

# UPS Energy Module

MAXWELL ULTRACAPACITORS

MORE POWER. MORE ENERGY. MORE IDEAS.™

**Maxwell**  
TECHNOLOGIES

# UPS Energy Storage

- UPS Energy Storage for Bridge Power
- Power quality against brown outs and spikes
- Lowest cost of ownership
- Lowest operating costs



# Agenda

- Background
- Why Ultracaps
- Product
- Summary

# Background

## Target Application: Bridge Power UPS

- Backup power for data centers, hospitals, telecom, industrial buildings, industrial equipment
- Transition to permanent backup such as a fuel cell or motor-generator set
- Provide short term power for transition to long-term back up power, such as fuel cell, mg-set
  - Typical 15-20 seconds, up to 1 minute

# Background Technology Alternatives

- Lead-acid batteries are the dominant energy storage to date
  - Low initial cost
  - “Known” quantity
  - Regular replacement every 1-5 years depending upon design and application
- Flywheels are a high power alternative (>100KW)
  - High maintenance costs
  - Large power chunks
  - High energy density
  - Long lifetime

# Technology Comparison

|                | <b>BOOSTCAP<br/>Ultracapacitors</b> | <b>Batteries</b> | <b>Fly Wheel</b> | Notes                                                                                                         |
|----------------|-------------------------------------|------------------|------------------|---------------------------------------------------------------------------------------------------------------|
| Maintenance    |                                     |                  |                  | Ultracaps can run maintenance free for 10-15 years.                                                           |
| Conditioning   |                                     |                  |                  | Ultracaps require no long initial conditioning.                                                               |
| Lifetime       |                                     |                  |                  | Ultracaps can run maintenance free for 10-15 years.                                                           |
| Initial Cost   |                                     |                  | Good, >200kw     | Ultracaps have highest initial cost but the lowest cost of ownership.                                         |
| Power Density  |                                     |                  |                  | Ultracaps provide the highest power density. Power can be added in small increments.                          |
| Energy Density |                                     |                  |                  | Batteries provide the highest energy density.                                                                 |
| Space Required |                                     |                  |                  | Ultracaps and fly wheels are installed in standard cabinets. Due to power density, they take the least space. |

# Why Ultracaps

- Lowest Total Cost of Ownership
- Long lifetime – 8-14 years
- Maintenance free
- Predictable wearout
- No toxic materials
- Fast recharge, fast system recovery
  - No C rate limitations on lifetime
  - Immediate use upon installation, no battery forming
  - Less downtime
- High power density
  - 5.5KW per kg
  - 7.5 KW per 1U/rack unit

## Total Cost of Ownership Model

Ultracapacitors have been utilized in many applications with new applications developing constantly. The key benefits ultracapacitors offer in comparison to batteries are:

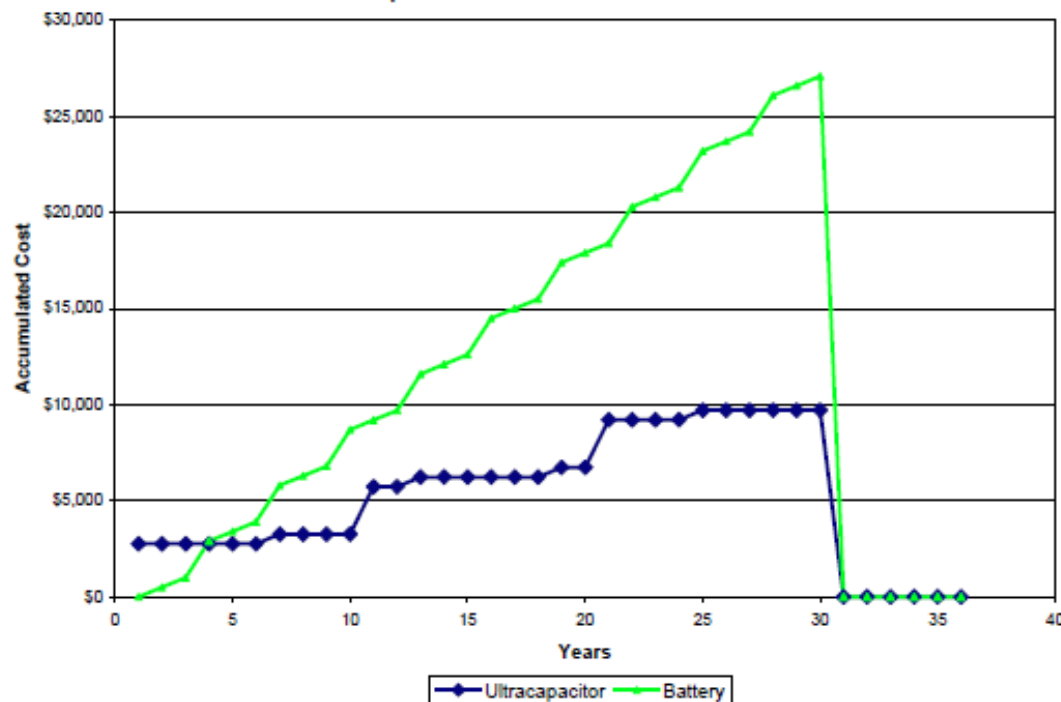
- Indefinite shelf life
- Greater than 10 years operational life
- Reduced maintenance requirements
- Reduced disposal concerns
- Improved low temperature performance

