Power System Dynamics, Control and Monitoring
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Lecture - 29
Transient stability (Contd.)

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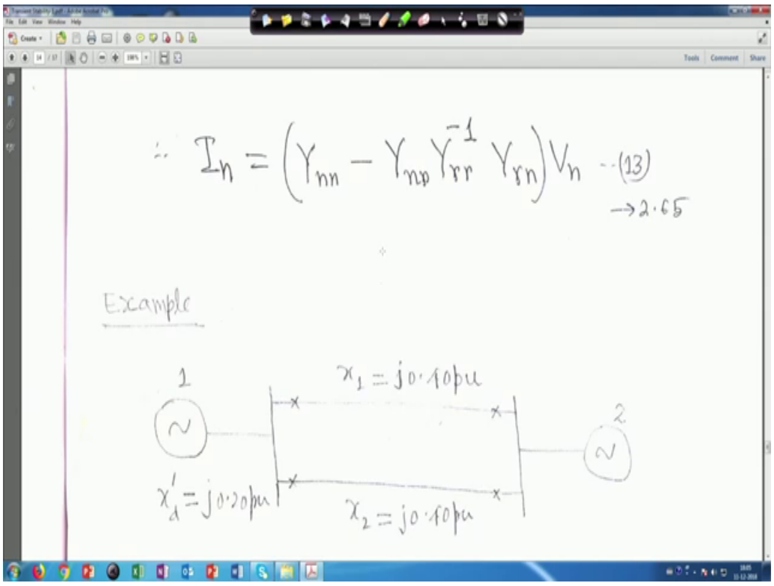

Ok. In the previous class we have finished this one that I n is equal to bracket Y n n minus Y n r into Y r r inverse into Y r n bracket close then multiplied by V n, this is equation-13 right. Now, we will take one example right. This example is your double circuit line right, the problem is something like this is double circuit line. For the generator one that x d dash is given right j 0.2 per unit. And is a double circuit line x 1 is given j 0.40 per unit, this is also x 2 j 0.40 unit. And of course this is another generator, but x d is not given right.

So, in this problem we have to find out prefault, then fault, and then post fault admittance matrix right. And fault has occurred actually three phase fault has occurred in that your middle of the line it is the middle of the line that we will see later right. So, we have to find out that your what you call that what you call that reduced your what you call that admittance matrix right.

So, in this case so in this case now prefault case. So, these are these are all reactances given in per unit. So, first you convert it to admittance, then reciprocal of it, so x d dash will be 1 upon j 0.20, so it is minus j 5 per unit right. And bus number here where generator here generator-1, and generator-2 is given, but from this problem we have to we have to create that your bus. So, this is this x d dash is given. So, this is as that is why the generator terminal bus is marked as one right.

And then this x d dash is given point j 0.20 that means, you have to take the reciprocal of this, because this will become admittance, so it is minus j 5 per unit. Similarly, for this one that j 0.40 and j 0.40, so 1 upon j 0.40, so minus j point 2.5 per unit similarly, here also it is written at the bottom just hold on right.

So, in this case here also it is minus j your 0.25 per 2.5 per unit right. And this is the here no x d dash is given, so this bus is marked as bus-2, and this is marked as a bus-3. And this is one, because x d dash was given. So, all these things are actually are in per unit, and these are all admittance values these are all admittance values right.

Now, when we when we calculate this thing, you know that when you found that your Y matrix for prefault you have three bus. So, in general that Y matrix per prefault will be capital Y 11 Y 12 Y 13 right, then Y 21 Y 22 Y 23 right, and then Y 31 capital Y 32 then capital Y 33, this was studied from the load flow studies. So, same thing is here right. So, first is you find out small y 1, and small when we represent this one first we find small y, and off diagonal we will take minus of the small y right.

So, in this case for in this in this case, suppose you are trying to find out all these your what you call small y values Y 11, then your Y 13 all sort of things. If you take Y 11 right Y 1 1, it is minus j 5 per unit for this one right. Similarly, if you take Y 13, it will be minus your what you call j 5 per unit, because no charges what you call no charging admittances are considered here or no load is given here right.

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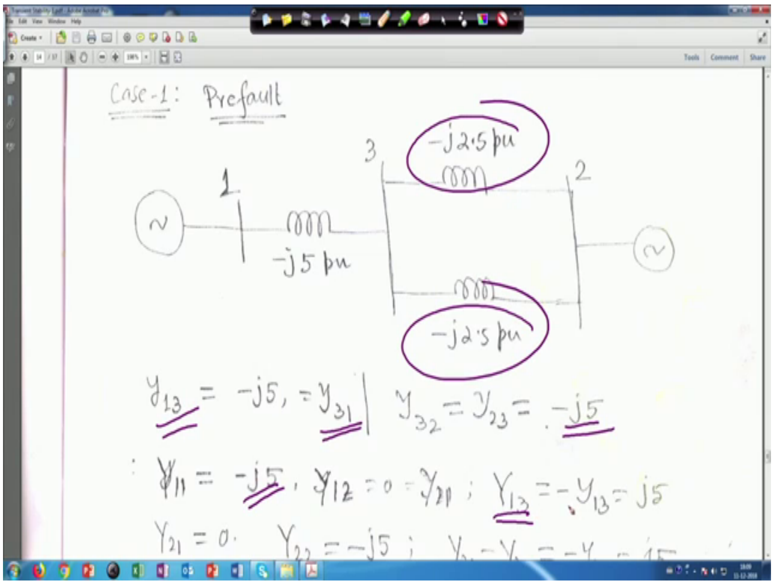

So, in this case what will happen that if you look into this that Y your Y 1 1 that is Y 1 3 right I told you, it is small y 1 3 is equal to minus j 5 is equal to y 3 1 right. Similarly, y 3 2 if you take y 3 2 is equal to y 2 3 minus j 5, because this is admittance, so minus j 2.5 this is also admittance minus j 2.5 they are in parallel, so it will added, because it is admittance right. So, y 3 2 is equal to y 2 3 that is minus j 2.5 minus j 2.5, so total is minus j 5 right.

Similarly, Y 1 1 it will be simply minus j 5 right. And Y 1 2 is equal to no connection between 1 and 1, so Y 1 2 0 is equal to Y 2 1 right. And similarly, your now capital Y 1 3 is basically minus of that small y, so minus y 1 3, so it is j 5 right. So, this you know from your load flow studies for forming bus admittance matrix right.

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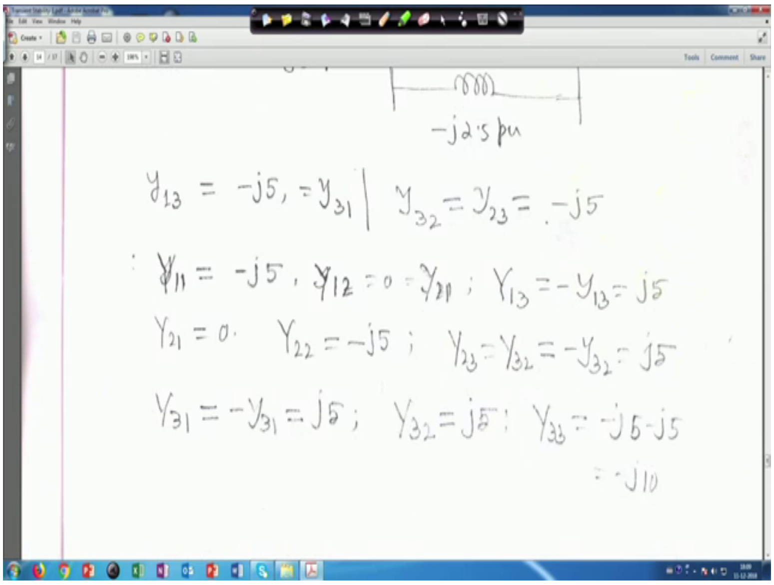

Similarly, capital Y 2 1 is 0, capital Y 2 2 will be minus j 5, similarly capital Y 2 3 is equal to capital Y 3 2 is equal to minus small y 3 2 is equal to j 5 right. And Y 3 1 is equal to capital Y 3 1 will be minus small y 3 1 is equal to j 5 right. And capital Y 3 2 will be j 5, and Y 3 3 will be minus j 5 minus j 5 is equal to minus j 10, it is actually minus j 10 right minus j 5 minus j 5 right.

