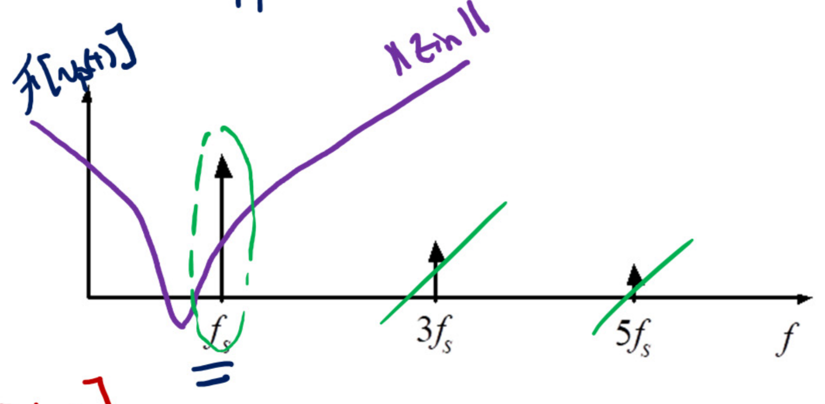
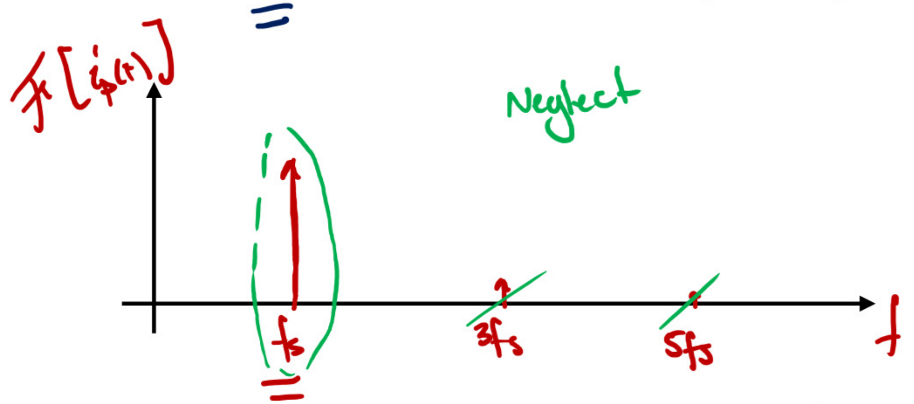
Sinusoidal Analysis (Ch 19)

→ 2nd Edition of Fund. of Power Elec
Chapter 22 in 3rd Edition

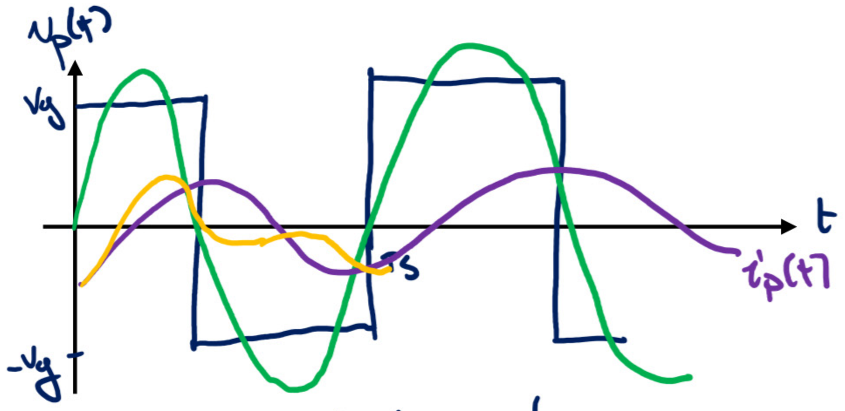
Fundamental Harmonic Approximation





Based on bandpass tank, fundamental even more dominant

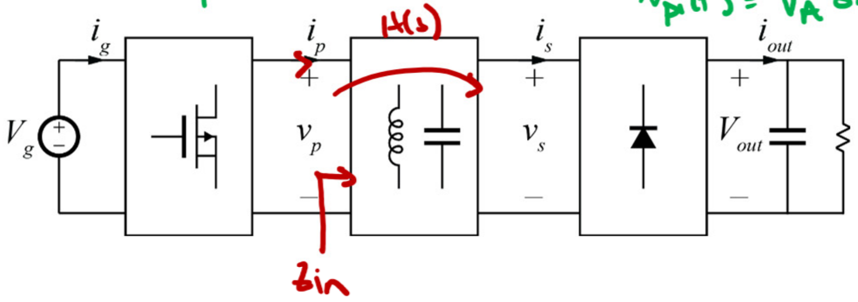
Things like ZVS cannot be accurately assessed in FHA



