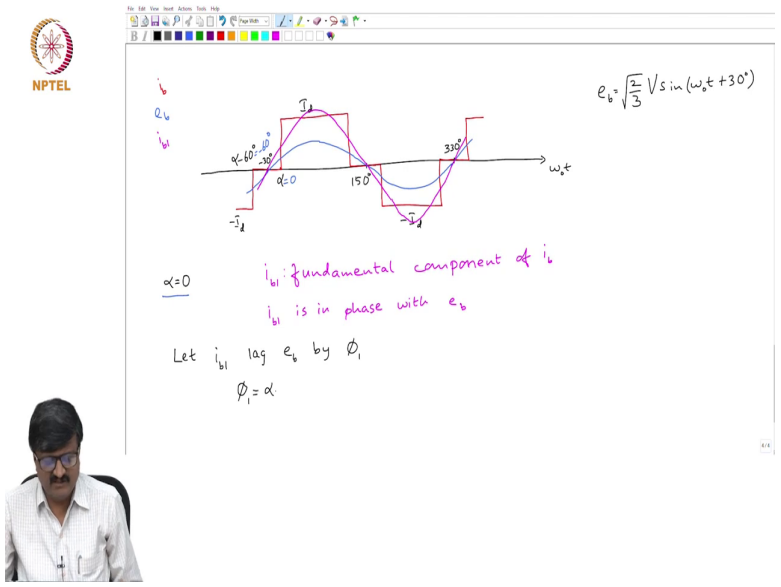
DC Power Transmission Systems
Prof. Krishna S
Department of Electrical Engineering
Indian Institute of Technology Madras

Lecture – 19
Instantaneous power on AC and DC sides in a 6 pulse LCC neglecting inductance

(Refer Slide Time: 00:19)



Let us see the AC side current. We have already opened the waveform of the AC side current, we also found out what is RMS value, what is RMS value of the fundamental, what is RMS value of the harmonic component ok. So, the waveform is in a waveform for say ib; ib is one of the AC side currents. So, it has only 3 possible values; ib has 3 possible values, I d or minus I d or 0. So, it is equal to I d for 120 degrees it is equal to minus I d for 120 degrees and it is equal to 0 for another 120 degrees. So, the waveform is like this.

So, it is either equal to I d or minus I d or 0. So, whenever its equal to I d it remains at I d for 120 degrees and whenever its minus I d it is a remaining at that value for 120 degrees and it is equal to 0 for 60 degrees before going to I d. Now it is equal to 60 degrees before going into minus I d.

So, at what instant a it goes from 0 to plus I d? Say this is a waveform of I b yeah alpha. So, alpha is the instant at which valve 3 is turned on. So, ib is non 0 only when either valve 3 is on or valve 3 is conducting or valve 6 is conducting so, that is alpha. So, if that is alpha what is the instant at which it goes from minus I d to 0? It is actually alpha minus 60 its alpha minus 60.

Student: (Refer Time: 02:59).

Sorry?

Student: (Refer Time: 03:02).

Minus I d to 0.

Student: alpha plus (Refer Time: 03:04).

Alpha plus.

Student: (Refer Time: 03:05).

Yeah alpha plus 300 is same as alpha minus 60 right ok. Now, this ib is the current that is flowing through the voltage source e b. See we have a 3 phase voltage source connected in y or star on the AC side. So, ib is the current flowing through the voltage source with voltage e b. So, what is the expression for e b? e b is root 2 by 3 V sin omega o t; what is the

expression? See we have been using one particular expression that is sin omega o t plus 30 degrees. Now, let us take a special case, alpha is a 0, suppose alpha is 0 ok.

If alpha is 0 then if I want to plot e b, suppose I want to plot e b. So, where is the 0 crossing of e b say negative to positive 0 crossing of e b? Say when I say alpha is equal to 0 this is equal to 0 ok. So, and this is equal to minus 60 degrees if alpha is 0. I am assuming that alpha is 0. So, if alpha is 0, then where is the 0 crossing of e b? There are 2 0 crossing in each cycle; positive to negative, negative to positive. Suppose I take the negative to positive 0 crossing of e b, at what value of omega ot there is a negative to positive 0 crossing?

Student: Minus 30 degrees.

Minus.

Student: 30 degrees.

So, minus 30 is somewhere here right. So, this is minus 30 degrees. So, suppose I take this duration of a 60 degree interval and if I take the midpoint of that what is this midpoint of this 60 degree interval, what is the value of omega ot at this instant?

Student: (Refer Time: 05:45).

Student: 150.

150 ok. So, that is 150. So, this is 150 degrees then again if I take this 60 degree interval and take the midpoint of that interval this is I am again taking the another interval where ib is 0 that is of width 60 degrees midpoint is.

Student: 330.

