High Voltage DC Transmission

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Module No. # 06

Lecture No. # 03

AC DC Power Flow

Let us start the lecture number 3 of this module. This will be the last lecture of AC DC load flow, but not of this module because in this module, I will be also discussing about the transient of HVDC as well as the AC system together that will be done in the lecture number 4. In lecture number 2, we discussed the two methods; one method was the sequential AC DC load flow and second was the extended variable method.

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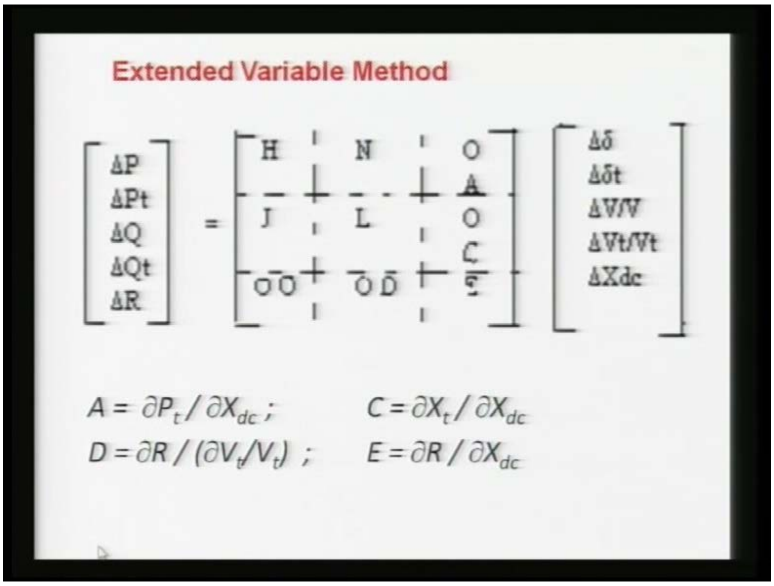

In that we were calculating the various elements of the Jacobean, you can see the extended variable method, because we are extending the DC variables here, the X d c and we are having the corresponding column and the row and the three equations R 1, R 2 and R 3 those are corresponding to three basic HVDC equations. So, also we saw the total X d c is seven variables and out of that we have to specify the four variables and that will decide your control mode and three variables we are going to determine through this extended variable method or the load flow method.

The elements corresponding here the various elements the A C D and E, A is corresponding to a P t is a P t is your power at the two terminal rectifier terminal and the inverter terminal so it is two variable here, this is a vector is represented corresponding to the derivative of your X d c. So this a is 2 by 3 matrix, this is also your 2 by 3 matrix because this is corresponding to your reactive power at the rectifier as well as the inverter, so two rows and here the three variables, so three columns so it is 2 by 3.

Here, the three equations are there so this will be 0, the D will be 3 by 2, because this is corresponding to the voltage terminal again we are having the two terminal, we are talking then it is rectifier and inverter so 3 by 2 and this is your 3 cross 3 matrix.

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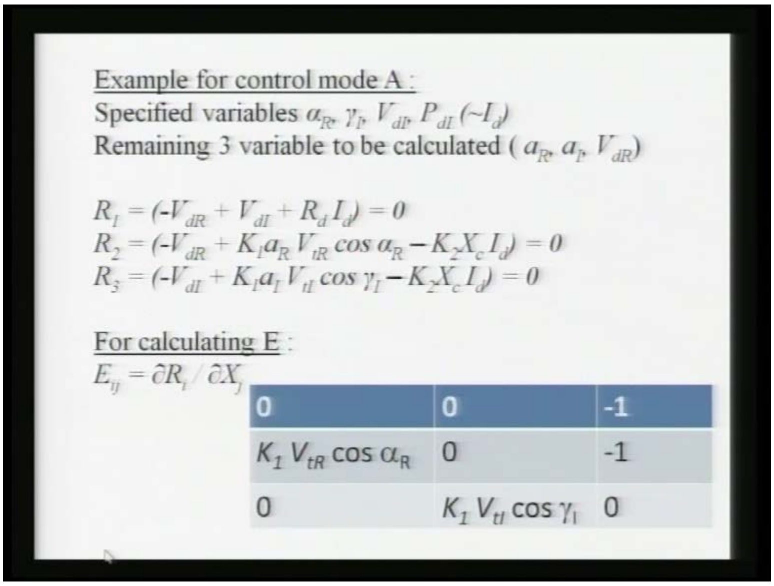

And in the last turn, we were calculating and we found that this matrix, we decided to calculate e I j means, we saw for one example that is your control mode a, where we are having the specified variables your alpha R that is a rectifier delay here the extinction angle of inverter and the V d I is the inverter voltage and the power at the inverter end.

So, these are the specified, then the remaining three variable that should be calculated is a R that is a rectifier tap changer position, inverter tap changer here, tapping specifically and the V d R rectifier DC voltage. So, three variables we have to solve and since we are having the three equations here R 1, R 2 and R 3, then we have to write the elements. So, here if it is R 1 then, this should be differentiated by this and we can see it is 0 because this is independent of a R, this should be differentiated by a I, then this also is independent but if we are here differentiating with the V d R you will find this value so minus 1 is appearing.

Similarly, what I have changed is I have done here K 1 and K 2 because here it is no doubt the K 1 is some 3 under 2 term and by pi is appearing into K. So that whole term here it is written as K 1 because I do not want to read the big mathematics so here K 1 is nothing but K multiplied by 3 under 2 upon pie.

Similarly, here K 2 is nothing but 3 upon pie so in terms of that if you are differentiating this equation here, with respect to a R you can say it is a dependent so this will be 0 partial differentiation of R 2 here if you are differentiating this will go up, here K 1 V t R cos alpha is appearing now if you are differentiating it is a independent of a I, it is 0 and if you are differentiating here you are getting minus 1 which is there.

Similarly, if you are differentiating this equation, then corresponding will be your third row here a R is independent, so it will be 0. If we are going for a I we are having this term so this a I will go up, so K 1 we have written V t I cos gamma I and if you are going to differentiate here it is independent you are getting the 0, so this is the element corresponding to this. Now, if you are going to calculate this A and C, that is not 0, here most of the terms are here 0 and is very simple one.

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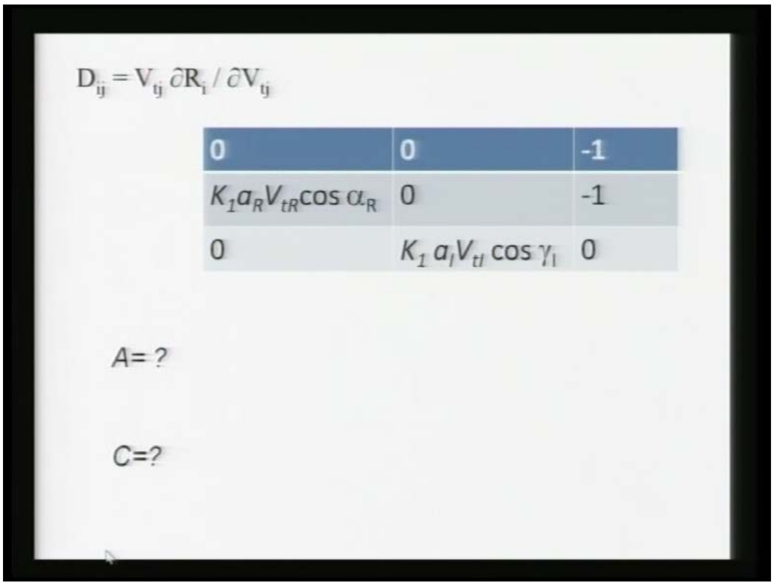

But, the let us see the calculation of t, corresponding to those here, the d calculation we are differentiating with the V t j here why I am writing because one V t will be R means we are differentiating this, I can write the D matrix.

