

## Performance Parameters

$$FormFactor = \frac{V_{rms}}{V_{avg}}$$

$$CrestFactor = \frac{V_{peak}}{V_{rms}}$$

$$DistortionFactor = \frac{I_{1rms}}{I_{rms}}$$

$\phi$  : phase difference between fundamentals of current and voltage

$$DisplacementPowerFactor = \cos(\phi)$$

$$TruePowerFactor = \frac{P}{S} = DPF \frac{I_{1,RMS}}{I_{RMS}}$$

$$THD = \sqrt{\left(\frac{I_{rms}}{I_{1rms}}\right)^2 - 1}$$

## Single Phase Diode Rectifier

$$V_{av} = \frac{2\sqrt{2}V_s}{\pi}$$

$u$ : commutation period

$$\cos(u) = 1 - \frac{2\omega L_s I_d}{\sqrt{2}V_s}$$

$$I_{d,avg} = \frac{\int_b^f i(\theta)d\theta}{\pi}$$

$$I_{d,shortcircuit} = \frac{V_s}{\omega L_s}$$

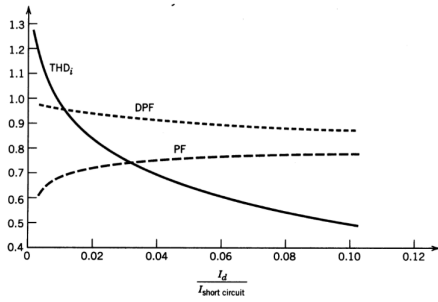


Figure 1: Characteristics of source current wrt  $w \cdot L_s$  (battery on load side)

## Three Phase Rectifier

### • Half Wave

$$V_{av} = \frac{3\sqrt{6}V_s}{2\pi}$$

Crossing points (integration) on the waves are from  $\pi/6$  to  $5\pi/6$

### • Full Wave

Full Bridge Rectifier Average Output  $V_s$ :rms value of source voltage

$$V_{av} = \frac{3\sqrt{6}V_s}{\pi} - \frac{3\omega L_s I_d}{\pi}$$

## Single Phase Controlled Rectifiers-Thyristors

### • Idealized Circuit $\alpha$ : firing angle

$$V_{av}(\alpha) = \frac{2\sqrt{2}V_d}{\pi} \cdot \cos \alpha$$

### • Effect of $L_s$

$$\cos(\alpha + u) = \cos(\alpha) - \frac{2\omega L_s I_d}{\sqrt{2}V_s}$$

$$V_d = 0.9V_s \cos(\alpha) - \frac{2\omega L_s I_d}{\pi}$$

### • Inverter Mode

$$ExtinctionAngle = \gamma = 180 - (\alpha + u)$$

## Three Phase Controlled Rectifiers-Thyristors

### • Idealized Circuit $\alpha$ : firing angle

$$V_{av}(\alpha) = \frac{3\sqrt{2}V_{LL}}{\pi} \cdot \cos \alpha$$

### • Effect of $L_s$

$$\cos(\alpha + u) = \cos(\alpha) - \frac{2\omega L_s I_d}{\sqrt{2}V_{LL}}$$

$$V_d = \frac{3\sqrt{2}}{\pi} V_{LL} \cos(\alpha) - \frac{3\omega L_s I_d}{\pi}$$

