Power System Analysis
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Lecture - 34
Load Flow Studies (Contd.)

Ok. Now, the off diagonal elements of J 1 are it will be single term only because it is delta P i upon delta, delta k for example, for example, this one your same thing rewriting for this one that P 2 expansion right.

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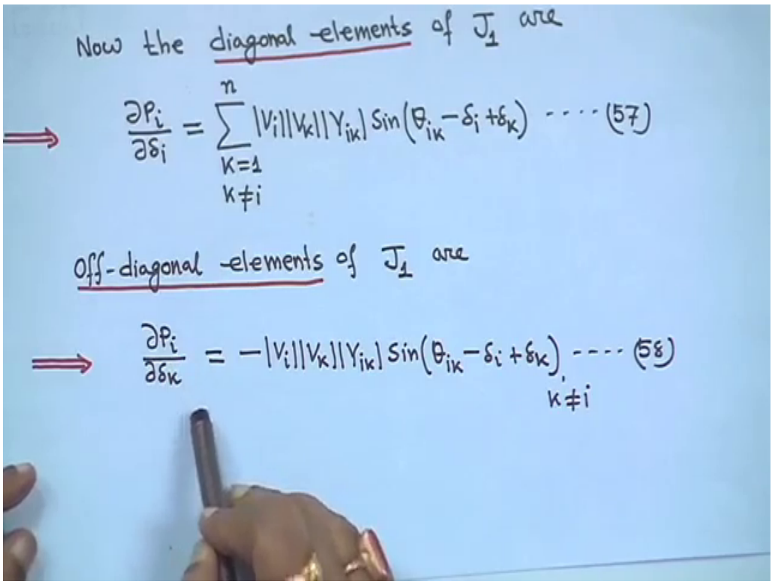

Same thing trying to rewrite right; and for example, P 2, P 2 is equal to right, V 2 then V 1.

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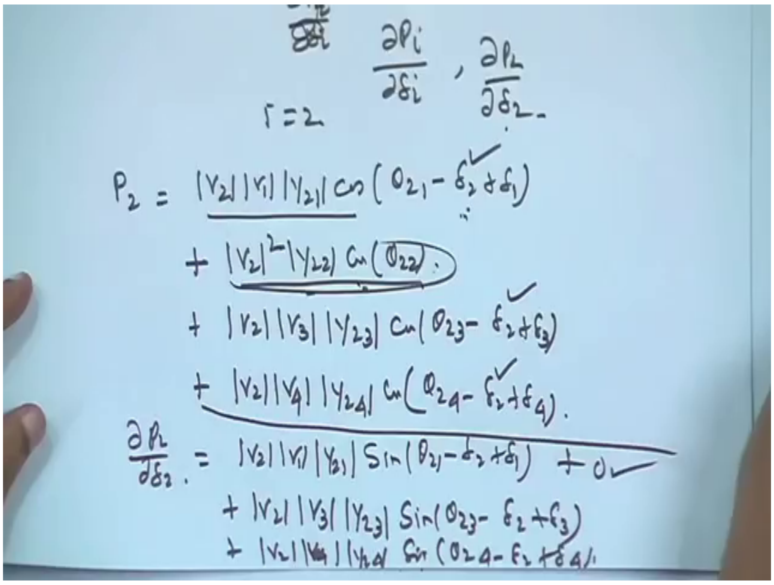

Then Y 2 1 then cosine theta 2 1 minus delta 2, plus delta 1 plus V 2 square

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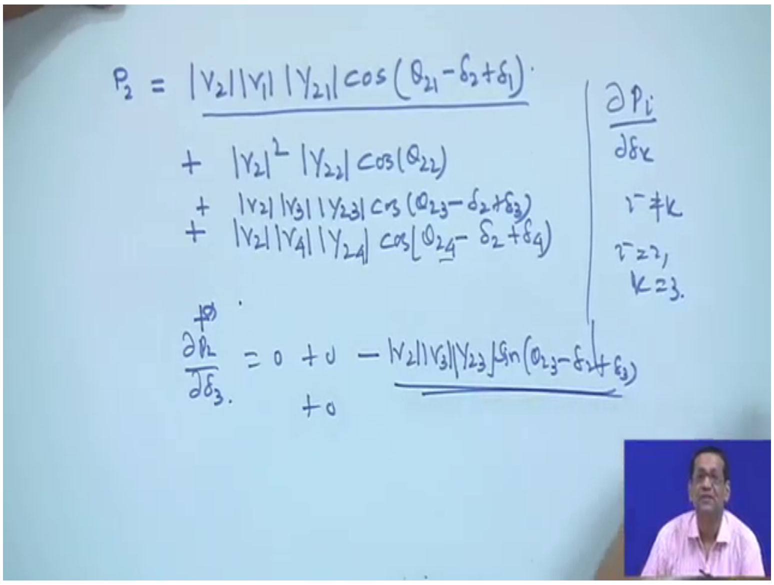

Then Y 2 2 cosine theta 2 2 plus V 2 V 4 then Y 2 4 cosine theta 2 4 minus delta 2 plus delta 4, plus your this is that last term I have written third term will be somewhere here right. I am putting here V 2 then V 3 then Y 2 3 right, then cosine your theta 2 3 minus delta 2 plus delta 3 right.

Now, if you take suppose it is they you have to take delta P i upon delta, delta k they, they write say delta P i by delta, delta k right. So, i i not is equal to k P i is equal to there is a diagonal element that we have seen. So, i not is equal to k say i is equal to 2 and say for example, k is equal to 3 now if; that means, if you take derivative; that means, delta P 2 by delta, delta 3. So, this term is independent of delta, delta 3. So, it will be 0 right, second term also 0 right, and third term is there with it will be your what you call minus, your this is your cosine. So, derivative is minus right. And it is your delta 3.

So, it will be for example, V 2 V 3 Y 2 3 then sin theta 2 3 minus delta 2 plus delta 3 right. And it is independent of delta 3. So, last term is also 0. So, only single term right. That is why that you are the off diagonal elements right. It will be always your single terms, but diagonal elements k not is equal to I, but it will be summation of this term right.

