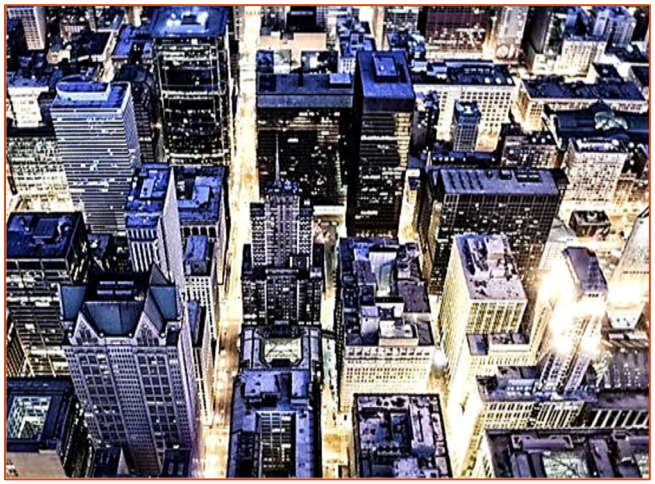
Electronics You Might Not Have Learned in College Lesson 7: Alternating Current Generation and Transformers

An Online Continuing Education Course for Engineers

Course Number: E-7008

Credit: 7 Hours / 7 PDH / 7 CPD

ALTERNATING UTILITY CURRENT GENERATION AND TRANSFORMERS



This lesson grew to be much more information than what was expected. AC power is used everywhere in our modern society, and there are so many ways to generate and transmit it to millions of users. There are massive hydroelectric dams, atomic power plants, wind farms, coal and oil-burning electric plants, and solar collectors. All this is to create energy to light our homes, refrigerate and cook our food, heat our houses and water, and power our television sets and charge the batteries in our phones. But, electric power does so much more. It powers traffic signal lights, street lights at night, light stores, schools, offices, and restaurants, and powers airports and electric rail transportation. Our thousands of manufacturing plants use electric power to do everything from tracking parts to huge electric furnaces to melt and forge steel.

There are very few places in the world where we cannot see power lines carrying millions of watts of energy across hundreds of miles. From simple wood poles to huge steel towers, three-phase power is strung to nearly everywhere on earth. Aside from water and food, electricity is considered the main need for civilization.

The use of power is so universal and has had so many inventions of new uses that it is nearly impossible to condense the lessons down to a shorter list. After completing this course, the student will have at least introductory knowledge of the following items that are covered in this lesson.

- The early history of electric generation from the Baghdad battery to the first dry cell batteries and electrostatic generators
- The war of the currents, the battle between Edison, Tesla, and Westinghouse for dominance of either AC or DC power
- How self exitation of generators works
- The difference between AC and DC generators and the use of magnetics for power generation
- What is a DC generator, and what are its advantages and disadvantages
- What are the main components of an AC generator, and what are its advantages and disadvantages
- What are the similarities between AC and DC generators
- How are currents magnetically induced in wires
- What is Lenz's law, and why is it important
- Introduction to a simple DC generator and motor
- Water analogies for DC and AC currents
- What is AC current, and how is it generated

- What is RMS voltage and current, and how are they calculated
- What is the effect of AC frequency changes
- History of transformers, induction coils, and theory of transformer operation
- Water analogies for inductive coils and transformers
- Why power is transported at high voltages, and basic power equations
- Power loss in conductors and wire resistance
- Ideal transformers and deviation of real transformers from ideal transformers, and transformer isolation
- Examples of transforming voltage and current
- Preservation of energy, magnetic flux, magnetizing force, and remanence
- Hysteresis losses and eddy currents
- What are volts, amps, watts, and center-tapped transformers
- What is leakage flux and core losses
- Using the Steinmetz equation, no-load test calculations, and transformer EMF equations
- Transformer polarity markings, energy losses
- Construction of transformer cores, laminated steel cores, eddy current mitigation, and air gaps in cores
- Ferrite core transformers, toroid cores, air cores, and winding transformers.
- Using Litz wire to reduce losses in transformers
- Transformer taps, transformer cooling, insulation
- Classification parameters for power transformers and applications for larger and smaller transformers
- What are standard voltages used for distribution power
- Back-up electric generators, generator terminology, specialized generator types, DC generators, homopolar generators, magnetohydrodynamic generators, AC generators, and induction generators
- Linear electric generators, variable speed generators, constant frequency generators, backup generators at power stations, and mobile generators
- A wide variety of other uses for generators, such as for powered bicycles, power generation on sailboats, generators on recreational vehicles, electric scooters, gensets (powered generators), human-powered generators, and measurement of shaft speed.

NOTES ON HOW THIS LESSON IS WRITTEN

It is assumed that anyone taking this course is familiar with most technical terminology, even if their area of engineering expertise is outside the world of electronics. **Even though previous lessons of this course are not needed to understand this lesson, the student should have some knowledge of basic electronics, which provides the confidence to do this session.** Most terms that might be new to the student are CAPITALIZED or **bolded** the first time they appear. Usually, they will be explained, or their meaning becomes clear in the following narrative. In some cases, it might be necessary to look up the

terms if their meaning remains foggy. Generally, things that are considered important will also be in bold letters.