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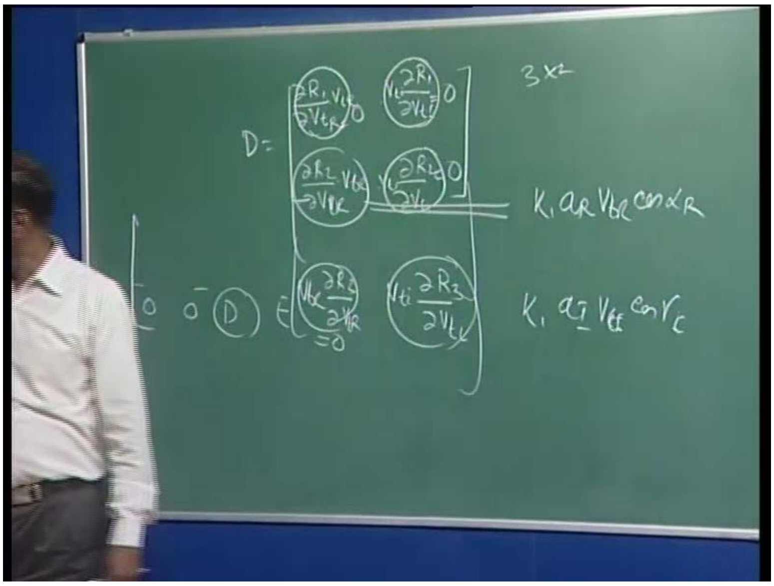

D is corresponding to 0 0 D and it was e so it was corresponding to your R 1, so I can say R 1 here it is your V t into V t because the V t is two in our case so here if I write this R into R 1 del V t I into your V t I then here, it will be your del R 2 here this is V t R into V t R here del R 2 V t I and here V t I just we will multiply it.

Similarly, here it will be your V t R del R 3 for del V t R and in here R 3 del V t I so it will be your 3 cross 2 matrix. Basically, the slide is not correct it is copied from the previous one so we have to delete and will see what are the values we are getting.

Now, this R 1 whether it is dependent if you are differentiating R 1 with the t there is no V t R so this term will be 0 because the R 1 here if you are differentiating the V t R, there is no V t R so it is 0. Now this V t I is also 0, now the second term here is 0, this is 0 here, K 1 a R here V t R, will also be there, mind it because we are multiplying here, so this value we are going to have is, K 1 a R V t R cos alpha R. Now, this will be with V t I it is not there it will be 0, so this is again 0 so everything is 0 because this equation now with the V t R is 0, so I can say it is equal to 0 but this will have value and this is K 1 a I V t i cos gamma I so this will be the value, what I did I just wrote it easier, no need to remember just simply write R 1 R 2 R 3 these are the rows corresponding and the variables here the V t R and V t is are there, so this is your d.

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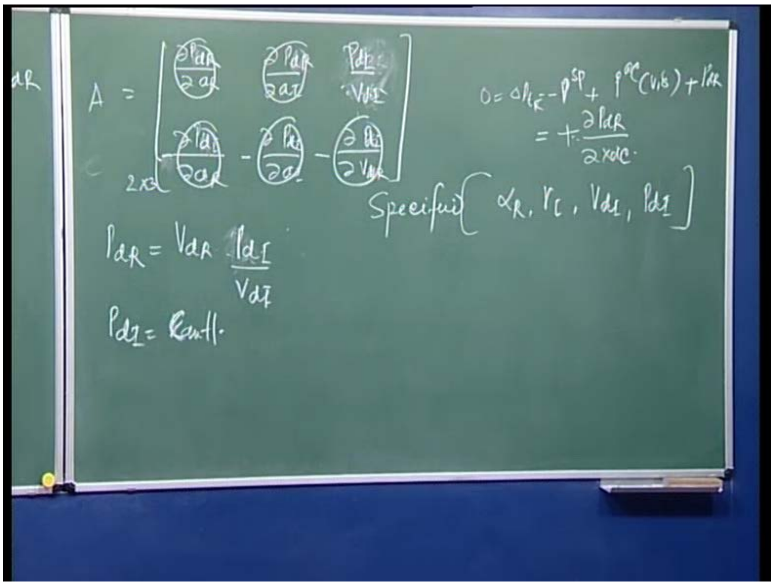

If you are calculating this A and C because in A and C, it is not R 1 R 2 R 3 see this matrix here, this a is corresponding to your real power of the terminals of the HVDC derivative of X d c means, I can say a already even though we have defined also in this, I can write this will be 2 cross 3 matrix, because the P the t R and the t I are the 2 rows here so I can write del P t R del whatever in this case your X 1 and this is your a R because in this case we are having our unknowns a R a I and your V d R the three are the X d c in this case, so this will be P t R a I and here P t R V d r.

Similarly, here we have to write this P t I, a R here P t I or a I and here P t I del V d R means, we require a function of P t R, that is in terms of a R means, we are interested to write the equation of the P d S basically and this P t is the total power, that is a change in the power, if you remember and this we wrote here then P t here, at that bus rectifier terminal it was P specified by minus, I said the P AC that is voltage and angle here, just you remember minus, I said here P d R and this P d R is function of your V t R V t I and X d c and this is a general function, maybe it is variable depending upon 2.

Now if you are differentiating this V d o or Xdc, this will be 0 this will be 0, because they are the independent, this is AC here only this is dependant Xdc, this is a function of Xdc and the V t R V t I so if you are differentiating here means effectively it is a minus here I can say P d R over Xdc.

Here the minus term is appearing so this we can add here this minus will not appear why this you remember we can write this equation here we want is equal to 0 then you can this minus this plus and this plus because the Jacobean element how you are writing this h n and j L here if you are writing this is a negative element then it will be also negative so this is if you are because this will be the same sign here with this sign means what I say here you can write this f X is equal to 0 this is also equal minus f X is equal to 0.

So, if you are differentiating taking the Jacobean here so you are just doing minus in this way or that way both are same thing means here you can say this is your this is minus this is plus and this is plus here because anyway we want is 0 this value and then you are differentiating you can say this is 0 this is your Jacobean elements. So, in Jacobean what we do we take it as positive so that is why it is in the positive coefficient so main care here is that we take this is nothing but it is your element of your h n we normally take it in this way so same expression you have to write otherwise this will be adding and subtracting together so you can add get the converge solution.

So, in this case normally we prefer this again this depends upon whether sign is a plus or minus this will be decided by how h n and j L you are defining. So normally we do take this as a positive elements jacobian element so that is why it is additive of this.

So, here we are also taking the positive here mind it here this is for the rectifier so the rectifier here this and this is added together if we are going for inverter this will become negative because it is just coming just like a generator so only difference in the real power however the reactive power always it is taken as load and it will be coming out from the bus.

So, now means this differentiation is nothing but I can say it is a P d R upon Xdc, so I can replace here it is your DC power of the rectifier ends here the DC power at the rectifier end and here is a DC power at the rectifier. Similarly, we can at this here this P d I I can write but this sign will be negative here why I wrote negative here because the converter it is just coming out inverter going in so it is a sign change so this minus sign will be coming still it is not sufficient.