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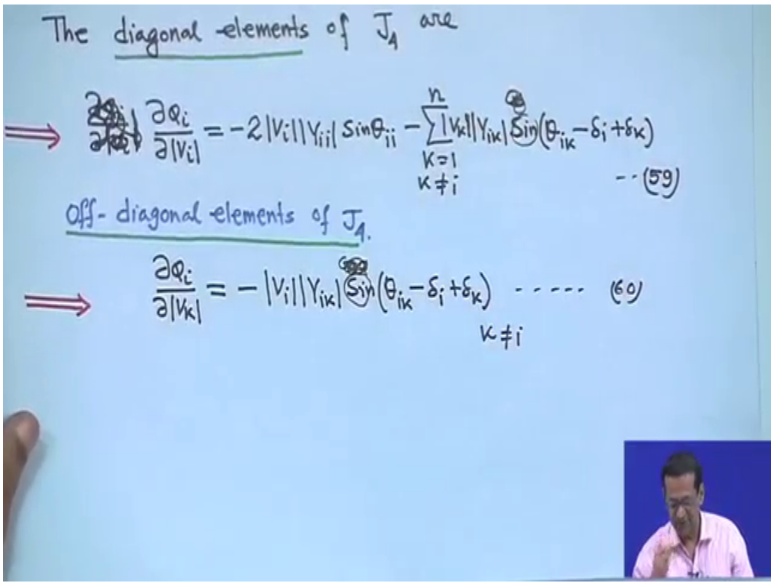

So, this is off diagonal elements of J 1 this is equation 58, but k not is equal to i so similarly the diagonal elements of J 4 right. So, in this case what will happen that diagonal elements of J 4 that is Q i again I have to expand and I have to tell you what is this, this is a first let me tell you delta Q by delta V i magnitude of course, the magnitude minus 2 V i then magnitude Y ii sin theta ii minus k is equal to 1 to n k not is equal to i this is V k magnitude, magnitude Y k Y ik this is sin right; then theta ik minus delta i plus delta k right. And here also summation of all, but look this term is also there and this is k not is equal to i.

So, what this expression if you expand hold on, hold on, this expression Q i that is equation 51 this is your expression of Q 1 right. So, Q i rather So, suppose you want that you are what you call the way you do delta P 2 upon delta, delta 2 here also you do like this. Suppose i is equal to 2 right. Say i is equal to 2 then these equation you can write

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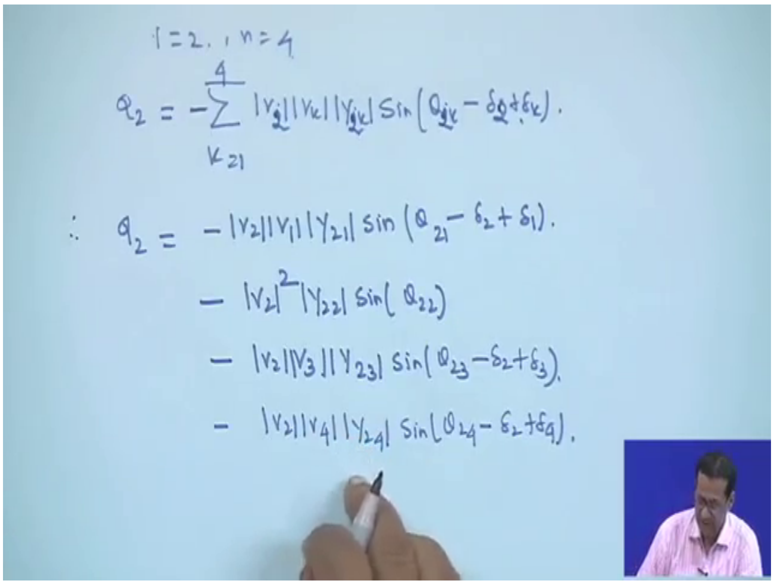

That equation 51 you can write that Q 2 is equal to sigma k is equal to 1 to 4 because n is equal to 4 right. Then it is your minus sign is there right. Then V i then V k then Y ik then sin then theta ik minus delta i plus delta k.

Now, sorry this is i is equal to 2. So, it will be V 2 right. This will be Y 2 k, V 2 Y 2 k this is also theta 2 k and i is equal to 2 means this is delta 2 right. Now if you expand this one then it will be minus V 2 then V 1 then Y 2 1 then sin theta 2 1 minus delta 2 plus delta 1 right. So, then minus when k is equal to 2. So, it is V 2; that means, it is V 2 square then Y 2 2 then sin it is theta 2 2 minus delta 2 plus delta 2 will be cancel. So, it is theta 2 2 then minus your V 2 then V 3, then Y 2 3, then sin theta 2 3 minus delta 2 plus delta 3 right. Then minus your V 2 then V 4 then Y 2 4 then sin theta 2 4 minus delta 2 plus delta 4 right.

This is you are doing it. Now if you take derivative with respect to say diagonal elements you want if you take derivative with respect to your say V 2 delta V 2.

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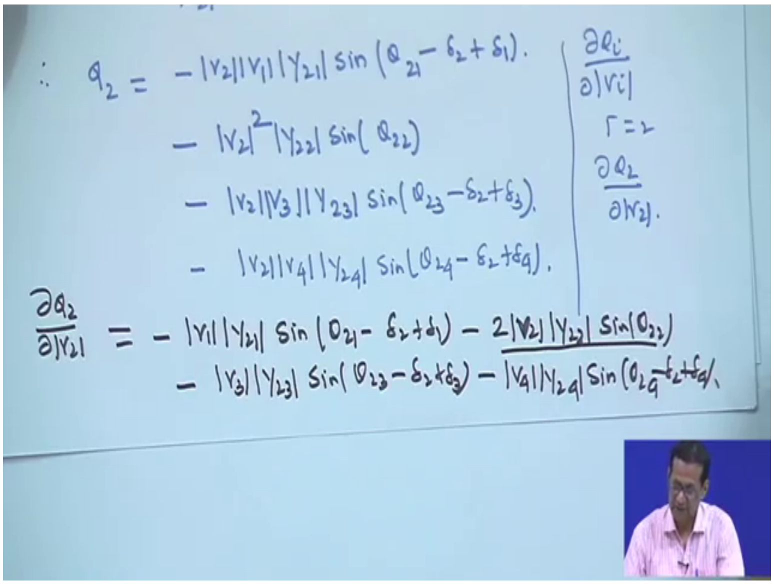

