Power System Analysis
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Lecture - 35
Load Flow Studies (Contd.)

Next is after you got this delta P 2 0 delta P 3 0 values and delta Q 2 0 and delta Q 3 0 values right then we that equation is there delta P is equal to your J 1 delta delta so; that means, this delta P 2 0 delta P 3 0 Jacobian, this is J 1 matrix we have computed.

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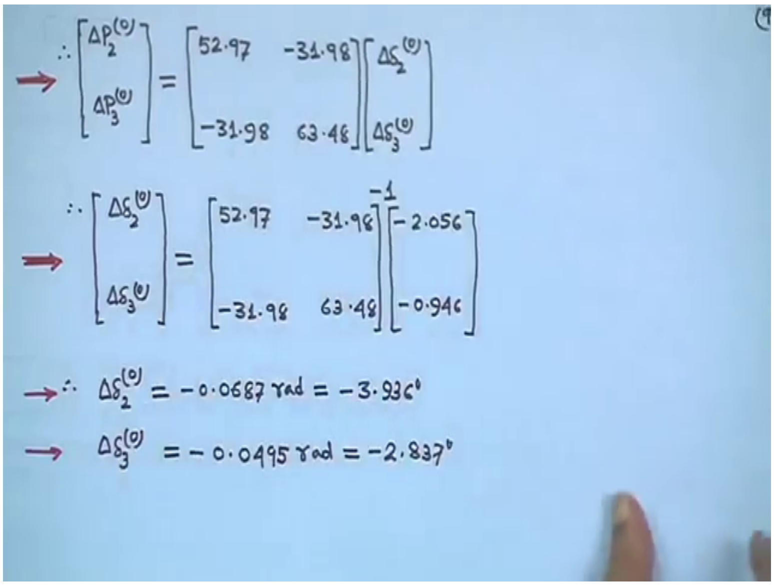

And this is delta delta 2 0, delta delta 3 0, for the pi 0 3 I mean P is equal to 0 that is initially that is your in that way you can say this is the first iteration actually right then the delta delta 0 delta is a 0 is equal to this matrix inverse. So, 52.97 minus 31.98, this 1 minus 31.98 63 point be inverse then minus 2.056 and minus 0.946.

Because delta put 0 is delta P 2 0 or minus 2.056 and delta P 3 0 you computed minus 0.946. So, delta delta 0 is becoming minus 0.08687 radian that is equal to minus 3.936 degree and delta Q 3 0 is equal to minus 0.0495 radian is equal to minus 2.837 degree. Let me tell you one thing that in Jacobian matrix right when basically your what you call that here we are taking inverse right, but a small system 2 in to 2 or 3 in to 3 small system if that is, but if Jacobian matrix is large right I mean system suppose 100 bus 200 bus problem at that time that we there inverse if you try to find out it may give error right different techniques are there to solve this equations solve this equation if matrix size is large right that is beyond the scope because within this time frame particularly it is not possible to show right.

But here it is taken small example, but different methods are there to solve this because basically it is a linear equation; it is a linear equation is it not? It is a linear equation so, but if you try to take inverse and for large system and though Jacobian size is large that you may not get the result right. So, correct result. So, that is why different techniques are there to solve this right. So, one simplest method is solving linear is a back substitution, but some other efficient techniques are there right in any way. So, this is that your; what you call this is you got delta 2 0 delta 3 0. So, these 2 are your delta 2 delta delta 2 and similarly delta Q is equal to J 4 delta be magnitude.

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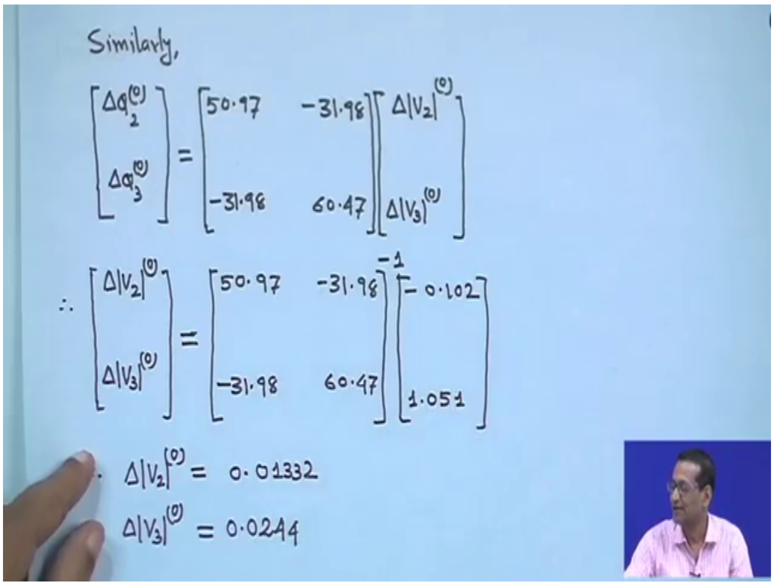

So; that means, delta Q 2 0 delta Q 3 0 is the J 4 matrix this is our J 4 matrix then delta V 2 0 delta V 3 0 right.

So, delta Q 2 0 delta Q 3 0 you have computed. So, delta V 2 0 delta V 3 0 this matrix inverse this is actually inverse I have put this one to the power minus 1 here also this one also we have put this matrix to the power minus 1 this is inverse right and; that means, your here also and delta Q 2 0 you computed minus 0.102 and delta Q 3 0 1.051 with that delta V 2 0 we got 0.0132332 and delta V 3 0.0244 right.

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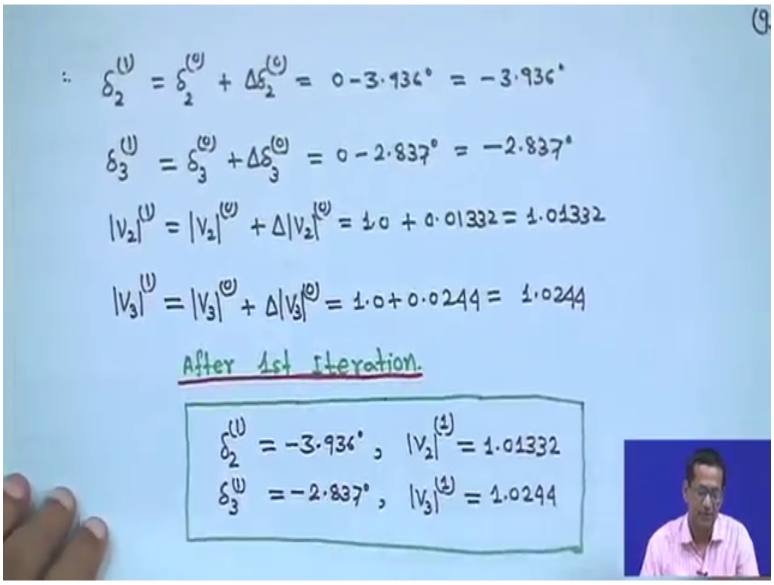

Therefore, delta 2 1 that delta 2 0 plus delta delta 2 0 so initial value of delta 2 0 the 0 minus 3.936 so minus 3.936 degree.