So, if you if you look into look in the diagram that is Y 3 3 that is Y 3, so Y 3 3 will be this one your this one this minus your say I am just making it is minus j 5 right. And another thing is that these two are in parallel. So, their equivalent is minus j 5, so is equal to minus j 10 per unit right, so that means, this is your Y 3 3.

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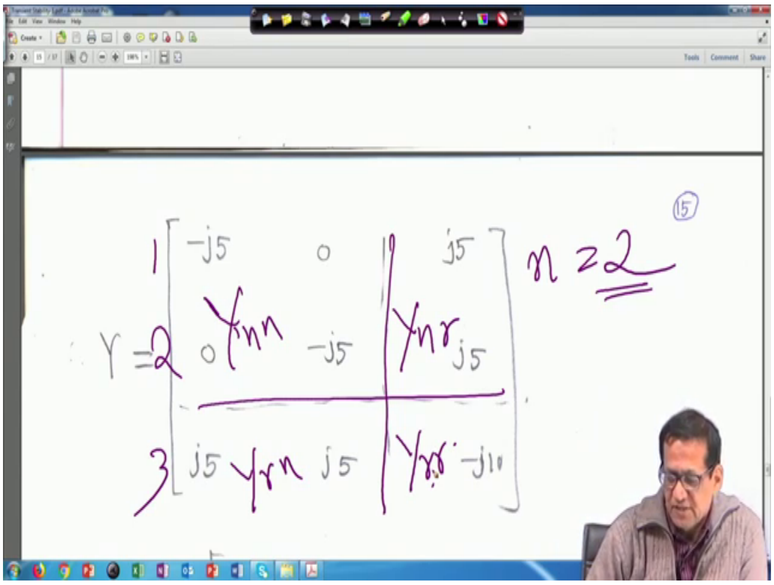

Therefore, prefault bus matrix is minus j 5 0 j 5 0 minus j 5 j 5 and j 5 j 5 minus j 0, but we have two machines. So, this is your three bus problems. So, this is 1, this is 2, this is 3 right you have three machines. But, we have to reduce the Y matrix in the n into n, because n is equal to here 2, because we have two machines that is why this is partition right. And this matrix we will call that is your Y n n that is Y n n means this is 2 2 your number of machines are two, so you represent Y n n. And this is your Y n r right, and this is Y r n, and this is Y r r right; this we have seen this one before right.

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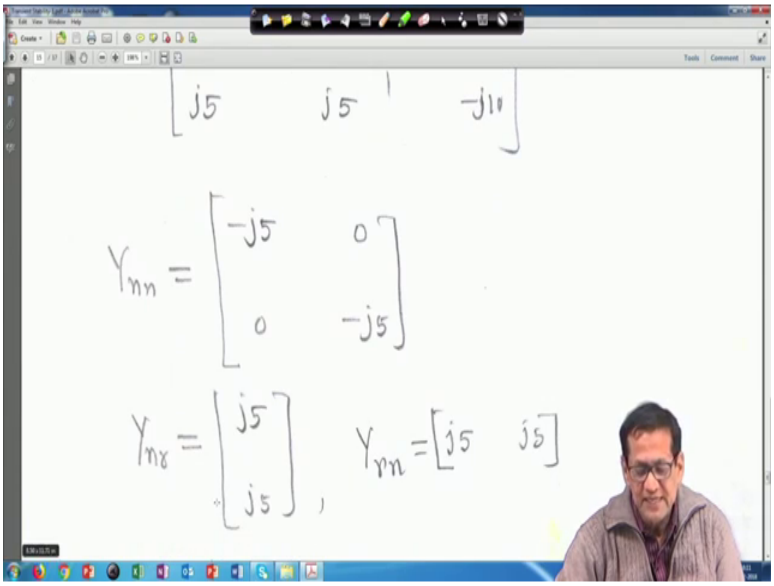

So, now you have to reduce it into 2 into 2 matrix. So, if we follow this using this so this is my Y n n I told you, and this is Y nr, and this is Y r n, and Y r r simply is a single element right, this is single element.

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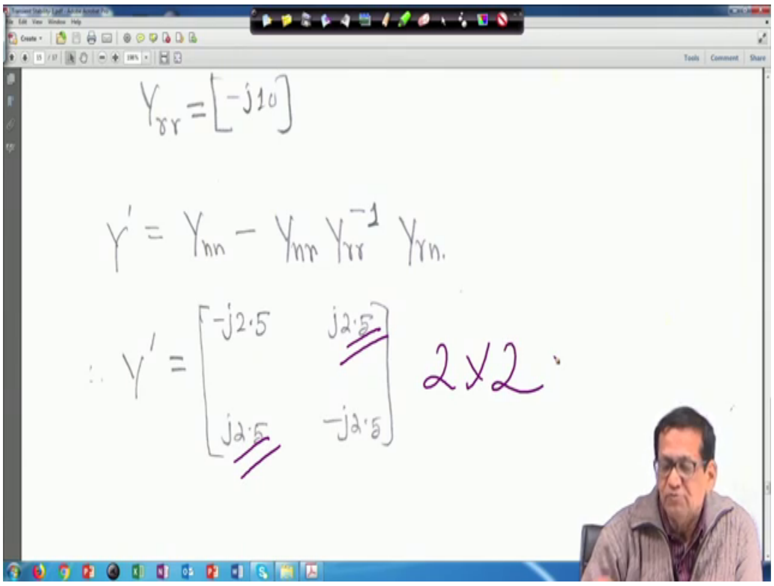

So, if we put all these things here right here, so Y dash will be what you call if you put and substitute, so Y dash will be minus j 2.5 j 2.5 j 2.5 minus j 2.5 right. So, this is actually this matrix is generally a symmetric matrix or three phase fault right, so because Y 1 2 is equal to Y 2 1. This is of course this is a simply 2 into 2 matrix right, so this is your prefault matrix.

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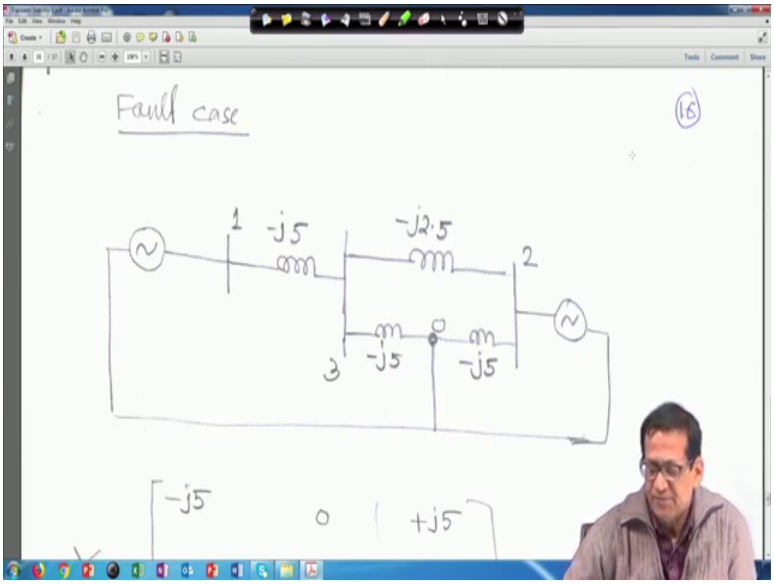

Now, next is next is fault case. Now, three phase fault has occurred in the middle of the line. So, if it is three phase fault has occurred in the middle of the line, you go one of I will go back to the diagram right. So, fault has occurred in the middle of the line say in the middle of the line the fault has occurred, better we will go to the original diagram right.