Suppose you want it is in general you have to find out delta Q i upon delta V magnitude i now we have taken i is equal to 2 right. Therefore, say delta Q 2 by delta V 2 right. If you take derivative this one with respect to your what you call V 2 then this delta Q 2 by delta V 2 this diagonal term right. So, first term will become minus V 1, then Y 2 1, then sin, then theta 2 1 minus delta 2 plus delta 1.

Now second term, this term it will become minus 2 V 2 because you are taking derivative with respect to V 2 2, V 2 then Y 2 2; then sin theta 2 2 right. Minus this one also you are taking with respect to this thing, then it will be V 3 then Y 2 3 then sin then theta 2 3 minus delta 2 plus delta 3; the last, 1 minus V 4 then Y 2 4 right. Then sin then your theta 2 4 minus delta 2 plus delta 4 right; that means, all the 3 terms are there this is also there, this is also there right.

So, here no question all 4 terms are there. So, that is why in this case you are what you call in this case this delta Q i upon delta V i that is this is the, this is the term it is there is general 2 V 2 Y 2 2 if 2 instead of 2 you replace i that is all right. So, it will be delta Q i upon delta V i minus 2 V i Y ii sin theta ii minus k is equal to 1 to n k not is equal to i V k Y ik sin this sigma i was theta ik minus delta; that means, other 3 terms are there apart from this term this one this one is there this is i th term not included there that is why, but multiplied by 2 you can include only V 2 Y 2 2 sin theta two, but others term minus V 2

Y 2 2 sin theta 2 will be there outside so that is why k not is equal to i and this is the term and this is minus 2 V i your Y i sin theta i.

Similarly if you participate del Q i upon del V k for k not is equal to i same as before like delta we will get single term, minus magnitude V i Y ik sin theta ik minus delta i plus delta k. For example, if you try to find out delta Q 2 upon delta V 3 for this exactly thing right. You will see no V 3 is here it will go no V 3 is here it will go V 3 is here only this term will be there, but here no V 3 this will also be 0. So, only here only one term will be remain one term will be there. So, that is why for off diagonal elements it is a single term right. For diagonal element summation plus for hyphen that is minus this 1 minus is there; so minus here minus here right.

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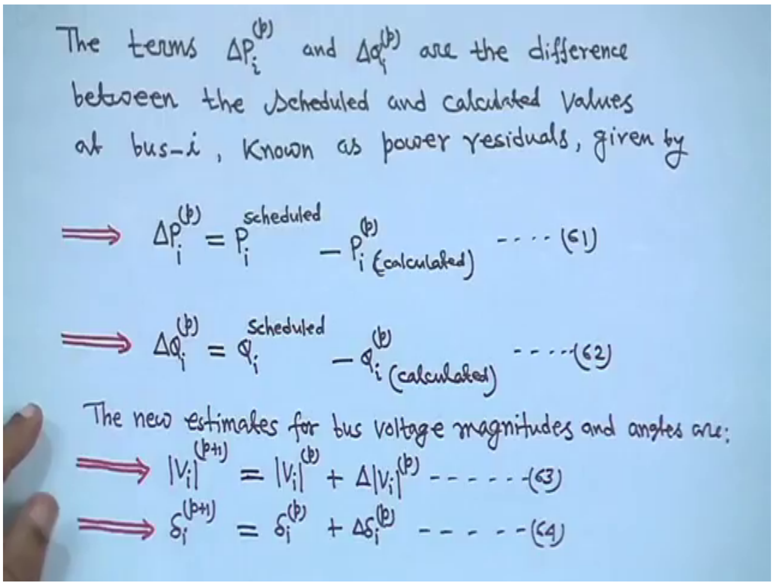

So, this is the off diagonal elements this is equation 60. The terms delta P delta P i and delta Q i at P th iteration right. These are the P th iteration are the difference between the scheduled and calculated values of at bus i known as power residuals; that means, delta P i at iteration P P i scheduled means that P i injection whatever we got in the Gauss-Seidel method that is known. And P i calculated at P th iteration means that is equation 50 and 51 from where you have to calculate; that means, this equation hold on, just hold on.

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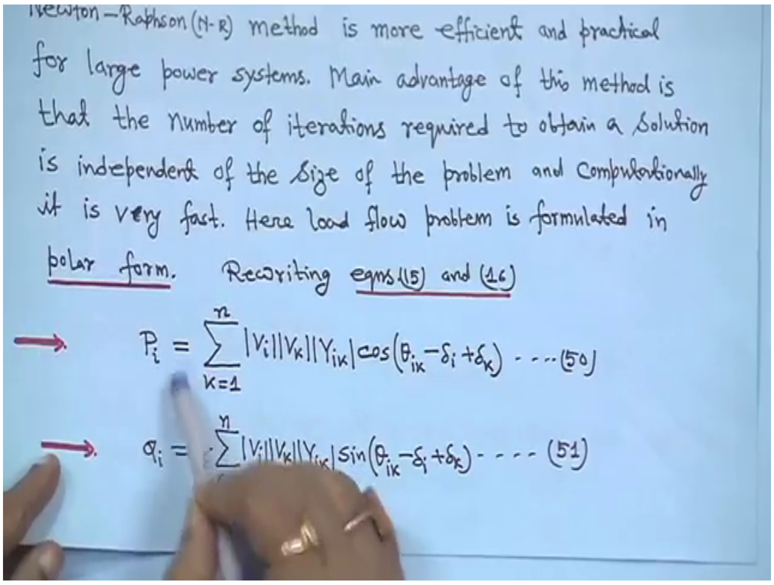

That means, this equation, this one you have to calculate at every iteration right. And this one is your what you call is your the this thing is known because at every your if it is a if it is a P bus or P q bus that P i is scheduled you know right, but if it is a P Q bus Q i is schedule also which to be known to you right.

