Chapter 5

RECTIFICATION OF UTILITY INPUT USING DIODE RECTIFIERS

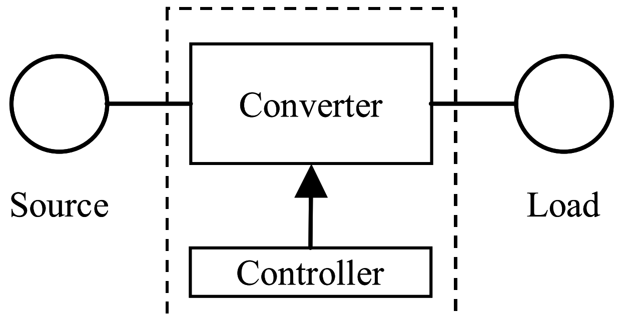


Figure 5-1 Block diagram of power electronic systems.

Linear and Nonlinear Loads

Linear Load

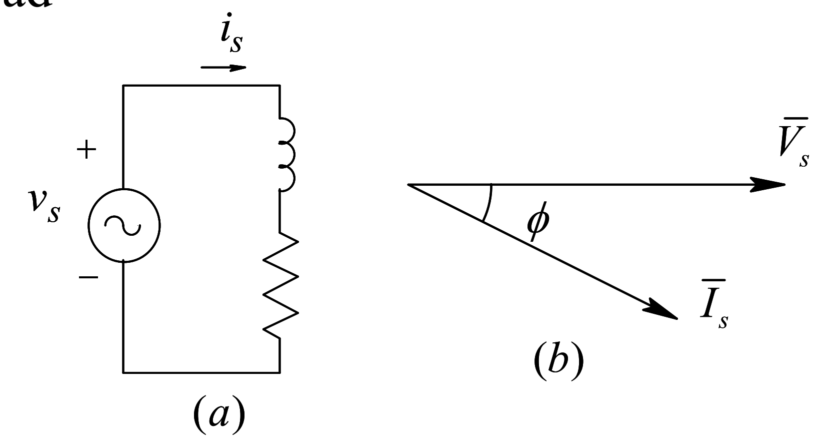


Figure 5-2 Voltage and current phasors in simple *R*-*L* circuit.

$$P = V_s \, I_s \cos\phi$$

$$PF = \frac{P}{V_s I_s} = \cos\phi$$

$$I_s = \frac{P}{V_s \cdot PF}$$

Nonlinear Loads

Non-linear Loads

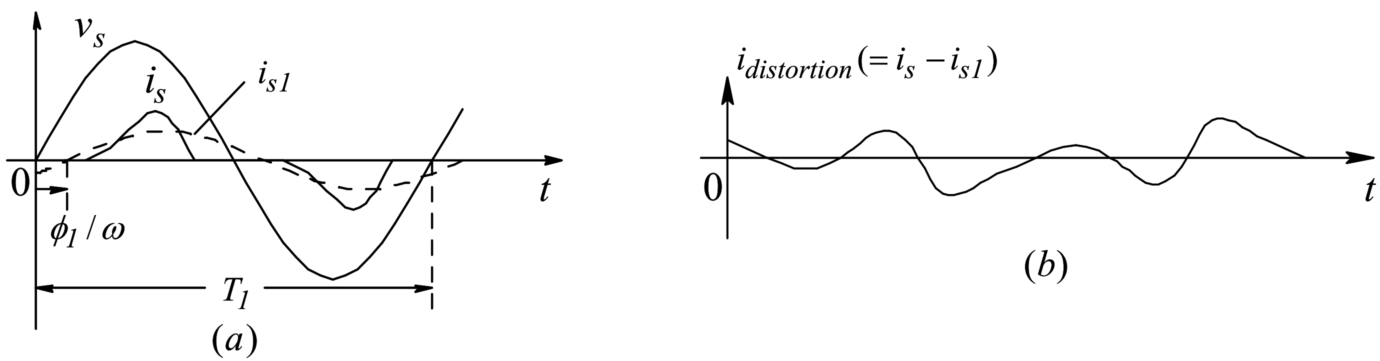


Figure 5-3 Current drawn by power electronics equipment with diode-bridge front-end.

