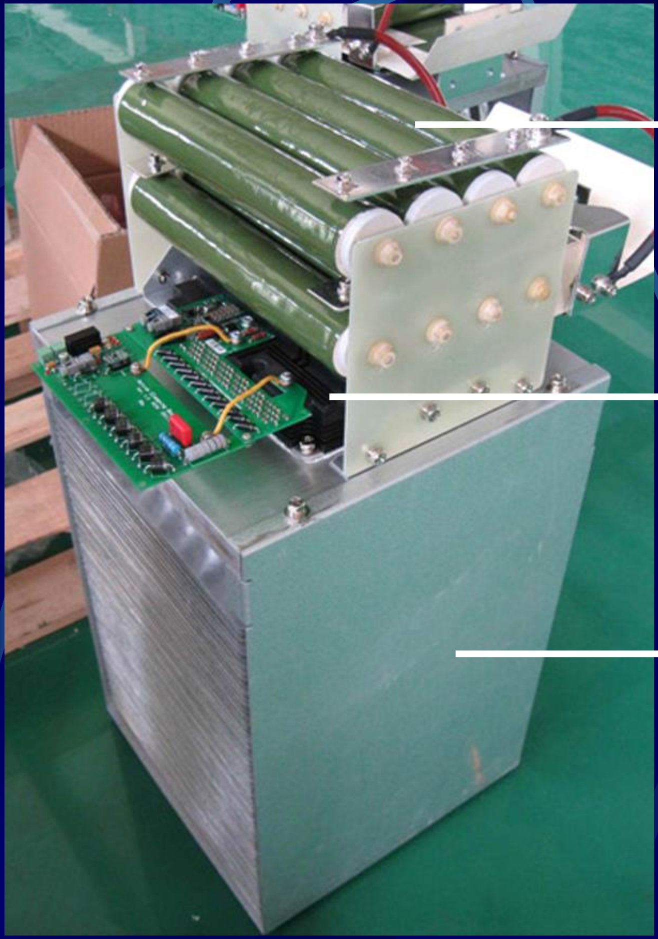
Chapter 6

Snubber Circuits

Power Electronics

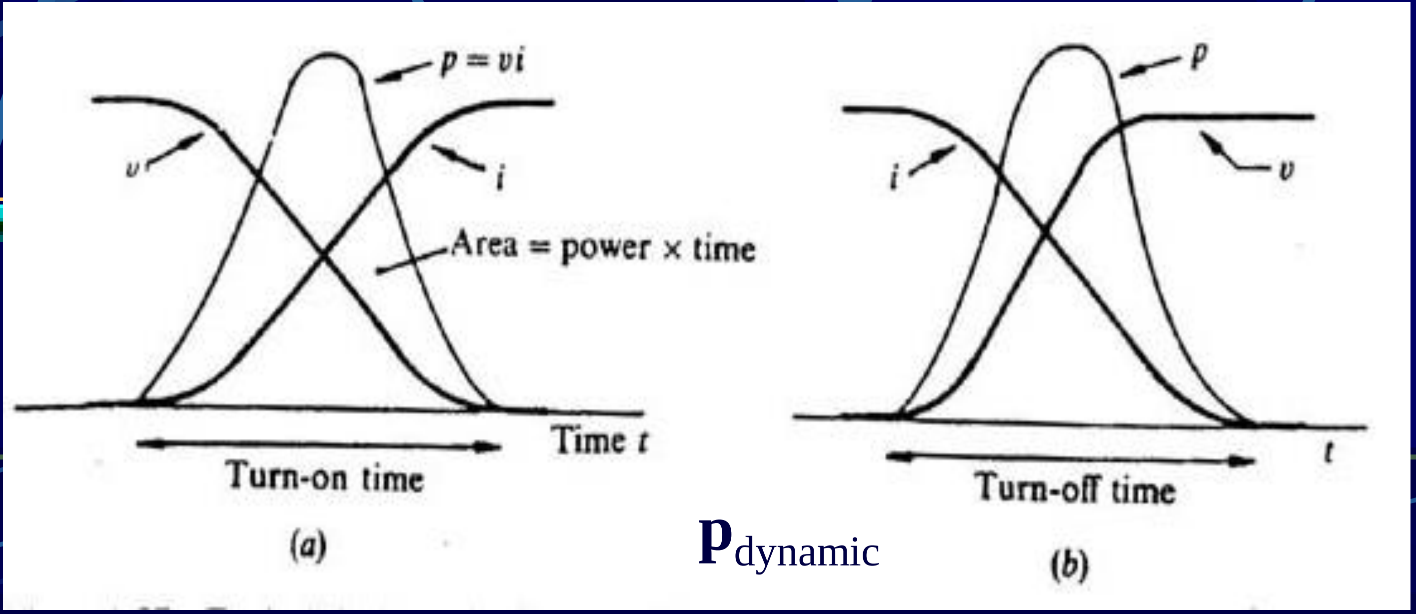


Snubber design during switching transients

IGBT

Heatsink

Problem 1: Switching Power Losses of Power Devices



$\mathbf{p}_{\text{dynamic}}$

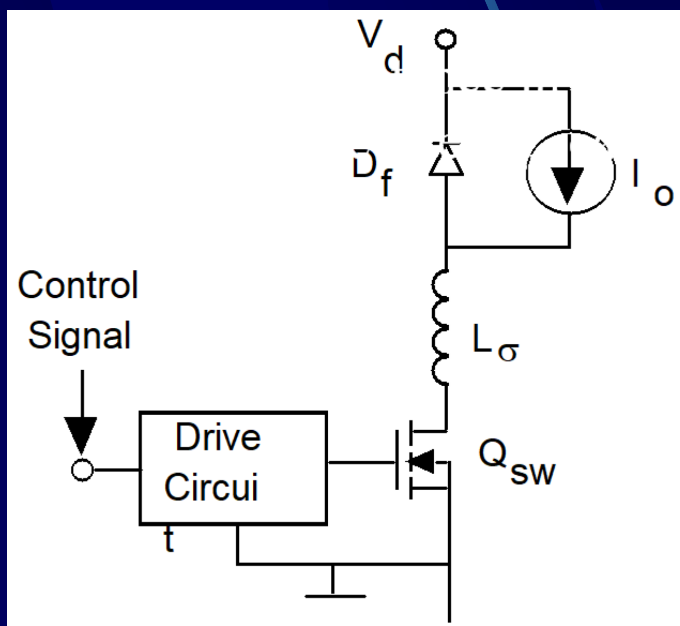
$$\mathbf{W_{dynamic} = \int_{turn\text{-}on} i(t)\, v(t)\, dt + \int_{turn\text{-}off} i(t)\, v(t)\, dt}$$

