DC Power Transmission Systems
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Lecture – 54
DC link control: Control variables

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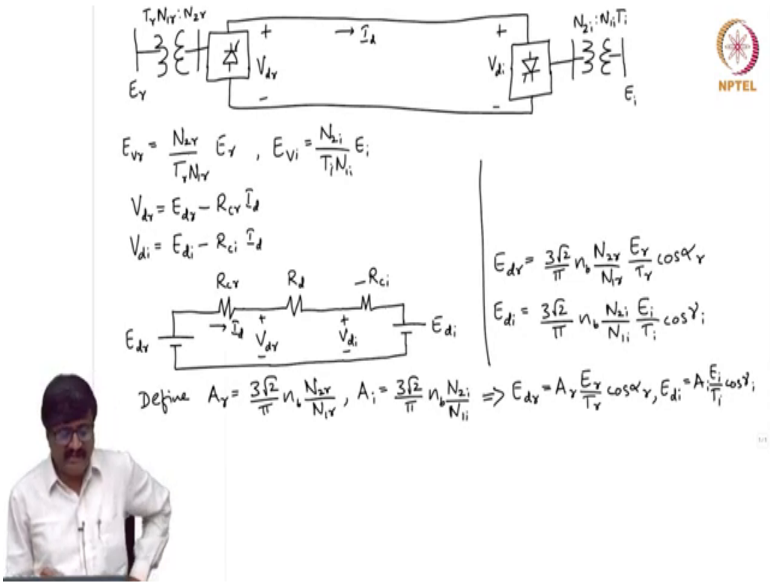

So, this is the schematic diagram of the system. I have the rms value of line to line voltage of the AC bus on the rectifier side as E r. And I have the turns ratio including the off nominal tap T r N 1 r is to N 2 r and the rms value of the line to line voltage of the AC system bus on the inverter side is E i and this is N 2 i is to N 1 i divide N 1 i T i.

So, the voltage at the DC bus on the rectifier side is V dr, the current is I d and the voltage at the DC bus on the inverter side is V di. Now, we got some equations E d r is a no; I mean before that I will introduce a few things, E vr is N 2 r by T r N 1 r into E r. Similarly, E vi the valve side voltage is equal to N 2 i divided by T i N 1 i in to E i.

So, we derived some relations V dr can be written as E dr minus did we derive this? We related V dr E dr id and R cr minus R cr I d. Then we also derived the relationship between V di I d E d i?

Student: Minus R c (Refer Time: 02:34).

Minus R cr I d ok. So, if we try to draw an equivalent circuit corresponding to these two equations, the last two equations. I have a voltage source in series with a resistance, the voltage source is E dr; the resistance is R cr and the current is I d.

Similarly, if I take the second equation and I call this voltage as E di. Suppose, the voltage here is V dr and the voltage here is V di and the same current I d flows here also, and corresponding to the line a transmission line suppose there is a resistance. So, let me call this resistance as R d. So, if I have to satisfy the second equation what should be the resistance here?.

Student: Minus (Refer Time: 04:04).

Minus R ci ok. So, if I have to please note this R cr and R ci are not actually physical resistances, there is no loss corresponding to R cr and R c i. Please note that they are due to leakage inductances, I mean if you look at the expression for R cr and R ci it is in terms of the leakage inductance or leakage reactance.

So, there is no loss corresponding to these two. So, we should not assume that there is a loss due to R cr and there is a generation due to minus R ci ok. So, the only loss is due to R d R d is the physical resistance, it is the resistance of the transmission ok. So, we got an expression for E dr what is E dr you recall E dr 3.

Student: 3 root (Refer Time: 04:59).

2 root 2 by pi n b N 2 r by N 1 r E r by T r cos alpha r is this ok? Did we derive this or not? See, I do not want to again go back to the ones which are already derived. So, how we derived this equation? Similarly, if I look at E di no? No means I mean, maybe I would have.

Student: (Refer Time: 05:50).

I have written in terms of E v r that is all. So, substitute the expression for E v r. E v r is N 2 r by tr N 1 r into E r that is all. So now, I am writing in terms of E r instead of E vr I am writing in terms of E r. Similarly, E di is 3 root 2 by pi n b N 2 i by N 1 i E i divided by T i cos gamma i. Now, if you look at this expression for E dr or E di you will note that three root 2 by pi is a constant nb is a constant N 2 r N 1 r are constants ok.

Similarly, in the expression for E di, 3 root 2 pi nb N 2 i N 1 i they are all constants. So, I define a constant A r, A is just a constant r subscript r means for rectifier as 3 root 2 by pi nb N 2 r by N 1 r. So, please note I put all the constants as 1 factor A r that is all. So, then define one more constant A i; A is a constant i subscript i stands for inverter 3 root 2 by pi nb N 2 i by N 1 i.

So, if I make these 2 definitions then if you look at the expression for E dr; E dr is A r into E r divided by T r cos alpha r and E d i is equal to A i E i T i cos gamma i. Now, please note E r is not a constant E r is dependent on these AC system on the rectifier side. So, the voltage available on the AC system may change with time.