$v_p(t)$ → actual waveform

$v_{p1}(t)$ → fundamental harmonic

$v_{p1}(t) = V_A \sin(\omega_s t + \varphi)$



for many ac-link converters, H(s) has a bandpass characteristic

for size

equivalent of diode rectifier through XF

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

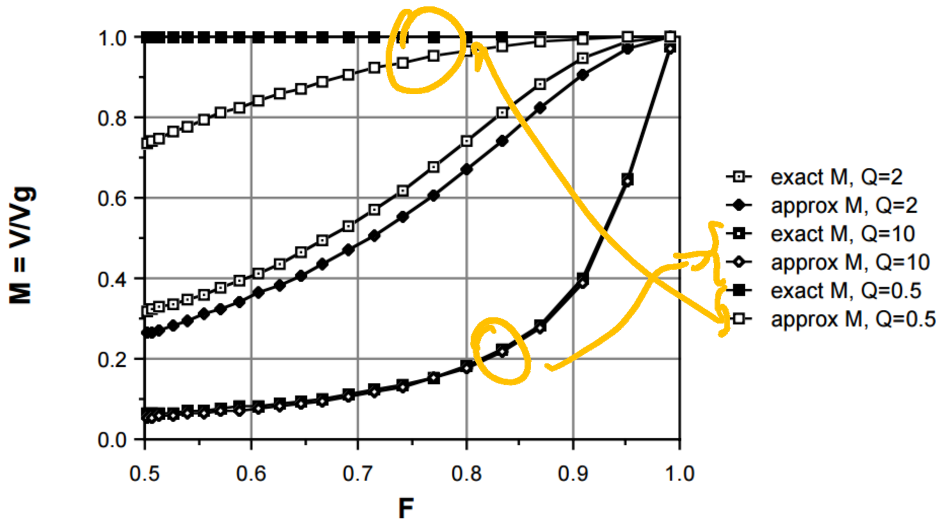
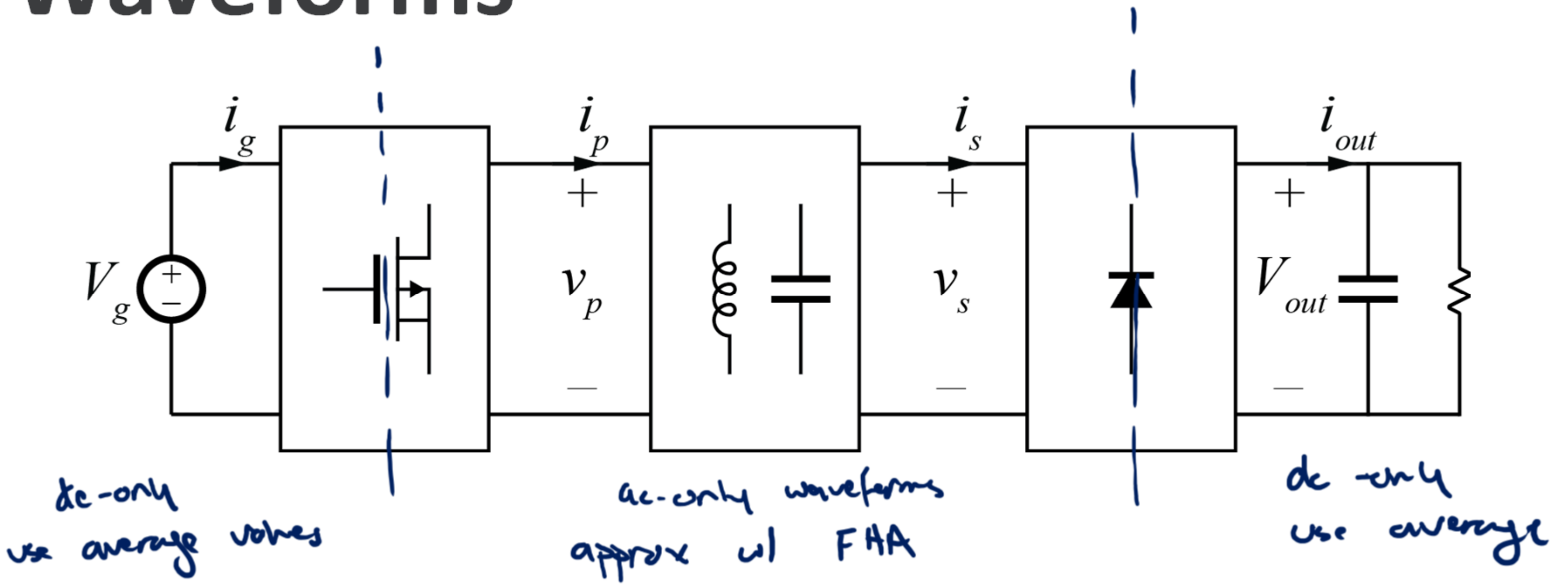