$$\mathbf{P_{dynamic}} = f\, \mathbf{W_{dynamic}}$$

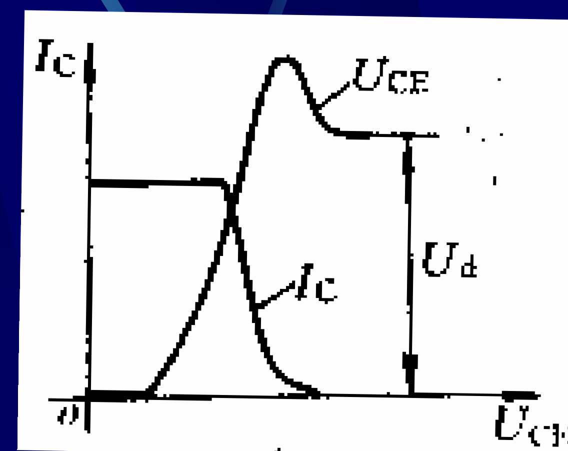
--- significant at high-frequency operation

Problem 2: Surge Voltage at Turn-off

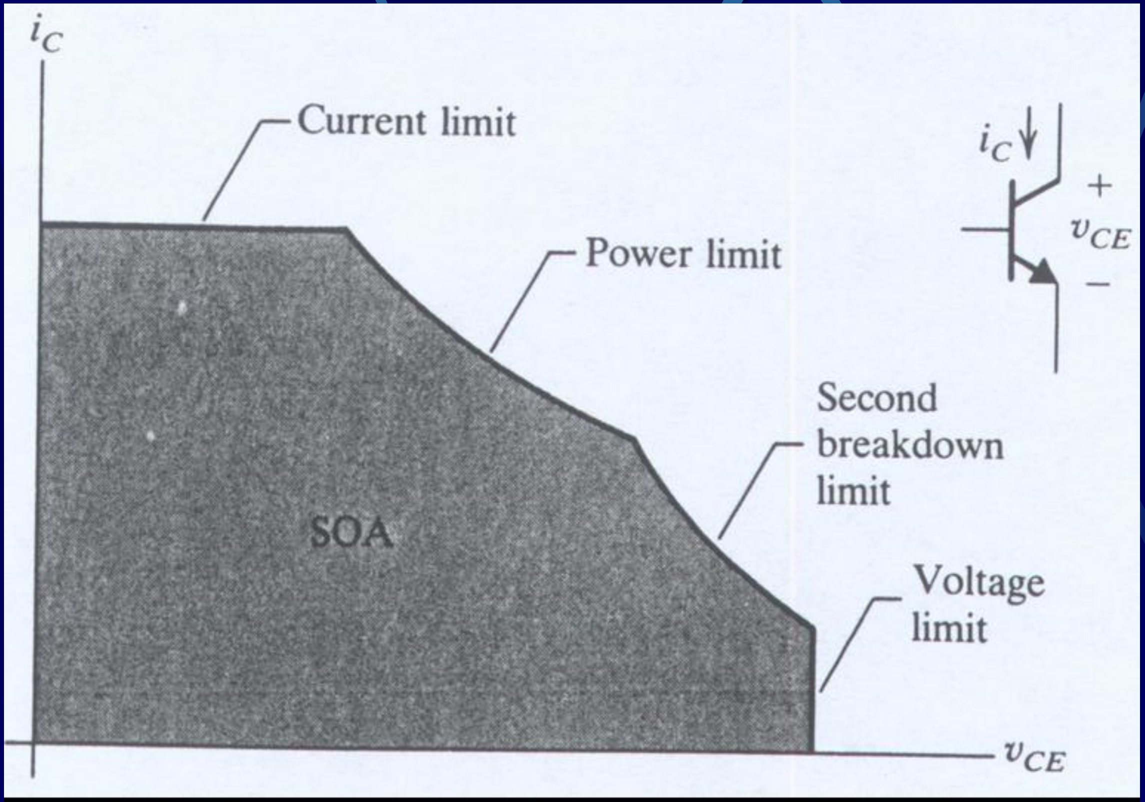
Stray inductance in series with high-voltage side of power device Q_{sw} causes overvoltage at turn-off.



