EEE-102 Basic Electrical Engineering
Homework #6 Losses

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https://psquare-lab.github.io/teaching/

1 Electricity Fundamentals

An atom consists of a positively charged nucleus surrounded by a swarm of negatively charged electrons. While most electrons are tightly bound to the nucleus, good conductors, like copper, have free electrons that move easily, constituting an electric current.

Three important electrical properties of power are:

1. **Current (I)**: Measured in amperes, it refers to the rate at which electrons flow. Electric power (P) is given by $P = I \times V$.
2. **Voltage (V)**: Measured in volts, it is the potential difference that causes charge to flow.
3. **Resistance (R)**: Measured in Ohms (Ω), it opposes electric current flow.

Resistance in a conductor depends on the material's resistivity, length, and cross-sectional area. Resistance increases with length and temperature and decreases with greater cross-sectional area.

2 Resistive Losses

Ohm's Law defines the relationship between voltage, current, and resistance as:

$$V = I \times R$$

Since power is given by $P = I \times V$ and substituting Ohm's Law,

$$P_{\text{loss}} = I^2 \times R$$

This means resistive losses increase with the square of the current. To reduce losses, power transmission is done at high voltage to minimize current.

3 Example Problem

A load requiring 120 W is located 50 ft from a generator, operating at 12 V. A 14-gauge wire with a resistance of 0.2525 Ω per 100 feet is used. Compute power losses.

3.1 Solution

Total wire length: 100 feet (to load and back), resistance: 0.2525 Ω.

At 12 V:

$$I = \frac{P}{V} = \frac{120}{12} = 10 \text{ A}$$

$$P_{\text{loss}} = (10)^2 \times 0.2525 = 25.25 \text{ W}$$

Loss percentage:

$$\frac{25.25}{145.25} \times 100 = 17.4\%$$

At 120 V:

$$I = \frac{120}{120} = 1 \text{ A}$$

$$P_{\text{loss}} = (1)^2 \times 0.2525 = 0.2525 \text{ W}$$

Loss percentage:

$$\frac{0.2525}{120.2525} \times 100 = 0.21\%$$

4 Additional Problems

4.1 Problem 1

A transmission line carries a power load of 500 W over a distance of 200 ft using a 12-gauge wire with a resistance of 0.201 Ω per 100 feet. If the system operates at 24 V, calculate the power loss in the wire.

4.2 Problem 2

An industrial machine requires 5 kW of power and operates at 480 V. The machine is connected using a 10-gauge wire with a resistance of 0.1 Ω per 100 feet over a total distance of 500 feet. Compute the resistive losses and compare them to a scenario where the voltage is increased to 960 V.

5 AC vs. DC Transmission

High-voltage transmission is essential for minimizing losses. Historically, AC was favored due to easy voltage transformation using transformers. However, modern technologies have made high-voltage DC (HVDC) a viable alternative in some cases.