So, that is why these 2 you calculate in every iteration right. And how to do this thing and find out that your what you call that that convergence criteria know. So, in that case same as before same as before you will take delta P max right.

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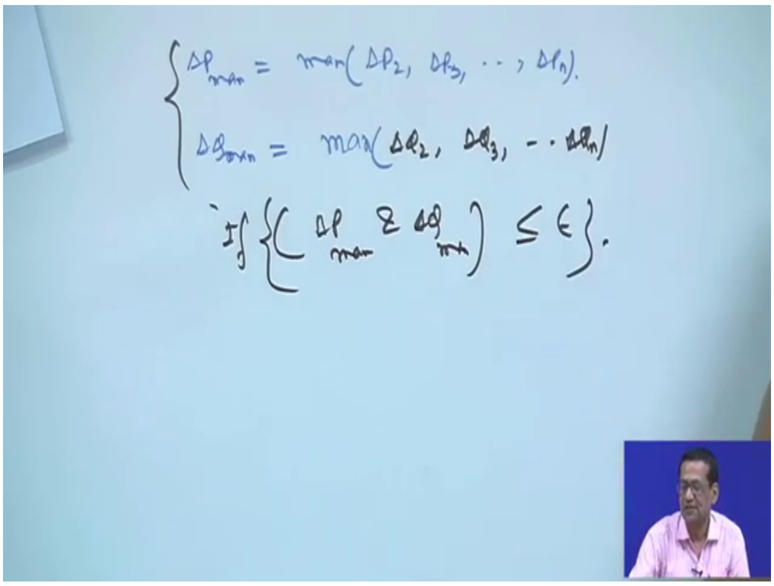

Is equal to maximum of at delta P 2 delta P 3 right and delta P i you take max of these at I mean every iteration you have to check it right. Similarly delta Q max is equal to max of right. I mean take the maximum of this one then delta Q 2 delta Q 3 up to delta Q n right. This 2 max you take if both right. If delta P max and delta Q max are both less than equal to epsilon, epsilon may be 10 to the power minus 4 minus 5 then solution as converged right.

So, that is why every a every iteration you have to check that current value and the previous value of your difference of the current value and this thing and in this case what you have to do is, here you have to take absolute value right. You take this one absolute right. So, that; that means, you have to take the absolute I forgot to put this one right. So, the new estimates for bus voltage magnitude and angles are it now you have to update that V i p plus 1 the current value will be V i p plus delta V i p and delta i p plus 1 will be delta i p plus delta, delta P is the iteration count.

So, this is equation 63 and this is equation 64. So, algorithm So, first step is you have to read system data; that means, all the data you have to just read it right, whatever data require.

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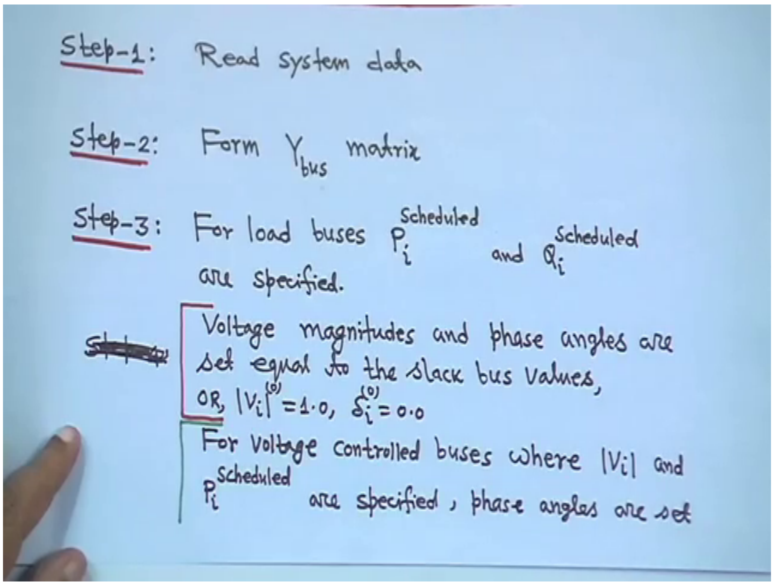

Step 2 you have to form the bus admission matrix Y bus right. Then step 3 for load buses P i schedule and Q i schedule both are specified; that means, a load buses means P Q buses right. Set this you have to see this, your PP bus we will see later right. So, voltage magnitudes and phase angles are set equal to the slack bus values that is V i initial values will be one and angle delta is these are the initial values for all i right.

So, for voltage controlled buses where magnitude V i and P i schedule are specified phase angles are set equal to the slack bus angle that is a initial values for the PP buses right. So, step 4 for load buses P i and Q i P is the iteration count right.

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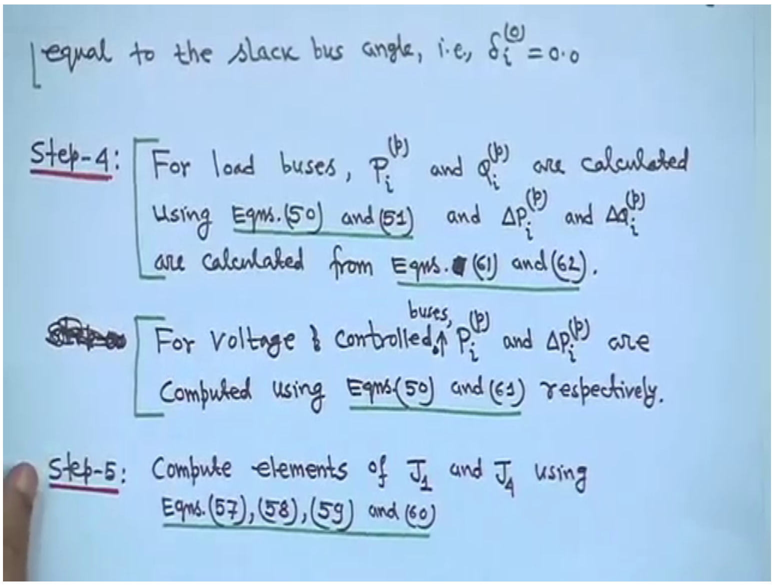

So, are calculated using I told you because in equation 50 and 51. And delta P i and delta at every iteration P are calculated from equation 61 and 62 just now I showed you the difference right. This one, this one 61 and 62 the difference right and for voltage controlled buses P i p and delta P i p are computed using equation 50 and 61 right.

