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Switching Techniques in IGBT

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Abstract: The aim of this review paper is to study the switching techniques used in IGBT to reduce switching losses. Since the major drawback of IGBT is high losses at higher switching frequencies so various switching techniques to improve the efficiency will be described in this paper. The advantages of soft switching over the hard switching will also be discussed in this paper.

Keywords: Hard switching, IGBT, Zero current switching, Zero voltage switching.

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I. INTRODUCTION

IGBTs are widely used in voltage source converters to improve the stability and efficiency of HVDC transmission system. The major problem in using IGBT is that due to higher switching frequency, switching losses becomes more evident. Switching losses are the losses due to peak current or voltage. To reduce these switching losses, switching technique has been developed. This technique will play an important role in future expansion of electric transmission.

Simultaneous peak voltage and current cause higher switching losses leads to low efficiency and high stress in hard switching. To minimize its effect, snubbers are used which reduces di/dt and dv/dt ratings. But passive snubbers may create some losses due to charging and discharging of capacitor. Soft switching techniques are used to overcome the problem of switching losses. These techniques forces current or voltage to be zero before the device begins switching state, thus voiding overlapping during switching transition resulting in energy losses. Soft switching technique includes two methods via zero voltage switching and zero current switching.

II. HARD SWITCHING

In this technique, losses occurs due to simultaneous increase in current or voltage. The power peaks occurs twice during each switching cycle thus, increasing losses with the increasing frequency.

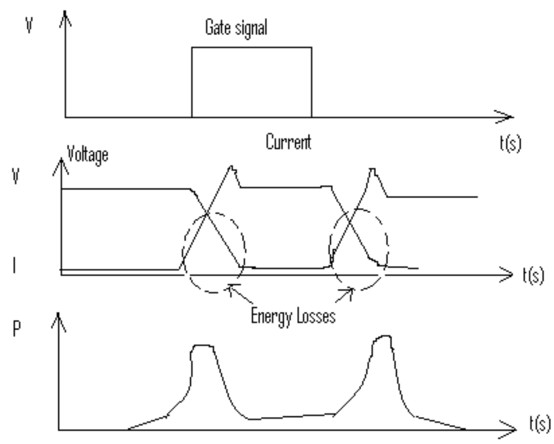

Fig.1 Energy losses during turn on and turn off

In order to reduce energy losses, it is necessary to alter turn on and turn off transients such that the current or voltage waveform is delayed at the transition instant.

III. SNUBBERS

RC and RCD snubbers are used to reduce the rate of rise of current and voltage. In RC snubber circuit, value of C is selected such that it is greater than output capacitance while value of R is equal to parasitic impedance of the system. As a result resonant ringing is greatly reduced.

In resistor capacitor diode snubber circuit, the current is diverted to snubber capacitor when the device turns off, thereby, charging diode and resistor. The snubber capacitor is discharged through device and resistor during turn on.

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Value of capacitor is adjusted according to the maximum permitted rise time and peak voltage the capacitor will charge to. This will result in reducing high peak voltages across the device.

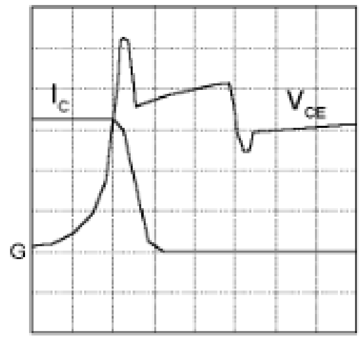

Fig.2. Turn off waveform of IGBT using snubber

Besides reducing switching losses, passive snubber circuits create some losses due to charging and discharging of capacitor. This can be overcome by passing back the energy into the system to be utilized again.

IV. SOFT SWITCHING TECHNIQUES

Soft switching methods are more efficient and better than hard switching as these methods can reduce the overlapping of voltage and current during the transition, thereby modifying the waveform of hard switching. These techniques forces current or voltage to be zero before the device begins switching state, thus voiding overlapping during switching transition resulting in energy losses.

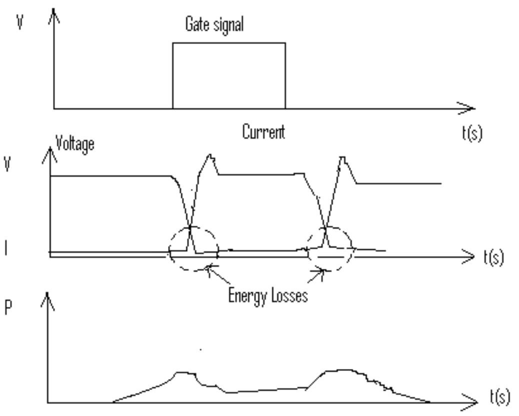

Fig.3. Switching losses reduced

IV.1. Zero Voltage switching

It means turning on or off of switch when voltage across it is zero. ZVS eliminates the capacitive turn on losses and It is suitable for high frequency operation. ZVS is more beneficial to MOSFET than IGBT due to higher output capacitance of MOSFET and ZVS is useful in reducing losses associated with capacitance. However, the major losses in IGBT is due to high currents resulting from stored charges.

