**DC Power Transmission Systems**
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**Lecture - 35**
**Characteristics of 6 pulse LCC: Part 1**

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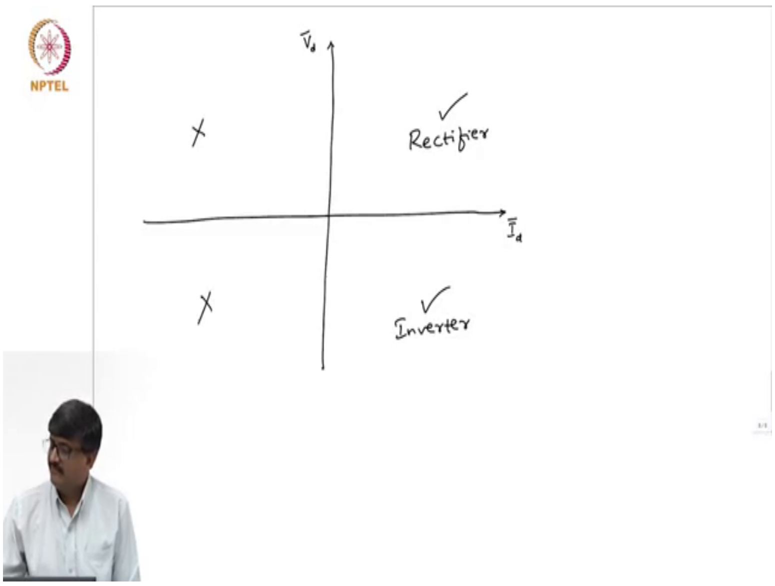


So, let us try to consider operation in this plane. So, I have a plane, so on the abscissa I have the per unit current I d bar and on the ordinate I have the per unit voltage unit. So, with the question is can I have operation in only 4 quadrants? So, by all 4 quadrants I mean; is can I have V d positive as well as negative can I have a I d positive as well as negative. So, if you have noticed we started with the analysis assuming that I d, actual I d is positive. So, I d bar is also positive.

So, we do not get operation in the second and third quadrant. So, we have operation only in the first quadrant and the fourth quadrant of course, V d can become negative because negative V d corresponds to invert operation positive V d corresponds to rectifier operation.

So, the first quadrant is nothing but, rectifier operation, in the second quadrant corresponds to no sorry, fourth quadrant corresponds to inverter operation. So, let us see; so let us see whether we can try to get some characteristics in this plane, I d versus V d. So, for that I need to give some numbers for these equations.

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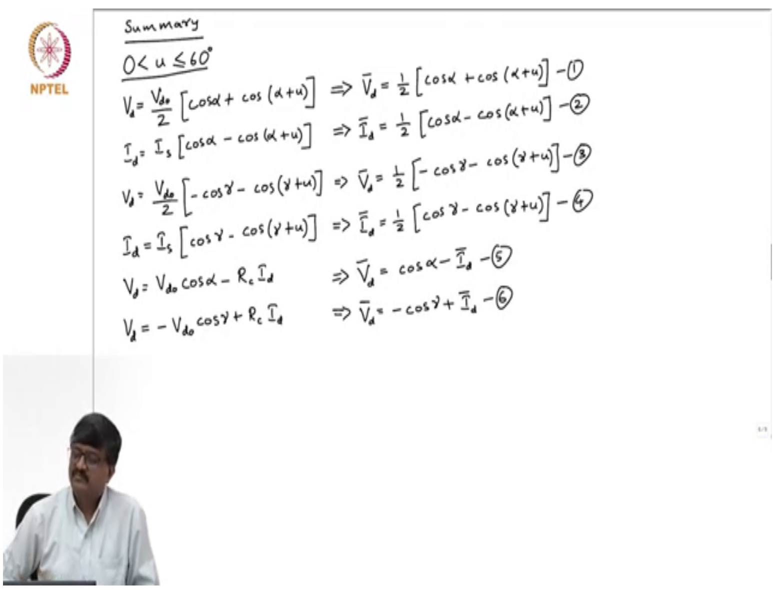


So, let me call this as equation number 1. The equation in per unit modules, so this is 2, 3, 4, 5, 6. So, I will come to the case of u greater than or equal to 60 and less than equal to less than 120 degrees later. So, let me first take off this u greater than 0 and less than or equal to 60, for u greater than 0 and less than or equal to 60 degrees.