So, because in the voltage controlled bus, delta P you can compute, but delta Q you cannot compute because Q is unknown right. So, compute elements of J 1 and J 4 using equation 57, 58, 59 and 60; that means all the Jacobean elements right. You have to compute right. For example, this one this is your diagonal elements this is off diagonal element for J 1 and this is diagonal element for J 4 off diagonal element for J 4. All you have to compute using 57, 58, 59 and equation 60 right. So, this one you have to compute after this you have to solve equation 55 and 56 for computing delta, delta and delta V right.

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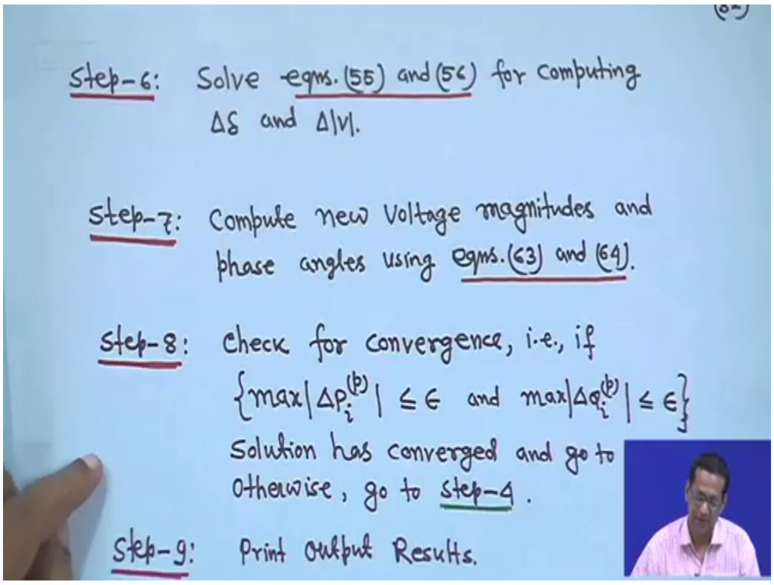

So, you have to now those delta P is equal to J 1 delta, delta and your delta Q is equal to J 4 delta V right. So, those equations you have to solve equation 55 and 56 for delta, delta and delta V those 2 equations right. Next is compute new voltage magnitudes and phase angle using equation 63 and 64; that means, this one using 63 and 64 right. Now check the convergence that if mod delta P i less than epsilon and max of this one less than epsilon i told you right. So, there I took the mod here after taking the difference taking mod same thing right. Solution has converged and go to step 9 otherwise if you have if you have taken in this expression if you have taken already mod right. So, that sin turned out positive thing taken care of right.

So, mainly 2 mod here right; mod here because already we have taken the mod right, so here I have already taken if you already taken mod here then do not take mod here and if you do not take mod here take mod here right. So, solution has converge and go to step 9. Step 9 means, you printout the result write all the outputs right. So, use using this thing you have to solve that example 2 using decoupled Newton Rawson method and perform 3 iteration. That is, what you call that your Gauss-Seidel method.

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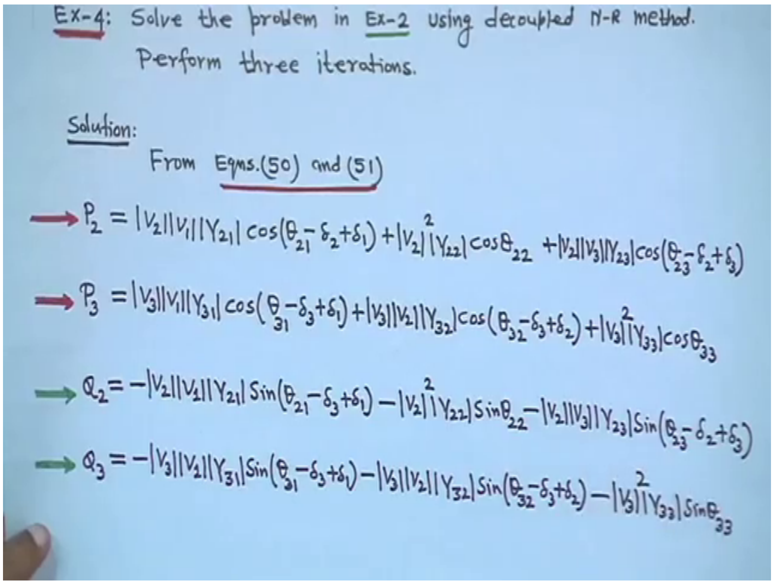

We have taken that example know example 2 once again. I am showing we have kept the same data; same example otherwise different example will bring confusion right.

So, we have get the same example just let me see where is that example has gone, just one minute, just one minute let me see where it has mixed up let me see where the diagram has gone just hold on. Just hold on otherwise does not matter it has the same data same thing right. It has it has it has mixed up with the pages anyway the same example right. And the same data same Y matrix everything remains same now equation 50 and 51 right. It has that example has your 3 bus problem right. So, that is bus one is a slack bus and bus 2 and bus 3 are picky bus right.