So, here we will come. So, fault has occurred in the middle of the line. If it is in the middle of the line, this side it will be your this reactance will be half, so this side it will be 0.2, and this side also it will be 0.2 right. So, when fault has occurred, when you replace with the admittance this will be minus j 5, and this side also will be minus j 5 per unit right, so that means just hold on, so that means your this diagram when fault has occurred.

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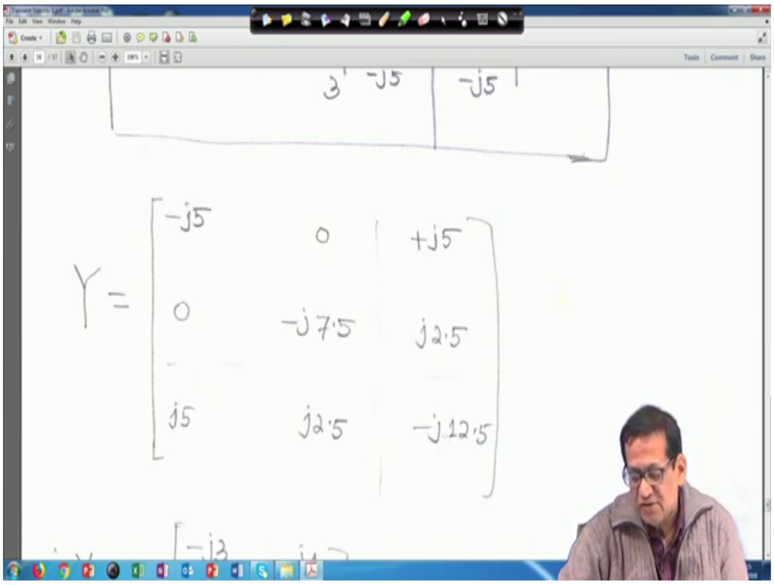

So, that is why this is actually your minus j 5 that is why this is minus j 5, this is and the three phase fault has occurred right. So, if you construct the Y matrix, it will be minus j 5, because this is minus j 5 Y 1 1, Y 1 2 is 0, and Y 1 3 that is your it is minus your of small y 1 3, so it will be plus j 5, this you know from your load flows studies.

So, similarly let me move little bit up. So, similarly Y 2 1 is 0, Y 2 1 no connection between 2 and 1, Y 2 1 0 and Y 2 2 Y 2 2 means that this one that this one will be added, and fault has occurred here, and then this one will added. So, it will be minus j 5, and minus j 2.5. So, it will be minus j 7.5 right.

And why your what you call 2 3 will be simply as your what you call that minus your class j 2.5 right, because your this thing your that minus of y small minus small y 2 3 right. So, if you look into that that 2 to 3, then 2 to 3 that means this is bus number-3 only this one will come, because fault has occurred. So, please do not consider this one right this side. This side should not be considered only 2 to 3. So, it is minus small y to 3, so that is why it is plus j 2.5 right.

Similarly, similarly when we will come Y 3 1 Y 3 1 it is simply minus j 5, because plus j 5 because it a skew symmetric matrix, then Y 3 2 same philosophy Y 2 3 is equal to Y 3 2, it will be j 2.5. And when it will Y 3 3 when it will be Y 3 3, then this one will be added, this one will be added, and this one will be added right.

So, in that case it will be combined as 12.5, because the minus j 5 minus j 5 and minus j 2.5, so minus j 12.5, so that is why that is why this is j 5 j 2.5 and minus j 12.5 right. And this is your what you call that simply this is during fault simply, we will partition simply we will partition right. And this is your Y n n, and this is your Y n r, this is your Y r n, and this is your Y r r it is single element.

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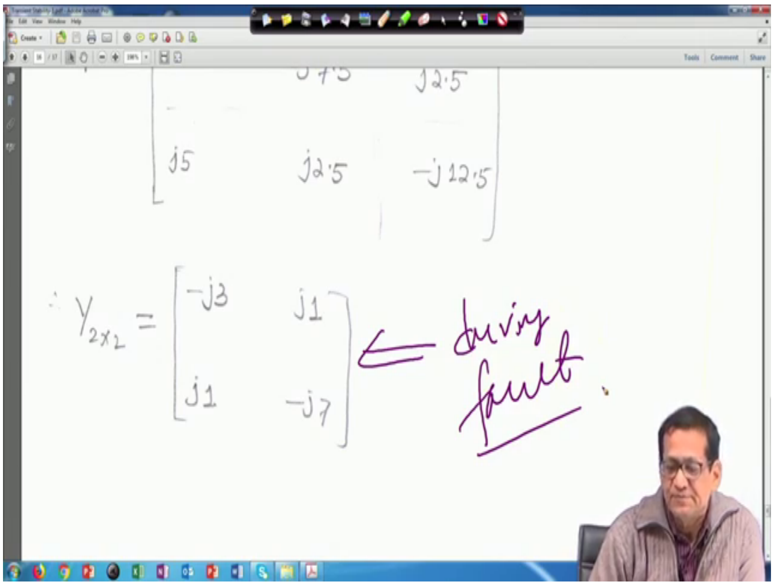

And follow the same procedure, same formula used and if you compute then if you if that matrix was matrix reduction right reduce matrix, then final answer will be your this much that Y 2 into 2 matrix will be minus j 3 j 1 j 1 minus j 7. This is also symmetric matrix, because Y 1 2 is equal to Y 2 1 right. So, this matrix this matrix is that is your during fault right this is during fault right.

So, next one is that your post fault. Post fault means, that this line when fault is cleared right, we will go back to we will go back to the diagram that when fault is cleared right, suppose this line it is actually removed; now it has become a single circuit line. So, in that case this one and this one will be there but this is removed right, during when fault is cleared, so that means, we will go back to this and in post fault condition.

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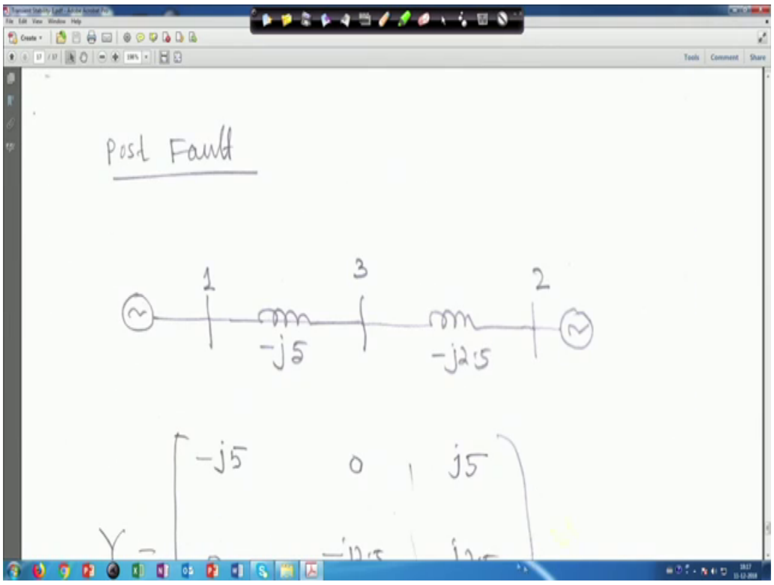

So, this is post fault, so that line is not there.

