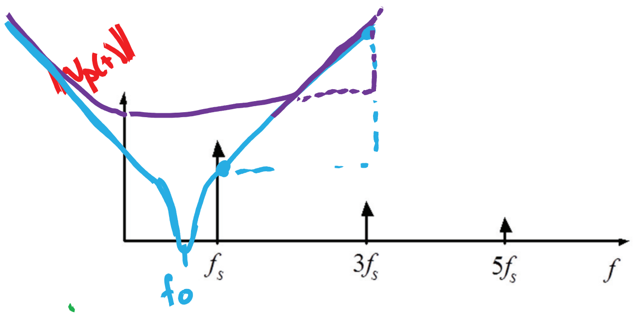
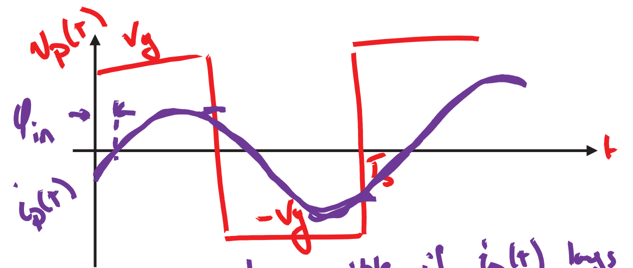
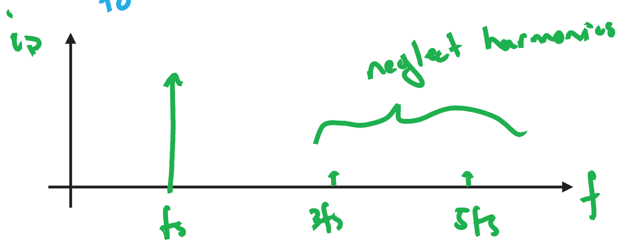
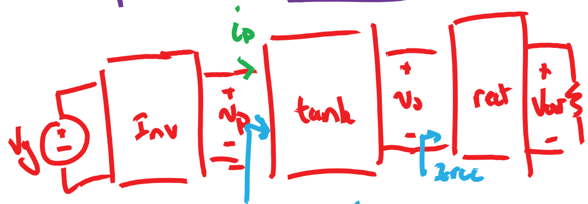
Sinusoidal Analysis (Ch 19)





ZVS may be possible if $i_p(t)$ lags $v_p(t)$ → inductive loading of inverter





$z_{eq} = sL + \frac{1}{sC} + Z_{rec}$

- if tank has good bandpass characteristics @ f_s
  - Can approximate all ac waveforms as single frequency

Sinusoidal Analysis: Comments

- Generally most accurate when operating near resonance with a high Q
- Effective quality factor Q_e depends not only on resonant tank, but also on loading
- Analysis neglects switching intervals; can only predict where ZVS **cannot** be obtained

exact → state plane analysis
approx → sinusoidal approx

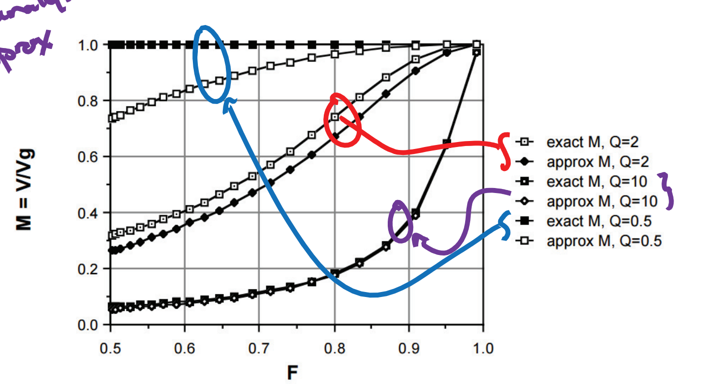
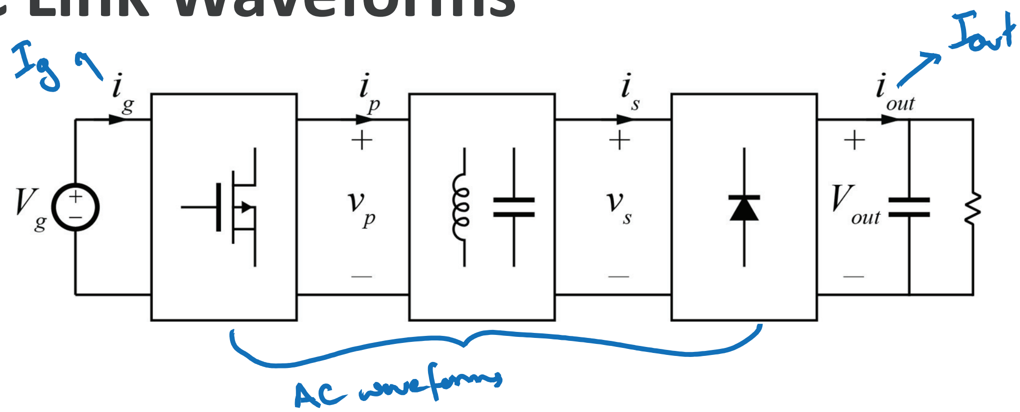


Fig. 2.14. Comparison of exact and approximate series resonant converter characteristics, below resonance. → diode rectifier full bridge