So, that equation 50 and your 51 you expand for i is equal to 1 to 3; that means, this equation this equation for i is k is equal to 1 to sorry, k is equal to 1 to 3 you expand similarly for this one you expand for i is equal to 2 i is equal to 3. So, if you expand then P 2 is the this expression. P 3 is this expression, Q 2 is this expression and Q 3 is this expression right. So, you expand this equation. So, I am not reading this right. If you expand you will get this one then what you do? You take the you have to find out that your diagonal elements and off diagonal elements, then what you will do? After that you have to take all the derivatives right.

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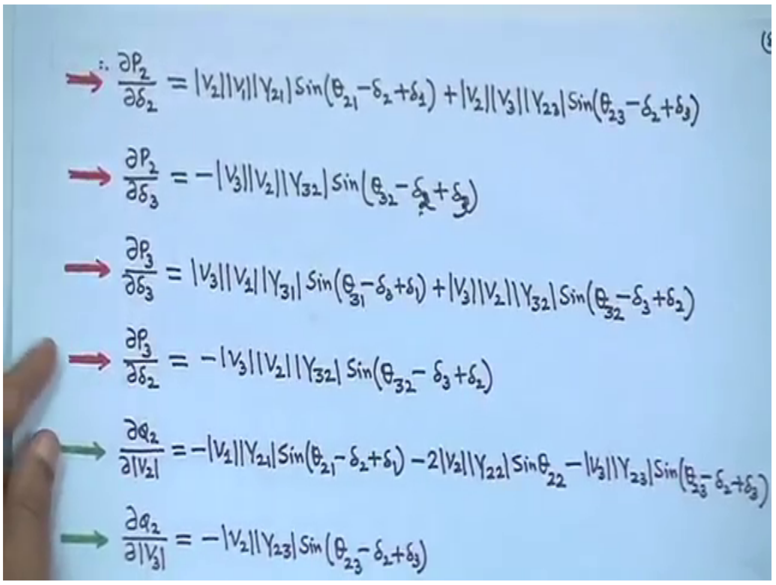

So, in that case you have to take delta P 2 upon delta, delta 2 if you take the derivative then it is V 2 V 1 magnitude are understandable. Just saying V 2 V 1 Y 2 1 sin theta 2 1 minus delta 2 plus delta 1 then plus V 2 V 3 Y 2 3 sin theta 2 3 minus delta 2 plus delta 3. This is delta P 2 upon delta, delta this is a first diagonal elements. Then delta P 2 delta, delta 3 is minus V 3 V 2 Y 3 2 sin theta 3 2 minus delta 2 plus delta 3 right. Then delta P 3 delta, delta 3 is equal to V 3 V 1 Y 3 1 sin theta 3 1 minus delta 3 plus delta 1 plus V 3 V 2 Y 3 2 sin theta 3 2 minus delta 3 plus delta, delta 2; similarly, delta P 3 delta, delta 2 minus V 3 V 2 Y 3 2 sin theta 3 2 minus delta 3 plus delta, delta 2 delta 2 right.

And this one your delta Q 2 upon delta V 2 now you take, because all this expression Q 2 Q 3 all are given here for you right. All are given here. So, if you take derivative of this one delta Q 2 delta V 2 then minus V 1 Y 2 1 then your sin theta 2 minus delta 2 theta 2 1 minus delta 2 plus delta 1, minus 2 V 2 Y 2 2 sin theta 2 2 minus V 3 Y 2 3 sin theta 2 3, minus delta 2 plus delta 3 therefore, delta Q 2 upon delta V 3 it is a single term off diagonal minus V 2 Y 2 3 sin theta 2 3 minus delta 2 plus delta 3 right. Next 2 more terms are there right.

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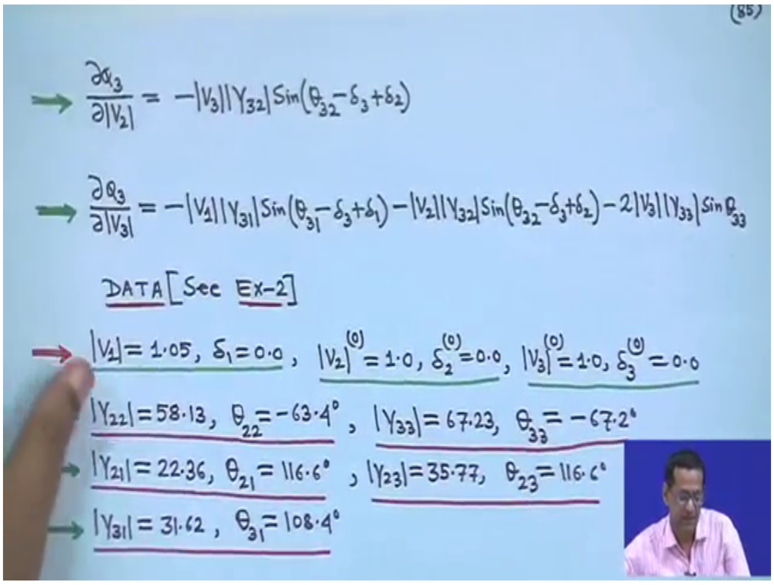

Next is next is delta Q 3 upon delta V 2 minus V 3 Y 3 2 sin theta 3 2 minus delta 3 plus delta 2. Similarly delta Q 3 upon delta V 3 will be minus V 1 Y 3 1 sin theta 3 1 minus delta 3 plus delta 1 then minus V 2 Y 3 2 sin theta 3 2 minus delta 3 plus delta 2 then minus 2 V 3 Y 3 3 sin delta sin theta 3 3 right.

Now, data example 2 same data we are taking. So, all the data's are given here magnitude of Y it is angle then V V 1 initial values you have taken 1.05, but the other initial angle values instead of taking flag voltage here also you should have taken 1.05, 1.05, but I have taken this is 1 0 this is also 1.0, but slack bus voltage is 1.05.