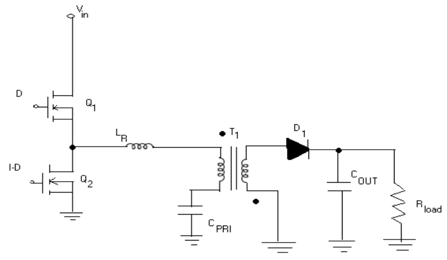

Fig.4. Zero voltage switching converter

During turn off the energy in the transformer primary winding is transferred to the load and capacitor. The capacitor begins charging and the switch is turn off with no voltage across it.

IV.2. Zero Current switching

In this technique the current is forced to zero during switching transition resulting in very low losses. To induce zero currents transients an inductor is allowed to resonate with capacitor to create sinusoidal currents. The switching devices are then turned off when the current goes through the zero point transition.

It can be seen from the waveform that whenever current reaches zero, transition takes place. The turn off losses are significantly reduced but turn on losses are not greatly affected due to sinusoidal nature of current inducing conductivity modulation lag within the device.

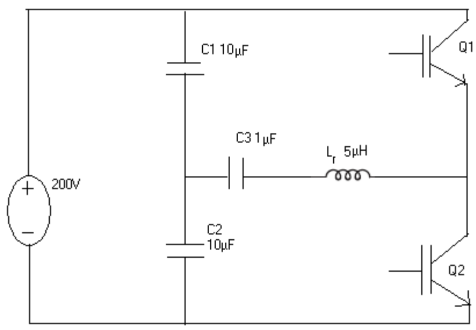

Fig.5. Zero current switching circuit

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V. COMPARISON BETWEEN DIFFERENT SWITCHING TECHNIQUES

With the growing technology development of power devices, switching mode power conversion moves towards high frequency operation, which can lead to high power density and fast dynamic response. For inverters, in addition to these benefits, operation at high frequency is required to reduce the audible noise, the volume and weight of filters, as well as improved quality of output voltage. However, at high frequency operation, switching losses and electromagnetic interference (EMI) become significant and is analyzed in detail.

Power semiconductor device commutation can be grouped into two techniques: hard and soft. With hard switching, the devices are required to change their states i.e. on and off, while they are subjected at both finite current and voltage values. High switching stresses produced by the overlapping of voltage and current result in high switching losses. Soft switching techniques aim is to reduce the mentioned overlap between voltage and current during the commutation. Thus it is possible to reduce switching losses, enabling high frequency operation and achieving higher power density, with reduced audible noise, volume and weight of filters, as well as high output voltage quality.

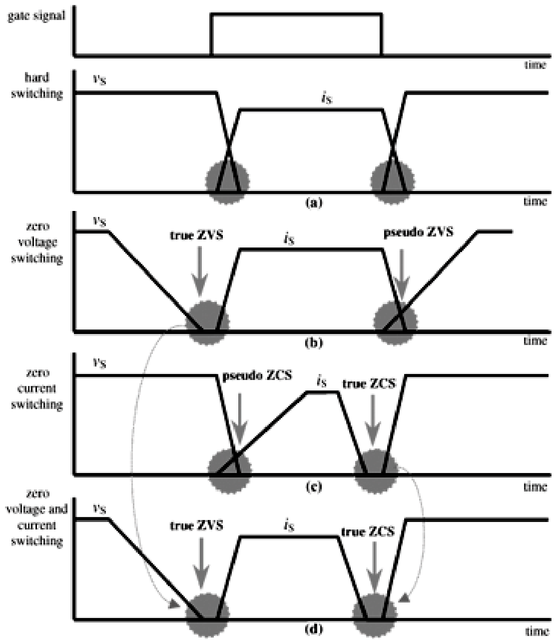

Fig.6. Comparison between switching techniques

VI. CONCLUSION

Soft switching for all power semiconductor devices have proven to be better than hard switching. Losses has been greatly reduced by using ZVS and ZCS techniques which enables high frequency operation and achieving high power density. Finally this increases the performance of igbt valves which can further enhance the efficiency of voltage source converter.

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