DC Power Transmission Systems
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Lecture - 34
Normalization

So, let us summarize some of the equations that we have derived so far.

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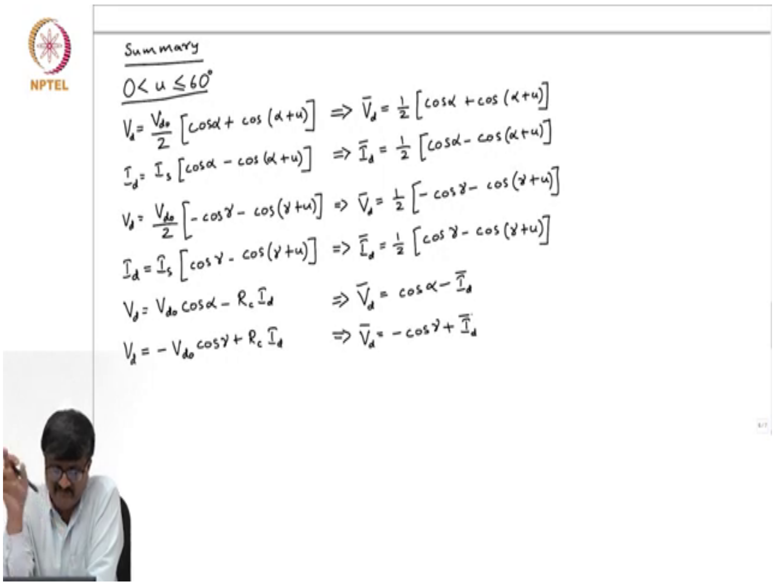

So, we will divide this into two sets of equations; one set is for u greater than 0 and less than or equal to 60 degrees, the other set is for u greater than or equal to 60 degrees and less than 120 degrees. So, we got a few equations for u greater than 0 and less than or equal to 60 degrees. So, write all these equations; the first equation is relating V d, V d o, alpha and u. So, V d is equal to V d o by 2 cos alpha plus cos alpha plus u; I d is equal to I s cos alpha minus cos alpha plus u.

Then we also got an equation relating V d, V d o gamma. So, we have V d is equal to V d o by 2 minus cos gamma minus cos gamma plus u. Similarly there is an equation relating I d, I s, gamma and u. So, I d is I s into cos gamma minus cos gamma plus u and there is an equation relating V d, V d o, alpha, R c, and I d. So, we got V d equal is equal to V d o cos alpha minus R c I d. And the last equation that we consider always the relation between V d, V d o, gamma, R c I d, so that is V d is equal to minus V d o cos gamma plus R c I d. So, these six equations were obtained for u greater than 0 and less than 60 degrees. We got similar equations for u greater than or equal to 60 degrees and less than 120 degrees.

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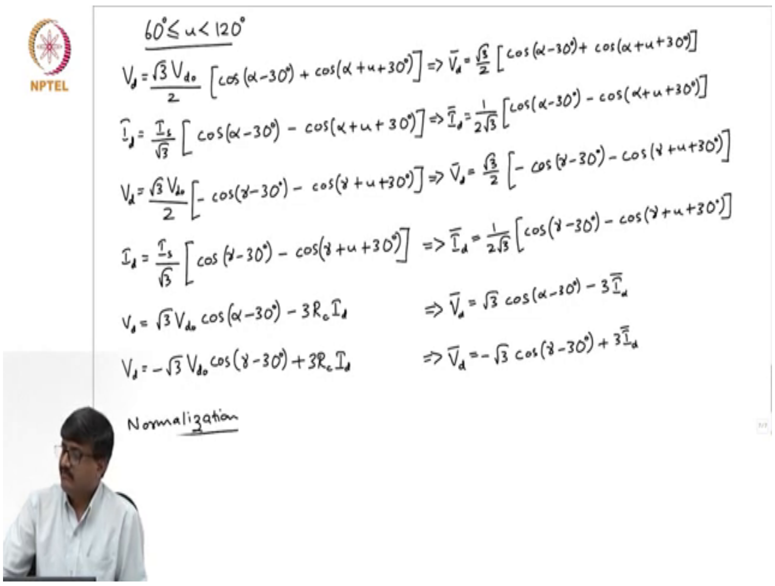

