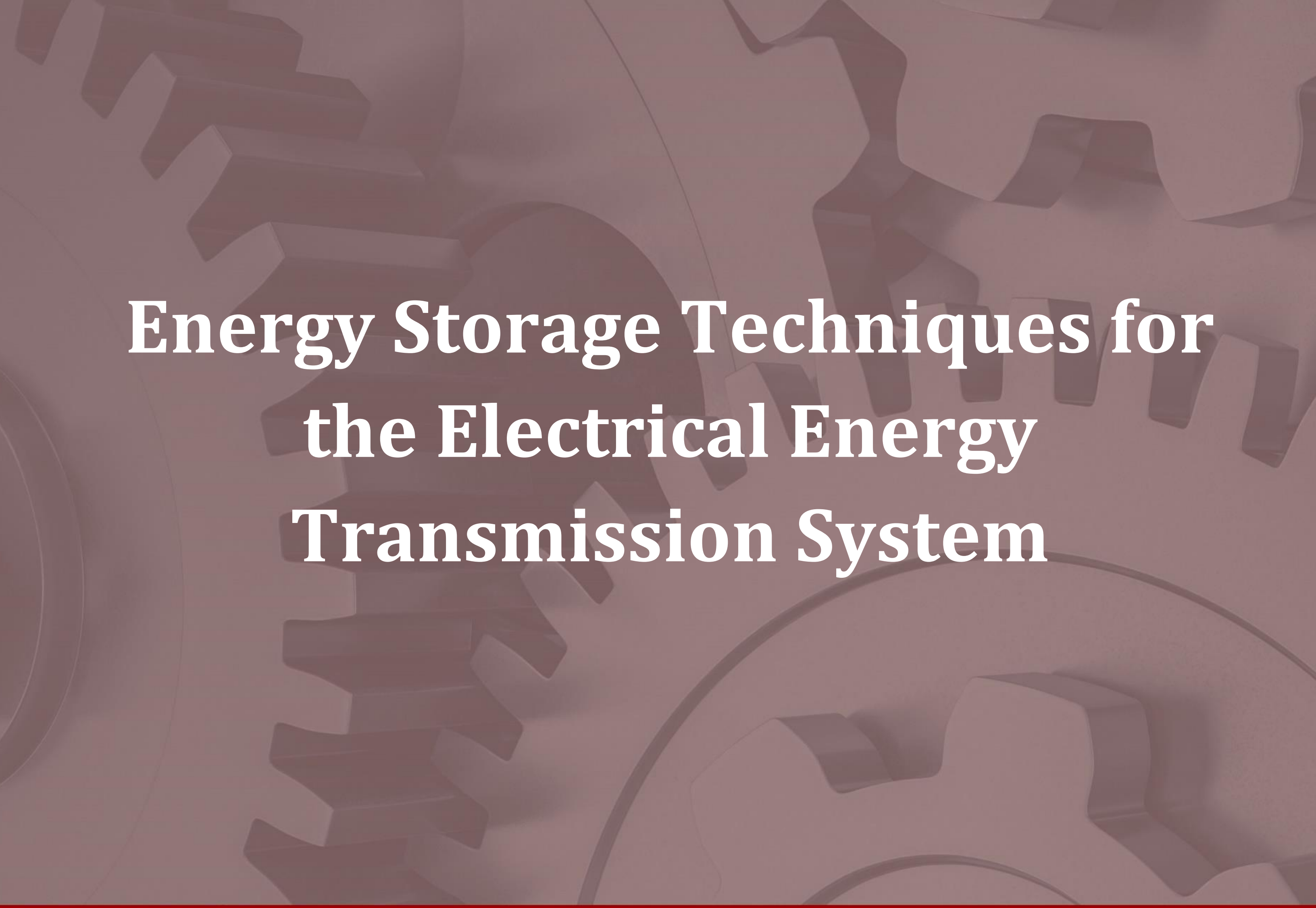

Energy Storage Techniques for the Electrical Energy Transmission System

An Online Continuing Education Course for Engineers

Course Number: E-1031
Credit: 1 Hour / 1 PDH / 1 CPD

Energy Storage Techniques for the Electrical Energy Transmission System

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1. Introduction

Energy storage has become very important as electrical energy generation is changing from traditional techniques to renewable techniques. Traditional techniques include, but are not necessarily limited to, burning coal, crude oil, natural gas, and uranium. Renewable techniques include, but are not necessarily limited to, solar, wind, hydro, geothermal, biomass burning, and a new technique called hydrokinetic energy. One problem with many renewable energy techniques is that the source is not usually available 100% of the time—the sun doesn't shine all day, the wind is not always blowing, and even hydro and hydrokinetic energy depends upon rainfall, which is not consistently available everywhere, even where rainfall is expected on a regular basis. Snowmelt is seasonably dependable but only lasts for a limited time.

