Power System Analysis
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Lecture – 45
Three phase fault studies

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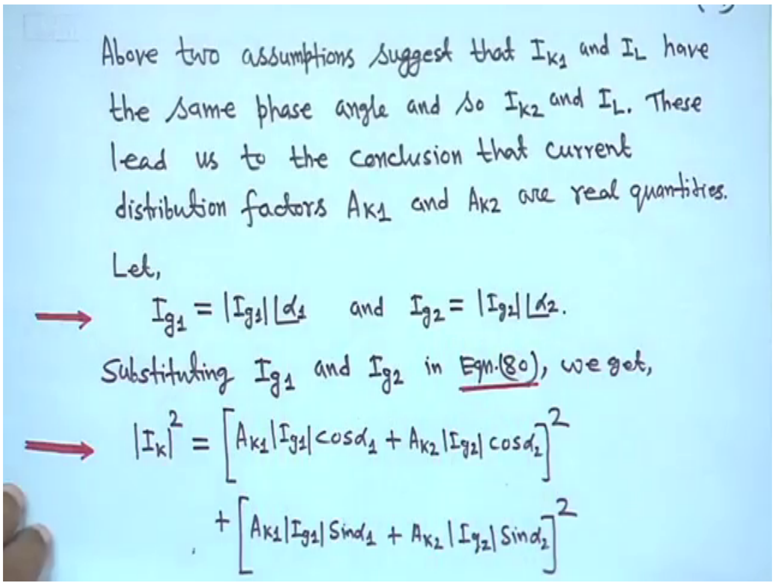

Ok. So, now,. So, this here now we assume that let us assume I g, 1 actually magnitude Ig 1 its angle is alpha 1 and I g 2 actually magnitude I g 2 angle alpha 2 right.

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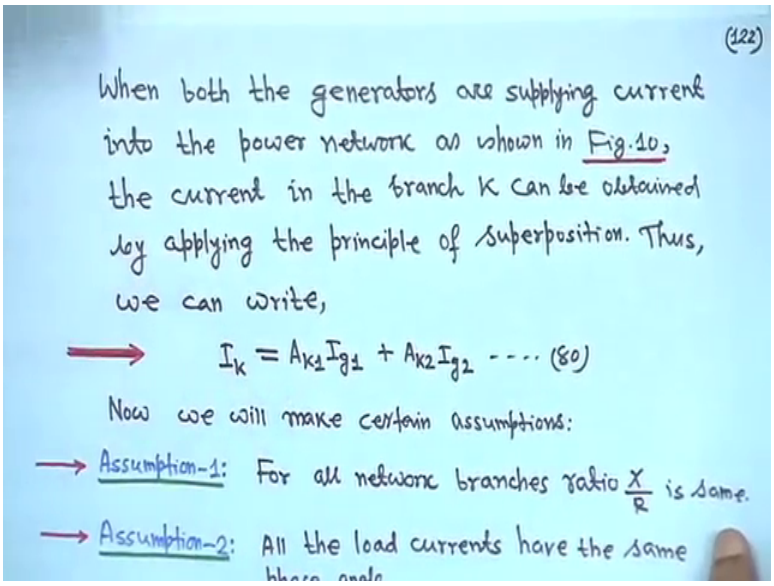

So, what we will do in this equation I am writing one or 2 lines for you, in this equation 80 right in equation 80 you put that one right.

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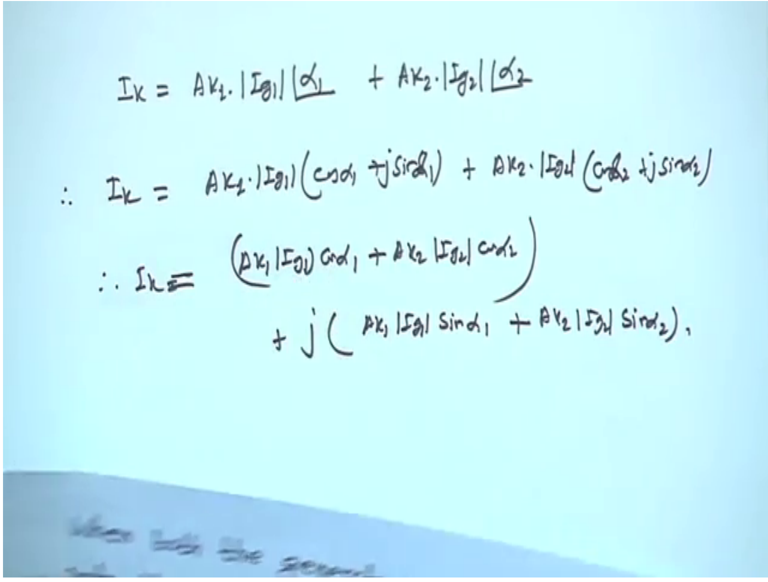

That means your I k actually, I k is equal to your A K 1, I g 1 angle alpha 1 right and similarly this one A K 2, I g 2 angle alpha 2 right; that means, this one you can write A K 1, I g 1, cosine alpha 1, plus j sin alpha 1 right.

Then similarly this one A K 2 then magnitude I g 2 right, in bracket sorry cosine alpha 2 plus j sin alpha 2 right so; that means, what? That means, I k 1 you can what you call you can write you take you are in separate you are you just real and imaginary part make it together, this side first you collect the real one. So, it is A K 1, Ig 1, cosine alpha 1, plus A K 2, I g 2 cosine alpha 2 this is of real part and then imaginary part j it is A K 1, I g 1 your sin alpha 1 plus A K 2, I g 2 then your sin alpha 2 right.

