POWER LINES

Interactive Physics Simulation

To visit this simulation :

http://interactives.ck12.org/simulations/physics/power-lines/app/

Intriguing Question

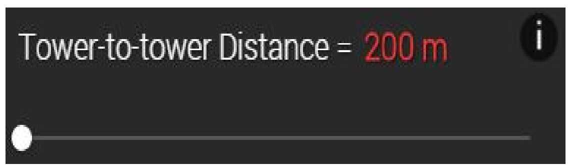
How do high-voltage lines carry electricity?

Illustrative Video

Power stations generate alternating current and voltage. Electrical transformers are used to increase the electric potential enormously (to hundreds of kilovolts). Power lines have small, but not zero, resistance, that depends on their material, diameter, and length. This nonzero resistance means that when the wires carry current, small voltage drops occur from one tower to the next. Is much electric power lost? Let's play around in the simulation.

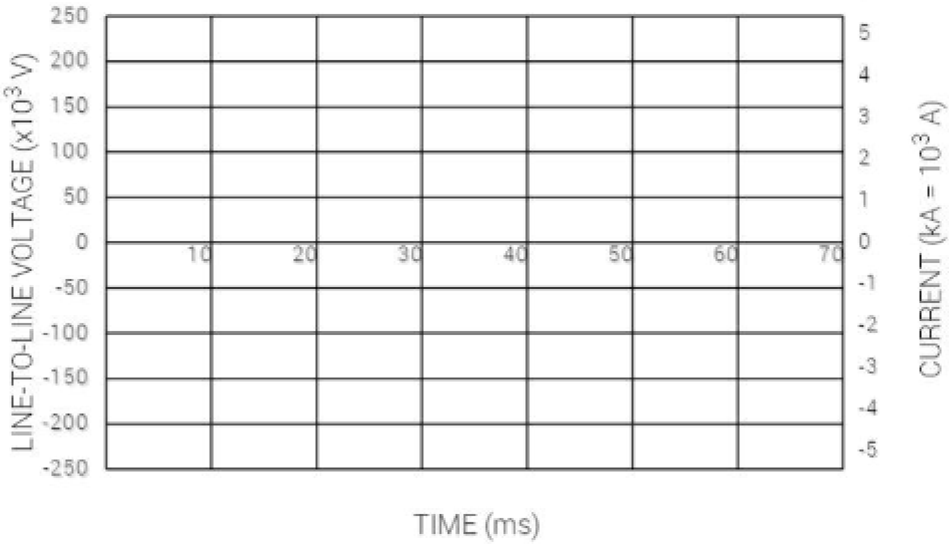
Interactive Simulation

RMS Current - Since the current swings from positive to negative, through zero, its average is zero! The 'rms' (or root-mean-square) gives us a ballpark sense of the overall amount of current flowing one way or another at any given amount of time.

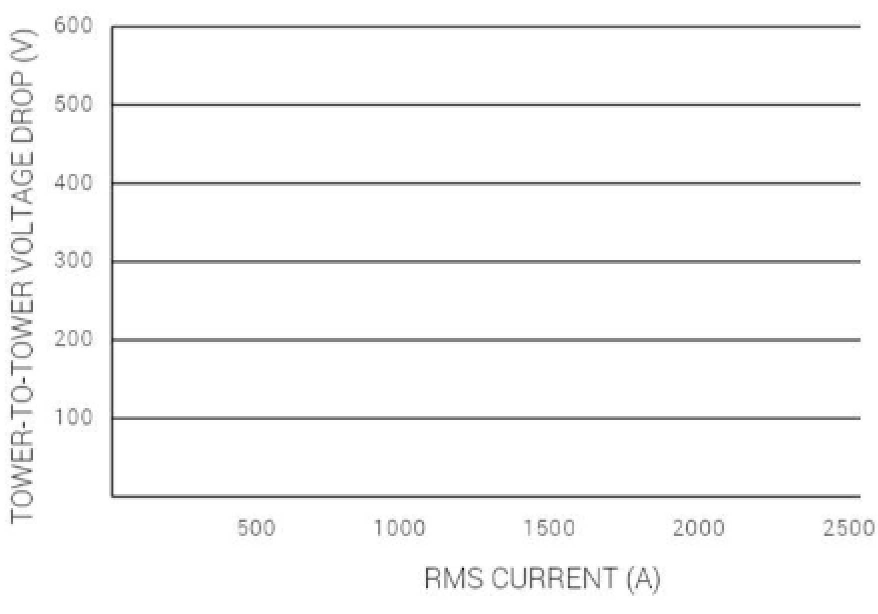


Tower-to-tower Distance - Each unit of length of wire has some resistance - so the longer the wire, the more the electrical resistance.