Total Harmonic Distortion: $\%THD = 100 \; x \; \dfrac{I_{distortion}}{I_{s1}}$

Displacement Power Factor: $DPF = \cos \phi_1$

$$PF = \frac{I_{s1}}{I_s}(DPF) = \frac{DPF}{\sqrt{1 + THD^2}}$$

- ❑ Nonlinear loads reduce power factor

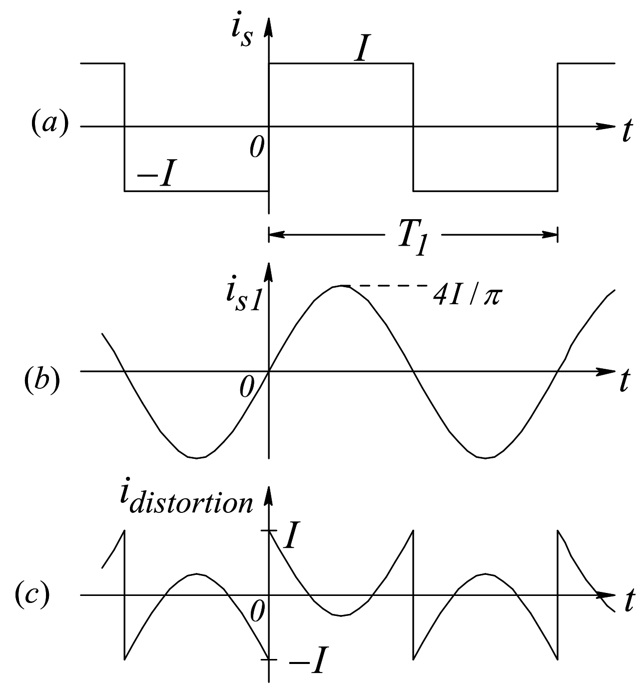
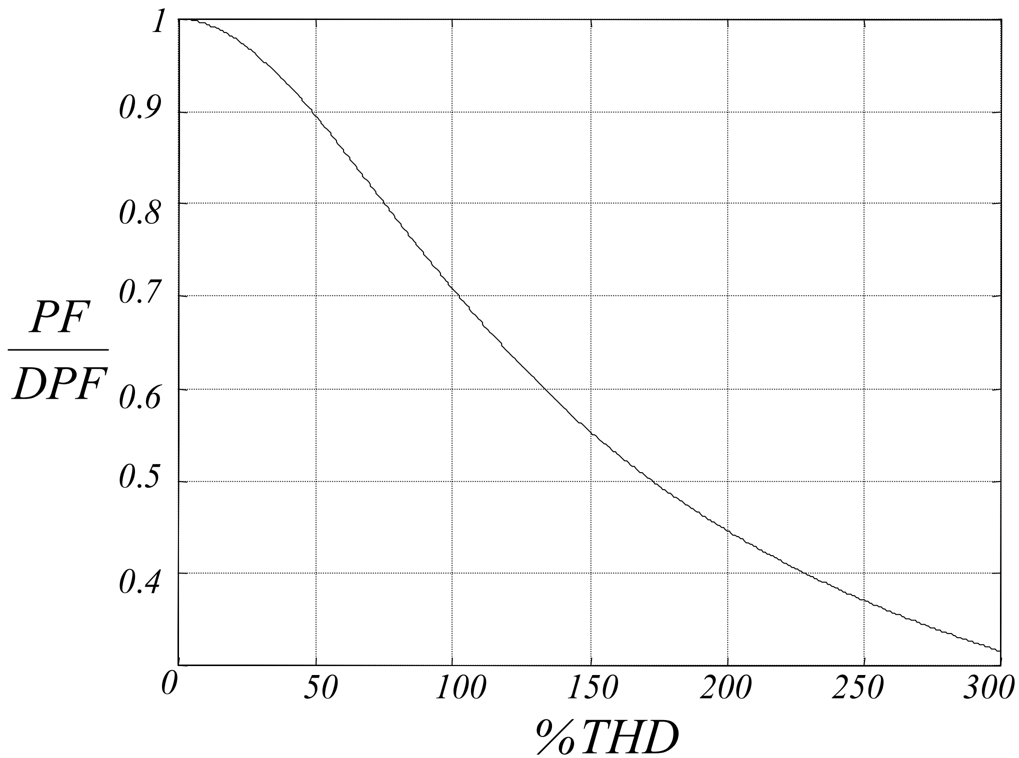


Figure 5-4 Example 5-1.

Harmonic Currents Lower Power Factor



- Ratio of actual power factor to displacement power factor decreases with increasing THD

Harmonic Guidelines

	Odd Harmonic Order h					Total Harmonic Distortion(%)
I_{SC} / I_1	$h < 11$	$11 \leq h \leq 17$	$17 \leq h \leq 23$	$23 \leq h \leq 35$	$35 \leq h$	
< 20	4.0	2.0	1.5	0.6	0.3	5.0
$20 - 50$	7.0	3.5	2.5	1.0	0.5	8.0
$50 - 100$	10.0	4.5	4.0	1.5	0.7	12.0
$100 - 1000$	12.0	5.5	5.0	2.0	1.0	15.0
> 1000	15.0	7.0	6.0	2.5	1.4	20.0