So, what you do, you take the magnitude of these right you take the magnitude of this and then square it. So, if you do so, right I mean after making this just hold on after making this you just take the take the magnitude of this and then you square it. If you do so, you will get magnitude of I k square is equal to A K 1 magnitude with I g 1 cosine alpha 1 plus A K 2 magnitude I g 2 cosine alpha 2 whole square right plus A K 1 magnitude I g 1 sin alpha 1 plus A K 2 magnitude I g 2 sin alpha 2 whole square right.

Then what you do, you expand it right and then your sin square alpha 1 cosine square alpha 1 there should be 1. If you take similarly cos square alpha 2 sin square 1.

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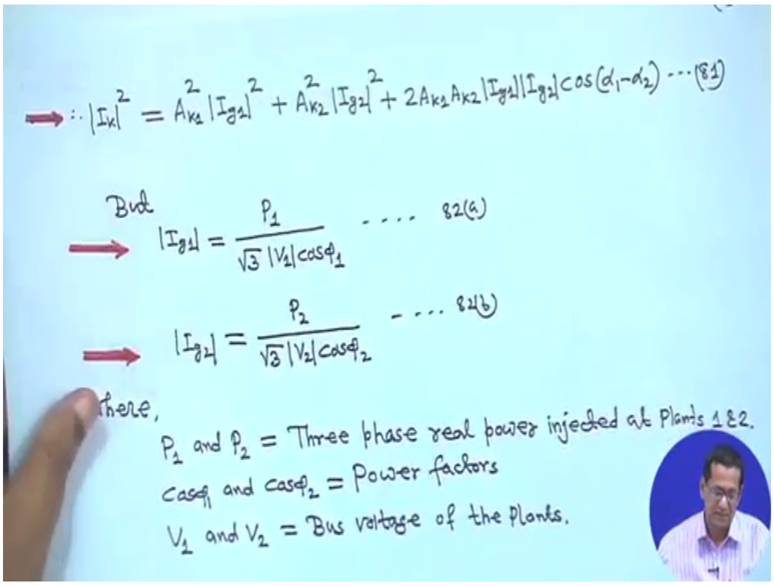

So, these 2 term plus your if the plus it will be 2 into this one, cosine alpha 1 alpha 2 here also 2 into this one sin alpha 1 alpha2. So, all the 4 terms your all the terms will be common, and ultimately it will become cosine alpha 1 minus alpha 2 right.

So, you just expand and simplify this is simple thing; that means, you will get mod I k square is equal to A K 1 square I g 1 square magnitude, again and again I am not telling understandable then plus A K 2 square I g 2, square plus 2, A K 1, A K 2, I g 1, I g 2 it will become cos alpha 1 minus alpha 2 this is equation 81 right.

Now, we know in general P is equal to your power is equal to root 3 vi cos phi therefore, for generator one magnitude I g 1 is equal to P 1 upon root 3 V 1, cosine phi 1 right cos phi and cosine phi 1 or phi 2 are the power factor angle at generating station 1 and 2 respectively. So, that is I g 1 is equal to P 1 upon root 3 V 1 your cosine phi 1, this is equation say 82 a I have given. And among magnitude I g 2 is equal to P 2 upon root 3 magnitude V 2 cosine phi 2 right this is given equation 82 B right; where P 1 and P 2 is equal to 3 phase real power injected at plants one and two right. Cos phi 1 and cos phi 2 is equal to power factors V 1 and V 2 is the bus voltage of the plants right.

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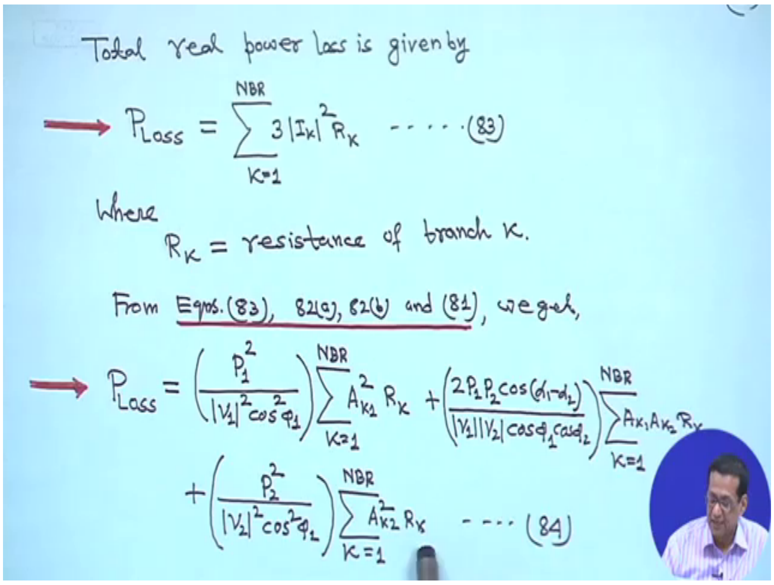

So, the next what we will do this next one is that what is the 3 phase power loss total right. So, in that case the total real power loss is given by K is equal to 1 to NBR. NBR means total number of branches right in the transmission network. So, k is equal to one to number of branches that is why NBR right. Is equal to 3 into magnitude Ik square into Rk it is a 3 phase. So, that is why multiplied by 3 right.

So, this is equation 83; now this I k square in this I k square this I g 1 and I g 2 you substitute, I have not writing all the step now you have understood everything right. So, this I g 1 and I g 2 you substitute here right in this expression I k square, and then you put it we see root 3 is there if you square it will be 3 here also 3 so that 3 will be canceled actually right. So, you put it here and use this expression and simplify.