So, let me summarize those equations also; 60 degrees less than or equal to u less than 120 degrees. So, V d is equal to the root 3 V d o by 2 cos alpha minus 30 degrees plus cos alpha plus u plus 30 degrees; then the equation relating I d I s, alpha and u is, I d is equal to I s by root 3 into cos alpha minus 30 degrees minus cos alpha plus u plus 30 degrees.

V d is equal to root 3 V d o by 2 minus cos gamma minus 30 degrees minus cos gamma plus u plus 30 degrees. And the relation between I d I s, gamma and u for 3 and 4 valve conduction mode or of course from 3 valve conduction mode is, I d equal to I s by root 3 cos gamma minus 30 degrees minus cos gamma plus u plus 30 degrees. Then you have two more equations involving R c. So, V d is root 3 V d o cos alpha minus 30 degrees minus 3 R c I d. Now V d is equal to minus root 3 V d o cos gamma minus 30 degrees plus 3 R c I d.

So, I have 6 equations, so for 3 and 4 valve conduction mode and 3 valve conduction mode and 6 equations which is applicable for 2 and 3 valve conduction mode as well as 3 valve conduction; because both these sets of equations are valid for u equal to 60 degrees. Now we are all familiar with what is known as normalization; normalization is something which is common in power system analysis.

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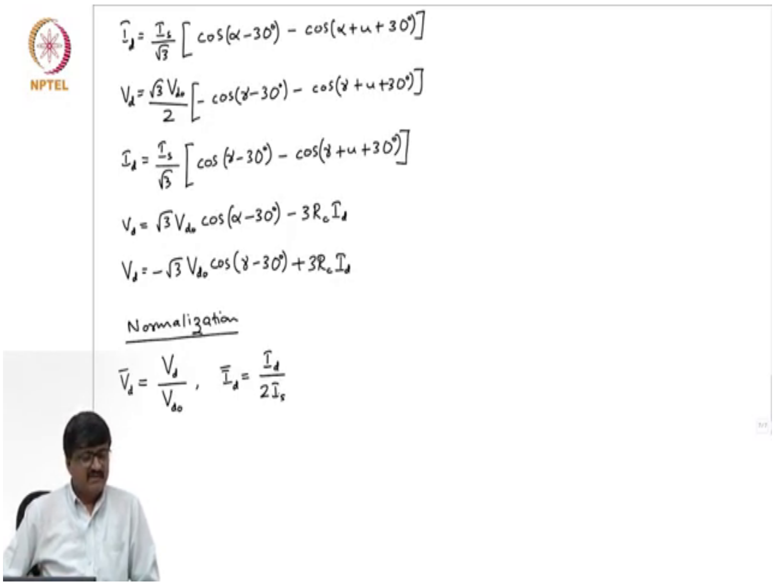

So, it will help in simplifying the equations. So, let us see how we normalize the equations which are applicable to the converter; of course, we will consider only the right quantities on the DC side. So, we need to find what are the suitable phase values? So, if I take the DC side voltage or the DC side current; then I need to find the appropriate phase values, so I get normalized value or the quantity implied by dividing the quantity by the DC value.

So, if I take the DC side voltage V d, the average value of the DC side voltage V d. So, we choose the base value as V d o, so I normalize the DC side voltage by dividing it by V d o to get what is known as the V d in per unit. So, I differentiate between the actual V d and the V d in per unit by a bar.

So, V d bar is the DC side voltage in per unit, which is defined as the actual V d divided by the phase value V d. Similarly if I take the current I d, the normalized current or current in per unit on the DC side is defined as the actual current divided by the base value. So, here we choose the base value as 2 I s.

