Chapter 17

Electric Utility Applications

- These applications are growing rapidly

HVDC Transmission

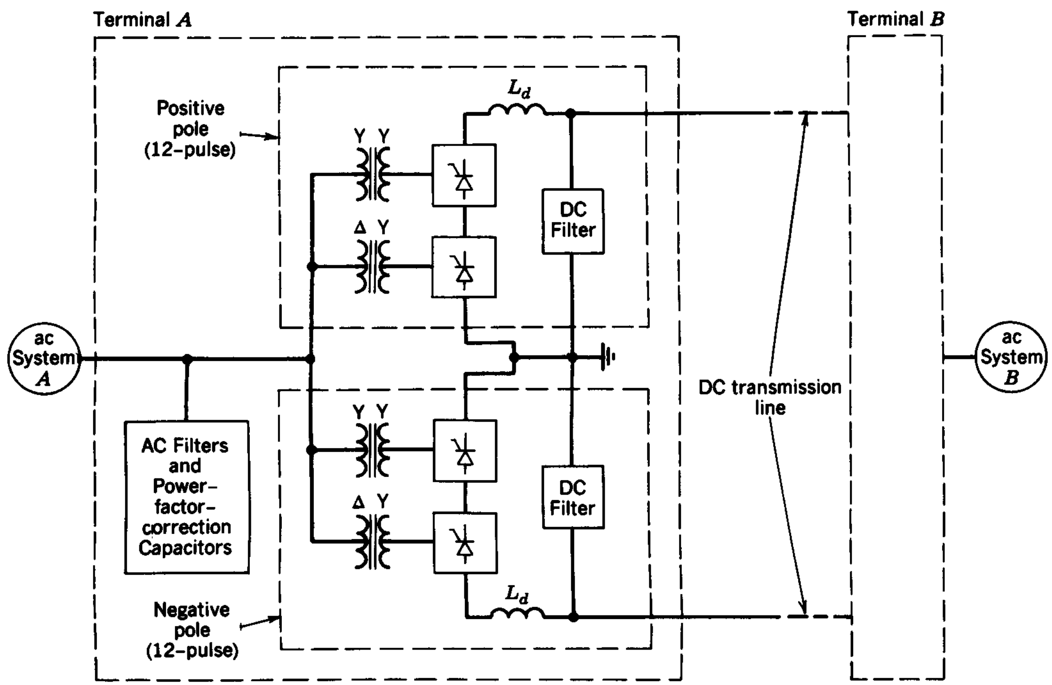


Figure 17-1 A typical HVDC transmission system.

- There are many such systems all over the world

HVDC Poles

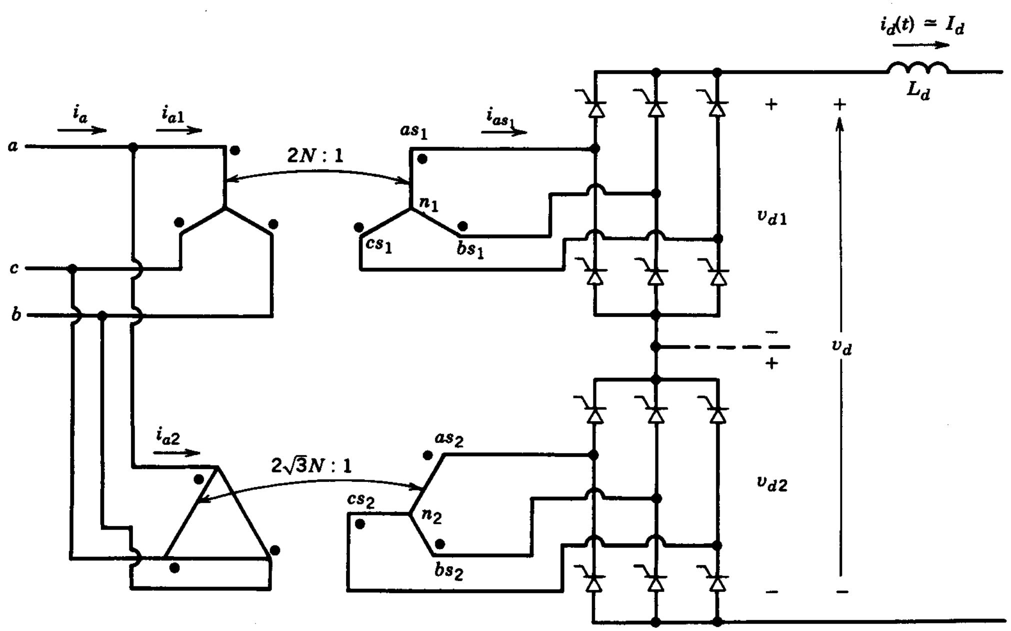


Figure 17-2 Twelve-pulse converter arrangement.