Now, we should know that is what is the P d R at that terminal buses if we remember thus we wrote the first one to three equation then later be right the equation for the power means the power equation, what I write here the P d R it is nothing but your V d R into I d and you can see this is a function of here one of the control variable here I am taking I d as a constant because the specified variables are alpha R gamma I V d I and P d I here.

So, from here you are fixing these variables means your I d is constant, so it is independent of V d R now, so here I d is a constant or you can write this here is P d I divided by V d I I have no problem, because these values are given to you now this P d I is a constant value the P d I here is the constant and we have already specified value here these are the specified variables of the DC.

Now, you can see here from here if you are differentiating this is 0, this is 0, and here if you are differentiating means, you are going to get your P d I by your P d I that is I d, this is a constant, so whatever you are derivating it will be 0; so this is you’re a. So it is simple but if you will go for C it is not so simple, because in C now you have to calculate the reactive power real power is simple equations.

Now, we have to write this reactive power and the reactive power, we can write in terms of upper end power. So upper end power equation also I derived, and I wrote the various upper end power, if you remember I wrote 1 2 3 of the basic equation, then I write the two mode the real power equations, then I wrote a equation for current and then later I write the S d R S d is so here, I require this S d R it was what is this value K 3 root 2 a R V t R into I d by pi here.

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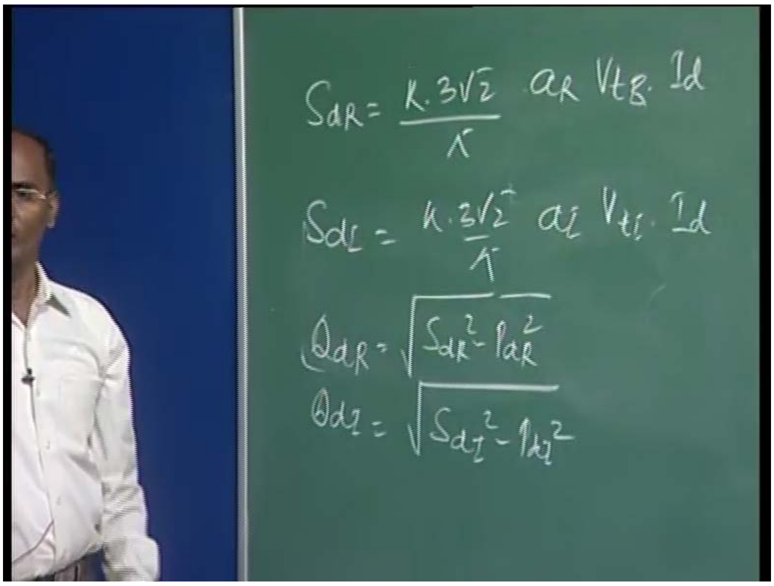

Similarly, we wrote for here S d I it is K 3 under root 2 over pi a V t I into I d we have this we have the P here P d R and the P d I now we have to calculate the Q d R and Q d I. So your Q d R we have to write a function now we are getting this function because this is your one of the variable this t is here it is coming in the AC so we are is not taking care here because other elements have already taken care of this and I d in this case is also constant.

So, here you have to write the Q d R as here S d R square minus P d R square and here I have to write the Q d I it is your S d I square minus P d I square. So this is the constant and we have to now differentiate this now with the reference to other variables means now here I can write the c here it is nothing but here simply I have to write Q here I have to write Q here I have to write Q here I have to write Q here simply I have to write Q remaining will be same.

Moreover here this sign in this case will be positive because the Q is taken load at both inverter as well as the rectifier terminal. So this element you have to again you have to derive this from here with this equation and then you have to differentiate it so you are going to get some terms here it is not zero.

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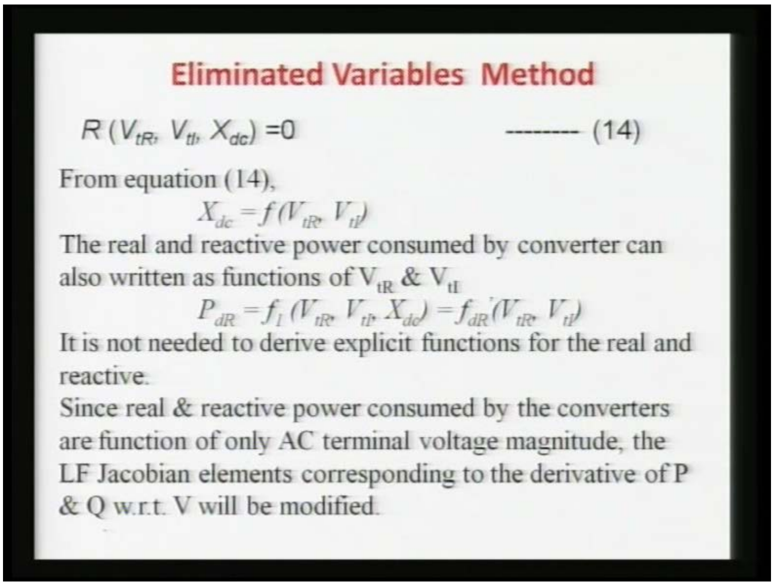

Now, let us come to our eliminated variable methods or variable elimination method is different names are given in the different papers, now what we are doing, that Jacobean we were extending now, we saw that is R 1, R 2, R 3, here it is a function of V t R, V t I and X dc variables, this is the vectors R 1, R 2, R 3, equations are basically nothing but they are the function of your rectifier terminal voltage that is, AC terminal voltage and inverter AC terminal voltage and then, X dc s are seven variables.

From here, if it is 0, we can simplify X dc in terms of this value means, just you can write X dc whatever now X dc will require for solution here, in this case X dc here for this control mode here, it is these 3 values. So, we can just simplify and we can get it because the three equations are there, we do not want the explicit equations because it is a partial derivative is not thus, you have to have a exact value without dependant of any other variables, it can be because we are doing the partial derivative and also we are solving these equations, by any derivative solutions.

So, it will be automatically taken care, so that is why here, it is written that we are not deriving the explicit equations because these are the non-linear equations as well and it is not possible that you can have independent of all these three.

So, here the P d R, I can write the P d R which were appearing here is a function of again this value, may be this dependant on this X dc means, from this 3 X dc here, can be replaced and we can get another function, that is having only the V t R and V t I means, in that we are not interested to have the X dc S and if you are having this and this is in your Jacobean form, because we require the AC terminal voltage of rectifier and as well as the inverter and then in whole remaining part, it is going to be modified. So, in the normal Jacobean, what is happening because I wrote this equation here now, this is also going to be a function of your V t R and V t I, X dc we have derivated from equation 1 to 3. So, having this AC and then you can differentiate this.

So, what happens once, you are differentiating here, with reference to your V t I and V t R, for others it will be not changed but the V t R and V t I this term is going to be added in this Jacobean term because this is also having V t R and V t I, so only at the two points, when the rectifier and inverter this term is going to be added.

