Power Electronics Notes - D. Perreault

$$V_{eq} = \sum_{n=0}^{\infty} B_n \cos(n\omega t + \phi_n)$$

$$\text{If } H(\omega) = \frac{V_o(\omega)}{V_x(\omega)} \Rightarrow V_o = \sum_n |H(n\omega)| \cos(n\omega t + \phi_n + \measuredangle H(n\omega))$$

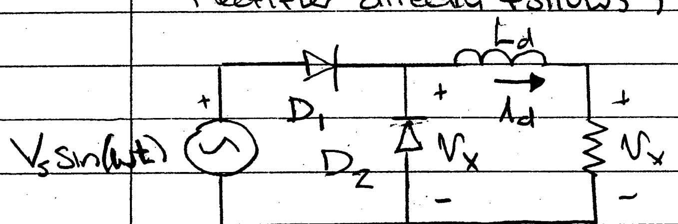
* Main point: we can replace difficult to handle part of circuit with an equivalent voltage source, then use linear circuit theory to analyze from there.

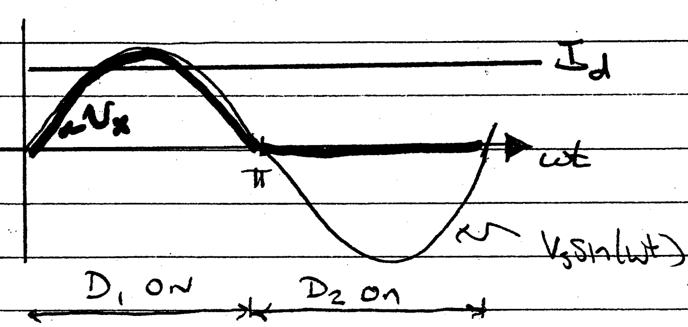
SUMMARY OF ANALYSIS TECHNIQUES
- → Method of assumed states
- → Periodic Steady State
- → Equivalent Source Replacement

★★ Introduction To Rectifier Circuits

Reading: KSV Chapter 3

START w/ simple half-wave rectifier (full-bridge rectifier directly follows)





in PSS

$$\langle V_o \rangle = \langle V_x \rangle = \frac{V_s}{\pi}$$

$$\text{If } L_d \text{ big} \rightarrow i_d \simeq I_d = \frac{V_s}{\pi R}$$

$$\text{If } L_d/R \gg \frac{2\pi}{\omega} \Rightarrow$$ we can approximate load ckt as a constant current

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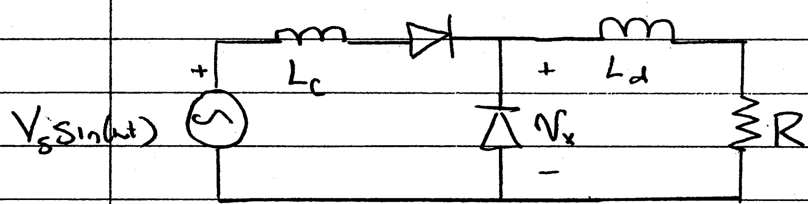
★ Load Regulation

Now Consider adding some ac-side inductance L_c (reactance $X_c \triangleq \omega L_c$)

→ Common situation. Transformer leakage or line inductance, machine winding inductance, etc.

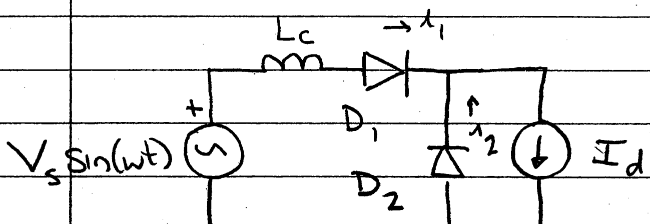
→ L_c is typ. $\ll L_d$ (filter inductance) as it is a parasitic element.



Assume $L_d \sim \infty$ (so ripple current is small)

∴ We can approximate load as a "special" current source

→ "special" since $\langle V_L \rangle = 0$ in P.S.S. ∴ $I_d = \langle V_x / R \rangle$



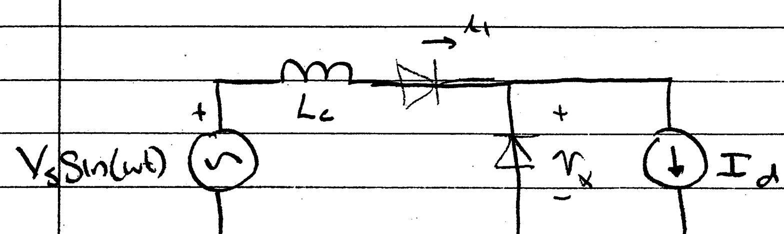
Assume we start with D_2 conducting, D_1 off ($V_s \sin(\omega t) < 0$)

What happens when $V \sin(\omega t)$ crosses zero?