- IEEE – 519
- Limits on allowable harmonic currents drawn by loads of various relative magnitudes
- Relative magnitude of load currents is based on Short Circuit Ratio (SCR)

$$SCR = \frac{I_{sc}}{I_{s1}}$$

Where I_{sc} is the short circuit current and I_{s1} is the fundamental current of the load

Short-Circuit Current: I_{sc}

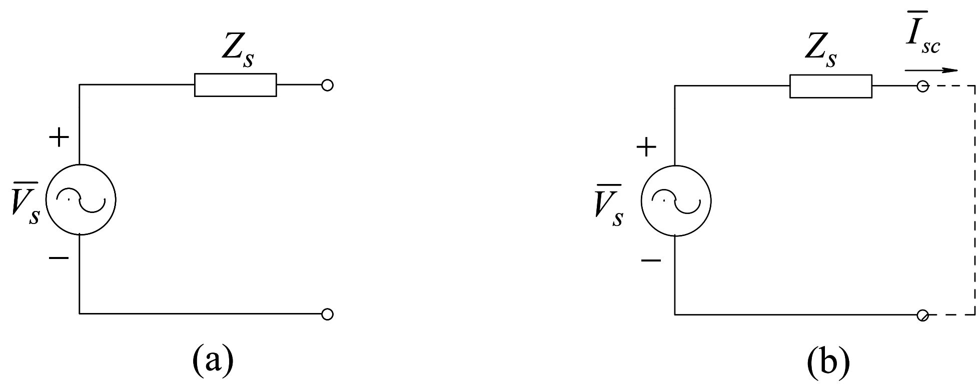
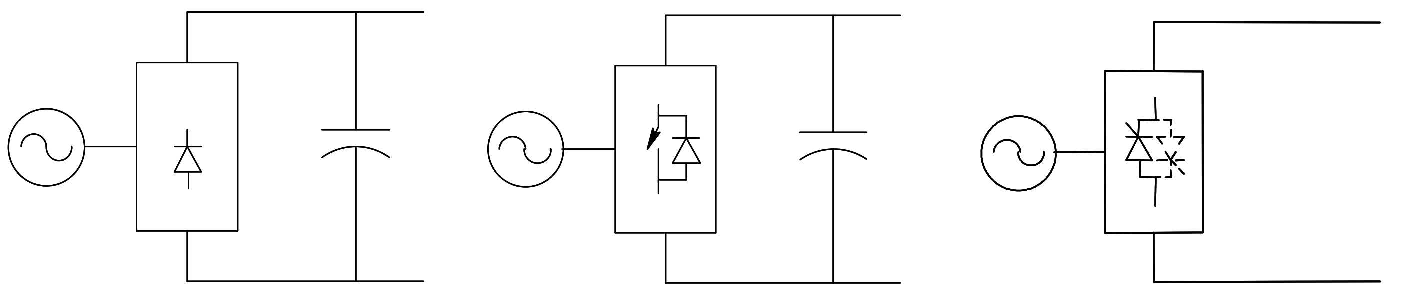


Figure 5-6 (a) Utility supply; (b) short circuit current.

Types of Electric Drive Front-Ends



(*a*) (*b*) (*c*)

Figure 5-7 Front-end of power electronics equipment.

- ❑ Diode-bridge rectifiers
- ❑ Switch-mode converters
- ❑ Thyristor converter

Single-Phase, Diode-Bridge Rectifier

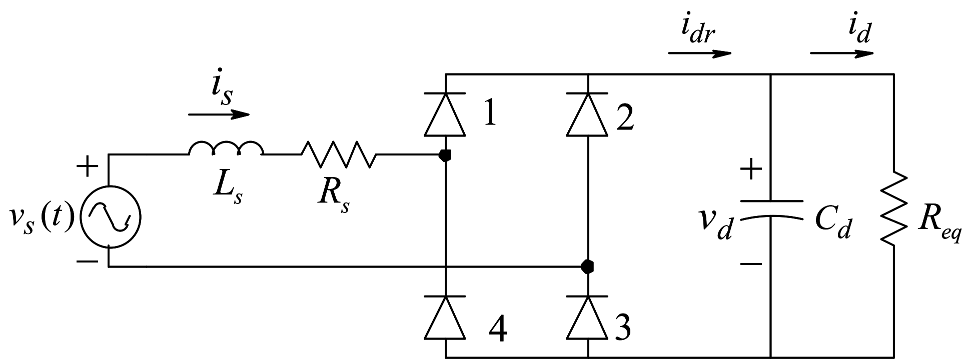


Figure 5-8 Full-bridge diode rectifier.