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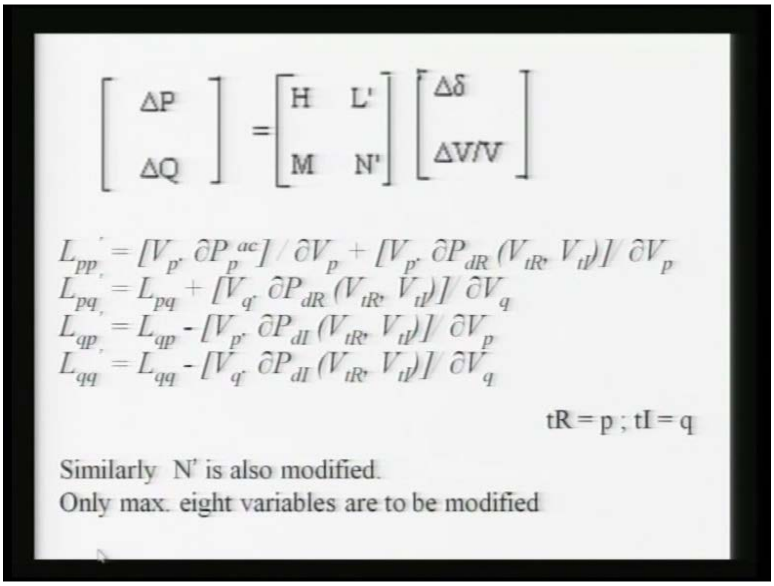

So, this will come only when you are going to differentiate with the V t R and V t I and you will find the Newton rap son equation in the polar form here, this corresponding to only voltage because corresponding to delta there is no change because we have not changed only because this P d R is a function of V t I and V t R only no delta.

So, here H and M are constant, only here the L and M are now going to be modified, due to the DC variables or DC part because the power is going from this rectifier and coming into your inverter, so the elements of this are going to be modified, only corresponding to the terminal voltage of R, in such rectifier and inverter.

So, it is two here, corresponding to P means, here the P t R and P t I here corresponding to V t R and V t I means, in this the maximum four elements. So, the maximum here, that is why written the 8 variables are to be modified, why I am talking maximum, I am not saying only eight because it depends upon what is the type of bus, if it is your not a load bus, it is a generator bus, it will not appear that will be V t R and V t I. If your one rectifier terminal is a slag bus, that will not come here because this is only the other than slag bus.

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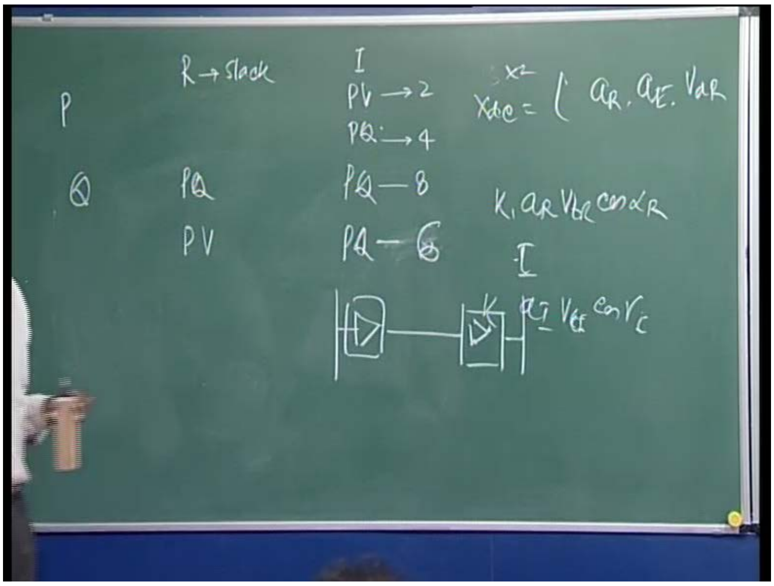

So, it depends upon which type of the terminal, I can say rectifier where you are taking and this is going to be inverter, this is I. So, what type of bus in your AC load flow? whether it is a P V bus, whether it is a P Q bus, whether it is a slag bus, so if one is slag bus here, then corresponding to that there will be no change, so if it is a slag bus let us suppose rectifier is slag bus, so I am sure this will be not a slag bus but it may be a generator bus, so if it is a generator bus and another is your slag bus, then only we are going to have the two terminals, two variables of this and there will be nothing here.

This will only arise, when we are having the load bus, are you getting my point because you must be very careful that, what is the type of bus, if this is slag bus because you know P here this slag is not included, so this and also in Q slag is not there, so this bus there is no change, R will be not there, only in I now we have to see what is this, the possibility is, I can say if, R is your slag and this I can be P V bus and can be your P Q bus.

So, if this is slag bus R, so neither it will be having here, nor it will be having here, so the two rows are gone, two rows means again the two here the voltages also, we are not concerned, so four gone, so here if it is a P Q, then we will have 4 elements, if we are having the P Q this bus, then we are going to have 2 elements only. If we are having both here P Q means, we are having a good chart, here P Q and P Q then we are going to have 8 completely, if you are having this is one is your P V and another is your P Q, then here I can say 8 and here how much? It is going to be 6 because 4 corresponding to this 2 corresponding to this. Now if we are having P V P V, then 4 then we come here.

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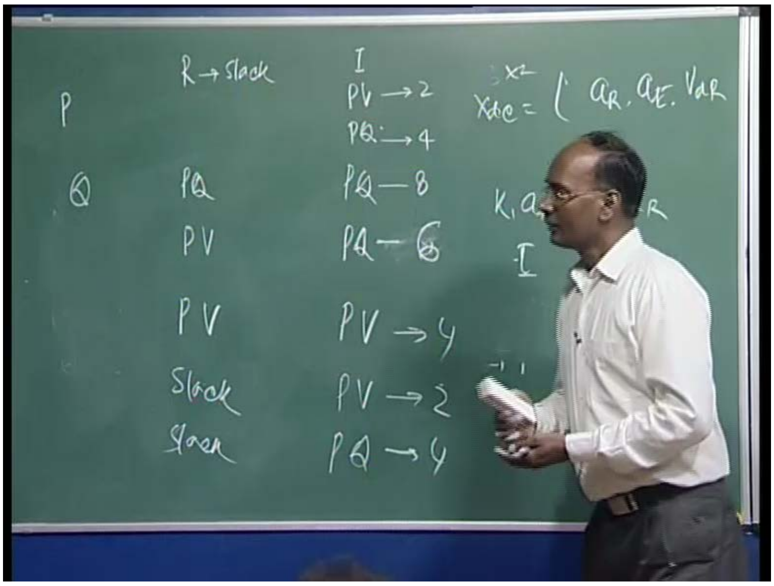

Now, all possibility here, I can write if we are having P V, P V then we are having 4, if we are having another slag here, if we are having P V then it is 2 and if it is here P Q slag, then we are having 4. So, these are the elements, only these elements are modified and it is very easy to modify so, that is why this elimination variable method, is very variably used means, we always try to use because only the limited number of elements, just you have to change in that modification again you have to go further.

Now, let us see how the elements are going to be modified corresponding to the R end means rectifier and inverter end.

