Design of Power Electronics Converters
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Module: Snubber Design
Lecture 30
Introduction to Snubbers

Welcome to the course on Design of Power Electronic Converters. Today we will begin with the module of Snubber design. So, first of all, let us see what is this snubber and what role does it play in power electronic circuits.

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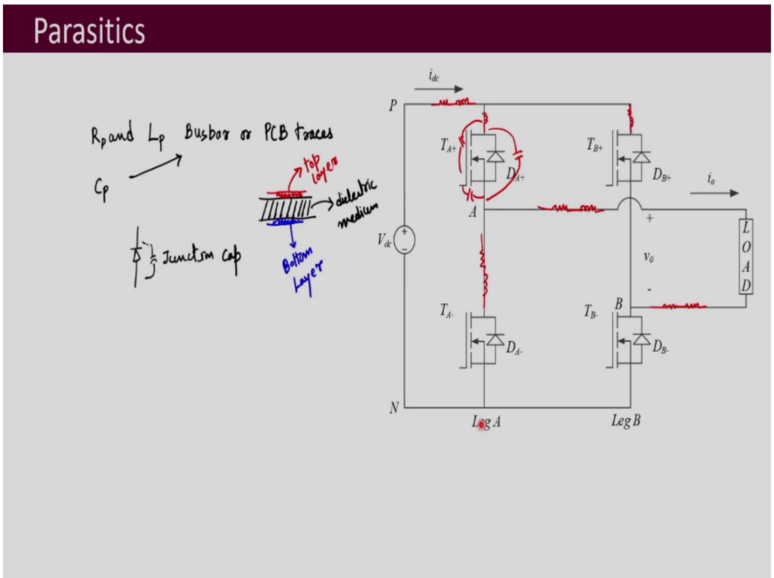

Before discussing snubbers, we should know what are the different parasitics that play a role in a power electronic circuit. For that, I have taken the example of H bridge converter. So, now this is the converter that we had analyzed and this is what whatever we had analyzed was an ideal circuit these switches were ideal, all these conductors, wires, which were connecting the different elements in the poly electronic circuit, they were also ideal. But when you are going to realize it, when you will be practically implementing it, either you will be using a PCB or you may be using a Busbar structure to connect all these different different devices and your loads in with the source.

So, at that time, the wires are not going to be ideal they will have their parasitics associated with them. So, this line which is being shown as a straight line, and there is an ideal line which no resistance, no inductance nothing associated with it that is not what it is going to be. So, what we will be having here is that you will have some parasitic inductance over here and also some resistances and then here also some inductor like that, so, resistance parasitic inductance all throughout the circuit we will be having it.

So, then they definitely will have their effect and that effect is usually in terms of some spikes in voltages and currents. So, what are the different parasitics? So, one parasitic I already told you is the resistance parasitic resistance and your parasitic inductance if we call it as Rs and your Lp. So, this is let us give it the name Rp here, Rp and Lp associated with your Busbar structures or your PCB traces. Then, further if you have seen a PCB then there is usually what you have is a dielectric medium.

So, this is your dielectric medium which is actually the board, the PCB board and on both sides of it you will be having some traces. So, let us say this is your upper trace and here below you have the lower trace. So, if we will let us say this is a double sided 2-sided PCB, so, then if you cut it, so, the here you this is your bottom layer and this upper one is your top layer. So, when they will be having the tracks or the traces and different tracks pass through these different sides of the PCB.

So, they will have different voltages also on them. And that means you have a dielectric medium and different voltages across them. And so that is like a formation of a capacitance. So, this is not only true for your when traces are on both the sides of the dielectric medium if you have 2 parallel conductors, they will or they may also have some capacitance if the voltages are different, but that usually is going to be much lesser this is a source of relatively important or significant capacitance parasitic capacitance.

So, then we will be also having parasitic capacitance is CP associated with your Busbar and a PCB traces. So, further if you recall then when we studied transistors IGBTs and MOSFET we said that there is parasitic capacitance between gate to drain, between gate to source and also between drain and source. So, they also are going to play a role in the circuit performance and then that also when we analyzed the ideal circuit we did not take into account but they will have their own effect which will be deviating from the ideal waveform that we have studied.

Further another source of parasitic capacitance is this junction capacitance of the diode. So, if you recall that also we had discussed we had seen this that here whatever the junction is formed, so, you will be having this junction capacitance we saw that in the datasheet of the diodes, so, those junction capacitances they also are one source of these parasitic elements.

So, all these are they all these play a role in the turning on and turning off the waveform shape that we get.

