Modeling Power Grids with Snap Circuits

Wisconsin Energy Institute
UNIVERSITY OF WISCONSIN–MADISON

Overview: Students use snap circuits to model power generation, distribution, and use in a traditional grid vs microgrid system. Students use the model to develop explanations for how to help keep the lights on in communities during power outages and explore some of the characteristics of microgrids that allow for integration with small-scale renewable energy sources.

Levels
Middle and High School

Subjects
Physics, Earth Science, Environmental Science, Engineering

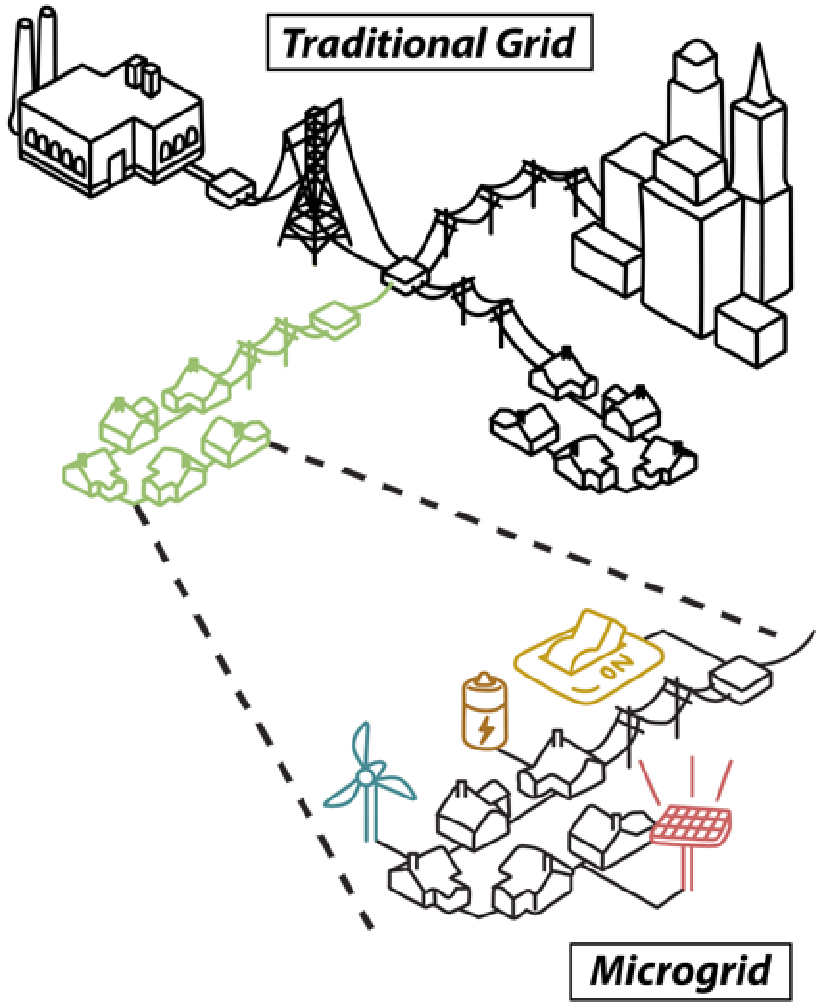
Objectives
- List the key characteristics of a microgrid and describe the similarities and differences with a traditional grid system.
- Design, build, compare and evaluate different models of traditional grids and microgrids using Snap Circuits.
- Explain how microgrids can improve the reliability of power delivery and integrate with renewable power sources such as wind and solar.