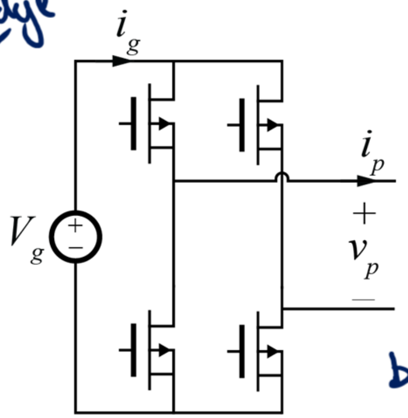
Fig. 2.14. Comparison of exact and approximate series resonant converter characteristics, below resonance.

AC Link Waveforms



Switch Network Sinusoidal Analysis

Full Bridge Inverter



Fourier Series:

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

for $v_p(t)$

$$b_{p1} = \frac{2}{T_s}\int_0^{T_s} v_p(t)\sin(2\pi f_s t)\,dt$$

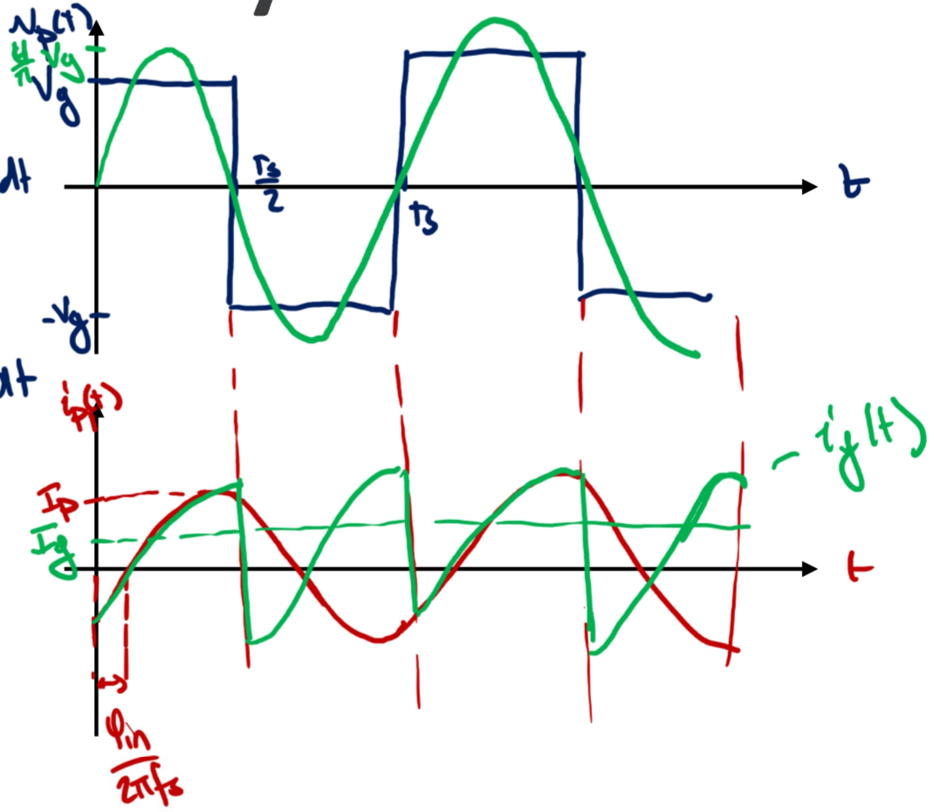
$$b_{p1} = 2\cdot\frac{2}{T_s}\int_0^{T_s/2} V_g \sin(2\pi f_s t)\,dt$$

