DC Power Transmission Systems
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Lecture - 48
Modes of operation of 12 pulse LCC

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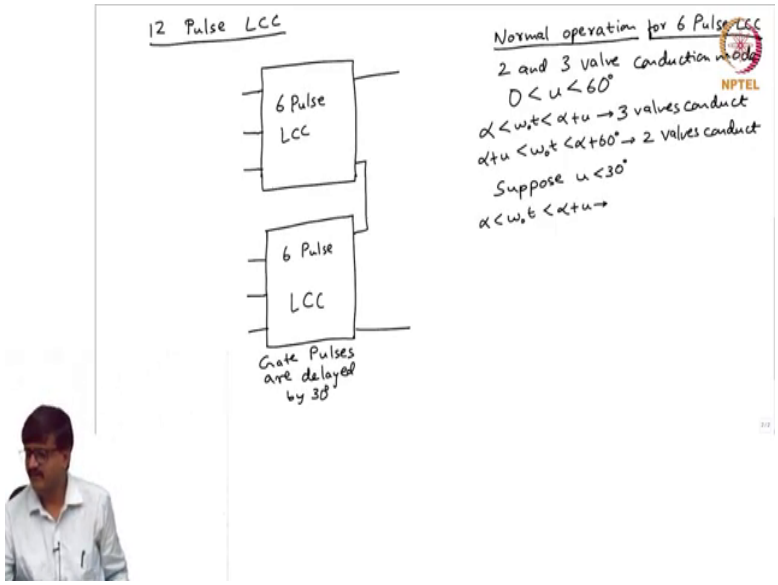

Let us continue our discussion on 12 pulse LCC. Now, we have seen the circuit, I will not try to draw the entire circuit diagram, but what I will do is; I will just show that there are two 6 pulse LCC's in addition to two transformers. For example, I can have one y y transformer and one y delta transformer.

So, there is a 6 pulse LCC, there is another 6 pulse LCC. So, there are three wires on the AC side, of both 6 pulse LCC's and the DC sides are connected in series ok. Now, the voltages

that appear on the AC side of the second 6 pulse LCC, are identical to the voltages which appear to the on the AC side of 6 pulse the first 6 pulse LCC except that.

Student: (Refer Time: 01:37) phase shift.

There is a phase lag of 30 degrees to the second 6 pulse LCC. Now, accordingly the instant of gate pulse will be delayed by?

Student: Minus.

Will be delayed with 30 degrees ok. So, with respect to the 1 st 6 pulse LCC, the 2 nd 6 pulse LCC gate pulses are delayed by 30 degrees. Now, you see that if you take any current suppose, I take fundamental current; the fundamental currents that are flowing on the AC side of the second 6 pulse LCC or lagging the fundamental currents of the first 6 pulse LCC. They are equal in magnitude, but lagging by 30 degrees.

If you take any harmonic component it is 30 degree into h. Similarly, on the DC side also it is if you take any harmonic components there are 6 there is a 6 th harmonic, 12 th harmonic. So, if you take the second 6 pulse LCC the harmonic component is lagging the corresponding harmonic component of the first 6 pulse LCC by 30 degree into h ok.

Now, the question is if I have normal operation, see normal operation means; both the 6 pulse LCC's or having 2 and 3 valve conduction mode. So, normal operation for 6 pulse LCC both 6 pulse LCC's is 2 and 3 valve conduction mode.

Let us assume that both 6 pulse LCC's are having normal operation then at any instant if I take all the 12 valves. So, now, in the 12 pulse LCC have 12 valves at any instant what is the number of valves that conduct? Assume that the voltages on the AC side of the 12 pulse LCC are balanced sinusoidal and the equivalent leakage inductances of the two transformers are equal. Say one point to notice, when I have 2 and 3 valve conduction mode the value of u is between 0 and?

Student: 60.

60 degrees ok. Now, both 6 pulse LCC's are having 2 and 3 valve conduction mode; that means, if you take any 6 pulse LCC at any instant either 2 valves are conducting or 3 valves are conducting. Now, if I take together all the 12 valves there are 12 thyristor valves at any instant, what is the possible number of valves that conduct?

Student: You left two cases, whether you use less than 60 or you use greater than 60.

Just to consider you will say let us assume.

Student: Sorry, less than 30 or greater than 30.

Less than 30 what happens? Let us take say if I take the first sub interval of any 6 pulse LCC it is from alpha to?

Student: Alpha plus u.

Alpha plus u. So, here how many valves conduct?

Student: 3.

3 valves. 3 valves conduct, and alpha plus u to alpha plus 60 degrees.

Student: 2 valves.

