Design of Power Electronic Converters
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Module Snubber Design
Lecture 36
RCD Snubbers - I

Welcome to the course on Design of Power Electronic Converters. We were discussing snubbers and we had seen RC snubbers. Now, let us look into the analysis of RCD snubbers.

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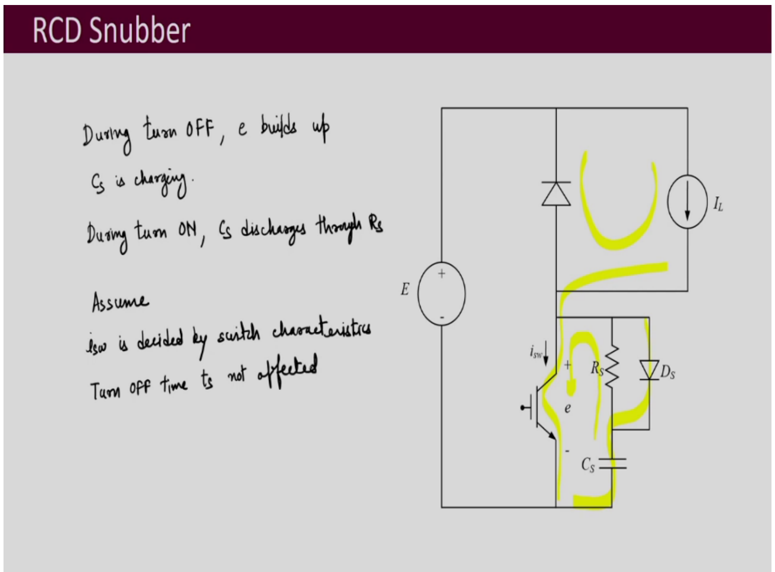

To explain RCD snubbers I am using this circuit, this is the familiar circuit, which we have used earlier also, it is a actually reduced version of the H-bridge converter. So, what we have here is the diode and then there is this switch here it is represented as an IGBT, but you can also use MOSFET here. So, whatever analysis we do, we basically we use any kind of transistor it is applicable.

And then we have this voltage source E and then there is this load I L, this is represented as a current source I L. And here this is the snubber part, which is your Rs, Cs and Ds, RCD snubber. And the voltage across the device is denoted as e and the current through this device is denoted as i sw. So, the circuit functioning is simple. So, whenever the switch is on the current flows through the switch and whenever the switch is off the current freewheels through this diode.

Now, let us look into what happens with this snubber. So, this is a turn off snubber. So, while the device is getting turned off and that time this diode is forward biased and it conducts and it bypasses this resistor Rs. So, this Rs is not having any role when this diode Ds is going to conduct. And the current then flows through Cs and it charges this capacitor Cs.

And so, if we consider this as a short then whatever is the voltage across this Cs that is going to be the device voltage e. For our analysis that is what we are going to take it as we will not consider the drop across the diode but the voltage across the capacitor as the voltage that appears across this device and that is the voltage e which appears when the device is going to turn off.

So, while charging during turn off it takes this path this Cs charges through this Ds and when turn on happens at that time the Cs discharge is through this Rs and the switch. So, what we are telling is that during turn off, your voltage e builds up and that is the time when your Cs is charging and during turn on Cs discharges through Rs. Now, one more thing that we are going to assume is that that during turn off your i sw is decided by the switch characteristics.

And for simplicity, we are assuming that the snubber is not affecting this current i sw during turn off, it is the voltage which is affected by the snubber action. Now, why are we making this simplicity and why are we assuming it? Because, I mean this switching actions, your switching characteristics, they are governed by very complex differential equations, we have to go to the device physics to properly understand them, and that taking into account designing the snubber becomes very, very difficult.

So, this analysis whatever we are doing, you should regard it as a qualitative analysis. And as I have told before also that the snubber what values that we choose, they are the first estimate, they are the values which are good to start with your experiment when you are designing your converter. You start with those values by your calculations by this analysis whatever equations that we get, whatever graphs that we obtain.

Using it, you are going to get some values for your snubber Rs and Cs and you will start your experiments with that design. And then as you perform experiments, you see the performance the actual performance the waveforms and then you can find tune on those values, that is how design are performed.

These Rs and Cs values, the snubber values, it is not possible to do their calculation I mean exact calculation theoretically, it will becomes very complicated. So, for analysis also we have to do some simplifications and that is this simplification, that you the switch current is not getting affected by the snubber action and the device voltage is getting affected.

And also, next assumption that accordingly will take is this, that your this switching time, which we call it as the ts that time is also not getting affected. In practice it is going to get affected, the snubber action will also change the turn on and turn off times. But for again sake of simplicity of analysis, we will assume that this switching time is not getting affected. So, let me write down that assumption as well. So, this turn off time ts is not affected, this is what we are assuming for simplicity.