# Total Cost of Ownership Model

- Today's hurdles or limitations to full adoption of the technology have been limited to initial cost.
- Ultracapacitors have significantly reduced in cost over the years and further cost reductions will be realized in the coming years as volumes continue to steadily increase.
- life cycle cost analysis is only looking at a return on investment (ROI) comparison of ultracapacitors vs. batteries for the internal bridge power requirement
- With the assumption of a 3 year battery replacement requirement it is assumed the price for the ultracapacitors will be reduced by one half by the next required replacement period (approximately 10 years).

# Total Cost of Ownership Model

The simulation depicted in figure it is seen the breakeven point for the two technologies occurs at 4 years with Ultracaps providing a cost benefit every year thereafter.



## Total Cost of Ownership Model

- Under the assumptions provided it is anticipated that over a 30 year period the total cost savings of an ultracapacitor based bridge power solution is approximately \$18,000.
- The assumption of maintenance cost is considered conservative when factoring in the total elements of the maintenance call (scheduling, logistics, labor, transportation, etc.) especially in remote locations.
- The most significant cost of the total life cycle costs based on a 3 year battery replacement schedule is the cost of the battery replacement.

# Total Cost of Ownership Model

➤ Compares lifetime cost of energy storage: BOOSTCAP ultracapacitors, batteries, flywheel

➤ Accounts for:

- Initial cost
- Maintenance costs
- Floorspace
- Replacement costs
- Leakage current

