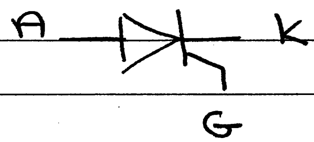
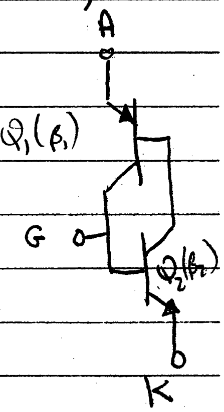
Power Electronics Notes - D. Perreault

★★ Phase-Controlled Converters
(Read: KSV Ch 5)

Thyristor Devices: SCR (Silicon Controlled Rectifier)





"Transistor" View of 4-layer SCR

SCR: Acts like a diode where you can select when conduction will start, but not when it stops.

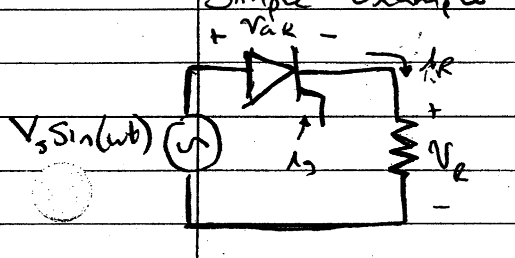
1. Stays off until a gate pulse is applied while $V_{AK} > 0$

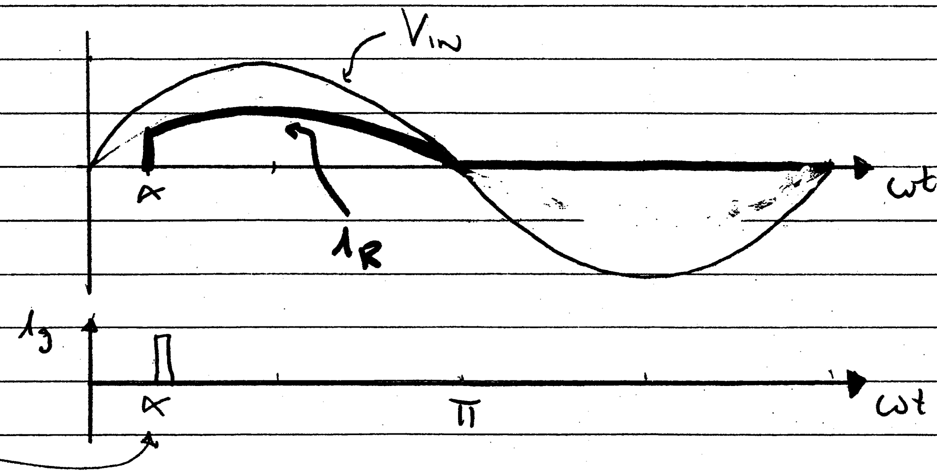
2. Once on, behaves like a diode & does not turn off until $i \rightarrow 0$

3. To Stay off (after $V_{AK} > 0$ again) must have i stay at 0 for a short time t_q (10-100 μs)

So the device is semicontrolled: we control the turn on point, but only turns off when circuit conditions force it to.

Simple Example:





Phase of thyristor turn on (wrt line voltage) is termed firing angle α

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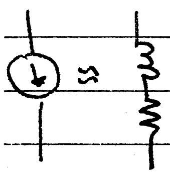
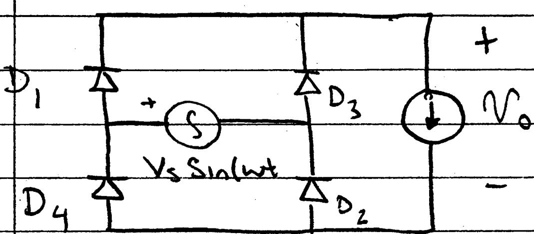
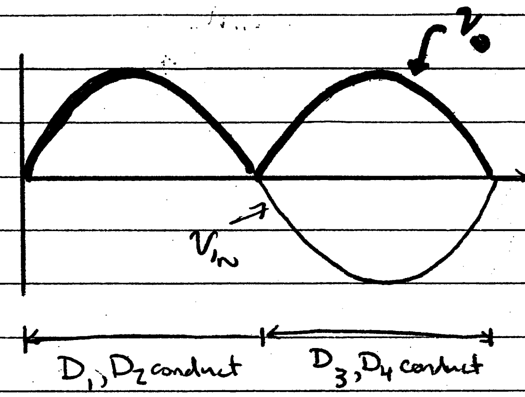
Consider a full-bridge converter (inductive/current load)

