DC Power Transmission Systems
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Lecture - 04
Power semiconductor devices

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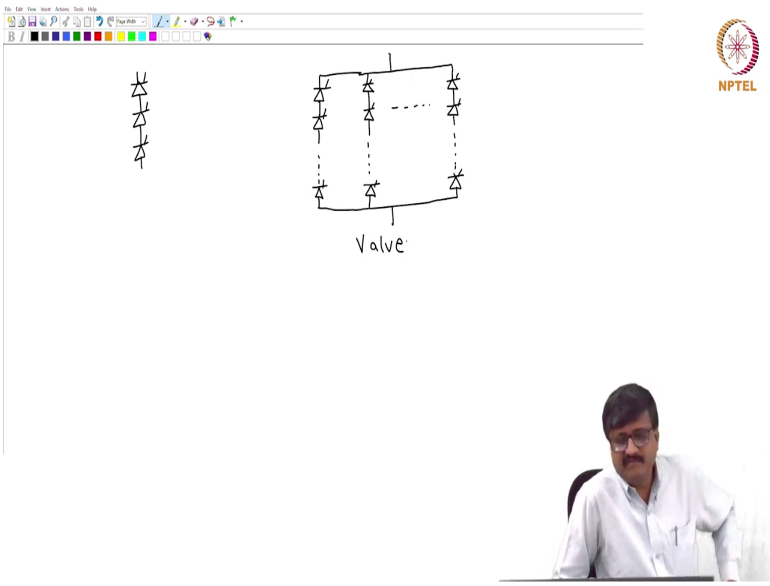

Before going to the first topic what I would like to do is spend some time on the assumptions that we do in this course so that I mean it will be retained for the entire course. So, there are some simplifying assumptions that are made as far as the devices are concerned. So, we do analyze a lot of foreign electronics circuits using these simplifying assumptions, you may be familiar with some of this, ok.

So for the sake of stating all these assumptions in the beginning so that, I will not be repeating these assumptions every time. So, when we do the analysis these assumptions are implied. So, first of all there are three categories of power semiconductor devices.

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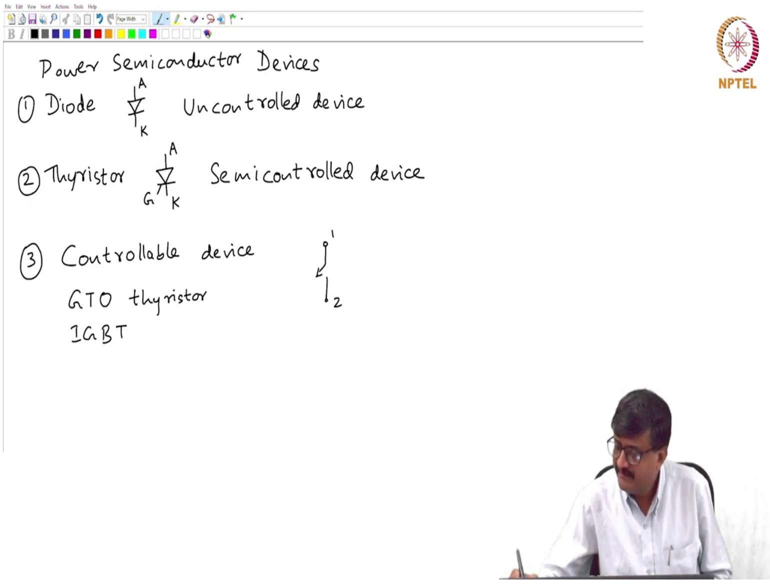

So, if you look at power semiconductor devices, yeah three categories; one is diode, all of you are familiar with the symbol of a diode. So, I have two terminals; A, A for anode and K for cathode.

Now, we all know that if a potential of anode is higher than that of the cathode by a certain value, it is forward diode and it starts conducting. Now the assumption that we make here is if the potential of the anode is just higher than cathode. So, the even if it is any value the potential difference between anode and cathode is any value greater than 0, ok then we say that it is forward bias and its starts conducting, ok. There are only two terminals A and K, both these are power terminals and there is no way to control the state of the device.

So, there are two states, on state and off state. So, if I want to go from one state to other it only depends on this power circuit in which it is connected. So, depending on whether it is forward bias or reverse bias either it conducts or it does not conducts, so, we say that a diode is an uncontrolled device.

