have a mutual inductance between phases; that means, between phase and a and b Z m, between phase b and c Z m, and between phase a and c that is also Z m and this is your I n right that neutral current. So, this is balanced Y connected load. So, you have to obtain that your sequence impedance. So, the line to ground voltage because this is a from your circuit theory your couple circuit you have studied.

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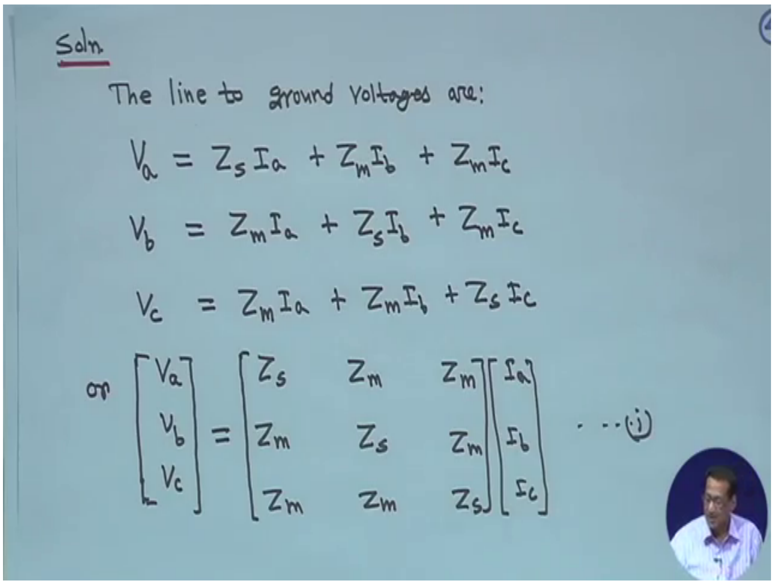

So, the line to ground voltage V a is equal to V a will be is equal to Z s I a plus Z m I b plus Z m your I c because the mutual inductance is there therefore, you can write V a is equal to Z s I a plus Z m I b plus Z m I c because mutual inductance is given between the phases. Similarly your V b is equal to Z m I a plus Z s I b plus Z m I c because you are writing for V b. So, Z s I b other two will be Z m I a plus Z m I c similarly when we write V c Z s I c the other two are Z m I a plus Z m I b.

So, this way we write line to ground voltages V a V b V c. So, this equation you put in matrix form that is V a V b V c equal to Z s Z m, Z m Z m, Z s Z m, Z m Z m Z s this is equation say 1. Now we will follow the same your philosophy this matrix as its mutual inductance is there between the phases.

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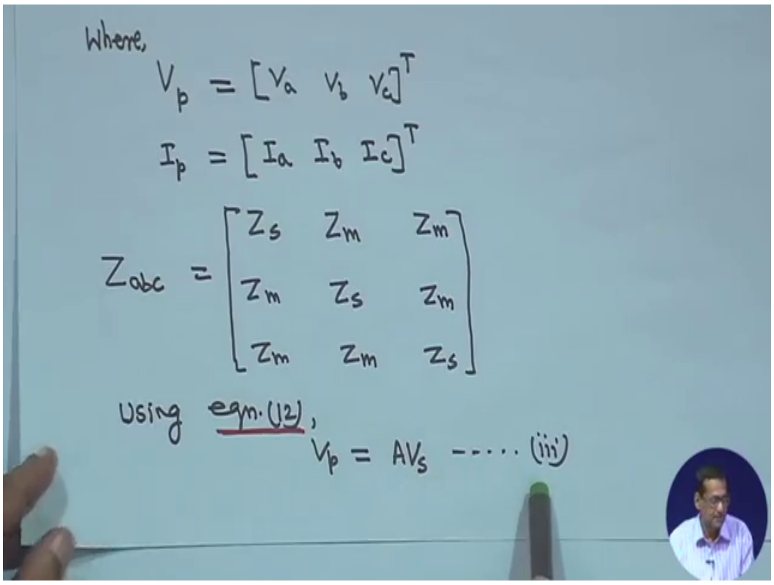

So, this matrix will define Z a b c that is that is we know of the same relation that V p is equal to Z a b c I p that is V p is equal to from this equation only V p is equal to V a V b V c transpose I p is equal to I a I b c transpose and this is your Z a b c matrix. So, V p is equal to your V a V b V c transpose I p is equal to I a I b I c transpose and Z a b c is equal to this one therefore, same relationship will go back to equation 12 there V p is equal to A V s and I p is equal to A I s.

