DC Power Transmission Systems
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Lecture - 46
12 pulse LCC: Part 1

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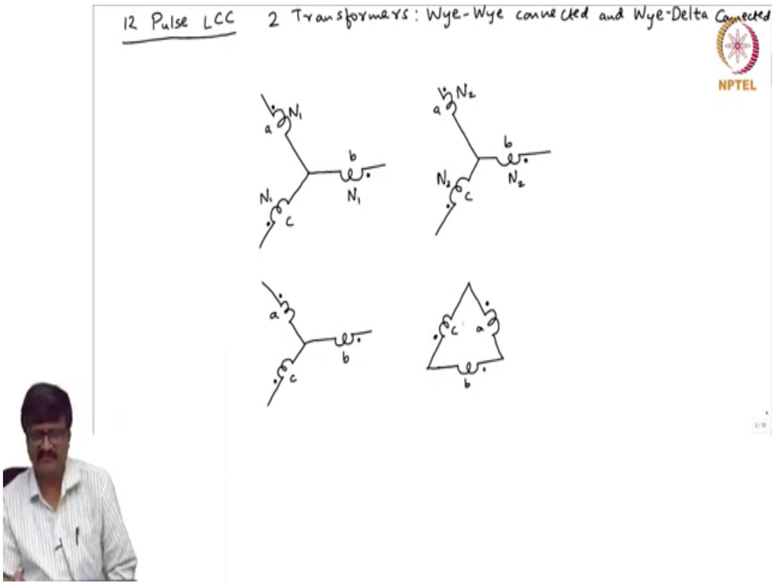

So, we will move on to a 12 pulse LCC. So, why we directly jump from 6 to 12? The answer lies in how we got 6, first of all, how we got 6 you recall.

Student: (Refer Time: 00:39).

We derived that ok.

Student: Yes.

Now, we first said that it should be a multiple of 3, it will help then we saw that a multiple of 6 will help.

Student: Yes.

So, the first possible circuit is 6 pulse. The next one is 12 pulse. As the name suggests there are 6 pulses in the 6 pulse converter 6 pulse gate pulses given. In the case of 12 pulse there are 12 pulses given. Now there is one gate pulse which is given. Now there is also pulsation on the DC side ok.

So, the number of pulsations is given the pulse number. At the same time since, we are using the switching frequency as nothing but the AC side frequency it is also the number of gate pulses you give that also gives the pulse number. So, in the case of 6 pulse in each cycle we give 6 pulses because there are 6 thyristors. In the case of 12 pulse there are 12 thyristors. So, we give 12 gate pulses to these thyristors. So, what is a circuit? So, I will first draw the circuit then try to see what advantages do we get with 12 pulse.

So, why should we go first of all from 6 pulse 12 pulse? I mean higher pulse number what is the use ok. We will see all those, we will answer all these questions in detail. Let me first draw the circuit. So, there are two transformers which are used in a 12 pulse LCC. One transformer is Wye Wye connected and another transformer is Wye delta connected. So, there are two transformers there is one Wye Wye connected or star star connected one is Wye Wye connected and the other one is Wye delta connected or star delta connected ok.

So, let me draw the circuit diagram. Now this is the circuit diagram of Wye Wye connected transformer. So, we normally use what is known as a dot convention. So, each winding is a 3 phase winding if you take any phase a phase or b phase or c phase the dot actually means the terminal which is always having the same polarity with respect to the other terminal for the both windings.

See suppose, I take this as a and which is as a phase. So, the dotted terminals of both these windings are at the same polarity with respect to the other terminal which is does not have a dot that is the purpose of dot convention.

So, let me say the number of turns here is N 1 and the number of turns here is N 2 ok. So, this is the Wye Wye transformer. There is one more transformer Wye delta connected transformer. So, one side is Wye the other side is delta. Now, we show the windings belonging to the same phase in parallel.

See for example, in the Wye Wye case also, if this is a phase and this is a phase they are shown parallel. So, similarly if I take this as b phase and this as b phase they are shown in parallel this is c phase and this is c phase they are shown in parallel ok. Even while drawing, we show it in parallel. I mean it will help us.

So, here also the windings belonging to the same phase will be shown in parallel. See; that means, the flux linking each turn of the a phase winding on the primary is same as the flux which is linking the one turn of the other a phase a phase winding that is what it means.

So, suppose I put a dot here, dot here, dot here and you would have notice not only showing in parallel, if the dot if you took at the a phase the dot is above in the primary side here also on the secondary side also its above in the Wye Wye case ok. The same thing is applicable even here

Student: (Refer Time: 06:05).