If you do so, then you will get Rk is the resistance of the branch k right. If you do so, that is why I am written from equation 83, 82 a, 82 B and 81 you will get right. You will get P Loss is equal to P 1 square divided by V 1 square cos square phi 1 the magnitude, but not telling again and again then in bracket sigma k is equal to 1 to NBR, it is A K 1 square Rk k th term. All the k th your k th coefficient right or this thing you put in the sigma, but other things you take it out plus 2 P 1 P 2 cosine alpha 1 minus alpha 2 divided by V 1 V 2 cos phi 1 cos phi 2 take it out, k is equal to one to NBR again number of branches A K 1 into A K 2 into Rk right plus P 2 square upon V 2 square cos square phi your phi 2 sigma k is equal to 1 to NBR, then A K 2 square into Rk this is equation 84; that means, this equals this I g 1, I g 2 substitute here with that I see I k square whatever will get you put it here then you mix you separate the 3 terms right.

Your one is this due to your this thing you are what you call P 1 square, P 2 square another is a product of P 1 P 2 this way you make it. Here the sigma is there sigma is there sigma is there right.

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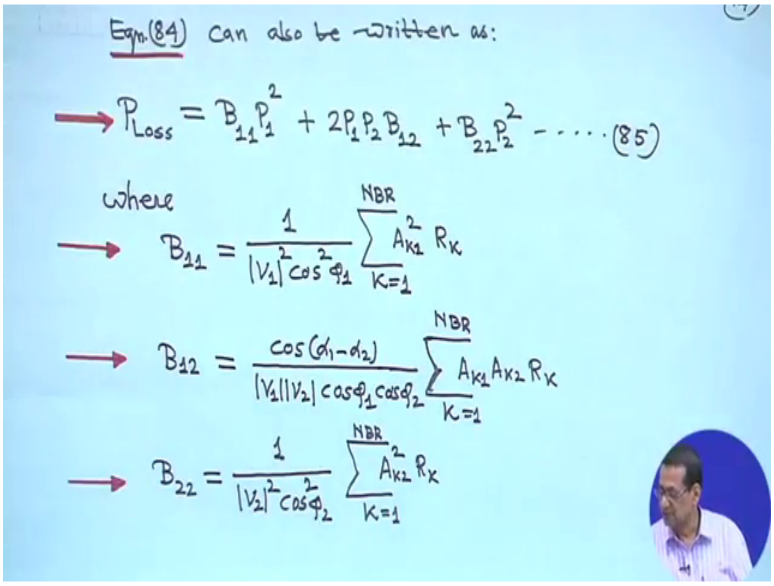

So, this is equation 84; now this equation this 84 equation right it is a equation 84 it can be written as P Loss is equal to your B 11, P 1 square; that means, this term right I will come to that B 11, P 1 square plus 2 P 1, P 2, B 12 plus B 22, P 2 square right.

So, listen one thing that this P 1 square P 2 square actually it is a taken generator one generator 2 no question of slack bus just reached on top you are generating power that pg one pg 2. Actually this P 1 P 2 is nothing, but pg 1 pg 2 right. So, only 2 generating units, but when you will do it in general of course, you have to see that pg 2 pg 3 up to pgm right, but anyway this is actually your P 1 if your what you call in terms of P 1 and P 2 right.

So, this where B 11 as we are taking P 1 square this means; that means, this is P 1 square into B 11, B 1 here actually is equal to 1 upon V 1 square, cos square phi 1 into your k is equal to 1 to NBR A K 1 square Rk; k is equal to 1 to NBR A K 1 square Rk. Similarly B 12 that is it is p it is your what you call this term only right that is equal to cosine alpha 1 minus alpha 2 divided by your what you call your V 1, V 2 cos phi 1 cos phi 2, because it is product P 1 P 2 is there. So, 2 P 1, P 2, V 1 2 and third term actually B 22, P 2 square; that means, coefficient of the P 2 square. That is your B 22 is equal to 1 upon V 2 square cos square phi by 2 sigma k is equal to 1 to NBR, A K 2 square Rk. So, this is actually called B coefficient right.

Now, if you look at the dimension of B coefficient B 11, B 12 look this P Loss when you put in real dimension it is megawatt right, but in this case this P 1 square P 1 square or P 1, P 2 square it is becoming megawatt square right; that means, what will be what will be the dimension of B 11 it will be megawatt inverse right; that means, a; that means, if whatever suppose it is given 0.2; that means, 0.2 megawatt inverse right. So, that is why because it is square it is megawatt square P Loss is megawatt. So, B B B the dimension is megawatt inverse right.

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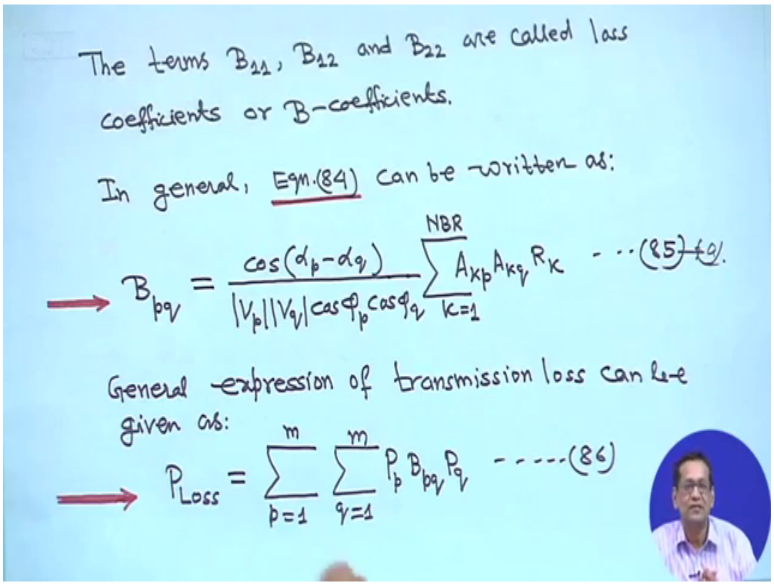