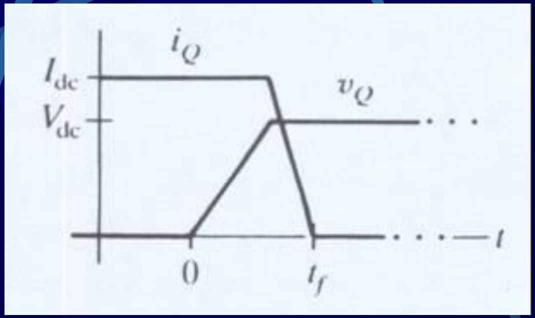
L_σ -- Stray inductance

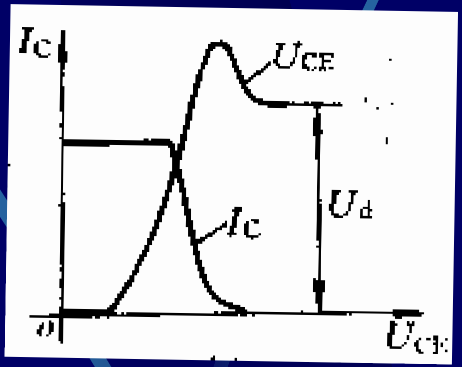


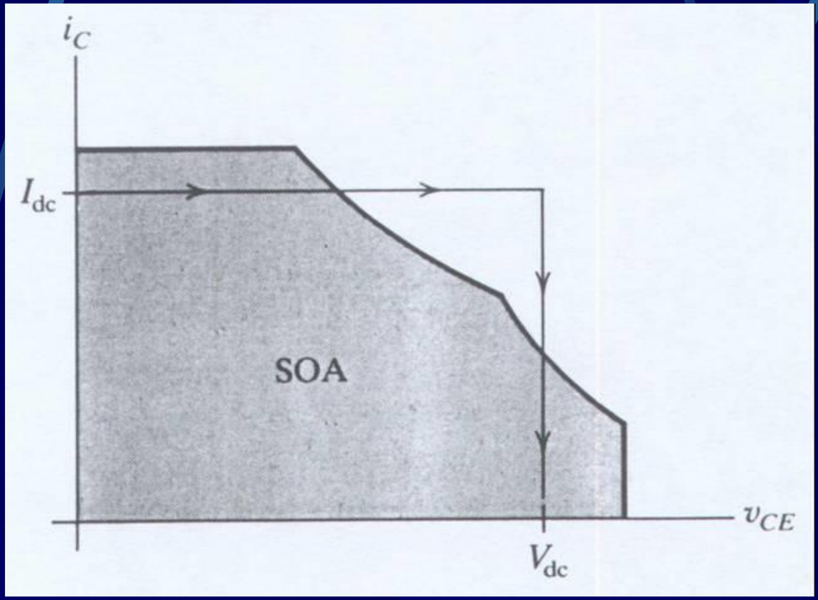
Safe Operating Area

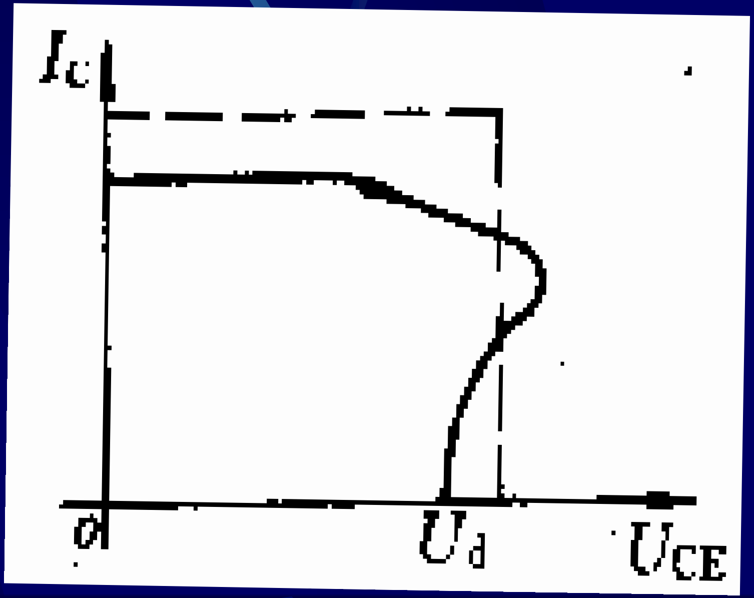


Switching Locus of the Turn-off Transition





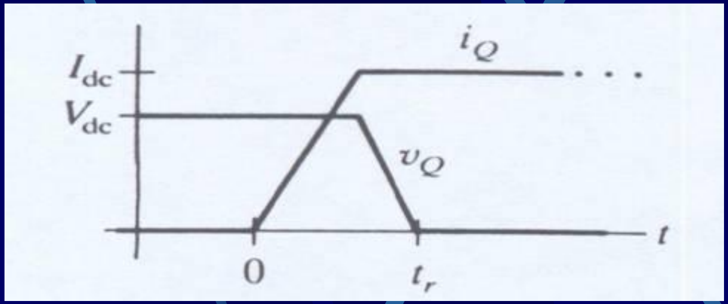


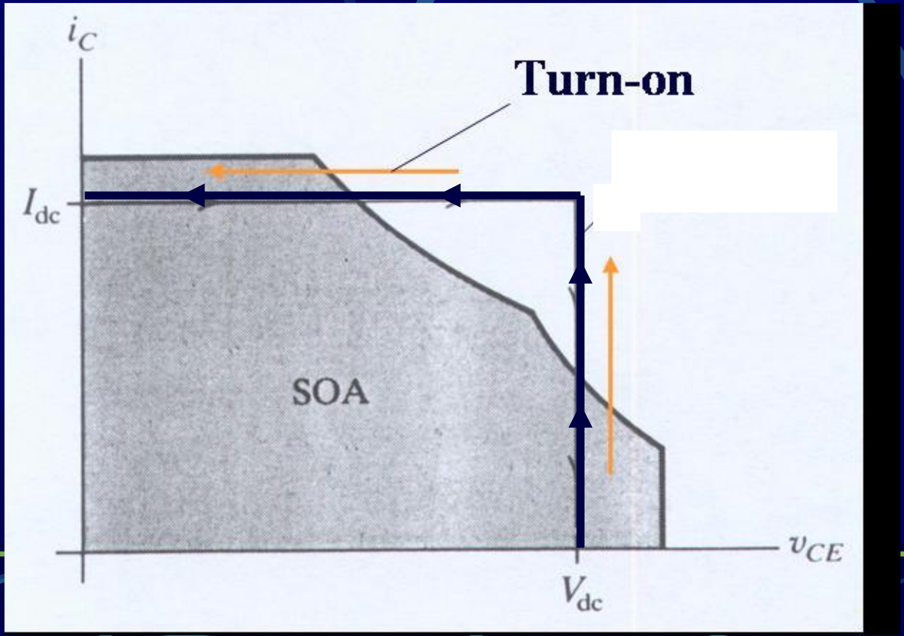


Without stray inductance

With stray inductance

Switching Locus of the Turn-on Transition





Snubber Circuits

to control, or limit,
the transient voltage and current of a power device
when it makes turn-off and turn-on commutations

keeping the voltage and current
within the safe operating area

Two kinds of snubber circuits:

- **turn-off snubber**

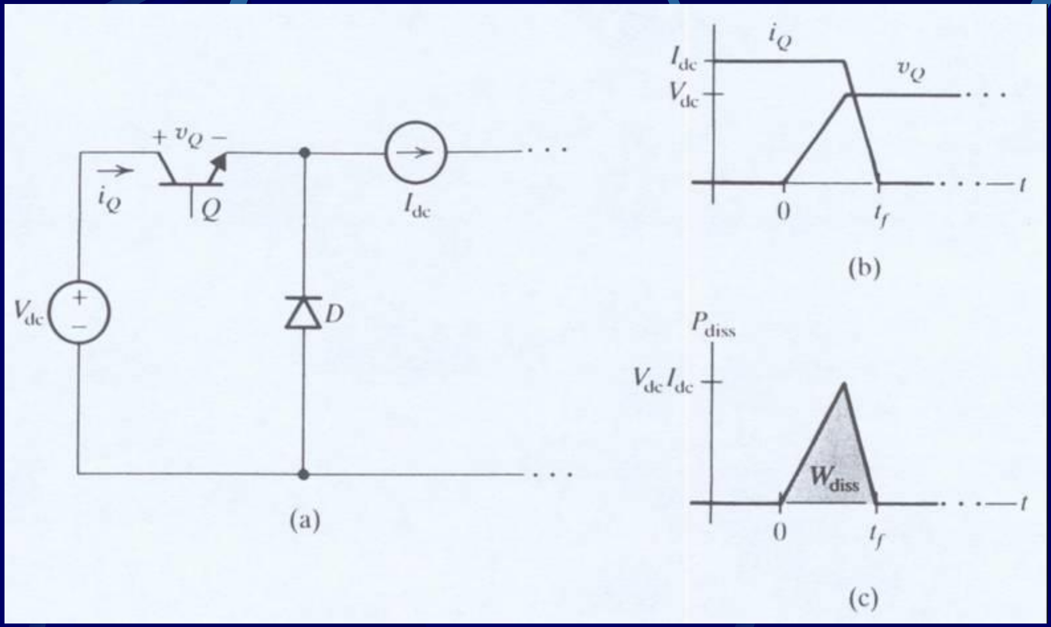
to control the turn-off by small capacitors

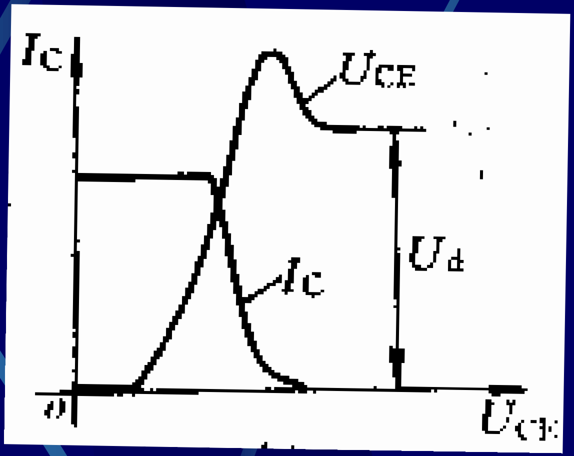
- **turn-on snubber**

to control the turn-on by small inductors

6-1 The Turn-off Snubber

Turn-off Dissipation



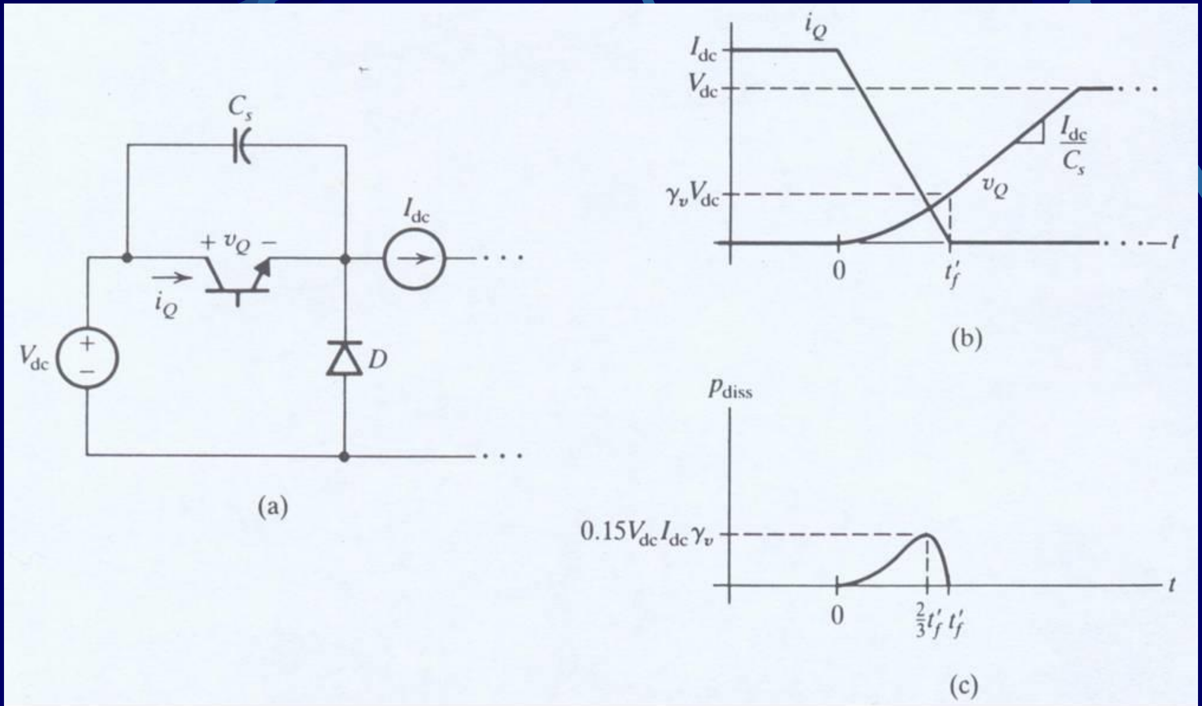


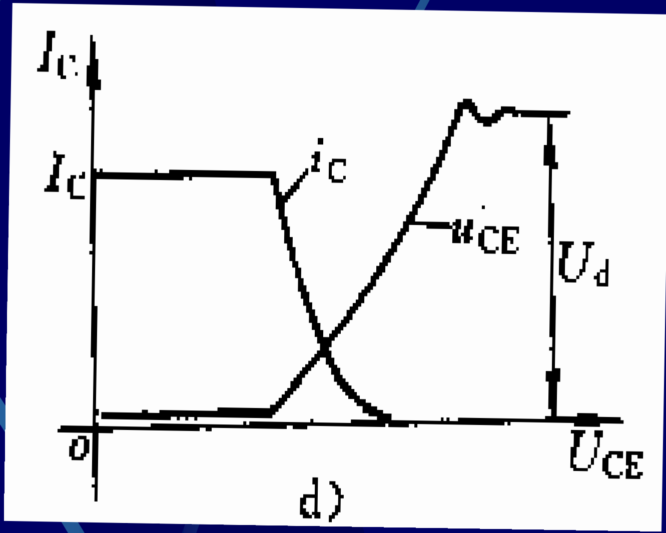
With stray inductance

$$W_{diss} = \int_0^{t_f} v_Q i_Q dt$$

If the switching frequency were f Hz, fW_{diss} would be dissipated in the transistor.

