DC Power Transmission Systems
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Lecture - 14
Analysis of 6 pulse LCC neglecting inductance: DC side voltage harmonics

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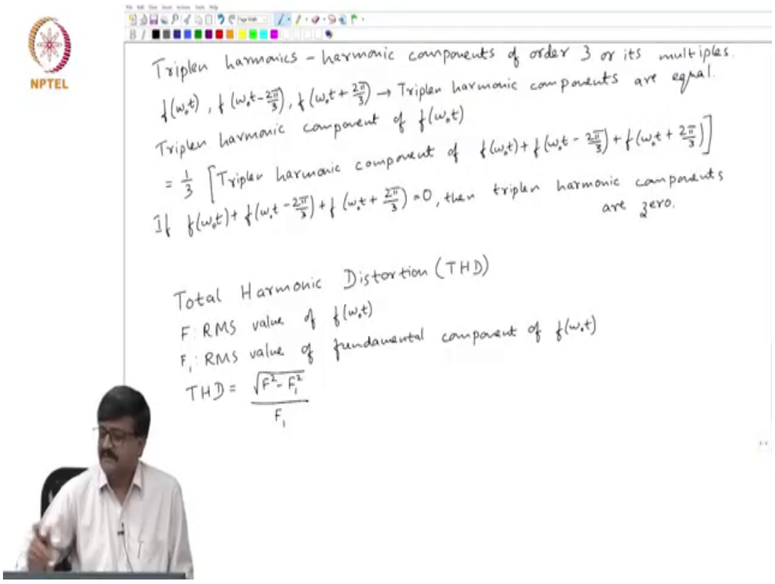

So, let us go back to our discussion on the converter that we were considering.

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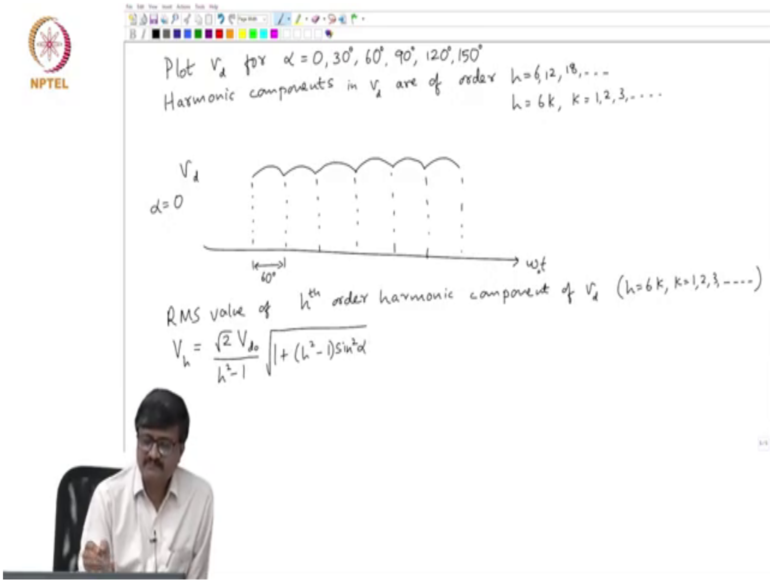

See, why we came to this is we saw that there is a DC side voltage V d, we just go the expression for the average value of V d. But there are harmonic components in V d. So, V d is given by 6 different expression. See, we saw that one cycle can be divided into 6 intervals of duration 60 degrees and in each 60 degree duration, see first duration we considered alpha to alpha plus 60 degrees, then alpha plus 60 degree to alpha plus 120 and so on. So, in each of this intervals V d has an expression. So, what are these expressions?.

I mean if you look at the expression what are these voltages? What is a the value expression for V d from alpha to alpha plus 60? We formed a table, right. So, from alpha to alpha plus 60 degree V d is e b minus ec. What is e b minus ec? It is nothing the line voltage. And alpha plus 60 to alpha plus 120, what it is? It is a different expression it is e b minus.