So, once this is done then this equation actually we can put in general form; for instead of one and 2 like the terms B 11, B 12 and B 22 are call these are loss coefficient or B coefficient right loss coefficient will be data right or B coefficient in general equation 4 forty eighty 4 are can be written as Bpq right instead of instead of your B 11, B 12, B 22 if we assume p and q, in general it can be written that Bpq is equal to cosine alpha p minus alpha q divided by Vp Vq cos phi p cos phi q k is equal to 1 to NBR Akp Akq, Rk this is 85 equation, 85 say right; that means, if you put P is equal to 1, q is equal to 1 you will find this is your cos 0 1 right it will be V 1 square and it will become your cos square phi 1 right and automatically you will get this is actually P 1 q 1 you will get A K 1 square into your Rk k is equal to 1 to n NBR right.

So, this is from this simple this expression all this bs this can be made as a general thing right. So, it is from here you can make it cos your alpha p minus alpha q, Vp Vq cos phi p cos phi q Akp Akq and then Rk. From here you can make it B Bpq and when p is equal to q you can this one you can make it when q is equal to p you can get it. So, all these things we will get it and this one is a quadratic relationship this one right.

So, this one also it can be generalized that P Loss is equal to P is equal to 1 to m, q is equal to 1 to m, it can be made pp Bpq pq this is equation 86. So, this loss expression also if you do this you will get p is equal to 1 to m, q is equal and in this case if you make m is equal to 2 then you will get this expression. We had 2 is there because this term will be repeated right this term will be repeated because B 12 is equal to say B 2 one this term will be repeated that is why 2 is here. So, ultimately if we expand this there will be 4 terms for m is equal to 2. So, what, but 2 terms will be common summation will be 2 P 1 P 2, B 12.

So, this term that is why when we are when we took your what you call that loss formula we took pi bij pj. So, this is the pgi or pgi bij pgj right this loss formula. So, this is actually quadratic equation, this is actually this equation is 86. Now economic load dispatch and loss formula whatever we have done this topic all the theory as concern some examples are given, all together I think before 8 examples are shown on this right. Your object will be not to practice as far as classroom is concerned very big formulas and other things right, and simple example right and meaningful example right a something something will be you can solve right. Take a any book and you will find this small thing only thing is that see that do not make any calculation error right I mean when you are using calculator. So, do not use do not make any mistake right these are the thing.

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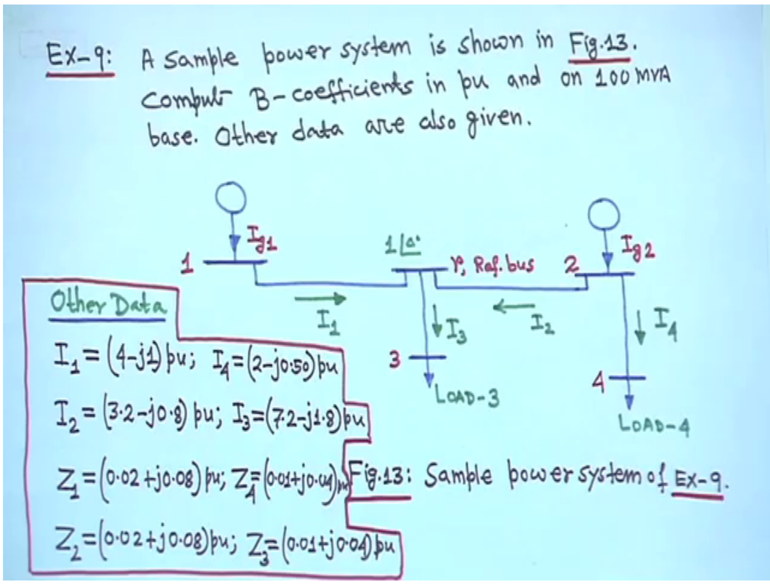

Now, next we will take 1 or 2 example on it right. So, here this example is taken like this here what we will do that a coefficient one part I will do it for you, other part I will give the answer, but you will do for yourself right. So, a sample power system is shown in figure 13, this is actually figure 13 right and your B coefficient come you have to compute B coefficient in per unit and on 100 MVA base, other data are also given. So, this is that network is given, and in this network this is one this bus actually has taken as say for example, reference bus. This voltage is given one angle 0 right and this is bus one current from this generator is I g 1, and this is bus 2 current from this generator is I g 2 right and this is and bus 3 and bus 4 they are load bus.

So, here that current is going through this load is I 3, and this is going to I 4 is going to the load 4 right. So, now some data you need some data. So, this is 1 2 3 4 there are 4 branches, and current direction is shown I 1 its. So, going like this say I 2 going like this, this is I 3 right and this is this I 4 is going to this load right. So, in that can this voltage is a reference bus voltage one angle 0. Now I 1 is given say 4 minus j 1, this I 1 is given 4 minus j 1 per unit. I 4 is I 2 is also given 3.2 minus j point 8. So, this I 2 direction is shown it is given 3.2 minus j point 8 right.