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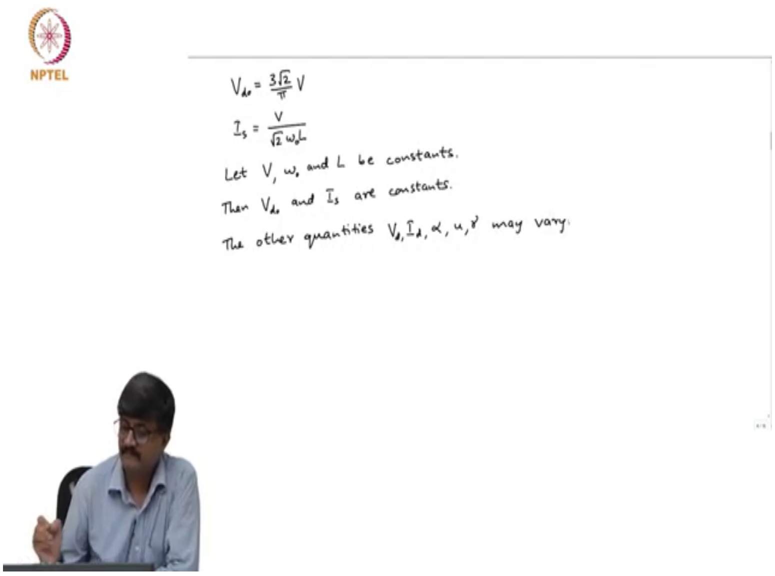

If you look at the expression for V d o and I s; V d o is 3 root 2 by pi V, where V is the RMS value of line to line voltage and I s is V by root 2 omega o L, omega o is the operating value of the angular frequency and L is the inductance in each phase on the AC side. So, if I assume V omega o and L to be constant. So, let V omega o and L be constants. So, it actually means V d o and I s are constants; then V d o and I s are constants. So, there are other quantities which may vary, there are, so the other quantities. So, what are the other quantities? The other quantities are V d, I d, alpha, u, gamma may vary.

So, what we will do is, we will try to rewrite the equations that we wrote just now in terms of the quantities in per unit. So, I have V d and I d in equations that I have written just now. So, I will normalize these equations and try to write these equations in terms of V d bar or I d bar, which are nothing, but the voltage and current in per unit.

So, if I look at these equations, I mean I get the equations in per unit either by dividing it by V d o, which is the base value of V d or dividing it by 2 I s which is the base value of the current. So, if you look at these set of equations for u greater than 0 and less than or equal to 60 degrees, I have 6 equations. So, the first equation as, I mean has to be divided by V d o; because all the quantities in this equations are voltage, ok. The second equation of course, all the quantities are current; so if I want the right quantities in per unit, I have to divide the second equation by 2 I s.

So, let us try to do this normalization by taking one equation at a time. So, if I take the first equation. So, I divide both sides of this equations by V d o; then I get on the left hand side V d by V d o which is nothing but V d bar. On the right hand side V d o in the numerator gets cancelled by the V d o in the denominator. So, I get on the right hand side 1 by 2 cos alpha plus cos alpha plus u.

So, I can do the normalization of current also. So, if I take the second equation, I divide the left hand right hand sides by 2 I s. So, I d by 2 I s is nothing, but I d bar on the left hand side. So, on the right hand side I get 1 by 2 cos alpha minus cos alpha plus u.

So, the third equation is V d bar equal to 1 by 2 minus cos gamma minus cos gamma plus u; and the forth equation is V d bar sorry, forth equation is I d bar equal to 1 by 2 cos gamma minus cos gamma plus u. Then the next equation is V d equal to V d o cos alpha minus R c I d. So, I have to divide this equation by V d o; the left hand side is V d bar, the right hand side is first option minus. So, the second term is R c I d, so if I divide this by V d o. So, if I use the definition of R c, then the second term on the right hand side of this equation after normalization is I d bar. And the last equation is V d bar is equal to minus cos gamma plus I d.