- Each pole consists of 12-pulse converters

HVDC Transmission: 12-Pulse Waveforms

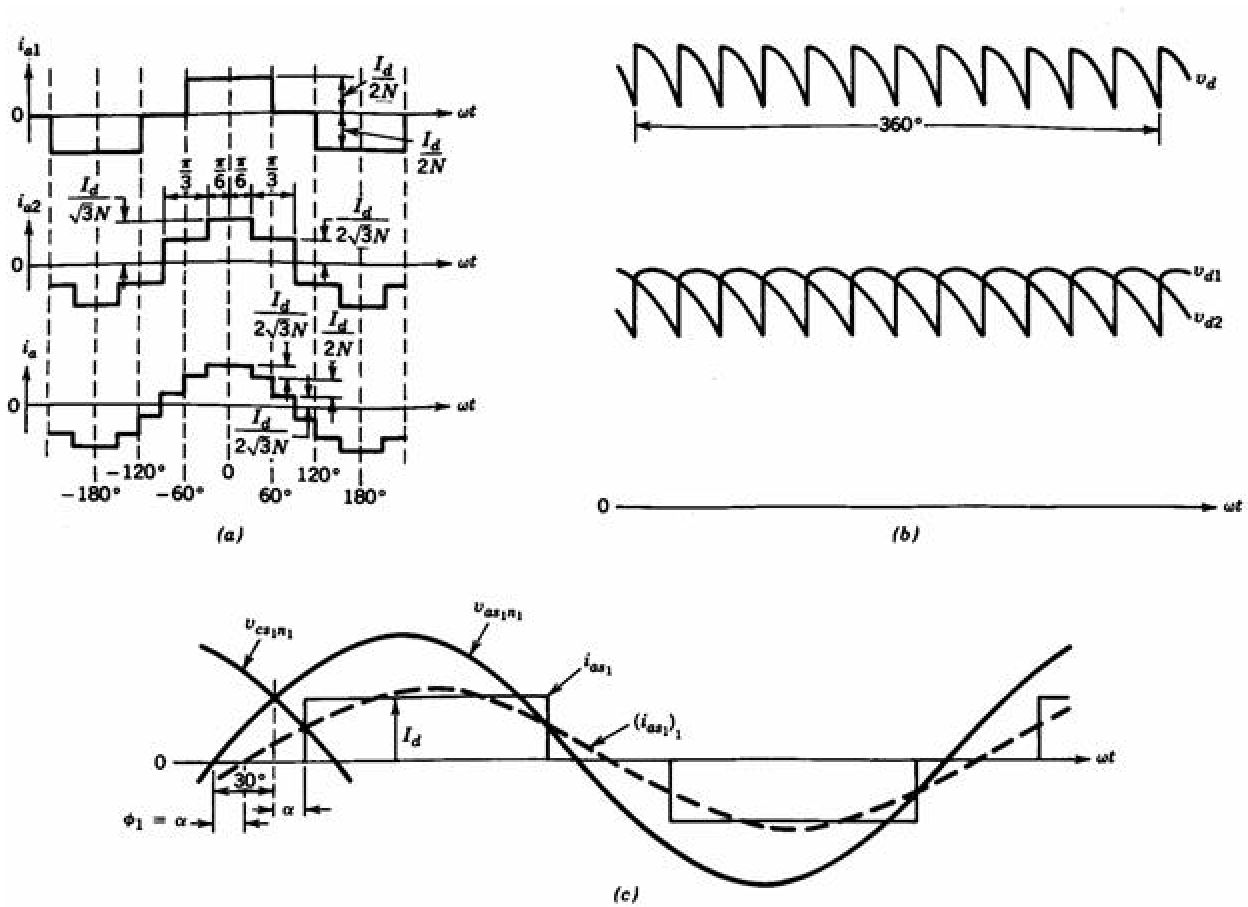


Figure 17-3 Idealized waveforms assuming $L_s = 0$.

- Idealized waveforms

HVDC Transmission: Converters

- Inverter mode of operation

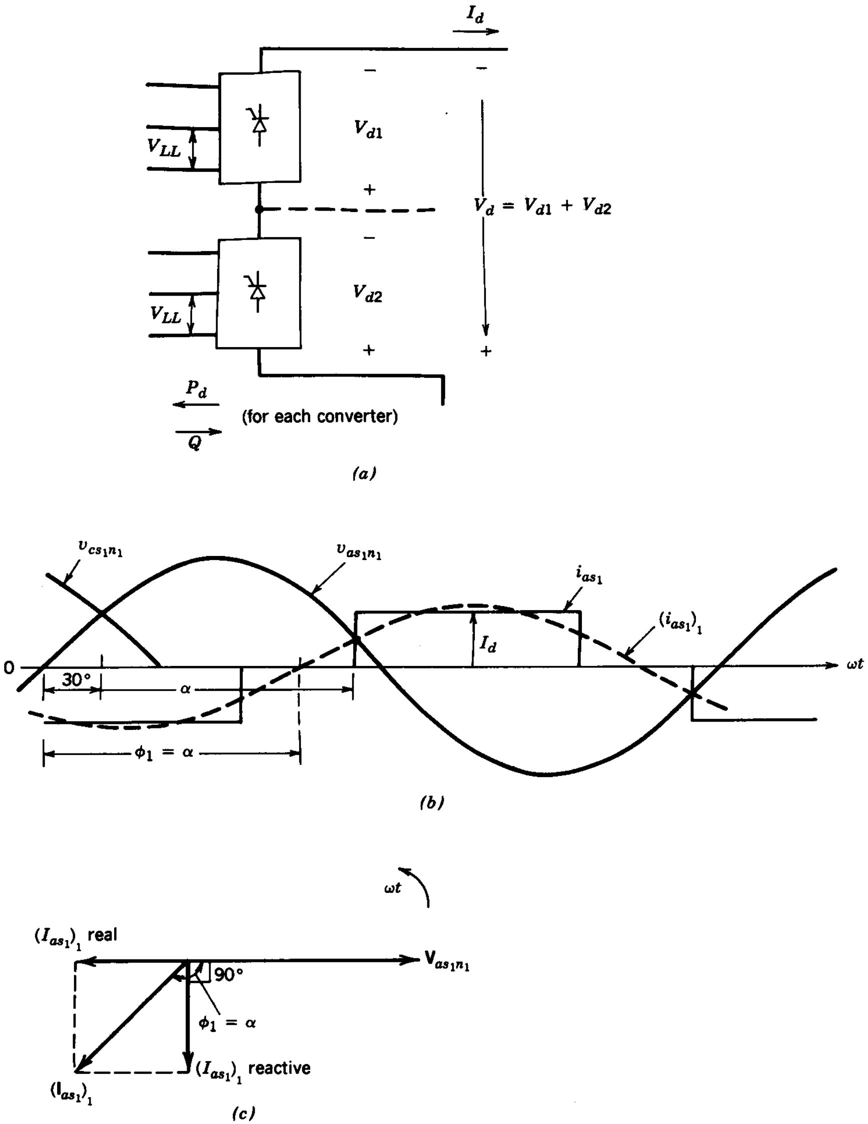


Figure 17-4 Inverter mode of operating (assuming $L_s = 0$).