Then I then I 4 is also given this is I 4, 2 minus j 0.5 per unit, and I 3 this is I 3 is given 7.2 minus j 1.8 per unit these are given right. Now Z 1, Z 1, Z 2, Z 3, Z 4 this is branch 1, branch 2, branch 3, branch 4. So, Z 1 is given 0.02 plus j your 0.8, and Z 2 is 0.02 plus j

0.08, Z 4, Z 3 is given 0.01 plus j 0.04 and Z 4 is 0.01 plus j 0.04 these all are given this data are given.

Now, we have to find out this B coefficient for this example right. So, what we will do first you this is that 2 loads are there this is load 3 and load 4 which is it and that is at bus 3 and bus 4. So, let me I 3 and I 4 is the total load current, because these 2 I 3 and I 4 going to the load right.

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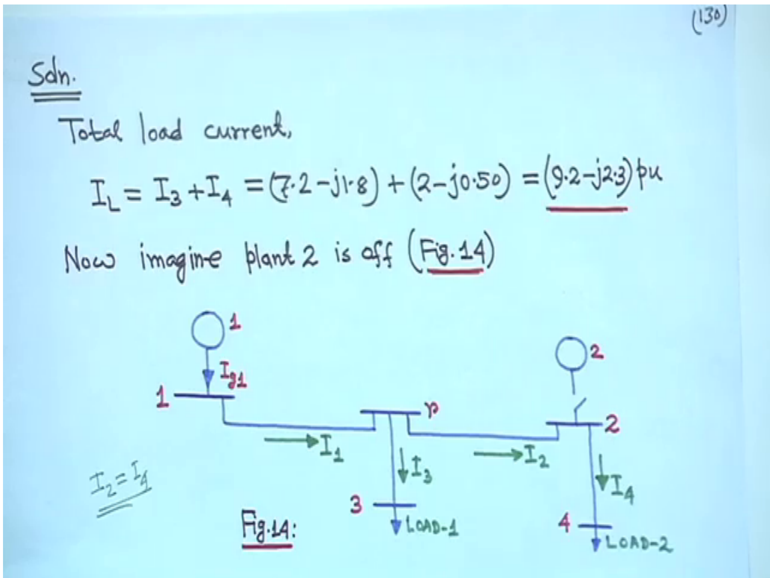

That means your total load current right is equal to IL is equal to I 3 plus I 4, I 3 is 7.2 minus j 1.8, plus it is 2 minus j 0.50 is equal to 9.2 minus j 2 0.3 per unit is a total load current.

Now, the way we have derived this thing a formula same way we will do it now imagine plant 2 is off; that means, this generator 2 is not there it is off right this is figure 14, I have written here figure. As soon as the generator 2 is off look at that that the direction of the current will change because from this generator only current will flow this and this will going to the load. So, this is off this is off. So, direction of the current will change right that is why that this direction of the current is change.

So, this is all this is off; that means, I 2 actually is equal to I 4 right. So, if it is so, then this at this point we apply Kirchhoff's first law right so; that means, your I 1 is equal to I

2 plus I 3 plus I 2 and here, it is I 2 is equal to I 4 because same current is going here this is off right.

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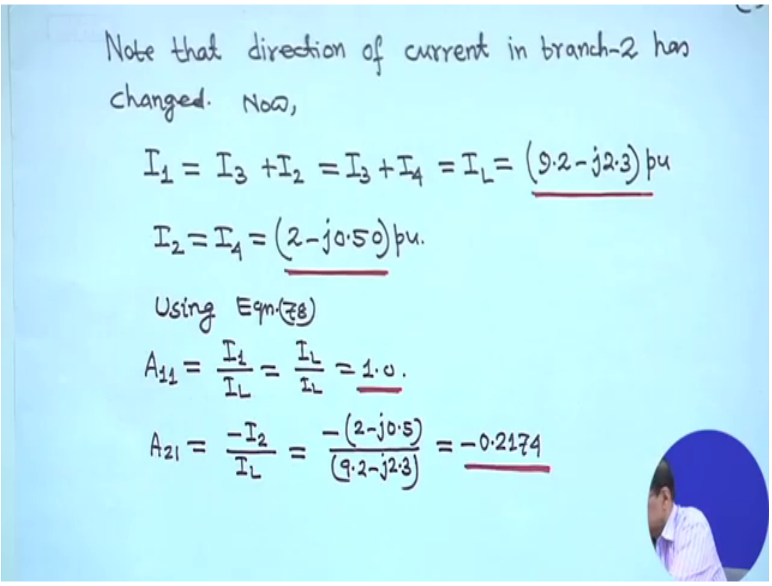

That means; that means, your I 1 is equal to you apply Kirchhoff's first law here I 1 is equal to I 3 plus I 2 that is I 3 plus I 2 is equal to actually I 3 plus I 4, because I 2 is equal to I 4, I have written here I 2 is equal to I 4 right. So, is equal to your total load current IL, because this is the I 3 and I 4 the total load current is equal to 9.2 minus j 2.3 per unit right and I 2 is equal to I 4. So, I 2 is equal to I 4 is equal to 2 minus j point 50 because I 4 is equal to 2 minus j point 50 right. So, all these currents we have got.

Now, using equation 78 A 11 right if you go to equation let me find out right just hold on anyway, it has been mixed up I am telling you that A 11 actually is equal to I k 1 upon the total load current right. So, this equals if you use 78, A 1 is A K 1 your I k Ik 1 upon IL right. So, in that case k is equal to one the first branch. So, I 1 upon IL its equal to IL upon IL, because I 1 is equal to IL because I 1 is equal to just now I have told you that your where it has gone again right this this is IL total load current right and I 1 is equal to actually I 2 this I 3 plus I 2 is equal to I 3 plus IL, this is I 1 this I 1 is equal to actually IL, because I 1 is equal to I 3 plus I 2 is equal to I 3 plus I 4 right.