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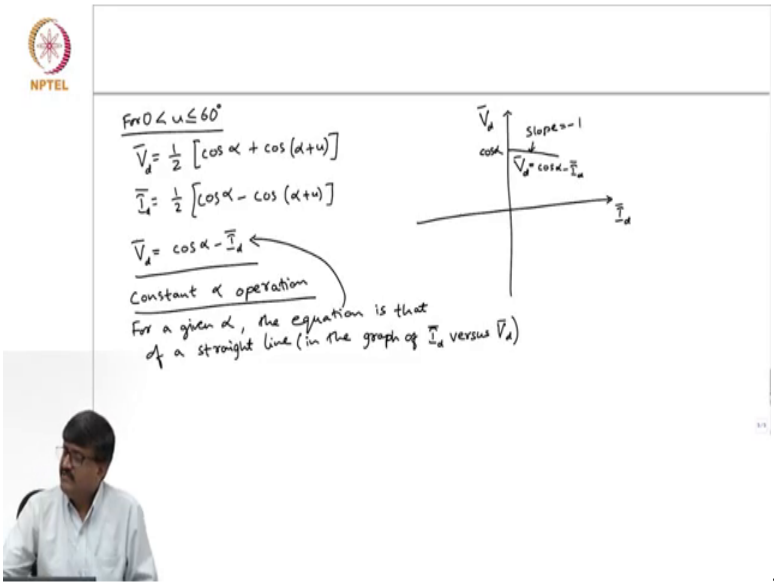


Now, let me go back to these two equations 1 and 2. So, I have equation 1, relating V d bar alpha and u and equation 2, relating I d bar alpha and u. So, using 1 and 2, so if I want a characteristic in the V d I d plane, I can get rid of say alpha r e. So, its I mean we really see that it is easy to get rid of u by adding these two equations. So, if I add these two equations then I get an equation relating V d I d and alpha.

So, what I am trying to say is let me just take these two equations and rewriting this equations, V d bar is half cos alpha plus cos alpha plus, I d bar is half cos alpha minus cos alpha plus. So, if I add these two equations, then alpha is sorry u is eliminated and I get V d bar equal to plus alpha minus I d bar.

So, if I take the plane in which I have I d bar on the abscissa and V d bar on the ordinate. So, if I keep alpha constant; so if I keep alpha constant, then this equation V d bar equal to cos alpha minus I d bar is the equation of a straight line. So, I get a straight line and the straight line intersects the V d bar axis at cos alpha and the slope of the straight line is minus 1.

So, if I keep alpha constant what I get is constant alpha operation. So, it is if I have constant alpha operation then for a given alpha then the equation, I mean I am referring to this equation; the equation is that of a straight line. So, it is a straight line in the graph of I d versus V d instead of equations 1 and 2, suppose I take equations 3 and 4 ok.

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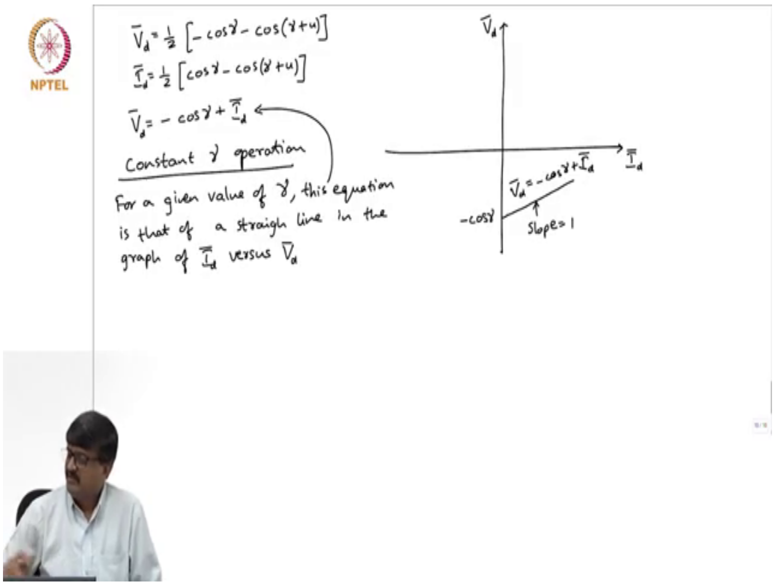