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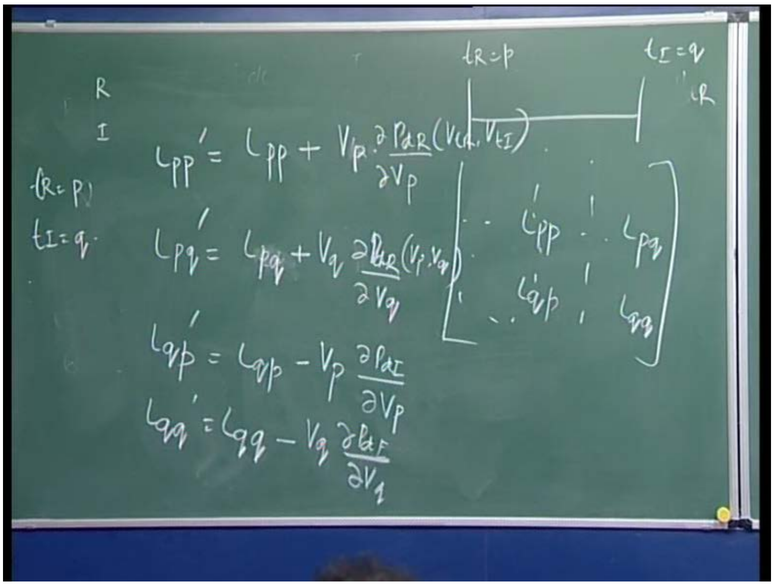

Now, let us see this L, as I said only we are going to modify the corresponding to R that is, rectifier and the inverter, so the corresponding to the p, we are going to write, L p p, why I am writing the p, I am writing this terminal t R, is as a p, otherwise we can write t R, t R because what is the name of this bus, this is terminal R, this is your terminal I, it is q here, it is p, it is easy to just denote.

So, I can say L p p here, which is going to be modified, it will be corresponding to this with that variable here means, it was in original, when we are not adding, so this is known as your L p p now whether it is a plus or minus depending upon what is this value here, we are going to write this, plus if it is a rectifier, now I am writing the t R is p here, so it is a rectifier end, so in rectifier that is taken as a load.

So, this value we can write as V t R or I can write this V p here p into p d R her this element is to be added, so that is why here it is written, the V p p d R and this function whatever, now we are having the simplified equation again the V t R and V t I. So, this P d R is only the difference, with the previous P d R here, now this is only function of V t R and the V t I or you can say it is a function of V P and V Q. I am writing here the V t I as q, so at the rectifier here, these are the only values which are going to change, now then L p q it is prime L p q.

Now, here we are going for the inverter, this will be again the positive because the same equations we are deriving because this L p here the t R we are writing the expression, means your element here in this complete L, I can say it is your L p p here, somewhere L p q and here I am writing this L q p and somewhere L q q. So, these are the various elements by a source, again in whole this order of the complete L is the variable V and this is n minus 2 number of busses corresponding to this value is number of p q buses because the voltage where we are going to determine.

So, here the 4 elements are going to be modified, so I am writing here p, is again the t R now, it is differentiated with this V t R and here we are differentiating the V t I, so this is plus V q, I can say del p d R here, V q and again this is a function of v p n, v q. So, that is why here it is written as plus, if we will see and then we are having this differentiation of q, I am assuming that is a inverter terminal. Now, we can also get this q p, we are just writing the power equations for inverter and differentiating here with the reference to the P terminal voltage, so this is L q p here, we are writing the power inverter then power sign is a change, than your Jacobean sign.

Because, here the Jacobean sign, whatever your element having, it is going to be added at the rectifier terminal, at the inverter terminal the DC variable, is just treated as generator, so it will be negative here and then it will be V p, p d I, here V p and L q q prime, here L q q minus V q del P d I, over del V q. So, these are the 4 elements corresponding to Q it is going to be changed. Similarly, we can also get for m and no need to write here, we can just simply write here, instead of this, we are writing N now here the P will be changed by q, here it will be the plus for all the case because the q is taken as a load, so instead of negative here, that becomes positive as well, for the q so here, in this case if you are writing n p p prime then, it will be plus V p into del q d R differentiated with your del p.

Here, it will be again same, n P q prime will be n P Q plus here, the V Q into del P d R differentiated with del V q R here, if you are writing n q p prime, will be n Q P plus here, will be there and here change is Q here, also this n and n here plus and you are going to change q d I. Only the problem, what happens to write the equations here, the P d R and p q R is simpler in the DC system but once you are going for the reactive power, you can see the equation going to be complex, slightly you have to modify because you are calculating the S d R from the P d R, you are going to calculate the q d R Q d, so you will find some elements appearing.

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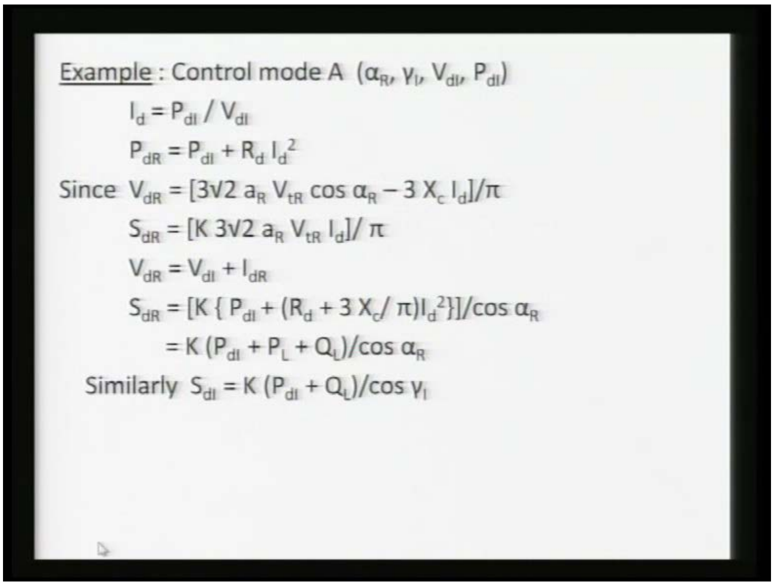

Now, for this case also, if we can just calculate this example, that is a controlled mode a in this case also, we can just try to calculate, so let us see how we can get the different elements corresponding to their control mode a, if you remember same we solved for extended variable method as well, so where your variables alpha R gamma I V d I and P d I are given to you means, we require three variables.

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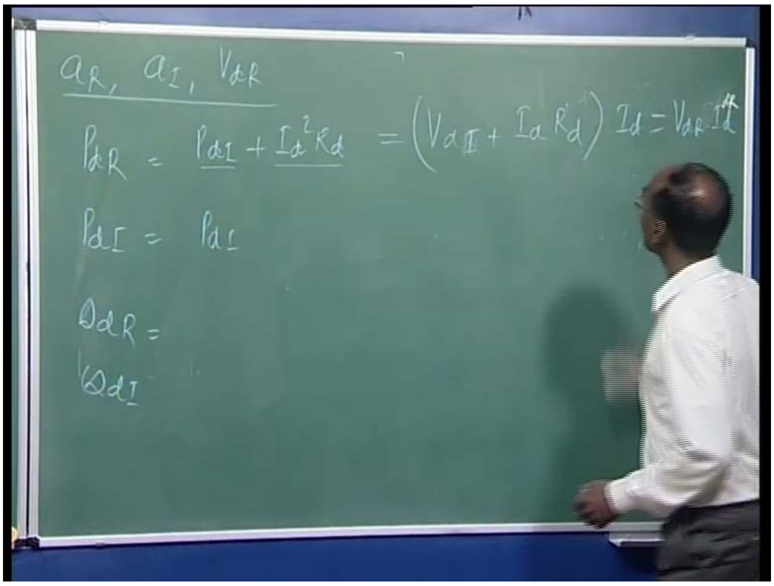

Again, this is a R, a I and it is V d R, so these 3 are your X dc basically but since it is a extended elimination variable method, we do not want this, it is not coming at all because already we are just simplifying R 1, R 2 and R 3 equation in terms of V t I and V t R.