So, here it is. So, I 1 is equal to IL right; that means, A 11 will be I 1 upon IL that is one similarly A21 that here that direction and the original diagram direction was this way I 2 this way I 2, but as soon as this is off direction has changed. So, minus sign will be there right because this is off direction of I 2 is change from the original one, that is why a minus sign is there right and A21 will be minus I 2 upon IL, that is minus 2 minus j point 5 upon 9.2 minus j 2.3 that will become actually minus 0.2174 right that is your what you call your A21 right.

Then from the branch 3 it is simple actually, but the numerator denominator denominator you always IL. So, A31 will be I 3 upon Il. So, I 3 you know 7.2 minus j 1.8 divided by 9.2 minus j 2 point. that is coming 0.7826 right. Similarly for branch 4 I 4 1 is equal to I 4 upon IL right. So, it is 2 minus j 0.5, divided by 9.2 minus j 2.3 that is 0.2174 right.

Similarly, the plant one is off I mean this one this one you will do of your own this plant one is off right as soon as plant one is off right; that means, no current will come from generator. So, I 1 will become 0, right and plant 2 is this. So, this current direction all other will remain same, but this one I 1 will become 0, that is why A12 is 0 rest I have computed.

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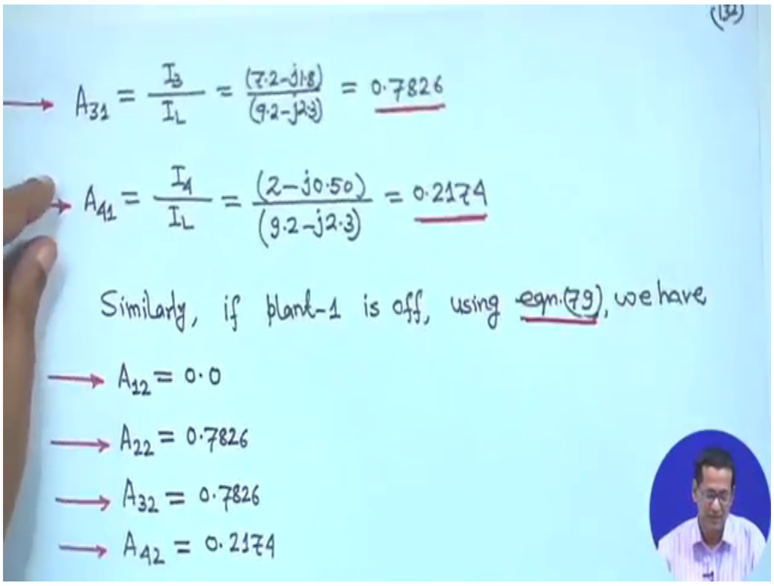

So, accordingly you can easily compute this right following the same procedure right.

So, I am giving you the final one A 21 is equal to 0.7826, A32 is equal to 07826 and A 42 is equal to 0.2174 right. So, once; that means, all the a coefficient are computed.

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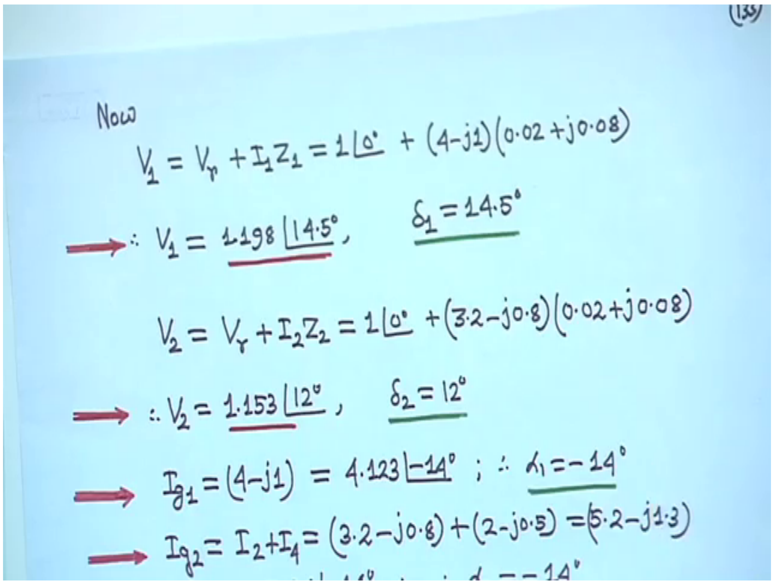

Now again we will come back to that diagram just hold on this diagram right. So, in that in this diagram if this is the reference voltage right and all the branch impedance Z 1 Z 2 Z 3 Z 4 all are given all data are given here, all data are given here; that means, V 1 is equal to you can write V r plus I 1 1 right. So, V 1 is equal to your V r this is a reference voltage V r one angle 0 right. So, it is actually it is V r right this is Vr.

So, V r, V 1 is equal to V r plus I 1 Z 1. So, V r is one angle 0, I 1 is known and Z 1 is also known everything is known. So, you will get V 1 is equal to 1.198 angle 14.5 degree; that means, delta one is equal to 14.5 degree that is the v your what you call at bus one the voltage angle is 14.5 degree. Similarly V 2 is equal to V r plus I 2 Z 2 right. So, V r is one angle 0 and I 2 is equal to 3.2 minus j 0.8 and this is Z 2 0.02 plus j 0.08 then we V 2 is 1.153 angle, 12 degree then we delta 2 is equal to 12 degree right.