So, let me rewrite those equations 3 and 4. So, I have V d equal to half into minus cos gamma minus cos gamma plus. I d is equal to half cos gamma minus cos gamma plus u.

So, as I did in the previous case, I can actually eliminate u using these two equations. So, if I subtract the second equation from the first equation then I get V d bar equal to minus cos gamma plus I d bar. So, if I take this plane where I have I d bar here and V d bar here. So, if I keep gamma constant, then this equation that I have got is the equation of a straight line. So, I have a equation of a straight line. So, the slope of this straight line is plus 1.

So, this slope is equal to 1. So, what I am trying to do is draw the straight line which is represented by this equation V d equal to minus cos gamma plus I d. So, when I d is 0, V d is equal to minus cos gamma. So, this straight line intersects the V d axis at minus cos gamma. So, what I get by keeping gamma constant is constant gamma operation.

So that means; if I have a constant gamma then the equation that I have is that of a straight line. So, for a given value of gamma, this equation is so, I mean this equation is that of a straight line in the graph of I d versus V d. So, this was obtained by eliminating u from two equations.

Now, instead of eliminating u, so in the previous case also we eliminated u and got the relation between V d I d alpha. So, here we have eliminated even got a relationship between V d I d gamma. I can take equations 1 and 2 and eliminate alpha. So, let us see how that can.

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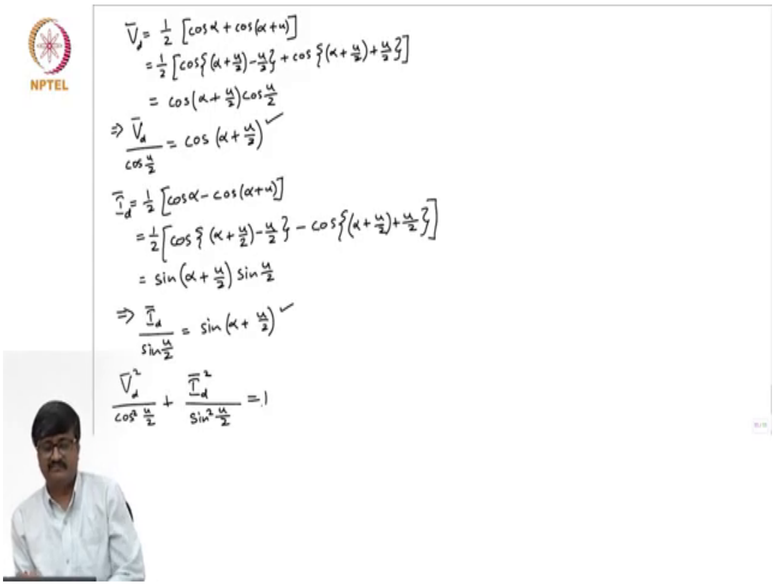


So, let me take the equations 1 and 2, V d is half cos alpha plus cos alpha plus. And I have I d equal to half cos alpha minus cos alpha plus u. So, I will write this as half cos alpha as alpha plus u by 2 minus u by 2. Similarly, I will write the second term as cos alpha plus u by 2 plus u by 2. So, this can be should be equal to cos alpha plus u by 2 into cos u by 2.