To simplify this, no doubt this you can see, this I d is constant because the P d I and V d I are there, so we derive this equation, now this power at the rectifier end, we require the following variables this P d R, we require this P d I, for this and then we require Q d R and Q d, so these 4 variables we required, already the P d R we know, it is in terms of P d, I we can write here, it is your P d I plus, the last is I d square I d.

Means, if you remember what I wrote earlier this V d R into V d I into I d means, what I wrote, this V d R into I d is the P d R means, this V d R into I d. I do not want the V d R X dc as I said, we want to eliminate it, X d R what is your X here, V d R we do not want at all because it is elimination variable methods. So, these 3 variables should not appear at all because the other 4 variables they are specified, that will be there, you can eliminate at all.

So, here we do not want V d R and this V d R we know, thus we can write, this is another equation, so here if we are just multiplying means, we are getting the P d I and I d R and all the things are known in this case. Now, the P d I is the constant now, I can just remove this and that is why here I have written P d R, this is P d I plus, the last of the line DC.

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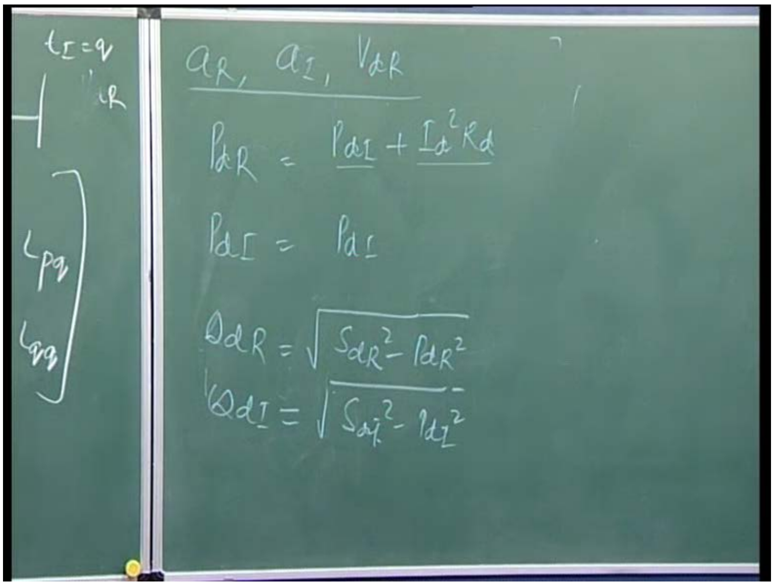

Now, to calculate this S d R because we require S d R, before going for this means, I can say S d R square minus P d R square and similarly, here we have to write S d I square minus P d I square, as I said now from here, if you will see the S d R this equation we wrote, in this case this variable we are having, so we have to eliminate this, we do not want this we want this V d R, we want this alpha because alpha is specified and other I d we know, so we do not want this.

So, how to do this? here in the P d R you can see there is nothing, those variables, in S d R we can see, we have it so, what we are going to do, from here the value alpha R, we can just V d R no doubt is the one of the variable but the V d R we know it is a function of V d I plus rd, so that we can eliminate again so, from here what I did, this a R, V t R we are taking and thus we are replacing here, so we will get a function or so let us derive this value.

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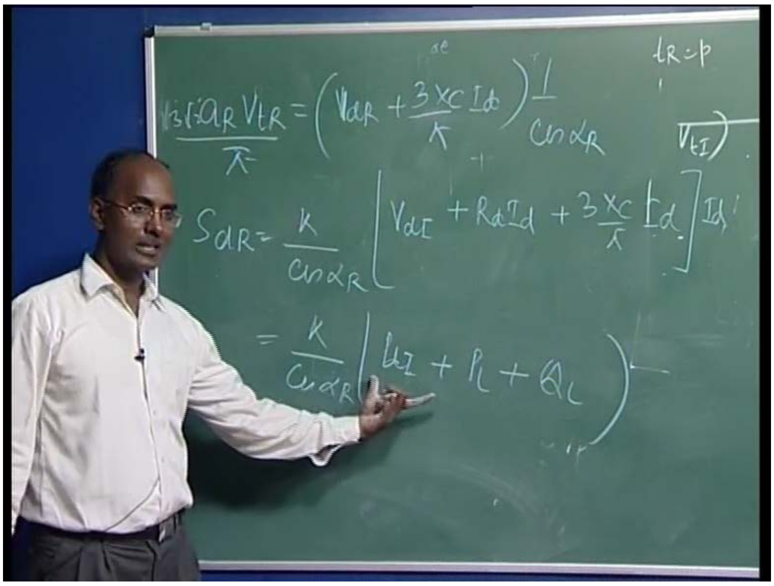

So, from here I can say it is your a R, V t R will be equal to V d R, it will be going that side, so it is V d R plus 3 X C by pi I d, 1 over here, we can take this coefficient because already it is lying here, we had this term also, this term we can take it here, so 3 under root 3 a R, V d R, we can write 3 under root 2 so pi we can also take here so, this is your value divided by cos alpha R.

Now, V d R also we will replace before, that now I can put this value here, so your S d R I can write, this value here directly, means it is nothing but K times of this because S d R you can say, K times of this value is there so, I can write here K divided by cos alpha R, here V d R also I want to replace it is, V d I into rd I d, one equation we wrote here, in terms of V d R, whatever V d I is there then, the dropping the resistance that will be your V d R, here plus 3 X C over pi into I d into Id.

So, what we are getting in this case, it is nothing but K with cos alpha R, here it is V d I into I d it is P d I, this value is your loss, I can write it is pl, R d I square here, this is also I d square and X C R this is again the loss, in terms of your reactance so, here I can say it is Q L. So, we are getting this function S d R in this, now you can see, this value is also constant, this is independent of V t I and V t R, this is already independent of your V t R and V t I, so if you are differentiating this, with respect to your V t R and V t I it will be 0, this is independent of this V t R, V t I the differentiation of this will be 0, here this will be 0, here also it will be 0.

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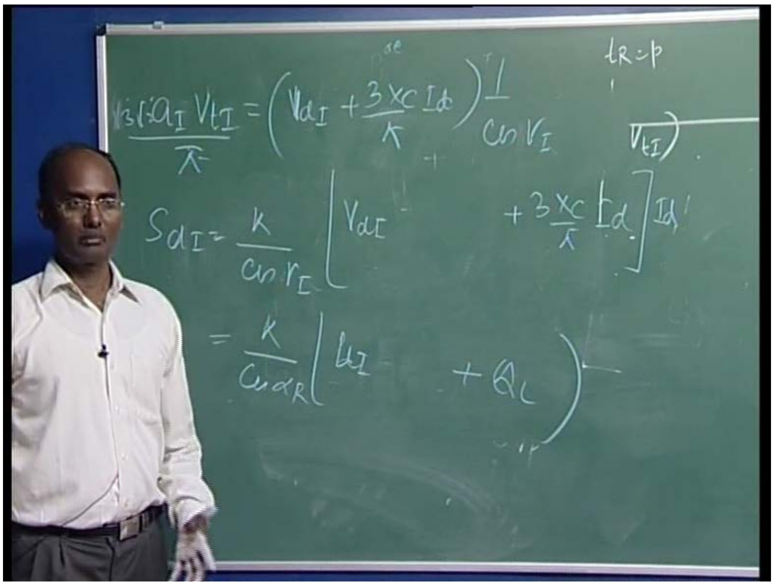

Similarly, you can see S d I, what changes we are doing instead of this, a I will be there means, I can write it is I here V t I, here it is I and instead of this, I have to write gamma I and if you put the value here, I it will be gamma I here.

