DC Power Transmission Systems

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Lecture – 42

6 pulse LCC with resistance, inductance and voltage source on the DC side: Part 2

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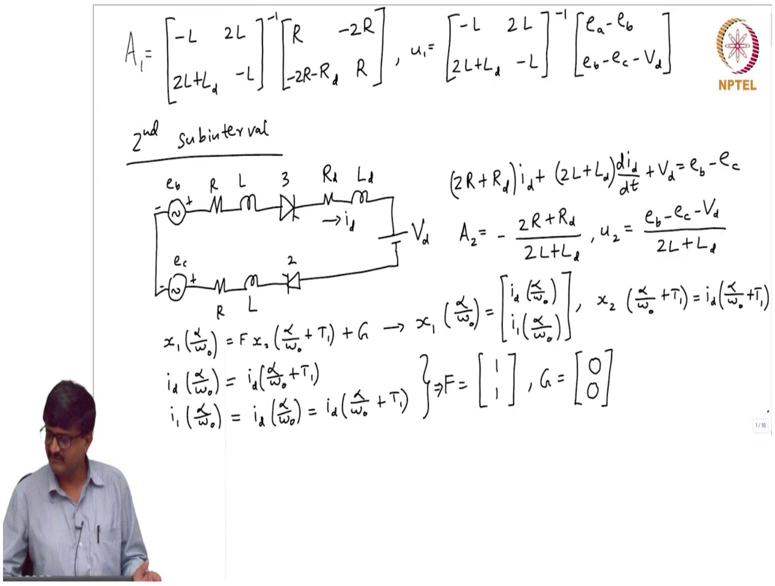

I will write the expression for A 1. So, I will straight away write the expression, please check whether it is true minus L 2 L, 2 L plus L d minus L inverse into R minus 2 R, minus 2 R minus R d R. So, this is A 1, is this and of course, so u 1. So, u 1 is minus L 2L, 2L plus L d minus L inverse e a minus e b, e b minus e c minus V d.

So, if I want A 2 and u 2, I should consider the second sub interval of this 2 and 3 valve conduction mode. So, if I take the 2nd sub interval then I have an equivalent circuit; we just shows only those elements that conduct on 0 current. So, 2 and 3 valves conduct. So, this is valve 3, this is valve 2. And I have Rd, Ld and V d on the DC side R L R L.

So, I have e b and e c, the two voltage sources e c. So, if I denote the DC side current by id, the equation that I get by applying Kirchhoff's voltage law is. So, there are 2 resistances with value R and 1 resistance R d. So, 2 R plus Rd into id plus 2 L plus L d into d id by dt plus Vd is equal to e b minus e c. So, if I write this in the standard form, I have d i d by dt on the left hand side and the remaining terms on the right hand side.

So, I get A 2 as minus 2 2 R plus R d divided by 2 L plus L d, I am straight away writing it. So, A 2 is nothing, but the coefficient of id when I write this equation in the standard form. See the standard form is the derivative of the state variable on the left hand side; that is d i d by dt on the left hand side, rest of the terms on the right hand side. And u 2 is just the remaining term on the right hand side. So, that is e b minus e c minus V d divided by 2 L plus Ld. So, we have got everything except F and G.

So, if I want F and G then I have to relate state variables at the beginning of the first subinterval to the state variable at the end of the second sub interval. So, the 2 state variables or id. So, what are the state variable in the first sub interval id and?

Student: i 1.

i 1. Now in the second sub interval it is id. So, this is the general equation. So, if I take x 1 x 1, the first element of x 1 is id. So, what is id at alpha by omega o? So, can I write it in terms of x 2? So, how to write it in this form? See, what I need to do is; I write, I have to write an expression for id and I have also have to write an expression for i 1 at alpha by omega o.

Student: (Refer Time: 05:40).

No. So, how to get it in this form? See here, in this equation; x 1 at alpha by omega o is nothing but, id at alpha by omega o, I 1 at alpha by omega o. So, that is x 1 at alpha by omega o and x 2 at alpha by omega o plus T 1 is, what? id at alpha by omega o plus T 1. Can I relate id at alpha by omega o and id at alpha by omega o plus T 1?

Student: (Refer Time: 06:30).

They are.

Student: Same.

Same, why?

Student: Because it is periodic.

id is periodic with period T 1. Say id is a DC side current. So, the period of id is T 1. So, id at alpha by omega o is same as id at alpha by omega o plus T 1 then what about i 1 at alpha by omega o ok. Now can I relate i 1 at alpha by omega o and id at alpha by omega o, I mean; why 1 should do this becomes clear shortly, can I relate these 2?

Student: (Refer Time: 07:17) both are equal.

Hmm?

Student: (Refer Time: 07:23) at alpha by omega 0 i 3 is 0.

