Ultracapacitors

For Use in Multi-Megawatt Applications

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Introduction

- Ultracapacitors are receiving increased attention as a temporary power source for many applications.
- Traditionally considered for only low power applications, ultracapacitors are now being considered for use in high-power applications.
- The shift in focus has been made possible through the invention of the asymmetrical ultracapacitor.

Introduction

- Voltage source inverters are available to exchange real and reactive power with the AC power system. This ability expands the usefulness of these devices for electric utilities to include generation, T&D, and customer service.
- Energy storage is the means to make this possible
- Existing solutions for energy storage include SMES, batteries, and flywheels.

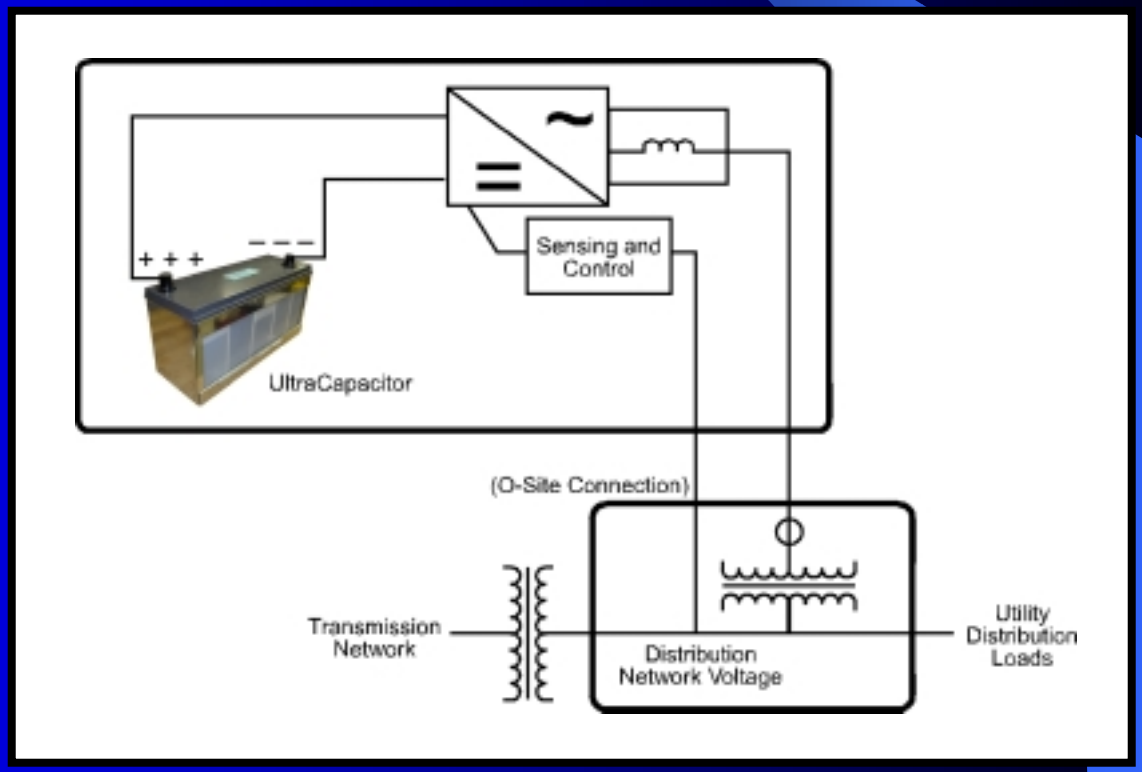
Voltage Source Inverter (VSI)

Shunt or Parallel Connected

Examples: DVR | DSTATCOM | UPFC

Introduction

- EPRI PEAC is investigating the use of ultracapacitors designed for use with utility-scale inverters.



Sample Schematic

Presentation Overview

- Utility applications of voltage-source inverters with energy storage.
- Provide information on asymmetrical ultracapacitors.
- Provide details on work done at EPRI PEAC with ultracapacitors
- Specification for a multi-megawatt system based on asymmetrical ultracapacitors.

Applications with Energy Storage

Spinning Reserve – Area/Frequency Control – Transmission Line Stability – Voltage Regulation – Power Quality and Uninterruptible Power

Applications with Energy Storage

Spinning Reserve – Area/Frequency Control – Transmis[illegible] Line Stability – Voltage Regulation – Power [illegible]and Uninterruptible Power

- Spinning Reserve
  - Definition: The generation capacity that a utility holds in reserve to prevent interruption of service to customers if an operating generator fails.
  - Requirement: 20-100 MW, 300-1500 MJ, (15-second quick-start diesels)

Applications with Energy Storage

Spinning Reserve – Area/Frequency Control – Transmission Line Stability – Voltage Regulation – Power Quality – Uninterruptible Power

- Area/Frequency Control
  - Definition: The ability for grid-connected utilities to prevent an unplanned transfer of power between neighboring utilities and the ability to regulate frequency.
  - Requirement: 100 MW to 1,000 MW for power and 0.1 MWh to 10 MWh for energy.

Applications with Energy Storage

Spinning Reserve – Area/Frequency Control – Transmission Line Stability – Voltage Regulation – Power Quality and Uninterruptible Power

- Transmission Line Stability
  - Definition: The ability of the system to keep all components on a transmission line in sync and prevent system collapse.
  - Requirement: 100 MW with 500 MJ, <5 seconds.