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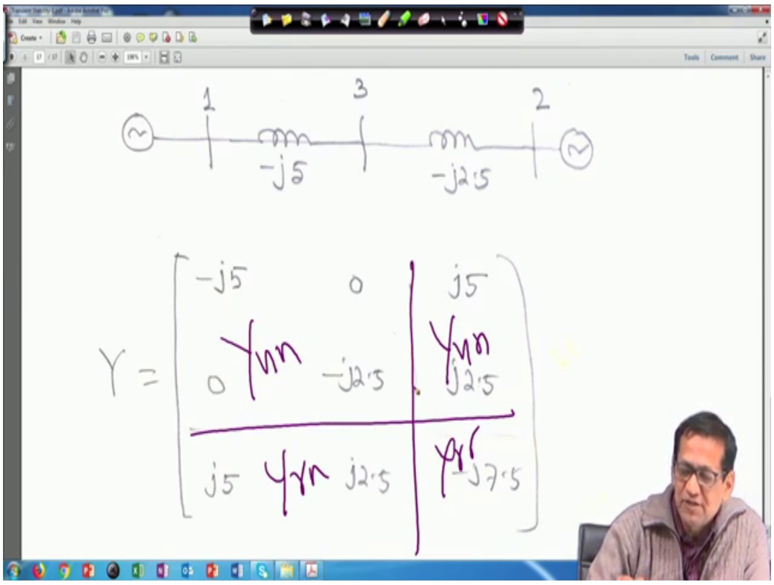

So, 1, 3 and 1, 2, 3, and it is easily you can compute the looking at this network, simply you can compute that your bus admittance matrix right. And your and again you will partition, because it is a 2 into 2 right it is a bus. And so this is your Y n n that is Y 2 into 2, this is Y n r, this is Y r n and this is Y r r right. And for following the same equation, you just go for matrix reduction.

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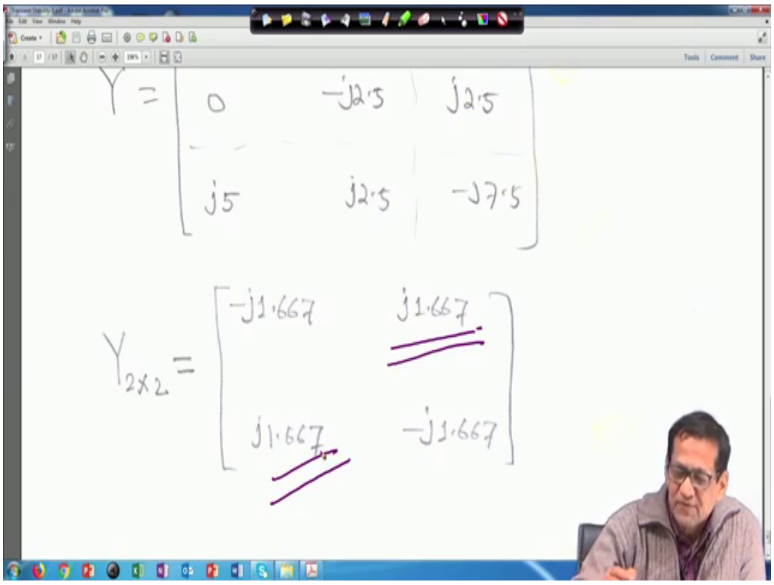

So, if you do so if you do so, it will be your what you call this will be the answer right. So, I have not only one step of first one, the prefault case I showed the calculation, but this one you can easily do it, but this will be a symmetric matrix. If you do not get symmetric matrix, then somewhere might have your what you call you might have done wrong calculations right, generally it is a symmetric matrix. So, we will go to another example just hold on.

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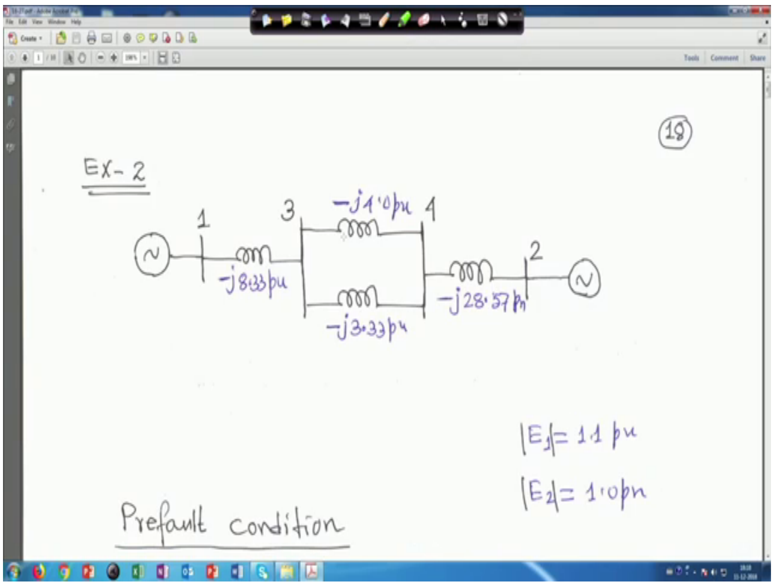

So, we will take another example. So, in this case these example these example that you are two generators are there two generators are there, but this side also all these x d dash all these things that it has this these are all given in admittance. I mean all these parameters that x d 1, dash x d 2 dash line parameters all have been converted to your admittances. So, these are these are all these values, these value, these value, these value, and these value. They are actually admittances right, so this is given. And another thing is given that your magnitude of E 1 voltage E 1 for this bus that your 1.1 per unit and magnitude of E 2 is given 1.0 per unit right, and this is E 1, this is E 2.

And then that prefault condition if you just form that your Y matrix right, if you form the Y matrix, so you have 4 bus 1, 2, 3, 4 four bus right. And this voltage E 1, E 2, it is the generator terminal voltage bind the transient reactance, but this is this we have converted to admittance the admittance, but these two are actually transient reactance, you have converted to admittance. And this voltage E 1, and this voltage E 2, basically this is the voltage magnitude right that is bind your transient reactance. So, this is your prefault condition Y matrix will just looking at this, you can easily make it right. So, this is my prefault condition.

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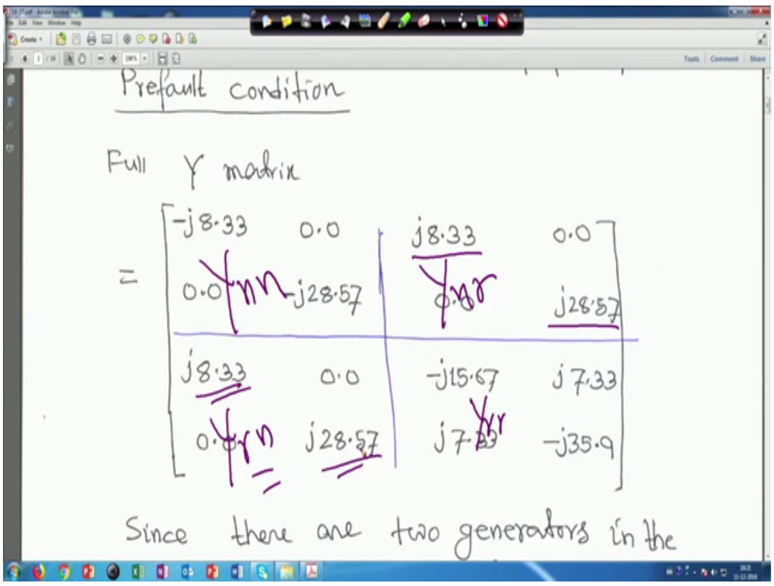

That is the matrix order will be 4 into 4, because we have 4-bus system, finally we have to reduce it to 2 into 2. And we have to find out the power delivered prefault and post fault, during fault and post fault conditions that is why these two voltage magnitudes are given say right. So, looking at this looking at this you can easily call these are all admittances right. Looking at this you can easily your what you call you can construct the Y matrix. So, Y matrix actually it is full Y matrix it is prefault condition, this is 4 into 4 matrix right. So, easily you can make it or small y you can calculate, small y 1 1, y 1 2, y 1 3 like this up to your y 4 1, y 4 2, y 4 3, y 4 4 small one. And capital one is equal to the sum of our small one and off diagonal will be minus of small one right. So, this way you can construct the full matrix.

After this we partitioned it, we have partitioned it right. And this is your in this case for this example this is your Y n n, now it is Y n r, it is 2 into 2 matrix. So, all are 2 into 2 matrix, this is Y r n also 2 into 2 matrix right. And this is your Y r r it is also 2 into 2 matrix right. And if you if you look into that, these two matrix are same j 8.33, j two eight 28.57, this is also j 8.33, and j 28.57 right. So, using this same formula right that your bus reduction same formula. So, since there are two generators in the system, the reduced matrix will be of order of 2 into 2 right.