So, i 3 0, so.

Student: (Refer Time: 07:26).

They are equal right.

Student: Yes.

They are equal.

Student: Hm.

See alpha by omega o is the instant at which 3 is turned on.

Student: Yeah.

So, it just before 3 is turned on i 1 and i d are same. So, just at the instant of turning on i 3 is 0. So, i 1 is equal to id. Now from the previous equation this is also equal to i d by i d at alpha by omega o plus T 1. So, from this can I get F and G? So, from this I get F and G, both are of size 2 cross 1. So, what is F? What is G?.

Student: F is 1 plus 1.

F is?

Student: 1 1.

1 1, G is?

Student: 0.

So, G was actually not required in this case. Now why I use G is that is a general solution, so there are cases where G is non zero. So, that is why we need that G. So, far this case, G is actually not required at all because it is 0 ok. So, this is as far as 2 and 3 valve conduction mode is concerned. So, if this is clear we will move on to. See essentially we are trying to find a x 1, x 2, A 1, u 1, A 2, u 2, F and G that is all.

So, given any circuit, if I know these things I can go ahead and solve the equation get the lowercase T 1 and the solution ok. So, the solution can be obtained in a closed forms. So, we have an expression for the solution, but that requires the knowledge of T 1, the lower case T 1. So, that one can get only by solving a non-linear algebraic equation ok. If this is clear then we will consider the same circuit, but 3 and 4 valve conduction mode.

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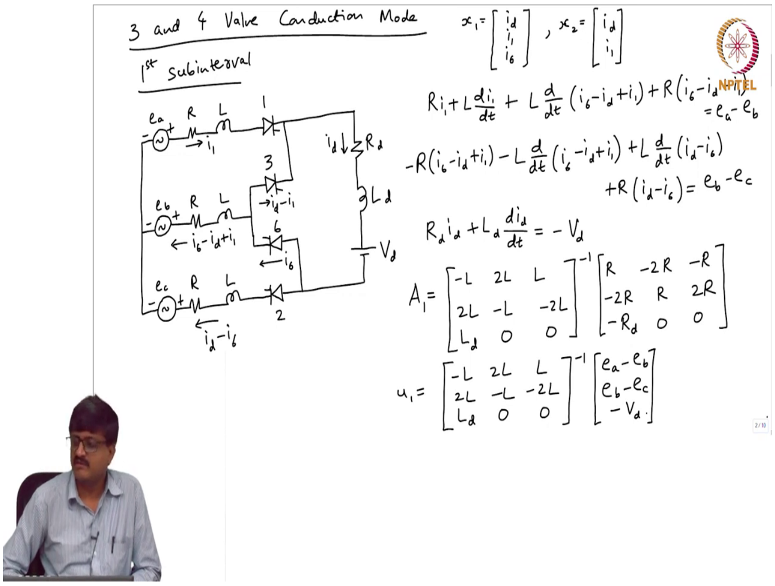

So, again what we will first do is try to take the first sub interval and draw an equivalent circuit showing only those elements that conduct non zero current. So, there is one loop current id flowing through Rd, Ld, Vd and we consider one of the elements of x 1 as the current through the outgoing valve that is i 6. So, i 6 becomes 0 at the end of the first sub interval and of course, the other current that I consider as a state variable is i 1. So, the current through valve 3 is id minus i 1 and the current through e b is suppose I showed this in this direction.

So, it is i 6 minus id plus i 1. So, there are 3 loops and I have to apply Kirchhoff's voltage law to this 3 loops. So, x 1 is the state vector for the first time sub interval. So, I have to take i 6 of the last element of x 1 ok. So, the other two elements of x 1 are id and i 1, id and i 1. So, this also gives x 2 straight away. So, x 2 is same as x 1 without the last element; that is id i 1. Of course, x 2 is applicable for the second sub interval.

So, let us apply the Kirchhoff's voltage law to the 3 loops; the first loop consisting of e a eb R L and the valves 1 and 3. So, it is R i 1 plus L d i 1 by dt plus L d by d t of i 6 minus id plus i 1 plus R i 6 minus id plus i 1. So, this is equal to e a minus e b, that is the first equation. Now if I apply Kirchhoff's voltage law to the loop consisting of e b, e c, R, L and the valves 2 and 6, then R into i 6 minus id plus i 1.

Student: id minus.

Sorry.

Student: i d minus (Refer Time: 14:33).

T 1 i will go in this direction fine.

Student: (Refer Time: 14:44).

Then this is minus L d by d t of i 6 minus id plus i 1. So, if I take the current through valve 2 it is i 6 sorry, i d minus i 6 plus L d by dt of id minus i 6, plus R id minus i 6. So, this is equal to e b minus e c. Then there is one more loop consisting of this valves 3, 6 Rd L d Vd. So, by Kirchhoff's voltage law; Rd id plus Ld d id by dt is equal to Vd, is equal to. In fact, minus Vd.

