ULTRACAPACITORS

Clark Fedor
Similar to normal capacitor, but stores charge in porous carbon that has a very high surface area.

Each layer attracts ions, + or -, and the layers are spaced nanometers apart.
Ultracapacitors
A brief history

- Effect of porous carbon holding large amounts of charge first discovered in 1957 by GE. They didn’t follow up on the discovery.
- Standard Oil re-discovered this when working with fuel cell technology in 1966. They also did not strongly follow up their discovery.
- Nippon (Japan) Electric Company eventually bought the license and commercialized it for use in computer memory.
- It has been a materials problem ever since.
- Also known as Supercapacitor or Double-layer capacitor
Energy Storage Advantages

- Can charge and discharge thousands (millions?) of times before wearing out
- Can charge and discharge quickly
- Highly efficient
- Less heating
- Stackability
- Wide temperature range

\[ E_{\text{stored}} = \frac{1}{2} CV^2 = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} VQ \]
## Comparison to Current Technologies

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Electrostatic Capacitor</th>
<th>Ultra-capacitor</th>
<th>Battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge Time</td>
<td>$10^{-6} \sim 10^{-3}$ sec</td>
<td>1~30 sec</td>
<td>0.3~3 hrs</td>
</tr>
<tr>
<td>Charge Time</td>
<td>$10^{-6} \sim 10^{-3}$ sec</td>
<td>1~30 sec</td>
<td>1~5 hrs</td>
</tr>
<tr>
<td>Energy Density (Wh/kg)</td>
<td>&lt; 0.1</td>
<td>1~10</td>
<td>20~100</td>
</tr>
<tr>
<td>Power Density (W/kg)</td>
<td>&lt; 10,000</td>
<td>10,000</td>
<td>50~200</td>
</tr>
<tr>
<td>Charge / Discharge Efficiency</td>
<td>~1.0</td>
<td>~10</td>
<td>0.7~0.85</td>
</tr>
<tr>
<td>Cycle Life</td>
<td>Infinite</td>
<td>&gt; 500,000</td>
<td>500~2,000</td>
</tr>
</tbody>
</table>

### Advantages

1. Power (20 times better)
2. 
3. All-weather, Tough environment
4. Semi-permanent life
5. Energy efficiency
6. No maintenance
7. Quick charging

### Disadvantages

1. 
2. Energy (10 times less)
3. 
4. 
5. 
6. 
7. 
Energy Storage
The Problem-Low Voltage Ratings

- Low Voltage, Low Energy Storage
- Ultracapacitors need to be stacked in order to meet voltage requirement.
- Like normal capacitors, overvoltage causes ultracaps to fail
Most ultracaps have a surge voltage of 1.05-1.2 times larger than rated average voltage. According to Maxwell, their capacitors “will accept as much charge as they are given.”
Energy Storage
The Problem

Set of 160 in Series, 16.875 F, 400 V from 2700 F and 2.5 V Ultracapacitors
What happens if one of the stacked ultracaps shorts?

Fuses could be used between capacitors to limit damage.

Excessive overvoltage will damage an ultracap as it would a normal capacitor.
Applications

- In conjunction with batteries in Hybrid/Electric Vehicles (connected with power electronics)
- Storage for wind, solar, fuel cell and other renewable energies
- Use in cell phones, iPods, laptops, any personal device that may need short bursts of power
- Much talk given to ultracapacitors eventually replacing batteries altogether...
Carbon nanotubes: further increasing surface area of ultracapacitors

Researchers at MIT have claimed their simulations allow for a carbon nanotube ultracap stores the same amount of energy as a battery of the same size.
EEStor: a company in Texas claiming serious advances in ultracapacitor technology, but it is staying very quiet about it, leaving many skeptical and many hopeful.

It claims 31 F at 3500 V in 336 pounds (yielding 350 Wh/kg)
Manufacturers

- Maxwell Technologies, Inc
- NessCap Co. Ltd.
- Epcos AG.
- And many more outside of the U.S.
References

Questions?