The next category of power semiconductor devices is thyristor. The symbol is similar to that of diode except for a minor addition and there is an addition of terminal as well. So, I have the anode and cathode terminals which were there in the diode also.

And there is an additional terminal gate terminal, G is the gate terminal. So, anode and cathode are power terminals whereas G is the control terminal. So, in the case of thyristor, if it is forward biased now the definition of forward bias is similar to the that of diode. If the potential of anode is greater than the potential of cathode then if a gate current pulse is given; that means, if a positive current flows from gate to cathode or if just a pulse of positive current flows from gate to cathode then it starts conducting.

So, we say that it is in on state. Now if it has to go to the off state; that means, if it has to stop conducting then somehow the power circuit should be in such a situation, I mean should be in such a condition that the current itself go to 00. Now, there is no way of providing a pulse as we did in the case of turn on using the gate terminal. See if I want to turn on so I can do the turn on as long as the thyristor is forward biased, I can turn it on by giving a signal using gate terminal.

So, I give just current pulse with that flows from gate to cathode like positive current pulse and that will actually turn on, but turning off is not possible by control, turning off is only dependent on the power circuits. So, if the current goes to 0 and not only the that is not only the condition required for turning off current should go to 0 and then it should remain reverse bias for a certain minimum duration only then it will turn off, ok.

So, there are a few things that are neglected. Now both in the case of diode or thyristor when the device is on the voltage across the device is actually 0. So, we neglect the voltage across this. So, that is what we mean by ideal device. So, we are we will assume that these are ideal devices.

Now this is actually justified, because we are talking about voltages of the order of kilo volts or I mean if you add up it is hundreds of kilo volts. So, a small fraction of a volt is actually negligible.

So, of course, it is not a just a fraction of a volt, because many such devices are connected in series. So, they will add up to actually make it significant term amount of voltage, but still negligible compared to the overall voltage, ok. So, that is why we say that the whenever the diode or thyristor is on the voltage across the device is 0. Similarly, the whenever the diode or thyristor is off there is a very negligible current, we ignore the current. So, we say the current is 0, ok.

And there are some more assumptions. Suppose, you give a gate signal in the case of a thyristor when it is forward biased. So, it will go from off state to on state. Now there is a certain non zero time taken to go from off state to on state. So, we assume again here ideal device, we say that the time taken is 0 so, it is instantaneous.

Now these are simplifying assumptions, ok. So, we assume that the time taken to go from off state to on state is 0, on the I mean, similarly the time taken to go from off state to I mean time taken to go from on state to off state is also 0.

So, essentially, we are neglecting losses also. So, there is neglecting of the conduction loss, we are also neglecting switching loss. Now please note most of the analysis that we do are independent of these losses, ok. So, we are not doing any analysis which will require the losses or which will require the time taken to go from on state to off state or off state to on state or which will require the voltage across the device when it is on. So, such things are not required for the analysis. So, these simplifying assumptions will help, ok.

So, as I said one can go from off state to on state by giving a control signal, but not the other way. So, that is why thyristor is called semicontrolled device that means, the control is only in one direction going from off state to on state not the other way. So, I gave some names directly, in fact the examples were given directly for controlled device semi controlled device, because they I mean we are aware of only one uncontrolled device that is diode and one semi controlled device that is thyristor.

Now, when I am saying we aware of only one example, I mean that these are the examples which are practical examples which can be used for power circuits at a transmission. Now, when it comes to the third category I will come to the example, but this is the category of controllable device.

Now, there are examples more than there is more than one example is possible here. What are the examples? By now you should be able to, you should be able to say what is this controllable.

Student: (Refer Time: 08:18).

First of all controllable means, I can go from on state to off state by giving a control signal, I can also go from off state to on state by giving a control signal.

See please note there are two circuits here, power circuits and the control circuits. So, the power involved in the control circuits is very small. The amount of power the amount of voltage, current and power in the control circuit is very- very small compared to a voltage, current and power in the power circuit, ok. For example, in the case of thyristor anode and cathode belong to the power circuit, ok. The current that flows from gate to cathode is that of the control circuit. So, the examples are.

Student: Transistor (Refer Time: 08:58).