So, delta 3 1 is equal to delta 3 0 plus delta delta 3 0. So, is equal to minus 2.837 degree right 0 minus 2.837 degree is equal to minus 2.837 degree. Similarly for voltage V 2 1 magnitude of course, V 2 0 plus delta V 2 that is 1.0 plus 0.01332, 1.01332 right and V 3 1 is equal to V 3 0 plus delta V 3 0 that is your 1.0 plus 0.0244 that is 1.0244. So, after first iteration we got delta 2 1 is minus 3.936 degree and magnitude voltage is 1.01332 and delta 3 1 we got minus 2.837 degree and V 3 1 is 1.0244 this is after first iteration right.

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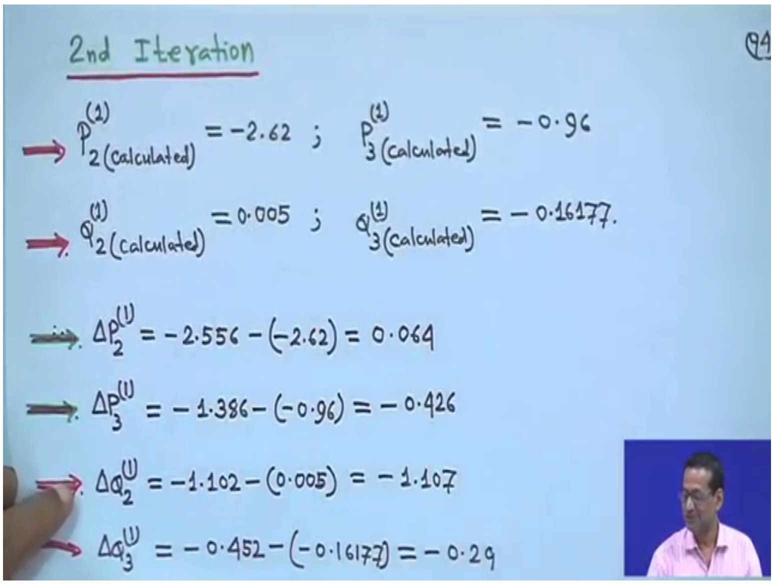

Now, for second iteration this all you will do of your own right everything shown to you using this using this new values using this new values right are all are all other parameters please calculate P 2 1 calculated we I we got minus 2.62 P 3 calculated one we got minus 0.96; Q 2 1 calculated we got 0.005 and Q 3 1 calculated we got minus 0.06177 with this delta P 2 1 is P 2 calculated minus your these thing what you call that schedule minus calculated right. So, schedule value is this value is fixed actually schedule value is fix only calculated value you have to match right mismatch you have to see these are the schedule value and these are calculated value see it is coming for 0.064 delta P 3 1 is coming minus 0.426 right delta Q 2 1 is coming minus 1.107 and delta Q 3 1 is coming minus 0.29.

So, these are the; that means, solves; that means, your solves has not converse right because these are these are significantly large right, so there after these.

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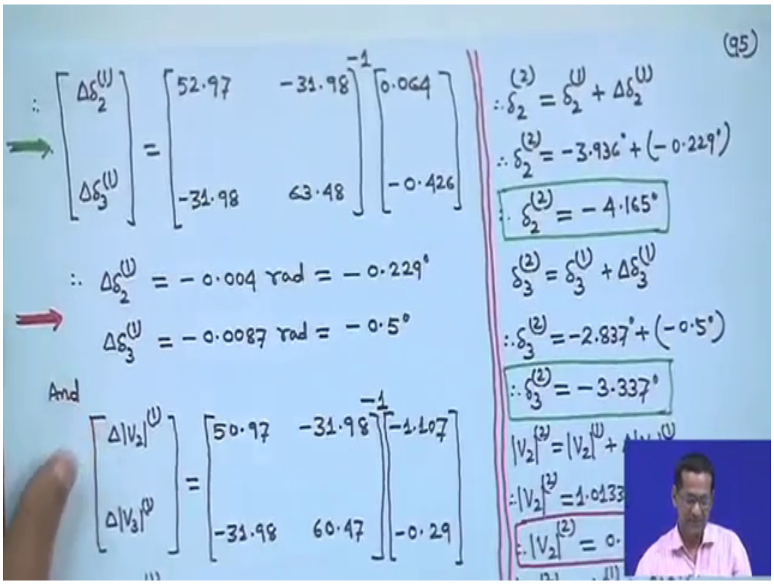

After these Jacobian was not changed this is the remain J 1 remain same. So, delta delta 2 1 delta 3 1 this Jacobian J 1 is inverse right it is retained. So, it is 0.064 it is minus 0.426 that is your delta your what you call delta P 2 delta P 3 with this we get delta delta 2 1 is minus 0.229 degree and delta delta 3 1 is minus 0.5 degree. Similarly your delta V 2 and delta V 3 is this, this is J 4 this matrix is J 4 its inverse minus 1 is written inverse and your this is your delta your this thing Q 2.

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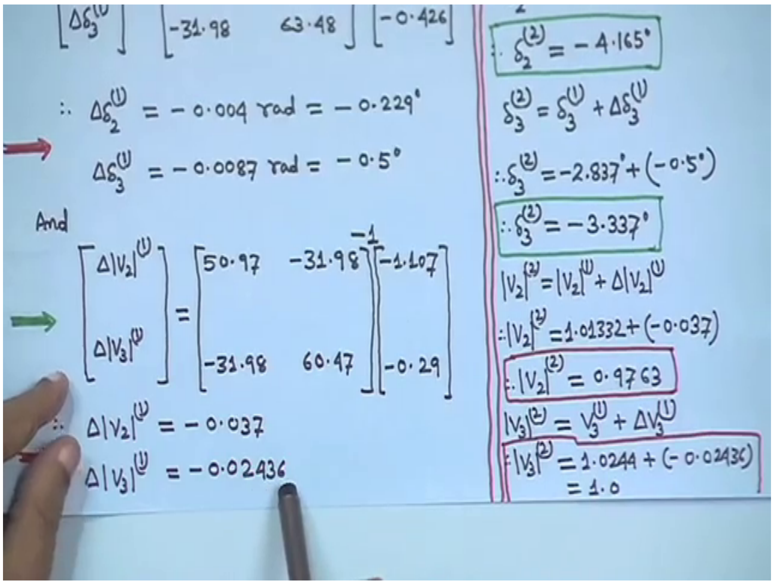

And this is delta Q 3 right with that we got delta V 2 1 is minus 0.037 delta V 3 1 minus 0.02436 right with this with this delta 2 2 we got this your minus 4.165 degree right that delta 2 2; delta 2 1 plus delta delta 2 1 delta delta 2 1 right. Similarly your delta 3 2 also you will get using this one you will get minus 3.337 degree, similarly voltage built to is equal V 2 1 plus delta V 2 1 that will gets 1 plus 0 1 3 3 2 plus in bracket minus 0.037, it is coming 0.9763 right.