So, I do similarly ah some manipulations and get an equation relating I d alpha and u. So, I write again this as half cos alpha plus u by 2 minus u by 2, then the second term is minus cos alpha plus u by 2 plus u by 2. So, this can be shown to be equal to sin alpha plus u by 2 sin u by 2. What I do here in the this equations? So, I take a cos u by 2 which is on the right hand side to the left hand side. So, I write this as V d by cos u by two is equal to cos alpha plus u by 2. Similarly, if I take this equation I shift sin u by 2 to the left hand side. So, I get I d by sin u by 2 equal to sin alpha plus u by 2.

Now, I take the square of this equation on both sides and I take the square of this equation on both sides. So, after squaring add the left hand sides of the two equations and the right hand side of the two equations. So, if you take the square of cos alpha plus u by 2 and add it to the square of sin alpha plus u by 2, you get one on the right hand side. So, on the left hand side, we get V d square divided by cos u by 2 plus I d square divided by sin square u by two on the right hand side you get. So, if I look at this equation, I have I d, V d and u in this equation.

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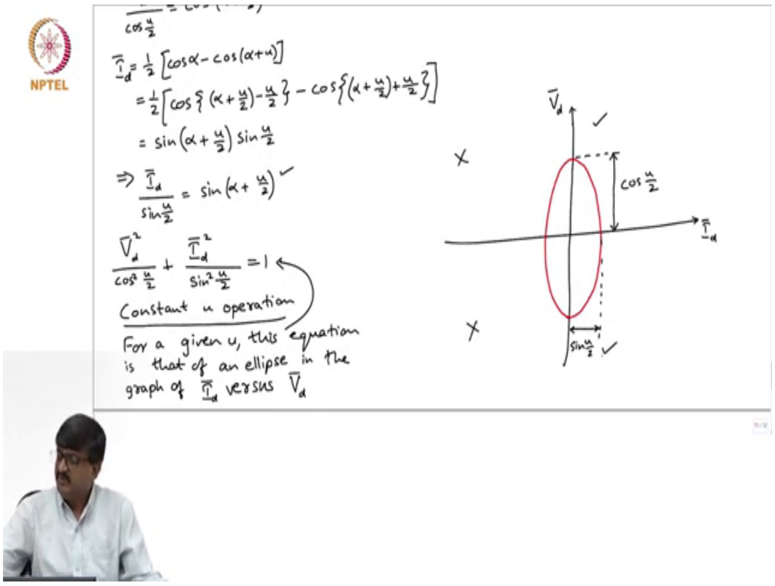


So, if I keep u constant then what I get is constant u operation. So, if u is constant then, this equation is the equation of the curve. So, what is this curve? So, this curve is that of an ellipse. So, for a given u this equation; this equation is that of an ellipse. So, in the graph of V d in the graph of I d versus V d. So, if I take the graph I may have I d here and V d here then of course, if I draw the complete ellipse it is here, it is like this of course, operation is not possible in the second and third quadrant.

So, I am just showing it in the second and third quadrant, but its operation is possible only in the first and fourth quadrants. So, operation is possible here, but not here. So, if I complete the ellipse I get it in all the four quadrants. So, here this distance is cos u by 2. So, in earlier if I take a line parallel to a V d axis than the distance from the V d axis of this line is sin equal to. So, what we get is an ellipse, if I have constant operation.

So, point to notice if I have constant alpha operation then in the graph of I d versus V d I get a straight line with slope minus 1, for constant gamma operation I get a straight line with slope plus 1 in the graph of I d versus V d and for constant u operation; I get an ellipse in the graph of I d versus V d.

So, these were obtained for u greater than 0 and less than equal to 60 degrees. Suppose, u is greater than or equal to 60 degrees and less than 120 degree, then what happens?