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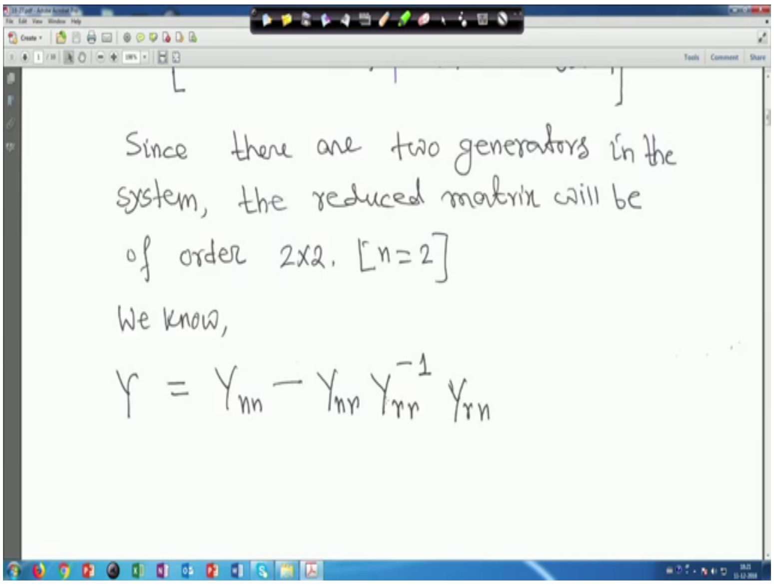

So, we know this thing that Y is equal to Y n n minus Y n r, then Y r r inverse into Y r n this you know. So, we will substitute all I told you that Y n n, Y n r, Y r n, Y r r.

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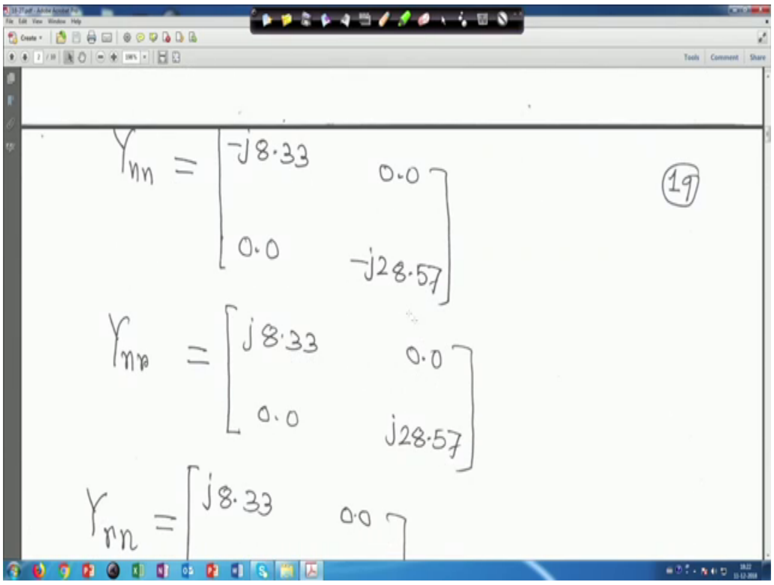

If you substitute all, so Y n n I told you this is Y n n, this is Y r r right and this is Y r n.

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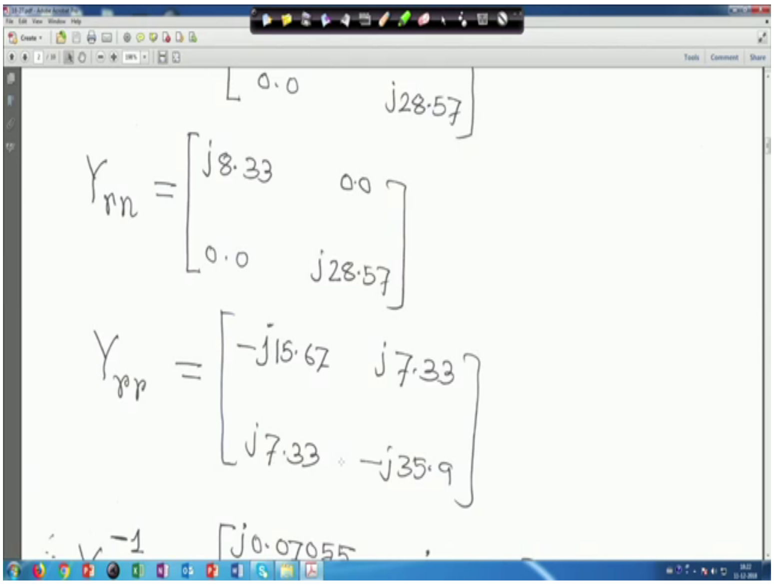

And this is Y r r right.

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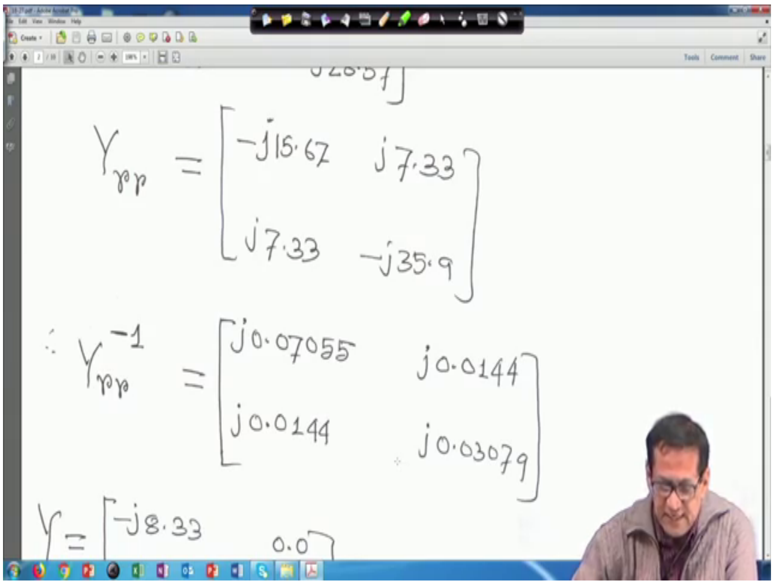

And if this is Y r r, if you invert this matrix, if you invert this matrix then it will be like this right. So, it is a 2 into 2 matrix. You can easily invert it. You take j common and just simply you invert that one that is all, and multiplied by j again right.

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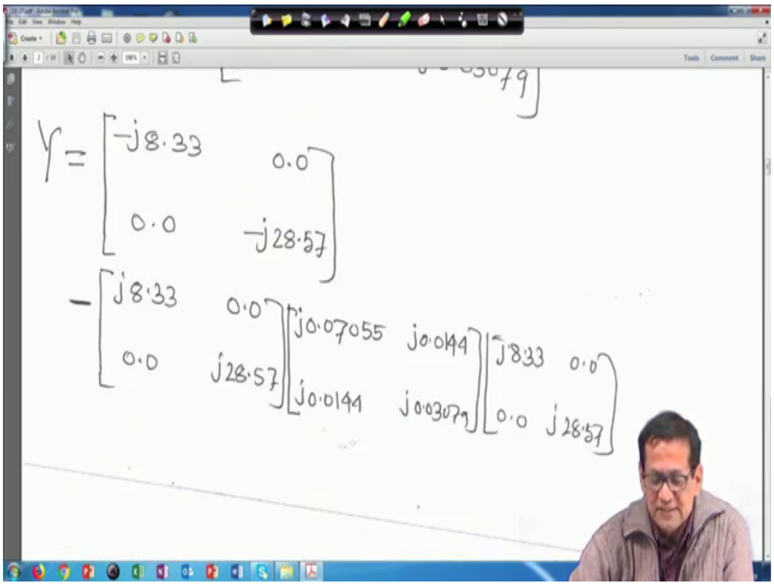

So, once you have done this right, then Y is equal to this is your Y n n minus i mean I mean here Y n n minus Y n r, then Y r r inverse Y r n right. So, here you here this is your what you call this is your Y n n right; and this is Y n r; this is your Y r r inverse and this is Y r n right. And you multiply these three matrix. And whatever you will get, you subtract from this matrix right.