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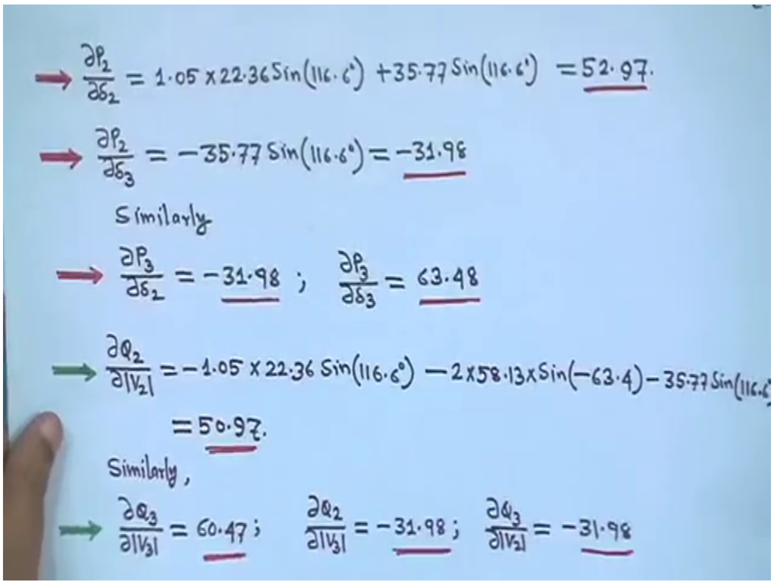

With this parameter, with this parameter delta P 2 upon delta 2 delta, delta 2 substitute all it will be 52.97 delta P 2 upon delta, delta 3 you substituting the minus 31.98. Similarly delta P 3 upon delta, delta 2 is minus 31.98 and delta P 3 upon delta, delta 3 you will get 63.48.

Now, all the parameters are we substitute here delta Q 2 upon delta V 2 you will get 50.97. Similarly delta Q 3 upon delta V 3 you will get 60.47 delta Q 2 delta V 3 you will get minus 31.98 and delta Q 3 delta V 2 you will get minus 31.98. You put all these values and you compute right. Then initial then in Jacobean matrix that with

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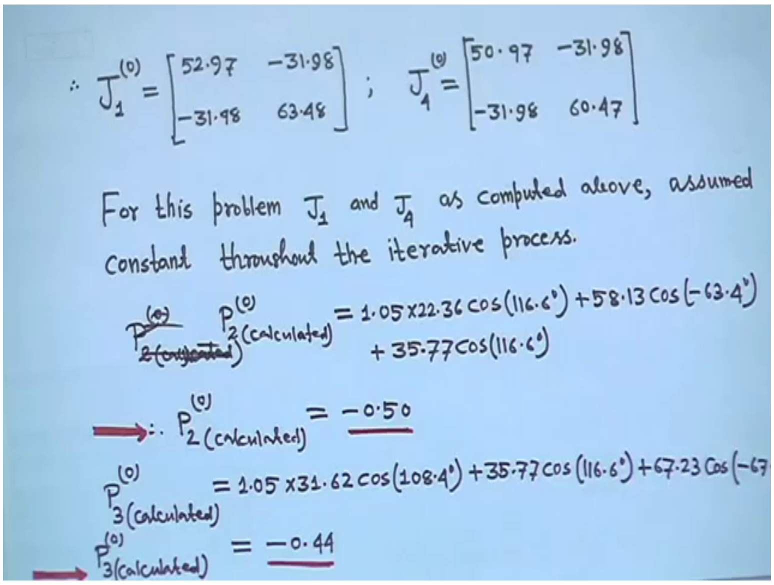

This initial parameters that initial value of Jacobean elements of the Jacobean matrix that is 52.97 minus 31.98 minus 31.98, 63.48; similarly J 4 also 50.97 minus 31.98 minus 31.98 60.47, so this is J 1 this is J 4 2 into 2 matrix right.

For this problem actually if we every iteration you will get new values of V and delta right. And every iteration if we compute Jacobean matrix then it procedure will computationally it will take more time. It will also if we use calculator also it will take your time. So, what we will do it, that whatever Jacobean matrix here Jacobean elements you have got this values right. This will be retains in all this iteration constant. So, we will not calculate Jacobean in the next iterations and so on. So, this 2 values will retain as a constant we will not change it in the second or third iteration right.

This is just actually this example taken to So, that how Newton Rawson method works right. So, therefore for this problem J and J 4 are computed above assume constant throughout the iterative process. So, this we will not touch we will not compute in the next iterations right. Next is P 2 calculated right? P 2 calculated means this formula using this formula right. This 50 and 51 this derivation is there put i is equal to 2 get the expression i is equal to 3 all these expressions is given actually right. Just I will show you, all this expressions are given this P 2 expression expand your, expanded form it is given put all the initial values here in P 2. That is your P 2 calculated you are computing actually right. Therefore, this P 2 0 that is at P is equal to if you see P is equal to 0 iteration count.

So, P 2 substitute all the values in this equation all the values you will get your P 2 it is calculated at around P is equal to 0, initial thing that is minus point minus 0.5 right. Similarly P 3 calculated in this expression you substitute all those values all those initial values you substitute. You will get P 3 calculated will be minus 0.44 right. Similarly just hold on, similarly that here also Q 2 expression is given Q 3 is given So, put all this parameters here.

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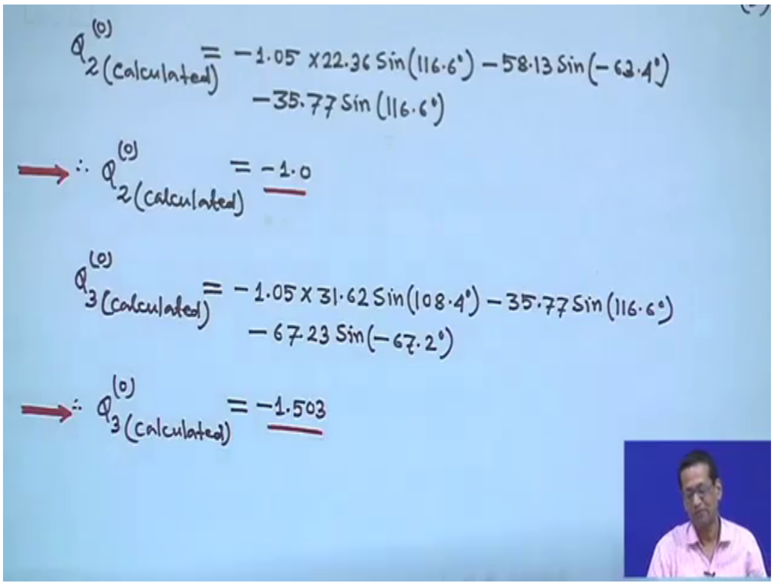

So, Q 2 calculated that is at the that is initial values So, all these thing it is becoming actually minus 1.0 substitute all and calculate it is minus 1.0 similarly Q 3 calculated minus substitute all in this expression of Q 3 Q 3 in this expression right. And you will get it is minus 1.503 right. This is your all calculated.