→ D_1 off no longer valid

→ but just after turn on i_1 still $= 0$

∴ D_1, D_2 both on during a <u>commutation period</u> where current switches from D_2 to D_1



D_2 will stay on as long as $i_2 > 0$ ($i_1 < I_d$)

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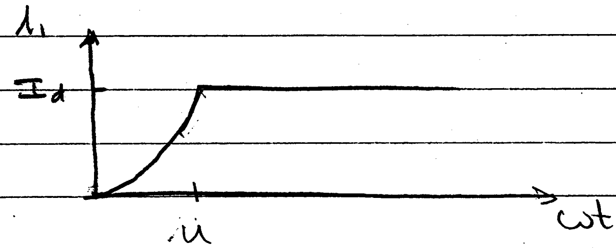
Analyze:
$$\frac{d\lambda_1}{dt} = \frac{1}{L_c} V_s \sin(\omega t)$$

$$\lambda_1(t) = \int_0^{\omega t} \frac{V_s}{\omega L_c} \sin(\omega t)\, d(\omega t)$$

$$= \frac{V_s}{\omega L_c} \cos(\varphi) \Big|_{\omega t}^{0}$$

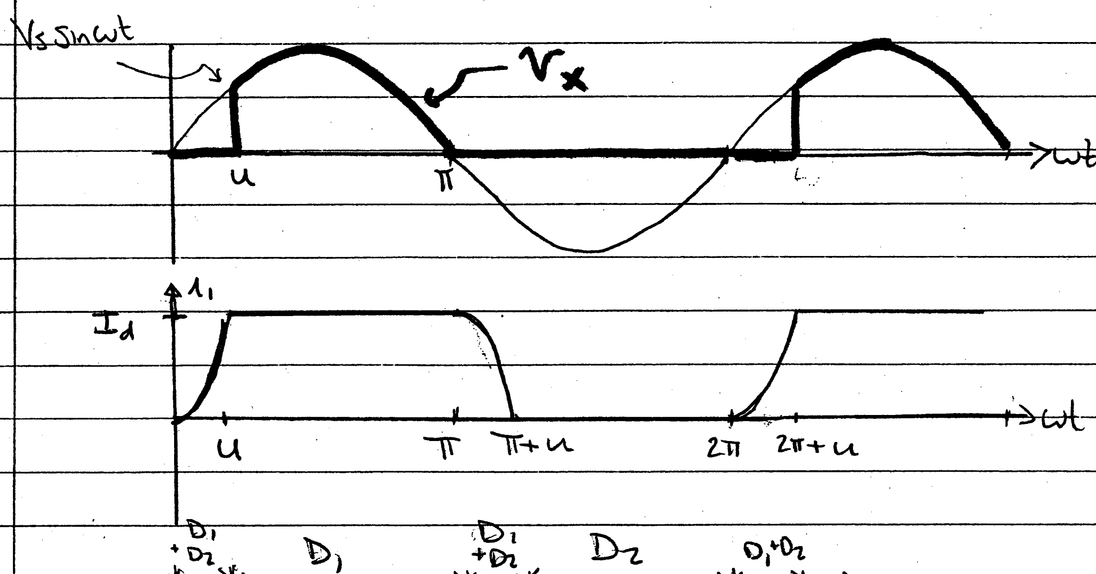
$$= \frac{V_s}{\omega L_c} \left[1 - \cos(\omega t)\right]$$



commutation ends at $\omega t = u$ when $\lambda_1 = I_d$

$$I_d = \frac{V_s}{\omega L_c}\left[1 - \cos u\right]$$

$$\Rightarrow \boxed{\cos u = 1 - \frac{\omega L_c I_d}{V_s}}$$ ☆ Commutation period.



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As compared to the case of no commutating inductance, we lose a piece of output voltage during commutation. We can calculate the average output voltage in P.S.S. from $\langle V_x \rangle$

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

$$= \frac{V_s}{2\pi}\left[\cos(u) + 1\right]$$

from before $\cos u = 1 - \frac{\omega L_c I_d}{V_s} = 1 - \frac{X_c I_d}{V_s}$

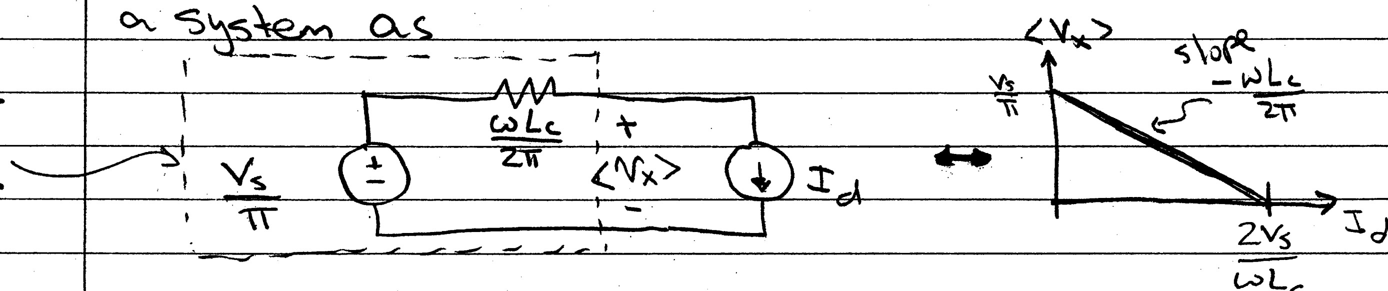
$$\boxed{\langle V_x \rangle = \frac{V_s}{\pi}\left[1 - \frac{\omega L_c I_d}{V_s}\right]}$$

So average output voltage drops with

1. Increased current
2. Increased frequency
3. decreased source voltage

we get the "Ideal" no L_c case at no load.

We can make a dc-side thevenin model for such a system as



No actual dissipation in box "resistance" appears because output voltage drops when current increases

★ This LOAD REGULATION is a major consideration in most rectifier systems.

→ voltage changes w/ load
→ max output power limitation

} All due to nonzero commutation time because of ac-side reactance.

⇒ This effect occurs in most rectifier types (full-wave, multi-phase, thyristor, etc.)