And similarly V 3 2 you will get 1.0244 plus in bracket minus 0.02436 which is approximately that is one this is the result we have got after second iteration I did in try for third iteration if you try for another iteration or. So, it will be better. So, all the data are given, but you have understood that how we will move step by step an you would Newton-Raphson method.

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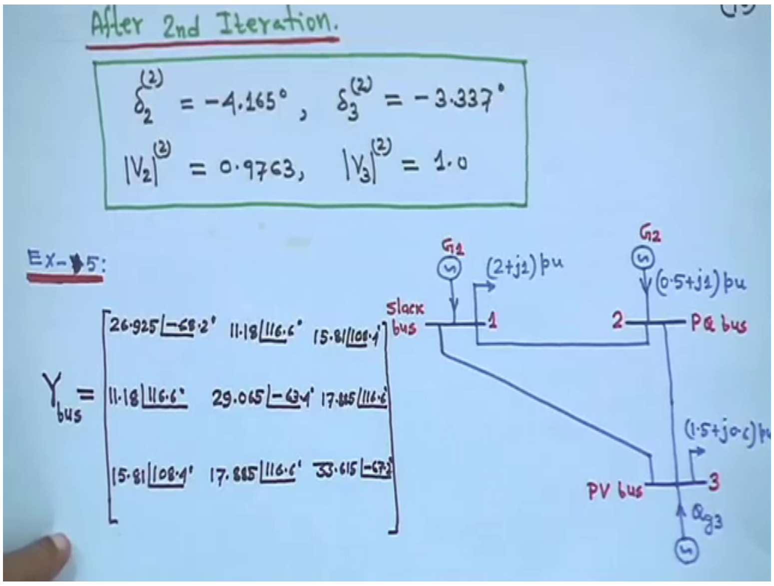

So, after second iteration delta 2 is minus 4.165 degree and delta 3 you will get minus 3.337 degree V 2 after second iteration 0.9763 per unit and V 3 2 you will get 1.0 per unit right. So, this is actually your what you call that after second iteration when considering all your what you call all busses are your P Q bus 3 bus problem same problem has Gauss Seidel method same problem, but one thing I did not make the in tabular form you can check the your what you call after second iteration what result you have got in Gauss Seidel particularly voltage and its angle right and what you have got it, but for this one I have not calculated line flows a line losses because the methodology has been shown to you right.

So, it is there is no question I did it repeat that one right it. So, everything is understandable to you now right now we take another example of Newton-Raphson method that is using P U bus. So, this is the diagram this is the diagram. So, this is 3 bus problem right. So, bus one it is slack bus right and another thing is adverse 1 2 plus J 1 that data this is this is actually a dummy parameter right.

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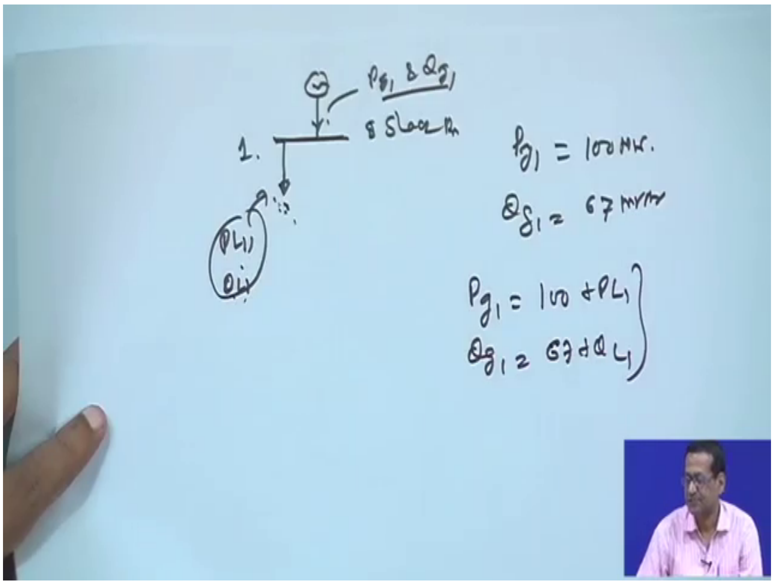

So, I told you once that if slack bus is there the slack bus is there suppose this is your slack bus this is your slack bus right. So, generator is here right suppose bus one is a slack bus. So, just hold one. So, bus one is a slack bus right and in that case your this P g 1 and Q g 1 are computed actually when solution has converge.

But if you have a some load right if you have some load for example, if it is pl one and Q l one. So, this parameter the this pl one this thing Q l 1 it actually it acts as a dummy parameter during iterative process it does not need anything does not I mean comes in to that iterative process, but suppose, but after load flow is converse suppose you have got P g 1 value. For example, say I am just telling say you got 100 megawatt and suppose Q g 1 you got say 67 megawatt after the load, but these are the dummy parameter, but if load is connected suppose if it is like this then actually P g 1 will be after that you add this one actually it has to be this one that we it will come from this and Q g 1 it will it will be your 67 plus Q l 1 these 2 have to add, but if anything is there during iterative process this are not required right.

So, but in this case in this case I have just given it intentionally that are slack bus to plus J 1 per unit right. So, this is a dummy parameter right and this P Q bus it is it is given that your 0.5 plus J 1 right whatever injection is coming and P V bus it is given 1.5 plus J 0.6 this is the load right, but some as it is a sometimes we call is as a generation bus generator bus right because Q g you have to you have to bring it from somewhere; that means, although Q l the although Q l is Q l 3 is known, but Q g 3 is not known; that means, net power injected at this bus suppose it is Q 3 is equal to Q g 3 minus your 0.6 as Q g 3 is unknown. Therefore, Q 3 is unknown right although load is given.