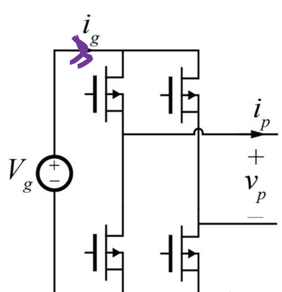
AC Link Waveforms



$v_p(t)$ = real signal

$v_{p1}(t)$ = sinusoidal approximation @ f_s

Switch Network Sinusoidal Analysis



Fourier Series:

$$b_1 = \frac{1}{\pi}\int_{-\pi}^{\pi} f(x)\sin(x)\,dx$$

Apply to $v_p(t)$:

$$b_1 = \frac{2}{T_s}\int_0^{T_s} v_p(t)\sin(2\pi f_s t)\,dt$$

$$b_1 = \frac{2}{T_s}\, 2 \cdot \int_0^{T_s/2} V_g \sin(2\pi f_s t)\,dt$$

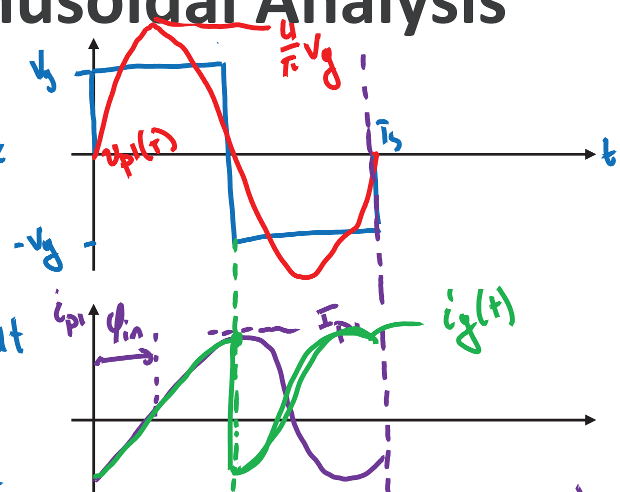
$u = 2\pi f_s t$

$du = 2\pi f_s\,dt$

$$b_1 = \frac{4}{T_s} V_g \int_0^{\pi} \sin(u)\frac{du}{2\pi f_s}$$

$$b_1 = \frac{4}{T_s} V_g \frac{1}{2\pi f_s}\left[-\cos(u)\right]_0^{\pi} = \frac{4}{\cancel{T_s}} V_g \frac{1}{\cancel{2\pi f_s}}(\cancel{2})$$

$$\boxed{b_1 = \frac{4}{\pi} V_g}$$



$i_{p1}(t) = I_{p1}\sin(2\pi f_s t - \varphi_{in})$

Input Current

$$i_{p1}(t) = I_{p1}\sin(2\pi f_s t - \varphi_{in})$$

$$\langle i_g\rangle = I_g = \frac{2}{T_s}\int_0^{T_s/2} i_{p1}(t)\,dt$$

$u = 2\pi f_s t - \varphi_{in}$

$du = 2\pi f_s\,dt$

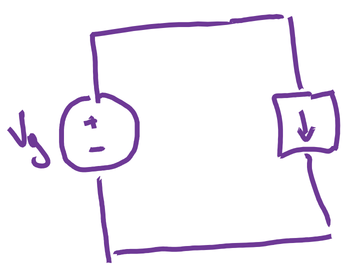
$$= \frac{2}{T_s}\int_0^{T_s/2} I_{p1}\sin(2\pi f_s t - \varphi_{in})$$

$$= \frac{2}{T_s} I_{p1}\int_{-\varphi_{in}}^{\pi-\varphi_{in}} \sin(u)\,\frac{du}{2\pi f_s}$$

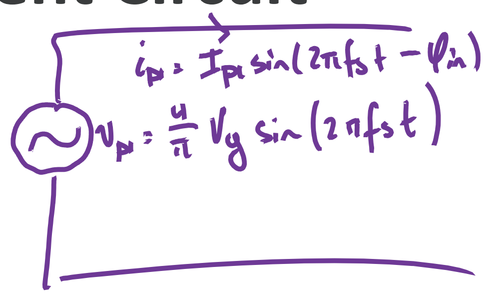
$$= \frac{2}{T_s} I_{p1}\frac{1}{2\pi f_s}\Big[-\cos(u)\Big]_{-\varphi_{in}}^{\pi-\varphi_{in}} = \frac{\cancel{2}}{\cancel{T_s}} I_{p1}\frac{1}{\cancel{2\pi f_s}}\left(\cos(\varphi_{in}) + \cos\varphi_{in}\right)$$

$$\boxed{I_g = \frac{I_{p1}}{\pi}\,2\cos\varphi_{in}}$$

Switch Network Equivalent Circuit



$I_g = \frac{2}{\pi} I_{p1}\cos\varphi_{in}$



$\omega_s = 2\pi f_s$

$$P_g = V_g I_g = \underline{V_g \frac{2}{\pi} I_{p1}\cos\varphi_{in}}\ \checkmark$$

$$P_p = v_{p1} i_{p1} = \frac{4}{\pi} V_g I_{p1}\sin(\omega_s t)\sin(\omega_s t - \varphi_{in})$$

$$\langle P_p\rangle = \frac{1}{T_s}\int_0^{T_s} P_p(t)\,dt$$

use identity

$$\sin(u)\sin(x) = \frac{1}{2}\left(\cos(u-x) - \cos(u+x)\right)$$

$$\langle P_p\rangle = \frac{4}{\pi} V_g I_{p1}\frac{1}{T_s}\frac{1}{2}\int_0^{T_s}\cos(-\varphi_{in}) - \cos(2\omega_s t - \varphi_{in})\,dt$$

$$= \frac{4}{\pi} V_g I_{p1}\frac{1}{\cancel{T_s}}\frac{1}{2}\cancel{T_s}\cos(\varphi_{in}) = \underline{\frac{2}{\pi} V_g I_{p1}\cos\varphi_{in}}\ \checkmark$$