Control of HVDC Transmission System

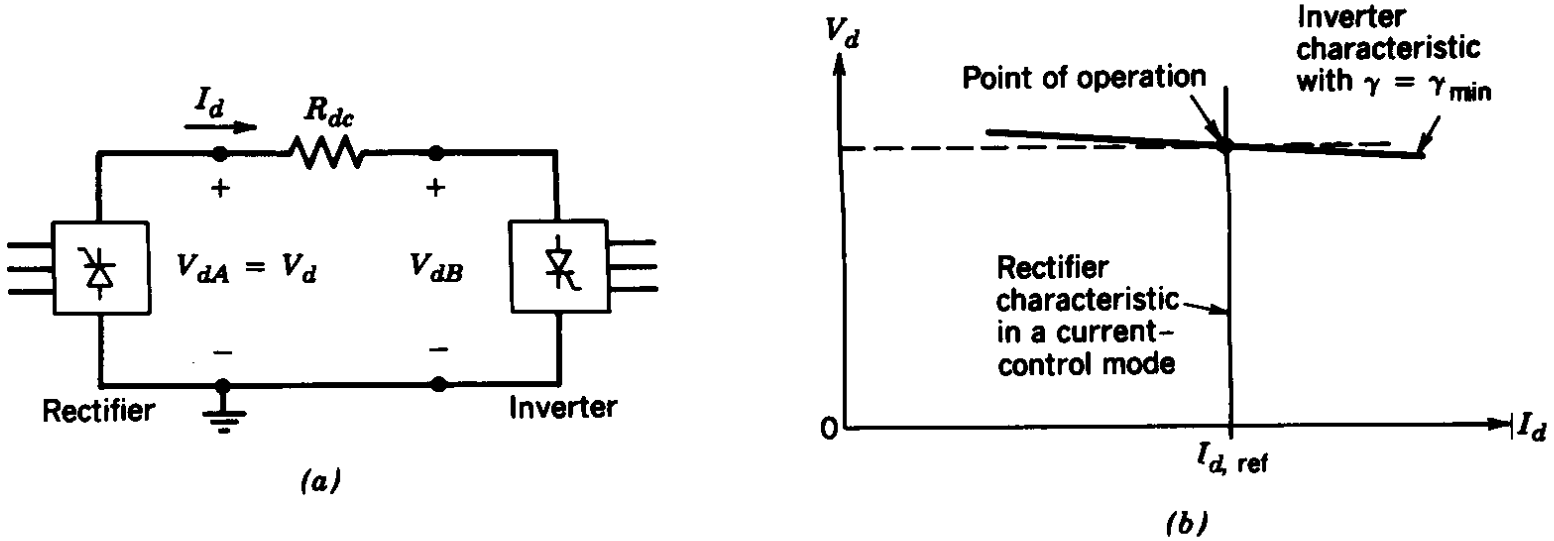


Figure 17-5 Control of HVDC system.

- Inverter is operated at the minimum extinction angle and the rectifier in the current-control mode

HVDC Transmission: DC-Side Filters

Tuned for the lowest (12^{th} harmonic) frequency

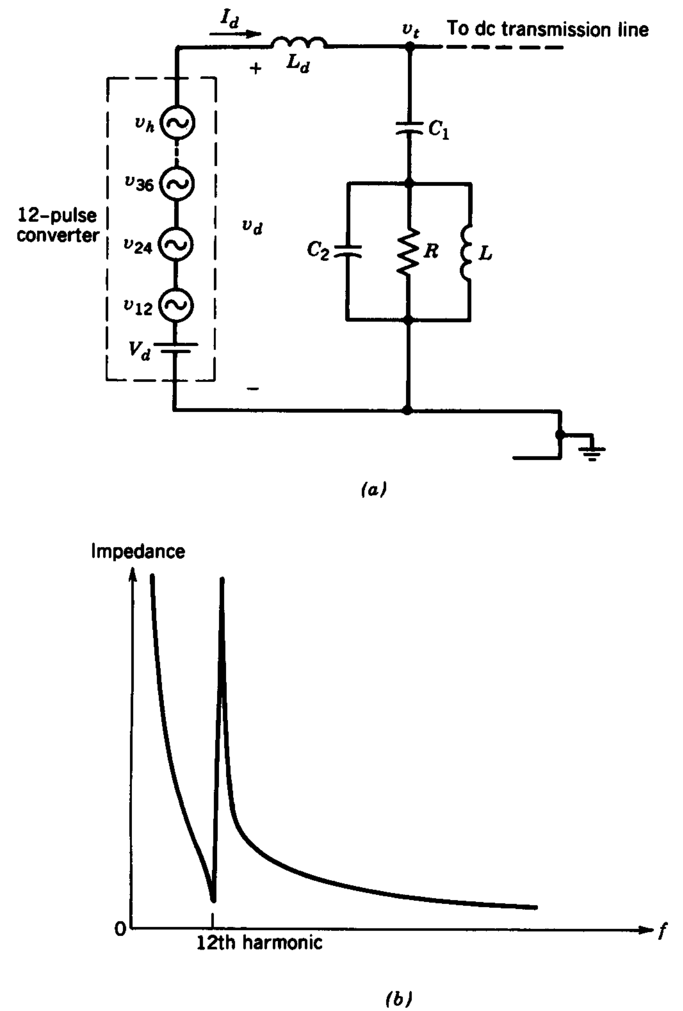


Figure 17-6 Filter for dc-side voltage harmonics: (*a*) dc-side equivalent circuit; (*b*) high-pass filter impedance vs. frequency.