Diode Version



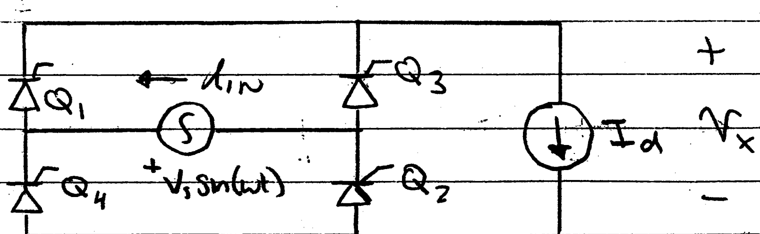


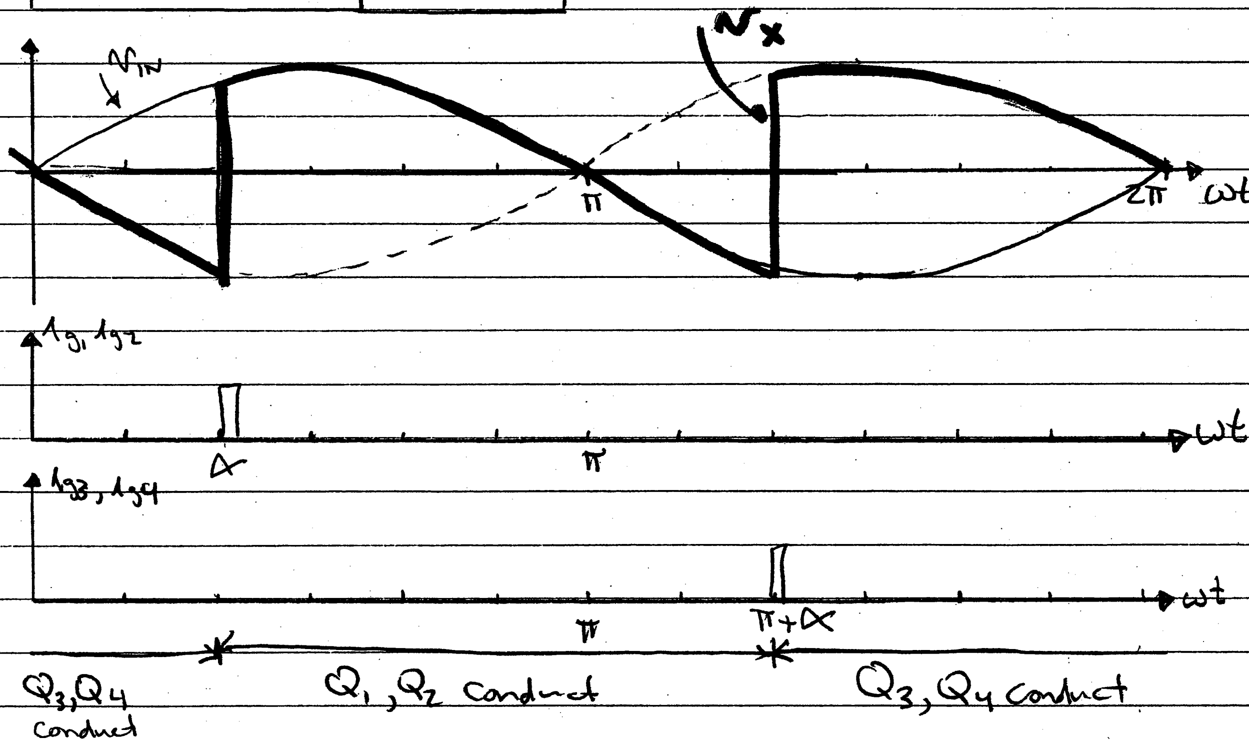


$$\langle V_o \rangle = \frac{1}{\pi}\int_0^{\pi} V_s \sin\varphi \, d\varphi = \frac{2V_s}{\pi}$$