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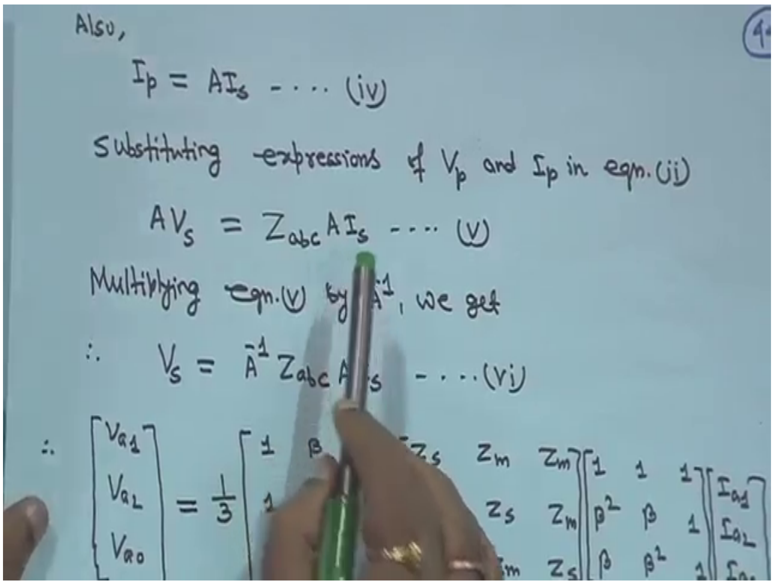

That means; that means, your V p is equal to your A V s same relationship equation 12 and I p is equal to A I s same relationship and this one V p you support here a your what you call V p is equal to your you put your A V s your A in to v s and here also I p is equal to put I A I s. If you put that that A V s will become Z a b c in to A I s multiplying equation this 5both side.

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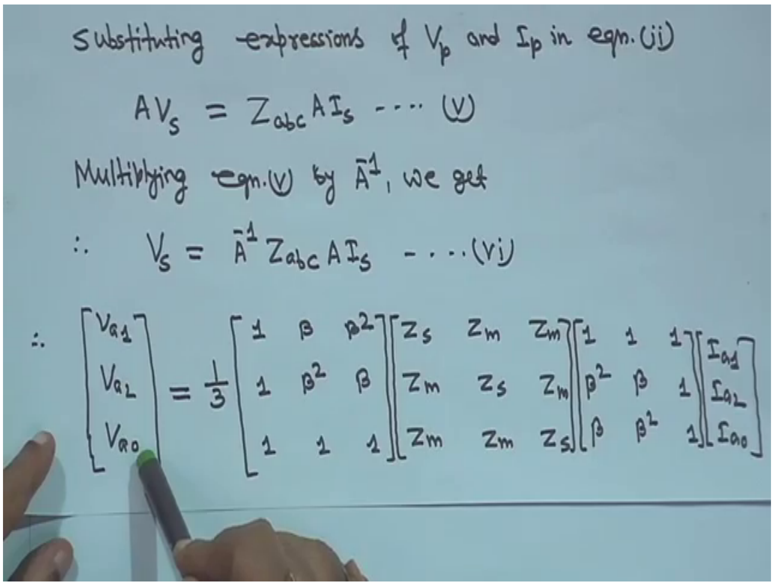

You multiply by a inverse if you multiply by a inverse then it will be V a 1 V a 2 V a 0 is equal to one third this is a inverse is equal to one third this one then this is your Z a b c this is your a you know all this things you have given and this is your I a 1, I a 2, I a 0 multiply all.

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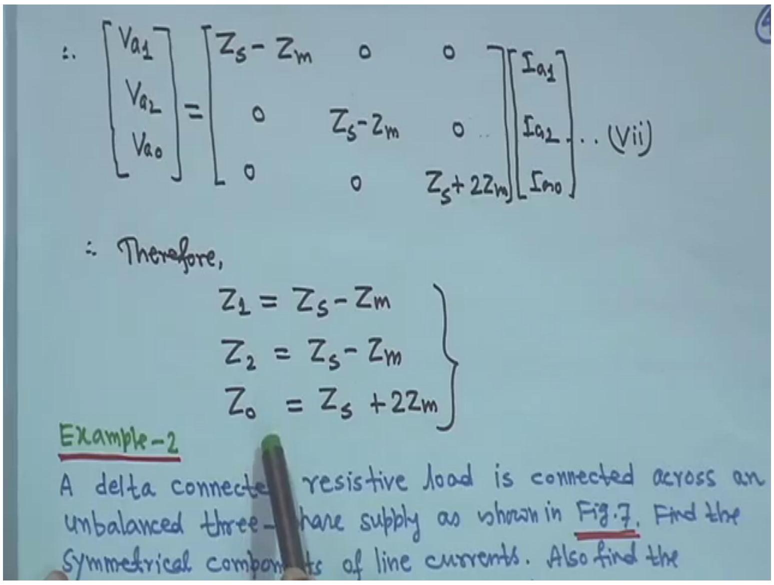

If you multiply then what will happen that this it will become V a 1 V a 2 V a 0 is equal to become Z s minus Z m 0 0, it will become 0 Z s minus Z m 0 and it is 0 0 0 Z s plus 2 Z m I a 1, I a 2 I a 0 this is equation 7 2 sorry 7 right because here. So, many equations are there 4 your four five 6 and previously also 2and 3 therefore, Z 1 is equal to positive sequence will be Z s minus Z m negative sequence also Z s minus Z m and zero sequence will become your Z s plus 2 Z m right