While reading this course, it may be noted that some material is repeated or explained in different ways throughout the lesson. Also**, the student might notice that if there are different terms or symbols to express one thing, they might all be used interchangeably during the course lesson. For example, a 10-ohm resistance might be expressed also as a 10 Ω resistor, a 0.01 K resistor, or a ten-ohm resistor.** This is intentional to aid the student's retention of the various terms, eliminate the need to go back in the literature for reminders, provide various approaches to explain new things that might help those who think and learn in diverse ways, and also help them become familiar with terms that might be used interchangeably by different technicians and engineers.

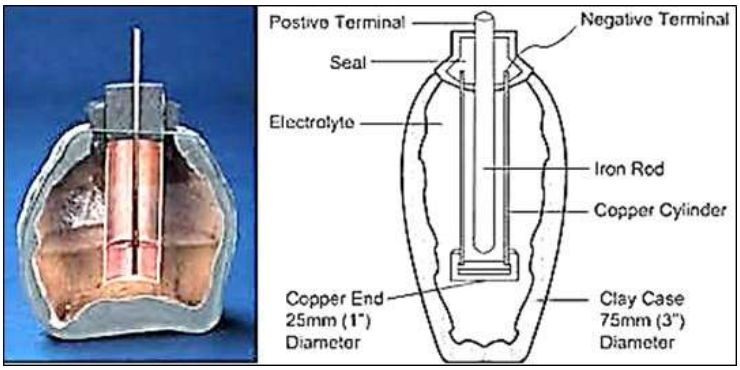
EARLY HISTORY OF ELECTRIC GENERATION

EARLY MYTHOLOGY

The science of electricity really wasn't invented by any one person. The friction of moving clouds causing massive lightning strikes has been known since our ancestors first walked the earth. Lightning was seen to be very powerful, even if no one could control or understand it. As with many other seemingly miraculous events, humans needed to form religions, myths, and gods to give lightning meaning. Some of the most prominent mythologies featuring lightning gods are the Greeks with their chief god, Zeus, the Nordic people with Thor, the Hindu god, Indra, and the Slavic god, Perun. Due to early people's fear and awe of the destructive power of lightning bolts, deities who are able to control lightning are commonly described as powerful rulers of the sky and weather. Generally, they wield fierce weapons such as Zeus's thunderbolts or Thor's hammer. Lightning is such a powerful and magical phenomenon; it was only natural that thousands of lightning gods and myths would spread through all civilizations.

Slowly, over thousands of years of observation, curiosity, and invention, science and explanations began to replace the ignorance and myths of the past. Early observations and experiments with static electricity were done as long ago as 600 BCE by Thales of Miletus, Greece. In his 1600 book De Magnete, William Gilbert coined the term "electricity" from the Greek word electron, which was their word for amber. By differentiating the attractive force of static observed in rubbed amber from magnetism, Gilbert started the foundation for modern electricity and magnetism studies. He also coined terms like "electric force" and "magnetic pole" for magnetism. Benjamin Franklin's kite experiment in 1752 helped link lightning to electricity. In 1800, Alessandro Volta invented the first practical battery, and finally, Nikola Tesla and Thomas Edison pioneered AC/DC power systems and practical applications in the late 1800s that led to the exponential rise in modern electrification.

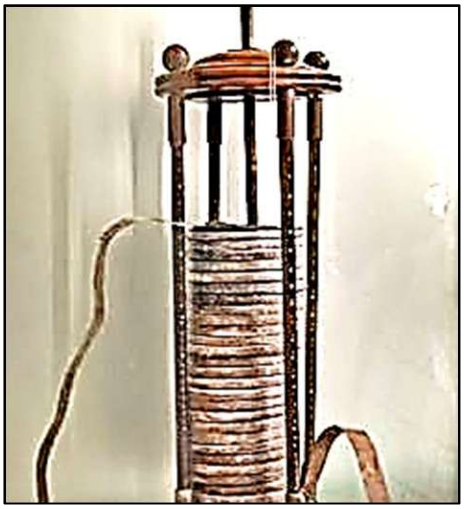
THE BAGHDAD BATTERY



Possibly the oldest known battery is called the Baghdad Battery, which is shown at right. It is a clay jar that contains an iron rod, a copper cylinder, and a stopper. If filled with an acid, such as vinegar, it could have produced one to two volts of electricity. It is a 2,200-year-old artifact discovered near Baghdad, Iraq, dated to the Parthian period (roughly 250 BCE to 250 CE). Its exact purpose is still debated, with theories suggesting it was used for electroplating or for a magical or religious ritual. There have been some speculations that several of these cells connected in series might have been used for electroplating. However, no evidence of any such use has been discovered**. Since there is no consensus on whether it was actually used to generate voltage, it is more considered a novelty than an actual discovery of electricity.**

ELECTROSTAT OF THE FIRST RECOGNIZED BATTERY

Alessandro Volta invented the first true battery in 1800. It came to be known as the voltaic pile, which consisted of pairs of copper and zinc discs piled alternately upon each other. They were separated by a brine-soaked cloth and are considered to be the first battery to produce a continuous electrical current. The differing electronegativities of the metals created an electrical current as it flowed from the zinc to the copper through the electrolyte that was supplied by the brine.