Cable Thickness - Thicker wires have more conducting paths through which the electrons can travel, and therefore have lower overall electrical resistance.



Line-to-Line voltage Vs. Time and Current Vs. Time - This is a graph of the voltage and current in the cable. Both are oscillating because power lines like these carry alternating current (AC). In the United States, these oscillate back and forth 60 times per second, which is why the period of oscillation is so very short. When a value is oscillating back and forth, its average value is zero, so we have also plotted the RMS (root-mean-square) current and voltage, which give you a sense of the average magnitude of each.



Tower-to-Tower Voltage Drop Vs. RMS Current - This is a plot of the RMS voltage drop (vertical axis) vs. the RMS current (horizontal axis) in the power line. The slope of this graph is a measure of the electrical resistance of the length of wire.

Interpreting Results

If the RMS current is 2500 A and the tower-to-tower distance is 800 m, what cable thickness will result in a tower-to-tower voltage drop of 100 V? *(Set the RMS current slider to 2500 A and the tower-to-tower distance slider to 800 m. Then, adjust the cable thickness slider so that the tower-to-tower voltage drop (V), as indicated on the Y-axis of the graph on the upper right, reads 100 V.)*

If the RMS current is 1000 A, what tower-to-tower distance and cable thickness will result in a tower-to-tower voltage drop of 200 V? *(Set the RMS current slider to 1000 A. Then, adjust the tower-to-tower distance slider and cable thickness slider so that the tower-to-tower voltage drop (V), as indicated on the Y-axis of the graph on the upper right, reads 200 V.)*

Adjust the sliders to produce the greatest possible tower-to-tower voltage drop. *(Adjust the RMS current slider, the tower-to-tower distance slider, and the cable thickness slider to maximize the tower-to-tower voltage drop (V), as indicated on the Y-axis of the graph on the upper right.)*

Challenge ME!

- What is the least amount of electrical resistance you can generate in the simulation? The highest?

- If a bird stood on one of the wires, it would be safe from electrocution. But if it touched two wires or a wire & the ground, it would be in danger. Why?

- Why is the average current zero in an alternating current system?

Need Help?

Check out the Power Lines Walkthrough video at: https://youtu.be/-npq-heD_7A

Interesting Questions

How far do electrons really go?

A water wave carries momentum and energy from one place to another without any water actually moving that distance. Electricity is similar - the electrons repel each other enormously, and a slight move of one sends a ripple effect down the circuit much faster than any electron actually moves. In alternating current, the situation is even more constrained - the electrons simply move back and forth without progressing. The flow of electricity is something more than just electrons moving.

How is electricity generated?

Most (not all!) electrical power plants use magnetism and motion to generate electricity. Since the 19th century we've known that a magnet moving near a wire (or vice versa) will cause current to flow in a wire. A coal plant differs from a hydroelectric plant and from a nuclear power plant just in how the magnet (or wire) put in motion - in most cases, water is heated to steam and the steam pressure is used to spin a turbine. Solar panels work in an entirely different way - light energy (photons) energizes electrons directly.

What is a transformer?

An electrical transformer is a device that allows the voltage of an alternating current device to be stepped up or down as needed. The product of voltage and current - the power delivered - doesn't increase or decrease (energy is conserved!). This means that a transformer that steps up to a higher voltage (say from 120 V to 120,000 V) will deliver less current. A transformer relies on Faraday's Law of Magnetic Induction: oscillating current in a coil of wire on one end of the transformer generates an oscillating magnetic field. This field induces an oscillating current in a second coil of wire. The number of turns in those wires can be adjusted to step the voltage up or down.

Why are rubber and plastic good electrical insulators?

Unlike metals, which conduct electricity quite well, materials made from organic compounds (Carbon, Hydrogen, etc.) are very poor electrical conductors. This is because there are few or no electrons that can be easily dislodged from those elements and shared among all the atoms in a substance. In metals, the outermost electrons are very weakly bound to the atoms, and so are easily shared for conduction.

Physics Concepts | Click on the link below to learn more.

- Voltage and Current - http://www.ck12.org/physics/Voltage-and-Current
- Electric Conductors and Insulators - http://www.ck12.org/physics/Electric-Conductors-and-Insulators
- Ohm's Law - http://www.ck12.org/physics/Ohms-Law
- Electric Current - http://www.ck12.org/physics/Electric-Current
- Energy Transfer in Electric Circuits - http://www.ck12.org/physics/Energy-Transfer-in-Electric-Circuits