So, that point corresponds to 330. Now my intention is to draw e b. So, if I draw e b, it will have a positive sorry negative to positive 0 crossing at minus 30 and positive to negative 0 crossing at 150; because minus 30 to 150 is of width 180 then 150 to 330 is 180 again 180. So, e b is like this ok. So, this is e b.

Now I define 1 more quantity ib 1; is the fundamental component of ib. So, I have already shown I b, if I shown the same figure ib 1 which is a fundamental component of ib. So, by definition fundamental component is a sinusoidal waveform. See any fundamental or harmonic component is sinusoidal waveform ok. So, if I take this sinusoidal waveform ib 1, how is it in related to e b in phase? It is in phase it is in phase with e v. So, if I tried to draw ib 1.

So, ib 1 is in phase with e b ok. So, i b 1 is in phase with e b. So, this is the case if alpha is 0. Now for any general value of alpha ok, so, let us say let ib 1 lag e b by say some phase angle. So, I will give some notation for this phase angle say phi 1; see I am using the subscript 1 because it is the angle by which the fundamental component of ib is lagging e b ok. Now in general for any value of alpha, can I relate phi and alpha? See what is phi 1 for alpha equals 0?

Student: 0.

0. Now if alpha is not 0 then what is phi 1, suppose alpha is 10 degrees what is phi 1?

Student: (Refer Time: 10:22).

Alpha is also if alpha is 10 degrees phi 1 is also?

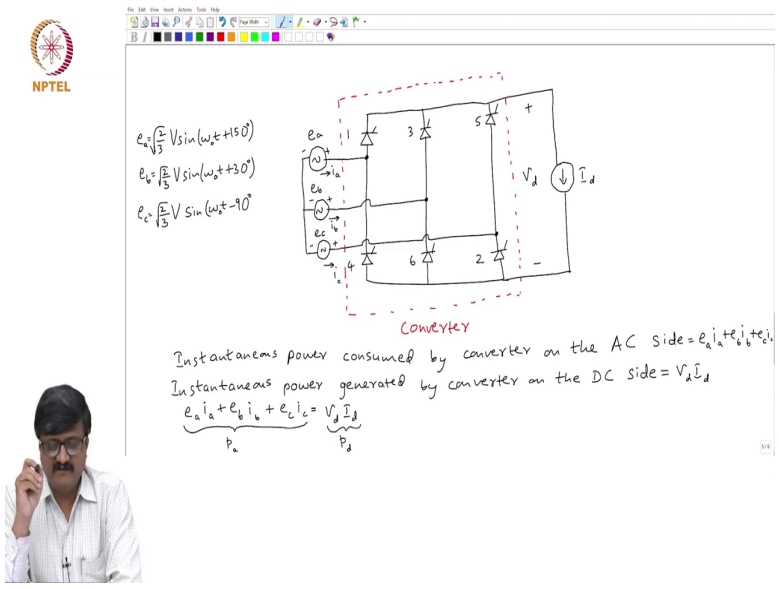
Student: 10 degree.

Is that obvious?

Student: Yes.

So, for any value of alpha phi 1 is equal to alpha. So, can I say that phi 1 is equal to alpha? So, I mean I just introduced a notation phi 1, but it happens to be same as one of the notations already used. So, phi 1 is the angle by which ib 1 lags e b. So, that happens to be equal to alpha ok. Now, we will use this result and get some more relations.

(Refer Slide Time: 11:12)



So, if I take the converter 1 3 5, these are the valve numbers 4 6 2. So, this is our converter the DC side is represented by a current source a constant current source I d, the voltage across the DC side terminals is V d. The AC side is represented by just a voltage source balance 3 phase sinusoidal voltage source plus minus plus minus plus minus e a, e b, e c. So, we have expressions for e a, e b, e c, e a is root 2 by 3, V sin omega ot plus 150 degrees; e b is root 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 current that is flowing here is i a, the current that is flowing here is ib the current that is flowing here is ic.

So, please note our converter is just consisting of 6 thyristor valves nothing more than that whatever is shown as voltage source is a representation of the AC side and whatever is show as on the DC side that is the current source is the representation of the DC side that is all. So, the converter is just these 3 legs or 6 thyristor valves shown within this reded dashed lines. So, this is the converter ok. Suppose, I take the instantaneous power consumed by converter on the AC side, what is this? The instantaneous power that is consumed by the converter on the AC side.

Sorry.

Student: a u is (Refer Time: 15:15).

Yeah it is just e a ia plus e b ib plus e c ic; e a ia plus e b ib plus e c ic ok. Now what is the instantaneous power? See why it is consumed by the converter because it is supplied by the voltage source. Say the current leaving the voltage source is leaving from the positive terminal. So, it is the power which is generated by the 3 phase voltage source and it is consumed by the converter.

Suppose I take the instantaneous power generated by converter on the DC side what does this? V d I d, current is of course, a constant I d voltage is V d. Now why we say power generated? We are taking it as V d I d. So, we see that I d is leaving the positive terminal ok. Now what do you say about these two powers?