The electrical grid must be able to supply electrical energy when and where it is needed. This is a real balancing act, as the energy is used by customers at the same time that it is generated by the electrical power companies. The users (us) draw the energy from the grid and could cause the voltage to drop at the same time that the generator is supplying energy to the grid. Figure 1.1 gives us some idea of how this happens. As the load changes with customer usage, the customer voltage could change. The power company has to adapt. With typical thermal generating techniques, the generator operator just pushes the generator a little harder and raises or lowers the grid voltage to compensate as the load changes. Controls could make this happen automatically. If we are using renewable energy techniques as the power generator, it is not as easy to adapt. Most renewable energy techniques are just not that controllable. They change with conditions, seasons, and time of day. Therefore, some way has to be developed to add extra energy to the grid if the customer load varies and voltage changes. As we move to more and more renewable energy, various energy storage techniques have been developed to help solve this problem. They all have their advantages and disadvantages.

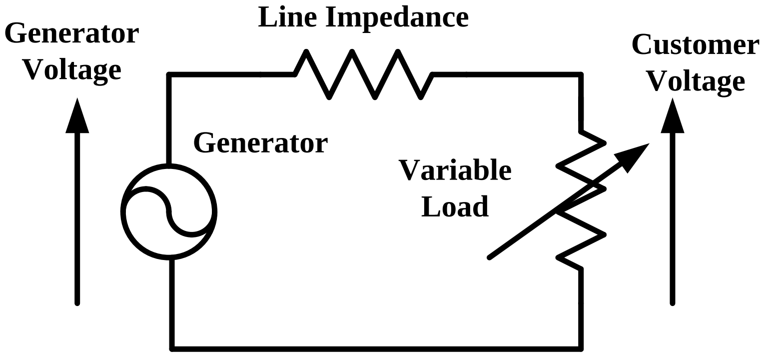
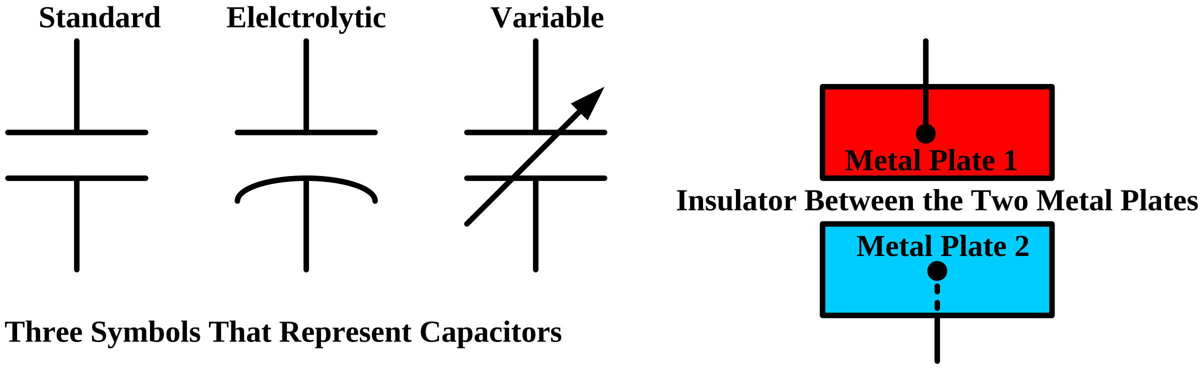


Figure 1.1 How a Typical Variable Load Could Affect Electrical Grid Voltage

With the above in mind, let’s look at various energy storage techniques. Energy storage can be mechanical, chemical, thermodynamic, or electrical. We will start by using capacitors as an electrical energy storage technique, which is an electrical/chemical technique. Some capacitors have a chemical insulator.

2. Capacitors as Energy Storage Devices

One of the simplest energy storage devices is a capacitor. A capacitor is simply 2 metal plates separated by an insulator. Figure 2.1 shows three electrical symbols that represent capacitors and a picture of how they are made. In this particular case, the symbols and the device are very much alike. All through this course, we will be making drawings of models of devices, which are not really actual devices. To get an idea of actual devices, we either have to hold them, get near them, or dissect them. I recommend that you do that if it is possible.



Three Symbols That Represent Capacitors

Actual Diagram of How Capacitors Are Made

Figure 2.1 Three Symbols Used to Represent Capacitors and Picture of How They Are Made

In practice, the metal plates, or conductors, can be made of almost any conductor, although aluminum is most often used. This is because aluminum is easy to work with, can be easily rolled into thin thicknesses, and is relatively inexpensive. The insulator can be any material that does not conduct electricity easily.