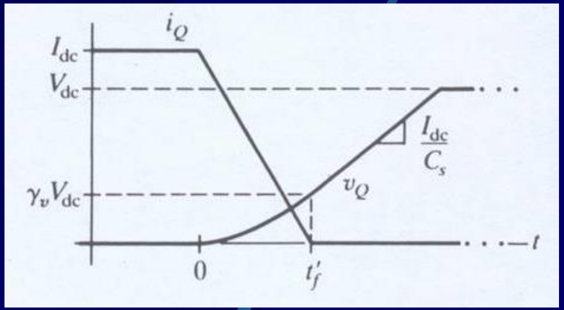
A Basic Turn-off Snubber

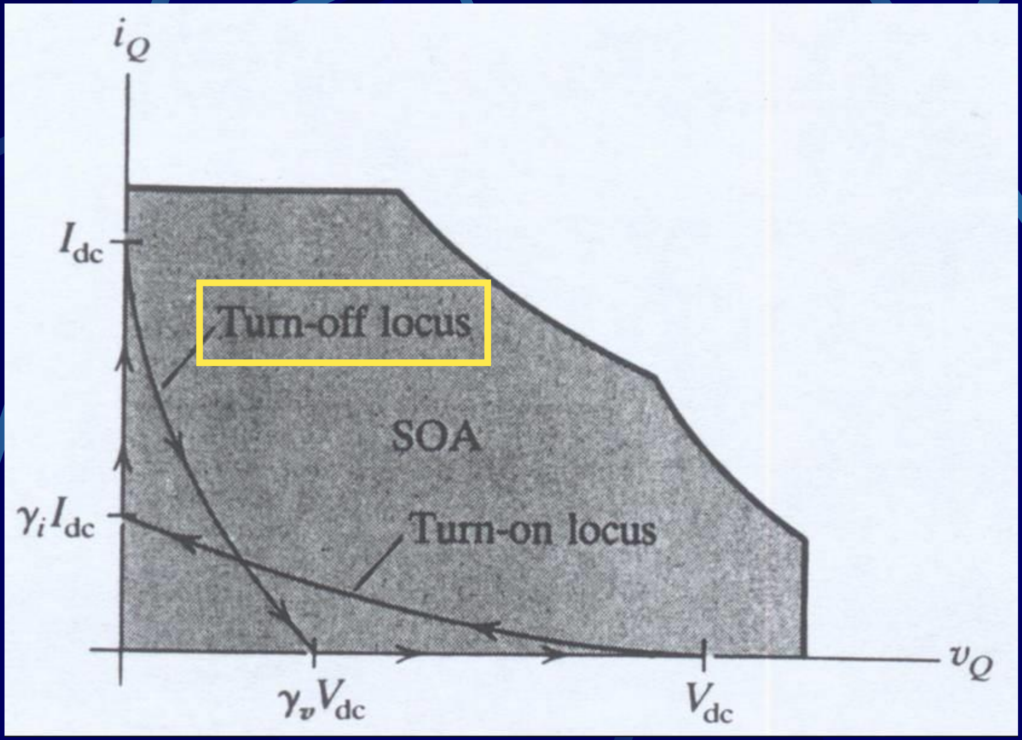




With stray inductance

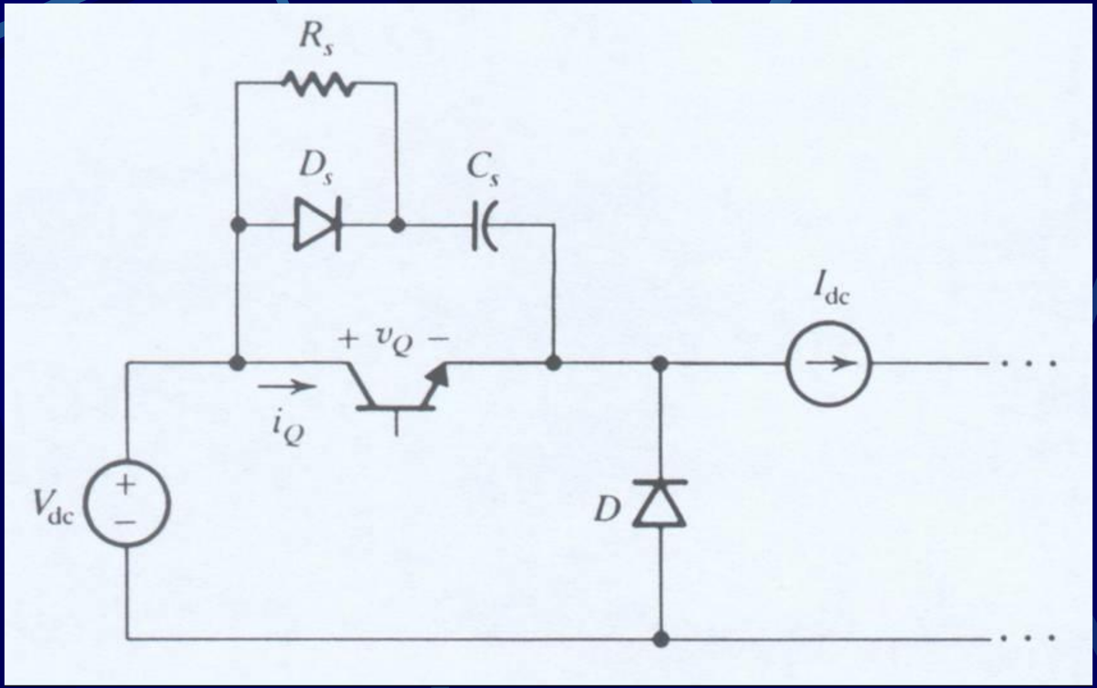
C_S -- to limit the rise rate of the voltage during the turn-off transition.





The tunn-on and turn-off switching loci of the transistor when a basic snubber circuit added.