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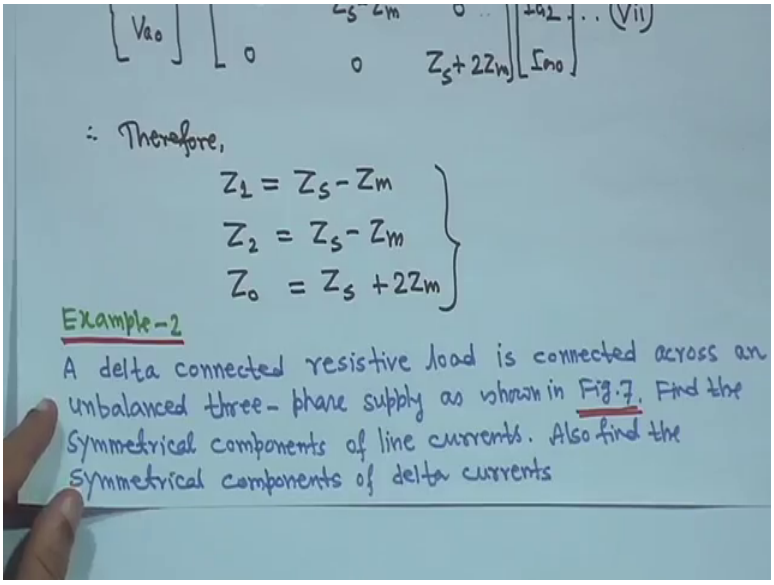

So, next example is a delta connected resistive load. So, this we have understood only thing is that just on before that only thing is that this multiplication you have to make it in correct way because 3 matrix multiplications are there and this beta operation beta operation you have to manipulate in better way such that you will get this correct answer. So, next is example 2; a delta connected resistive load is connected across an unbalanced 3 phase supply as shown in figure 7 I will give you that show you that find the symmetrical components of line currents, also find the symmetrical components of the delta currents. Both you have to find out symmetrical component of line current and as well as your symmetrical component of this delta current. So, this thing this example is like this it is a your diagram it is a delta connection, it is branch it is resistive 3 R 3 R and 3 R taken.

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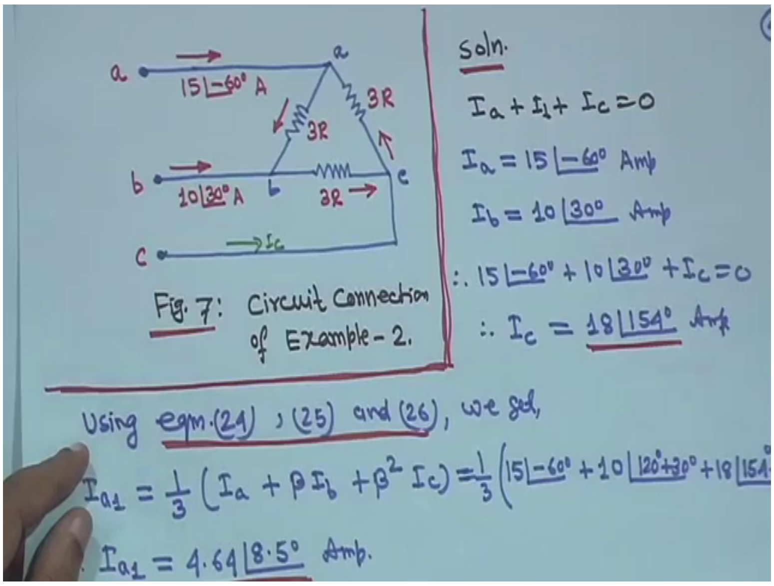

In phase a current is 15 angle minus 60 degree ampere, in phase b your 10 angle 30 degree ampere. So, current is c current in your here current here you can easily find it out I c because I a plus I b plus I c is equal to 0. So, first what you will do come to here I a plus I b plus I c is equal to 0, I a is equal to given 15 angle minus 60 degree ampere, I b is given 10 angle 30 degree ampere therefore, 15 angle minus 60 plus 10 angle 30 plus I c is equal to 0 therefore, I c you will get 18 angle 154 degree ampere. So, 3 current 3 line currents you have got and they are unbalanced. Now using equation 24 25 and 26 that 24 actually I a 1 is equal to one third I a plus beta I b plus beta square I c. So, it is one third it is I a 15 angle minus 60, I b is equal to your 10 angle 30. So, it is multiplied by beta.

So, it is ten angle 120 degree plus 30 degree and plus 18 I c is angle 154 degree 154 plus 240 degree. So, if you simplify this you will get I a 1 is equal to 4.64 angle 8.5 degree ampere. Only thing is that these calculations you have to make correctly sometime I repeat that all this calculations actually while done by me.