- ❑ Power levels up to several kW
- ❑ Current drawn from utility in short pulses

Peak-Charging Circuit

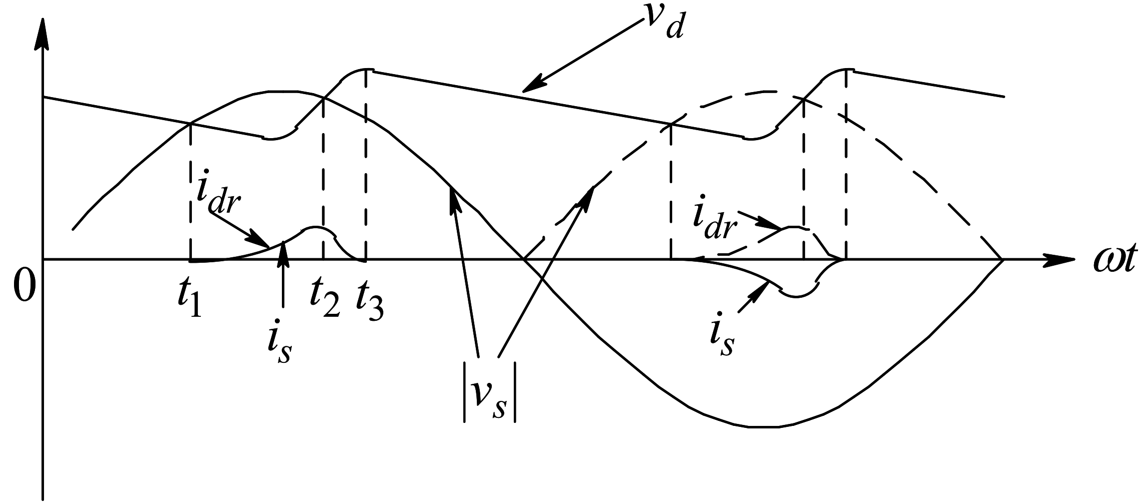


Figure 5-9 Current and voltage waveforms for the full-bridge diode rectifier.