2 valves conduct ok. Now, let us consider different cases; suppose u is say less than 30 and of course; obviously, it is greater than 0. Greater than 0 less than 30. Suppose, u is less than 30 then what happens to sorry alpha less than omega o t less than alpha plus u.

Student: The first one.

In total?

Student: In total.

Say for the first I have already said.

Student: 3 valves.

3 valves.

Student: (Refer Time: 06:11).

Let me try to draw one more diagram.

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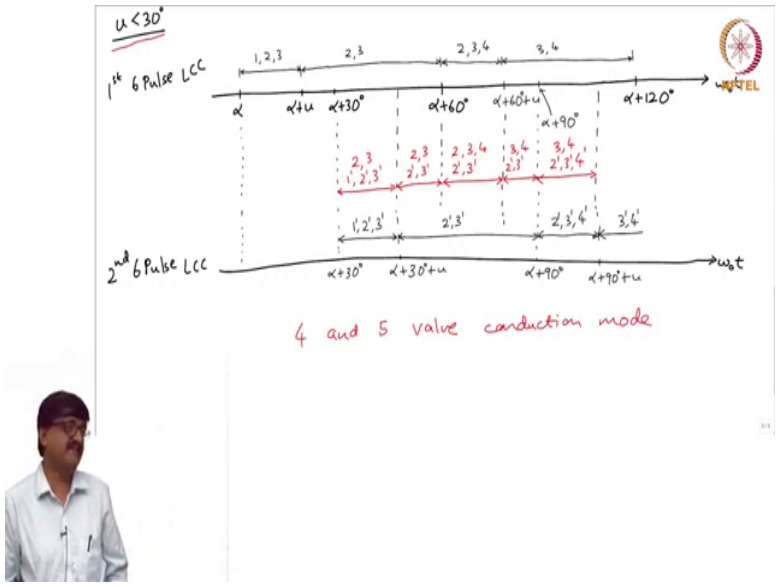

So, suppose this is omega o t ok. This is the 1 st 6 pulse LCC, suppose this is alpha. I also show what are the valves that conduct in the 2 nd 6 pulse LCC also ok. Suppose, this is alpha plus 60 degrees, alpha plus 120 degrees. Now, let us take the case u less than 30 degrees. So, suppose this is alpha plus 30 degrees, and since u is less than 30 degrees. So, I so; I show alpha plus u here. Say alpha plus u is less than alpha plus 30, because u is less than 30. So, if I take alpha to alpha plus u what are the valves that conduct?

Student: (Refer Time: 08:08).

Student: 1, 2, 3.

1, 2, 3; 1, 2, 3. Alpha plus u to alpha plus 30. In fact, I need not even show up to I mean separately for alpha plus u to alpha plus 30 and alpha plus 30 to alpha plus 60 I go up to this point. So, alpha plus u to alpha plus 60.

Student: 2, 3.

2, 3 then. Now, I also show alpha plus 60 degree plus u. So, from alpha plus 60 to alpha plus 60 plus u. What are the valves that conduct?

Student: 2, 3, 4.

2, 3, 4. Then alpha plus 60 plus u to alpha plus 120 degrees, it is 3, 4. That is something you have studied ok. Now, I will also number the second 6 pulse LCC thyristor also as 1, 2, 3? I mean there should be no cross of confusion because I am showing them separately. So, that is why I am showing separately for second 6 pulse LCC. Now, when is the valve 3 of the 2 nd 6 pulse LCC turned on? Alpha plus?

Student: 30.

30. Then if I take u again, u will be same for both 6 pulse LCC's. So, if this is alpha plus 30 degrees; this is alpha plus 30 degrees plus u. So, this instant which are I had not shown earlier is alpha plus 90 degrees. So, if I take the duration from alpha plus 30 degrees to alpha plus 30 degrees plus u. What are the valves that conduct in the 2 nd 6 pulse LCC?

Student: 1, 2, 3.

1, 2, 3. Then from alpha plus 30 plus u to alpha plus 90 degrees, it is 2, 3. Then, I also show alpha plus 90 degree plus u. So, from alpha plus 90 to alpha plus 90 plus u valves that conductor 2, 3, 4. Then, after that it is 3, 4 ok. I think it is better if I slightly change the

notation see instead of 1, 2, 3 valves I will use a prime. 1 prime, 2 prime, 3 prime for the second 6 pulse LCC, 4 prime we also there ok.

Now, if I together write the valves that conduct among all the 12 from alpha plus 30 to alpha plus 30 plus u. It is 2, 3; 1 prime, 2 prime, 3 prime. This is from alpha plus 30 to alpha plus 30 plus u. Then if you take alpha plus 30 plus u to alpha plus 60, it is 2, 3, 2 prime, 3 prime. Then, if I take alpha plus 60 to alpha plus 60 plus u. 2, 3, 4 2 prime, 3 prime. Then alpha plus 60 plus u to alpha plus 90 degrees it is 3, 4; 2 prime, 3 prime, 4 prime. Then alpha plus 90 degree to alpha plus 90 plus u 3, 4, 2 prime, 3 prime, 4 prime. I made a mistake here sorry. So.