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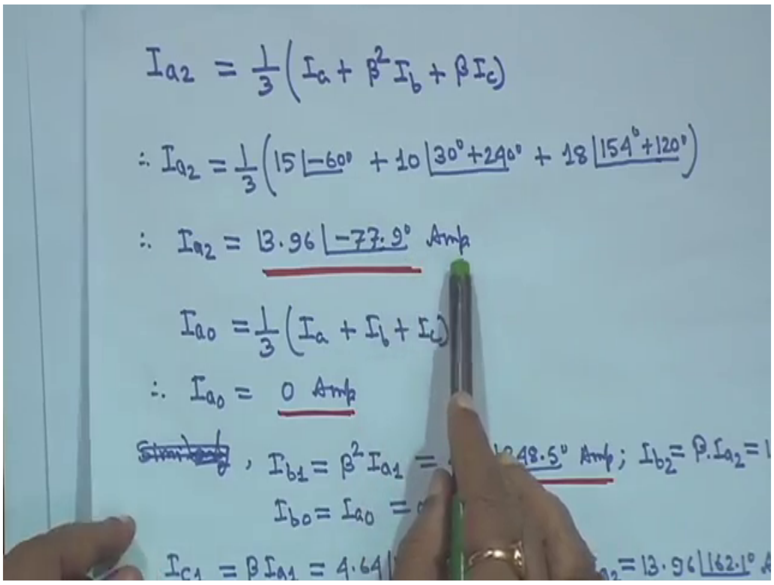

So, if there is any mistake in calculation other things just let me know. So, similarly I a 2 is equal to one third again that is from equation 25 this equation from equation 25, I a 2 is equal to one third I a plus beta square I b plus beta I c we substitute all this values that is I a 2 is equal to one third 15 angle, minus 60 degree plus 10 30 plus 240 degree plus 18 angle 154 degree plus 120 degree.

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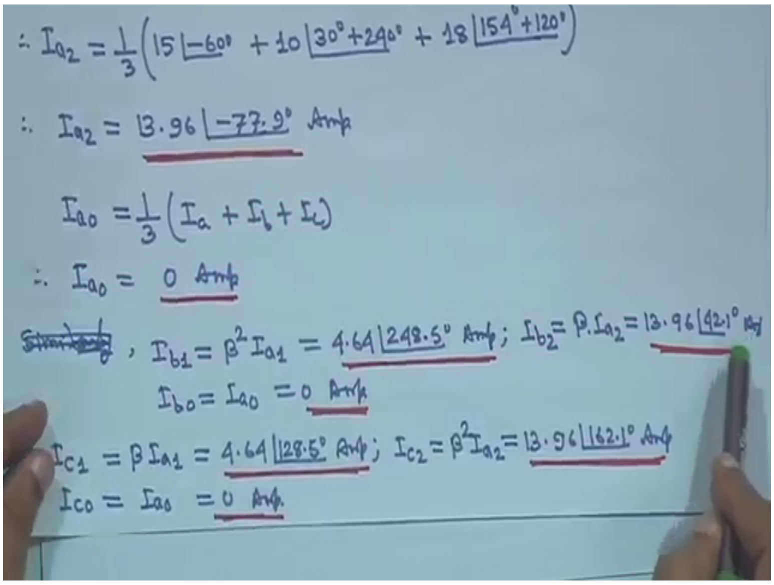

So, I a 2 will get 13.96 angle minus 77.9 degree ampere. Now I a 0 is equal to one third you know I a plus I b plus I c and this is and that is I that is already that condition is given because the delta connection it is I a plus I b plus I c is 0 therefore, it is I a 0 is equal to 0 ampere. Now go to the your this is I a 1, I a 2, I or I a 0 we got now go to I b 1, I b 2, I b 0, I c 1 I c we know that I b 1 is equal to beta square I a 1. So, we know this this will become 4.64 248.5 degree ampere. We know I b 2 is equal to beta I a 2 that is 13.96 angle 42.1 degree ampere, and I b 0 is equal to I a 0 is equal to 0 ampere. Similarly I c 1 you can get now I c 1 is equal to beta I a 1 you will get 4.64 angle 128.5 degree ampere. I c 2 will get beta square I 213.96 and this angle is 162.1 degree ampere and I c 0 is equal to I a 0 is equal to 0 ampere. So, will got I a 1, I a 2, I a 0 we got I b 1, I b 2, I b 0 we got I c 1, I c 2, I c 0. Now you have to find out something else that is that this your delta load you convert it to star now you have to convert this delta in to star.