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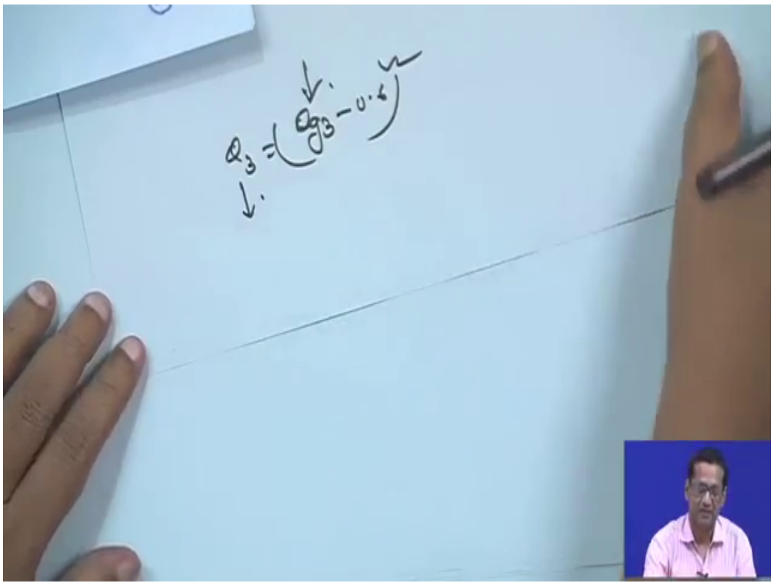

But this one is not known right; that means, Q 3 injected power is not known for this bus your for this bus it is your Q 3 injected power is equal to Q g 3 minus 0.6 right although load is known Q l 3 is known, but this is your unknown; that means, Q 3 is also unknown right. So, this bus is a this bus is taken as P V bus right and Y bus matrix for this 3 bus problem is given all the parameters are all the parameters are given right so, but still I am reading this one if the font size is little smaller here my hand writing here become little small smaller. So, I am reading it for you that first one is Y 1 1 26.925 the angle minus 68.2 degree, this is 11.18 angle 116.6 degree, this is 15.8 angle 108.4 degree this is this symmetric matrix.

So, 11.18 angle 116.6 degree this is 29.065 angle minus 63.4 degree and this is 17.885 angle 116.6 degree this one again 313 and 31 same. So, 15.81 angle 108.4 degree 17.885 angle 116.6 degree.

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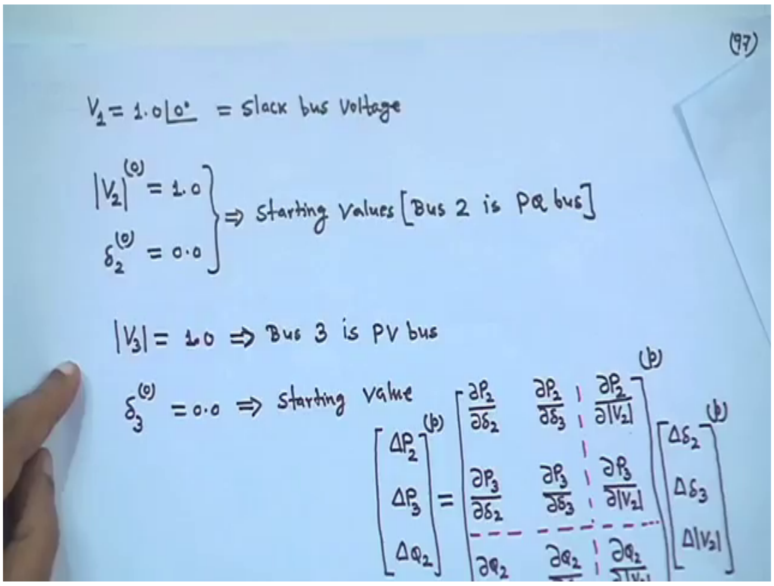

And 33.615 angle minus 67.2 degree. So, this thing is given Y bus matrix is given and all the initial values slack bus voltage V 1; V 1 also is given right slack bus voltage V 1 we are taking one angle 0 degree this is the slack bus voltage for this problem now for P V bus V 2 V bus 2 is a bus 2 is a this thing it is a P Q bus 2 is a P Q bus.

So, starting values V 2 0 magnitude we will take one and delta will be taken there is a starting values of bus 2 is a P Q bus right and bus 3 is a V 3 bus you sorry it is a P V bus right here voltage magnitude you want to maintain at 1.0 magnitude bus 3 is a, but an initial values of voltage angle here bus 3 it is delta 3 is 0 0 0 right. So, question is the first we have to form the Jacobian. So, in this case I told you that whether it is P V bus or P Q bus J 1 will remain same right.

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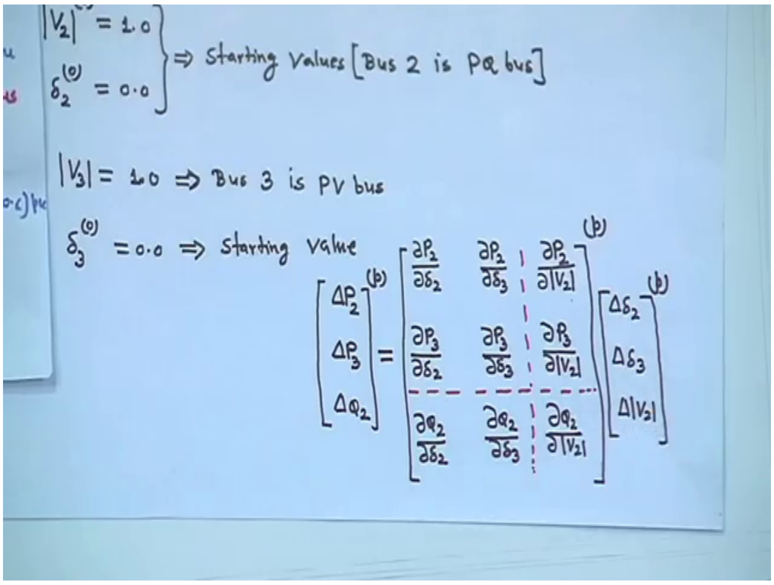

So, this is delta P 2 upon delta delta 2 delta P 2 upon delta delta 3 delta P 3 upon delta delta 2 delta P 3 upon delta delta 3 this is delta delta 2 delta delta delta 3 and this P actually for iteration count right. So, as bus voltage magnitude is fixed that is V 2 is your magnitude 1.0. So, there is no question of delta V 2 iterative process delta V 2 will never come because this voltage magnitude here is fixed at one per unit at one per sorry at bus 3 that voltage magnitude is fixed.

So, in that column vector this side; right that delta V 3 will never come because V 3 as delta V 3 is fixed magnitude. So, no question of delta V 3 that is why, but V 2 will be there delta V 2 will be there because bus 2 is a P Q bus right that is why delta delta 2 delta delta delta V 2 this 3 variables are there that is why this; this one J 1 J 2 it will be first one will be delta P 2 upon delta V 2 this one.

Second cases it will be delta P 3 upon delta V 2 and third case this one delta Q 2 upon delta delta 2 delta Q 2 upon delta delta 3 and this is delta Q 2 upon delta V 2 right and this is V 2. So, delta V 3 will not be there because bus 3 is a P V bus and V 3 voltage magnitude is fixed, so no iterative question for your bus 3 voltage magnitude. So, delta V 3 should not be there pp given for iteration count I hope this is you have understood now how to form the Jacobian matrix for P V bus the small example I have taken such that you can understand right.