### • Output Waveforms

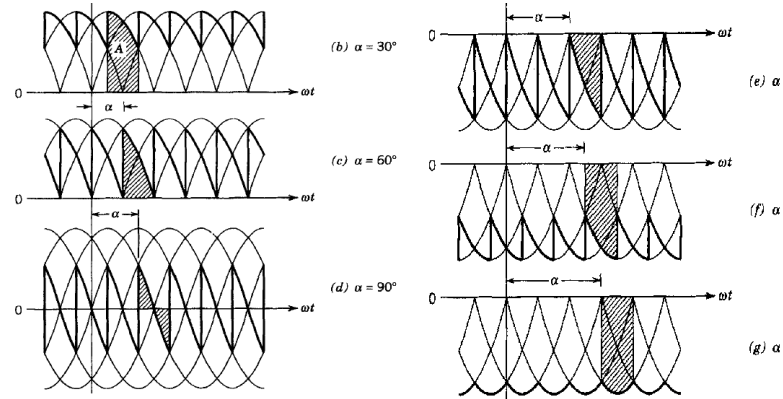


Figure 2: Output Voltage Waveforms

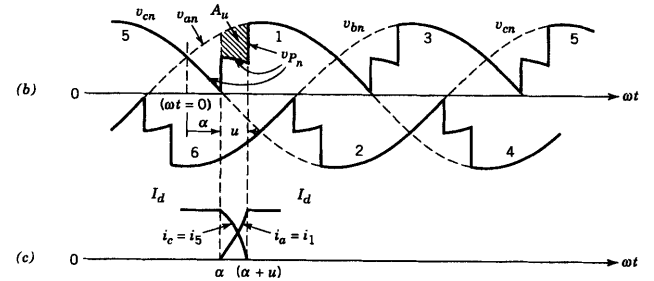


Figure 6-25 Commutation in the presence of  $L_s$ .

Figure 3: Effect of Commutation

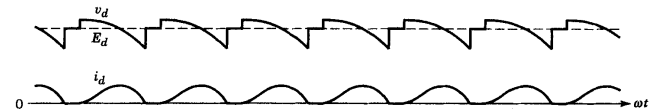


Figure 6-30 Waveforms in a discontinuous-current-conduction mode.

Figure 4: Discontinuous Current Conduction Mode

## Trigonometric

$$\sin A \cos B = \frac{1}{2} [\sin(A - B) + \sin(A + B)]$$

$$\sin A \sin B = \frac{1}{2} [\cos(A - B) - \cos(A + B)]$$

$$\cos A \cos B = \frac{1}{2} [\cos(A - B) + \cos(A + B)]$$

$$\cos A + \cos B = 2 \cos\left(\frac{A+B}{2}\right) \cos\left(\frac{A-B}{2}\right)$$

## BUCK

$$\frac{I_o}{I_d} = \frac{V_d}{V_o} = \frac{1}{D} \quad I_o = i_{L,\text{peak}} \frac{D + \Delta_1}{2}$$

$$I_{LB} = \frac{T_s V_d}{2L} D(1 - D) \quad \therefore \frac{V_o}{V_d} = \frac{D}{D + \Delta_1} \quad \Delta_1 = \frac{I_o}{4I_{LB,\text{max}} D} \quad \frac{V_o}{V_d} = \frac{D^2}{D^2 + \frac{1}{4}(I_o/I_{LB,\text{max}})}$$

$$I_{LB} = \frac{1}{2} i_{L,\text{peak}} = \frac{t_{\text{on}}}{2L} (V_d - V_o) = \frac{DT_s}{2L} (V_d - V_o) = I_{oB}$$

$$I_{LB} = \frac{T_s V_o}{2L} (1 - D) \quad D = \frac{V_o}{V_d} \left( \frac{I_o/I_{LB,\text{max}}}{1 - V_o/V_d} \right)^{1/2}$$

## BOOST

$$\frac{V_o}{V_d} = \frac{T_s}{t_{\text{off}}} = \frac{1}{1 - D} \quad I_{oB} = \frac{T_s V_o}{2L} D(1 - D)^2 \quad I_{LB,\text{max}} = \frac{T_s V_o}{8L}$$

$$I_{oB,\text{max}} = \frac{2}{27} \frac{T_s V_o}{L} \quad I_{oB} = \frac{27}{4} D(1 - D)^2 I_{oB,\text{max}} \quad \therefore \frac{V_o}{V_d} = \frac{\Delta_1 + D}{\Delta_1}$$

$$I_d = \frac{V_d}{2L} DT_s (D + \Delta_1) \quad I_o = \left( \frac{T_s V_d}{2L} \right) D \Delta_1 \quad D = \left[ \frac{4}{27} \frac{V_o}{V_d} \left( \frac{V_o}{V_d} - 1 \right) \frac{I_o}{I_{oB,\text{max}}} \right]^{1/2}$$