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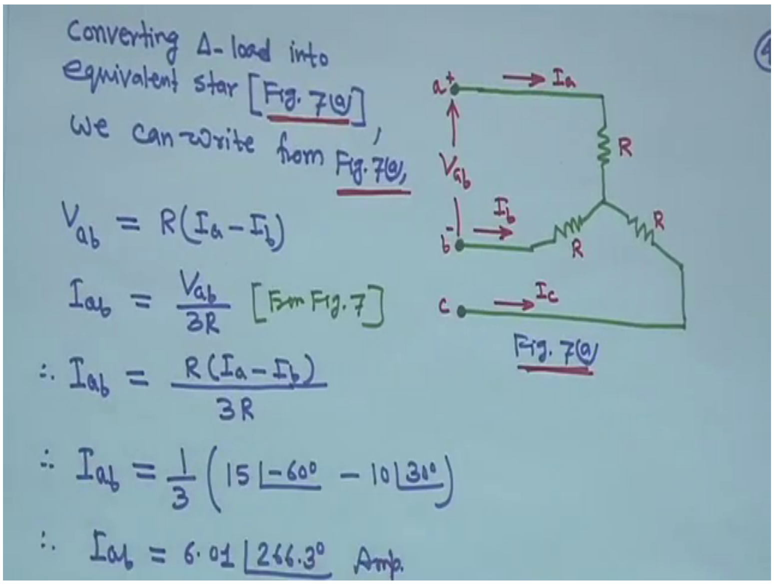

So; that means, if you convert to star it will become R R R because if it is delta. So, it is given 3 R 3 R 3 R. So, if you convert this star if it is 3 R in to 3 R, divided by 3 R plus 3 R plus 3 R. So, ultimately it will become R that is why this is R this is R and this is R and current here it taken as I a I b I c and voltage it is V a b right.

Similarly, V b c and V c here. So, in this case here your what you call in this case if you this V a b is difficult to you can make in this loop say KVL. So, it is your I a in to R minus I b in to R is equal to V a b; that means, V a b is equal to R I a minus I a b that is your I a b is equal to V a b up on 3 R right. So, and your and this and sorry V a b is equal to R in to I a minus now I a b is equal to from here I a b is equal to this current going a to b. So, this current is I a b. So, I a b is equal to from this figure it is equal to V a b up on your what you call 3 R, this that mean this is actually I am for your as it is your this thing it will help you in bracket I am writing actually it is from figure your 7 right it is from figure 7. So that means, I a b from this figure you can write that your V a b divided by 3 R so; that means, this V a b is equal to R in to I a minus I b therefore, you put V a b here that will be R in to I a minus I b divided by 3 r; that means, your R R will be cancel and I a b will be one third 15 angle minus 60 degree because I a is equal to 15 angle minus 60 degree and I b is equal to 10 angle 30 degree. So, minus 10 angle 30 degree. So, I a b you will get 6.01 angle 266.3 degree ampere, this is your I a b.

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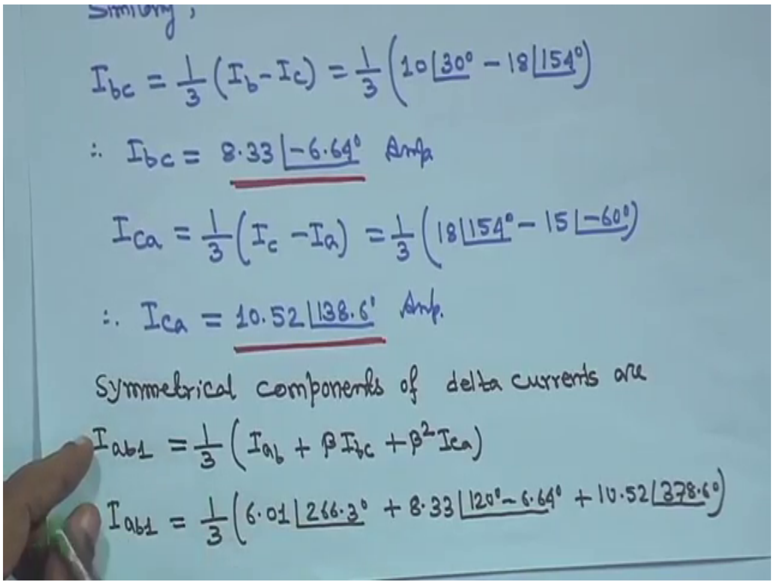

Similar way I mean similar way you can compute I b c and I c a. So, I b c also the same very easy to remember for this kind of thing only one third will be there. I b as per the data taken. So, I b c is equal to one third I b minus I c. So, one third 10 angle 30 minus I c is 18 angle 154 degree.

It is coming I b c is equal to 8.33 angle minus 6.64 degree ampere. Similarly I c a will be one third I c a is equal to one third I c minus I a is equal to one third angle 18, angle 154 degree minus 15 angle minus 60 degree. So, I c a will be 10.52 it will simplify angle 138.6 degree ampere. Now this is I a b, I b c, I c a we have got now go to the positive sequence, negative sequence and your zero sequence component current say for say I a b. So, same philosophy same formula. So, I a b 1 will write one third because we have got I a b, I b c, I c a we have got it. Now I a b 1 that is positive sequence component current of the line a b. So, that is I a b 1 is equal to one third I a b plus beta I b c plus beta square I c a. So, you substitute all these values. So, I a b is equal to one third I a b 6.01 angle 266.3 degree plus 8.33 your it is your I b c what that is 8.33 angle minus 6.64 degree, but beta. So, 120 degree minus 6.64 degree plus your beta square I c a. Beta square I c a actually I c is equal to 138.6 degree right and with that beta square means 240.