So, I will leave it to you to write this equations in the standard form. See if I will repeat what is standard form standard form of the first order differential equation, see all this are first order differential equations. So, in the standard form we get the derivative of the state variables on the left hand side the remaining terms on the right hand side.

So, from that I get A 1 and u 1. So, I will straight away give the answer. So, please verify that; A 1 is minus L, 2 L, L, 2 L, minus L, minus 2 L, L d, 0, 0 inverse into A 1 is of size 3 by 3. R, minus 2 R, minus R, minus 2 R, R, 2 R and minus R d, 0, 0, this is A 1. And u 1 is the same of first factor that i is appearing in A 1; that is minus L, 2 L, L, 2 L, minus L, minus 2 L, Ld, 0, 0 inverse into ea minus eb, eb minus ec, minus Vd ok. Now, this is for the first sub interval.

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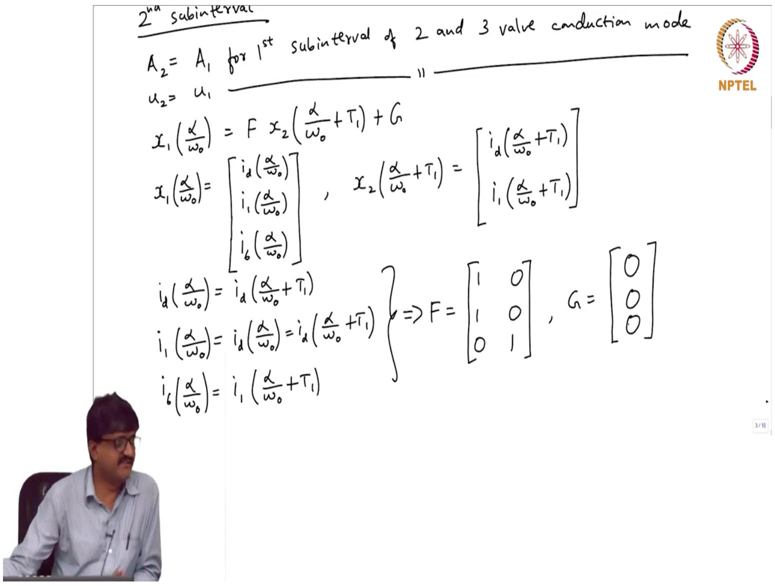

If I want the second subinterval should I again try to get the equation. So, R I have already got this. See the second sub interval is nothing, but the first subinterval of 2 and 3 valve conduction mode. So, I have already got x 2 x 2 is already written. What is A 2 and what is u 2? So, A 2 is equal to A 1 which was obtained for first subinterval of 2 and 3 valve conduction mode.

Similarly, u 2 is nothing but, the u 1 for the first subinterval of 2 and 3 valve conduction mode. So, the only things that remain are finding F and G. So, if I go by the general equation, x 1 by x 1 at alpha by omega o is equal to F into x 2 alpha by omega o plus T 1 plus G. So, now we have x 1, what is x 1 at alpha by omega o?

So, it is id at alpha by omega o, i 1 at alpha by omega o and i 6 at alpha by omega o. And the first time on the right hand side as x 2 at alpha by omega o plus T 1. So, this is id at alpha by omega o plus T 1 and i 1 at alpha by omega o plus T 1.

So, to get F and G what I should do is; take one element of x 1 at a time and try to get some relations. So, based on what happened in the first sub interval I can I say that i 1 id at alpha by omega o see based on sorry, what happened in the 2 and 3 valve conduction mode. So, what is id at alpha by omega o?

Student: (Refer Time: 20:30) equal to id (Refer Time: 20:32).

id at alpha by omega o plus T 1, because id is periodic with T 1. Then the second element of x 1 is i 1 at alpha by omega o. So, that is again id at alpha by omega o. So, which is nothing but, id at alpha by omega o plus T 1. Then finally, i 6 at alpha by omega o. So, what should this be what is i 6 at alpha?

Student: (Refer Time: 21:14).

Student: (Refer Time: 21:15).

i 6 is 0 at alpha by omega.

Student: (Refer Time: 21:21).

Student: (Refer Time: 21:23).

It is not into i 1 at.

Student: (Refer Time: 21:26).

So, see i 1 and i 6 are identical except for a phase shift of 60 degrees which is nothing but T 1.

Student: T 1.

So it is i 1 at alpha by omega o plus T 1. So, from these 3 equations can I say what is F. what is a size of F?

Student: 3 cross (Refer Time: 021:47).

3 cross?

Student: 3 (Refer Time: 21:50).

Size of F.

Student: (Refer Time: 21:52).