The energy of a capacitor is given by **$W = ½ C * V^2$.** For a capacitor, in the SI system of units, the energy (W) is usually given in watt-seconds or joules, the capacitance (C) is usually given in Farads, and the Voltage (V) is usually given in volts. A big problem with using capacitors as energy storage devices is that it takes a really big capacitor to store large amounts of energy. They also tend to discharge over time, as the insulator is quite often not a perfect insulator. The capacitance of a capacitor is given by the equation, $C = (\varepsilon * A)/d$ where ε (permittivity) is a constant determined by the insulator, A is the area of the plates in meters^2 and, and d is the distance between the plates in meters. In practice, ε is different for different insulators. This is usually written as $\varepsilon = \varepsilon_r * \varepsilon_0$ where ε_0 is equal to $8.854 * 12^{-12}$ Farads per meter and ε_r depends upon the insulator. ε_r has a value of 1 for a vacuum and about 1 for air. The value ranges from about 2 to 50 for many standard insulators and can have a value of about 250,000 for calcium carbon titanate.

Because of the fact that large capacitors take a lot of space, capacitors are not usually used as electrical energy storage devices in the power industry. They also tend to self-discharge because perfect insulators are almost impossible to make. A vacuum is the best insulator. Capacitance is usually given in microfarads (ufarad) for capacitors that can be made. Figure 2.2 is a picture of typical capacitors. The picture shows standard capacitors, electrolytic capacitors, and variable capacitors. Electrolytic capacitors have much higher capacitance values than standard capacitors. They also have to be connected with the proper polarity. Their lifetime is also somewhat limited. The electrolytic capacitors in the drawing are the six with the plastic covers.

Figure 2.2 A Picture of Various Types of Capacitors

By Eric Schrader from San Francisco, CA, United States - 12739s, CC BY-SA 2.0, https://commons.wikimedia.org/w/index.php?curid=37625896

A new type of capacitor has been developed that is called a Super Capacitor. They are usually low voltage devices, typically 5 volts. Many are being made that have a 1 Farad capacitance. I used one of these devices to hold power on some digital logic circuits in a temperature controller that I made, and it worked quite well in the application. The low voltage rating makes them not very usable in the electric power storage area. Figure 2.3 is a picture of a Super Capacitor. The one shown is a 5.5 volt, 1 Farad device. The maximum energy storage of this device is $W = ½ * C * V^2$, which is equal to 15.125 joules. To put this into perspective, 1 joule or watt-second is equal to 0.738 foot-pounds. That means that 15.125 joules are equal to a little over 11 foot-pounds. That is not a lot of energy. From another perspective, it takes about 270,000 foot-pounds of energy to light a 100 watt light bulb for just one hour.

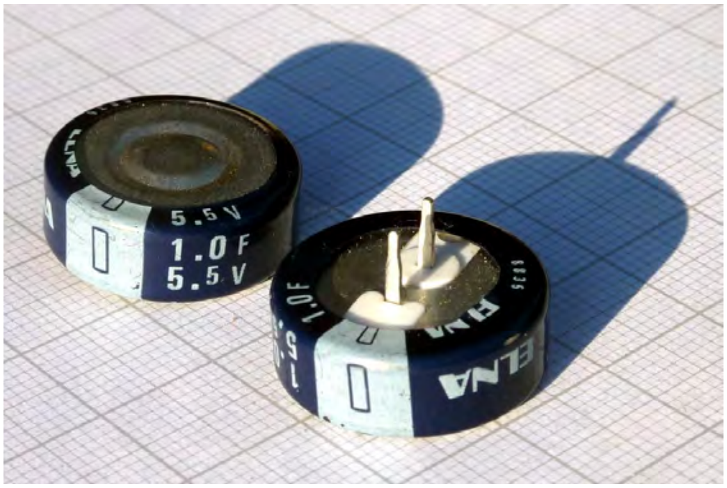


Figure 2.3 Picture of a Typical Super Capacitor

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As a matter of interest, leyden jars were among the first capacitors that were used as electrical energy storage devices. Figure 2.4 shows the construction of a leyden jar and an actual picture.