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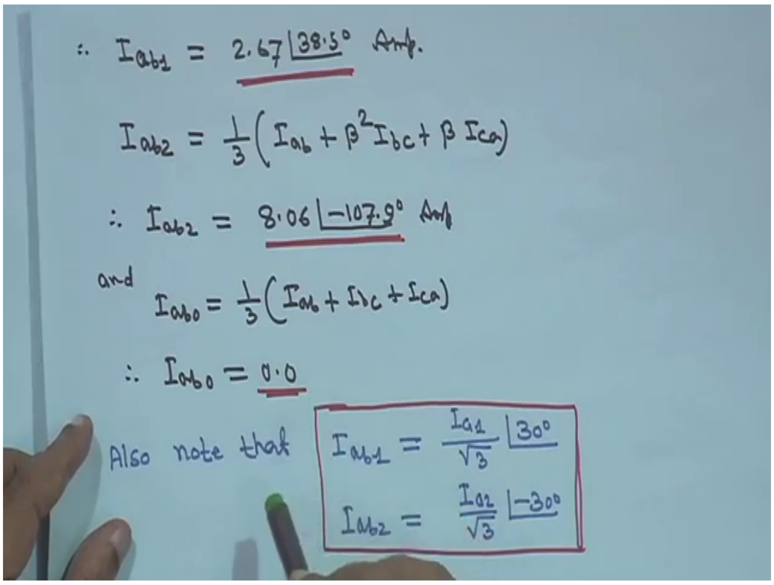

So, 10.5 angle 378.6 degree. So, if you simplify I a b 1 that will become your 2.67 angle 38.5 degree ampere. Similarly I a b 2 is equal to one third I a b plus beta square I b c plus beta I c a I you please do this one you substitute I a b, I b c, I c a and beta square and beta all this angles and please simplify you will get I a b 2 is equal to 8.06 angle minus 107.9 degree ampere.

And I a b 0 it will be one third I a b plus I b c plus I c a, I a b 0 will become 0 also note that just you can verify that I a b 1 actually which I a 1 by root 3 angle 30 degree. You know I a 1 you substitute here divide by root this thing root 3 you will see this is becoming actually a b 1 is equal to I a 1 root 3 30 degree. Similarly here also I a b 2 will become I a 2 by root 3 angle minus 30 degree actually this holds. So, this is I have just written in brackets. So, this is the; that means, that I a that your I a b 1 and your this is that positive sequence component of your phase current your this thing what you call phase a right. So, this relationship holds. So, this is that only thing is that you have to compute thing correctly and you have to remember certain things now slowly and slowly we will see something else.

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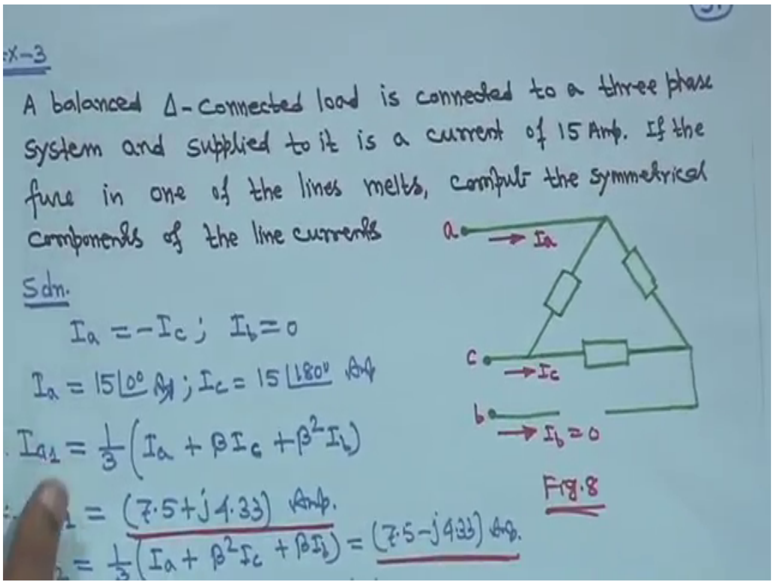

Now, another one is these are problem like problem type or at the same time you know the thing how things can be done. For example, you have a delta connected load right and 3 phase supply it is a 3 phase supply a b c, and it is a current of (Refer Time: 20:29) and it and supplying a current of 15 ampere right, but if the fuse in one of the lines melts actually it is a then compute the symmetrical components of the current. So, I mean one of the line that is suppose it is cut fuse melts; that means, gone.

