SCR & Triac Snubbing

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Purdue University

ECET 257

Power & RF Electronics
Overview

- High side vs low side switch
- Critical Rate of Rise of Current
  - problem
  - SCR schematic solution
- Critical Rate of Rise of Voltage
- Triac
Low Side Switch

Switch closed

\[ V_{\text{across } R_{\text{load}}} = 120V \]

Switch opened

\[ V_{\text{across } R_{\text{load}}} = 0V \]
\[ V_{\text{on bottom of load}} = 120V ! \]
even though load is off
High Side Switch

Switch closed
\[ V_{\text{across Rload}} = 120V \]

Switch opened
\[ V_{\text{across Rload}} = 0V \]
\[ V_{\text{on load}} = 0V \]

Do it this way!
Overview

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Critical Rate of Rise of Current

\[ \frac{di}{dt} \]

I \rightarrow T \rightarrow R \text{ down} \\
\rightarrow I \text{ up} \rightarrow T \text{ up} \\
\rightarrow R \text{ down} \rightarrow I \text{ up} \\
burns out a channel
Critical Rate of Rise of Current - \textbf{Fix}

Inductors oppose $\Delta I$
Critical Rate of Rise of Current - Fix

Inductors oppose $\Delta I$

$$v_L = L \frac{di}{dt}$$
Inductors oppose $\Delta I$

$$v_L = L \frac{di}{dt}$$

$$L = \frac{V_{\text{line peak}}}{\frac{di}{dt} \text{ SCR spec}}$$
Inductors oppose $\Delta I$

$v_L = L \frac{di}{dt}$

$L = \frac{V_{line \ peak}}{\frac{di}{dt} SCR\ spec}$

If load is motor, separate $L$ not needed.
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Critical Rate of Rise of Voltage

Parasitic $C_{anode - gate}$

noise on anode coupled to gate

+ noise => + $v_{gate}$ =>

SCR ON

crane fatality
Critical Rate of Rise of Voltage - fix

Capacitors oppose $\Delta v$
Capacitors oppose $\Delta v$

Ignoring $L$, given a step at $V_{\text{anode}}$

$$v_c = V_P \left(1 - e^{-\frac{t}{RC}}\right)$$
Critical Rate of Rise of Voltage - fix

Capacitors oppose $\Delta v$

Ignoring $L$, given a step at $V_{\text{anode}}$

$$v_c = V_P \left(1 - e^{-\frac{t}{RC}}\right)$$

$$\frac{dv_c}{dt} = \frac{V_P}{RC} e^{-\frac{t}{RC}}$$
Capacitors oppose $\Delta v$

Ignoring $L$, given a step at $V_{\text{anode}}$

$$v_c = V_P \left( 1 - e^{-\frac{t}{RC}} \right)$$

$$\frac{dv_c}{dt} = \frac{V_P}{RC} e^{-\frac{t}{RC}}$$

$$\left. \frac{dv_c}{dt} \right|_{\text{worst}} = \left. \frac{V_P}{RC} \right|_{t=0}$$
Critical Rate of Rise of Voltage - fix

\[ \frac{dv_c}{dt} \bigg|_{\text{worst}} = \frac{V_P}{RC} \bigg|_{t=0} \]

\[ C = \frac{V_{DRM}}{R_{load} \times \frac{dv}{dt} \text{ SCRspec}} \]
Cap Discharge

During charge, $V_C$ may $= V_{\text{line pk}}$

When SCR fired

$R_{\text{SCR}}$ 0.x $\Omega$

C rapidly discharges through SCR

$I_{\text{C discharge}} \sim V_{\text{line pk}} / R_{\text{SCR on}}$

$= 160V / 0.2\Omega = 320A$

$I_{\text{SCR}} = I_{\text{load}} + I_{\text{C discharge}}$

$R_S$ limits $I_{\text{SCR}} < I_{\text{TSM}}$

$R_S > \frac{V_{\text{line pk}}}{I_{\text{TSM}} - I_{\text{load pk}}} \approx \frac{10V_{\text{line pk}}}{I_{\text{TSM}} - I_{\text{load pk}}}$
Rs bypass during charge

C must be directly across SCR during charge to short out spikes

R limits I during discharge

Bypass R with diode

\[ I_{\text{diode pk}} = \frac{V_{\text{DRM}}}{X_C} \]
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Triac
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Use if $R_S \ll R_{load}$

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Use if $R_s << R_{load}$

Otherwise use two snubbers.