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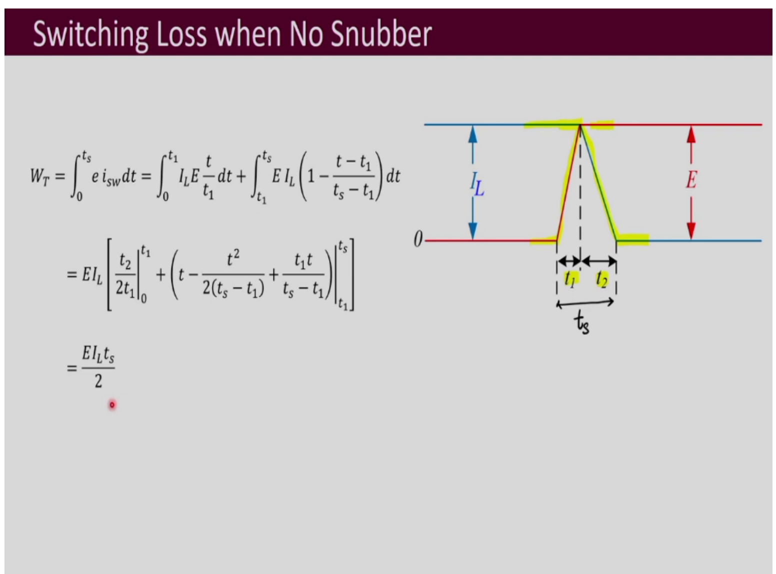

So, before doing the analysis for RCD snubber let us get some equations. So, when no snubber is used. So, when no snubber is used, you know that during turn off, what happens is that it is your voltage which first builds up. So, for this time t1 first the voltage builds up, this is where your voltage is building up for this time t1 and after that the current false and that is that happens at time t2.

So, during time t1 the current does not change it remains the same and when the current falls at that time the voltage is already reached to its final value E which the device is supposed to block.

So, this time t1 plus t2, we will take it as the turn of time ts. Now, let us look into the switching loss that we can derive from this. So, let us say this is the transistor loss or the device loss and this is the total loss because there is no snubber so we will call it as WT is the total loss which is basically your the devices switching loss during turn off.

So, here you have this

$$W_T = \int_0^{t_s} e i_{sw} dt = \int_0^{t_1} I_L E \frac{t}{t_1} dt + \int_{t_1}^{t_s} E I_L \left(1 - \frac{t - t_1}{t_s - t_1}\right) dt$$

So, you do this integration and when you reduce it, what you will be getting is this

$$W_T = E I_L \left[\left. \frac{t_2}{2t_1} \right|_0^{t_1} + \left(t - \frac{t^2}{2(t_s - t_1)} + \frac{t_1 t}{t_s - t_1} \right) \right]$$

$$W_T = \frac{E I_L t_s}{2}$$

So, this is the loss that is going to take place when there is no snubber. So, this we have done as a reference because, from the analysis we will be comparing the snubber loss plus device loss with the condition when there is no snubber that means, with the only device loss. So, let us now see the RCD snubber analysis.

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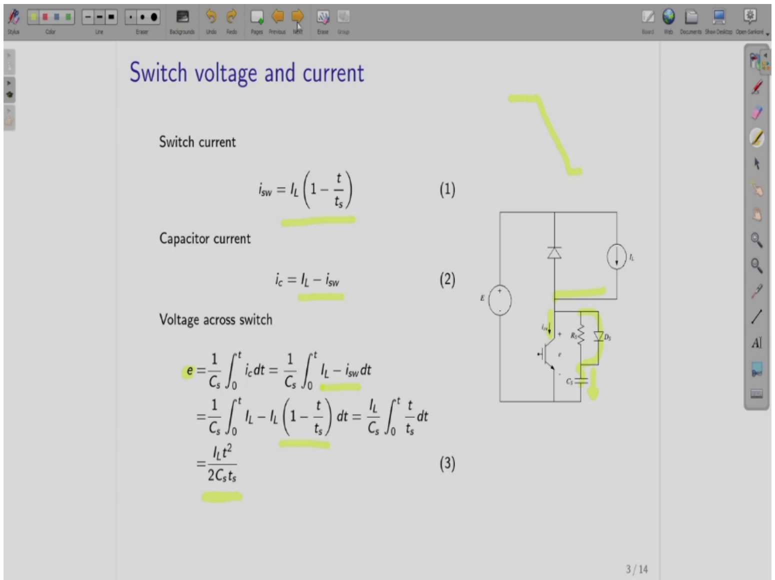

So, this is the same circuit which is redrawn here and then this switch current i sw this will be written as

$$i_{sw} = I_L\left(1 - \frac{t}{t_s}\right) \quad (1)$$

we have this capacitor current, this capacitor current ic,

$$i_c = I_L - i_{sw} \quad (2)$$

which is going to be the difference of I L minus i sw. So, this is the current I L. And so, you subtract i sw from it and so this is what is going to flow through your capacitor.

And voltage across the switch which is e

$$e = \frac{1}{C_s}\int_0^t i_c dt = \frac{1}{C_s}\int_0^t I_L - i_{sw} dt$$

substitute for this i sw from here and then you reduce it in,

$$e = \frac{1}{C_s}\int_0^t \left\{ I_L - I_L\left(1 - \frac{t}{t_s}\right)\right\} dt = \frac{I_L}{C_s}\int_0^{t_s} \frac{t}{t_s} dt$$

you integrate. So, this is what you are going to get

$$e = \frac{I_L t^2}{2C_s t_s} \tag{3}$$

now ts is the turn off time.