OTHER EARLY BATTERY INVENTIONS

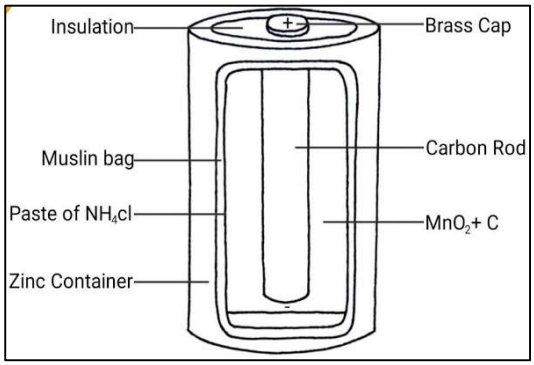
Building on the battery stack, Gaston Planté invented the first rechargeable battery in 1859 (the lead-acid battery). An example of an early rechargeable battery is shown at right. The rechargeable battery is a technology still in use today, particularly for backup battery storage and automobile ignition. It used lead plates and sulfuric acid to create approximately two volts per cell. Soon, cells were combined in larger batteries. The most common were "3 cell" and "6 cell" batteries. In the 1950's, automakers switched to 12 V battery systems to handle more accessories such as power windows, radios, and air conditioning systems.

While cases for early batteries were mainly glass, newly discovered plastics have been used for most battery cases to date. The batteries were somewhat problematic due to their "gassing" of dangerous fumes and evaporation of electrolyte (acid) solutions.

Sonnenschein introduced early commercial versions of valve-regulated technology in the late 1960s and by Gates Energy Products in the early 1970s. Sealed lead-acid (SLA) batteries were developed in the 1970s, eliminating spillage and evaporation. Modern Absorbed Glass Mat (AGM) and gel batteries emerged from these developments, making maintenance-free batteries suitable for a wider range of applications.

EARLY DRY CELL BATTERIES

The first "dry cell" battery was developed by German physician Carl Gassner in 1888. He converted the Leclanché cell by using a paste instead of a liquid electrolyte, making it portable and spill-proof for the first time. This made possible a lot of new electrical inventions, such as the flashlight (torch in England), which could be carried around and needed no cords.



ELECTROSTATIC GENERATORS

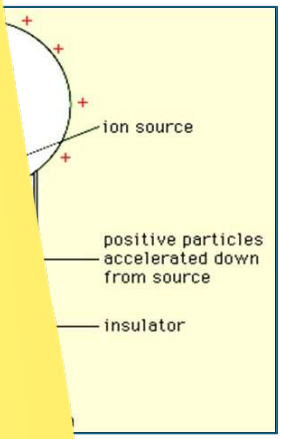
Electrostatic generators were invented before the connection between magnetism and electricity was discovered. By using moving electrically charged belts, plates, and disks that carried charge to a high potential electrode, they operated on electrostatic principles. The charge was generated using either electrostatic induction (where a charged object causes the redistribution of electric charge in a neutral object without physical contact) or the triboelectric effect (electric charge transfer between two objects when they contact or slide against each other). Static generators created very high voltage and low

current. They had such low current that people could "zap" each other with the voltage with no effect other than a slight shock.

Since they were very inefficient and required a lot of insulation because of their high voltage, electrostatic generators had low power ratings. They were never used for the generation of commercially significant quantities of electric power. Their only practical applications were to power early X-ray tubes and, later, in some atomic particle accelerators.

People have been experimenting with static electricity since a human petted a cat. However, the history of true electrostatic generators designed to create charges h mid-1600s. Otto von Guericke created a sulfur ball that would ho e like wool, using friction to generate st for the static charges.

However, later scien and Benjamin Frankli spheres and pads to c Plate-style machines w followed quickly by the that could actually store



The Van de Graaff gener invented in 1931. It was generating static electricit to transfer charge to a hig output of the generator sh (10,000 volts). Depending son could get quite a painful shock. Howe jury. Generally, they were only novelties that amu the picture to the right, whos positively charged and repelled itself. Van de Graaff generators are still widely used today to create high-voltage static charges.

To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course.

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FARADAY DISK GENERATOR

Michael Faraday discovered the operating principle of electromagnetic generators in the years of 1831–1832. The principle is that an electromotive force is generated in an electrical conductor that encircles a varying magnetic flux. The principle was later called Faraday's law of induction.