- Current pulses widen as L_s is increased

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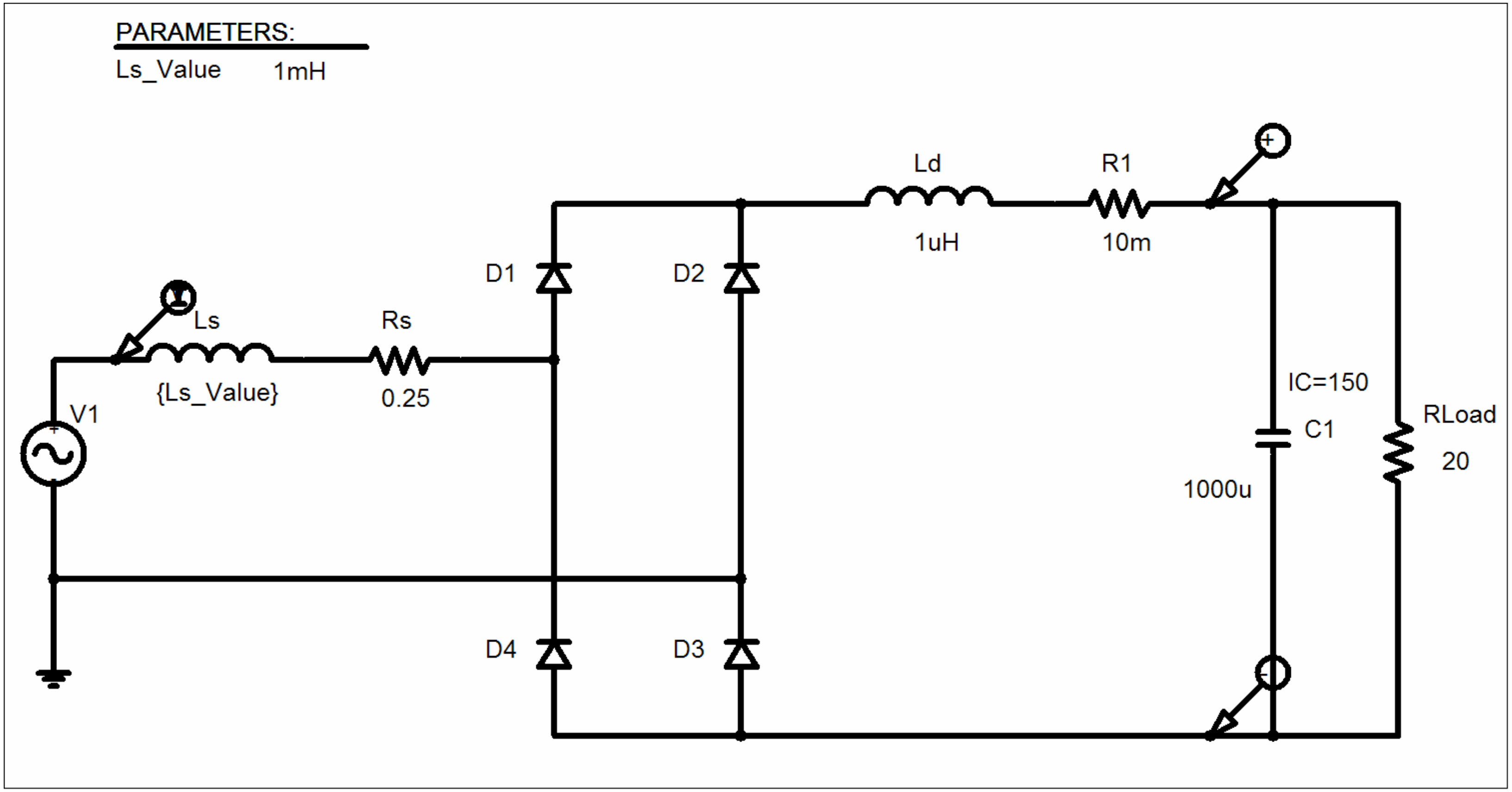
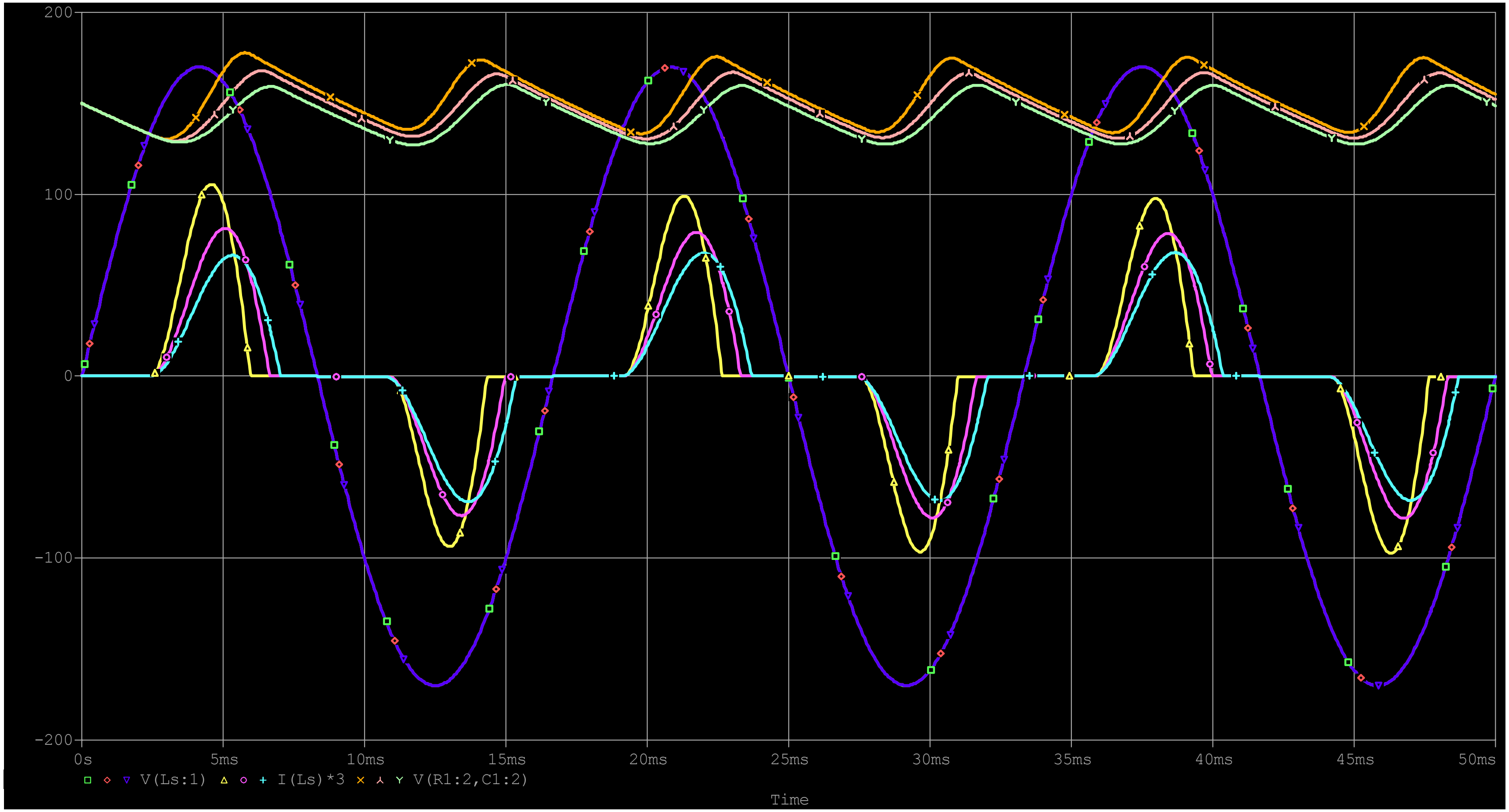