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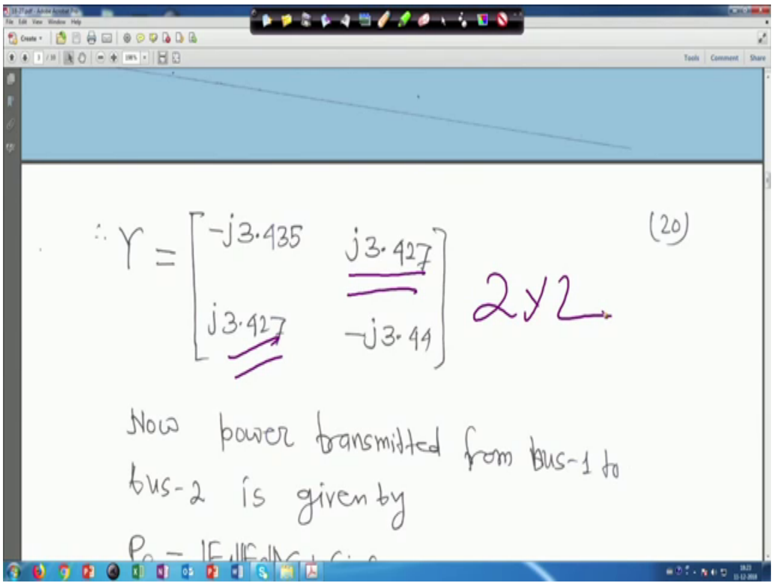

Then you will get that your what you call that 2 into 2 matrix that is your Y is equal to minus j 3.435 then j 3.427 j 3.427 and minus j 3.444 right. That means this matrix also symmetric matrix, because Y 1 2 is equal to Y 2 1. This is your prefault that is 2 into 2 bus reduction matrix that is your reduced matrix that is your 2 into 2 now. Now, power transmitted from bus 1 to 2, bus-2.

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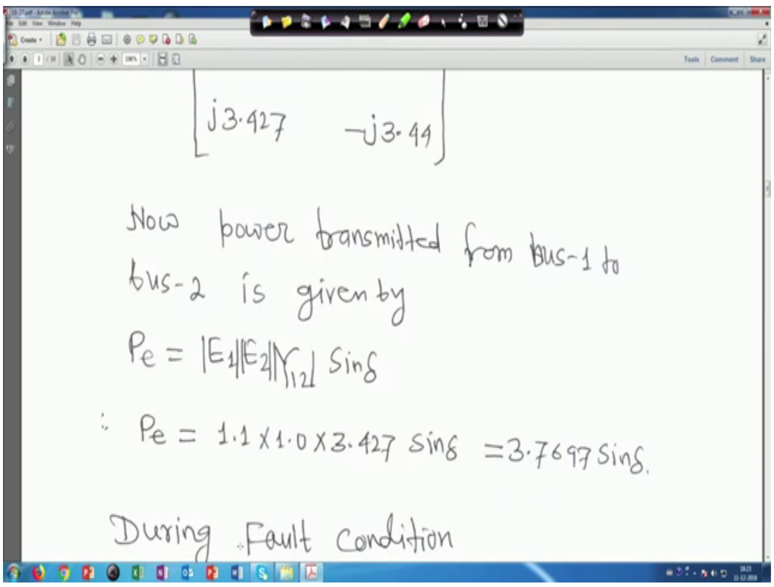

So, that is we know this equation from bus-1 to bus-2 after deduction that p e is equal to mod E 1 mod e E 2 Y 1 capital that mod capital Y 1 2 sin delta. So, E 1, E 2 values are given in initially I told you. And Y 1 2 that is your this one magnitude of this one that is your this is my Y 1 2. So, magnitude of Y 1 2 is equal to 3.427 right. So, here you will substitute, then initially I told you E 1 and W 2 values are given.

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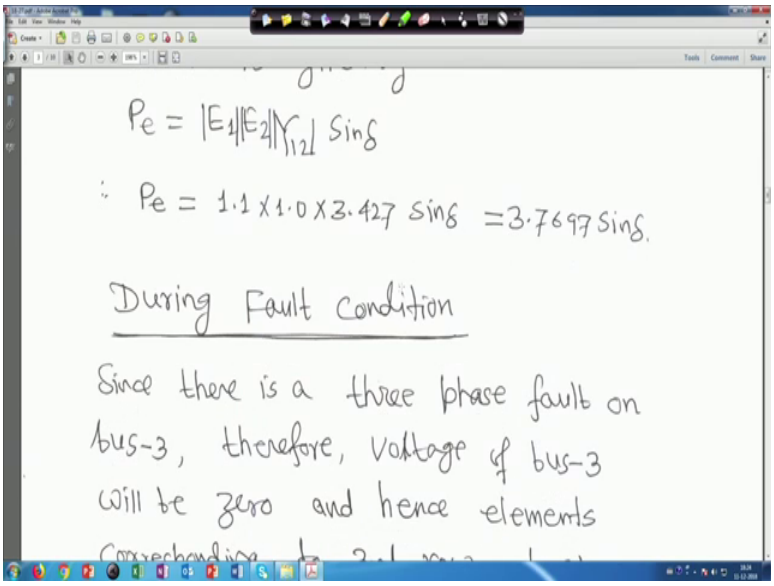

So, that means, during your prefault condition that P e is equal to 1.1 into 1.0 into 3.427 sin delta. So, this is actually 3.7697 sin delta. This is your prefault condition right. Now, during fault condition, so since there is a three phase fault on bus-3 that means, if you go back to the, we will go back to the diagram. So, at there is a there is a three phase fault at this bus, at this bus, there is a three phase fault right. So, at this bus, there is a three phase fault. So, in that case what will happen, the straightforward what we will do if three phase fault has a occurred in that bus.

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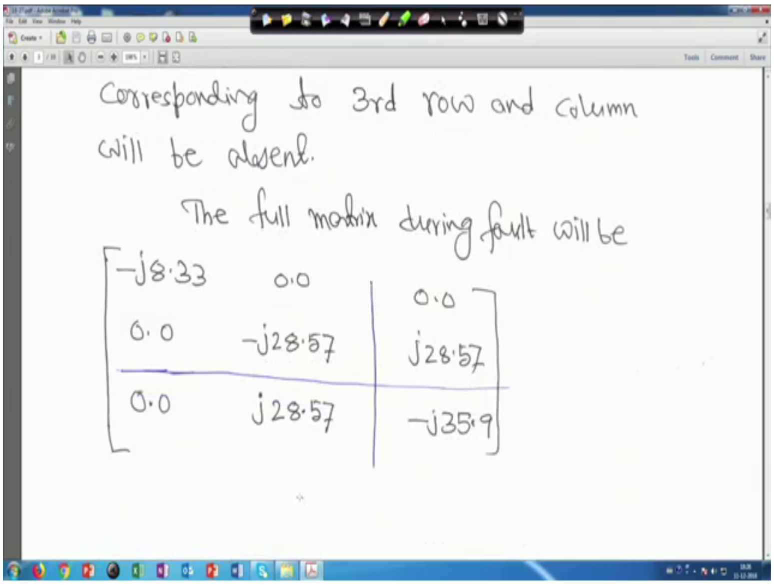

So, what we will do that here right. So, therefore, voltage of bus-3 will be 0, because three phase fault occurred at bus, hence the element corresponding to third row and third column will be absent. I mean they will be 0, that means, from this matrix from this matrix right, this matrix fault has occurred at bus-3 right, at bus-3 that means, the third row this third row and this third column it should not be there.

