DC Power Transmission Systems
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Lecture - 10
Analysis of 6 pulse LCC neglecting inductance: Jumps in voltage across a valve

So, in the last class, we actually completed a table. So, the last column of the table is voltage across a valve.

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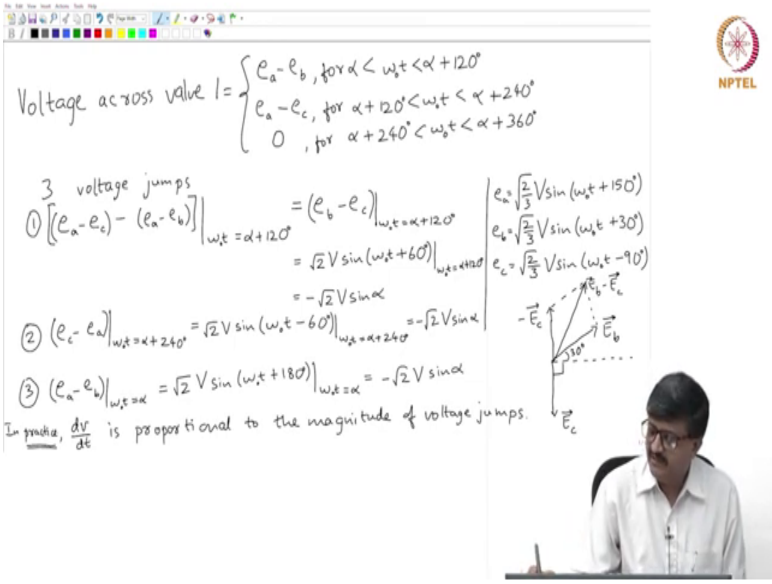

So, we took one of the valves; valve 1. So, if I look at the voltage across valve 1. So, we got the expressions for these voltage across valve 1, for all the 6 intervals ok. So, if you look at the expressions, there are 3 expressions; either it is equal to e a minus e b or it is equal to e a minus e c or is equal to 0.

So, it is equal to ea minus e b in the first two intervals that we considered. So, this is a for omega o t greater than alpha and less than alpha plus 120 degrees. Then, it is equal to e a minus e c for omega o t greater than alpha plus 120, and less than alpha plus 240 degrees. And it is 0, for omega o t greater than alpha plus 240 degrees and less than alpha plus 360 degrees.

So, the inference that one can get from the last column of the table that we have written in the last class is that, we can actually find out I mean is actually the summary what I have written on the just a summary of that last column.

So, we can find out what is the magnitude of the voltage jump. So, there is a discontinuous voltage across valve 1 in general. So, the valves are subjected to dv by dt stress of course, there is a specific value which is the maximum that can be withstood by the thyristor valve. So, one should not exceed it. So, if I look at I mean I will come to dv by dt later, the rate of change of voltage with time. But, let us first see, what is the magnitude of the voltage jumpok.

So, what is the magnitude of the discontinuity? So, there are 3 voltage jumps [inaudible]. So, jump is just a discontinuity. Now, if I want to find the magnitude of this jump so, what I should do is; So, I suppose the jump occurs, if you look at the expression for the voltage across valve 1 at alpha plus 120, there is a jump.

So, it goes from e a minus e b to e a minus e c. So, to calculate the jump, I will take the value just after alpha plus 120 and from that subtract the value just before alpha plus 120 that is all it ok. So, what I do is, I calculate the value of the expression just after alpha plus 120; that is e a minus e c. So, from this subtract e a minus e b, which is the expression just to before alpha plus 120.

So, I have to evaluate this quantity at omega o t equal to.

Student: (Refer Time: 04:02) Alpha plus 120.

Alpha plus 120; so, if I evaluate this are alpha plus 120, I get the magnitude of the jump. So, I know the expressions for e a, e b and e c. So, I will actually fix the expressions for e a, e b, e c. So, if you recall, we wrote the expressions in terms of the rms value of line to line voltage. So, e a is root 2 by 3 V sin omega o t plus 150 degrees. Now, the purpose of choosing this 150 for the voltage e a is, I mean for the sake of having the instant of natural conduction for valve 3 as 0; that is the only point; there is nothing more than that ok. So, one could have chosen any arbitrary value that.