So, if this is a phase this is a phase oh sorry, I made a mistake. So, this is a phase. Similarly, if this is b phase this is b phase and if this is c phase this is c phase. So, if you look at b phase again. If the dot is shown to the right on the primary side even in the secondary side we show it to the right. So, I mean this I wrote this abc just for the sake of explanation, I mean I no longer need this in the further unless erase this it was just written for sake of showing the dots and the location of the dots ok.

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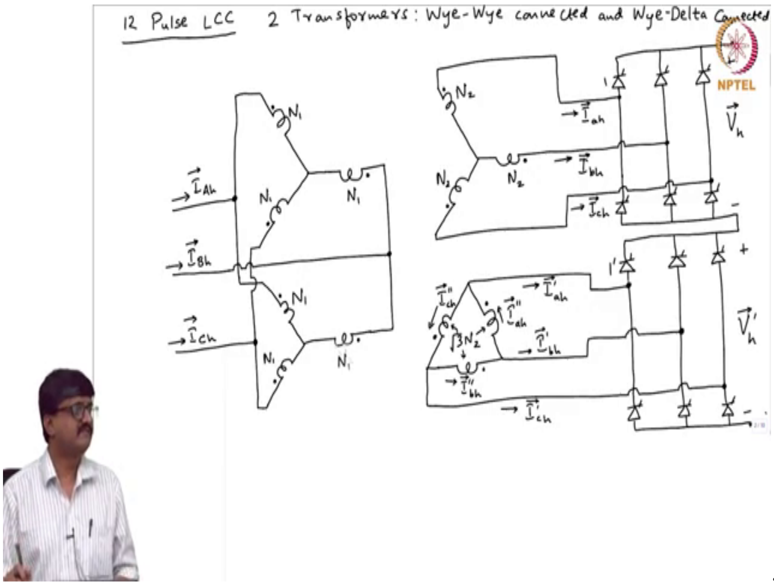

So, the number of turns here is also N 1. So, we will see what should be the number of turns in each winding on the delta side. So, before that to answer that question about the number of turns, we will complete the circuit. So, the idea is to have two 6 pulse LCCs. So, we have two 6 pulse line commutated converters.

So, this is one 6 pulse line commutated converter. So, there are 3 terminals that are brought out on the AC side. So, I connect this terminal of this winding of the Wye Wye connected transformer to this AC side terminal of the 6 pulse LCC. This is connected to then there is one more 6 pulse LCC.

And we connect a terminals of this delta side to the AC side terminals. And there are 2 DC sides corresponding to 2 6 pulse LCCs, what we do is we connect the negative terminal of the first 6 pulse LC AC LCC to the positive terminal of the second 6 pulse LCC. So, finally, we get only 2 terminals here on the DC side of the 12 pulse LCC and we also short the terminals of the Wye side of the 2 transformers. So, I take this terminal of the Wye side of the first transformer and connected to this terminal of the second transformer Wye side ok.

Then I take this terminal and connect it to this terminal and finally, take this and connect it to this terminal and I also bring out these 3 terminals corresponding to the 3 phases. So, this is 1 terminal this is 1 terminal this is another terminal and I will give some names for the currents that flow into the AC side of the 6 pulse LCCs. Now, I use the complex notation or phasor notation so, not instantaneous the phasor notation. So, the AC side currents are not just sinusoidal they have harmonics. So, what are the harmonics that are present on the AC side in the currents.

Student: (Refer Time: 12:15).

So, what is the first harmonic that is present? What is the order of the first harmonic?

Student: Fifth.

Fifth then?

Student: 7.

7 then 11, 13 and so, on. Now there is a fundamental component as well as harmonic component. So, I use a notation like this is a phase current. So, I with a subscript a and another subscript h and since this is complex I put an arrow I a h.