Simulation Results



Three-Phase, Diode- Bridge Rectifier

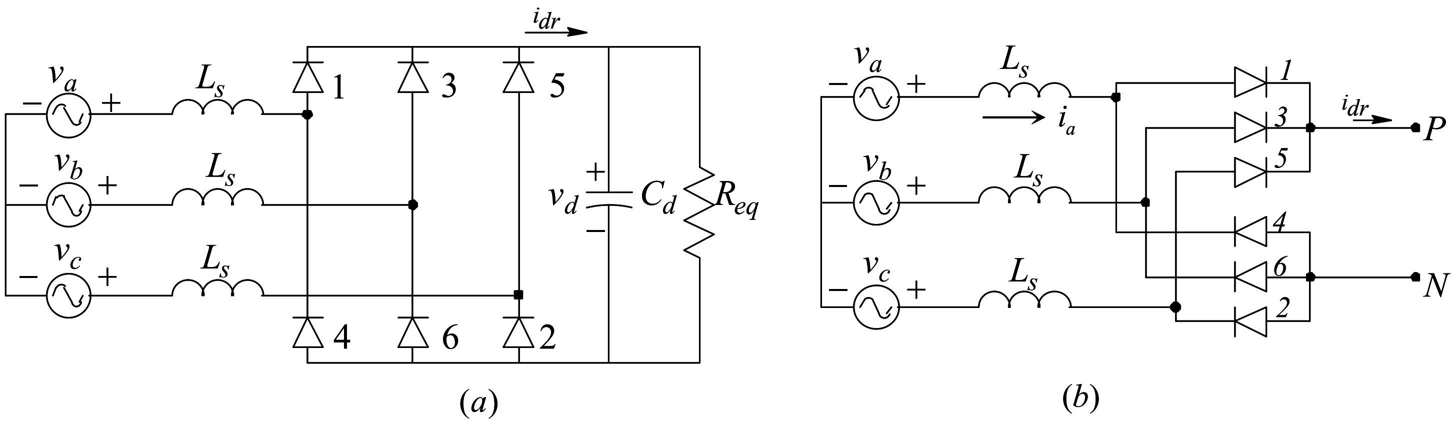


Figure 5-11 Three-phase diode bridge rectifier.

Voltage and Current Without C_d

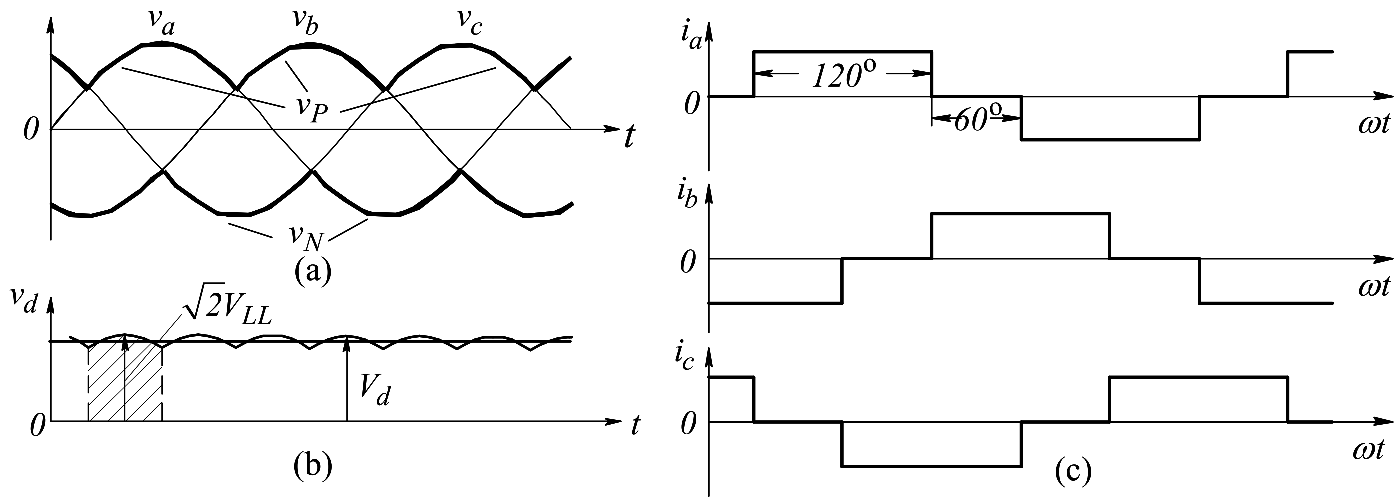


Figure 5-12 Waveforms in a three-phase rectifier (a constant i_{dr}).