So, I just chosen 150 for the sake of taking one of the valve say valve 3 the, instead of natural conduction of which is 0 ok. So, if I substitute the expressions for e a, e c and e b, what do I get? Of course, I mean, I can substitute a only for e b and e c because, there is a simplification here, e a minus e a; so, it is e b minus e c ok. So, it is e b minus e c evaluated at omega o t equal to alpha plus 120.

So, what is this a e b minus e c? So, we can note that the expressions are like this, let me write the expressions e a is root 2 by 3 V sin omega o t plus 150 degrees; e b is root 2 by 3 V sin omega o t plus 30 degrees; and e c is root 2 by 3 V sin omega o t minus 90 degrees.

So, given these expressions for e a, e b, e c; can I straight away say what is e b minus e c without doing any trigonometric? See, it is easy to visualize these voltage as phasors. So, if I take say I want e b minus e c. So, let me take e b. So, what is e b? The phasor E b is shown with an angle phase angle 30 degrees ok. So, I suppose I take the angle of the phasor as the phase angle in the of the instantaneous waveform. So, I just take the argument of the sin function minus omega o t. So, that gives the phase a phase angle.

So, that is taken as the angle of the complex E b, then E c. What is E c? E c is having a phase angle minus 90. So, the complex E c is shown with an angle minus 90. See, our all our references see, all our phasors are with respect to the positive real axis. We are we do not explicitly show the real axis and the imaginary axis, but whenever we draw a phasor as a complex number, it is in the complex plane ok. So, what I mean to say is this angle is 30 degrees and this angle is 90 degrees. But, what I want is E b minus E c. So, I should add minus E c to E b.

So, minus E c is obtained from E c by rotating it by 1 180 degrees. So, this is minus E c. So, if I want E b minus E c, add E b and minus E c. So, complete this parallelogram I get this. So, this is E b minus E c. So, I just to use this a convention of showing a complex number by an arrow over that ok. So, I have shown arrow over E b, E c, minus E c and the E b minus E c. So, one can easily say, what is the phase angle of E b minus E c. What is the phase angle?

Student: 60 degree.

60 degrees and what is the.

Student: (Refer Time: 08:39).

Peak value? So, peak value of e b is root 2 by 3 V. So, it is root 2 V. So, I can straight away write the expression the instantaneous expression for e b minus e c as root 2 V sin omega o t plus some angle, which is nothing but the phase angle of E b minus E c which is.

Student: 60 degree.

60 degrees. Now, what I am trying to point out here is should I always draw this phasor diagram. I mean with practice many times, you need not even rather phasor diagram. Looking at the expression for e b and e c, I should be able to immediately or quickly write the expression for e b minus e c. So, that should be possible. So, the reason is all these are a balanced voltages.

So, if you take any of these e a, e b or e c, they are equal in magnitude and displaced by 120; due to which, I can easily write the expression for the differences. So, the differences in fact a line voltage. If e a, e b and e c are phase voltages, so difference between any two is line voltage; and I can easily write the expression without even drawing this phasor diagram ok. So, this has to be calculated at omega t omega o t equal to alpha plus 120 degrees. So, what is this?

Student: (Refer Time: 09:59).

So, I get an expression for the first voltage and plus minus root 2 V sin alpha. So, this is the magnitude of the jump that occurs at alpha plus 120. So, there is a one more jump at alpha plus 240, and one more at alpha plus 360. So, if I go to the next jump, the second voltage jump; so, we are talking about the voltage jumps across valve 1 ok. So, if I look at any other valve, the waveform across the valve will not change with valve of course, for all valves the same wave form with the are only thing is, it there will be a phase shift that is all except for the phase shift its identical.

So, the expression is 0 minus e a minus e c evaluated at alpha plus 240. So, it is e c minus ea. So, 0 minus of e a minus e c; that is, e c minus e. So, this is calculated at omega o t equal to alpha plus 240. So, should I draw again the phasor diagram to find the expression?