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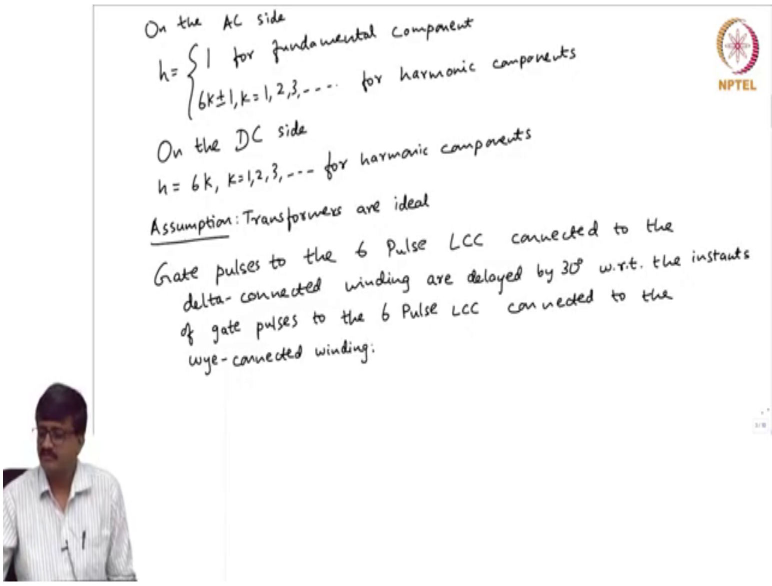

Now, here this h on the AC side on the AC side, what we mean is h takes a value of either 1. So, if it takes 1 it is for fundamental component. And if it takes a value 6 k plus minus one where k is either 1, 2, 3 or so, on up to infinity. So, this is for harmonic components.

So, what I am trying to say here is at any at a time I take one value of h. So, the possible values of h are on the see this is please note this is the AC side. So, the possible values of hr 1 for fundamental 5, 7, 11, 13, 17, 19 so on. So, at a time I take one value of h. So, like that I can do analysis for all the values of h. Similarly, if I take the next b phase the current here is let me take the current here is I b h and the current that is flowing in this wire is I c h.

Now, there are currents flowing into this AC I mean in the AC side terminals of the second LC LCC also 6 pulse LCC. So, I call this current asI a h prime then the current here is I b h prime. And the current that is flowing here is I c h prime ok. Now there are a few more things that are left out here I did not say what is the number of turns in the delta side winding. What should what should be the number of turns? Root 3 N 2 why?

Student: (Refer Time: 15:25).

Yeah the line to line voltage which is applied to the AC side terminals of the 6 pulse for both should be same. So, if I supply the primary winding with the same voltage, they are connected in parallel please note that primary windings are connected in parallel. So, if I apply voltage on the primary side and if I want the same magnitude voltages to be applied to the c 2 6 pulse LCCs.

The number of turns should be root 3 N 2. So, whether it is this winding or this winding or this winding. The number of turns is root 3 N 2.Now, I will also show some currents which are flowing through this delta connected windings. Now, what will be this current what subscript can I use a b or c.

Student: b.

Um b. please note look at I b h the current which is flowing through this ok. So, this winding is parallel to this. So, this is also b phase winding. So, whenever there is a b phase winding I will use the subscript I b h to differentiate between the other two currents I use a double prime ok.

So, notice that I have shown the currents as entering the sorry current is leaving the dots in the first Wye Wye I mean the secondary side of the Wye Wye transformer also in the delta side of the second transformer. When, if I want the current here this is a side or a phase or b phase or c phase?

Student: (Refer Time: 17:15).

This is nothing but.

Student: a phase.

a phase; I a h double prime. So, here also current is leaving the dot and finally, the current here is c phase current I c h double prime ok. Now, I will also show the currents that flow in these wires ok, let me took one by one what is this one? The current here the current here a phase current or b phase or c phase.

Student: a phase.

a phase. So, it is I a h I use an uppercase a just to differentiate from the other. So, here the current is entering the dot, it is a primary winding current is entering the dot. Then the current that is flowing here is phase which be the b or c.

Student: (Refer Time: 18:15).

B I b h and this is c phase. So, i use uppercase abc for the current ch ok. Now on the DC side also there are voltages the DC side voltages, but the harmonics in the DC side voltage are not of the same order as the currents harmonics on the AC side say this is on the AC side the definition of h. Now, if you look at the DC side voltage, what are what is the order of harmonics? It is multiple of.

Student: 6.

6. So, on the DC side, we say h equal to 6 k k equal to 1, 2, 3 for harmonic components. Now, if you say harmonic component harmonic component is a sinusoidal waveform only thing is it has frequency depending on the order of the harmonic component. So, I can you do have notice that see when I say I a h where h is 5 its a fifth order harmonic component. So, it is sinusoidal. So, if I have sinusoidal contact and represent it by a phasor.

So, I use an arrow over the notation to mean that it is a complex quantity. So, it has a magnitude and an angle. Similarly, if I take the voltage on the DC side of the 6 pulse LCC if I take any harmonic quantity it is a sinusoidal quantity. So, I can still represent that by a phasor say V h say the average is DC, but the harmonic is AC the harmonic is sinusoidal. So, I can represent it by a phasor. So, similarly I take this 6 pulse LCC, I call the harmonic component as V h prime. So, the definition of h is different for DC side and AC said please note that. Is this clear?