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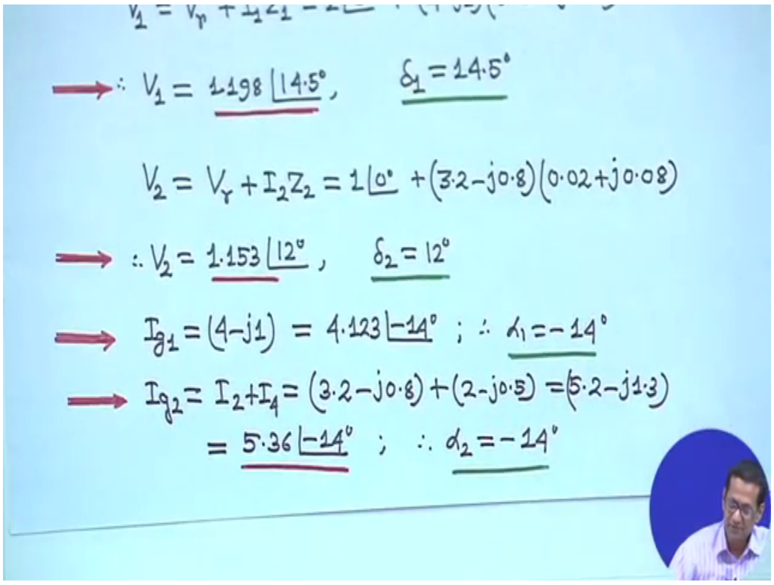

That means your general current I g 1 is given, this generator current your I 1 is actually I g 1 is equal to I 1 right and I 1 data is given 4 minus j 1 this is given; that means, your I g 1 is equal to 4 minus j 1 that is 4.123 angle minus 14 degree. So, alpha 1 is equal to minus 14 degree; that means, that current angle generator one current angle is minus 14 degree, and I g 2 is equal to I 2 plus I 4 because this is I g 2 at this point you apply Kirchhoff's first law at this bus. So, I g 2 is equal to I 2 plus I 4 right therefore, this I g 2 is equal to I 2 plus I 4. So, I 2 is given I 2 is given I 4 is also given.

So, you put it here I 2 plus I 4 3.2 minus j 0.8, plus 2 minus j 0.5 that actually coming a 5.36 angle minus 14 degree, then alpha 2 that is the angle of the a current of generator 2 is minus 14 degree right.

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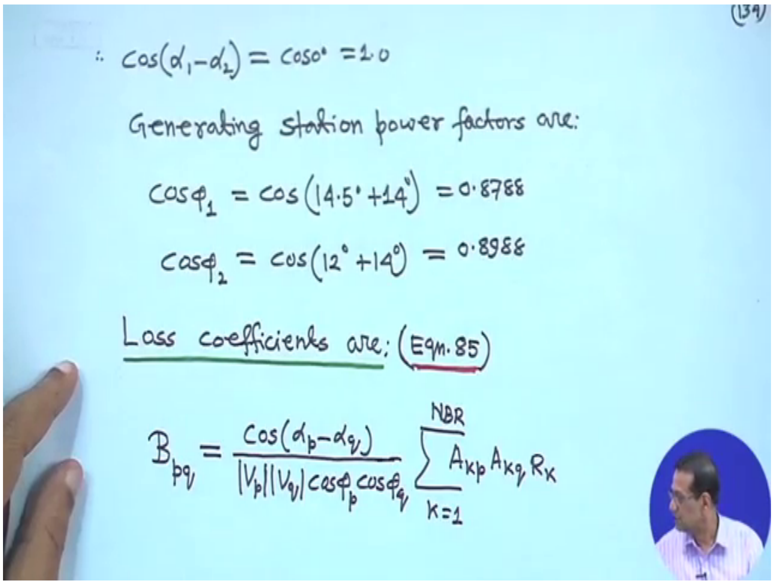

So, once you have got this then this thing your cosine alpha 1 minus alpha 2 is equal to one right because both alpha 1 and alpha 2 just both alpha 1 and alpha 2 they are same 14 minus 14 degree minus 14 degree. So, alpha 1 minus alpha 2 is 0. So, it is cos 0 is equal to 1 right and generating station power factor that is cosine of 14.5 plus 14 degrees.

So, take for example, V 1 it is 14.5 degree and if you take the current I g 1 right your I g 1 is minus 14 degree.

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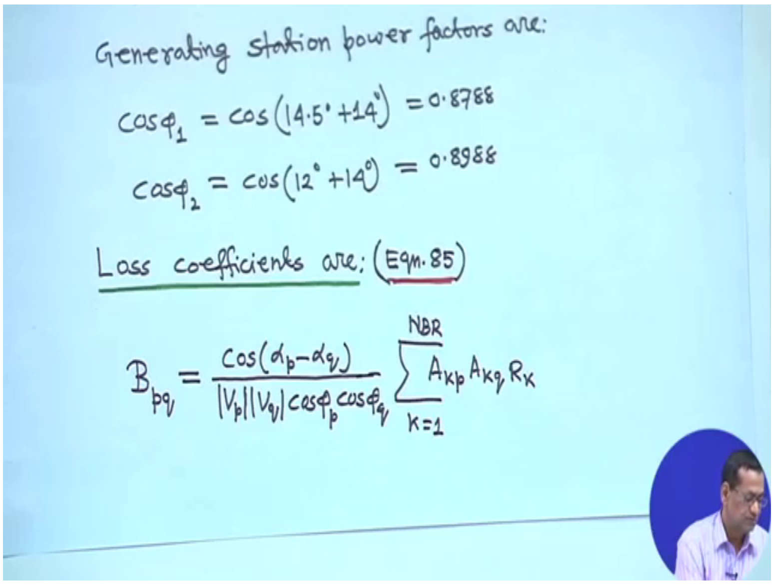

So, from a reference line right it is something like this your I have told you earlier also. So, if you this is a reference line right. So, this is your voltage angle this is your V 1 these angle is actually 14.5 degree, and the current is this side lagging actually from the reference if you take this is I g 1 right and it is a angle is your 14 degree it is lagging.