| UPS Backup Power Cost of Ownship   |          |                          |                                                                                                                    |                          |                 |                |
|------------------------------------|----------|--------------------------|--------------------------------------------------------------------------------------------------------------------|--------------------------|-----------------|----------------|
| System Requirements                |          |                          | Ultracapacitor System Information                                                                                  |                          | General Inputs  |                |
| UPS Power Rating                   | 200000   | VA                       | Energy Storage Power Control Information<br><div>560 V max</div> <div>560 V nominal</div> <div>300 V minimum</div> |                          | Electrical cost | 0.1 \$/kwh     |
| UPS Power Factor/Efficient         | 0.95     |                          |                                                                                                                    |                          | Floorspace cost | 36 \$/sq ft/yr |
| Power                              | 190000   | W                        |                                                                                                                    |                          |                 |                |
| Max Running Time                   | 15       | sec                      |                                                                                                                    |                          |                 |                |
| Total energy Required              | 792      | Wh                       | Product<br>BRAK0130-P056 B0<br><br>10 series X 3 in parallel.                                                      |                          |                 |                |
| Total Service Life =               | 14       | years                    |                                                                                                                    |                          |                 |                |
| Cost Inputs                        |          |                          |                                                                                                                    |                          |                 |                |
| Ultracapacitor Information         |          | Battery Information      |                                                                                                                    | Fly Wheel Information    |                 |                |
| Initial Costs                      |          | Initial Costs            |                                                                                                                    | Applicable only >50KW    |                 |                |
| Initial Costs                      |          | Initial Costs            |                                                                                                                    | Initial Costs            |                 |                |
| Ultracapacitors                    | 30       | Batteries                | 40                                                                                                                 | Fly Wheels               | 1               |                |
| \$/ultracapacitor                  | \$1,500  | \$/battery               | \$425                                                                                                              | \$/flywheel              | \$42,000        |                |
| Initial ultracapacitor cost        | \$45,000 | Initial battery cost     | \$17,000                                                                                                           | Install cost per fw      | \$5,700         |                |
| Life Costs                         |          | Life Costs               |                                                                                                                    | Life Costs               |                 |                |
| Maintenance period                 | 14       | Maintenance period       | 5                                                                                                                  | Bearing Life             | 5               |                |
| Maintenance cost                   |          | Maintenance cost         | \$50                                                                                                               | Maintenance Cost         | \$5,100         |                |
| Replacement period                 | 14       | Replacement period       | 5                                                                                                                  | Pump Life                | 7               |                |
| Replacement cost (labor)           | \$1,000  | Replacement cost (labor) | \$1,333                                                                                                            | Maintenance Cost         | \$4,150         |                |
| Relative hardware price            | 100%     | Relative hardware price  | 100%                                                                                                               | Operating Costs          |                 |                |
| Handling & disposal                | \$900    | Handling & recycling     | \$0                                                                                                                | Floorspace               | 15              |                |
| Operating Costs                    |          | Operating Costs          |                                                                                                                    | Annual Cost              | \$540           |                |
| Floorspace                         | 15       | Floorspace               | 15                                                                                                                 | StandbyPower             | 0.38            |                |
| Annual Cost                        | \$540    | Annual Cost              | \$540                                                                                                              | Annual Electrical cost   | \$333           |                |
| Standby Power                      | 0.0 kw   | StandbyPower             | 0.00 kw                                                                                                            | Service Life Costs       |                 |                |
| Annual Electrical cost             | \$8      | Annual Electrical cost   | \$0                                                                                                                |                          |                 |                |
| Total BOOSTCAP life cost           |          | Total Battery life cost  |                                                                                                                    | Total Flywheel life cost |                 |                |
| \$52,667                           |          | Total life cost \$61,327 |                                                                                                                    | \$74,270                 |                 |                |
| Projected savings Maxwell BOOSTCAP |          | \$8,660 14%              |                                                                                                                    |                          |                 |                |

# Summary ROI Example

## ➤ 200KVA/190W system

- 15s run time
- 14 year UPS life
- Ultracapacitors
  - Max DC voltage: 560V, min. DC voltage 300V
  - Initial cost: \$45,000
  - Total Cost of Ownership (TCO): \$52700
- Batteries
  - Initial battery cost: \$17,000
  - Battery replacement: 3 years
  - Total Cost of Ownership (TCO): \$98100