The definition of h is different for AC side and DC side that is what is written here. Now, if I want to analyze this so, what I suggest is that this is the circuit of the 12 pulse LCC. So, it consists of 2 6 pulse lccs and 2 transformers 1 Wye Wye connected 1 Wye delta connected. So, the question is why should one go for 12 pulse. So, I mean what is there in 6 pulse which is a disadvantage which we will go away here.

Obviously, there should be some advantage of this with respect to 6 pulse that is why we make some complicated arrangements and go for 12 pulse right. So, we will see, what is the purpose of going for 12 pulse but for that we need to do some analysis and for simplifying the analysis, we will make one assumption that the transformers are ideal. So, the assumption is transformers are ideal.

So, it actually means that there is no resistance, no leakage, no core loss resistance, no magnetizing inductance all these are not there in the ideal transformer. Now, if we decide that the number of turns in the delta connected winding should be root 3 N 2, I mean we know what is the purpose of that we saw we said that the voltages should be same.

The magnitude of voltage should be same. Now, if I give gate pulses at some instant to the first LCC suppose, I say this is valve one of the first LCC this is valve say one prime. Now if I give the gate pulse to valve at some instant do I give a gate pulse to valve 1 prime at the same instant. If not when should I give?

Student: (Refer Time: 22:35).

30 degrees. Now the reason is because of Wye delta transformer the voltages that are applied to the second LCC are lagging or leading the voltages applied to the first LCC with respect to

the voltages applied to the first LCC the voltages that are applied to the second LCC are lagging or leading.

So, to explain which one is lagging.

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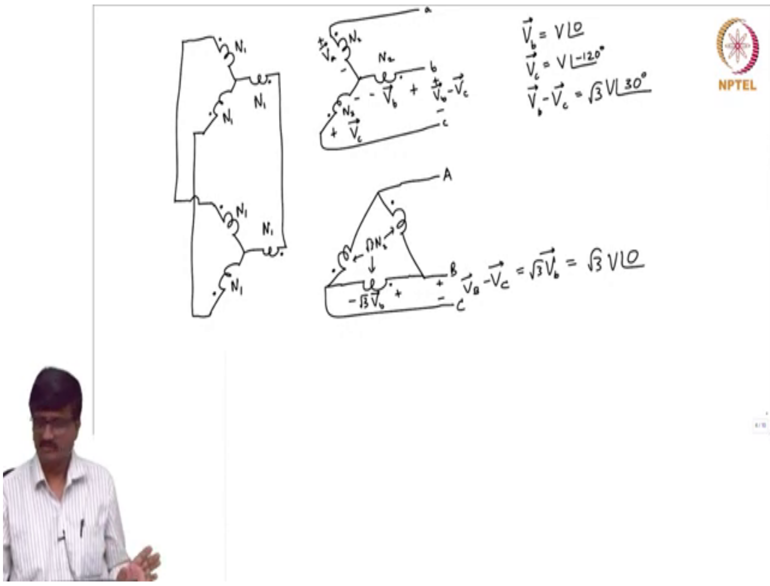

I will show the 2 transformers. Now I will show you on the dot. So, we know all these things all these windings have N 1 turns and this is N 2 N 2 and these 3 have root 3 N 2 all the 3. So, let me call this voltage as V a and let me call this voltage as say V b what I mean let me use the same. So, I took this is a phase and this is b phase sorry.

So, this is a phase V a this is V b. So, this is phasor V a phasor V b. Similarly, this is Vc. So, this is terminal a a phase b phase and c phase. So, let me call this as a b c. Now between a and b, what is a voltage? Suppose, I take let me suppose I take one of these as reference. So, let me assume that I have only sinusoidal voltages. So, suppose V b is some V at an angle 0 then V c is the same voltage magnitude at an angle.

Student: (Refer Time: 26:01).

Minus 120. So, if I want the voltage between b and c it is V b by Kirchhoffs voltage law it is V b in terms of V b and V c I can say what is the voltage between b and c by Kirchhoffs voltage law it is Vb.

Student: Minus Vc.

Minus Vc ok. So, it is Vb minus Vc?So, what is V b minus V c V at an angle 0 minus V at an angle minus 120 will give me what resultant magnitude is.

Student: (Refer Time: 26:33).