3 cross 2, 3 cross 2. So, first row, what are the elements?

Student: 1 0.

1 0, second row?

Student: (Refer Time: 22:04).

1 0, third row?

Student: 0 1.

0 1. So, you we get everything in the first term itself. So, again when you look at G, what is the size of G?

Student: 3 cross.

3 cross.

Student: 1.

1. Size of G is same as x 1. So, it is same as this size of x 1 and all elements are 0. This general solution is something which will be very helpful and of course, 1 as to use a computer to solve for T 1 otherwise calculator cannot be used for solution of such non-linear equations, but there is before we using a computer there is 1 integration that you have to do manually. Please note there is an integration.

So, if you recall in the solution for the scalar T 1, lowercase T is the subscript 1 there is a non-linear equation involving an integral. So, only after simplifying this integral, you can solve the non-linear equation. Now, how to do the integration? See if that integration will involve u 1 and u 2, see if you look at u 1.

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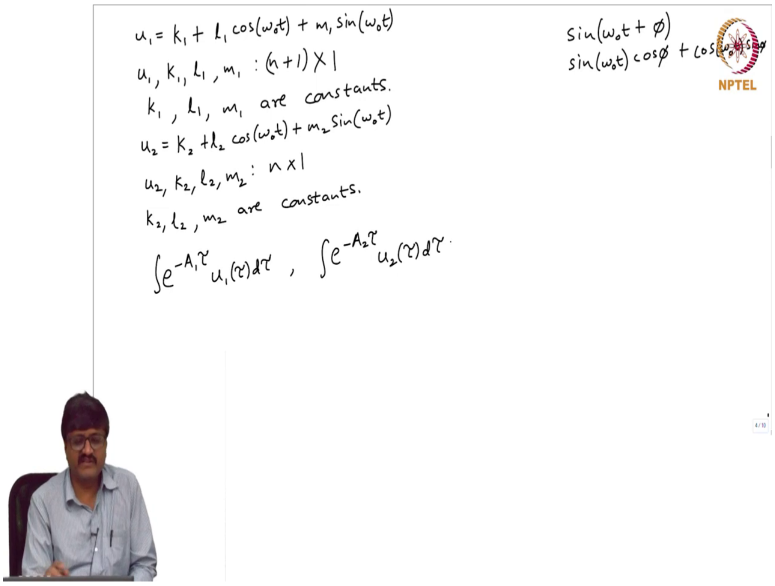

Now, in general this u 1 depends on what is there on the DC side and what is there on the AC side. Now on the AC side, what you have is only sinusoidal voltage sources on the DC side you have either a constant current source or a constant voltage source. So, if you look at all the cases that we have considered so far, whether it is u 1 or u 2. It is dependent on some constant or sinusoidal terms. Constant can be due to the DC side volt voltage source and the sinusoidal quantity can be due to the AC side voltage source.

Can I say that it is sum of 3 column vectors; where, the first column vector is a L 1 which is having the same size as u 1 let me say, k 1, k 1 which is having the same size of as u 1, then L 1 cos omega o t plus m 1 sin omega o t. In general, see many times you come across this expressions in terms of e a, e b, e c.

So, you have this sin omega o t plus some angle 150, 90 150, 30 minus 90. So, in general this can be written as sin omega o t cos phi plus cos omega o t sin phi. Where, this cos phi and sin phi are constant because phi is a constant, but the other terms other factor sin omega o t cos omega o t are functions of time. So, what I am trying to say is I can in general write u 1 as a constant plus a constant factor times cos omega o t plus a constant factor time sin omega ot. Can I do that? Because, I will get terms like sin omega o t plus phi.

Of course there is a coefficient to that which is a constant. So, that gets absorbed in this l 1 and m 1. So, size of k 1 or L 1 or m 1 is same as that of u 1 ok. So, k 1 l 1 m 1, so if I take k 1. So, if I take either u 1 or k 1 or l 1 or m 1. What is the size? What is the size of these? It is same as x 1 which is nothing but, n plus 1 cross 1. Size of x 1 is n plus 1 we use the notation n for the size of x 2. So, is this clear?

So, these are all constants k 1 l 1 m 1 are constants they are constant column vectors. Similarly if you take u 2 it can be written as k 2 plus l 2 cos omega o 2, omega o t plus m 2 sin omega o t. So, again we are the size of u 2, k 2, l 2 and m 2 are n cross 1 they are column vectors and k 2, l 2 and m 2 are constants.

So, when you look at that equation non-linear equation which has to be solved for that scalar T 1. There are integrals of the type exponential of minus A tau u 1, see there you come across this type of integral exponential minus A 1 tau, u 1 of tau, d tau exponential of minus A 2 tau u 2 of tau d tau being integrated. So, these are the integrals that you are come across.