Computer Aided Power System Analysis

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Lecture - 50
Fault Analysis (Cont)

Hello friends. So we will come to this lecture on Computer Aided Power System Analysis. In the last lecture we have started the discussion of formation of Y bus of an unbalanced power network and in this lecture also we would be continuing with this topic.

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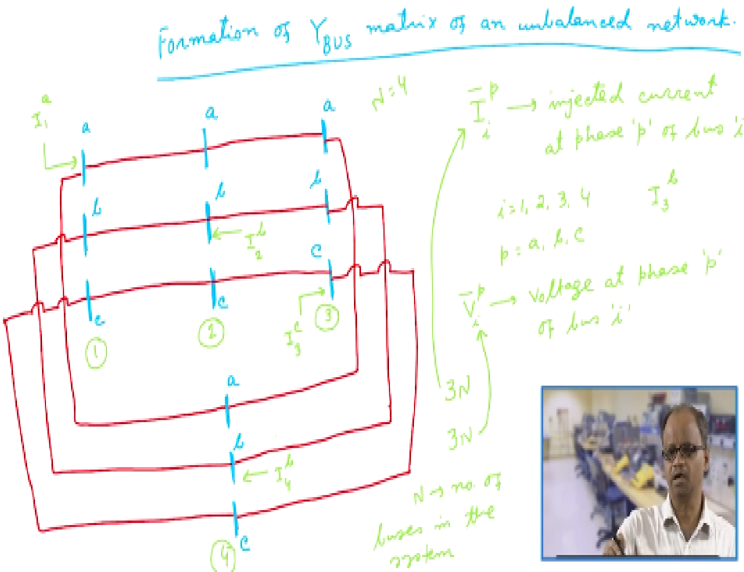

So what we have been discussing is that we have shown a very simple 4 bus network, bus 1, bus 2, bus 3 and bus 4 with this connection and we also noticed that in contrast to the single phase case in the case of a three phase unbalanced system there would be actually 3 N number of injected current as well as 3 N number of voltages. So therefore we should say that there is actually 3 N number of injected current.

So the total number of injected current is 3 N and total number of voltage is also 3 N and so what I will have. For example, here I will say that it is I1a similarly here I1b, I1c and similarly here for example it is I2b similarly here let us say it is I3c and similarly for example here I4b and so on and so forth. So now when we are talking about Y bus matrix so we actually find out a matrix which would be relating this 3 N injected currents with 3 N voltages.

So in this case we have to find out the matrix which would be relating this 12 injected current with this 12 voltages. Now to do that we need to now essentially model or rather essentially represent a transmission line.

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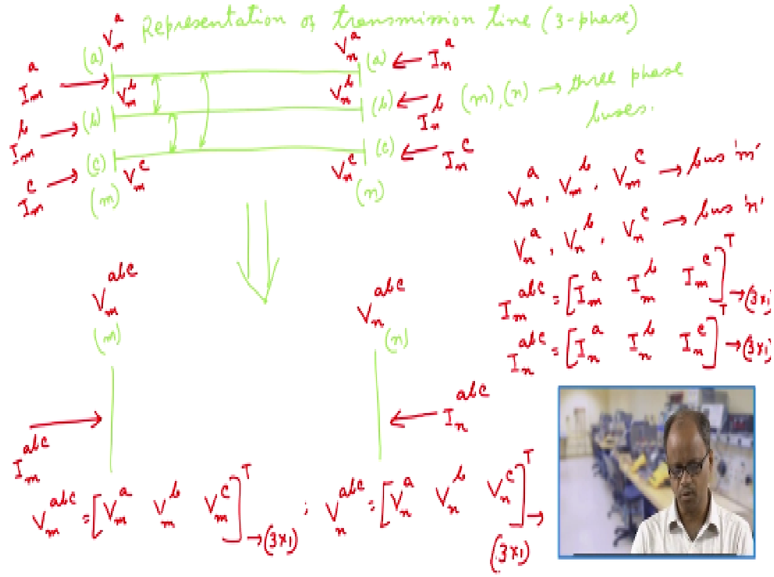

So now we have to now do something like representation of transmission line. So representation of transmission line representation of transmission line. We are actually talking about three phase. Now suppose now here for this representation of a transmission line we do take some particular notation. Now suppose I do have a bus m and bus n this is bus n. Please note that this is bus m and n are 3 phase buses bus m and n are 3 phase buses right.

So let us say bus m and n bus m bus n so this is phase a this is phase a this is phase b this is phase c and this is also phase a this is also phase this is also phase c and in between there is a line in between there is a 3 phase line. So this is phase a, phase b, phase c. Now in the case of single phase circuit what we have represented by a single phase circuit that it has got some series impendence as well as some shunt half line charging susceptance.