Root 3 V at an angle.

Student: 30.

30 degrees. Now, if I take between b and c in the delta say I took between b and c. So, here between b and c it is V b minus Vc Vb and V c are the voltages of b and c with respect to neutral. Now, what is this voltage across this winding?

Student: (Refer Time: 26:28).

Say this is b a phase winding or b phase or c phase?

Student: b phase.

b phase winding ok. So, if the b phase winding in the first transformer is Vb it has a voltage Vb what is the voltage in the second transformer which is delta connected.

Student: Root 3 Vb.

Root 3 Vb and what is this root 3 Vb? What is this root 3 what is Vb?

Student: V at angle 0.

V at an angle 0. So, that answers the question which 1 is lagging and which 1 is leading. So, I just took between 2 terminals b and c. You can take between a and b c and d also yeah a and b also gives the same.

. So, we saw that V b minus Vc is root 3 V at an angle 30 means, in the delta case it is root three root 3 at an root 3 V at an angle 0. So, the voltages of the delta winding are lagging the voltages of the Wye windi ng. So, now, let us. So, shall I go to the other page here. So, if I go back to this circuit. Now again I will answer asked the same question.

if gate pulses are given to valve 1 at some instant, gate pulses to valve 1 prime. So, I my intention is to operate the 2 6 pulse LCCs identically. So, same identical operation is expected from the 2 6 pulse LCCs ok. So, then at what instance should I give the gate pulse to valve 1 prime with respect to the instant of giving 8 pulse to valve 1.

Student: Simultaneously.

Same.

Student: (Refer Time: 28:48) always same.

See the voltages which are applied are identical in magnitude. So, the voltages which are applied to the 2 6 pulse LCCs are identical in magnitude, but 1 3 phase voltage which is supplied that is coming out from the delta is actually not identical in phase it is lagging the voltage which is applied to the first LCC by.

Student: (Refer Time: 29:14).

That is what we showed just now. The voltages of the delta winding are lagging the voltages of the Wye winding by 30 degrees the same voltages are applied to the 2 6 pulse LCC. Now, I want identical operation of the 2 6 pulse LCCs. So, if I give identical operation; that means, the gate pulse should be same at the same instant with respect to the respective 0 crossings. So, if I give any gate pulse at some instant to valve 1 in the first LCC, valve 1 prime in the second LCC the gate pulse should be at an instant which lacks or leads or at the same instant.

Student: (Refer Time: 29:48).

It should be.

Student: Same.

Same.

Student: (Refer Time: 29:52).

Why it is same? Student: (Refer Time: 29:56).

See there are 2 6 pulse LCCs I want identical operation, but the voltages that are fit on the AC side are identical in magnitude, but actually different in phase angle. 1 voltage is lagging the other voltage. So, the gate pulses should also.

Student: Lack.

Lack by the same amount. So, since the voltages are lagging by 30 degrees the gate pulses should also lag by 30 degrees. So, what I am trying to say here is gate pulses to the 6 pulse LCC connected to the delta connected winding are delayed by 30 degrees with respect to with respect to the instants of. So, I would say gate pulses. So, with respect to the instants of gate pulses to the 6 pulse LCC connected to the Wye connected winding fine.

So, now let me give some expressions for these complex currents are that I have shown I a h, I b h, I c h. So, if I will just remove this. So, this was just written for the sake of explaining that the gate pulses are delayed by 30 degrees yes. So, suppose I take this I a h. So, I said h can take a value of 1 or 5, 7, 11, 13 harmonic component.

So, it is either 1 or 6 k plus minus 1 for all a positive integer values of k ok.

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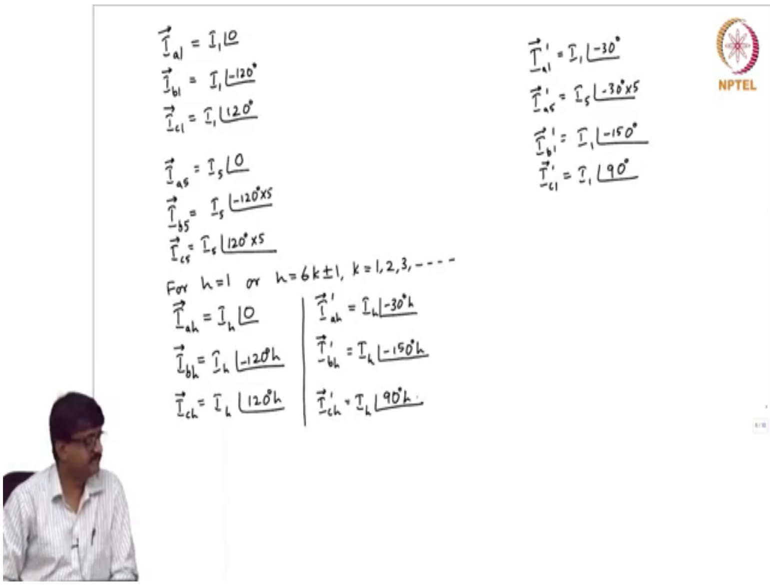