And they actually lead to some sort of spikes and ringing in the power electronic circuit. So, that is what is something we do not want, but parasitics you cannot get rid of it 100 percent. They are there you can try to minimize them, we can have a very good PCB layout, we can have a perfect Busbar structure, very compact design, so, that your strain inductances and resistances are very small, but they will be there we cannot eliminate them and so, their effect will also be seen in the waveforms of different components in the circuit. So, now what is the effect let us see that.

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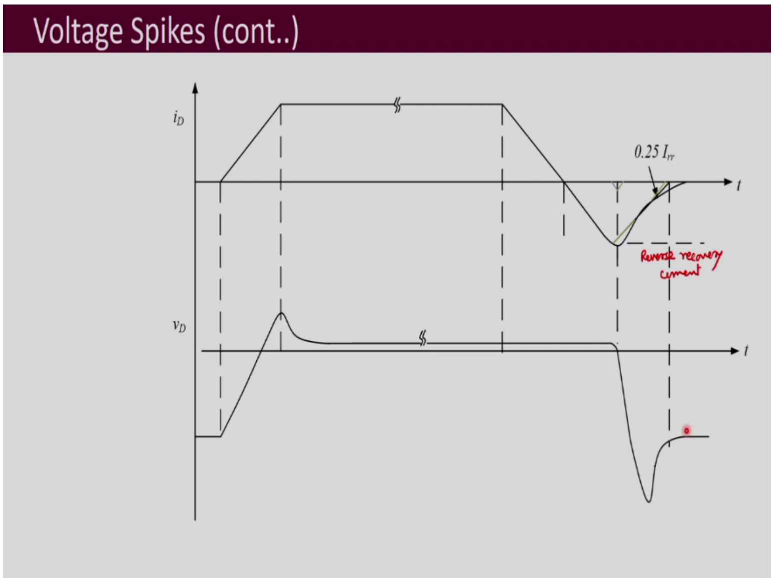

So, to some extent, we had discussed this when we discussed your turn ON and turn OFF characteristics of the devices of diodes and MOSFETs and IGBTs, now you have to recall this is the switching characteristics of the diode. We had seen this turn ON characteristics in the turn OFF and at that time I had told you it is the turn OFF which is more a problem then your turn ON and hear it turn OFF of the diode what happens is that you have this reverse recovery current.

So, this is your reverse recovery current and this reverse recovery current or when it reaches up to here almost to its peak value and that is the time when your voltage starts to build up across the diode till then the voltage is almost equal to the on state voltage drop and it increases and it has a shoot it is an overshoot, and that is the spike and this spike is because of the parasitics that are present because of the stray inductances that are there. So, if we have a higher stray inductances in the power electronic circuit the way you have designed it, then it will lead to higher spikes.

So, when I had explained you I had just shown you like this kind of a just a spike coming in and then just reducing. But in reality it is not it may not be like this, it is usually in the form of some ringing phenomena that you will observe. And finally, the voltage settles down to whatever the device is supposed to block.

And for that I had told you that whenever you are IGBT or MOSFET turns on at that time it is the diode which is turning off and the effect of diode turn OFF is more than the devices (the IGBT or the MOSFET) turn ON. So, it is usually the turn OFF, which is a problem, which has to be considered. So, that is why here in this course, also we will be discussing about turn OFFs snubbers rather than turn ON snubbers.

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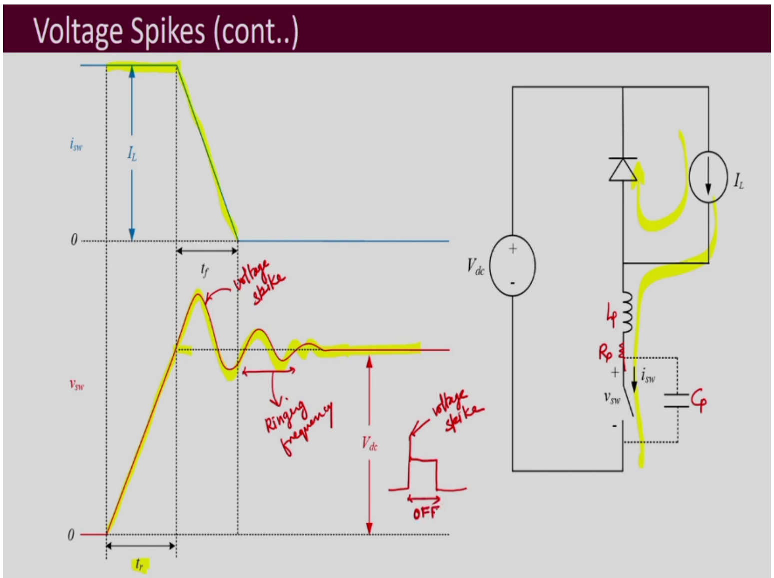

Now, to understand it further, let us take this circuit. So, this circuit is here, we are observing the switching of this device, this can be an IGBT or MOSFET turning and transistor and then we have got the freewheeling diode. So, here this is your load which is represented as a current source. And so, when this device turns on, at that time the current flows through this switch and when the device turns off at that time the current freewheels through this diode, so, it free means like this or it flows through this switch. Now, this one that I have shown this is the parasitic inductance.

