Ultracapacitors:
Growing the Market Through New Applications

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Energy Storage Cousins

**Capacitor**

\[ C = \frac{Q}{V} \]

\[ C = \varepsilon_r \varepsilon_0 \frac{A}{d} \]

\[ W = \frac{1}{2} CV^2 \]

**Ultracapacitor**

**Battery**

• Rearrangement of ions – FAST
  • No chemical reactions – HIGH CYCLE LIFE

**POWER DELIVERY DEVICE**

**ENERGY STORAGE DEVICE**

• Faradaic – HIGH ENERGY
**Diverse Markets**

**Smart Grid**
- Turbine Pitch control
- Smart Meters
- Solar Tracking
- Regulation services
- Substation systems

**Transportation**
- Hybrid buses
- Start/stop Micro-Hybrid
- Cold starting
- Board net stabilization
- Rail regeneration
- Material Handling

**Renewables**

**Industrial**
- Actuators
- Welding
- UPS

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Global Consumption By Market Segment

2011: $340 million
2015: $1.2 billion
2020: $7 billion

Aerospace/Defense, 5%
Smart Meters, 12%
SSD/Mem Module, 10%
Hybrid Bus, 22%
UPS, 8%
Other, 3%
Automotive, 6%
Wind, 34%

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Ultracapacitors In Wind Turbines

1. Blade pitch control
2. Pitch control emergency back-up
3. Pitch drive system
4. Wireless data transmission
5. Beacon lighting
6. UPS
7. Grid stabilization


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Ultracapacitors In Hybrid Buses

1. Hybrid electric drive
2. Cold start
3. Electrical system support
4. Bus stop LED lighting

Image source: http://www.reallynatural.com/pictures/gillig_hybrid_electric_bus%2Bside_view.jpg
Ultracapacitors In Passenger Cars

1. Regenerative breaking
2. Emergency breaking
3. Electric steering
4. Electrical/alternator voltage support
5. Start/stop (micro-hybrid)
6. Smart air-bags
7. Instrument cluster
8. GPS/safety/tracking voltage support
9. Power seats
10. Power windows/locks
11. Launch assist (mild hybrid)
Driving Style, Energy and Power

US06 Supplemental (Aggressive) Driving Cycle

Hypothetical Vehicle
Balancing Energy & Power...

Effective hybrid system performance

- Energy (Wh)
- Power (W)

- Battery
- Ultracapacitor
- Hybrid

Distance
Accelerate
...Cycle Life...

![Graph showing cycle life vs. depth of discharge for Li-ion batteries.](image)

**Li-ion**
- Need to oversize the battery
  - Shallow discharges
  - Increase the cycle life
- Portion of the battery never used
  - Weight
  - Volume
  - Cost

![Ultracapacitor: 1 million cycles...](image)

Ultracapacitor: 1 million cycles...
Driving your EV in hot and cold weather

- **Batteries**
  - Poor low temp performance
- **Ultracapacitors**
  - Stable across a wide temp range
  - Work well down to -40 C

- **Electrolyte conductivity**
- **Rate of chemical reactions**
  - Energy storage
  - Aging processes
Nonlinear Properties:
• Power Density vs. Energy Density (Ragone)
• Capacity vs. Discharge Rate (Peukert)
• Cycle Life vs. Depth of Discharge

Benefits:
• Longer time between discharges
• Longer battery life
• More efficient regenerative performance

Why does the ultracapacitor/battery combination work?
Hybrid Capacitors

350F

820F Hybrid

Power
Cycle Life

Energy

- Ultracapacitor and battery elements in a single cell
- Tunable properties
- No electronics at the cell level
Matching Application and Technology

- LED light source – low energy demand
- High light output
- Fast charge
- Discharge can be slow (long time)!
- Never replace batteries
- Match duty cycle with the technology

820F Hybrid
Ioxus Company Information

Ioxus Investors:

Founded 2007

Products Ultracapacitors; Hybrid Ultracaps Cells; Modules

Services Power systems engineering

Subsidiaries Advanced Energy Conversion, LLC
Ioxus Asia Limited
Power Systems, Ltd.

Locations Oneonta, NY (Headquarters)
Kusatsu, Shiga Prefecture, Japan
Schenectady, NY
Acquisition of Power Systems, Ltd.

More markets and applications

- **Acquired on February 8, 2012**
- Japanese manufacturer of ultracapacitor modules
- High power products based on flexible pouch cell technology
- Blue chip customer base in Japan
- Broad range of applications/active customers:
  - Harbor cranes
  - Stacker cranes
  - Large presses
  - Production lines
  - Automatic guided vehicles
  - Servo drive machine tools
  - Voltage sag compensators
  - Office copiers
  - Medical devices
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