Student: Ea.

Ea. It is a another line voltage. So, if you look at the 6 expressions in the 6 intervals, all these are line voltages. Now, these are all line voltages, all are equal; all are equal in magnitude and displaced by; displaced by?

Student: 60 degrees.

60 degrees. Actually, we can verify that see there is e b minus ec, there is also an expression for V d in another interval which is e c minus eb, ok. So, there are 6 wave forms which are equal in magnitude which are line voltages and displaced by 60 degrees. See, I hope there is no confusion. There are only 3 line voltages, why I am talking about 6. We have the 3 line voltages plus.

Student: Negative.

The negative of these 3. So, if I want to get the wave form of V d, what I should do? What is the best way of getting wave forms? See, if I want to draw; so, in this course what will be useful is use some package to draw the 6 waveforms and then try to trace use I mean manually using a pencil the waveform of V d.

Now, we get different waveforms based on different values of, see just by looking at the 6 waveforms we cannot get V d. I mean one more quantity as to be specified to draw alpha. So, what I would suggest is first I mean it is I will not suggest a free hand plotting of the 6 line voltages that you can do using any package. Just take a either a take it as a dotted line 6 line voltages, then over that you try to plot the waveform of V d. So, try to plot this.

So, let me give an exercise plot V d for different values of alpha. So, alpha is equal to, so let me start with 0 itself, 0 is a simplest thing, 0, 30 degrees, 60 degrees and so on, up to what value can we go? Is there any limit? 90, beyond that?

Student: (Refer Time: 03:53) let us say quantity.

Let it I mean it can operate as an inverter also. It can operate as an inverter also, ok. Let me list the values, 90 you can go fine. You can go to 90 also, then 120, then 1.

Student: (Refer Time: 04:14).

You can go up to 150. What about 180?

Student: (Refer Time: 04:17).

Can we go beyond this? Of course, we cannot go beyond this if I just take in steps of 30. Of course, I can go to 151, I can go to 152, ok. Now, can I go to 180 is the question. So, you try and see what happens if are you go up to 180, ok. I will not try to give the answer. So, I have given a hint. See, what is the exercise? Exercise is easy. You just take a print out of these 6 waveforms may be at dotted or a dash line as I a sinusoidal curve 6 waveforms which are sinusoidal displaced by 60 degrees over that plot V d, ok.

Try to sketch V d for different values of alpha of course, for different values of alpha. So, I have given 6 values of alpha, ok. So, we will come to why this should stop at something somewhere just below 180. Why we cannot do up to 180 or we will see that we cannot go even near 180 say for example, 175 and so on. So, we will see that we will come to that, ok. So, we will see why it cannot go. But, is it clear why we cannot go up to 180 or greater than 180? Look at the definition of alpha. See, what is alpha? Alpha I mean the name given to alpha is delay angle.

Now, it is nothing but the delay by which val 3 is stand on with respect to instead of natural competition, sorry instead of natural conduction. So, that is the definition. So, using the definition we can try to make out why there is a restriction on alpha, why we cannot have alpha equal to or greater than 180, ok. So, you will try to plot this you will get the answer, ok.

So, we have already got the average value of V d. Of course, for that we you know do not need a Fourier series, but there are harmonic components in V d. Now, the question is what are the; what is order of the harmonic components in V d; harmonic components in V d. See, V d is the this side voltage or of order h equal to what?

One point to notice that in this course all waveforms have the same period that is 2 pi, all waveforms have the same period 2 pi. See, even the DC side voltage see you can have a lesser value less value of the period. You can even have instead of 2 pi radians you can have see the instead of 360 degrees you can have 60 degrees also, but we will stick to a period of 360 degree for both the AC side as well as DC side, ok.