So, if I take I a 1 say I a 1. So, I take a special value of h can be see please recall what is the h value of h. On the AC side h can be either 1 or 6 k plus minus 1 on the DC side it is 6 k ok. So, if h is 1 I a 1 suppose I say the magnitude is I 1 at an angle 0 ok. If I take I b 1 again the b phase current with h equal to 1. Now what will be the magnitude?

Student: Magnitude.

Magnitude.

Student: (Refer Time: 33:13).

Magnitude is same as I a 1 and the angle is.

Student: Minus.

Minus 120degrees. Suppose I take I c 1 the magnitude is again same the angle is plus 120degrees this as far as the fundamental components are concerned. Now if I take some harmonic component say I a 5. I use the notation I 5 the RMS value of the fifth harmonic current is say I 5. Now what should be the angle.

Student:(Refer Time: 33:51).

Now, please note when we talk about taking reference I can choose independently the reference values for different harmonic components. So, I can again take this as 0. So, if I take b phase I b 5 it is having a same magnitude I 5. Whatever the phase angle?

Student: (Refer Time: 34:12).

Student: (Refer Time: 34:14) 120.

120 how did you get that?

Student: (Refer Time: 34:18) Now. So, can I say it is minus 120degree into 5.

Student: Yes.

Then I c 5 is again I 5 phase angle 120 twenty degree into 5. So, I take the fundamental angle into 5. Now, I could have simplified this see minus 120into 5 is nothing but.

Student: Plus.

120.

Student: Yes.

Minus 120 into 5 is 120 and plus 120 into 5 is minus 120 I could have simplified this, but I will written like this. Now the reason is what I am trying to convey is I need not actually write the expressions for this complex currents separately for fundamental, separately for fifth harmonic, separately for seventh I can write a general expression.

Suppose I take I a h see what I am trying to say is for h equal to 1 or h equal to 6 k plus minus 1 k takes any value. So, for harmonic components as well as the fundamental we can write a combined expression I mean which is general for generally applicable for all values of the h whether it is 1 or 6 k plus minus 1. So, what is that? So, can I say that I a h is.

Student: Ih.

I h at an angle 0 I b h is I h at an angle.

Student: Minus 120h.

Minus 120 degree into h. So, it is applicable even for h equal to 1 and Ic h is equal to I h at an angle 120degree into h. Now these are the currents which are fed to the first 6 pulse LCC.

Now, let me take the other currents which are fed to the second 6 pulse LCC. So, they have the notations I a h prime, I b h prime, I c h prime. So, even for these currents I can write a general expression which is applicable for h equal to 1 as well as 6 k plus minus 1. So, what is the magnitude of these currents?

Student:(Refer Time: 36:29).

It is I h all are the same magnitude I h. Now come to the angle if I take I a h prime what is the angle?

Student: Minus (Refer Time: 36:38).

Minus.

Student: 30 (Refer Time: 36:40).

Minus 30 say.

Student: Minus 30.

I a 1 prime is nothing but I 1 at an angle.

Student: Minus 30.

Minus.30 degrees. But if you take I a 5 prime.

Student: (Refer Time: 36:55).

It is I 5 what is the angle?

Student: Minus 30 (Refer Time: 37:02).

Minus.

Student: Minus 30 (Refer Time: 37:06).

Minus 30 into h; so, minus 30 in to 5 ok. So, what is the phase angle here. So, I can say this is minus.

Student: 30 h.

30 degree h ok. What about this?

Student: (Refer Time: 37:24) Minus 150 h. Say the idea is very simple if I take I b 1 prime it is I 1 at an angle.

Student: Minus 150.

Minus 150. If I take I c 1 prime it is I 1 at an angle ninety degrees. So, from that I get I b five prime, I b I mean 7 prime, I c 5 prime, I c 7 prime and so on. So, it is just multiplying that by h. Now these things are they familiar how multiplying by h gives phase angle. So, this is I c h prime is has a is having a phase angle 90 degree into h.