So, question is that that one formula was given that if you have n number of busses if you have if you have n bus total number of bus n.

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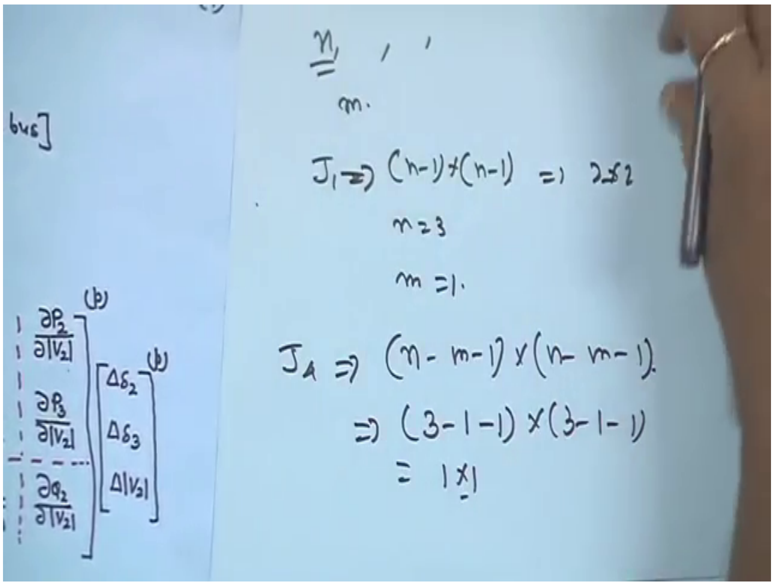

And one bus is a slack bus and you have m number of P V bus then J 1 will be as it is n minus 1 into n minus 1. So, for this example n is equal to 3, because 3 bus problem this is 3 bus problems. So, n is equal to 3 right; that means, this Jaco J 1 will be 2 into 2 matrix right and your J 4 this is your J 4 J 4 is delta Q 2 by delta V 2 single element only and you have m is equal to 1 1 P V bus is there. So, for the J 4 right it will be n minus m this is small example n minus m minus 1 right. So, this one will be your n is equal to 3 only one P V bus then minus 1 into 3 minus 1 minus 1 that is 1 into 1, so, J 4 1 into one single element right; so just for you understanding right.

So, this thing what you call this is J 1 J 2 J 2 is not anyone n into 1 right. So, here also it is not like that right it is it is a it is a 2 into 1 it is 1 into 2, but anyway for our iterative process what we will do this 1 and this J 2 and J 3 we will drop will not consider that we will not consider that right. So, if we do not consider that then what will happen that.

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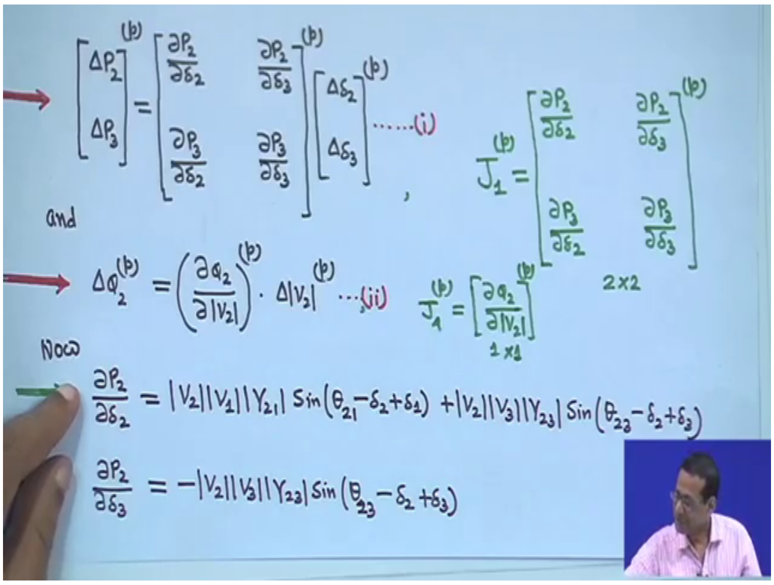

This decoupled load flow case this is delta P 2 delta P 3 P this is J 1 matrix delta P 2 delta delta this P I am not uttering again and again this is iteration count understandable right and delta P 3 delta 2 delta P 3 delta 3 delta delta delta this equation one I have taken right and J 1 P is this 1 is this written here also written here also right see and delta Q 2 J 4 actually it is a single element I just showed you. So, it is delta Q 2 upon delta V 2 into delta V 2.

Because this is your from this equation from this equation J 4 into this is thing. So, delta this is dropped this is dropped this one J 3 and J 4 dropped from this equation. So, delta Q 2 will be delta Q 2 delta V 2 into delta V 2 right so; that means, delta Q 2 P this one is equal to delta Q 2 upon delta V 2 into delta V 2 P iteration count I told you no need to tell again and again right. So, J 4 actually P is equal to 1 into 1 matrix I show you this is J 1 and this is J 4; so 1 into one matrix right.

So, now, that P 2 expression the delta P 2 upon delta delta 2 expression previously we have given for 3 bus problem. So, expression will remain same no change right and so, that delta derivation derivative also given previously. So, there will be no change because that was also 3 bus problem this is also 3 bus problem.

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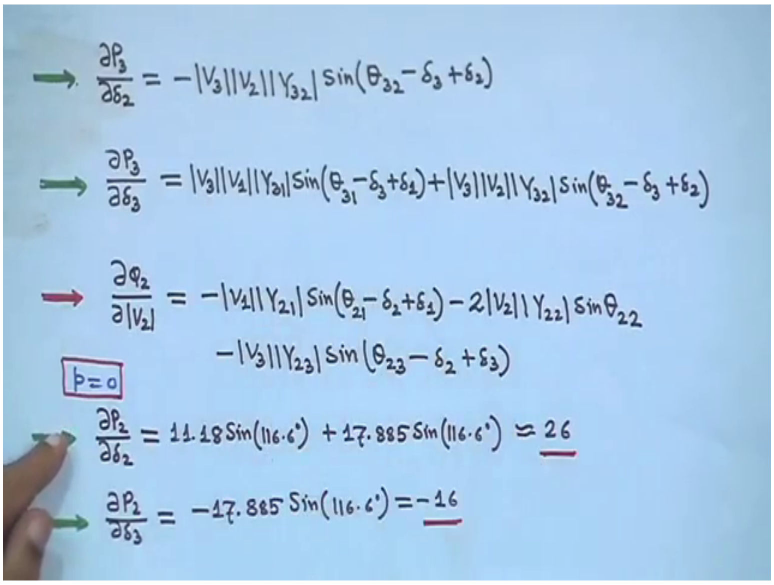

So, no change and delta P 2 upon delta delta 3 also same thing right, so, and similarly your delta P 3 upon delta delta 2 right same thing and delta P 3 upon delta delta 3 it is also the same thing right. So, so and similarly Q 2 expression was also given. So, delta Q 2 upon delta V 2 this is also the same expression. So, with this all the parameters are given Y matrix is given initial values are given you substitute in those expression right.