A More Practical Snubber

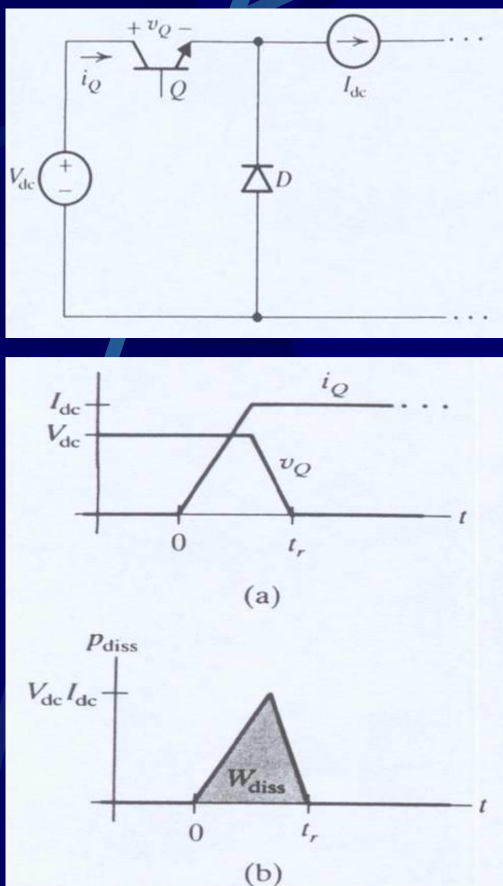


R_S -- to limit the discharge current when the BJT is turned on.

D_S -- to allow the charging current to bypass R_S during turn-off.