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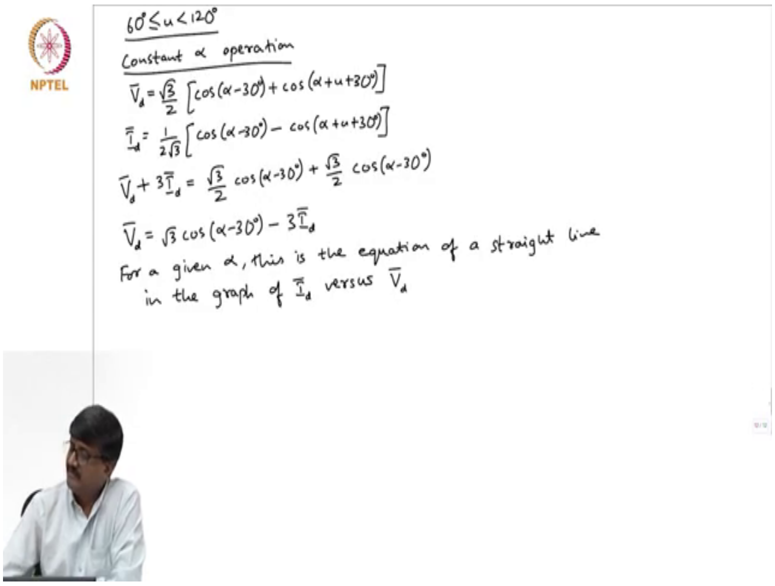


Let us see. So, you can get constant alpha operation constant gamma operation and constant u operation even for this range of. So, how do I get constant alpha operation? So, essentially I am asking what will be the equation of the curve if alpha is kept constant in the graph of I d versus V d.

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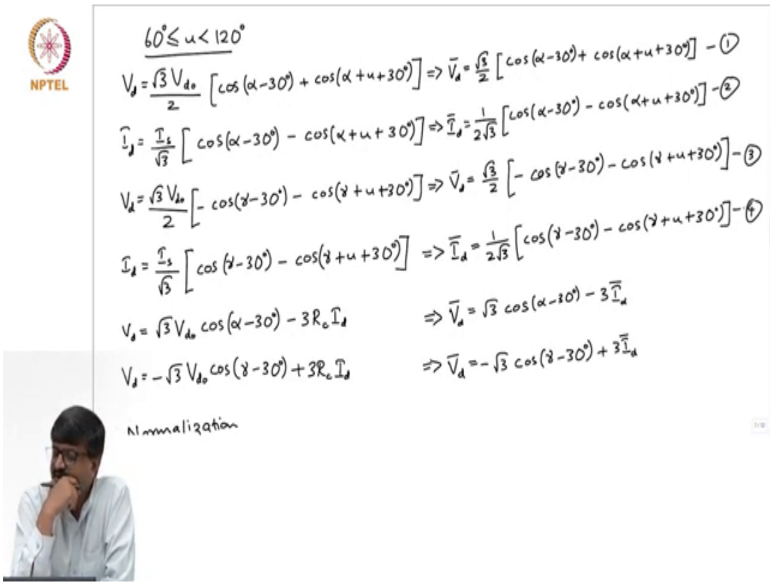


So, for that I have to consider the equations corresponding to the appropriate range of u that is greater than or equal to 60 degrees and less than 120 degree. So, let me call this as equation number 1 for this relation this is 2, 3, 4. So, if I take equations 1 and 2, I can eliminate u and get an equation relating V d I d alpha then I can see what will be the curve that I get for a given value of alpha.

So, if I take 1 and 2 add them then what do I get. So, I straight away write the result. So, take equations 1 and 2 if I add equations 1 and 2, then what do I get let me just do the few steps. So, I have constant alpha operation is might achieve. So, V d is root 3 by 2 cos alpha minus 30 degrees plus cos alpha plus u plus 30 degrees when I d is 1 by 2 root 3 cos alpha minus 30 degrees minus cos alpha plus u plus 30 degrees.

So, if I add the two equations of course, I have to multiply one of the equations by an appropriate factor and then add so, that you get (Refer Time: 19:49). So, if I take the left hand side of the first equation and add it to 3 times the left hand side of the second equation. So, I get root 3 by 2 cos alpha minus 30 degrees. And if I multiply the second equation by three and the left hand side I have to of course, multiply the second equation right hand side also by 3. So, the second terms on the right hand side gets canceled get canceled. So, what remains is plus root 3 by 2 cos alpha minus 30 degrees.