So, you will get delta P 2 upon delta delta 2 you will get a approximately 26 just you substitute just you substitute right similarly delta P 2 upon delta delta 3 upon substitution all you will get minus 16 right you put all these values all initial values are given. So, you will get it like this right.

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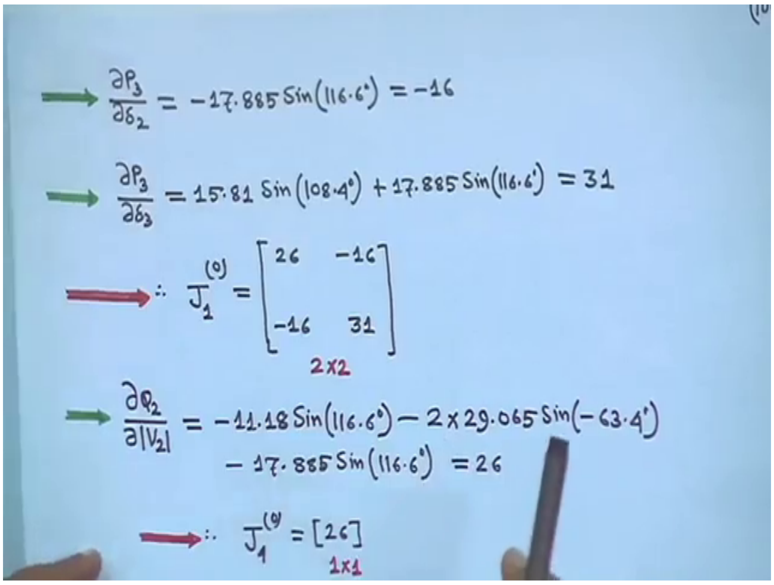

Similarly, delta P 3 upon delta delta 2 if you put all this it will become minus 16 and delta P 3 upon delta delta 3 upon substitution of all those values you will get it is thirty one. So, substitute all then Jacobian matrix initial will get 26 minus 16 minus 16; 31, it is a 2 into 2 matrix and this value will not change next iteration will take the this is constant right.

Similarly delta Q 2 upon delta b 2 that is J for only single element put all these values all the values whatever is given all the values you will get 26. So, J 4 0 is equal to simply 26 it is 1 into 1 matrix single element, but still I am writing it is 1 into 1 right.

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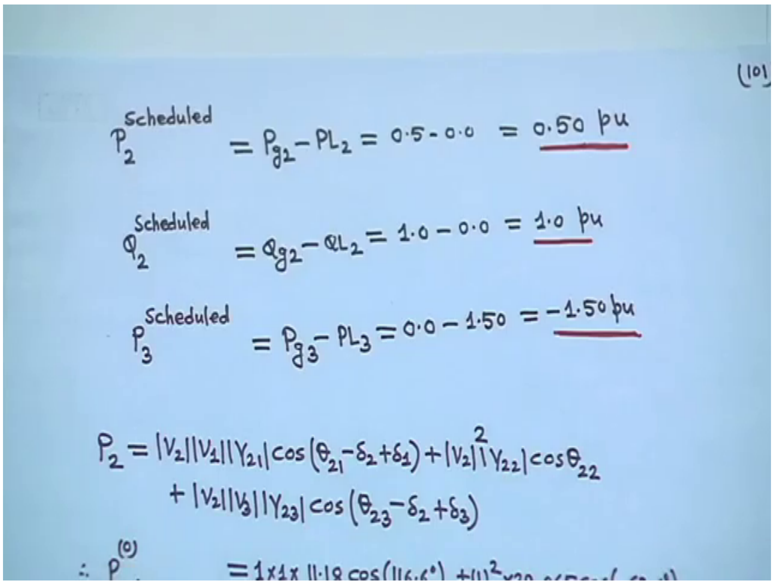

After this that your P 2 that your P 2 scheduled values right that is your P g 2 minus P L 2. So, at bus 2 your there was a no load. So, P g 2 is 0.5.

Let me see your the diagram has gone just see, but I have shown the diagram to you right you can I have got it I think here at P g 2 these the generation load is not shown here right load is not given here. So, that mean P L 2 Q l 2 both are 0. So, P g 2 minus pl 2 is equal to 0.5 minus 0. So, 0.5 similarly Q 2 that schedule power Q g 2 minus Q l 2, so 1 minus 0 that is 1 per unit right.

Similarly, P 3 schedule is P g 3 minus P L 3 right. So, at bus 3 your what you call this one that your P g 3 there is no P g 3 generation right no P g 3. So, it is 0. So, it is 0 minus 1.5. So, minus 1.5 0 per unit now here 3 bass problem; so, this P 2 expression also we have shown, but here I have given per P 2 expression using that equation 50 and 51 right for P pi. So, I is equal 2.

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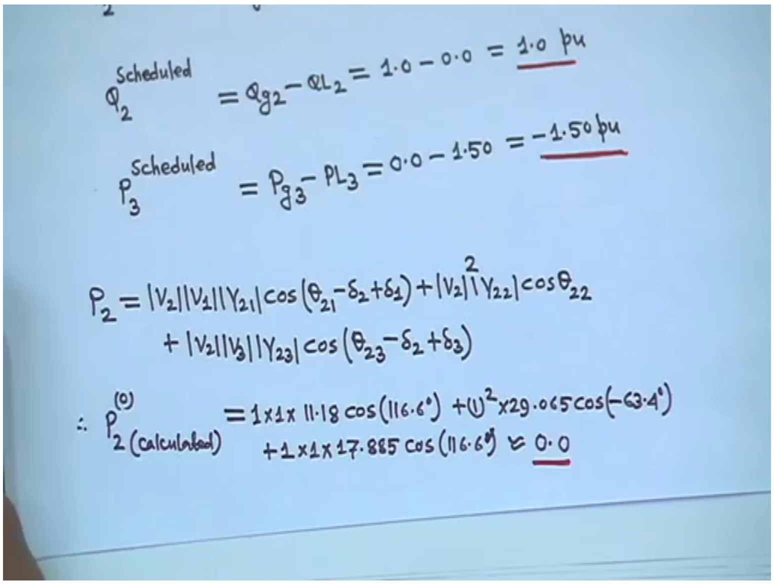

So, this is P 2 expression substitute all the values whatever you have got you will get P 2 0 calculated is approximately 0 right you substitute all these right. So, all the steps have been shown. So, now, everything will be easier for you if is a substitute if you substitute it will be a 0 approximately equal to 0.