Materials
- Snap Circuits Alternative Energy Kits (1 per group, 2-4 students)
- Approximate cost: $40 each

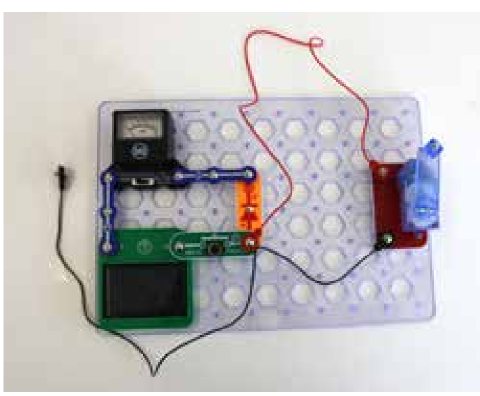
Activity Time
Two 50-minute class periods

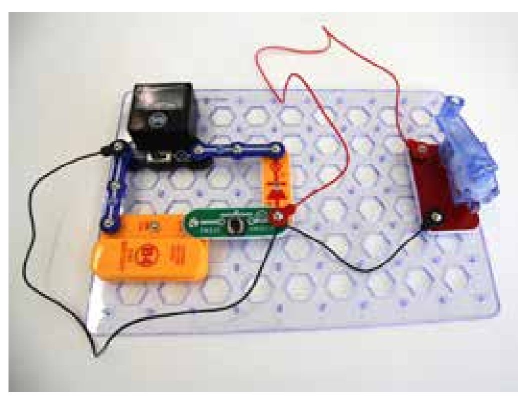
Standards
Next Generation Science Standards (2013)
- Scientific and Engineering Practices: asking questions and defining problems; evaluating different models; planning and carrying out investigations; analyzing and interpreting data; constructing explanations and designing solutions
- Disciplinary Core Ideas: energy alternatives; electricity; earth and human activity; engineering design
- Crosscutting Concepts: Traditional grids and microgrids
- Performance Expectations: See page 3 for details

NGSS Lead States. 2013. Next Generation Science Standards: For States by States. Washington DC: The National Academies Press



Classroom Microgrid Models





Overview:

Students use snap circuits to model power generation, distribution, and use in a traditional grid vs microgrid system. Students use the model to develop explanations for how to help keep the lights on in communities during power outages and explore some of the characteristics of microgrids that allow for integration with small-scale renewable energy sources.

Learning Objectives: Students will…

- List the key characteristics of a microgrid and describe the similarities and differences with a traditional grid system.
- Design, build, compare and evaluate different models of traditional grids and microgrids using Snap Circuits.
- Explain how microgrids can improve the reliability of power delivery and integrate with renewable power sources such as wind and solar.

Assumption of prior knowledge: Familiarity with electrical circuits and knowledge of the energy transformations associated with generating electricity.

Next Generation Science Standards (2013)

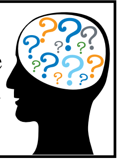
- **4-PS3-2** - Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
- **MS-ETS1-2** - Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- **HS-PS3-3** - Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy
- **4-ESS3-2** - Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.
- **HS-ESS3-4** - Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- **HS-ETS1-3** - Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Sequence:

Part 1: Modeling a simple main electric grid. The purpose of an electric grid system is to generate electricity and distribute it for its end uses, such as lighting, powering electronics, and heating. In this activity students will use a snap circuit model to answer the question "What needs to happen for the lights to come on in your building?"

Introduction and pre-assessment:

What has to happen for the lights to come on?

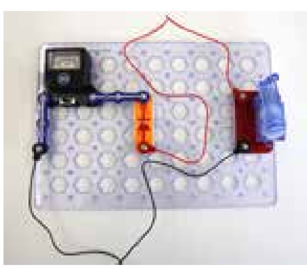


1. Introduce the guiding question, "What needs to happen for the lights to come on in your building?" Switch the light on and off in the classroom to engage students. In small groups, have students discuss and write down and/or illustrate their initial ideas. Slide 2.

Discussion

2. Pool ideas and probe student understanding of how electricity is generated, distributed, and used.
3. Using whiteboard, posters, etc. Sort student ideas into the three main stages: power generation, distribution, use. Come to a consensus definition of the purpose of the stage and list specific examples. Slides 3-4.

Modeling the grid with Snap Circuits:



Model Traditional Grid

1. Using the Snap Circuits Alterative Energy kits, have students working in groups of 2-4 to construct a model of a traditional grid system with power generation, distribution and use (Slide 5).

