DC Power Transmission Systems
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Lecture - 15
Analysis of 6 pulse LCC neglecting inductance: Fundamental and harmonic components of AC side current

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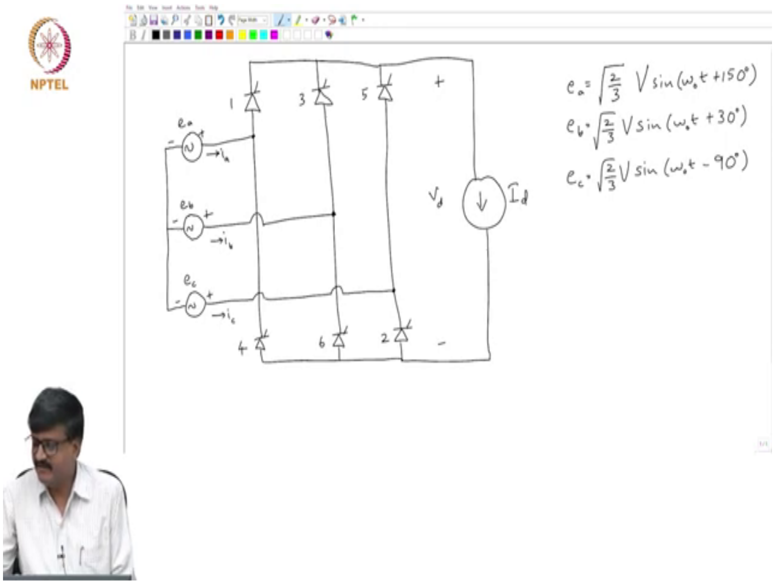

So, we are studying this converter, where on the AC side I have a balanced 3 phase voltage, this is connected in y. The voltage source is a 3 phase voltage source connected in y. So, the converter has 3 legs in each leg there are two thyristor wells. The DC side is represented by a constant current source I d. The voltage across the DC side terminals is V d.

So, the voltages on the AC side or e a, e b, and e c. So, we assume expressions for e a, e b, e c as 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, the valves are named as 1, 3, 5 as far as the upper commutation group is concerned and the lower commutation group the valves are numbered as 4, 6, 2.

So, we actually formed a table where it was shown that each cycle can be divided into 6 equal intervals and in each interval which are thyristor valves that conduct and what is the voltage across the DC side terminals and what is the voltage across one of the valves say valve one. So, what we will do is we will try to see what happens on the AC side. So, there are 3 currents on the AC side, let me call this instantaneous current I a, I b and I c.

So, as I was said the current on the DC side is ideal, it is constant, whereas the voltages on the AC side are ideal which are sinusoidal and balanced. So, there is a deviation from the desired value for the voltage on the DC side and we will see that even the currents on the AC side deviate from what is desirable. So, they are actually not sinusoidal balanced currents. So, let us look at one of the currents say I b.

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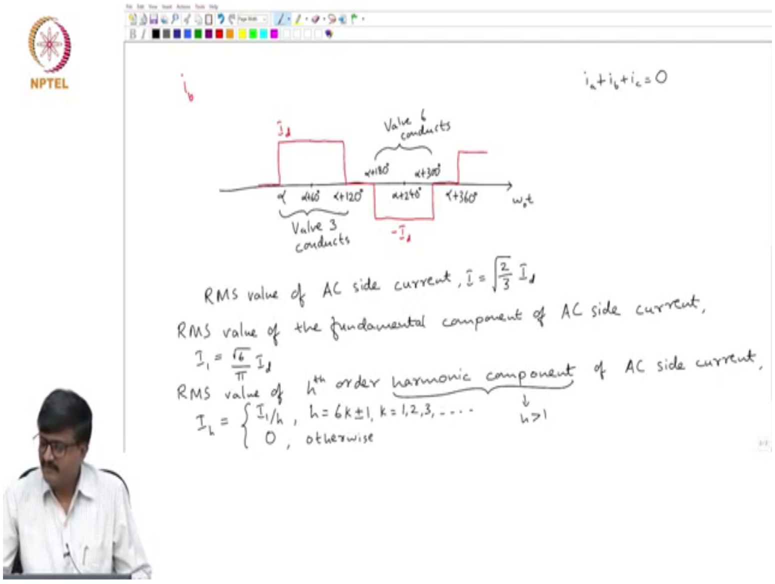

Suppose I want to plot I b as a function of omega o t,, ok. So, suppose I plot I b. Now, when will I b be nonzero, see look at this circuit. I b is nonzero when thyristor valve 3 conducts or thyristor valve 6 conducts. So, if there can be a duration where neither 3 nor 6 conducts, so then I b is 0. Now, what happens when 3 conducts?