Now, you have to compute that schedule value right. So, next is how this is you have shown it for Gauss-Seidel, but here it is.

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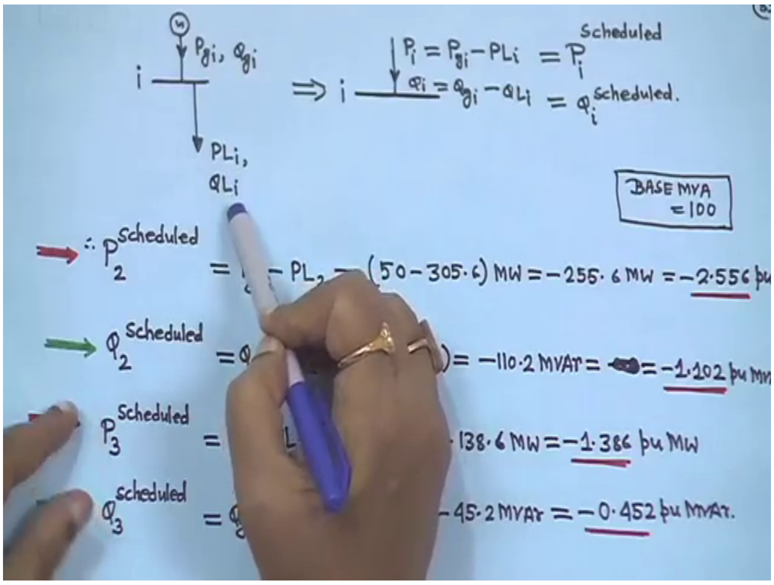

And suppose this is the load, I showed you earlier this is the load and these are generator this is but i right. So, it is P g i Q g i right. And load is PL i Q that is P g i plus J Q g i PL i plus JQL i just showing PL i Q L i P g i. So, net injected power here P i is equal to P g i minus PL i right. And Q i is equal to Q g i minus Q L i that is equal to your P i schedule and Q i schedule this is actually P g i minus PL i this scheduled power and Q g i minus Q L i is Q i scheduled power right; that means, P 2 scheduled when i is equal to 2 P g 2 minus P L 2. So, all data in that example 2 are given right.

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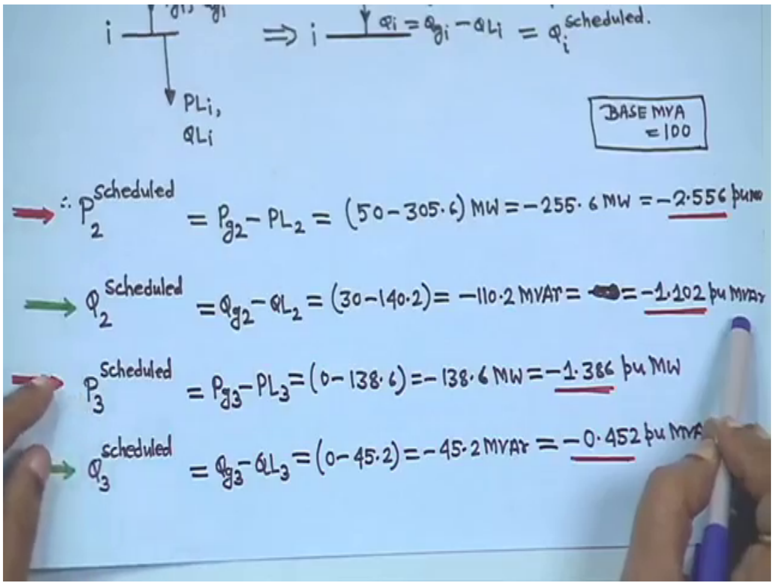

So, it is at minus 20, 255.6 megawatts so minus 2.556 per unit same as before. Similarly Q 2 schedule is equal to Q g 2 minus Q L 2 that is 30 minus 140.2 in per unit minus 1.102 per unit right. Similarly P 3 schedule P g 3 minus pl 3, there was no generator at bus 3 for that example 2 that if you and you will see the you have already seen it so 0 minus 138.6. So, it is minus 1.386 per unit divided by 100. Because base MVA is 100 right; similarly Q 3 schedule will be Q g 3 minus Q L 3 is equal to 0 minus 45.2 so ultimately minus 0.452 per unit megawatt right.

So, all these P 2 Q 2 P 3 Q 2 that scheduled value computed. Now delta P 2 will be P 2 schedule minus P 2 calculated. So, we got this one is this P 2 schedule is minus 2.556 minus P 2 calculated at minus 0.5 so minus of minus 0.5. So, it is becoming minus 2.056. Similarly delta P 3 0 is P 3 schedule minus P 3 0 calculated it is 1 minus 1.386 minus, minus of 0.44. Minus 0.946 because this was minus 0.44 calculated so on right.

Similarly, delta Q 2 is substitute if you substitute it is minus 1.102 minus of minus 1. So, point minus 0.102 and delta Q 3 0 is equal to Q 3 schedule minus Q 3 0 calculated. That is minus 0.452 minus of minus 1.503, So 1.051.

These are the differences initially we got right. So, all these thing a schedule value thing is clear to you. And calculated means using that equation you have to compute right. By calculator only or in though quite code then of course, in computer. So, these are the values.

Thank you (Refer Time: 29:51).