AN6175

Design of an RC Snubber Circuit for Dynex i² Thyristors

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There are many types of snubber that have been proposed to perform different duties in protecting a thyristor against overvoltage during the turn-off process; see for instance Application note AN6144 chapter 8. The simplest snubber circuit consists of a resistor and capacitor in series connected across the thyristor. If the equipment requires series connected thyristors for high voltage then each device will have its own RC network connected across it.

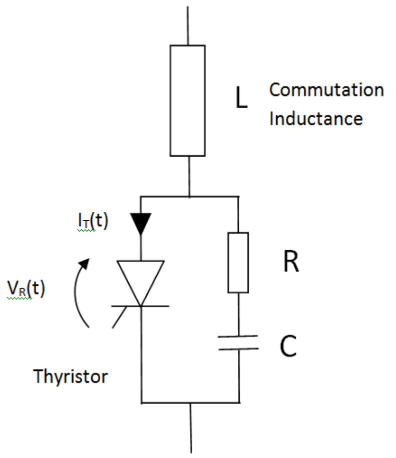


Fig. 1 Typical circuit with RC snubber and commutation inductance

The current and voltage transients typically seen during turn-off are shown in figure 2.

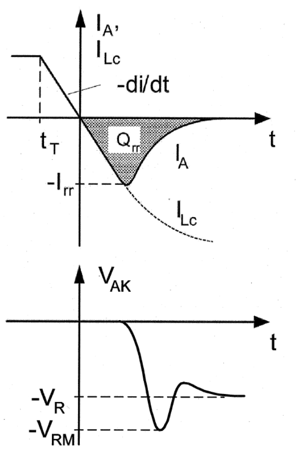


Fig.2 Current through and voltage across thyristor during turn-off.

V_R is the reverse voltage imposed on the thyristor by the circuit and V_{RM} is the peak of the transient over-voltage caused by the turn-off process. V_{RM} should be less than the repetitive voltage rating of the thyristor with a safety margin. The RC snubber is used to damp the oscillatory voltage to acceptable limits. The rigorous way to design the snubber is to employ a Pspice model of the circuit and adjust the values to R&C to achieve the desired effect. The method presented here is an engineering approximation which is easy to apply.

For the investigation of the voltage overshoot during turn-off it is necessary to analyse the circuit shown below

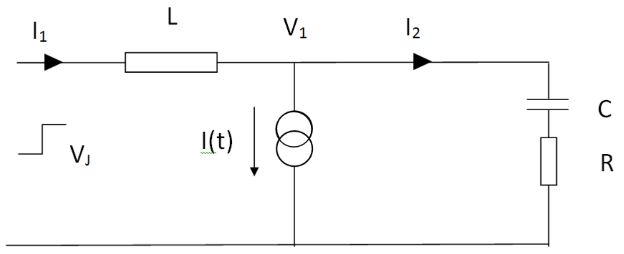
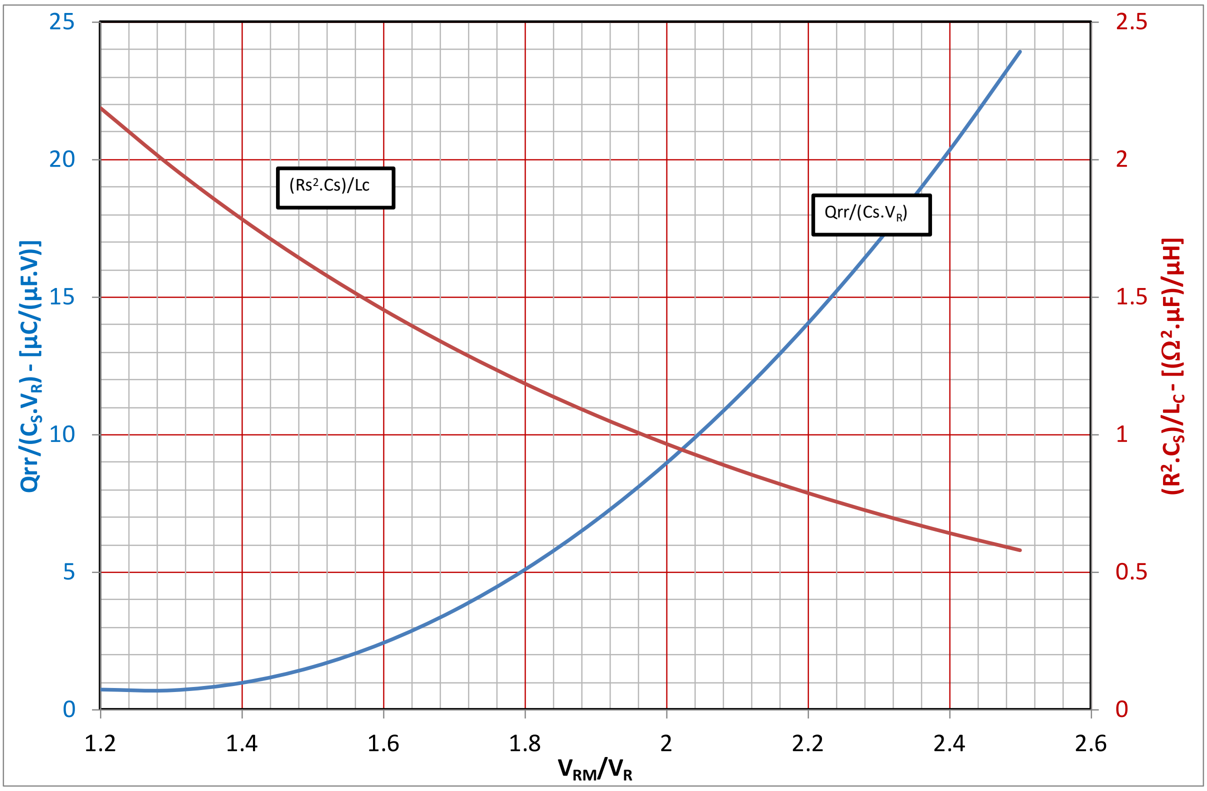