So, angle between this voltage V 1 and the current I g 1, this 14.5 plus 14 degree right; that means, this your this your where it has gone here right; that means, it is cos phi 1 it cos 14.5 plus 14 degree is equal to 0.8788 similarly for generator 2 same thing it is cosine 12 degree plus 14 degree that is 0.8988 degree sorry 0.8988 sorry right.

So, now loss coefficient equation 85 right this is the general formula Bp q is equal to cos alpha p minus alpha q upon Vp Vq magnitude of course, right cos phi p cos phi q sigma k is equal to 1 to NBR, Akp a Akq into Rk right now here total number of branch for this network is 4 we have total 1 2 3 4, 4 branches are there; that means, your NBR is equal to 4 the total number of branch right. So, now your NBR is equal to 4 and say P and p is equal to q is equal to one then you find out B 11.

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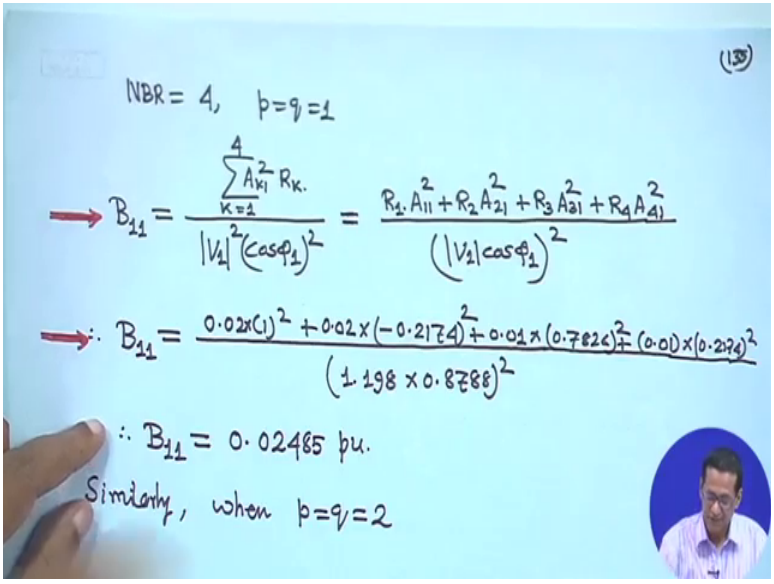

So, k is equal to 1 to 4 A K 1 square into Rk divided by V 1 square cos square phi 1 right is equal to we expand this term R 1 A 11 square plus R 2 A 21 square, R 3 A31 square plus R 4 A 41 square all the branch resistance you know because impedance is given. So, real part is R right.

So, it is V 2 square cos square phi 1. So, V 2 cos phi whole square right. So, put all these values because now all a coefficient known R1 is known, cos phi 1 is known V 1 is known everything is known just you substitute you will get B 11 is equal to 0.02485 per unit. Similarly when p is equal to q is equal to 2 right when p is equal to q is equal to 2 you will get B 22 is equal to k is equal to one to 4, A K 2 square Rk divided by V 2 square cos square phi by2. So, writing as a whole square right.

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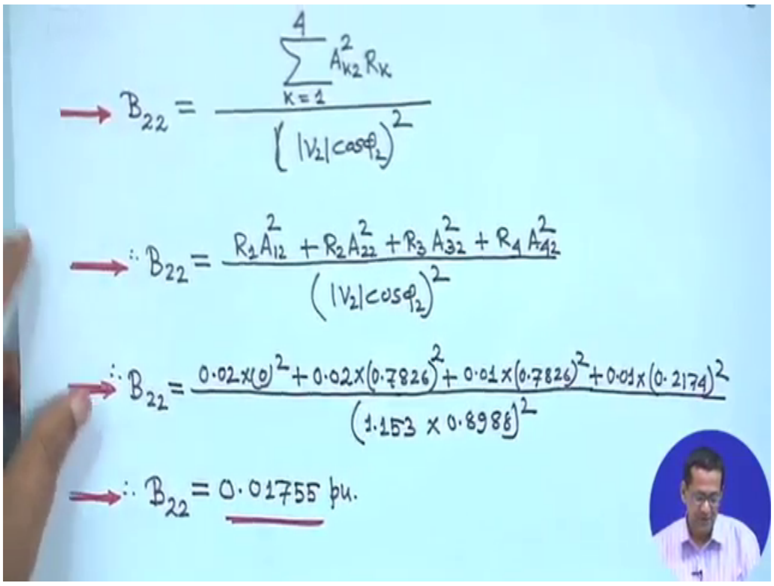

So, that means, you expand this and all the values are known to you, you substitute all these values you substitute all have been done listen all this all this calculations done by me only. So, if I that this every lecture I repeat this once or twice if you find any calculation or anything I will appreciate if you can mail me that where is the error then if any calculation error, then I can rectify myself I can correct this right. So, this B 22 will be 0.01755 right for.

Thank you for B 12 we will come again.