That means I b will become 0. So, what will happen? So, in that case if this is 0, but current is given just mention 15 ampere. So, in that case suppose I a is equal to we take 15 angle 0 that ampere reference one then I b is 0 that means, this I a and this I c also because there is no current here; that means, this is the path for I c; that means, your I c that I a is equal to then minus I c. So, in this case I b is equal to 0; that means, I c is minus I c means I c is equal to 15 angle 180 degree ampere. So, we know that we know that relationship I a 1 is equal to one third, I a plus beta I c plus beta square I b. So, you substitute all this values I a I b I c is any way 0 right and beta that angle. So, you will get I a 1 is equal to 7.5 plus j 4.33 ampere. Now similarly I a 2 if you calculate it is one third I a plus beta square I c plus beta I b, again I a I b I c you substitute and beta is there accordingly you make the angle put this angle. So, it will be 7.5 minus j 4.33 ampere and I a 0 will become one third, I a plus I b plus I c that is 0; that means, I a is equal to for cross cheek I a is equal to I a 1 plus I a 2 plus I a 0, I a 0 is 0; that means, I a 1, I a is equal to I a 1 plus I a 2. So, I a 1 is equal to this much plus this much. So, minus j 4.33

plus j 4.3 will be cancel ultimately it will become 15 angle 0. So, for a cross check this is a simple problem, but it is a good problem.

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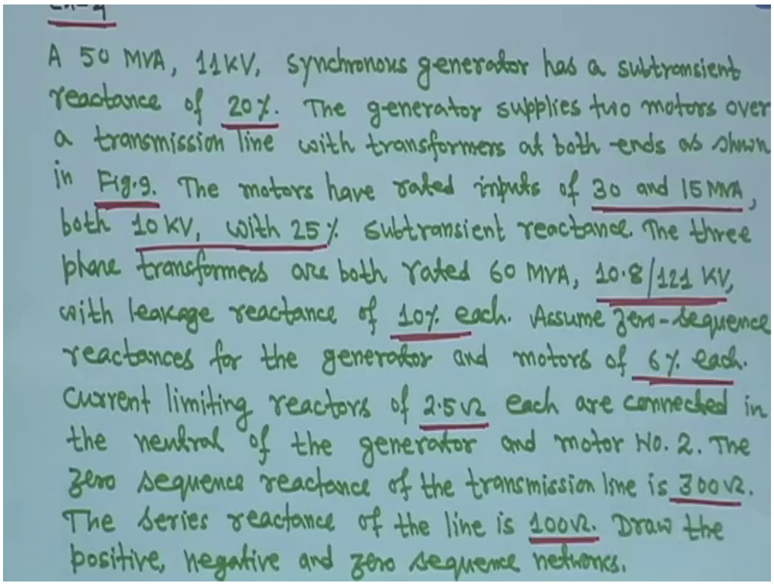

Next one whatever will show that we have studied that altogether per unit system that this problem itself is a whole page, but not that difficult one, but zero sequence thing that whole page problem is like this then I will explain the question is that that for per unit system that you that we have taken a particular base and accordingly all base of your base voltages of the line as well as the generator or transformer whatever it is accordingly it has been change. So, those things we have studied in that your per unit system, and here this for this problem we need those formulas right first we have to convert it to that old base impedance and then you the new base you convert it to per unit. So, this example directly I will write it because per unit system component as per as per as I remember everything has been given, and many problems have been solved. So, this one before giving the diagram is a very big problem, but just read carefully that diagram will be given. So, things will be easier say 50 MVA 11 k V synchronous generator I showed the diagram has a sub transient reactance of 20 percent. The generator supplies two motors over a transmission line with transformers at both ends as shown in figure 9. I will come to that the motors have rated inputs of 30 and 15 MVA both 10 KV with 25 percent subtransient reactance. The 3 phase transformers are both rated 60 MVA 10.8 slash 121 KV.

With leakage reactance of 10 percent each remains the per unit. Assume zero sequence reactances for the generator and motors of 6 percent each, current limiting reactors of 2.5 ohm each are connected in the neutral of the generator and motor number two there are two motors. So, it is motor number two the zero sequence reactance of both transmission line is 300 ohm. The series reactance of the line is 100 ohm. So, draw the positive negative and zero sequence network positive also get all the parameters positive and negative sequence is not at all a problem is that zero sequence right I mean you have to make it very carefully.

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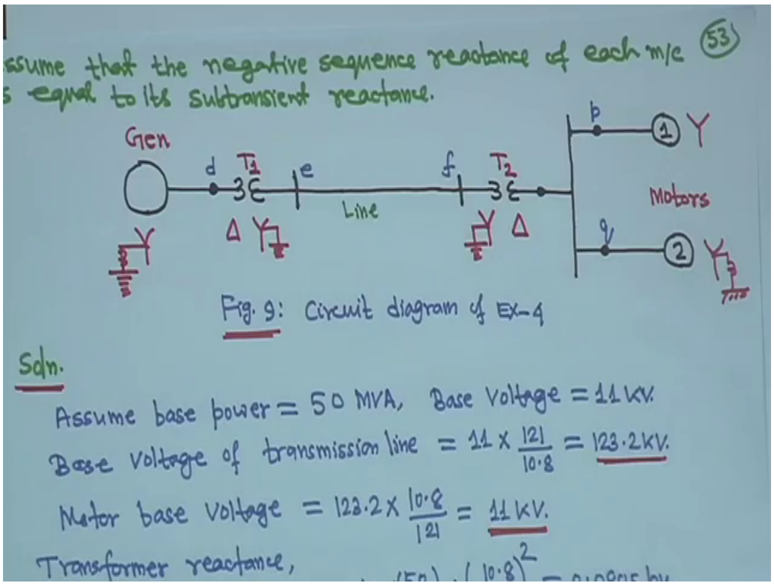