$$\therefore \frac{\Delta V_o}{V_o} = \frac{DT_s}{RC}$$

$$V_{\text{ripple,buck}} = V_o(1 - D) \left( \frac{f_c}{f_s} \right)^2 \frac{\pi^2}{2}$$

$$I_{oB} = \frac{T_s V_o D(1 - D)^2}{2L}$$

$$V_{\text{ripple,boost}} = \frac{V_o DT_s}{RC}$$

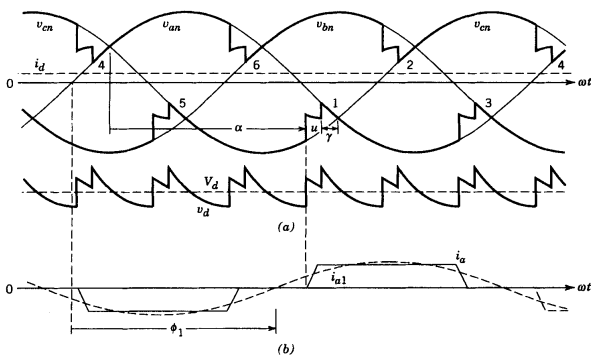


Figure 6-32 Waveforms in the inverter of Fig. 6-31.

Figure 5: Inverter Waveforms

$$\cos A - \cos B = -2 \sin\left(\frac{A+B}{2}\right) \sin\left(\frac{A-B}{2}\right)$$

$$\sin^2(A) = \frac{1}{2} - \frac{\cos(2A)}{2}$$

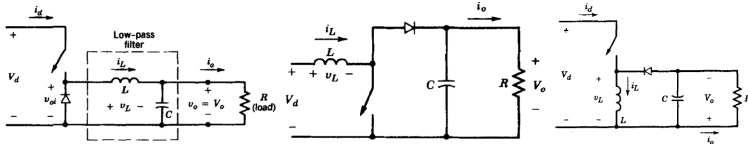
Symmetry	Condition Required	$a_h$ and $b_h$
Even	$f(-t) = f(t)$	$b_h = 0 \quad a_h = \frac{2}{\pi} \int_0^\pi f(t) \cos(h\omega t) d(\omega t)$
Odd	$f(-t) = -f(t)$	$a_h = 0 \quad b_h = \frac{2}{\pi} \int_0^\pi f(t) \sin(h\omega t) d(\omega t)$
Half-wave	$f(t) = -f(t + \frac{1}{2}T)$	$a_h = b_h = 0$ for even $h$ $a_h = \frac{2}{\pi} \int_0^\pi f(t) \cos(h\omega t) d(\omega t)$ for odd $h$ $b_h = \frac{2}{\pi} \int_0^\pi f(t) \sin(h\omega t) d(\omega t)$ for odd $h$

Figure 6: Fourier Transform Table

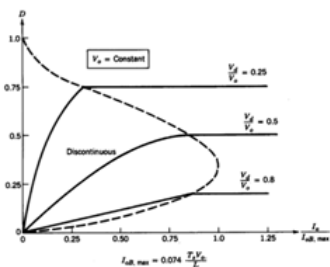
## Power Flow

$$P = V_s I_{s1} \cos(\phi) = V_d I_d$$

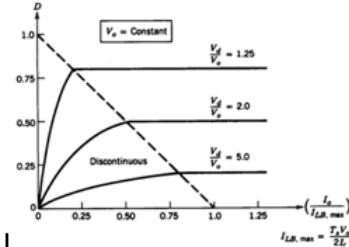
$$S = V_s I_s$$



In order to keep  $V_o$  constant



With Constant  $V_o$  ( $V_d$  can vary)



Convection Thermal Resistance    Conduction Heat loss    Fluid Temperature Rise

$$R_c = \frac{1}{Ah} \quad P = \frac{\Delta T}{R} \quad \text{for a liquid cooled system}$$

Radiation Heat Loss (Black body radiation)

$q_R$ : radiation heat flow (W/m<sup>2</sup>)

$$q_R = \rho \epsilon F (T_1^4 - T_2^4)$$

$$\Delta T = \frac{P}{Q \cdot d \cdot C_p}$$

$$\zeta = \frac{L}{2R\sqrt{LC}}$$

## Positive Output Buck-Boost Converter