So, the equation that I get is V d equal to root 3 cos alpha minus 30 degree minus 3 I d. So, for a given alpha this is the equation of a straight line with slope minus 3 in the graph of I d versus V d. So, for a given alpha this is the equation of a straight line in the graph of I d versus V d. So, similarly, we can get what is known as constant gamma operation.

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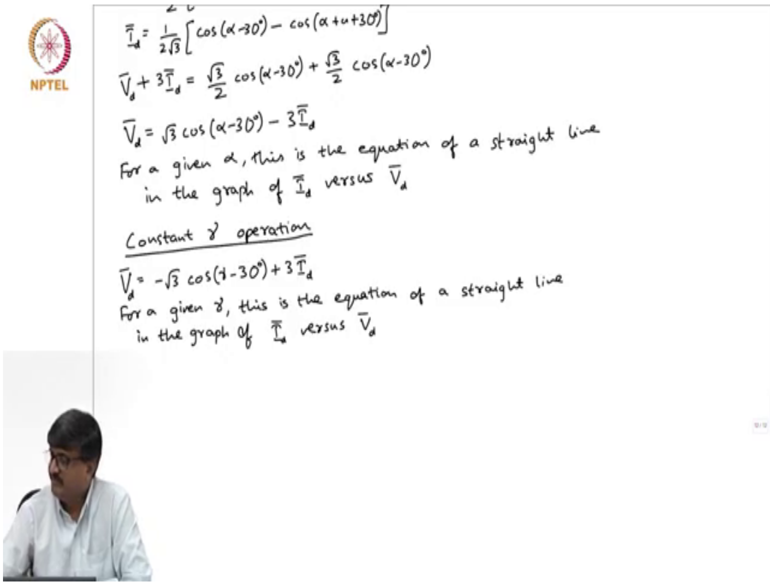

So, if I want constant gamma operation, then I have to go that to do set of equations. So, the equations corresponding to u greater than or equal to 60 degrees and less than 120 degrees, I have to take equations 3 and 4 and the eliminate u from the right hand side of these two equations.

So, you can do some manipulations and try to show that we can get a relation between V d, I d and gamma ok. So, write straight away the relation I leave it to you to see how can derive this. So, the equation that we get is V d bar is minus root 3 cos gamma minus 30 degrees plus 3 I d.

So, if I take a constant gamma, then this is the equation of again a straight line in the graph of I d versus V d. So, for a given value of gamma this is the equation of a straight line in the graph of I d versus V d. So, as in the case of u greater than 0 and less than or equal to 60 degrees, here also, we can get the constant u operation. So, let us see complicate constant u operations.

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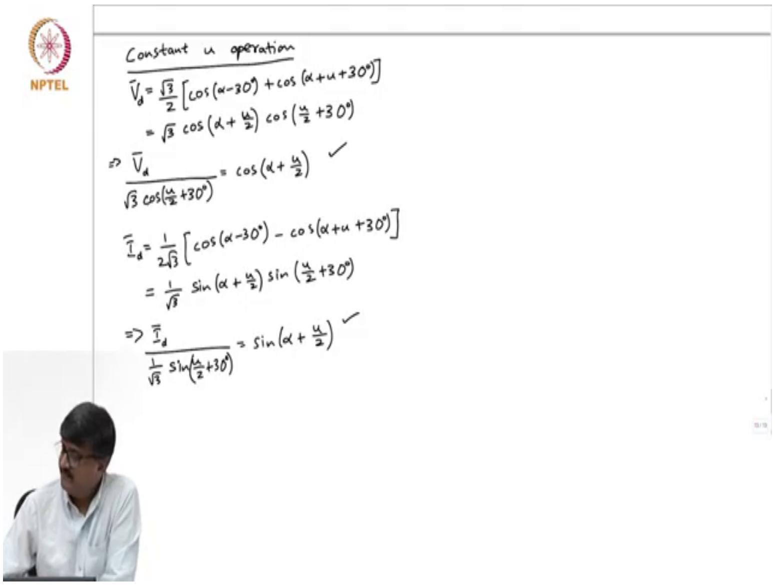