HVDC Transmission: AC-Side Filters

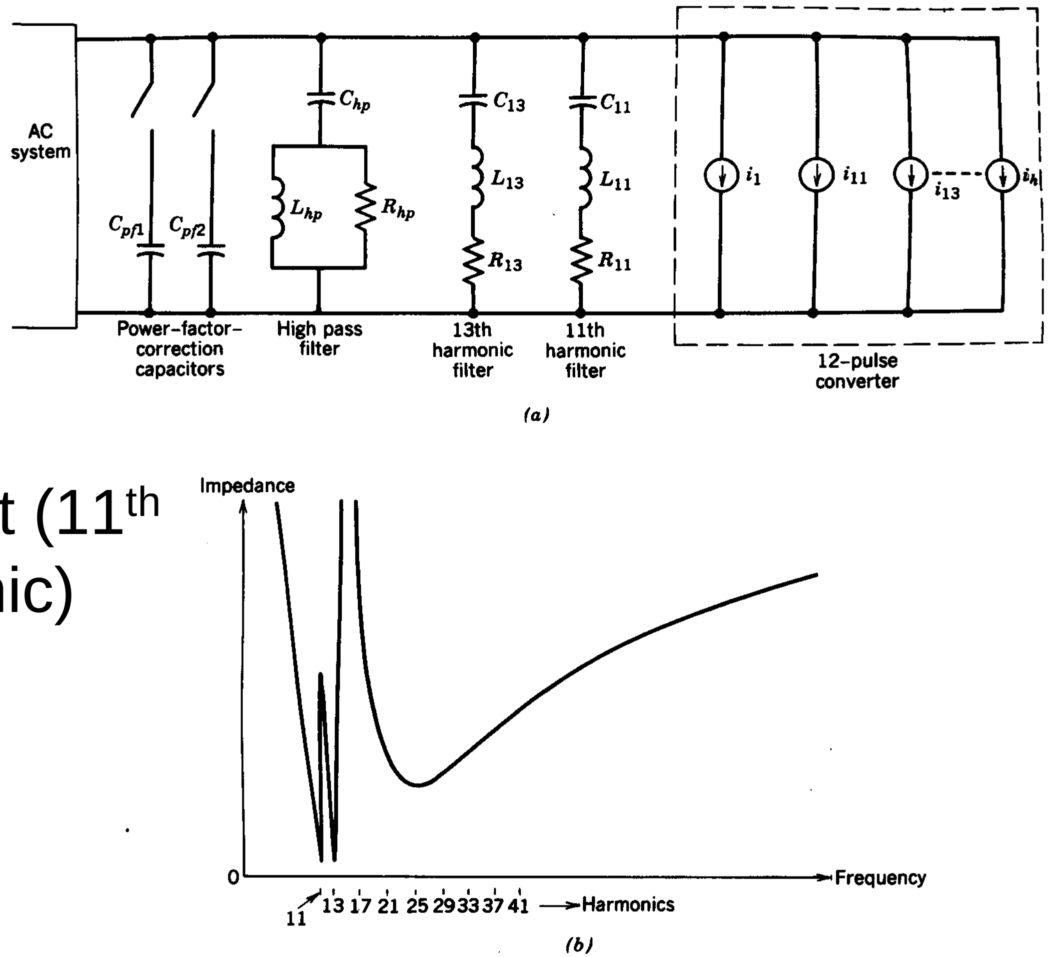


Figure 17-7 The ac side filters and power factor correction capacitors: (*a*) per-phase equivalent circuit; (*b*) combined per-phase filter impedance vs. frequency.