$$= 2\cdot\frac{2}{T_s}V_g\left[\frac{1}{2\pi f_s}\left(-\cos(2\pi f_s t)\right)\Big|_0^{\frac{T_s}{2}}\right]$$

$$= 2\cdot\frac{2}{\cancel{T_s}}V_g\frac{1}{\cancel{2\pi f_s}}\cancel{(1+1)}$$

$$\boxed{b_{p1} = \frac{4}{\pi}V_g}$$

$$v_{p1}(t) = \frac{4}{\pi}V_g\sin(\omega_s t)$$



$i_p(t) \rightarrow$ Dictated by Z_{in}

$$i_p(t) = I_p\sin(\omega_s t + \varphi_{in})$$

Input Current

for $i_{p1}(t) = I_p \sin(2\pi f_s t + \phi_{in})$

then the DC input current is

$$I_g = \frac{1}{T_s}\int_0^{T_s} i_g(t)\,dt = \frac{2}{T_s}\int_0^{T_s/2} i_{p1}(t)\,dt$$

$$= \frac{2}{T_s}\int_0^{T_s/2} I_p \sin(2\pi f_s t + \phi_{in})\,dt$$

$$= \frac{2}{T_s} I_p \left[\frac{1}{2\pi f_s}\left(-\cos(2\pi f_s t + \phi_{in})\right)\Big|_0^{\frac{T_s}{2}}\right]$$

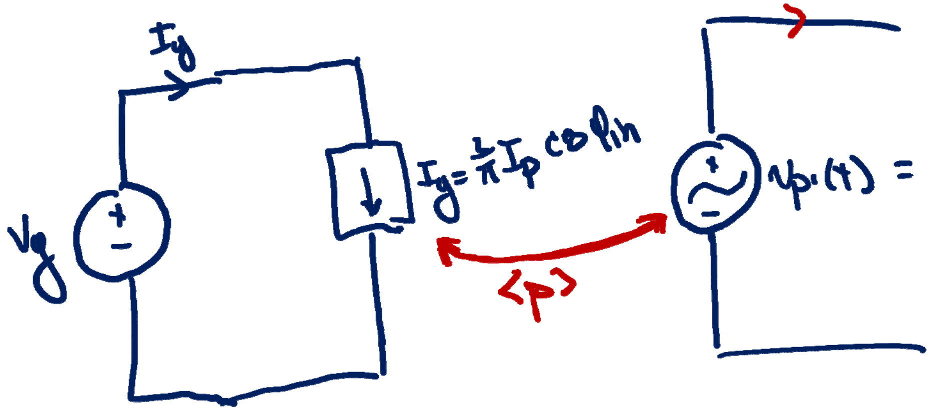
$$= \frac{2}{T_s} I_p \frac{1}{2\pi f_s}\left(-\cos(\pi + \phi_{in}) + \cos(\phi_{in})\right)$$

$$= \frac{\cancel{2}}{\cancel{T_s}} I_p \frac{1}{\cancel{2\pi f_s}} 2\cos(\phi_{in})$$

$$\boxed{I_g = \frac{2}{\pi} I_p \cos\phi_{in}}$$

Switch Network Equivalent Circuit (FHA)

$$i_{p1}(t) = I_p \sin(\omega_s t + \varphi_{in})$$



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

$$v_{p1}(t) = \frac{4}{\pi} V_g \sin(\omega_s t)$$

Phasor Model:

$$V_{p1} = \frac{4}{\pi} V_g \angle 0^\circ$$

$$I_{p1} = I_p \angle \varphi_{in}$$

$$P_{p1} = \frac{1}{2}\frac{4}{\pi} V_g I_p \cos\varphi_{in}$$

$$\rightarrow \frac{2}{\pi} V_g I_p \cos\varphi_{in}$$

$$P_g = V_g I_g = V_g \frac{2}{\pi} I_p \cos\varphi_{in}$$

$$P_{p1} = \frac{1}{T_s}\int_0^{T_s} v_{p1}(t)\cdot i_p(t)\,dt$$

$$= \frac{1}{T_s}\int_0^{T_s} \frac{4}{\pi} V_g \sin(\omega_s t)\, I_p \sin(\omega_s t + \varphi_{in})\,dt$$