So, if I want constant u operations; so let me go back to this equations. So, I have to again consider equations 1 and 2 and eliminate alpha. So, let me see, how we can do that. So, I have equations 1 and 2; equation 1 is V d equal to root 3 by 2 cos alpha minus 30 degrees plus cos alpha plus u plus 30 degrees. And the second equation is I d equal to 1 by 2 root 3 cos alpha minus 30 degrees minus cos alpha plus u plus 30 degrees. Now, I leave it to you to show that this is equal to root 3 cos alpha plus u by 2 into cos u by 2 plus 30 degrees.

Similarly, this can be shown to be equal to 1 by root 3 sin alpha plus u by 2 into sin u by 2 plus 30 degrees. So, if I want to eliminate alpha then I will retain the factor involving alpha on the right hand side and push the other term other factor to the left hand side and similarly, in the second equation also I will retain sin alpha plus u by 2 on the right hand side and push the other factors on to the left hand side. So, from this I get V d bar divided by root 3 cos u by 2 plus 30 degrees. So, this is equal to cos alpha plus u by 2.

So, in this equation also I push the terms on the right hand side, I push the factors on the right hand side other than sin alpha plus u by 2 to the left hand side. So, I will get I d bar divided by 1 by root 3 sin u by 2 plus 30 degrees. So, this is equal to sin alpha plus u by 2. So, if you look at either this equation or this equation on the left hand side I want the alpha and on the right hand side I have in the first equation cos alpha plus u by 2, the second equation I have sin alpha plus u by 2.

So, if you square both sides of these two equations and add them. So, the right hand side you get 1 and the left hand side you get an expression involving V d I d and u.

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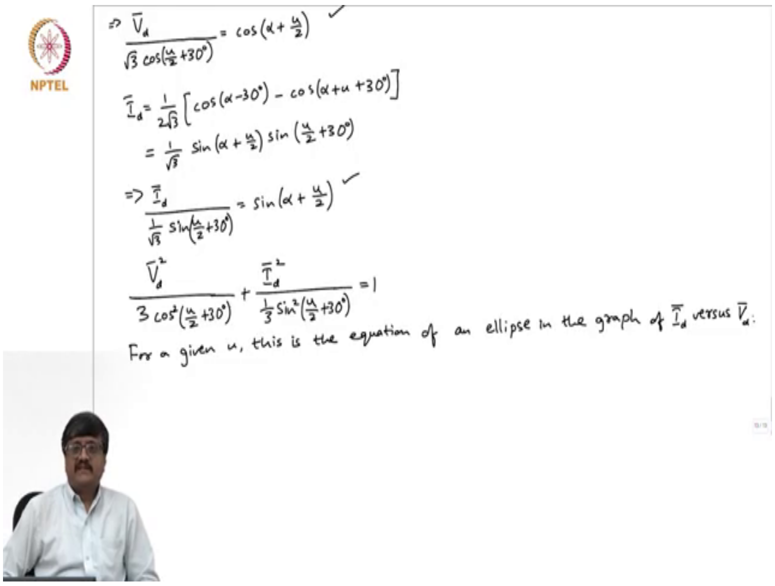

So, if I do that I get V d square divided by 3 cos square u by 2 plus 30 degrees plus I d square divided by 1 by 3 sin square u by 2 plus 30 degrees equal to. So, if u is constant then this is the equation of an ellipse in the graph of I d versus V d.

So, for a given u, this is equation of an ellipse in the graph of I d versus V d. So, we can get the different characteristics such as constant alpha, constant gamma, constant u, either for the case of u greater than 0 and less than or equal to 60 degrees or for the case of u greater than or equal to 60 degrees and less than 120 degrees. So, I stop here and we look at the other aspects of the characteristics in this graph of I d versus V d in relations.