- v_P follows whichever phase voltage is most positive at any moment
- v_N follows whichever phase voltage is most negative at any moment
- Without C_d, phase currents flow for a full 120° duration

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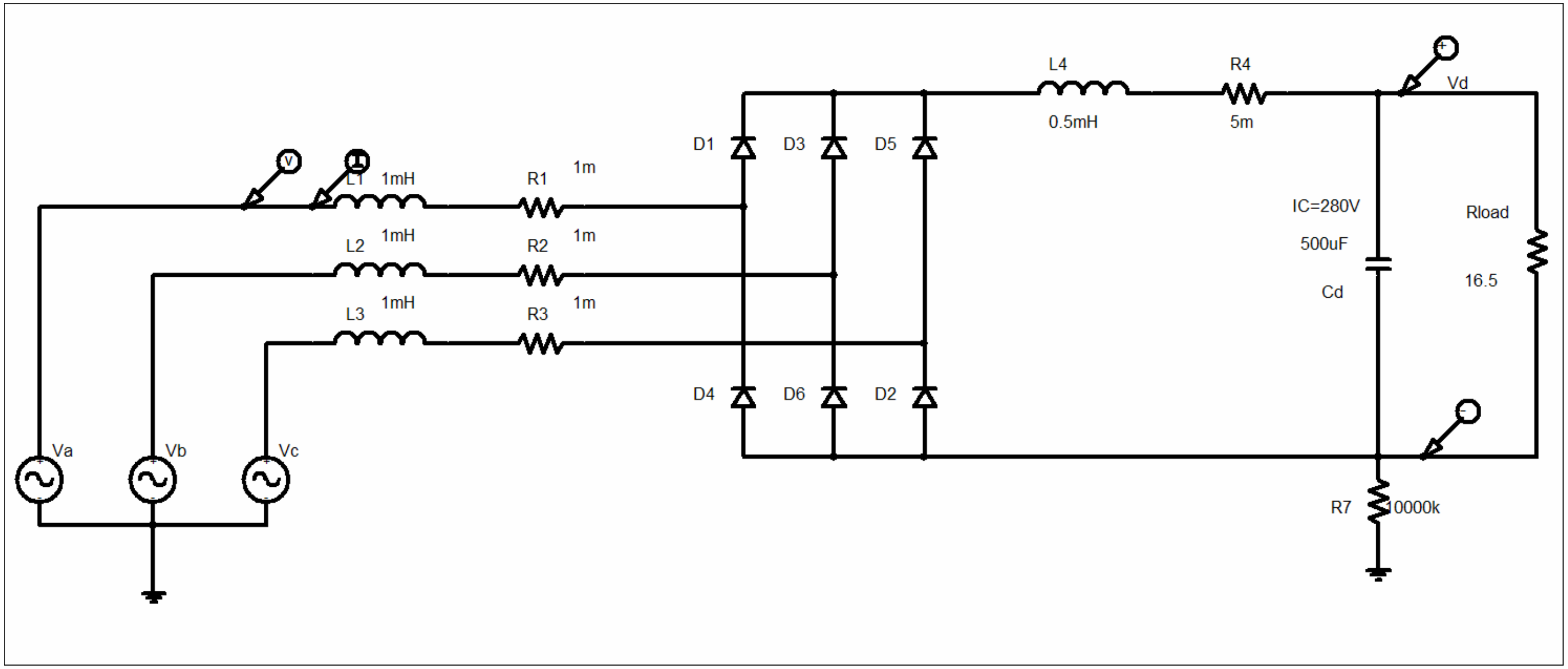
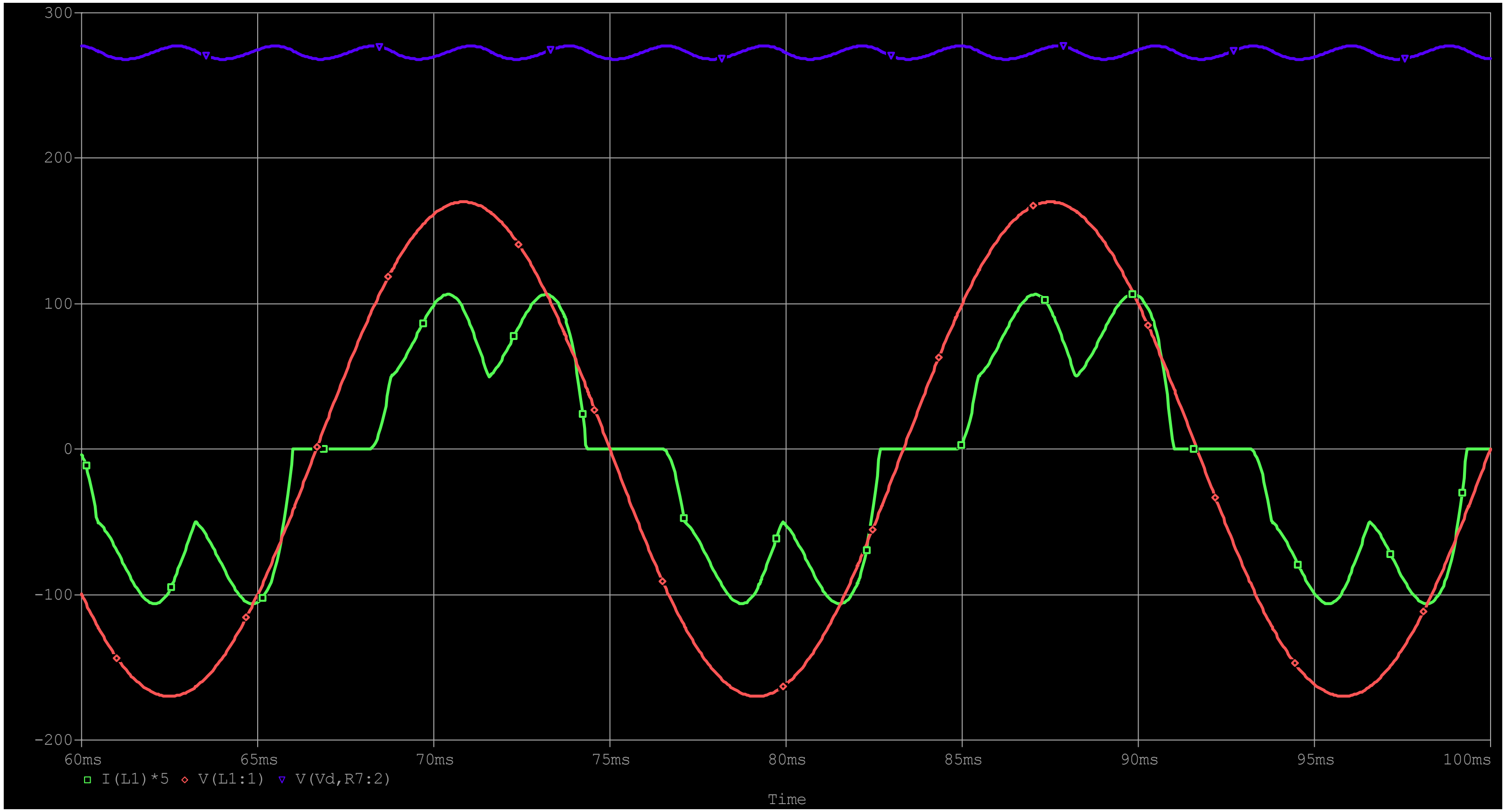