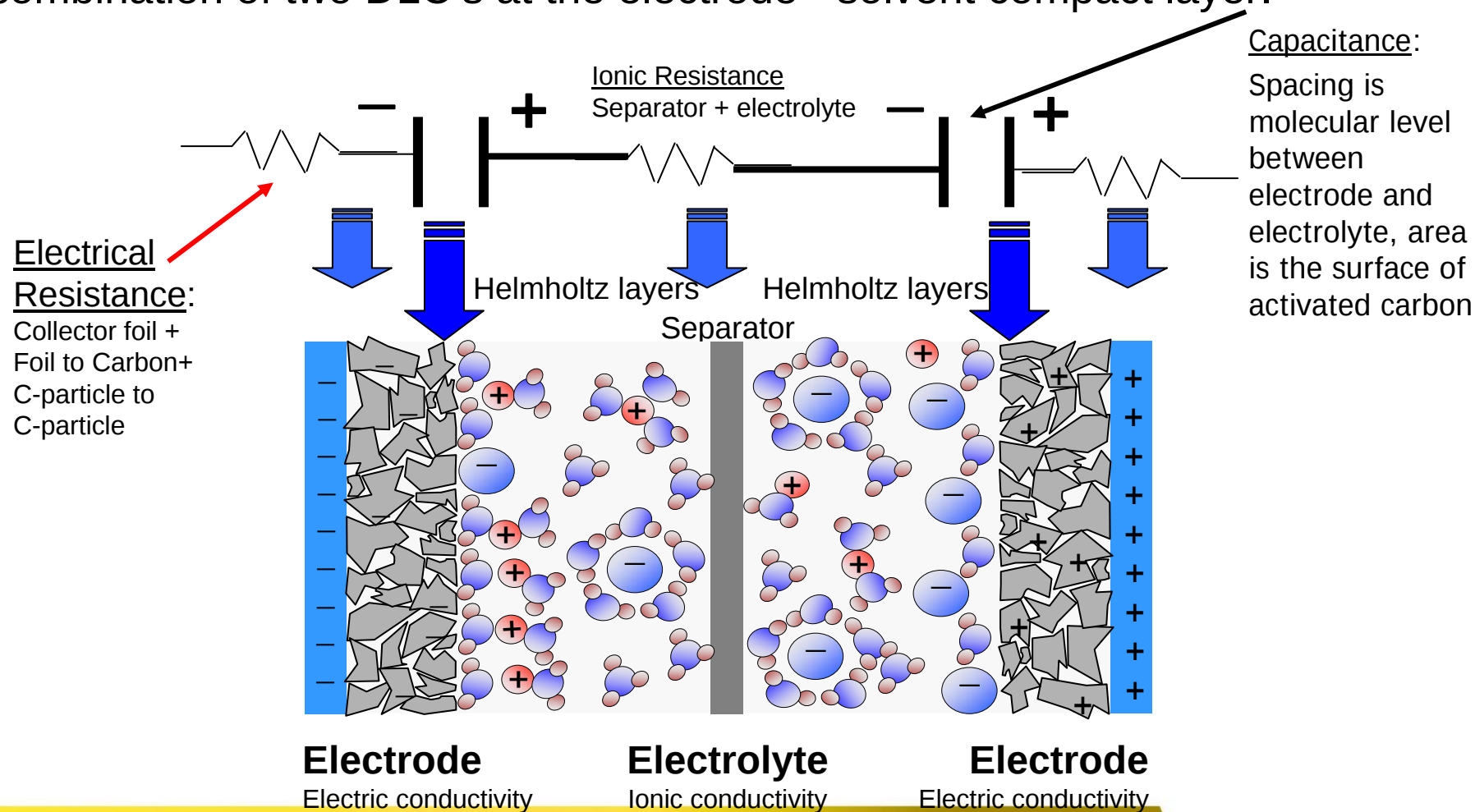
➤ Total Savings with Ultracapacitors: \$45.4K (46%)

# What is an Ultracap

- aka, EDLC, electrical double layer capacitor, supercap
- Electrical storage device which works on physical basis vs. chemical reaction of a battery vs. kinetic energy of flywheel
  - More robust to temperature (-40 to +65°C)
  - Long, continuous, predictable life
- “High energy storage” due to activated carbon surface area and molecular scale electrode spacing
- Failure mechanisms are known and predictable
  - Slow capacitance fade, resistance increase, pressure buildup over time
- “End of Life”
  - Defined as 20% capacitance decrease, 100% resistance increase

# Ultracapacitor Basics

- The ultracapacitor model commonly applied is that of the series combination of two DLC's at the electrode - solvent compact layer.



# Ultracapacitor Fundamentals – Not all EDLC are alike

## ➤ Maxwell is in full production

- Shipped millions of cells
- Over 1,500 hybrid busses
- 100,000s of automated meter readers (AMR)
- Power for pitch control in over 12,000 windmills since 2003

## ➤ Maxwell's Secret Sauce

- Electrode “dry” process
- Lower impurities leading to longer lifetime
- Protected by multiple patents

## ➤ Core device has a very long lifetime

- Cell assembly process is critical to MTBF

# Monitoring and Balancing

## ➤ Cell Balancing Goal: Maximize Lifetime and Reliability

- High reliability passive cell balancing
  - No user controls required
  - Always functioning to keep cells at the same voltage
  - Minimum components

## ➤ No monitoring required

- Optional overvoltage monitor built into the module
  - Monitors each cell
  - Provides 5V output signal if any cell exceeds voltage threshold

## Summary

- High reliability energy storage for bridge power UPS
- Ultracapacitors provide long life with no/fewer replacements over lifetime
- Ultracapacitors require less monitoring than batteries
- New 10KW module targeted for rack mount installations
- Maxwell Technologies has the most experience in manufacturing and support of ultracapacitors
- Maxwell UPS modules provide the lowest total cost of ownership for energy storage in large scale UPSs