So, I know the expression for instantaneous e c; I know the expression for instantaneous e a; so, e c minus e a will have a peak value root 2 V and the expression is root 2 V sin omega o t plus a phase angle I should add. So, if e c is having a phase angle of minus 90, e a is having a phase angle of 150, minus e a will have a phase angle of? So I want minus ea. So, e a is having a phase angle of 150. So, minus e a has a phase angle of

Student: (Refer Time: 11:54).

Shift by 1 180 degrees minus 30. So, e c is having minus 90, e a is having minus 30. So, a phasor of a phase angle minus 90, another one is minus 30 so, the resultant is having phase angle minus 60. So, this is minus 60 degrees. So, this is evaluated at omega o t equal to alpha plus 240 degrees.

So, what is this? So, if I substitute for omega o t, the value alpha plus 240; what do I get? I again get the same expression for the voltage amp as I got in the previous case, minus root 2 V sin alpha, is that ok. Then, there is one more jump, the third jump is happening at?

Student: Alpha itself.

Alpha itself alpha and alpha plus 360.

Student: Same.

Just one cycle. So, at alpha itself so, the expression is, e a minus e b evaluated at alpha. So, e a minus e b so, what is e a minus e b? Root 2 V sin omega o t plus a phase angle I have drawn. So, e a is having a phase angle of 150, e b is having a phase angle of 30, means minus e b will have a phase angle of?

Student: 30.

See e b is having a phase angle of 30 minus e b?

Student: 200 (Refer Time: 13:54).

Yeah better to get angles in between minus.

Student: (Refer Time: 14:01).

180 and plus 180.

Student: Minus 150.

Minus 150. So, I have 150 and minus 150;

Student: 0.

Not 0; 150 and minus 150. The 2 phasors are: 150 and minus 150; the resultant is minus

Student: Minus.

180 or plus 180 ok. So, this is root 2 V sin omega o t plus or minus 180 does not make any difference. So, this is evaluated at omega o t equal to alpha. So, again I get the same expression for the voltage jump, minus root 2 V sin alpha. So, all the voltage jumps are having the same magnitude in this case minus root 2 V sin alpha; there are 3 voltage jumps. Now, the question is, what is the stress dv by dt. The rate of change of voltage with respect to time.

So, the point we are trying to consider here is that, what should be the rating of the thyristor valve as far as dv by dt is concerned. See there is the voltage rating, there is a current rating, there is also a rate of change of voltage rating. So, the valve should be designed to withstand this dv by dt.

Of course, the question is what is alpha. So, we have to take the value of alpha which gives the maximum possible I mean maximum possible voltage jump. So, the maximum possible voltage jump you get or if I; if you take alpha is 90 ok. Now, what should be what is the value of dv by dt?

Student: (Refer Time: 15:42).

Sorry

Student: (Refer Time: 15:44).

This is jump. See, this is voltage jump is just the change in voltage. What I want is the rate of change of voltage with respect to time. What is the value?

Student: (Refer Time: 15:57) Have know the actual time the practical time name (Refer Time: 16:00).

Yeah, now there is a small difficulty here. Now, what we have been assuming here is.

Student: Ideal

Ideal device. So, in an ideal device, the time taken to go from one state to other on to off state or off to on state is

Student: 0.

0. So, this gives the value of infinity.

Student: Yes.

But, in practice what we need to do is, you take the transition time to go from one state to another and that is common for all the jumps. So, the transition time is almost common for all the jumps. So, what we need to do is you have to divide this voltage jumps by the transition. So, in practice, we have to take the time taken to go from the on state to off state or off state to on state and then that comes in the denominator what comes the numerator is this voltage jump. So, that gives the value of dv by dt ok. So, that is how the magnitude of voltage jumps actually become important.

So, one can say that dv by dt is proportional it is, I will not use this symbol for proportional; it is proportional to the magnitude of voltage jumps. Now, it has to be noted that in practice say, otherwise if I just assume an ideal device dv by dt will be infinity.

So, in practice means I am not ignoring the time taken to go from on state to off stare or off state to on state ok. So, the magnitude of voltage jumps gives me some idea of what should what will be the dv by dt so, that the valve has to be rated for that dv by dt. Now, we will look at the other columns of the table that we have written and try to get some more quantities ok. If this is clear, I will move on to the next quantity of interest.