But in the case of 3 phase transmission line what we have apart from the impedance of individual phase that is we will essentially (()) (04:24) series impedance corresponding to this line at this individual phase we will also have some other impendence corresponding to this individual phase we will also have some other impedance corresponding to this particular individual phase as well as we will also have their corresponding shunt charging susceptance corresponding to each and every individual phase.

But apart from that we will also have mutual impedances between phase a and b. We will also have mutual impedances between phase b and c and we will also have mutual impedances between phase c and a. So therefore apart from the self impedances of individual phases we will also have mutual impedances between any 2 phases. Same thing is also true for the shunt half line charging susceptance.

So then therefore we need to represent this all this individual impedances as well as this mutual impedances as well as impedances along with the individual phase half line charging susceptance as well as the mutual half line charging susceptance. So to do that what is done is that we do represent let us say bus m like a big bus I mean big line and then bus m bus n. So this is the bus (()) (06:07).

I mean this representation all this phases a, b and c have been actually kind of marched or (()) (06:16). Now here of course we do have Ima of course and then here also we do have Imb here also we do have Imc these are the 3 injected currents here also we have Ina here also we do have Inb and here also we do have Inc right. So these are the 3 injected currents at the individual phases of bus m and n.

Similarly, I have this voltages Vman, Vmb, Vmc so these are the phase voltages of bus m and similarly I do have Vna, Vnb, Vnc so this is the bus m voltages this is corresponding to m this is corresponding to bus n. Now for the purpose of representation or rather for the purpose of a concise as well convenient representation we do represent these 3 individual currents as a vector saying that it is Imabc so this is a vector.

Similarly, we also represent this 3 currents as Inabc. So what is Imabc so Imabc is essentially Ima, Imb, Imc transpose. So this is essentially 3 cross 1 vector right. Please note that all this currents are complex quantities I mean just to avoid unnecessary writing we are not putting the bars and etcetera so this is a 3 cross 1 current. Similarly, Inabc is also represented as a vector Inb, Inc this is also T 3 cross 1.

And this now here also we do have voltages Vma this voltage would be Vmb this voltage is Vmc. Similarly, this voltage will have Vna this voltage will have Vnb and this voltage will have Vnc and these voltages we do denote as Vmabc and this voltage we also denote this 3 phases voltage we do denote as mathematically as a 3 cross 1 vector. So then therefore we

Vmabc is actually we write as this and the similar is Vma, Vmb, Vmc transpose.

So this is also 3 cross 1 vector and Vnabc is also Vna, Vnb, Vnc transpose so this is also a 3 cross 1 vector. So then what we have done we have taken a 3 phase line and we are representing the injected current and the voltages at this 2 buses in a concise manner. So far these are nothing but the representation of the injected currents and the voltages at the buses, but what about the representation of the line.

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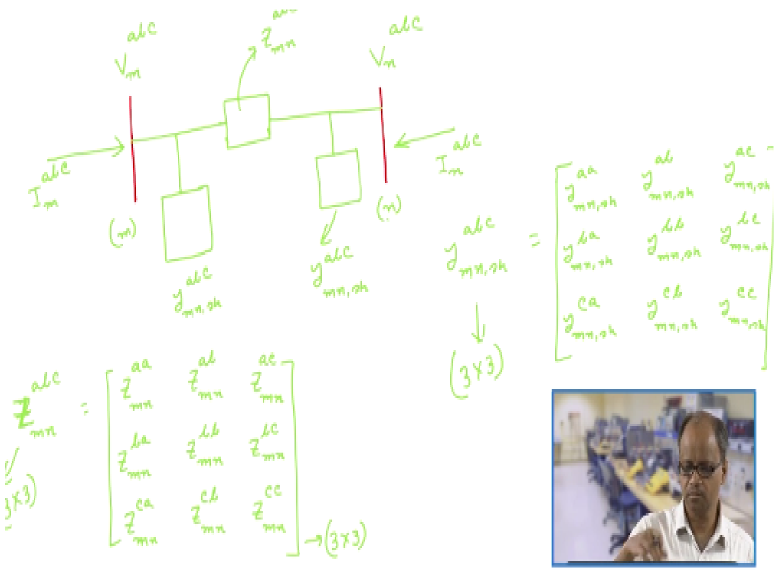

So for the representation of the lines what we do simply write like this. So what we have got is essentially so this voltage is Vmabc this voltage is Vnabc. Current is Imabc this current Inabc this is bus n and this is bus m and the line is represented by a matrix. It is a 3 cross 3 matrix and the half line charging susceptances are also represented by a 3 cross 3 matrix this is also represented by as 3 cross 3 matrix.