So, when I say harmonic component, see the harmonic component will have a higher frequency and a lower period, ok. So, when I talk of harmonic component of V d what I am talking about is the DC side voltage, so the desirable component of V d is the average value. The undesirable unwanted things are the harmonic components. So, going by the definition of the our period our period is 2 pi radians, what is the value of h which is the order of harmonic components in V d? What is the first harmonic component that you get in V d?

See, in the last class we got an expression for average value. So, I will not try to repeat that. We got an average value of V d, ok. We also saw that for some values of alpha the average value is positive, for some values of alpha it can be negative, ok. Now, whether it is positive or negative becomes more clear if you try to plot say for alpha equal to 30 or 0 the waveform will be always above the omega I mean always above the (Refer Time: 08:39), ok. So, you can easily make out that for some values of alpha it is positive or some values of alpha it is negative.

Now, the question is if I come to harmonic components what are the harmonic components that are there in V d. Suppose, I have the omega o t equal to omega o t access here. Suppose, I take alpha equal to 0 simplest case. So, if alpha is equal to 0, then I will have these are all line voltages, these are all pieces of line voltages. So, if I take one cycle, so one cycle is 360 degrees and it can be divided into 6 intervals each of duration 60 degrees. So, this is the waveform that we get for alpha equal to 0.

For alpha greater than 0 what will be the waveform? It will deviate from this. So, I want you to draw that. Though may have some idea you would have already learnt it as well, but you still draw that is the exercise that I given you, ok. So, each of these durations is 60 degrees, again sufficiently. Now, can you tell me what is the order of the harmonic components in V d, at least for this alpha equal to 0? Sorry.

Student: Even multiples of.

Even multiples of.

Student: 3.

Even multiples of 3. So, the first even multiples is?

Student: 6.

6. Then?

Student: 12.

12, right. It is right. I do not know why you are saying even multiple of 3, why not you say multiples of 6, multiples of 6, right. So, I can say that for h equal to 6 k, where k takes all positive integer values. So, though I have drawn the waveform for alpha equal to 0, even for a higher value or you know nonzero or positive value of alpha we can see that the harmonic components are of order 6, 12 and 80, so on, ok.

So, for any value of h which is equal to 6 k, where k is any positive integer, what is RMS value? We are interested in the RMS value, ok. Now, why we are interested in the RMS value? We want to see how much deviation is there from the ideal waveform. So, the ideal waveform or the desired waveform is a constant value of V d. We cannot get constant, but we want as close to constant as possible. So, the deviation from the desired waveform is given by the harmonic components.

So, we usually measured it by RMS value. So, if I take the RMS value of the h th order harmonic component. So, please note when I say h th order I am talking about the h th order for which the harmonic component is nonzero obviously. I have already said that harmonic components of order say if I take h equal to 1, then it is 0. What is h equal to 1 in this case? See, fundamental make sense only on the AC side.

What makes sense on the DC side is average, ok. So, h equal to 1 is not corresponding to fundamental on the DC. We talk about fundamental on the AC side. Fundamental component, we mention fundamental component only on the AC side, when we talk about DC side its average value, ok. So, if you take h equal to 1, 2, 3, 4, 5 then the harmonic component corresponding to these values of h is 0. Again 7, 8, 9, 10, 11, so any value other than 6 k the harmonic component is 0.

So, RMS value of h th order harmonic component of V d. So, I will use the notation V h, ok. So, please note what I am trying to say is h equal to 6 k, where k is 1, 2, 3, so on. So, for these values of h the harmonic component as an RMS value V h. So, for RMS value of harmonic component of order h, I use uppercase V with a subscript h, ok. So, the lowercase v was used for instantaneous uppercase V with a subscript h.

So, we know how to use Fourier series. I will give the answer, I will leave it to you to derive this, ok. So, the expression is root 2 V do. What is V do? You will be using this notations again and again.

Student: Maximum average.

Maximum average DC voltage, divided by h square minus 1 into square root of 1 plus h square minus 1 sin square alpha.