Student: Equal.

They should be equal.

Student: Yes.

See the reason is the converter is lossless just because we have a lossless converter can we say instantaneous power sourcing?

Student: No.

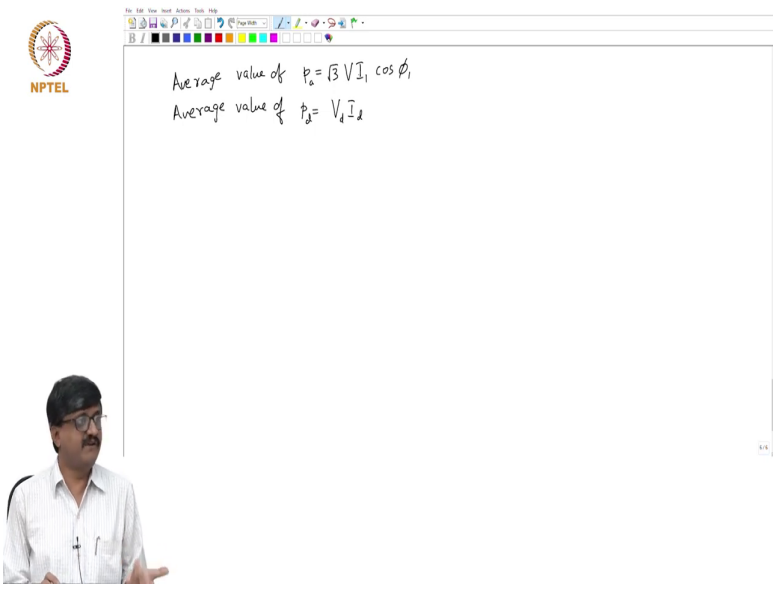
Not only that, the converter is lossless because all switches are ideal and there is there is no storage there is no inductor there is no capacitor in the converter.

Please note. See if there is storage the instantaneous power can just go in and not come out or a smaller value of instantaneous power can go out some instant, but a larger value can come out because what is coming out can be from the stored energy.

So, there is no inductor capacitor in the converter. So, that is why the instantaneous power consumed by the converter on AC side is equal to the instantaneous power generated by the converter on the DC side. So, what I am trying to say is e a ia plus e b ib plus e c ic is equal to V d I d. Now when I equate these two powers on the AC and DC sides I can also say that the average values of these are same.

See when two quantities are same means I mean instantaneous two instantaneous quantities are same, their average values is obviously, same. Now what is average value of the instantaneous power which is consumed by the converter on the AC side?

(Refer Slide Time: 18:05)



Let me take the average value of see, what I will do is I will just give a notation for this. So, I will call this power on the AC side which is consumed by converter on AC side as p a, a for AC suppose I call this as pd; both are instantaneous ok, p a and p d p a and p d are same, but if I look at the average value of p a.

Now can I write the expression for this average value of p a in terms of the RMS value of this voltage? See RMS value of the line to line voltage is V ok. So, can I write this in terms of RMS value of the voltage and RMS value of the fundamental component of the current? See the currents has harmonics, but what is the contribution of harmonics to power? I mean I am I am m I just want to check whether you are familiar with this result. See on the AC side there are sinusoidal voltages, current is not sinusoidal, but current has harmonics also. So, what is the contribution of harmonics to power?

Student: Average power is 0.

Average power is 0. Now when average power is 0 due to harmonic, so, the only contribution is coming from fundamental. So, can I relate this average value of p a to V then the fundamental RMS is I 1 we already have this notation I 1, they have fundamental RMS on the AC side. And any other quantity?

Student: Yes sir, cos.

Cos of; so, we just know defined phi 1 cos phi 1 into please note, this AC 3 phase side this is 3 phase side on the AC; AC side is 3 phase. So, it is?

Student: V (Refer Time: 20:03).

V is a line to line RMS, V is line to line to RMS.

Student: Root 3.

Root 3. So, it is root 3, this is something which you are all familiar with. Say suppose I had only fundamental current, this is the expression for power; root 3 into line voltage RMS into line current RMS into cos sine of the phase angle difference. This is a well know expression, but in addition to fundamental there are harmonics, but I am ignoring the harmonics because they do not contribute to power ok.

Similarly, if I take the average value of p d, see what we just know wrote was the expression for instantaneous value. What is the average value?

Student: (Refer Time: 20:49).

It is nothing but I can write it in terms of the average value of V d.

Student: V d I d.

I d ok. Now, I would suggest that you verify that these two are same. I mean it is a know result, but you can just verify. So, just verify. What do you need to do is substitute the expression for I 1 substitute the expression for V d and try to verify that these two expressions are same. So, the average value of pa should be equal to average value of p d; obviously, because p a itself is equal to p d.