Yeah, IGBT, I am talking about the one switch can be used in high power circuit. There may be many examples, but the once which are actually used in power circuits. Yeah, before IGBT there was one particular device GTO thyristor which stands for Gate Turn Off thyristor, of course, IGBT; Insulated Gate Bi polar Transistor. These two are very prominent. Nowadays, GTO transistors are no longer required, in fact IGBT is first prior.

Now the reason is the time taken from on state to off state or off state on state is much smaller in the case of IGBT. So, I mean it is always advantages if you can go from on state to off state very quickly, off state to on state very quickly. So, IGBT can do that much faster than GTO thyristor, ok.

Now, since there are two examples, there can be a few more of course, there are commercially a few more available, I will not try to list all of them. What I will do in this case is I will use a very general symbol. So, what I will do is I will just use a symbol like this, a switch with an arrow and two terminals, let me call say terminal 1, terminal 2.

Now, there is an arrow on the switch which means that whenever the device is on, the current is flowing and the current is always flowing in one direction from 1 to 2 and when the device is off so there is no current flow. Now, in this case I am not showing the control terminal though there will be a control terminal there is a control terminal in fact, but I am not showing them, ok.

Now, we will first start with a line committed converter. Before going to the purpose of having such a name or in the getting into the details of the operation of the converter, let me say few things about thyristor.

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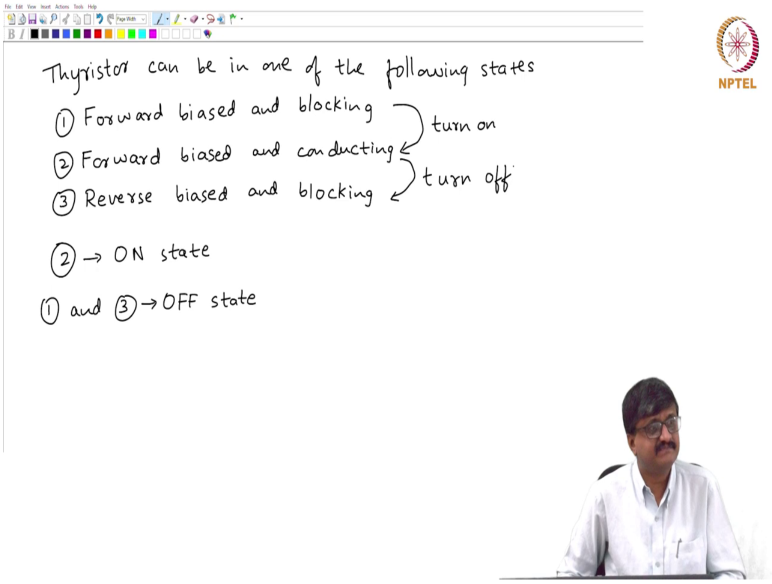

So, a thyristor can be in one of the following states. We have already mentioned a two states on state off state, but I will further classify this off state. So, that actually gives me three states for a thyristor, one is forward biased and blocking. The second state is forward biased and conducting, third state is reverse biased and blocking, yeah. By the way I am using the word block, I mean the thyristor block something. What does it block?

Student: Voltage.

Voltage, it blocks the voltage, ok. So, even though there is a voltage it does not conduct that is what is meant by blocking. Now among these three states which one is on state which one is say, I am not given a very preserved definition of on and off, but I meant, but I said that it is related to current flow. If there is a current flow we say it is on state if there is no current flow, we say it is off state, ok. So, only a state 2 is?

Student: On state.

On state, ok. So, 2 is ON state, 1 and 3 are OFF states. So, if I want to go from OFF state to ON state then can I go from 1 to 2 or 3 to 2?

Student: 1 to 2.

1 to 2, so, going from off state to on state is always from 1 to 2. So, we say that transition from state 1 to state 2 is turn on, this transition is called turn on. Now, if I want to go from ON state to OFF state, so, should I go from 2 to 1 or 2 to 3? It is invariably 2 to 3.

Reason is even if the current goes to 0, if I have a positive voltage of the cathode sorry of the anode with respect to cathode the thyristor I mean continues to conduct. So, there is minimum time require for the voltage of the anode with respect to cathode to be negative.

So, there is a minimum duration for which the voltage is required to be negative the voltage of the anode with respect to cathode. So, only then it completely stops conducting. So, this transition from 2 to 3 is called turn off.

So, what we saw in this class was I mean the contents on the with of historical developments and a very few assumptions that we make throughout the course, ok.