Student: I b is (Refer Time: 04:51).

What is the value of I b? I b is same as.

Student: I d.

I d. See, this I d has to flow somewhere. So, we will at a any instant I d will flow through one of the 3 valves, 1, 3, 5 and one of the 3 valves.

Student: 2, 4, 6.

2, 4, 6. So, the circuit as to be completed. So, the circuit is completed by one of the valves in the upper competition group, one of the valves in the lower competition group and two of the 3 phase voltages, ok. So, if 3 conducts then the current I b is equal to I d. If 6 conducts what is I b?

Student: Minus I d.

Minus I d, ok. So, let us try to draw the waveform of I b. So, if I take the instant at which 3 is turned on, so what is the instant at which 3 is turned on?

Student: (Refer Time: 05:48).

What is the instant? We have given some, no we are given a name for that. What is the instant or angle?

Student: Naturals.

No, I am not asking we are we are actually concerned a more general operation where it is not diode operation.

Student: Alpha.

Alpha. So, at alpha thyristor valve 3 is turned on. So, if thyristor valve 3 is turned on then alpha at alpha I b is equal to?

Student: I d.

Id. So, it is equal to I d. So, this is equal to I d. So, for how long this will remain at I d? Up to as long as 3 is conducting. So, upto what instant?

Student: Alpha plus.

Alpha plus?

Student: 120.

120. So, suppose this is alpha plus 120. So, up to alpha plus 120 degrees thyristor valve 3 is conducting. So, this is the duration for which valve 3 conducts. So, at alpha plus 120 what happens to I b? See, at alpha plus 60 degrees, one thyristor valve is turned on that is say suppose this is alpha plus 60 degrees, 4 is turned on thyristor valve is thyristor valve is 4 is turned on. At alpha plus 120?

Student: 5.

5 is turned on, ok. Now, when 5 is turned on let us go back to the circuit, when 5 is turned on then 3 is actually.

Student: Off.

Off; 3 is off. So, if 3 is off 5 is turned on, so I b will be nonzero only if 6 is conducting. But is there a possibility of 6 conducting when 5 is turned on?

Student: There is (Refer Time: 08:06) 4 is also conducting (Refer Time: 08:08).

No, there is no possibility. See.

Student: There is a possibility.

Why?

Student: (Refer Time: 08:13).

No, at the instant of tuning on of 5 is there a possibility of 6 conducting? No, it is actually a thyristor valve which is conduct 4 which is conducting.

Student: 4 is conducting.

So, since 6 is not conducting I b is 0. Say, I b will be nonzero only if and only if 3 is conducting or 6 is conducting. So, if neither 6 conducts nor 3 conducts then I b is?

Student: 0.

0. So, if I want to plot the waveform of I b from alpha plus 120 for say duration of 60 degrees, ok. So, suppose this is alpha plus 180 degrees. So, up to alpha plus 180 degrees I d is 0, sorry I b is 0, I b is 0. So, at alpha plus 180 degrees which thyristor valve is turned on?

Student: 6.

6. So, when 6 is turned on, then I b is nonzero and it is equal to?

Student: Minus I d.

Minus I d. So, I have a duration of 120 degrees for which valve 6 conducts. So, when valve 6 conducts I b is minus I d. Now, this continues up to what instant? So, I can show one more instant here alpha plus 240, degrees alpha plus 300 degrees. So, at alpha plus 300 degrees which thyristor valve is turned on?

Student: (Refer Time: 10:05).

Sorry 1 or 2.

Student: 2

2. So, when 2 is turned on, so go back to the circuit, when 2 is turned on, obviously 6 is not conducting. So, when 2 is turned on is there a possibility of 3 conducting? So, when 2 is turned on there is one more thyristor valve which is conducting, which one is that? At any instant 2 thyristor valve are conducting, one from the upper commutation group one from the lower commutation group. So, when 2 is turned on.

Student: 1 is conducting.

1 is conducting. So, 1 and 2 are conducting neither 6 nor 3 is conducting, so I b is 0; so I b is 0. So, I b will remain 0 for a duration of 60 degrees that is up to alpha plus 360 alpha plus 360. So, then the cycle repeats then the cycle repeats, ok. So, again it goes to plus I d so on.

So, even before alpha that is for omega o t slightly less than alpha I d will be, I d is 0, sorry I b is 0 sorry I b is 0, ok. So, this is the waveform of I b. Now, what I intend to do here is to get the expressions for harmonic components. So, it is not equal to the desired waveform, the desired waveform is sinusoidal. So, we see that there are harmonics, but one can easily say what is RMS value. So, what is RMS value, RMS value of AC side current?