Consider Thyristor (phase-controlled) Version

→ firing angle α





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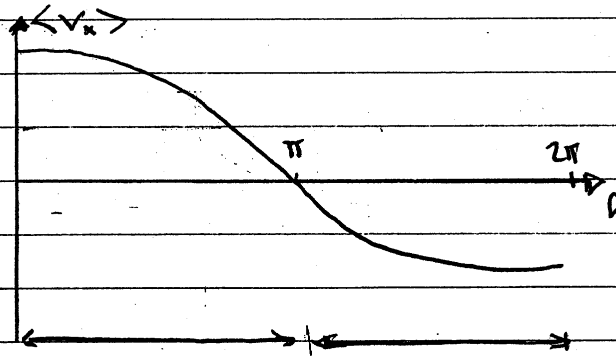
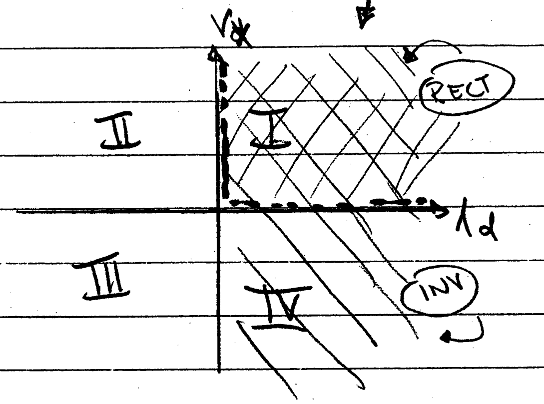
Lets analyze the output voltage $\langle V_x \rangle$

$$\langle V_x \rangle = \frac{1}{\pi}\int_{\alpha}^{\pi+\alpha} V_s \sin(\varphi)\,d\varphi = \frac{2V_s}{\pi}\cos\alpha$$



Rectification $\langle V_x \rangle > 0$ Power flows AC → DC

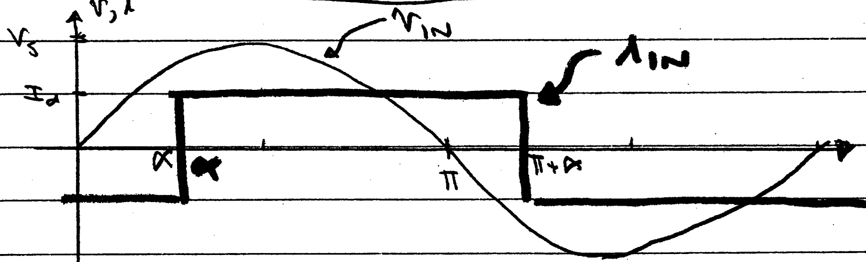
Inversion $\langle V_x \rangle < 0$ Power flows DC → AC



QUADRANTS OF OPERATION IN (V, I)

So with a phase controlled converter, we can regulate the output voltage by varying firing angle α. We can even cause power flow from dc-side to ac-side as long as $I_d > 0$ (e.g. pull power out of inductor + put into line.)

Consider the power factor of a phase-controlled converter



$$K_p = K_d K_\theta = \left(\frac{I_{1,rms}}{I_{rms}}\right)\cos(\Phi_1) = \frac{4}{\pi\sqrt{2}}\cos\alpha \simeq .9\cos\alpha$$