Tuned for the lowest (11th and the 13th harmonic) frequencies

Effect of Reactive Power on Voltage Magnitude

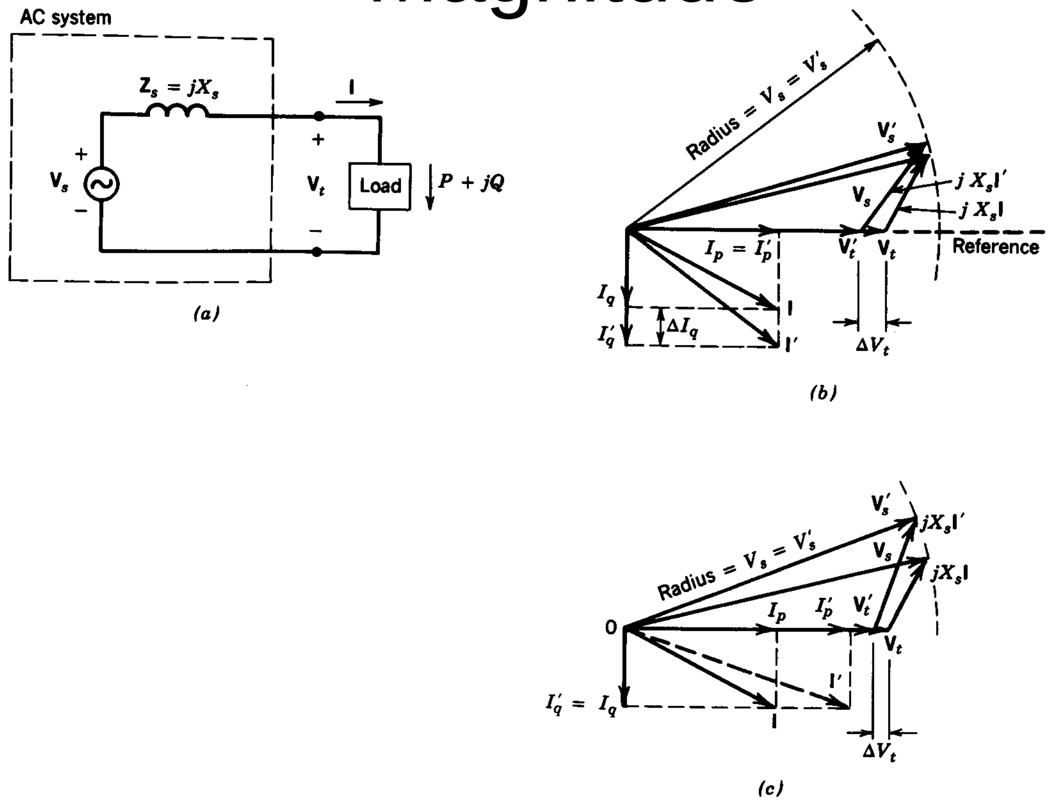


Figure 17-8 Effect of I_p and I_q on V_t: (*a*) equivalent circuit; (*b*) change in I_q; (*c*) change in I_p.

- Illustration of the basic principle

Thyristor-Controlled Inductor (TCI)

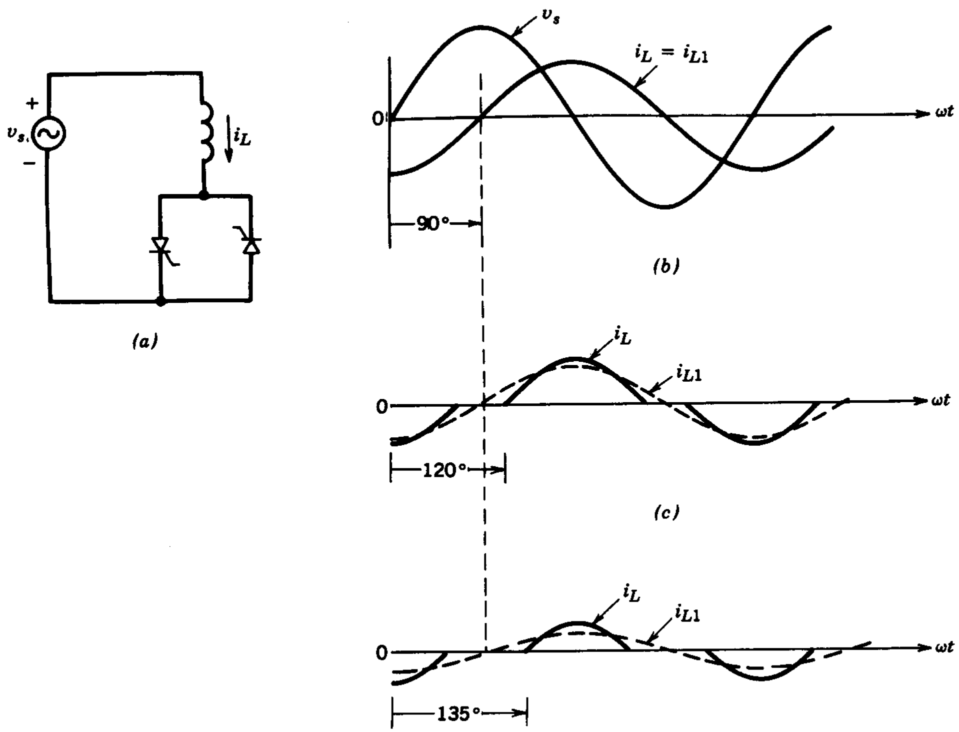


Figure 17-9 A TCI, basic principle: (*a*) per-phase TCI; (*b*) $0 < \alpha < 90°$; (*c*) $\alpha = 120°$; (*d*) $\alpha = 135°$.

- Increasing the delay angle reduces the reactive power drawn by the TCI

Thyristor-Switched Capacitors (TSCs)

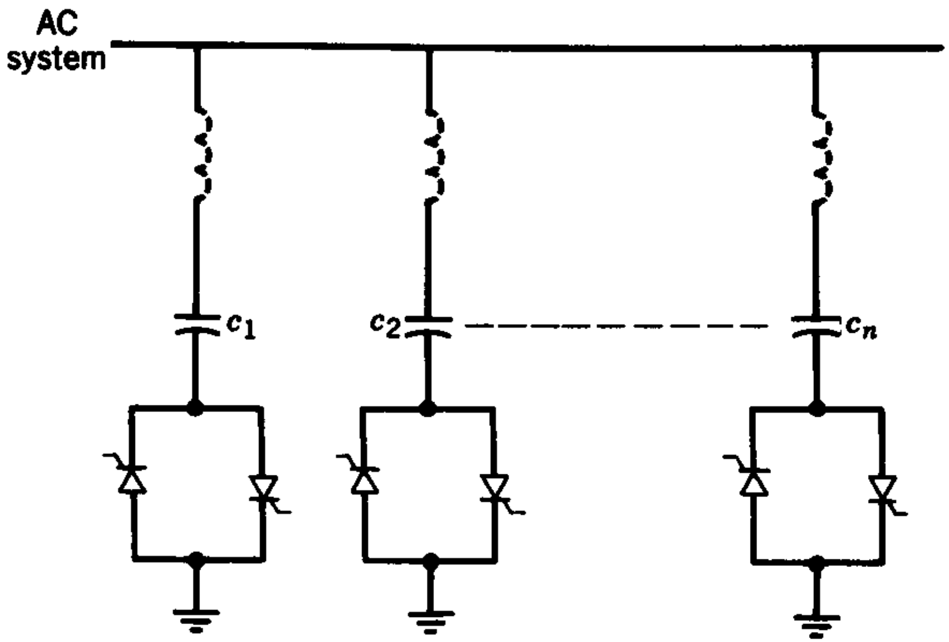


Figure 17-10 A TSC arrangement.