Simulation Results



Avoiding Large Inrush Currents

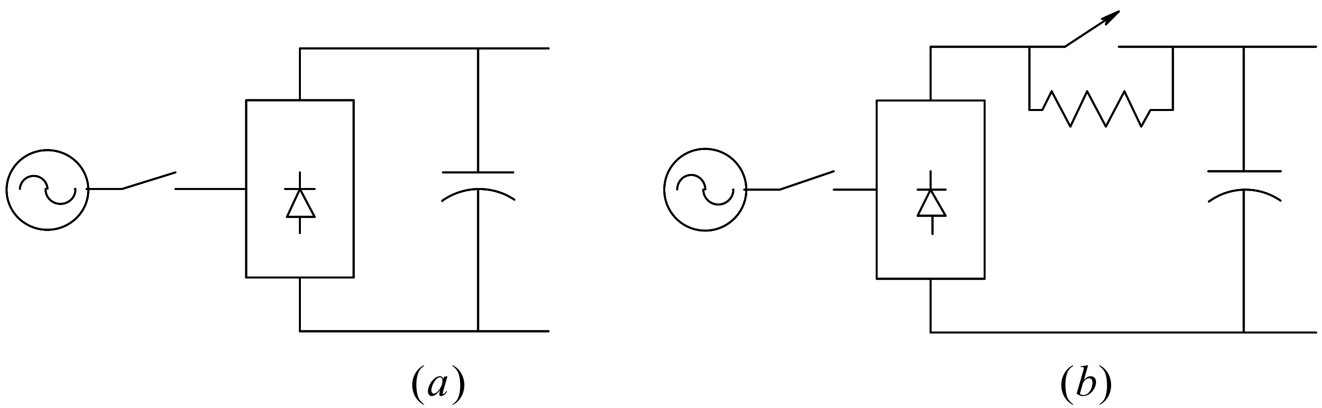


Figure 5-14 Means to avoid inrush current.

- Resistor limits inrush current at startup
- Resistor switched out during operation