So, let us call it Lp this is the parasitic inductance Lp, then we have capacitances associated parasitic capacitance is associated with the switch and so, we can give it the name Cp. So, this is your parasitic capacitance and further you will be also having some parasitic resistance. So, let us call it is Rp. So, what you see is what is forming here is an RLC circuit. So, when we have the turn OFF of the device so, at that time the device was initially carrying this current IL and when the turn OFF process begins if you recall then what we had said first the voltage builds up.

So, first the voltage builds up, but at that time there is no change in the current that the device is carrying here and this is also called as the rise time, the voltage rise time. After that rise time the voltage when it has almost reached to the value which is which it is supposed to block at that time this current starts to fall this is your fall time and during this time is when you have this voltage spike coming up. So, you will have this overshoot in the voltage and since this is an RLC circuit, you may have an under damping or over damping or a critically damped phenomena.

You have studied RLC circuits before in these 3 under damping overlapping or critically damped case happens in your RLC circuits depending on the values of R L and C the usual if your r is less than that is an under damped case and which is what is going to be this effect of R will be usually smaller than the effect of this L and C. So, corresponding to the natural frequency associated with your L and C you will have the ringing frequency and so, in this kind of intriguing phenomena is what you will be observing and there will be a spike (voltage spike) that you are going to observe.

And this will be your ringing frequency whatever is the time periods associated with this or you can call that as the natural frequency what it is usually termed as. So, usually this frequency is very high and so when you observe in an oscilloscope what you will be observing is like a spike waveform is a spike and not these ringing unless you zoom it. So, what you will be observing in your oscilloscope is something like this kind of voltage a waveform. So, that is that your voltage spike is what will be observed in this is the off time period of the device.

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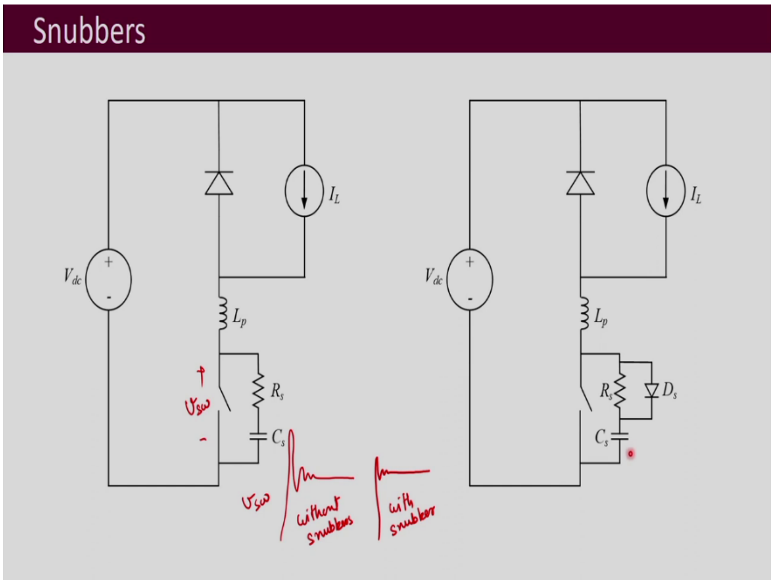

So, now as we saw that this is an RLC circuit that gets formed because of the parasitics and these spikes are unwanted in the voltage and we want to get rid of it because if the spike voltages may if it becomes too high then that may damage the devices. So, of course, to reduce the spike one is that try to reduce all the parasitics but as I told you, you cannot do you do it beyond a certain extent we cannot eliminate them, but we can reduce them. So, further what is the solution, what could we do to protect the devices against these over voltages produced by the spikes.

So, since this is an RLC circuit, if we change the values of R and C, then another different RLC gets formed and then that is going to affect the RLC spike voltage in the ringing phenomenon that is going to happen. So, let us say if you are going to add these R and C, which is your RC snubber across the device, so, the this RLC circuit that was getting formed those elements are different and so, the ringing frequency and your spike voltage that you will be observing that also will be different.