So, basically matrix, matrix will be reduced to that your 3 into 3, after that we will reduce that means, all these elements will be 0 during fault right. So, the I mean it will not be there all will be 0 0, and here also all will be 0 0. So, this should be removed, and this should be removed. So, this one, this one, this one will be there; this one, this one, this one will be there; and this one, this one and this one will be there. That means, matrix first will come down to 3 into 3; after that we will reduce it to 2 into 2 right.

So, because fault has occurred at bus-3, so your bus voltage three I mean voltage at bus-3 will be your 0, therefore third row and third column will be eliminated from that matrix. If you do so, if you do so, then this matrix will be 3 into 3 matrix will be during fault condition, then this is the matrix right, because that row and column third row and third column have been eliminated. So, in that case, what will happen, this is now my Y n n, and this is now Y n r and this is Y r n and this is Y r r. So, it is single element for this one right.

And we will bring it down to 2 into 2 matrix using the same relationship that is Y n n minus Y n r Y r r inverse into Y r n right. So, in that case your if you do so, so Y n n is equal to this much I told you, Y n r will be this much, Y r n will be this much and Y r r is single element right. And you know this formula you know this formula. So, simply we will substitute, and you just simplify you substitute and simplify.

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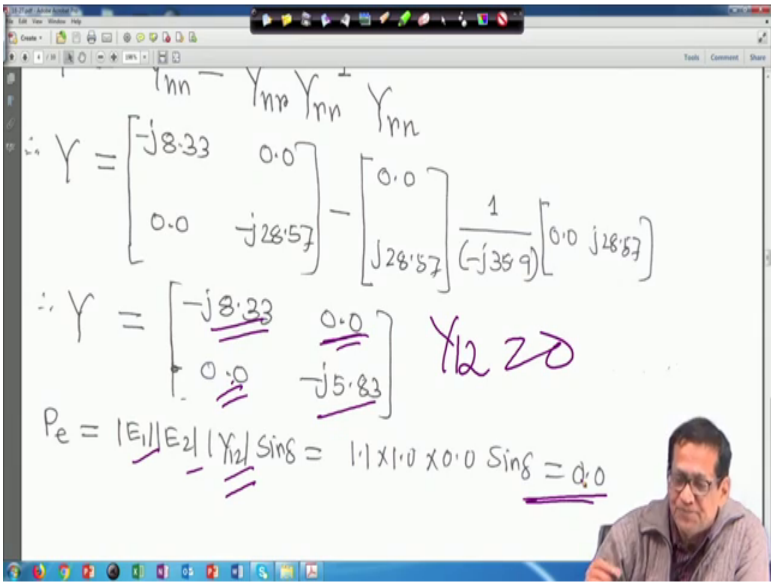

If you do so you will get that it is your minus j 8.33, 0, this is 0, and this is minus j 5.83 right that means, my Y 1 2 is actually is equal to 0. That means, during fault condition it is P e E 1 E 2 Y 1 2 sin delta. Ultimately we are bringing it down that your what you call that matrix reduction that is number of machines right in terms of number of machines the Y bus matrix order. So, basically E 1 E 2 Y 1 2 sin delta are all magnitude, but Y 1 2 is 0. So, during fault that power is 0, power delivered will be 0. This is matching with that. By chance if you this is small example by chance it does not it is only what you call two machine case right, and power you are only considering the power transform from 1 to 2. So, E 1 E 2 Y 1 2 sin delta right, so this is 0.

So, next one is that your post fault condition. We will not one thing I would like to tell that we will not show you any swing equation or these simulation thing, because this I mean this course itself is a mathematical course full of mathematics. And if I show you swing equations and that coding and other thing, then it will consume lot of time and it is not a classroom exercise. So, whatever I have planned that things which can be solved in the classroom right.

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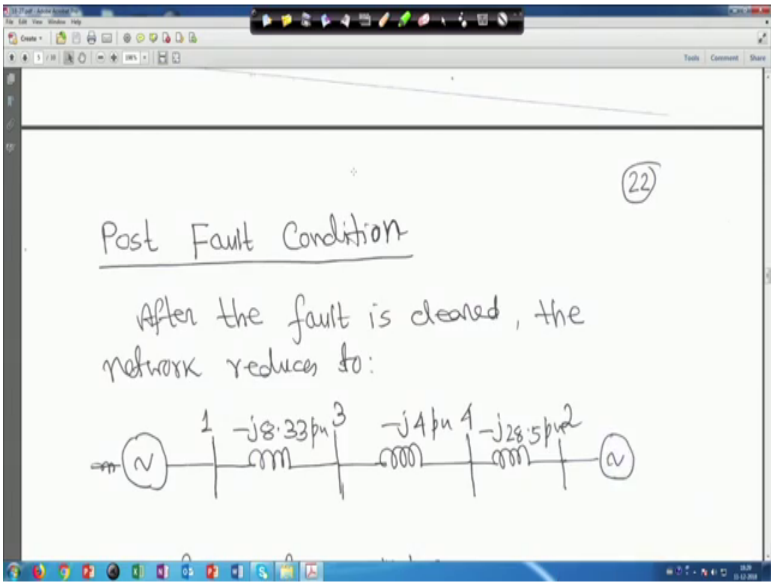

So, next one is that post fault condition. Actually during post fault condition that if you if you come back to this the condition for post fault is that just let me go to the diagram right here. For post fault conditions, when fault is clear, this line is out right. So, this line, this line and this line is there, these three lines are there right. So, this line is out when fault is cleared say. So, so in that case, in that case, just hold on let me go to that right.

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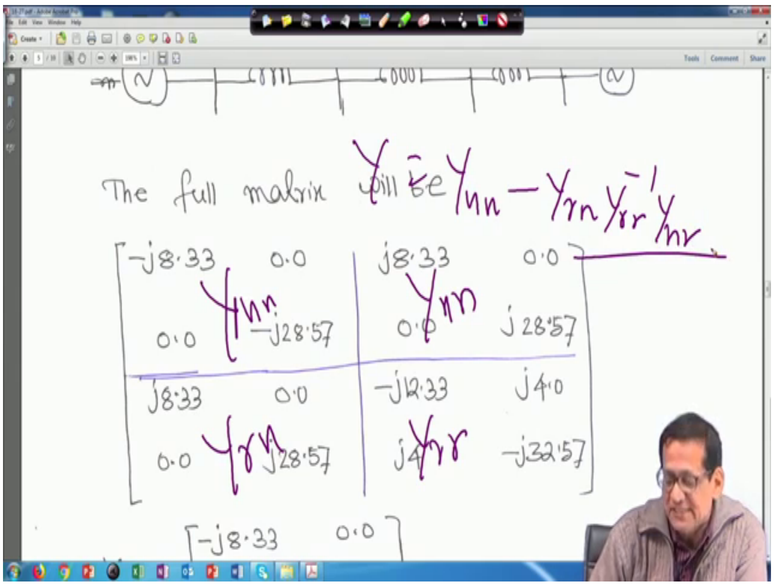

So, in that case we would simply construct, again it will be now 4 into 4 matrix right. So, you can easily construct that Y matrix 4 into 4 Y matrix. So, full matrix will be now it will be only during fault condition first row and first column are eliminated, because fault occurred at bus-3 right. So, that bus voltage three is 0. But for post fault when that line is removed right, and this is that your network diagram. And if you construct the Y matrix, it will be like this and you partition right you partition right.

So, this is your again this is 2 into 2 matrix Y n n, this is your Y n r, this is your Y r n and this is your Y r r right. So, and you use that same relationship that your Y in general Y is equal to Y n n minus Y r n then Y r r inverse, then Y n r right, you use the same relationship, then you will get, then it will be reduced to 2 into 2 matrix right.