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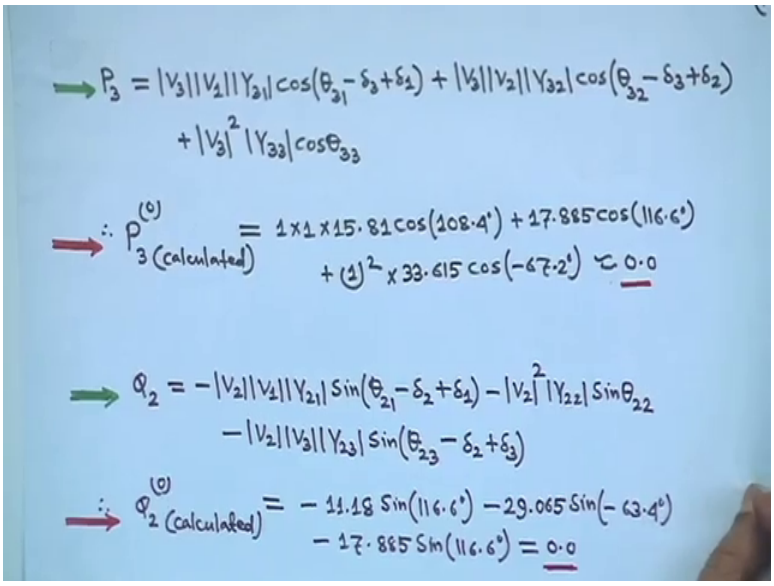

Similarly, similarly that P 3 P 3 also expression is given same as before put all the values all the values are known you now right if you do. So, you will find P 3 0 calculated also will become approximately equal to 0.0 right similarly that Q 2 whatever that all the values if you put the Q 2 expression also given before, but here also made it right using equation whether same equation and expansion right. So, for I is equal to 2 and put all the values then Q 2 0 calculated also will become initially approximately 0. So, all P 2 Q 2 P 2 P 3 and Q 3 calculated in this calculated values initially all are 0s right.

So, only thing is that all this data put correctly right all calculations I do hope I am made all this calculation correct, but we all are human being. So, we are you know facing calculator. So, there is a possibility of mistake calculation mistake from my side also. So, if you find any error or anything you should mail me such that I can rectify myself right and you always appreciate if you can find out any error or any mistakes or anything has been made it will be appreciated right.

So, such that I can rectify myself right. So, because it is a huge mathematics and so many calculations are there right throughout this course you will you know that it is mathematics. So, if I make in any calculation error anything anywhere. So, please let me know this such that I can rectify.

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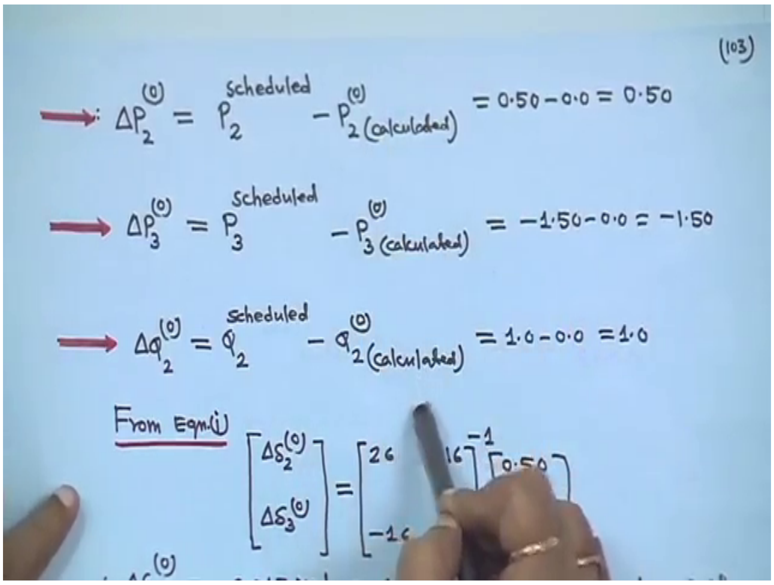

Therefore, delta P 2 0 is equal to P 2 schedule minus P 2 calculated. So, that is 0.5 minus this one this is 0.5 is step I am showing you such that you can understand actually the flow of your algorithm right and delta P 3 0 will be P 3 schedule minus P 3 0 calculated.

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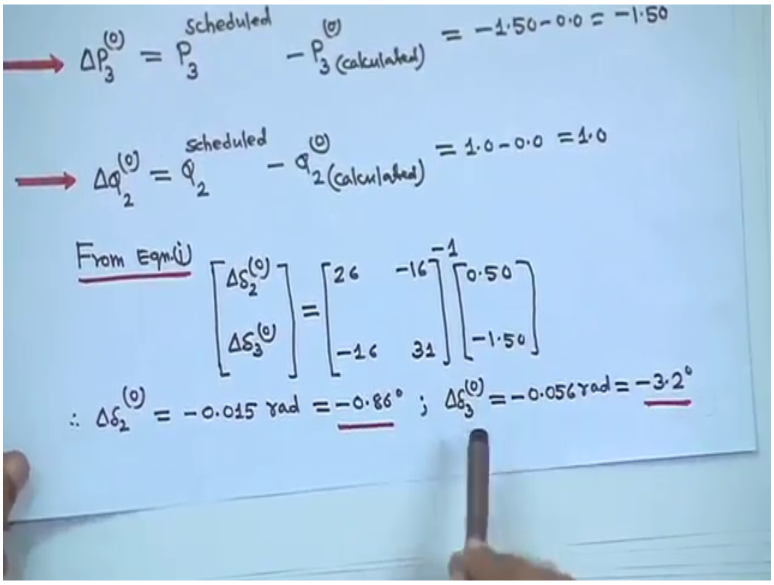

So, there because all calculated values you have got 0. So, they will remain same minus 1.5 similarly delta Q 2 0 is equal to Q 2 schedule minus Q 2 0 calculated. So, that is 1.0. Therefore, from equation this one; 1 delta delta 2 delta delta 3 that is initial values this is that J 1 matrix these already we have seen computed in bus I have put everywhere minus 1 right. So, overlook this one into your delta P 2 0 that is 0.5 and delta P 3 0 minus 1.50.

Then delta delta 2 0 is equal to minus 0.015 radian that is minus 0.86 degree convert into degree and delta delta 3 0 will be minus 0.056 radiant that is equal to minus 3.2 degree.