Student: (Refer Time: 13:42) to prime.

So, from alpha plus 60 plus u to alpha plus 90 it is 3, 4; 2 prime, 3 prime. To decide the operating mode say if you look at even the just the 6 pulse LCC, I have to consider. I mean should I consider the entire cycle consisting of 360 degrees?

Student: Ha.

I have to consider?

Student: (Refer Time: 14:05).

No in the case of 6 pulse LCC one interval is sufficient. I just took look at one interval that is divided into two sub intervals, and I just see what is the number of valves in the first sub interval in the second sub interval. So, in the 6 pulse LCC the interval size was 60 degree the width of the interval is 60 degrees. Now, in the case of 12 pulse LCC their width of the intervals is?

Student: 30 degree.

30 degrees. So, I can just look at any 30 degree interval and see what is the number of valves that conduct. So, you see that though I have shown for more than 30 degrees ok. So, at any instant either 4 valves conduct or?

Student: 5.

5 valves conduct. So, this is known as 4 and 5 valve conduction mode ok. Now, this is corresponding to u e less than 30 degrees. So, even for normal operation of the 6 pulse LCC I can have another possibility u greater than 30 degrees. So, what happens if u is greater than 30 degrees? Let us, quickly go through that also.

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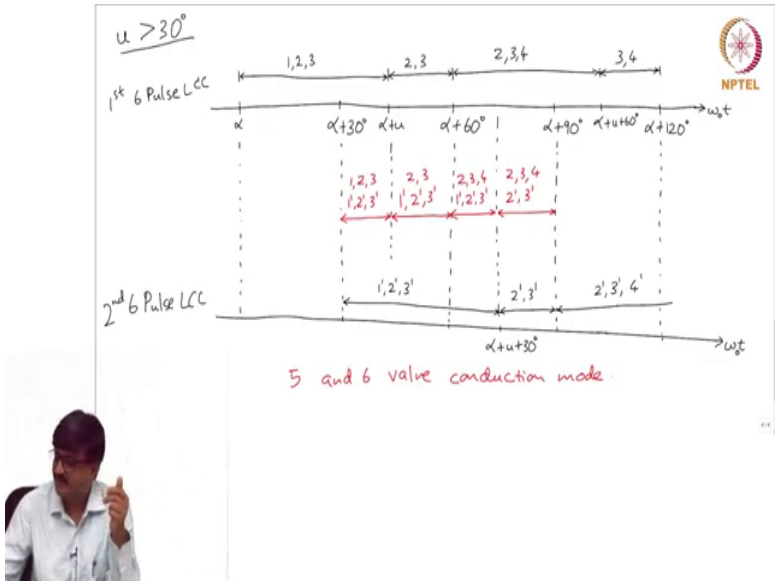

Suppose, u is greater than 30 degrees. So, let me try to again draw a similar diagram. So, I have this one straight line corresponding to omega o t axis for the 6 1 st 6 pulse LCC. Now, if

all if u is greater than 30 degrees alpha plus u is greater than alpha plus 30. So, alpha plus u is shown somewhere here ok. So, if I take alpha to alpha plus u, what are the valves that conduct from alpha to alpha plus u?

Student: 1, 2, 3.

1, 2, 3; from alpha plus u to alpha plus 60 degrees, it is 2, 3 and again alpha plus u plus 60 degrees is greater than alpha plus 90 and less than alpha plus 120 ok. So, from alpha plus 60 to alpha plus u plus 60 is the first sub interval of the second interval. So, here valves 3, 4 and 5 conduct. Then alpha plus u to alpha plus 120 is the second sub interval of the second interval valves 4 and 5 conduct.

Student: (Refer Time: 17:17).

Sorry?

Student: (Refer Time: 17:18).

Sorry.

Student: (Refer Time: 17:20).

I made a mistake, please correct this 2, 3, 4 and 3, 4 ok.

Now, I will show in addition to the angles that I have already shown in the first figure for 6 pulse LCC. Alpha plus u plus 30, and also alpha this may not be missed let me check. So, from alpha plus 30 if I take the 2 nd 6 pulse LCC, so if I take this interval. So, from alpha plus 30 to alpha plus u plus 30 what are the valves that conduct?

Student: 1 prime, 2 prime (Refer Time: 18:45).