- Transient current at switching must be minimized

Instantaneous VAR Controller (SATCOM)

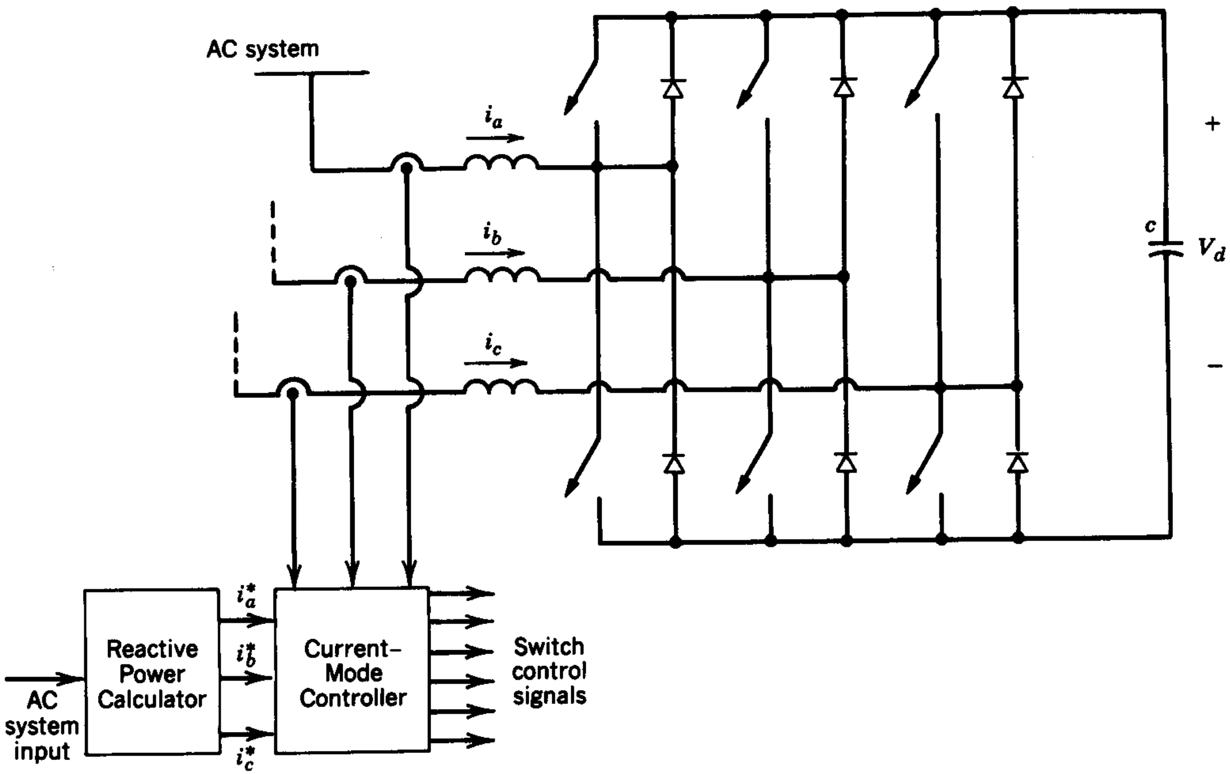


Figure 17-11 Instantaneous var controller.

- Can be considered as a reactive current source

Characteristics of Solar Cells

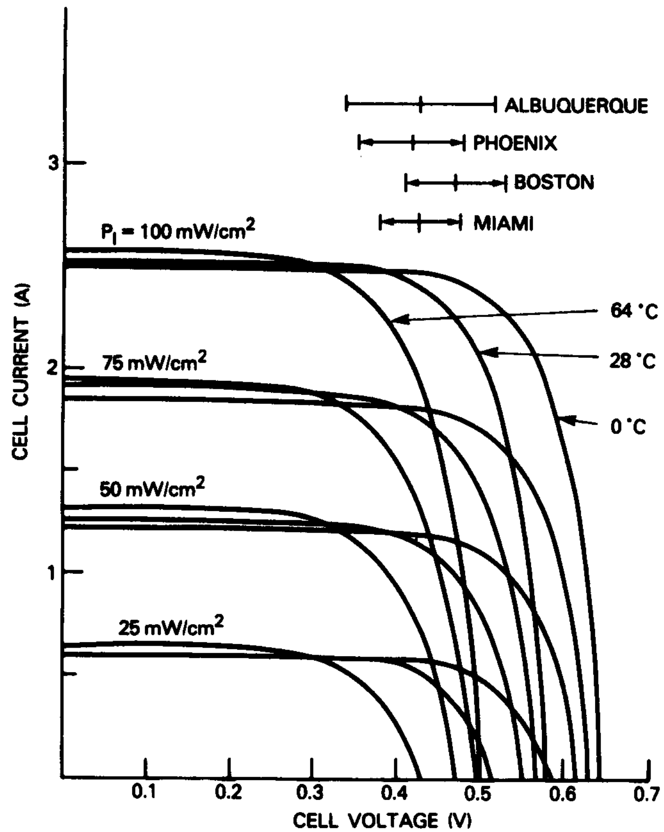


Figure 17-12 The *I–V* characteristics of solar cells. (*Source:* reference 10.)