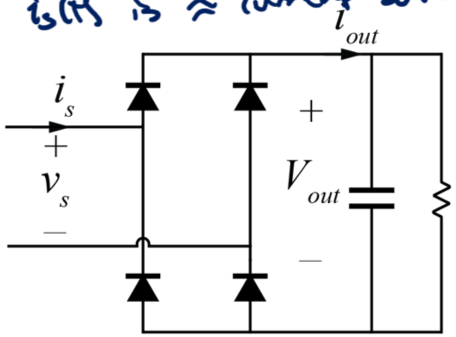
$$= \frac{1}{T_s}\frac{4}{\pi} V_g I_p \frac{1}{2}\int_0^{T_s} \cancel{\cos(2\omega_s t + \varphi_{in})}^{\,0} + \cos(-\varphi_{in})\,dt$$

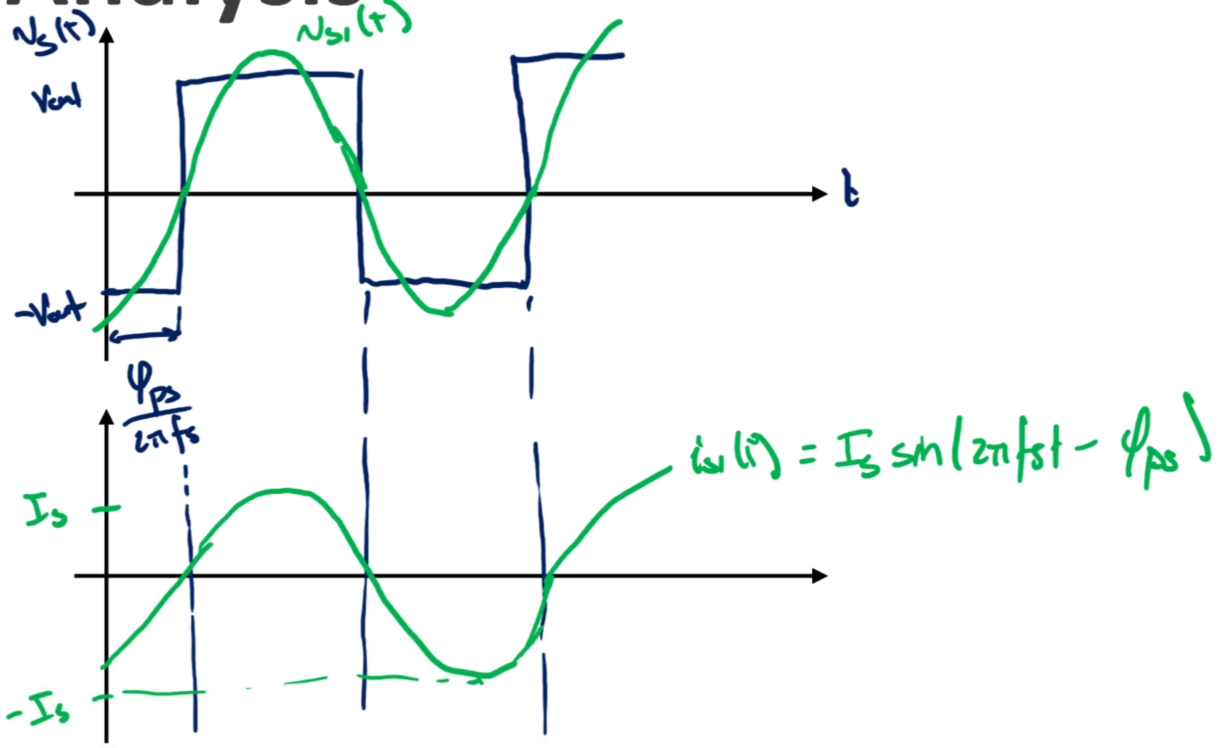
$$= \cancel{\frac{1}{T_s}}\frac{4}{\pi} V_g I_p \frac{1}{2}\cancel{T_s}\cos(-\varphi_{in})$$

$$= \frac{2}{\pi} V_g I_p \cos(\varphi_{in})$$

Diode Rectifier Sinusoidal Analysis

Voltage-loaded Diode rectifier
(assume $i_s(t)$ is ≈ current source)





By same analysis,

$$v_{s1}(t) = \frac{4}{\pi} V_{out} \sin(2\pi f_s t - \varphi_{ps})$$

Same analysis w/ $\varphi = 0$ by ideal diode rectifier

$$I_{out} = \frac{2}{\pi} I_s$$