Fig.3 Schematic of circuit for analysis of snubber design

The commutating inductance L and the RC snubber are shown. V_J is the commutation voltage jump. Analysis begins when the peak reverse current is reached in the device. I(t) = I_R exp(-t/□). By completing the analysis it is possible to arrive at the following nomogram for a critically damped snubber.



Worked example. (Values chosen to illustrate the iterative nature of snubber choice)

Consider the case where the stationary voltage V_R is 2000V and it is required to restrict V_{RM} to 3200V i.e. V_R/V_{RM} = 1.6. The commutation inductance is 100µH, so the commutation di/dt is 2000/100 = 20A/µs. The thyristor being used is the DCR3030V42. Fig.12 of the datasheet gives the stored charge against commutation di/dt and the value at 20A/µs can either be read from the graph to be 15,600µC or more accurately calculated from the formula for Qs_{max} as 15,567µC

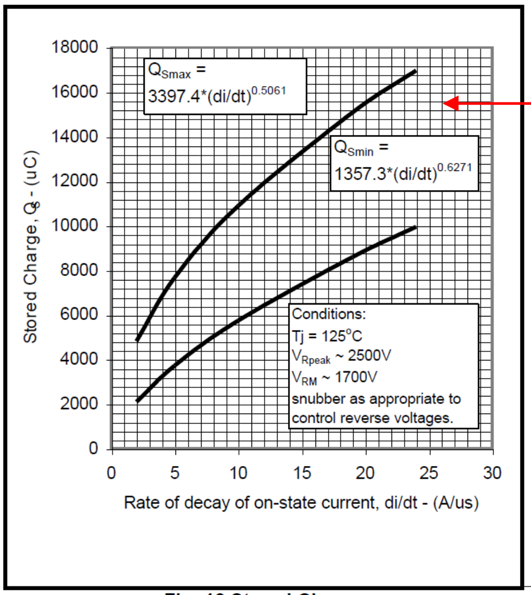
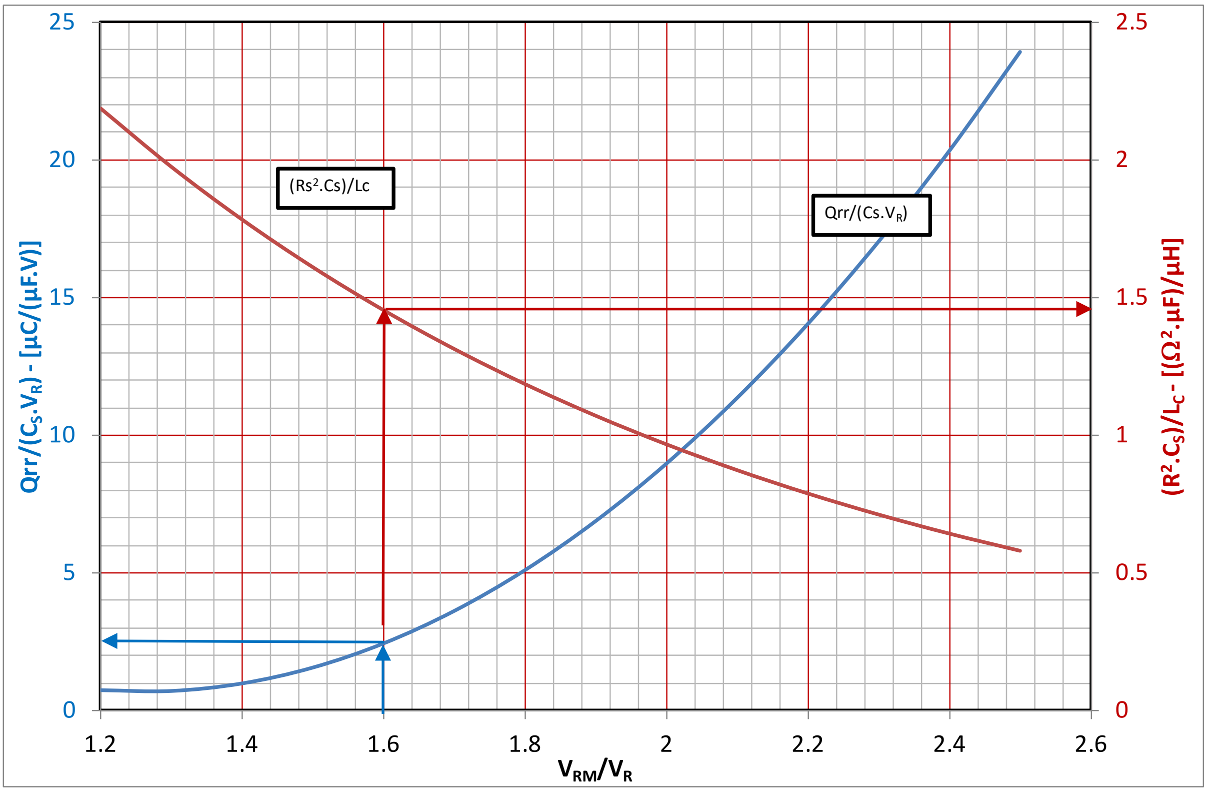


Fig. 12 Stored Charge



For VRM/VR = 1.6 we can read off that $Q_{RR}/(C_s.V_R)$ = 2.5 where we know Q_{RR} = 15,600µC and V_R = 2000V. Hence Cs = 15600/(2.5 x 2000) = 3.12µF.

Similarly we can also read that $(R^2.C_s)/L_C$ = 1.45 where C_s = 3.12µF and L_C = 100µH. Therefore R= sqrt(1.45 x 100/3.12) or sqrt(46.47) = 6.82 □.