Now, this V d I is already there, so this term will not appear means, here this is not there, and you can see this is also independent of V t R and V t I it means and if you are differentiating with this V t R and V t I because this is a constant, that is independent constant I mean and then you are also getting 0. So, all eight elements whether 8, whether 2, whether 6, whether 4, it will be 0, very simple the control mode a, means it is a simple Newton rap son Jacobean.

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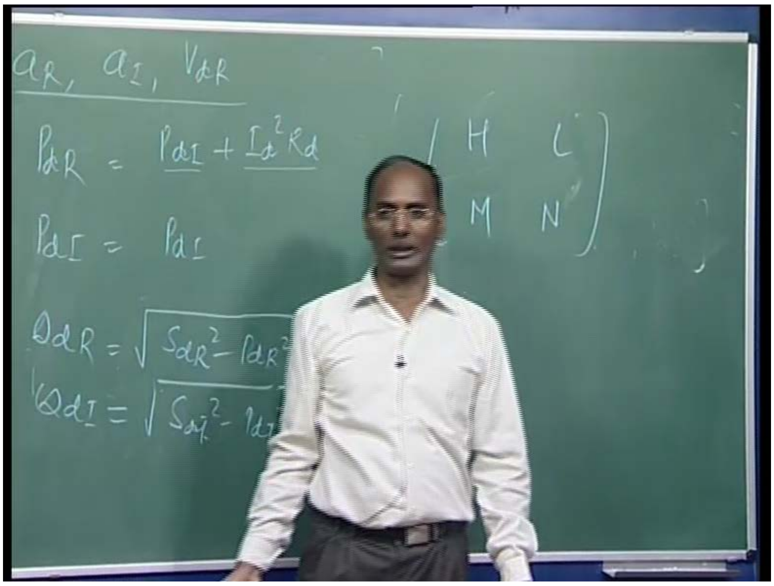

What we are getting, whatever is your L and N prime it is nothing but it is your same value, which was there, I wrote here H, L, M, N so, to avoid this confusion, even though earlier people are using this, that is why we go for j 1, j 2 and j 3, j 4.

So, it is very simple, so here you will find there is no change in the Jacobean data in control mode a and it is good but if a R is hitting the limit, then what will happen, we have to fix this and alpha R will be going to the picture. Means, your control modes where you are just fixing, if it is hitting then, it will be changed, if it is a rectifier side.

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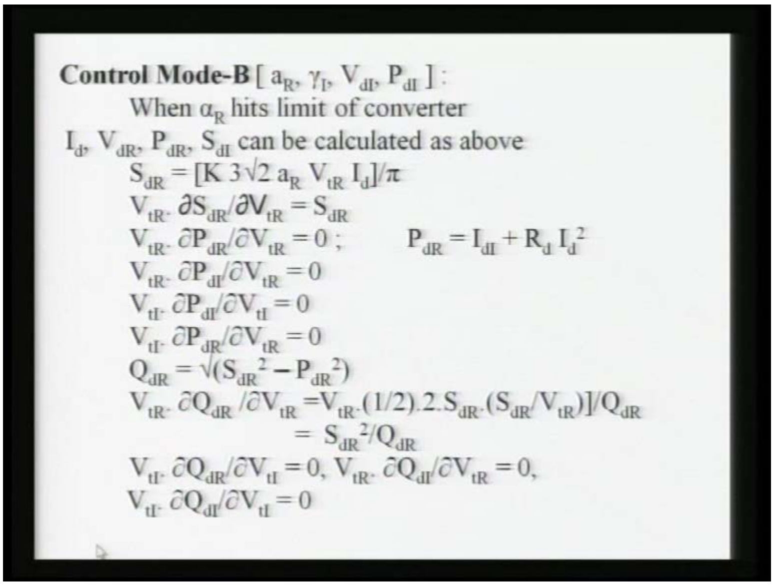

So, the control mode b, you will find it, where a R is fixed now, because a R is hitting limit, so a R is now fixed too, it is a limiting value gamma I V, d I and P d I is there now, these are specified and now we have to calculate then, remaining the variables should be calculated, what are the remaining variables that we need, now here it is going to be simply alpha R.

So, we have to eliminate alpha R a I and V d R from those equations, so it is again the similar procedure, we have to follow S d R we are writing here, the alpha R is now fixed, it is known to you, so this is the constant now, leave this here, the P d R will be as it is, no change your P d I is also there, there is no change, so this P d R and P d I are fixed this is fixed, differentiation with this will be 0.

So, that is why here this is related to L p p element, the modified element which we are adding means, here L plus some element, we were adding then, it was modified, so we are talking about this additional element, which is going to be modified here, so this elements which is written there, how much we are going to add or subtract.

So, this value is 0 for the corresponding to the P, means it is all here corresponding to 2 P, here the four elements are 0 and here all four elements are 0, this P d R, P d I, P d I here V t R is 0, here also 0, only we have to see here, one is your S d R, another is here in this a R V t R, a R is fixed, V t R is fixed, P d R is fixed, then it should be also 0.

V t R not fixed but we wanted the function of the V t R, because it can be a function of V t R and that is what we require, so this is not constant, here this term a R is fixed but this is a function of V t R, which we need it, if we will go here, this will be the constant again because in the similar function, what we derive for this one, this is not going to change the value.

So, this is the constant, the derivative of this means, two elements are constant now, only we have to see because this is dependent on V t R, V t I is not constant it is not dependent on that, in this equation you will not find the V t I anywhere but now this equation earlier, before we were writing, we were eliminating, if you remember here, a R and V t R together we were eliminating and then we were finding, it was a constant.

Now, here this a R is constant, V t R is a function, you cannot eliminate now, so this is a value, we are getting in this term, so what happen if, you are differentiating this, so in general you have to differentiate means, you are writing here differentiation of Q d R we will also find it is V t I is 0 because this S d R is function of only V t R, the V t I is 0 so, corresponding to that, will be also 0 and that is why it is written here.

The Q here is 0, this corresponding to V t is it is 0 means, we are getting here this Q d I and the Q d I with the both here is 0, one side here V t I, we are just making 0, only one element is going to appear in all the eight elements and again whether, this will be there or not it depends upon the type of this R, bus as well if, it is a P b bus, P Q bus on slag bus then, you have to see whether, is required if it is P b bus it is not required, if it is a slag bus it is not required, if it is a P Q bus then the Q is going to be there, in the Newton rap son Jacobean and then if you are modifying here, differentiating this, you are going to get this S d R square upon Q d R means, simply you can differentiate this, with respect to V t R.