Now this matrix we call as Zmnabc and we call this matrix as ymn shunt abc please note that this is half line and this also we call ymn shunt abc right. This particular shunt sh is included to note that this is the shunt and this is not the inverse of this. Now what is Zmnabc now Zmnabc is actually a 3 cross 3 matrix this is big Zmnabc this is big Z and this is a 3 cross 3 matrix.

So this we write as Zmnaa this as Zmnab this is Zmnac and similarly this is Zmnba, Zmnbb, Zmnbc and lastly Zmnca, Zmncb and Zmncc. So now please note that this is a 3 cross 3 matrix and these quantities are individual impedances. So this quantities are individual impedances all this are complex, but we are not including this we are not putting bar to (()) (13:50).

Similarly, ymn shunt similarly ymn shunt abc also would be denoted as some quantity. So we would write it as ymn shunt aa, ymn shunt ab and this is ymn shunt ac then we have ymn shunt ba, ymn shunt bb, ymn shunt bc and we have similarly ymn shunt ca, ymn shunt cb and ymn shunt cc. So this is also a 3 cross 3 matrix this is also a 3 cross 3 matrix. So for each and every line we will have this kind of representation right.

So now in our case now in our small example so now with this particular representation of the lines now how do I represent so our system that same small system.

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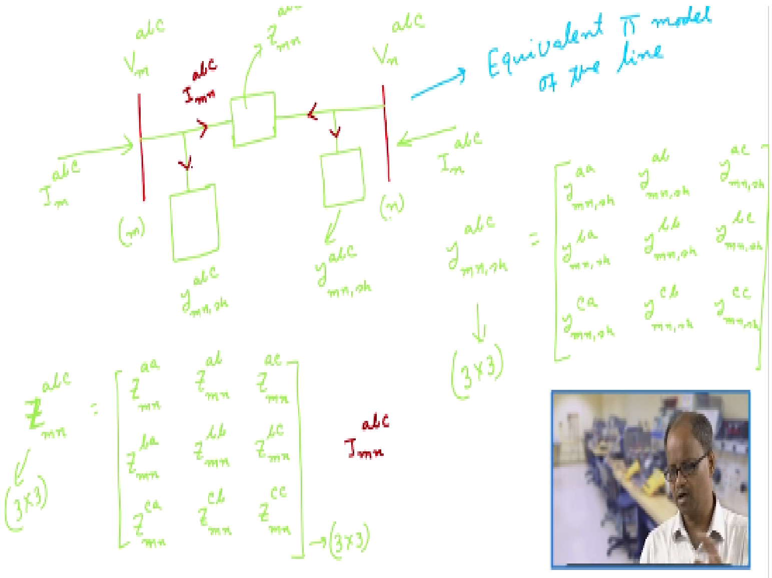

So what we have we have so now our small system is something like this bus 1, bus 2 writing it little broader bus 3 and we have a bus 4. So bus 1, bus 2, bus 3, bus 4. So we have this is bus 1, this is bus 2, this is bus 3, this is bus 4. Bus 1 has got current I1abc and we have already defined I1abc, bus 2 has an injected current I2abc, bus 3 also have an injected current I3abc bus 4 also have an injected current I4abc right.

Bus 1 has got a voltage vector V1abc this has got a voltage vector V2abc this has got a voltage vector V3abc and this has got a voltage vector V4abac. What about the lines? Lines are so we just note it like this. And then from and we had our system like this. So from 3 to 4 there is a connection, from 1 to 4 also there is a connection. So from 3 to 4 where there is one connection.

So we write like this so this was the shunt this is the shunt and from this also we have so essentially. Now if we look at this now this is essentially as equivalent this is essentially an equivalent pi model of the line. This is essentially an equivalent pi model of the line. You may be wondering that from where we will get this matrix. Well depending upon the configuration of this line that is what is basically the distance between individual phases.

And what is the tower height and etcetera, etcetera right given all this practical data right then this particular matrices. This matrix as well as this matrix can be easily calculated, but unfortunately that is essentially the out of scope of this course. So then therefore we are not calculating this, but as they can be calculate easily depending upon the physical data. So then we assume that this 2 matrices are available for each and every line.

Now what are this quantity now what are this matrices now we need to represent.

