

Design of an RC Snubber Circuit for Dynex i^2 Thyristors

Application Note

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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.

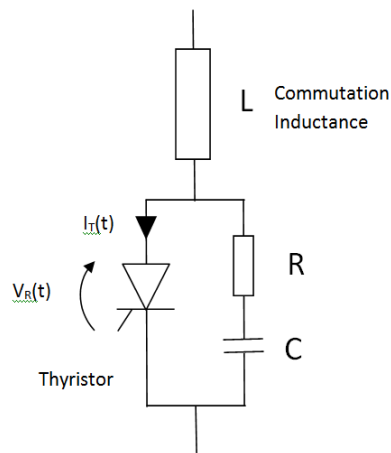


Fig. 1 Typical circuit with RC snubber and commutation inductance

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

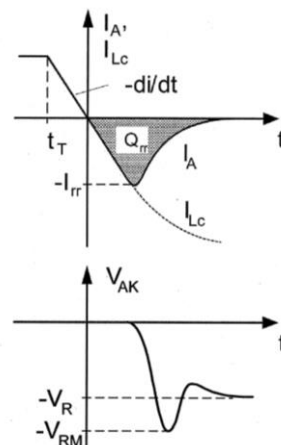


Fig.2 Current through and voltage across thyristor during turn-off.

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

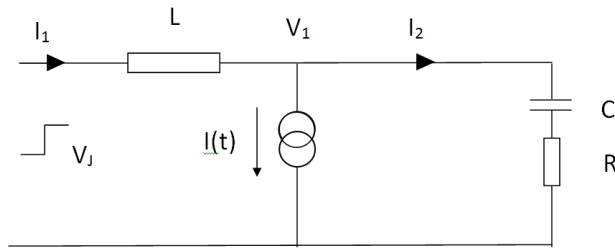
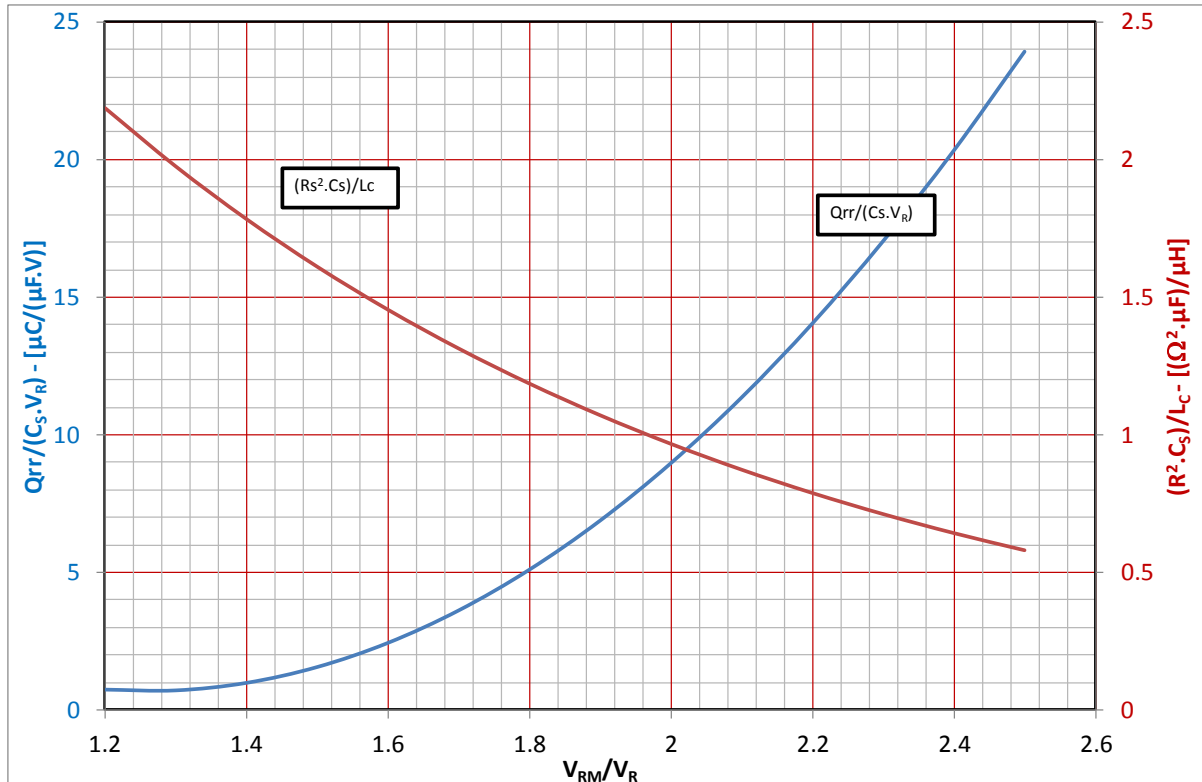


Fig.3 Schematic of circuit for analysis of snubber design

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. $I(t) = I_R \exp(-t/\tau)$. 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 $100\mu\text{H}$, so the commutation di/dt is $2000/100 = 20\text{A}/\mu\text{s}$. The thyristor being used is the DCR3030V42. Fig.12 of the datasheet gives the stored charge against commutation di/dt and the value at $20\text{A}/\mu\text{s}$ can either be read from the graph to be $15,600\mu\text{C}$ or more accurately calculated from the formula for $Q_{S_{max}}$ as $15,567\mu\text{C}$