So, what I want to say is that that without snubber let us say this was what was the shape of the waveform that you were getting. So, without snubbers and which numbers if we you properly choose the values of R and C this is what you may be observing the voltage across the device. So, this is your Vsw. So, this is voltage across the device. So, these are your Vsw waveforms. So, this is the change that you can bring by use of these snubbers you basically use different R and C values affect the RLC circuit that is getting formed and so you change the spike voltage.

So, this is one simple way of using RC snubbers. These are very widely used RC snubber is most widely used snubber in electronic converters. Another type of snubber which is used as your RCD snubber. So, here while charging the capacitor you actually you are charging it to through this diode Ds and when you are discharging, you will be discharging it through this Rs resistor. So, that is a is again in RLC a circuit is the elements are getting affected and you will have a different ringing in different spike voltage coming up.

This has certain benefits so over your simple RC snubber. So, this is also another type of turnoffs number, which is very widely used. So, in this course is I told you we will be discussing RC snubbers and RCD snubbers that are 2 different types of turnoff snubbers which are very widely used. We are not going to discuss turn ON snubbers although they also exist, you can go through the literature and turn ON snubbers. But mostly they are not that much used in practice as compared to your turn OFF snubbers.

Apart from your just this usual type of adding RC and RCD or L in case of turn ONs snubbers there are other types of snubbers also, some type of circuit can other type of circuit can also be added which can act a snubbers. So, those are also there. If you wish you can also read through them after going through these lectures, but in the RC and RCD are the simplest ones turn OFF snubbers which are very widely used.

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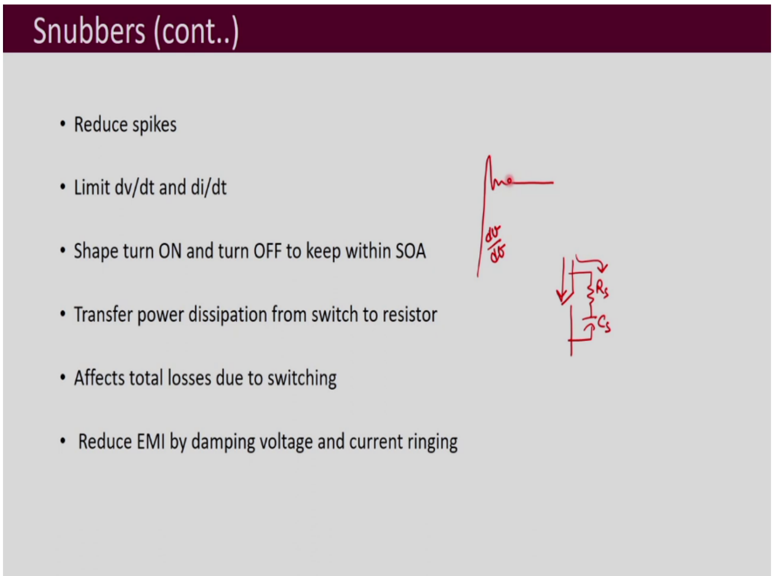

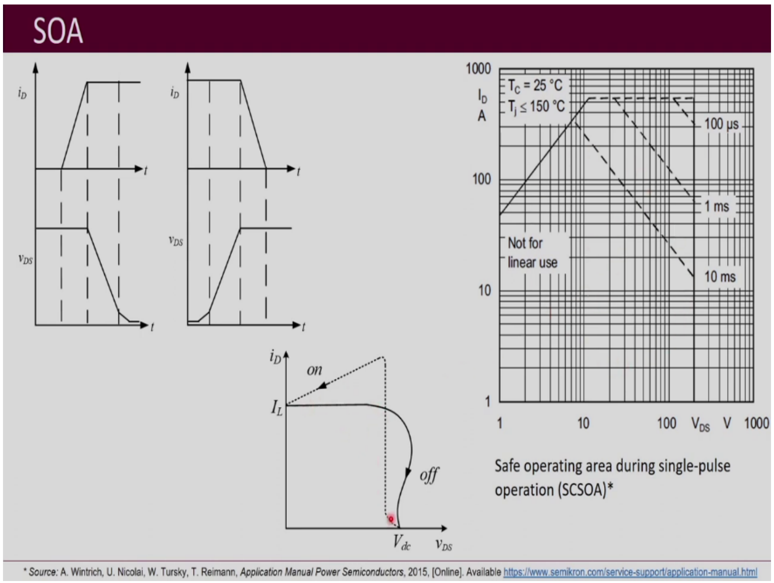

Now, what are the jobs that this snubber can perform? First is of course, this spike reduction that we just saw. Then further the next thing that it can do is limit the dv by dt in di by dt. So, what we mean by that is this is your rise in the voltage is getting affected. So basically, your dv by dt is going to be getting affected by your snubber. So, if your dv by dt is getting affected the rate of change of voltage is getting affected. So, obviously your rate of change of currents will also can then be affected by snubbers.