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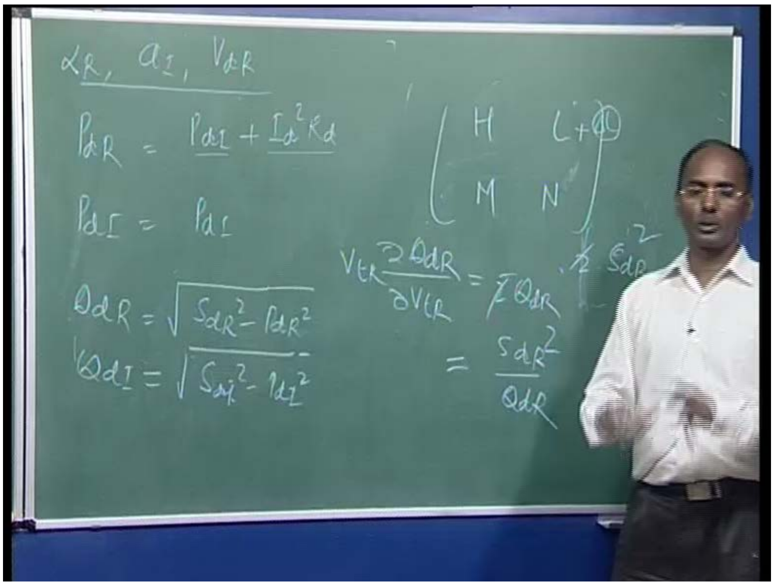

What you are going to get, I can say 1 over 2, this is 1 upon Q d R, hold this term because this is 1 by 2 so minus is coming down so, Q d R, I am writing here, then into the differentiation of this term, this term's differentiation is 0, this term we are going to get means it is your 2 into S d R, here differentiation of h d R by your V t R and since we are going to multiply V t R, here I have to write the V t R as well.

The V t R, V t R is multiplied here, I wrote for the differentiation of this 1 upon 2 Q d R into now we are differentiating the inside term, this will be 0 constant, so is a twice of S d R into the differentiation of the S d R with respect to the V t R, now you can see the S d R here, it is directly we have the function here S d R is the V t R, so this will go off but we are multiplying V t R again, the first term.

So, here you are differentiating and you are multiplying here, you are getting again this term is going to be your S d R means, it is your square this two and two is cancelled and you are going to get your S d R square over Q d R, so whole, in this mode you are going to have this one as well.

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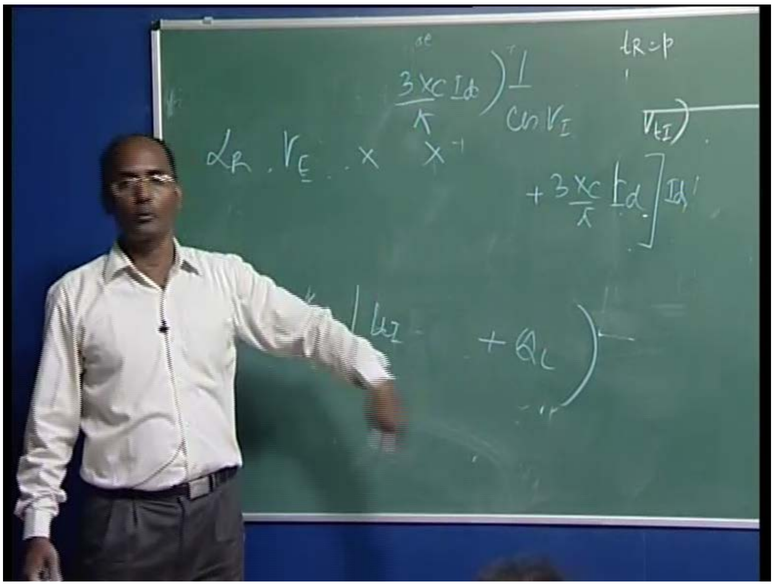

So, now you can say here, even though you can generalize also, if the variables are alpha R and gamma I, whatever the two variables we are specifying, all will be 0, if you are fixing these two, remaining here whether what your V d R and what you are writing, you will find that, all the four eight elements will be 0, if it is changed, then correspondingly you have to change it.

So, this is another control mode b, if it is given another control mode, here basically control mode A, B, C, D, which I am writing here, I wrote in the last lecture it is again dependent upon what you are talking, is not a very standard this control mode a means, this is a specified control mode, so for u even though it is given, what are the specified variable, what are the unknown variable, then you have to derive or you have to calculate the various elements of the Jacobean etcetera.

So, this is nothing but the extended variable methods and here we discussed the Newton rap son in terms of polar form, it is not possible to have as rectangular form because it becomes very complex, here it is not our meaning to make it complexity and if you find it is very simple, sometimes there is no need to modify here or maximum we are going to modify only the 8 elements. Then, we also find even though less than 8, depend upon the control modes, there is a possibility there is no need to modify.

So, very few elements are going to be modified, now the question you can say, if the Jacobean is not modified how HVDC is going to be taken care. If there is no change only

AC load flow means, where is a DC now, basically that DC term is appearing in terms of mismatch because here every time we are multiplying inverting this to calculate those variables, here no doubt we have del P and del Q, in del P and del Q that DC links variables are coming into the picture.

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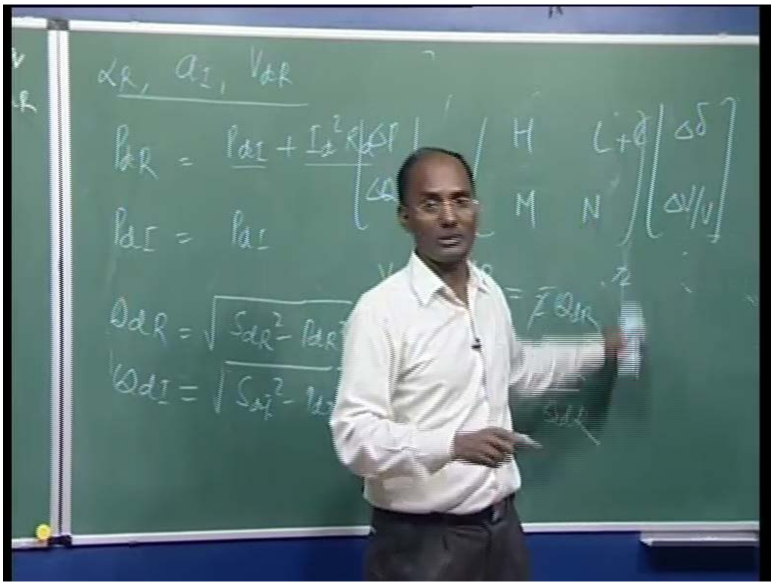

So, it is there, whether you are modifying here or not and then correspondingly we are calculating here, this change in the delta, change in the V by V and we are solving this equation. So, there is a possibility, that is only the two cases you are getting all 4, 0 because various combination of this 7 where the 4 are going to be fixed.

What we normally do here, in this case now, what is the check, even though we are not checking any variable of the DC variables here, which is going to violate which is not going to violate once, you are calculating this, you are just calculating this value of V t R and V t I and based on the V t R and V t I the DC variables can calculate it and once it is hitting here, then you can again modify. Because what will happen, you cannot get the solution converged because if you are not checking, suppose alpha is coming something 180 degree or your a is coming 200, in that calculation it means, that is not a solution.

So, once you are just converged here, you have to check these variable whether, they are in the specific limit or not because anyway you are checking the Q limits of the generators similarly, you have to check what is the limits of this HVDC variable at that and then again you have control mode will be keep on changing.

So, here once you have specified but once it is hitting then P Q and P V buses are changing for every direction, here also these values are going to be modes are on changing. So, you are keep on changing, modifying these elements, so you have to check which are going to hit, fix it, remaining you have to make it and keep on doing it. So, this is your HVDC, AC, DC load flow. Thank you.