   Option 1: Remove the instructions and images from the worksheet and let students create their own model from scratch with the materials in the kit.

   Option 2: Have students use the sample model from the illustration and directions on the worksheet.

2. After students work through the first two questions, discuss and address any questions and misunderstandings that come up related to the basic physics of electricity generation and circuits. Drawing a simple circuit diagram as a class or in small groups can be helpful.

3. Have students share examples for question #3 (types of generation, uses, etc). These can be added to the poster or whiteboard diagram under the components of the electrical grid (generation, distribution, use).
4. Discuss and/or construct a shared analogy map (student handout) comparing the microgrid model to the real electric grid. Then have students share some examples for how they used the Snap Circuits to model a power outage. (Slide 6).

Discussion

5. Assessment: Students can revisit and revise their answers to the guiding question "What needs to happen for the lights to come on?"

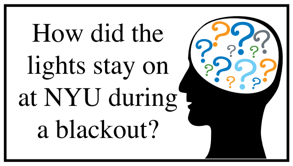
Extensions and variations:

- Students can investigate the process of generating power from different energy sources.
- Look at your state's energy portfolio and nearby power plants on the Energy Information Administration: http://www.eia.gov/state/

Part 2: Modeling a microgrid. A microgrid does the same things as a traditional grid: generates electricity and distributes it to end uses, but at a smaller scale. The main grid is an interconnected network of power plants, transmission lines, and communities that covers many states. But a microgrid is a small network of power sources and uses that can serve a city, neighborhood, or building. A microgrid can connect and disconnect from the traditional grid and offers flexibility to use smaller-scale renewable energy sources, such as wind and solar.

Students will propose explanation for why the lights stayed on in some places like New York University during the massive blackout in Manhattan during Hurricane Sandy. They will then modify their grid model to include features of a microgrid that could "island" from the main grid and keep the power on during a blackout.

Introducing the problem:



1. Show students the aerial night photo of Lower Manhattan during the Hurricane Sandy black out and have them share observations and questions. (Slide 7). Explain that the region with lights still on is the New York University campus.
2. Pose the question: "How did the lights stay on at New York University campus during the massive blackout during Hurricane Sandy?" Have students develop their explanations in small groups and then share out.

Modeling a microgrid with Snap Circuits: Student handout Part 2

Introduction to Microgrids

3. Introduce the concept of a microgrid and it's key elements using this video (https://youtu.be/qwVggeO_GTY) presentation graphics (Slides 9-11).
4. Students modify their grid model to include key elements of a microgrid: 1) ability to operate independently of main grid ("islanding") and 2) ability to incorporate multiple power sources (local, small-scale generation, and regional larger scale power plants).

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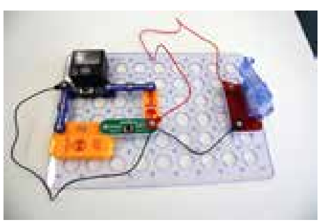
   Option 2: Have students use the sample model from the illustration and directions on the worksheet.



Model Microgrid

5. After students construct, use, and answer questions about their microgrid models in small groups, discuss answers as a class (PPT slide). Discuss limitations of the model and ideas for improvement.
6. Construct the Frayer diagram as a class, comparing the similarities and differences between a microgrid and traditional grid system.
7. Share some examples of how microgrids are used around the world (PPT slides).
8. Assessment: Students can revisit and revise their answers to the guiding question "How did the lights stay on at New York University campus during the massive blackout during Hurricane Sandy?"

Discussion

Extensions and variations:

1. Groups can work together and share Snap Circuit parts to improve their models so that they more easily island in the case of blackouts and switch between power sources.
2. Learn more:
   - Read about microgrids research at the Wisconsin Energy Institute, UW-Madison: https://energy.wisc.edu/news/micro-macro-uw-madisons-expansion-microgrid-idea
   - The Lawrence Berkeley National Lab description of microgrids and examples, https://building-microgrid.lbl.gov/about-microgrids-0

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