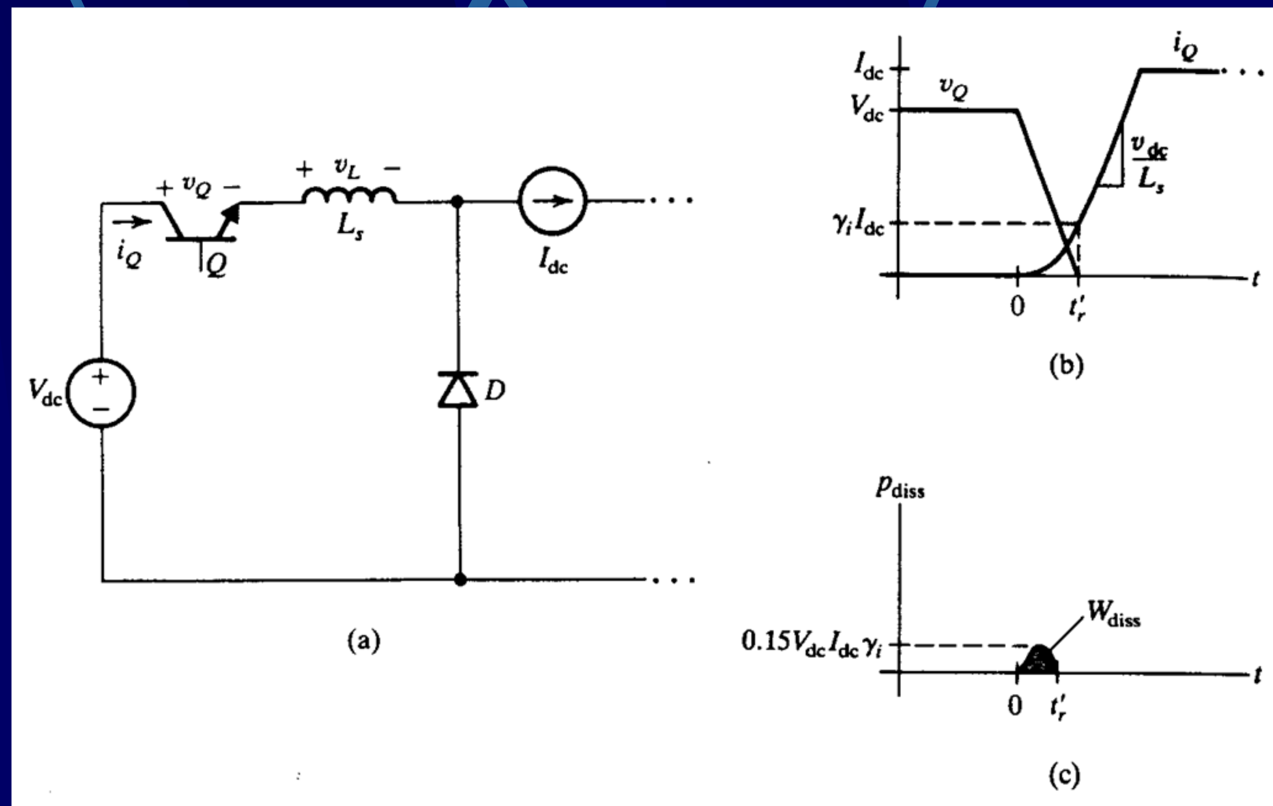
6-2 The Turn-on Snubber

Turn-on Dissipation

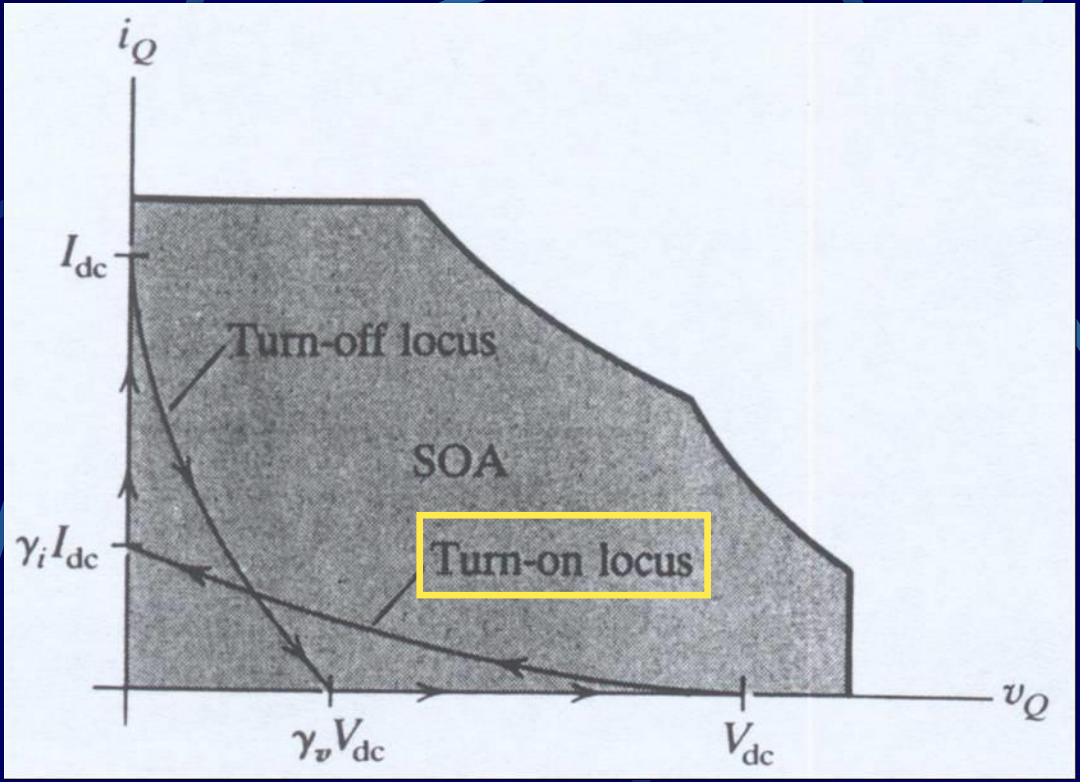


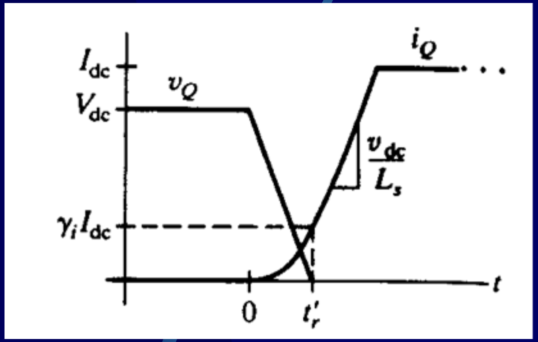
Without snubber

A Basic Turn-on Snubber



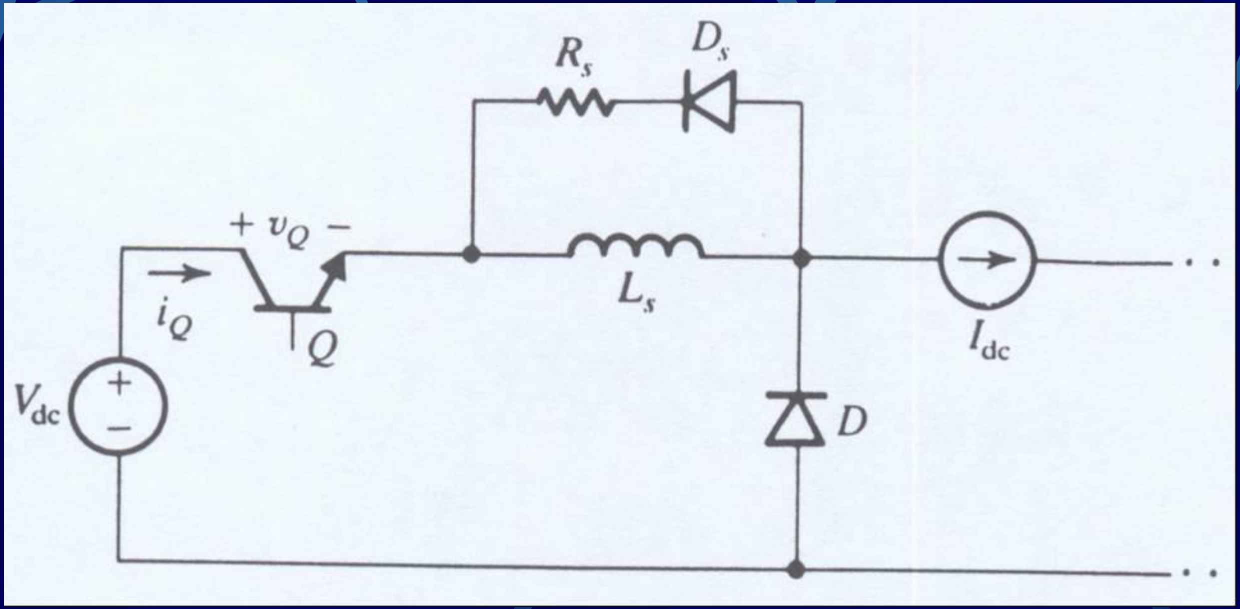
L_S -- to limit the rise rate of the current during the turn-on transition.





The turn-on and turn-off switching loci of the transistor when a basic snubber circuit added.