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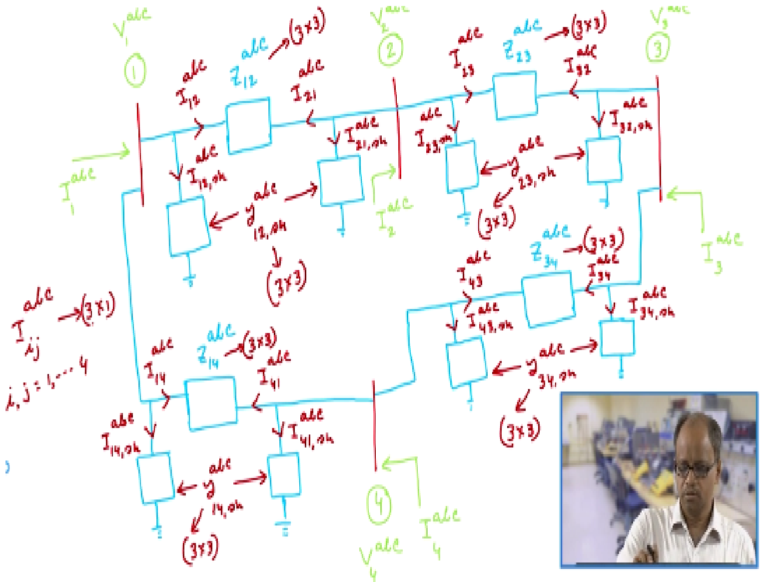

So this is this is essentially this is essentially a Z12abc and this Z23abc this would be Z14abc and this definition so we have already given and this is Z34abc. What about this matrices this matrices what would this is y12, shunt abc this is y please that, that all these are 3 cross 3 so this is 3 cross 3 this is also 3 cross 3 this is also 3 cross 3. This one is called y23, shunt abc so this matrices. Again this is also a 3 cross 3 matrix.

Similarly, this is also 3 cross 3 matrix and this is y14, shunt abc this is also 3 cross 3 matrix. We are assuming that each and every line has all this 3 phases. Theoretically some line can have 2 phase some line can also have one phase. In that case also this analysis can be carried out but so far we are essentially neglecting this because this will actually kind of little more complicate the analysis basic idea.

So this is also 3 cross 3 and this is y34, shunt abc so this is also 3 cross 3 matrix. So this is the equivalent circuit. So this is the equivalent circuit of the system. Now with this equivalent circuit so now what we have done we have simply so now we have got 4 bus and there are 4 lines first line, second line, third line and fourth line and now we are ready to analyze the system.

Now what happens now as I have in the case of a balanced system when we have discussed about the (()) (23:36) analysis. What we have done we have simply represented this injected current in terms of the voltages by applying KCL at each and every point. So here also we have to apply KCL at each and every point. So now so then therefore this now if I apply KCL at each and every point so now we can see that I1abc is nothing, but= this current+ this current and this current is essentially= this current+ this current.

So then therefore I1abc= this current+ this current+ this current right. Similarly, I2abc is essentially= this current+ this current+ this current+ this current because I2abc is actually this current+ this current and this current is this current+ this current is this+ this. So then I2abc is= this current+ this current and this and this. Now essentially this current is basically= this current+ this current. So then therefore I1abc= this + this+ this+ this.

What about I3abc? I3abc= this current+ this current and this is= this+ this and this current is= essentially this+ this. And what about I4abc? I4= this current+ this current and this current= this current+ this current and this current= this current+ this current. So now I1abc= this current+ this current+ this current+ this I2 is this+ this+ this I3 is this+ this+ this and I4 is this+ this+ this+ this. Please note that this I1abc is basically a 3 phase current.

So then therefore this current is also 3 phase current this current is also 3 phase current this current is also 3 phase current this is also 3 phase current right so all this essentially 3 phase current. Now if I note now how do I essentially denote this current let us say this current I12abc and this current I12, shunt abc. This current is I121abc and this current is also I21, shunt abc this current.

This current I can write as I23abc this current I can write as I23, shunt abc this current is I32abc this current is I32, shunt abc. This current is I34abc I34abc this current is I34, shunt abc this current is I43abc this current I43, shunt abc. This current I can say that this current I14abc this current is I14, shunt abc and this current I41abc and this current is I41 shunt abc. Now please note that all this currents are essentially 3 cross 1 vector.

So we note that all this current I i, j abc are all 3 cross 1 vector where I, j= 1 to 4 so all this currents are essentially 3 cross 1 vector. So then when you would be calculating this currents right we really cannot say that this- this* this we have to write something else. So now with this we are now ready to analyze this system. Now what would be our next step. Now here one thing we need to understand.

Now suppose here now to do this analysis let us go back a little bit and then try to understand. Now suppose I want to write down the expression of Imabc in terms of Vmabc and Vnabc so then what would be that. So I would say that this current= this current+ this current and I would say that this current= this current+ this current right. So essentially that is the same thing we have done here and how this current be written.

This current would be nothing Vmabc- Vnabc * inverse of Zmnabc. So then therefore this current if I say that Imnabc so then Imnabc can be written as now what would be the expression of (()) (29:59) so that is the question. So this issues that how to write down the expression of Imnabc and how to write down the expressions of this current and then add them together these issues would be discussing in the next lecture. Thank you.