So, it changes the dv by dt and di by dt and you can design it such that you can limit it to the extent that is required for your converter. So, further it shapes the turn ON and turn OFF to keep a within a safe operating area. So, this is your where the turn OFF processes that we had seen your turn ON this one is the turn ON and this is the turn OFF.

So, when you add these RC or RCD snubbers so obviously, this trajectory is going to get affected, the slopes are getting affected and so, the trajectory it follows during your turn ON and your turn OFF that is going to get affected. So, that means, this switch was supposed to live within your SOA as we are shaping into we can ensure that it is inside this safe operating area while turning ON and turning OFF with the help of proper snubber design.

So, that is what is one of the jobs which can be performed by snubbers, I mean basically snubbers can help you in doing that shape turn ON and turn OFF to keep it with in the safe operating area. Then next is your transfer power dissipation from switch to resistor. So, when we are having this switch and then you are let us say adding an RC snubber over here. So, some of the current which was flowing through the device is now going to get transferred to this snubber.

So, whatever was the loss that was earlier happening in this switch will now be transferred to this snubber. So, you are basically reducing the stress on the device. So, your transfer power dissipation from switch to resistor means resistor means this snubber resistor that is possible with the help of snubber then that is going to affect the total losses due to switching. So, earlier when you did not have any snubber all the losses was happening because of the switching of the device the turn ON and turn OFF of the device.

Now, as some of the currents are transferred to the snubber during turn ON and turn OFF. So, this device losses switching losses are changed and further some more losses are going to get added in the resistor. So, the sum of these 2 we would like it to be lesser than originally what it was without snubbers with the proper snubber design it should be possible. So, your total loss is during switching is affected by adding snubbers and we obviously design it such that so that the total losses are lesser than without snubbers.

Then another is reduce EMI by damping voltage and current ringing. Now, you might have heard this term electromagnetic interference, we will be discussing more about it later on in the course. But the major source of electromagnetic interference are these spikes and this basically this turn ON and turn OFF process when the voltage builds up or the current builds up or the current falls and the voltage falls.

At that time these are changing very fast and there are frequencies associated with them which can be very high and may fall in the range where your electromagnetic interference can happen with other electronic devices in the vicinity. So, as we reduce this dv by dt and spikes with the help of a snubber, so to some extent, we can reduce the EMI with the help of snubbers. I am not saying that its snubber is a great solution for reducing EMI, but it definitely affects the EMI to certain extent.

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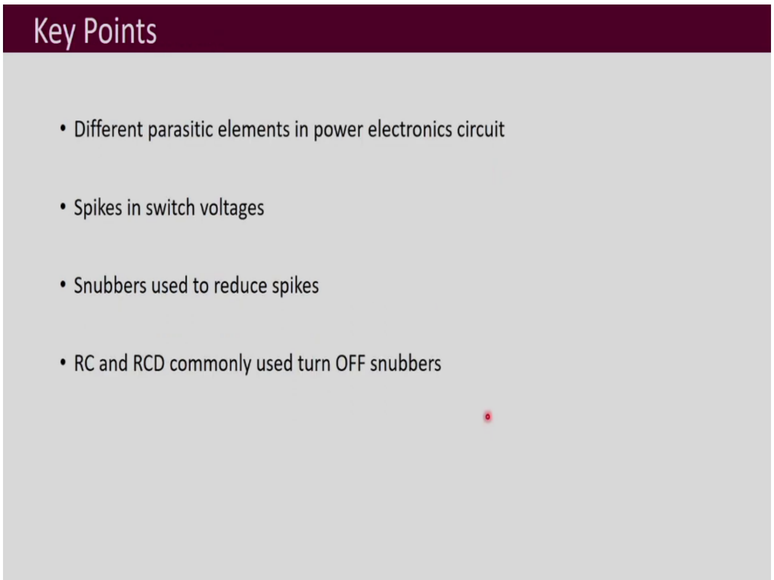

So, what are the key points of this lecture? What we discussed here is that the different parasitic elements present in power electronic circuits and they lead to spikes in switch voltages and that may damage the device. So, to reduce that we use a snubbers and the widely used to turn OFF snubbers, RC snubbers and RCD snubbers. Thank you.