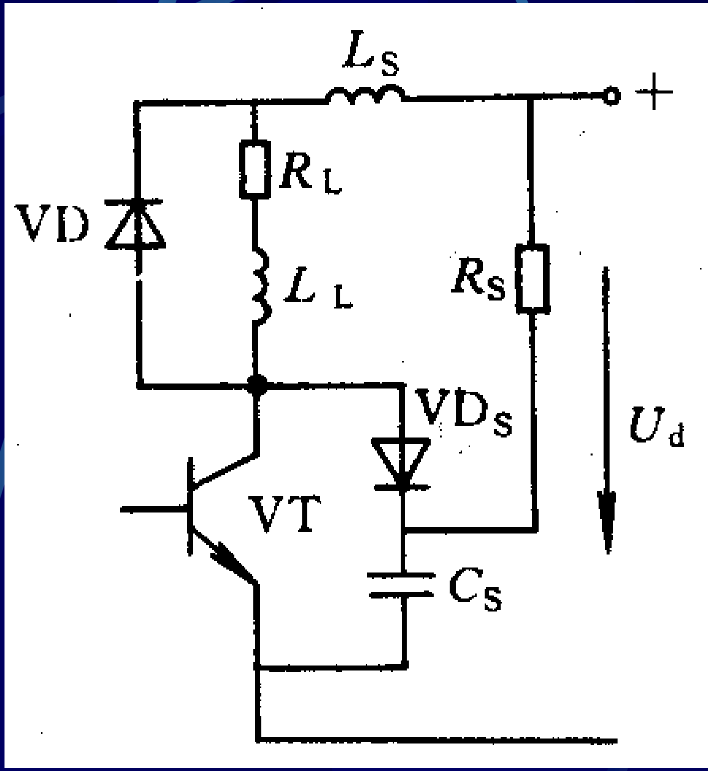
A More Practical Snubber



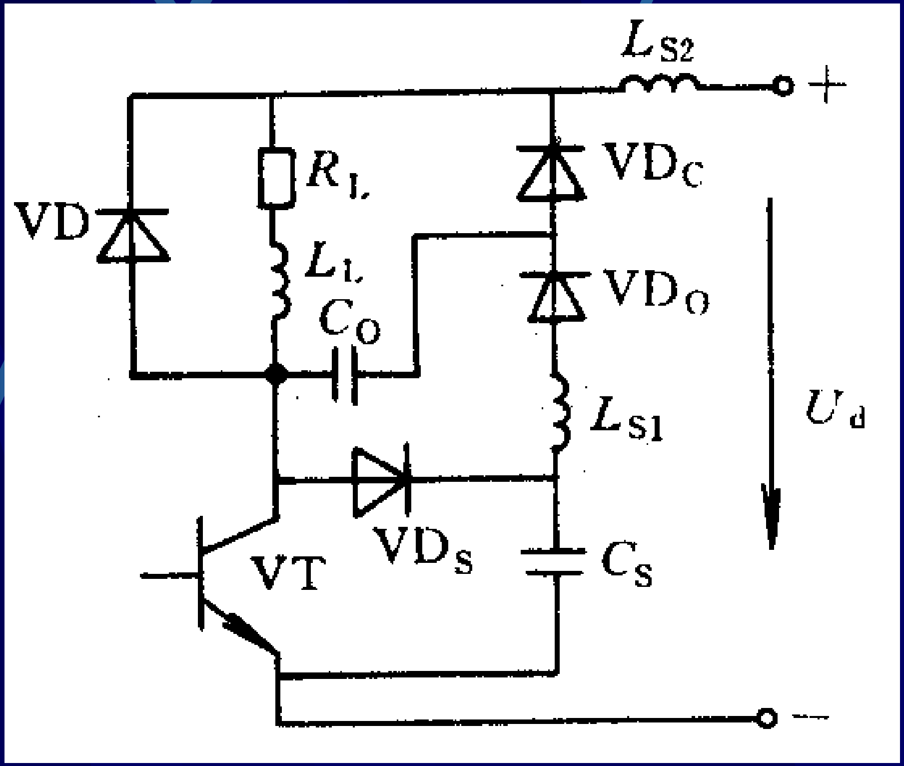
R_S – to provide an alternative path for L_S current when turn-off.

D_S -- to keep R_S from conducting during turn-on.

6-3 Energy Recovery Snubbers

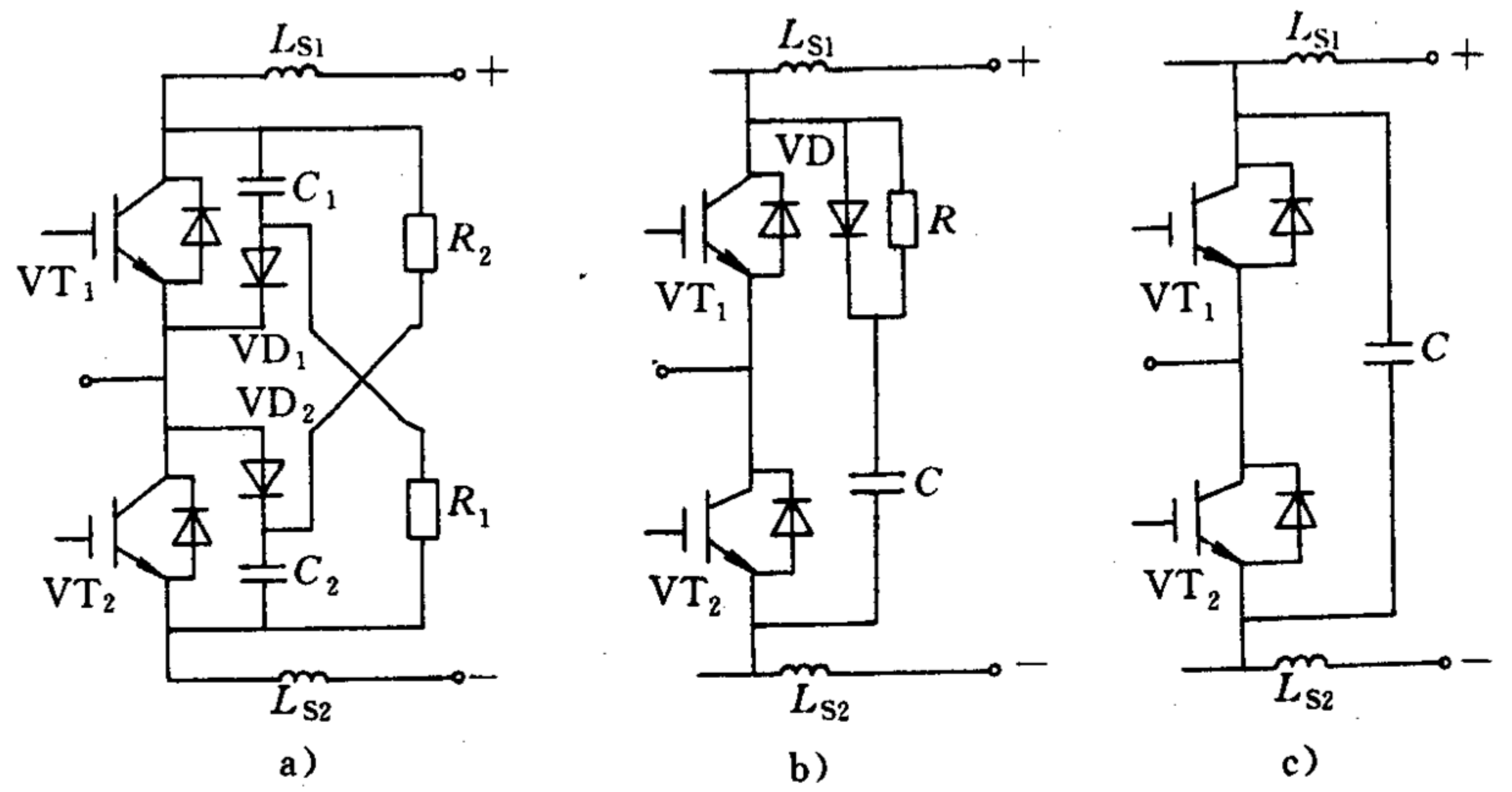


An clamp turn-off.



An energy recovery turn-off.

6-4 Snubbers in Bridge Inverters



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