So, maybe at 1 point in time it has some rms value for the line voltage after a few hours it may change though way a small value. So, it is around nominal value, but it may slightly change. So, it is not a constant E r is not a constant. Similarly, E i is also not a constant. So, that is why I am not including that in the definition of A r or A i ok. Now come back to this circuit this is equivalent DC circuit.

So, if you look at the current in the circuit I d, I d can be written as the difference between the 2 voltage voltages of the sources E d r and E d i divided by the effective resistance R cr plus R d minus R c i ok. So, I can write I d as ok. So, in place of E d r I will just straight away write the expression for E d r just now I got the expression for E d r A r E r by T r cos alpha r minus E di is A i E i by T i cos gamma I divided by the effective resistance is R cr plus R d minus R c i.

Now, R cr and R c i will slightly depend on tap ok. But, if I ignore that variation in R cr and R c i due to the change in the tap position then the only variables that are there in the expression for I d r. Sorry for the time being if I ignore the variations in R cr and R c i R cr and R ci are constants R d is any how a constant A r is a constant A i is a constant.

So, E r and E i are something which depends on the AC system on the rectifier side and the inverter side. Then T r is a control variable it is a tap. So, the user can decide the value of T r the tap portion on load tap similarly the on load tap on the inverter side T i is also a variable and there is another variable alpha r the user can control alpha r and gamma i is another variable which the user can control.

So, essentially there are four control variables. Now, please note there are two variable two more variables E r and E i. But, they cannot be controlled they depend on the system the AC system on the inverter side and the rectifier side. But, what can be controlled by the user or T r, T i, alpha r and gamma i. So, four control variables.

So, the four control variables r T r T i alpha r gamma i. Now, if you look at T r and T i they are the control variables due to the tap. So, if there are mechanical switches based tap then these are slow compared to alpha r and alpha gamma i. Now, you know that 1 can use.

I mean a mechanical switch or a thyristor base switch. So, if you look at the power converter the electronics switches are thyristors which are very fast? See, hope you would have noticed that there is a large difference between a mechanical switch and a power electronic switch.

Mechanical switches are slow in operations you it may take a few seconds or at least a fraction of a second maybe, but to initiate the moment from on position to off position or off position on position. But, if you look at thyristor how many you know how many times in a second it can switches on a switches off? Take the converter 6 pulse line commutated converter any take any thyristor.

Student: 50 times.

50 times. It is now if you look at there are many other faster switches. In fact, so the slow switch that we are considering here the slow polytron switch itself is switching on and switching off 50 times. You can think about such a frequency of switching for mechanical switches. Imagine switching on and switching off the switch for 50 times in a second. No you cannot do that. It is not you are not just make mechanically use some automation to do it, you still cannot do ok.

There are limitations in the frequency and there are many other limitations of course, but the main point here is it is not fast. It takes some time to initiate and it is not as fast as the power electronics switches. So, essentially the among the 4 control variables 2 control variables are slow. So, it takes time to change the 2 control variables T r and T i because, they are based on the tap changing transformer control variables and which are based on the mechanical switches ok. So, T r and T i.

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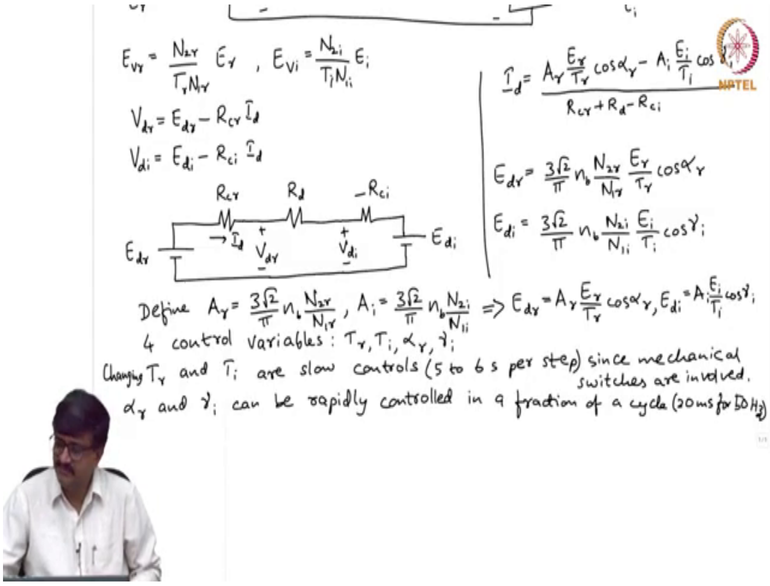

So, changing this T r or T i are slow controls. So, it is essentially a changing the tap position from one step to another step. So, even if you want to change one step of the tap it takes 5 to 6 seconds per step. Because they are mechanical switches since mechanical switches are involved.

So, there are two slow variables and the alpha r and gamma i can be rapidly controlled. Alpha r and gamma i can be rapidly controlled. So, here when we talk about controlling alpha r gamma i we do not talk about the time required in terms of seconds.

It is a fraction of a cycle in fact. So, in a fraction of a cycle. So, cycle means if I take 50 Hertz it is 20 milliseconds. So, for 50 Hertz frequency it is 20 milliseconds. So, it is not of the order of seconds it is of the order of 10s of milliseconds. So, it is much smaller and hence much faster.