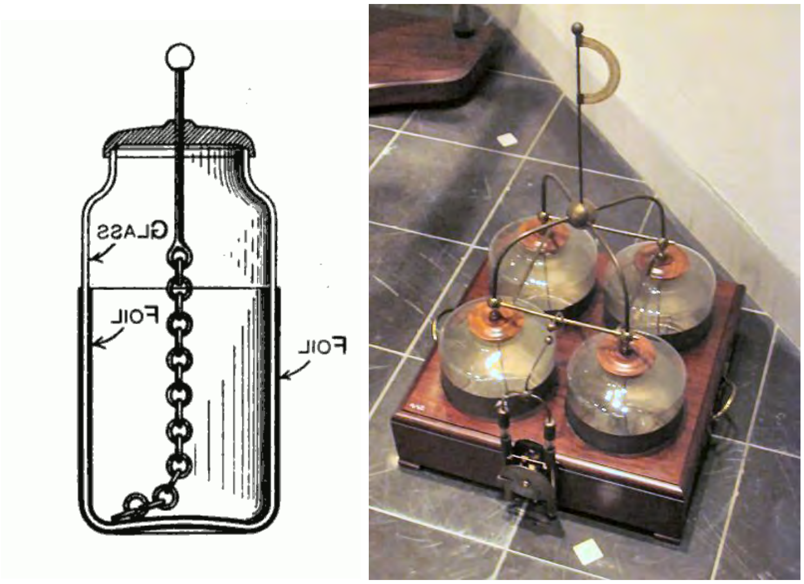

Figure 2.4 Pictures of Leyden Jars

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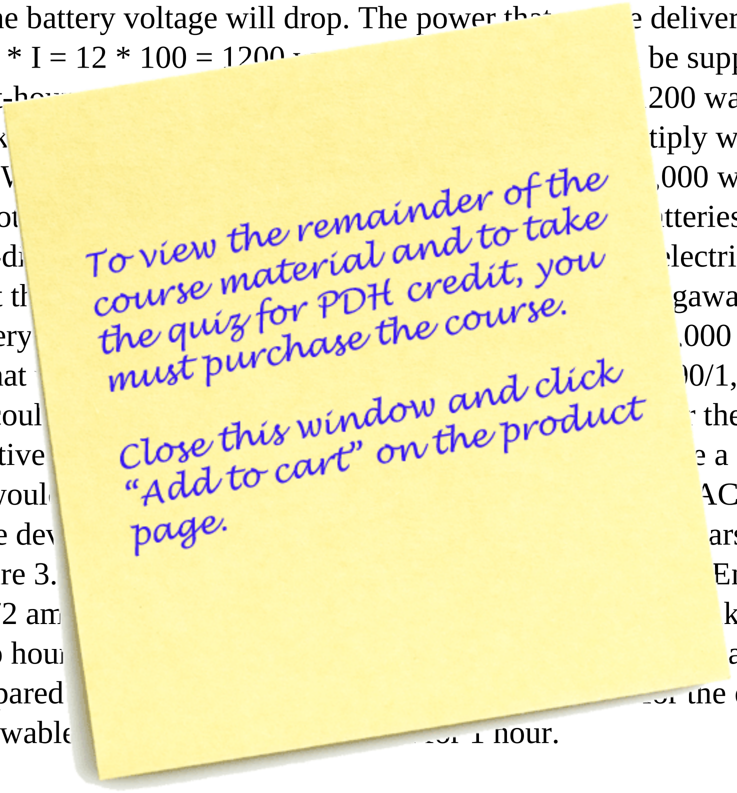
Leyden jars are actually high-voltage capacitors and were used for high voltage electrostatic experiments. Even though they could store a high voltage, the capacitance was relatively small, and thus, the energy storage was relatively small. The energy storage ability of almost any capacitor is relatively small. As another example, the big blue capacitor in Figure 2.2 is 4700 µ farads with a voltage rating of 35 volts. The maximum energy content is then $½ * C * V^2 = ½ * .0047 * 35^2 = 2.87875$ joules or watt-seconds. That would hardly make a small light blink, let alone run an air conditioner. Let's now look at a somewhat better, and perhaps the best technique, rechargeable batteries.

3. Rechargeable Batteries

Rechargeable batteries are a way of using chemicals to store electrical energy. They can store a lot more energy than capacitors. Batteries are rated by the number of hours that they can supply a certain current. A typical 12-volt lead-acid car battery can supply about 100 amp-hours of energy. That means that it can supply 1 amp for 100 hours or 100 amps for 1 hour. During the
discharge cycle, the battery voltage will drop. The power th e delivered at 100 amps is
1200 watts (P = V * I = 12 * 100 = 1200 be supplied in one hour is
equal to 1200 watt-ho 200 watts * 1 hour = 1200
watt-hours or 1.2 k tiply watt-hours by 3600
seconds per hour (V ,000 watt-seconds or
joules). That is a lot tteries do have a limited
number of charge-di electrical energy storage
techniques. To put th gawatt load for 1 hour, we
would need a battery ,000 watt-hours or 1000
kilowatt-hours. That 0/1,200 = 833.3). In real
life, the batteries coul the power grid, 1
megawatt is a relative a lot of equipment.
Also, the energy woul AC power to supply the
electrical grid. The dev ars they have become
very reliable. Figure 3. Energy Cell 800RE
with a rating of 672 am k can deliver is (W =
24volts * 672 amp hou at is still not a lot of
energy when compared the electrical grid to
operate when renewable for 1 hour.



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