- The maximum power point is at the knee of the characteristics

Photovoltaic Interface

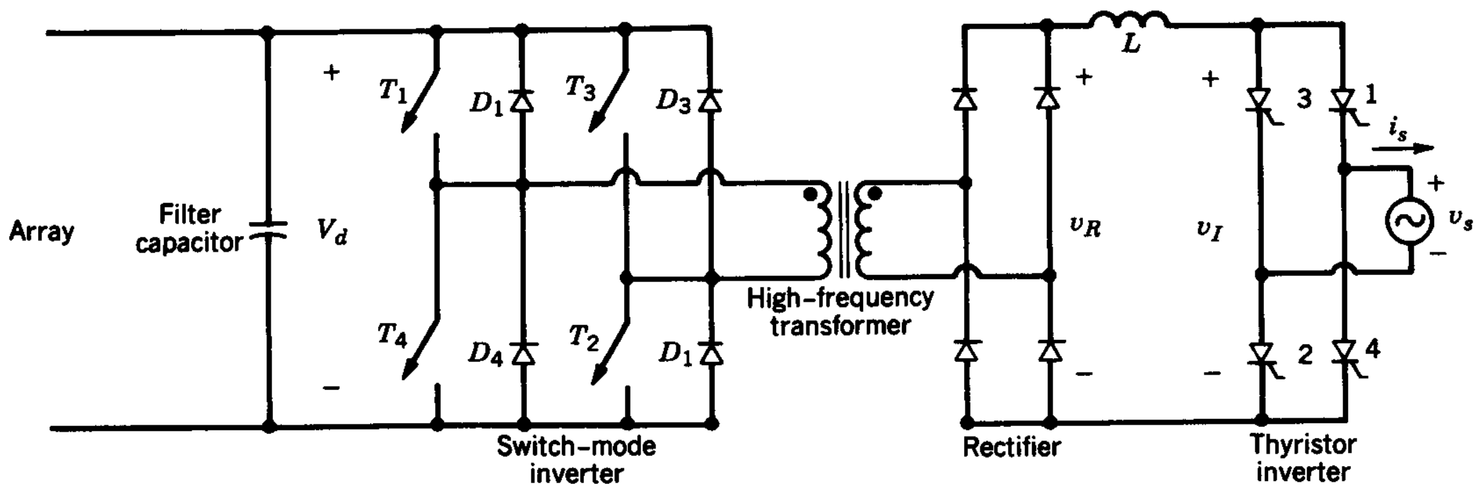


Figure 17-13 High-frequency photovoltaic interface.

- This scheme uses a thyristor inverter

Harnessing of Wing Energy

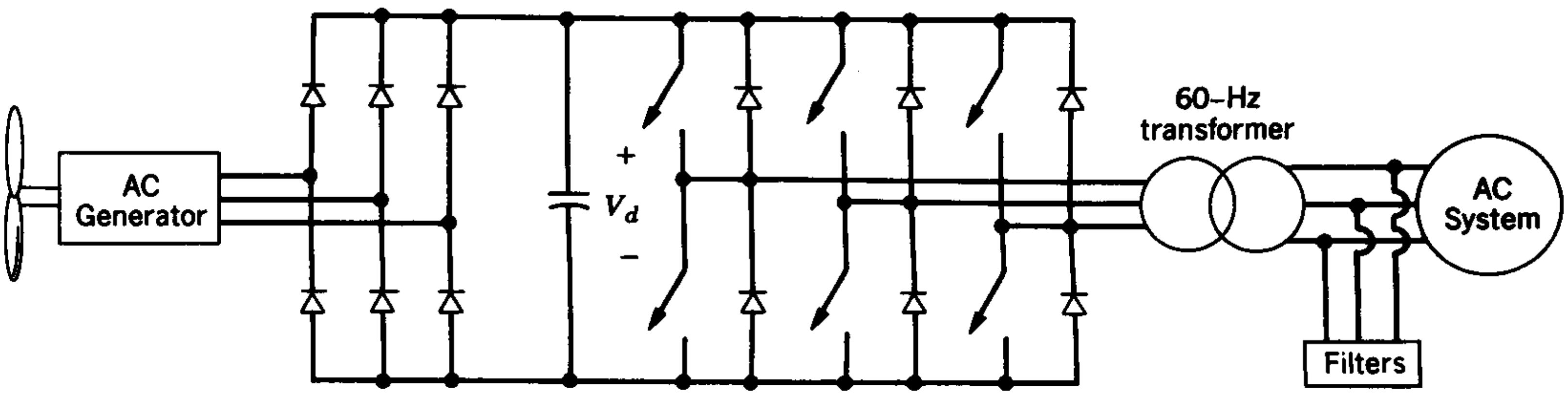
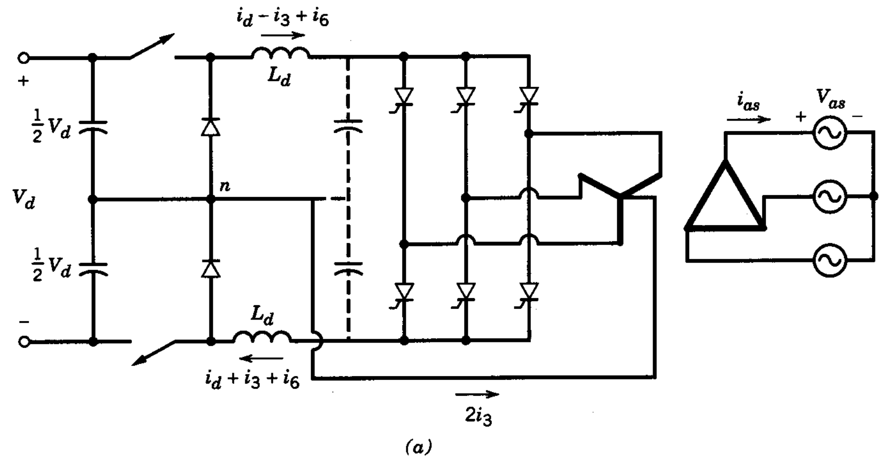


Figure 17-14 Interconnection of wind/hydro generator.