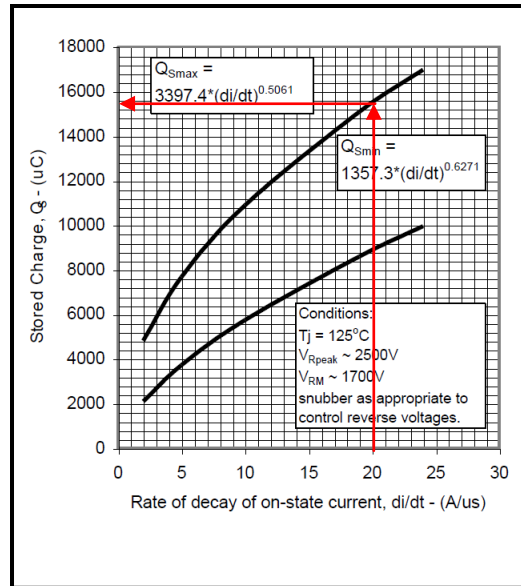
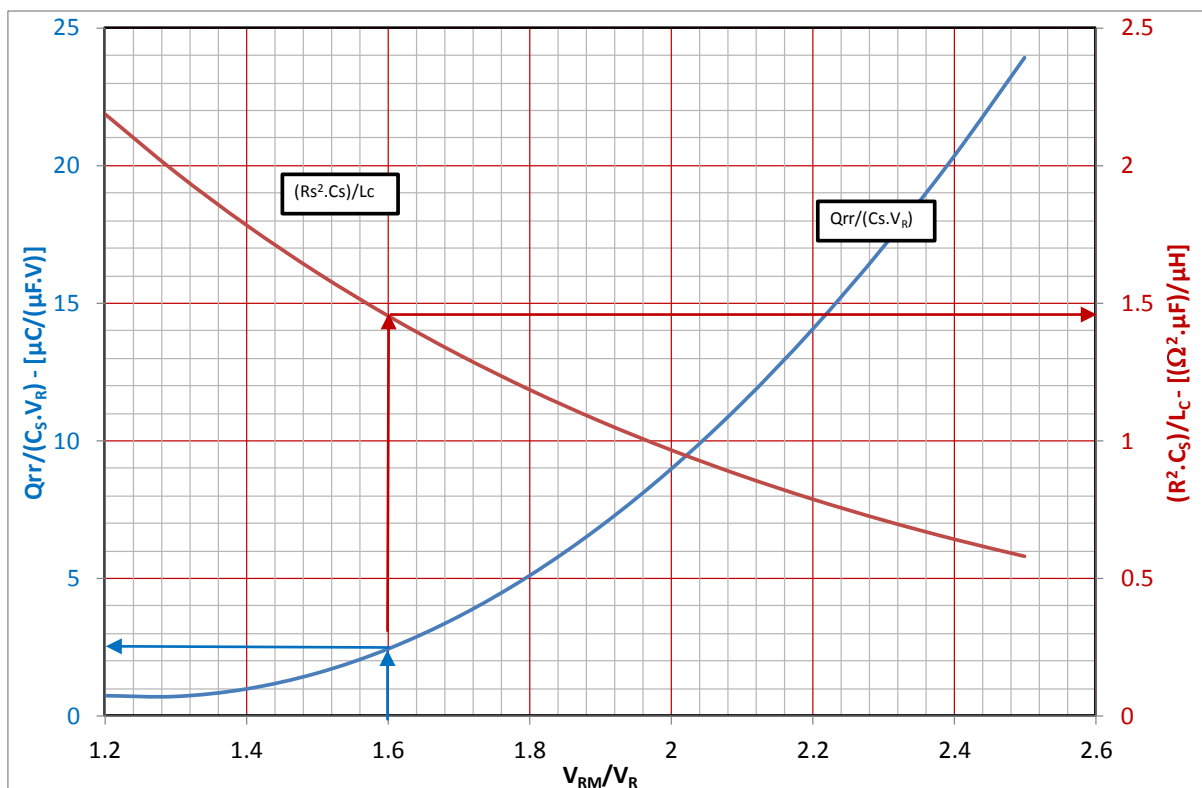


Fig. 12 Stored Charge



For $V_{RM}/V_R = 1.6$ we can read off that $Q_{RR}/(C_s \cdot V_R) = 2.5$ where we know $Q_{RR} = 15,600\mu\text{C}$ and $V_R = 2000\text{V}$. Hence $C_s = 15600 / (2.5 \times 2000) = 3.12\mu\text{F}$.

Similarly we can also read that $(R^2 \cdot C_s)/L_C = 1.45$ where $C_s = 3.12\mu\text{F}$ and $L_C = 100\mu\text{H}$. Therefore $R = \sqrt{1.45 \times 100/3.12}$ or $\sqrt{46.47} = 6.82 \Omega$.

Using standard values for capacitance and resistance we conclude the snubber to be $3.3\mu\text{F}$ and 6.8Ω .

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 $P = C_s \times V_R^2 \times f$. In the above $3.3\mu\text{H} \times 2000^2 \times 50 = 660\text{W}$

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 $150\text{W} = C_s \times 2000^2 \times 50$, so $C_s = 0.75\mu\text{F}$.

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

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

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

Thus $R^2 = (100\mu\text{H} \times 0.9)/0.75\mu\text{F}$, so $R = \sqrt{120}$ or 11Ω

and $I_{DS} = 182\text{A}$.

The above illustrates the difficulty that arises at high di/dt s 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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