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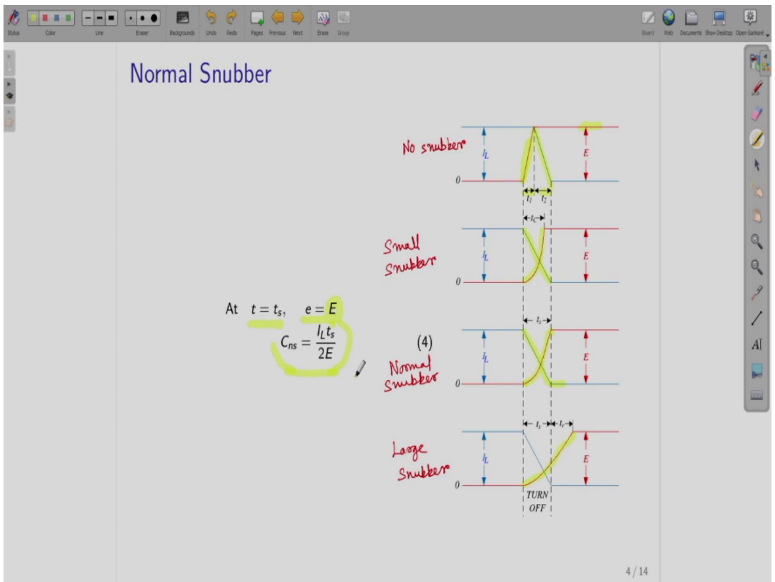

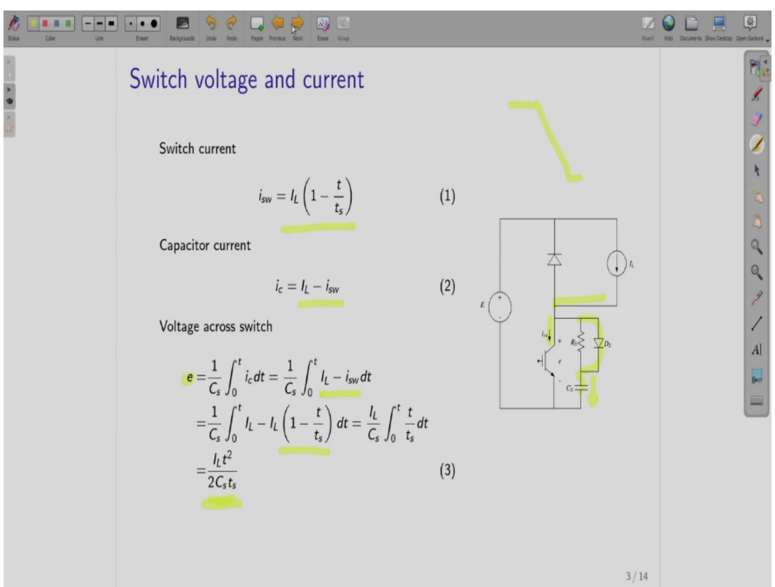

Now, let us look into these waveforms that are drawn here. So, first one is your no snubber case. So, this is for no snubber, this is what you are familiar with that there are two intervals t1 and t2 and first the voltage increases in t1 time interval and then it falls in the t2 time interval. Then, what we are telling is that when you have added the snubber, then this voltage, this voltage E this one is going to get affected.

So, this part is going to get affected. So, by that action, what happens is that, we assume that the current falls during this time period ts, during this turn off time period it falls from your I L value to the load current value to 0. And the current, but this voltage builds up across the capacitor, it gets charged. Now, while it gets charged depending on this value of capacitor the snubber capacitor C is chosen, it may so happen the voltage may build up before this turn of time period is over.

So, that is this case or it may so happen that it may exactly reach to the voltage E at time ts or it may so happen that it may build up slowly if the C is large enough and it may reach to that blocking voltage E later than the turn of time period ts. So, depending on that we divide the snubber in three parts one is your normal snubber. So, normal snubber means, this case where what you have is that the ts falls from I L to 0 in time ts period and this voltage E that builds up to this blocking voltage capital E in time ts period exactly.

So, this switch current is falling in the same pace, it is the same for all the three snubber cases. But in the normal snubber case it will reach to this blocking voltage exactly at time ts. And if it is smaller than that, then it will build up quickly and it will reach to the blocking voltage before time ts period. Let us say that time period is tc. So, in that case, we call that as a small snubber. And then third case maybe it is large enough and it builds up slowly. So, that is your large number.

So, if we have to write some equations. So, for normal snubber at t equal to ts, your this device voltage or the capacitor voltage is equal to the blocking voltage at that time capital E. And then if you substitute in equation (3) here this will become

$$C_{ns} = \frac{I_L t_s}{2E}$$

So, this is the equation for your normal snubber. This kind of gives a base value and relative to which you decide whether your small snubber or large snubber action is going to take place. So, for this lecture we will stop here. In the next lecture, we will continue on this analysis fault. Thank you.