K_d $\quad$ K_θ

$I_{1,rms}$ for square wave is $\frac{4}{\pi\sqrt{2}} I_d$

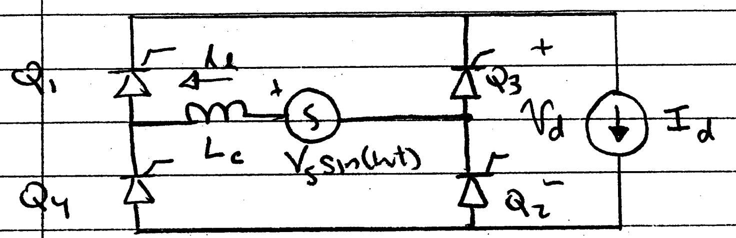
I_{rms} is I_d

phase shift of fundamental of square wave "in phase" w/ square wave

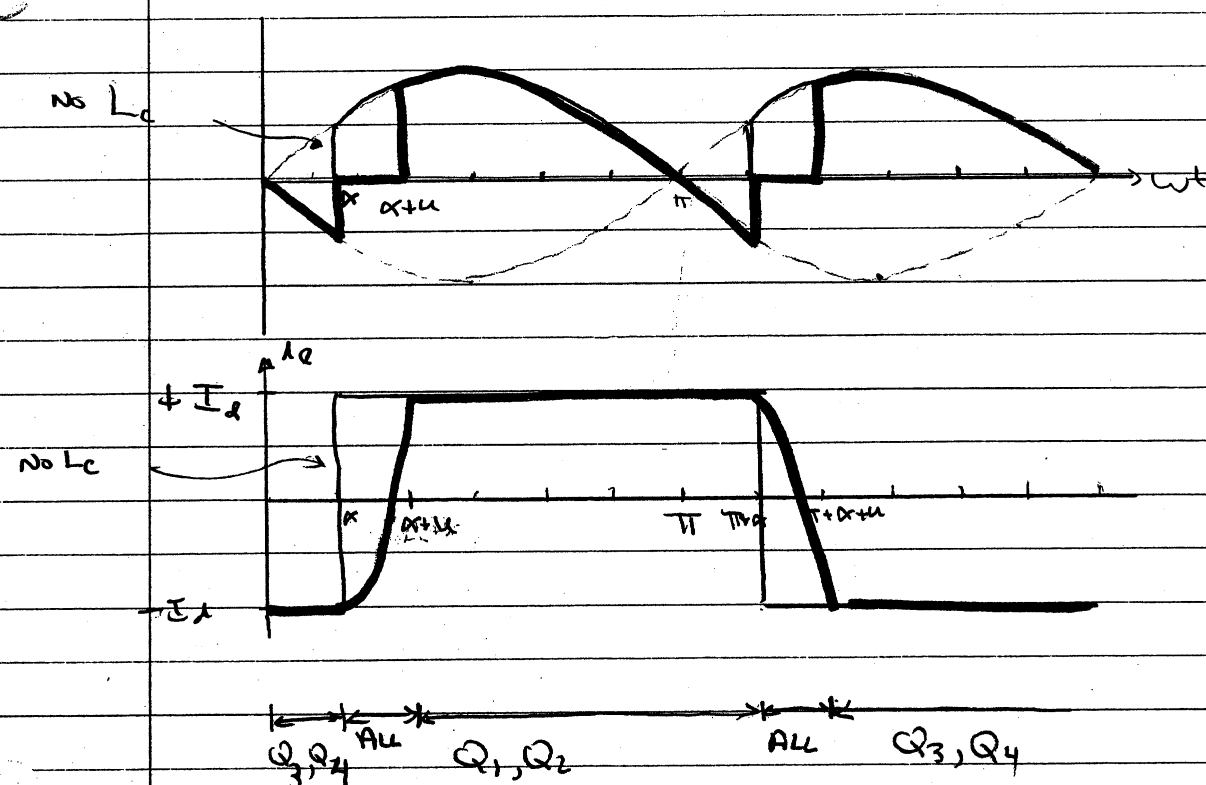
$\therefore \Phi_1 = \alpha$

So the power factor of a phase-controlled converter varies with firing angle α.

Consider the effects of ac-side reactance



Similar to the diode rectifier case, a commutation period exists during which all devices are on while current in L_c switches between $+I_d$ and $-I_d$ (between Q_1/Q_2 and Q_3/Q_4)



A similar analysis to the diode case shows that for the full-bridge thyristor converter

$$\langle V_x \rangle = \frac{2V_s}{\pi}\left[\cos\alpha - \frac{X_c I_d}{V_s}\right]$$

Note that the need to commutate devices places a limit on how negative the output voltage can be made as a function of $\frac{X_c I_d}{V_s}$ and α. This is analyzed in KSV Ch 5.

(Require $\alpha + u < \pi$)

Summary