Power factor correction

- It is very common that load (motors, power lines, etc) is inductive, i.e. $Q>0$.
- Common practice to bring the power factor to unity is to connect a parallel capacitor across the load, such that $Q_C=-Q$. (the method is easy and need not break the circuit).
Example 7.8, P345: power factor correction

In theory, the power factor can be corrected to unity by putting a capacitor in series with the load. However, it is found (ex. 7.9) that this configuration will result in significant increase in the current, and thus increase the power required by the generator.
Electrical Consumption: why is ac important

• Consider a city such as Newark, DE. Assume that 30,000 citizens wish to dry their hair at the same time; that would require approximately 50 MW (30,000 x 1500W = 45,000,000 W). (The actual Delmarva Power Fall 1995 figure was a peak demand of 2500 MW for 400,000 customers, yielding an average of more than 6000 W per user.)

• At 120 V, this power would require a current of \( I = \frac{P}{V} = \frac{50,000 \text{ kW}}{120 \text{ V}} = 400 \text{ kA}. \) A 10-gauge wire (5 mm\(^2\) cross-sectional area) can handle 30 A before overheating -- thus more than 13,000 such wires would be required or a wire of diameter 15 cm, both physically unreasonable!

• To deliver a particular amount of power, the current may be decreased by increasing the voltage, since \( P = I \cdot V \). For example, boosting the voltage to 80 kV results in a current of \( \frac{50,000 \text{ kW}}{80 \text{ kV}} = 600 \text{ A}, \) a much more manageable value. The ratio of currents between 80 kV and 120 V is 670 -- the energy lost in the transmission lines would be that ratio squared, approximately one-half million, since the power dissipated by the transmission lines is proportional to the current squared.

• If a device exists that can raise or lower voltages while maintaining power, with very little loss of energy, then power can be transferred over greater distances with less loss. Electric power stations can thus be situated further from residential areas. Such a voltage conversion is difficult with dc; however, the conversion from one ac voltage to another is straightforward when the electrical component known as a transformer is used.
Transformer

Transformation of Voltage:
\[
\frac{V_{\text{out}}}{V_{\text{in}}} = \frac{N_{\text{out}}}{N_{\text{in}}}
\]

- \(N_{\text{out}} > N_{\text{in}}\) step-up
- \(N_{\text{out}} < N_{\text{in}}\) step-down

Ideal Transformer:
\[
\begin{align*}
\text{P}_{\text{out}} &= \text{P}_{\text{in}} \\
(IV)_{\text{out}} &= (IV)_{\text{in}} \\
\frac{V_{\text{out}}}{V_{\text{in}}} &= \frac{I_{\text{in}}}{I_{\text{out}}}
\end{align*}
\]

Transformers may also be used to transform impedances; e.g., coupling the output of a stereo amplifier (\(R_{\text{out}} \sim 1\) kohm) to a speaker of 4 or 8 ohm impedance for maximum power transfer. Refer to pg. 794 of HRW for impedance matching applications.

Transformation of Resistance:
\[
R_{eq} = \left(\frac{N_p}{N_s}\right)^2 R_{\text{load}}
\]
Electrical Power Distribution

**Schematic of electrical power distribution**

- **Transmission lines**
  - Power plant: 18 kV
  - ~100s miles: 350 kV
  - City/urban: 18 kV

- **Distribution lines**
  - Residential: 115 V, 230 V
  - Industrial or commercial: 115 V
  - Power grid: 46 kV
  - Generating plant: 18 kV

- **Transformers**
  - 3Φ step-down transformer
  - 3Φ step-down transformer
  - Center-tap transformer
  - 4,800 V
  - Power grid: 4,800 V
  - 120/240 V

- **Connections**
  - residential: 115 V, 230 V
  - 3Φ step-down transformer
  - Center-tap transformer
  - 4,800 V
  - 120/240 V
  - Three-wire service

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