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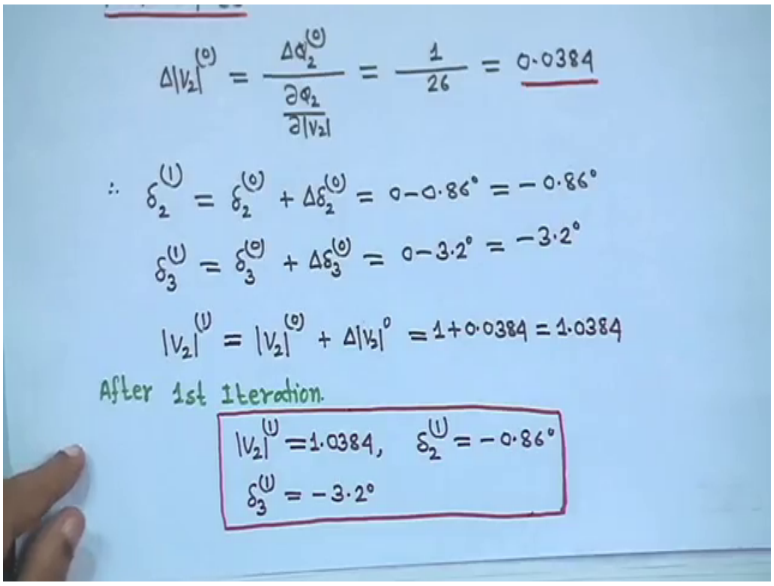

This is your delta delta 2 and delta delta 3 right and delta your from equation 2 that is delta V 2 right delta V 2 it is a single element to it is delta Q 0 upon delta Q 2 upon delta V 2. So, no matric inversion is return. So, delta Q 2 upon delta V 2 is 26 we have computed just you have seen and delta Q 2 0 is 1. So, one upon 26 that is 0.0384 right therefore, update this value delta delta 2 1 in past it has in delta 2 0 plus delta delta 2 0 that is 0 minus 0.86 degree; so, minus 0.86 degree.

And similarly delta 3 1 is equal to delta 3 0 plus delta delta 3 0 that is 0 minus 3.2 the minus 3.2 degree right therefore, V 2 1 magnitude one is equal to V 2 0 the voltage one right that is the P Q bus that is bus 2 is P Q bus plus delta V 2 0. So, 1 plus 0.00; 0.0384 1.0384 this is our after first iteration V 2 1 is equal to 1.0384 and delta 2 1 is minus 0.86 degree and delta 3 1 is minus 3.2 degree this is first iteration these value we got.

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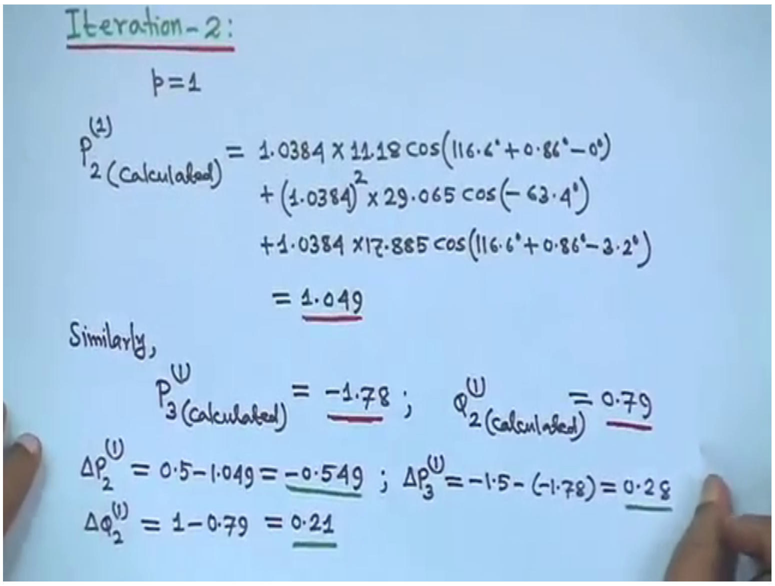

Next second iteration when P is equal to 1 you please calculate P 2 calculate use the same formula put all the put all the all the data previous data some data constant that you know and these all the all the in values whatever you have got whatever you have got here you put and then you calculate P 2 calculate for the second iteration you will get 1.049 right this time P 2 calculated.

Similarly P 3 calculated you put you will get minus 1.78 directly I writing the value, because you know this now right and Q 2 1 calculated if you calculate you will find 0.79

right. Therefore, delta P 2 1 you will 0.5 minus 1.0 that is schedule minus calculated right you will get minus 0.549.

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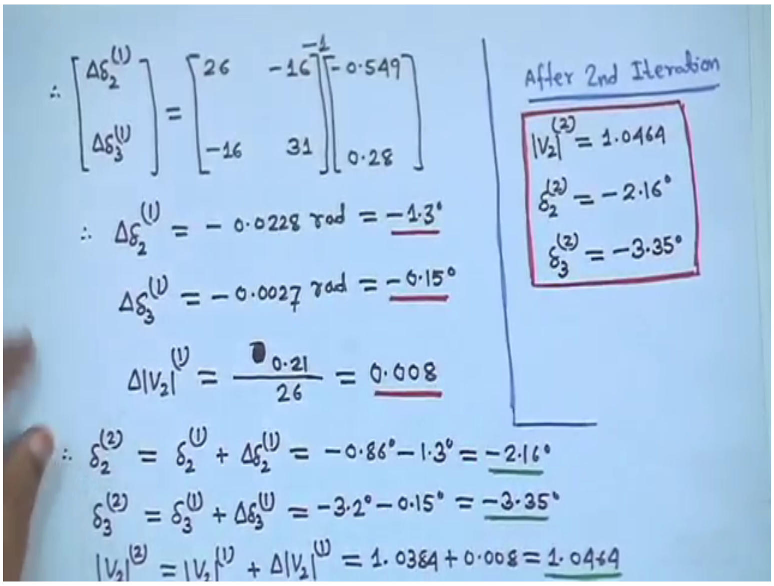

Similarly, delta P 3 will get 0.28 and similarly delta Q 2 you will get 0.21 right. So, with these your what you call that with these thing you will you will get in the second iteration that first you find delta delta 2 1 delta delta 3 1 same these matrix detain same it is in bus right minus 0.549 and this 0.2; 0.28 just we have calculated.

So, you will get delta delta 2 1 is minus 1.3 degree and delta delta 3 1 is minus 0.15 degree there and delta V 2 1 you will get 0.21 upon 26; so, 0.008 right with this you update. So, delta delta 2 will be delta delta 2 1 plus delta delta 2 1 minus 0.86 minus 0.1; 0.3; so, minus 2.16 degree delta 3 to will be delta 3 1 plus delta delta 3 1 that is minus 3.2 minus 0.15. So, minus 3.35 degree and V 2 2 will be V 2 1 plus delta V 2 1. So, 1.0384 plus 0.008 that is 1.0464.

So, after second iteration this is the result V 2 2 is 1.0464 delta 2 2 minus 2.16 delta 3 2 minus 3.35. So, when we are calculating P 2 your P 2 P 3 and your Q 2 right and its derivative all the time that your P V bus bus 3 voltage magnitude is always 1 in that right.

Thank you again will come to back.