1 prime, 2 prime, 3 prime ok. And, from alpha plus u plus 30 to alpha plus 90 it is 2 prime, 3 prime. Then beyond this it is 2 prime, 3 prime, 4 prime ok. Now, again let us take this duration; alpha plus 30 degrees to alpha plus u. So, the valves that conduct are 1, 2, 3 from the 1 st 6 pulse LCC 1 prime, 2 prime, 3 prime from the 2 nd 6 pulse LCC.

Then from alpha plus u to alpha plus 60 degrees, it is 2, 3 and 1 prime, 2 prime, 3 prime then from alpha plus 60 to alpha plus u plus 30; 2, 3, 4 and 1 prime, 2 prime, 3 prime and from alpha plus u plus 30 to alpha plus 90 it is 2, 3 4 and 2 prime, 3 prime. Though it is sufficient to consider only one interval of 30 degree duration for the 12 pulse LCC I have shown for two intervals that is for 60 degree duration I have shown.

So, you see that there are two sub intervals in each interval. So, in one of the sub intervals 6 valves conduct in the other sub intervals 5 valves conduct ok. So, this is 5 and 6 valve conduction mode. Now, though I have written u greater than 30 degrees I am still considering the normal operation. Say, one should note that this u is the commutation angle for the 6 pulse LCC ok.

So, if I go back to this ok. So, what we have considering is only 2 and 3 valve conduction mode for the two 6 pulse LCC's. We have seen two normal operating modes there are other operating modes. So, let us summarize all the operating modes.

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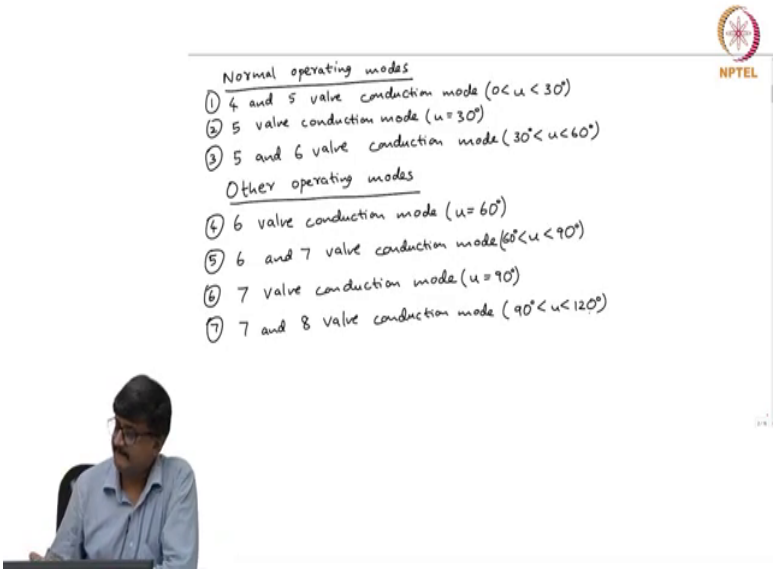

So, let us first see what are the normal operating modes. So, we have already seen two normal operating modes one is 4 and 5 valve conduction mode. So, this is applicable if u is greater than 0 and less than 30 degrees. We have also seen one more operating mode that is 5 and 6 valve conduction mode. So, this is applicable if u is greater than 30 degrees and less than 60 degrees. There is a possibility of even 5 valve conduction mode which is applicable if u is exactly equal to 30 degrees. So, 5 valve conduction mode which corresponds to u equal to 30 degrees.

So, these are the three normal operating modes of course, there are other operating modes corresponding to 3 valve conduction mode of the 6 pulse converter, or 3 and 4 valve conduction mode of the 6 pulse converters. So, the other operating modes are. So, if I have

both 6 pulse converters operating in 3 valve conduction mode then what I get is for the 12 pulse converter 6 valve conduction mode.

So, this is applicable if u is 60 degrees. If the 6 pulse converters operate in 3 and 4 valve conduction mode that is u is greater than 60 and less than 120 degrees then at any instant we will have either 6 valves conducting and or 7 valves conducting. Or it is also possible to have 7 valves conducting at any instant or 8 valves conducting or it is also possible to have 7 valves conducting at any instant. So, correspondingly we get 6 and 7 valve conduction mode. 7 valve conduction mode, and 7 and 8 valve conduction mode. So, these are the other operating modes. So, one can show that if u is equal to 90 degrees then we get 7 valve conduction mode.

Now, similar to the case of 4 and 5 valve conduction mode or 5 and 6 valve conduction mode. We can explain how we get 6 and 7 valve conduction mode or 7 and 8 valve conduction mode. We can also see that we get 6 and seven valve conduction mode if u is greater than 60 degrees and less than 90 degrees. And it can be shown that we get 7 and 8 valve conduction mode if u is greater than 90 degrees and less than 120 degrees. So, these are the different operating modes.