So, this is actually some assumption that assume that the negative sequence reactance of each machine is equal to its sub transient reactance that is also given. So, this is the diagram you have a generator, generator actually grounded star connecter and grounded this is transformer T 1 this is your delta star transformer star side is grounded this is transformer T 2 star delta here also star side is grounded here also your motor one this is actually motors this is motor one here is star, but no ground and this is motor two this two is written in the bracket in the circle inside the circle, here also I have written one and here it is this motor is grounded right. So, now, when you will do so, now, you will solve such kind of problem for such that you will not make any mistake or anything when you will calculate, you mark some point for example, this is d.

You can put a bus bar like a thing also no problem then you can make this is e and f this is the line actually, this is actually your line it is transmission line and this is this f here also we can mark by a mark by point I have d e your p q and this point I have not marked it, and if I marked I will show you later in the diagram right and this point is p and q this way first you mark it every place you mark it right then you will find things will be perhaps it will be easier for you. So, we have to draw positive negative and zero sequence diagram, once you get the parameters positive and negative is not at all a problem. So, only thing is zero sequence you have to understand little bit. So, assume base power is equal to 50 MVA and base voltage 11 k v, because this generator actually given 50 MVA 11 k v. So, what you are doing is that we are actually assuming base power 50 MVA and base voltage 11 k V right. So, now, base voltage of transmission line then it will be 11 into 121 by 10.8 k V because this transformer this transformer side actually it is your 10.8 121 k V. So, that is why that base will change for the line side it will be 11 in to 121 10.8 because transformer actually this is 10 your 10.8 by 121 k V. So, it is 11 in to 121, 121 by 10.8. So, that is line your base voltage 123.2 k V. Now motor base voltage then you have to go to this is the line right this transformer again ten point your 10.8 by your this thing 121. So, again it will be 123.2 in to 10.8 by 121. So, motor side again it will become 11 k V this all we have seen for per unit thing.

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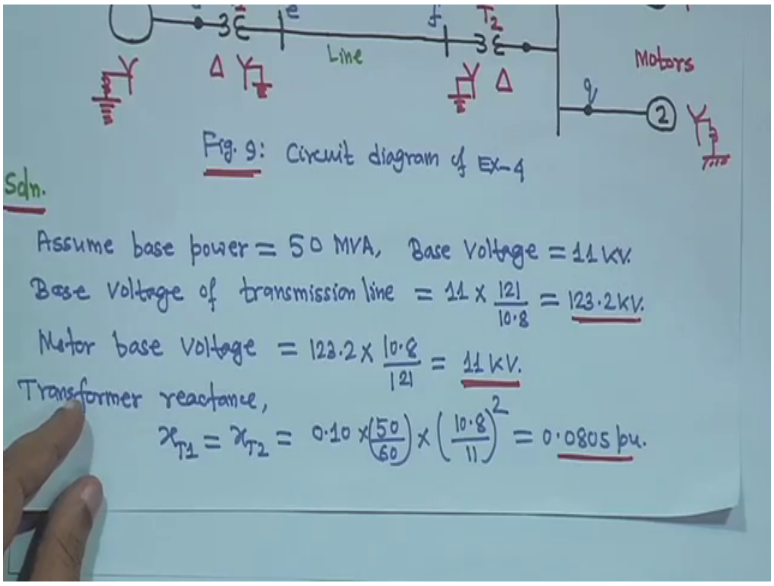

I hope you will understand this. So, transformer reactance, both are given x T 1 x 2 this is given 10 percent right, now what you have to do is that same that per unit system I have not written which equation number it is, but idea is that first this is your what you call that transformer is 60 MVA that your both the transformer rating is given let me see where these data are given that your here I have written no here it is given that the motors are rated at this and transformers where your the 3 phase transformers both 60 MVA right and rated at 10.8 121 k V so; that means, this transformer reactance this parallel rating impedance is given 0.1 right.

So, first is that transformer base the base impedance is 60 upon 10 point your what you call that 10.8 square by 60. So, with that if you multiply this will be the origin that is 10.8 square by 60 is there with that you multiply that is its say only value in its own ways. Now we have taken 50 MVA base and 11 k V. So, you have to divide by that 11 square by 50. So, that is why it is coming 0.1 in to 50 upon 60 in to 10.8 upon 11 whole square; that means, 0.0805 per unit this old your old base and new base of MVA as well as voltages; that means, per unit system details are given. So, that the details are given. So, far from there only I am writing right. So, this way x T 1 x T 2 will get 0.0805 per unit.

Thank you even welcome.