Using standard values for capacitance and resistance we conclude the snubber to be 3.3µF and 6.8□□

The final calculation is to determine what wattage of resistor is required to handle the repetitive charging and discharging of the snubber capacitor once every cycle.

Thus P = Cs x V_R^2x f. In the above 3.3µH x 2000^2 x 50 = 660W

And the snubber discharge current $I_{DS} = V_R/R_S$ i.e 294A

660W may be too much heat to dissipate from the resistor and it is wished to restrict the power to, say, 150W. Therefore 150W = Cs x 2000^2x50, so Cs = 0.75µF.

Thus $Q_{RR}/(C_s.V_R)$ = 15600/(0.75 x 2000) or 10.04.

Reading 10.04 from the left hand axis of the nomogram gives a V_{RM}/V_R of 2.04. Thus VRM = 4.04kV which is less than the voltage rating of the thyristor.

For V_{RM}/V_R = 2.04, $(R^2.C_s)/L_C$ = 0.9

Thus R^2 = (100µH X 0.9)/ 0.75µF , so R = sqrt(120) or 11□

and I_{DS} = 182A.

The above illustrates the difficulty that arises at high di/dts where large values of stored charge result and the desired value of voltage damping is impractical and the problem has to be re-worked to find a compromise between overshoot voltage and power dissipation in the resistor.

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