So, though I have drawn only one phase current I b, I a and I c are identical to I b accept for a pay shift of 120 degrees, ok. So, I a will be identical to I b accept that it leads I b by 120, I c is identical to I b, but it lags I b by 120 degrees. So, if I take RMS value of AC side current, so I b is an AC side current. So, let me use the notation I for RMS value of AC side current. So, can we try to give an expressions for this without any computation?

Student: Root 2 by 3.

Root 2 by 3, I d, ok. So, it is having a magnitude of I d for two-third of a period, ok. So, the RMS value will be square root of 2 by 3 into I d. Then, let us look at to the expressions for fundamental components and the harmonic components. So, if I take the RMS value of the fundamental components of AC side current, so I will call this I with a subscript 1.

So, I will leave it you to get an expressions for this I will give the answer it is root 6 by pi into I d. So, I get an expressions in terms of I d in terms of the DC side current, ok. So, it is just application of Fourier series. Now, I mean one has to note that this particular waveform has the particular, I mean has a symmetry. What is a symmetry? What symmetry?

Student: (Refer Time: 14:03) quadratic symmetry.

It has quadratic symmetry. We cannot say another beyond that. See order even is where difficult without knowing the value of alpha, ok. So, it has a quadratic symmetry so one has to integrate only for 90 degrees. But since there are duration for which the waveform is 0, you do not even need to integrate for 90 degrees you have to integrate for what other direction?

Student: Alpha to alpha plus 60 degrees.

60 degrees; 60 degrees, ok. So, that is the RMS value of fundamental components. If I want the RMS value of hth order harmonic components of the AC side waveform, AC side current. So, when I use the word harmonic component I mean h greater than or equal to 1, h equal to 1 means fundamental, ok. So, of course, we use the subscript 0 for average value, but when we comes to the quantities on the AC side average is 0. So, we are talking about AC side current, so average value is 0?

So, I h is the harmonic sorry RMS value of hth order of harmonic component. Of course, for some values of h it is 0. For what values of h it is nonzero?

Student: Odd values, odd values.

Odd values, for odd values. So, that means, by definition of harmonic h is greater than 1; that means, 3, 5, 7; h equal to 1 means fundamental. So, when I say harmonic I mean h equal to 3, 5. But what happens to the value of I h when h is equal to 3?

Student: (Refer Time: 16:15).

Why?

Student: Because 3 are balanced.

Yeah.

Student: I a, I b and I c.

I a plus I b plus I c is 0. So, when the 3 currents on the AC side I a plus I b plus I c is 0 we sign the last class that the third harmonic, not only third harmonic all the.

Student: Triplets.

Triplet harmonics are 0. So that means, even harmonics are already not there, so the triplet harmonics are also 0 that means, third harmonic is 0; 9th harmonic is 0; 15th harmonic is 0; 21st harmonic is 0 and so on. So, what remains are the harmonics of particular order it can be given by an expressions? So, what is the first harmonic component that is present?

Student: 5.

5. So, I will leave it to you to show that this I h can be written as, it can be written in terms of I d, it can be shown to be I 1 by h, whereas, see we have already shown that I 1 can be written

in terms of I d. So, the harmonic component can be written as I 1 by h. So, it is a 1 by h into the fundamental. So, this is the case if h is equal to 5 then.

Student: 6 k plus minus 1.

So, it can be written as 6 k plus minus 1, where k is taking all positive integer values. So, if you take k is equal to 1, you get two values 5 and 7; k is equal to 2, you get two values 11, 13; k is equal to 3, 17, 19 and so on, ok. So, these are the harmonics that are present in the AC side current and if it is equal to 0 otherwise. Of course, yeah. One point to note is harmonic component by harmonic component I mean h greater than 1, ok.

So, one should not get an impression that I 1 is 0 because I am talking about only harmonic components. As I said otherwise it is 0, I mean it may give a wrong impression that I 1 is also 0, I 1 is not 0. I 1 is given by root 6 by pi I d. So, I am asking you to derive this expressions for I 1, I h and if at all by chance if it is not clear to you that the RMS value I is equal to root 2 by 3 I d, then you have to do that also, ok.

So, see this is something which is a familiar expressions if which can be written straight away without any integration that is root 2 by 3 I d is equal to RMS value. But if it is not familiar I mean it is ok, you can still the definition of RMS root of the mean of this square, ok.

Now, what we have seen so far is the analysis of this and we got the expressions for the DC side average value and the harmonic components on the of the voltages on the DC side. And on the AC side the currents are not sinusoidal, so we got the expressions for RMS value, fundamental RMS as well as the harmonic RMS, ok.