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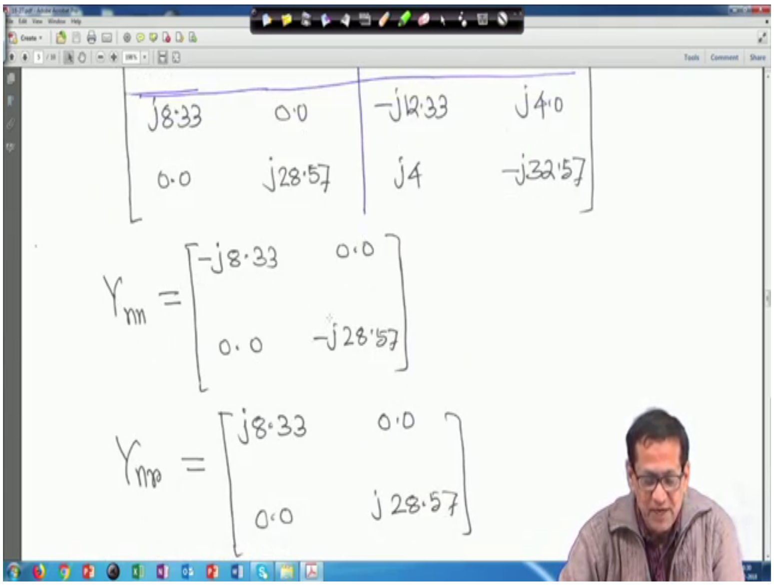

So, this is Y i n n, this is Y nr.

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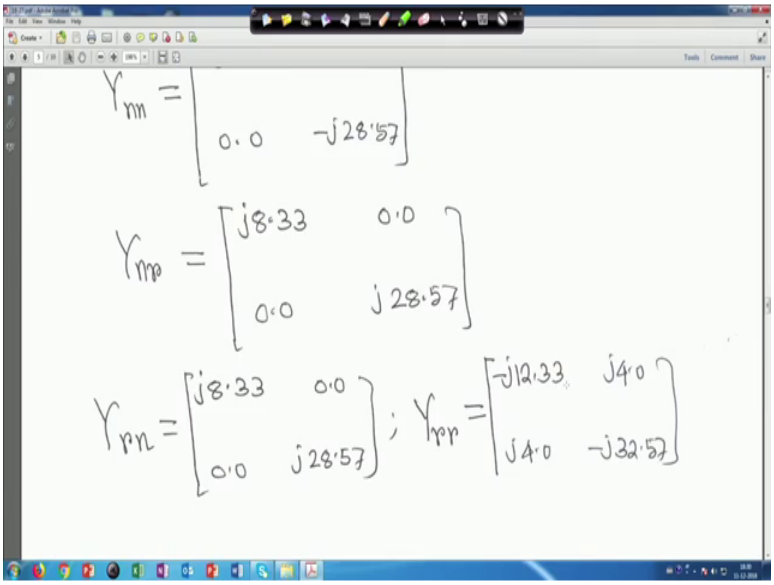

And this is Y r n and this is Y r r right you have to invert that Y r r right.

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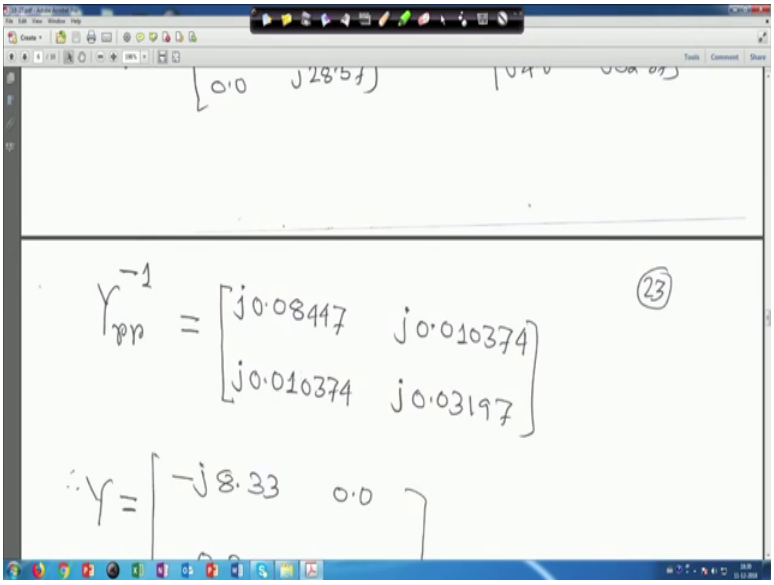

If you do so, so Y r r inverse will be this much right, I mean this is my Y r r and it is invert 2 into 2 matrix simply you can invert it right.

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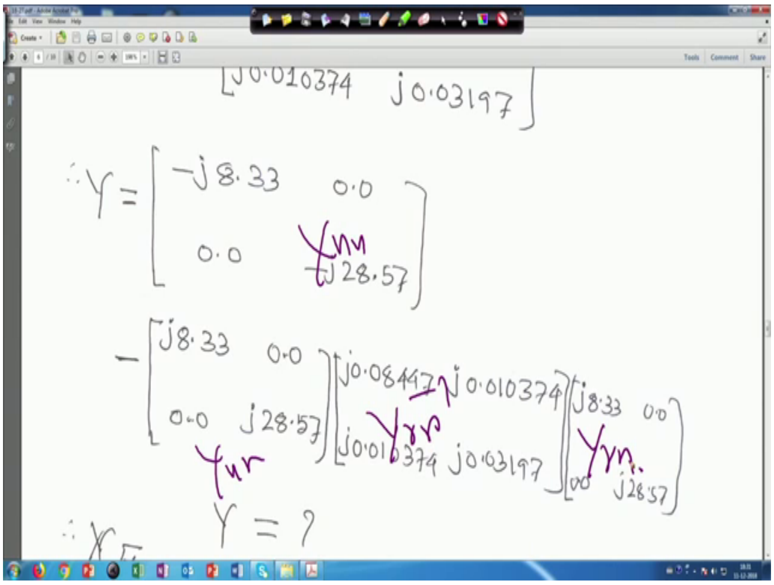

And then this is your Y this is your Y n n, this is this is your that Y n n that 2 into 2 matrix right. This is Y n r, this is your Y r r inverse and this is your Y r n right. And you multiply all and simplify.

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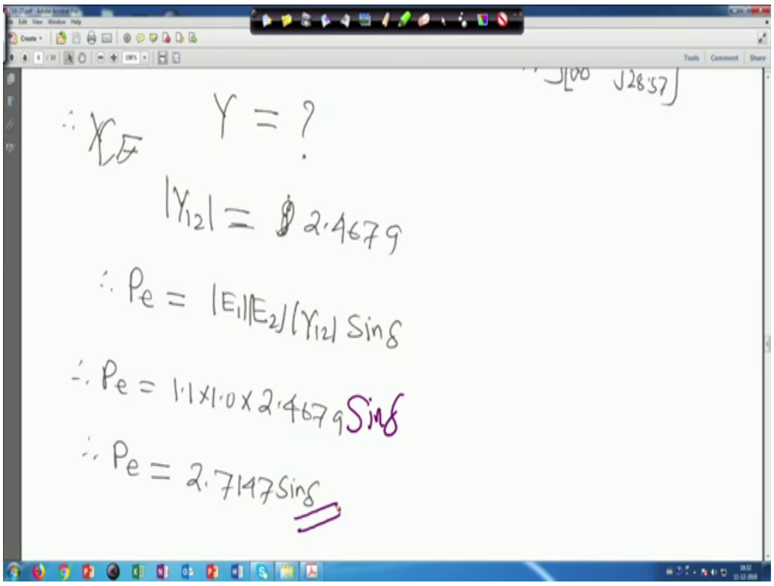

So, here this one your what you call I did not this is this is an exercise for you. I did not compute or I did not give the answer right, answer you will do it. Only thing is that Y 1 2 is equal to Y 2 1. So, Y 1 2 that I have written here that I have written here but you please find out what is Y 1 1 is equal to how much, and Y 2 2 is equal to how much you multiply and subtract that from Y n n right. And in this case P e will be E 1 E 2 Y 1 2 sin delta, this way when you compute you will get Y 1 2 2.4679 right. So, that means, my P e will be that E 1 1.1 E 2 one point 2.1 thing I have list here, it is into sin delta right. And P e is equal to 2.71 power transferred that from 1 to 27147 sin delta right.

So, thank you very much. We will be back again.