Now if you notice the equations that I have obtained from the original equations, so there is no V d o there is no I s. So, what I have on the in the revised set of equations is V d bar, I d bar, alpha and u; and of course, in some equation there is a gamma (Refer Slide Time: 13:18).

So, I do not have V d o anywhere, a after normalization I do not have I s, I do not even have R c, ok

So, I can similarly get the equations in per unit for this set of equations, which are which is applicable for u greater than and equal to 60 degrees and less than 120 degrees. So, the first equation is normalized by dividing by V d o. So, the left hand side is V d bar is equal to root 3 by 2 cos alpha minus 30 degrees, plus cos alpha plus u plus 30 degrees. Then the second equation is normalized by dividing by 2 I s; so I get I d bar equal to 1 by 2 root 3 cos alpha minus 30 degrees minus cos alpha plus u plus 30 degrees.

And the next equation is divided by V d o on both sides. So, I get on the left hand side V d bar. So, is equal to root 3 by 2 minus cos gamma minus 30 degrees minus cos gamma plus u plus 30 degrees. Next equation is divided by 2 I s, I get I d bar is equal to 1 by 2 root 3 cos gamma minus 30 degrees minus cos gamma plus u plus 30 degrees. The next equation I have V d, V do, alpha, R c I d; so after normalization I will not have V d o, I will not have R c.

So, I get V d bar equal to root 3 cos alpha minus 30 degrees. So, if I use the definition of R c. So, R c is defined as V d o by 2 I s. So, I get the second term on the right hand side of this equation as, 3 I d bar; and the last equation is obtained by dividing both sides by V d o, I get V d bar equal to minus root 3 cos gamma minus 30 degrees plus 3 I d. So, what we have done is; obtain the equations in per unit V d, per unit I d, instead of the actual V d and actual I d.

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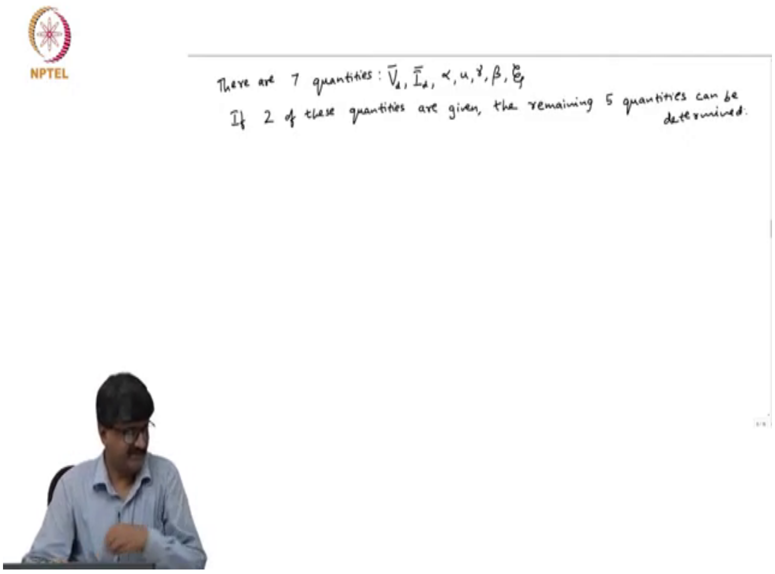

So, there are 7 quantities. So, let me write down what are the quantities. There are 7 quantities; the V d or V d bar which is the V d in per unit, I d bar is nothing but I d in per unit, alpha, u, gamma, beta, and psi. So, there are 5 angles and the voltage V d bar, the current I d bar.

So, among these 7; if 2 of these quantities are given, the remaining 5 can be determined. So, if 2 of these quantities are given; the remaining 5 quantities can be determined. So, we can use the different equations that we have derived. So, derive the values of these 5 quantities from the given values of 2 quantities, ok.