- A switch-mode inverter may be needed on the wind generator side also

Interface with 3-Phase Utility Grid



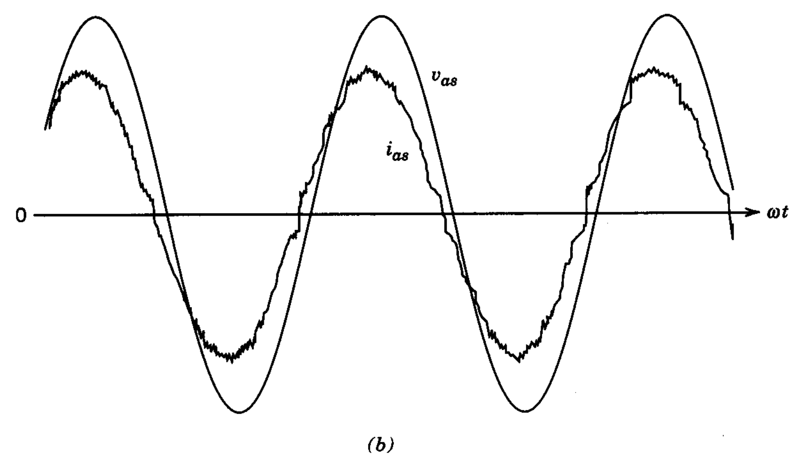


Figure 17-15 New topology, utility interface [12].

- Uses a thyristor inverter

Interface of SMES

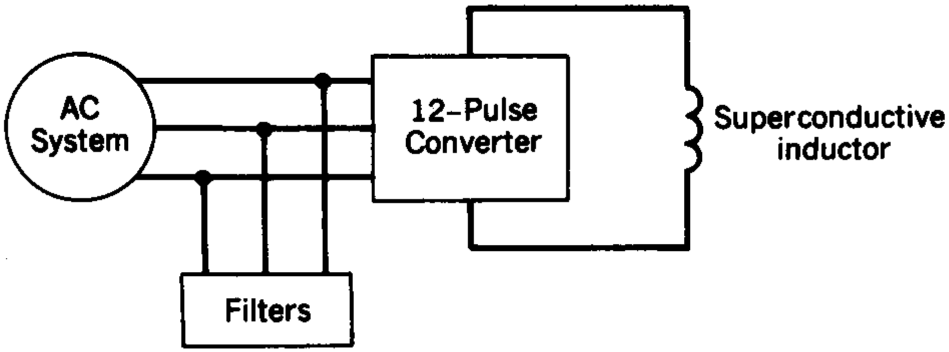


Figure 17-16 Superconductive energy storage inductor interconnection.

- Can be used for utility load leveling

Active Filters for Harmonic Elimination

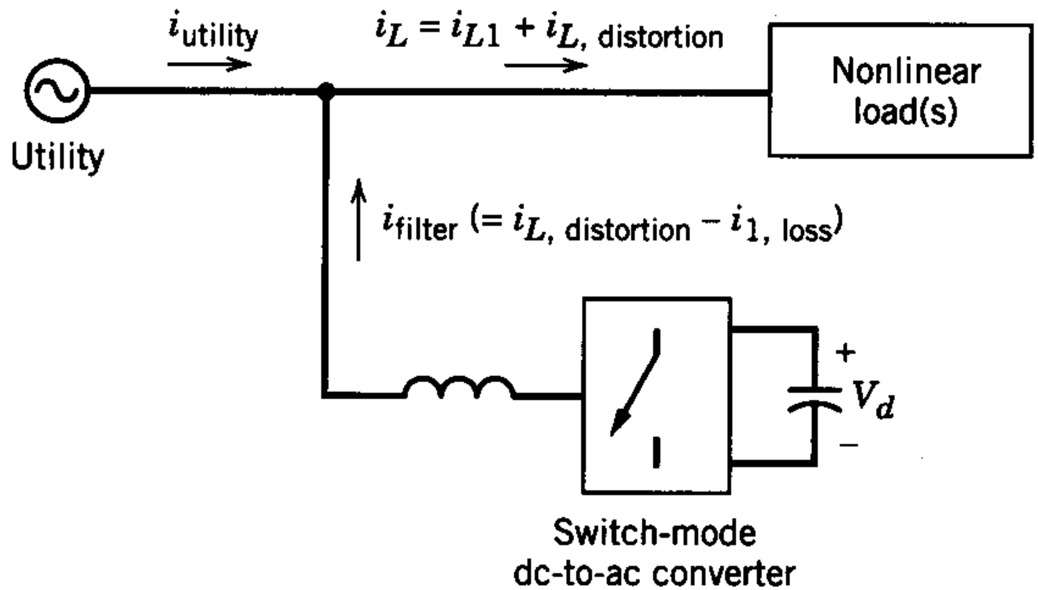


Figure 17-17 One-line diagram of an active filter.

- Active filters inject a nullifying current so that the current drawn from the utility is nearly sinusoidal