Applications with Energy Storage

Spinning Reserve – Area/Frequency Control – Transmission Line Stability – Voltage Regulation – Power Quality and Uninterruptible Power

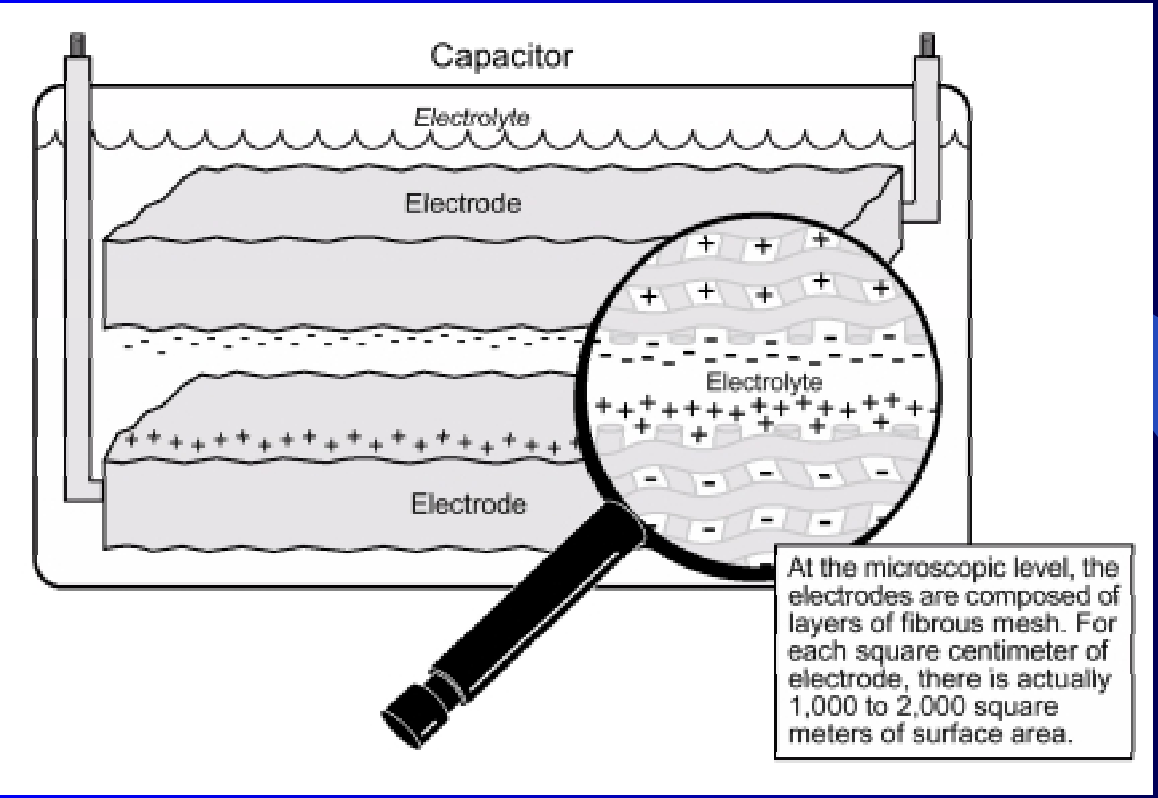
- Voltage Regulation
  - Definition: The ability to maintain the voltage at either end of a transmission line within five percent.
  - Requirements: 1 MVAR for less than 15 minutes

Applications with Energy Storage

Spinning Reserve – Area/Frequency Control – Transmission Line Stability – Voltage Regulation – Power Quality and Uninterruptible Power

- Power Quality and Uninterruptible Power
  - Definition: The ability to prevent voltage spikes, voltage sags, and power outages that last for a few cycles to a few minutes.
  - Requirements: 1-5 MW, 10-50 MJ

What is an Ultracapacitor?

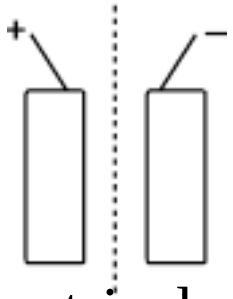


- Energy is stored electrostatically at the electrode/electrolyte surface.
- The large value of capacitance is due to the tremendous amount of surface area.

What is an Ultracapacitor?

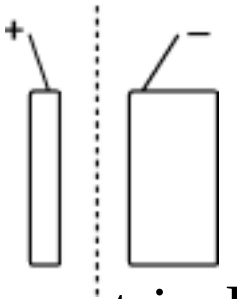
Ultracapacitors are configured into arrays using various-sized cells to fit the power and energy requirements for a specific application.

The Asymmetrical Advantage



Symmetrical

Cp Cm



Asymmetrical

$Cp = Cm = C$

$C_{total} = ½\ C$

Voltage of C = 0.8 V = V

$Es = ½\ CV^2$

$= ½(\ ½\ C)V^2$

$= ¼\ CV^2$

$Cp >> Cm$

$C_{total} = 2C$

Operation at ~1.6 V = 2 V

$Ea = ½\ (2C)(2V)^2$

$= 4CV^2$

Therefore, Ea = 16 * Es!

Advantages of Ultracapacitors

- High pulse-power capability with good energy density
- Can provide VAR and kW support
- No moving parts
- High number of charge discharge cycles (hundred of thousands)
- Modular design
- Can easily be configured for site specific power and energy requirements
- Compatible with existing voltage-source inverters

Advantages of Ultracapacitors

- State of charge is easily determined by measuring the terminal voltage
- Natural voltage balance
- Self-discharge rate is very low
- Excellent low temperature performance and wide range of operating temperature
- Non-hermetic packing
- Relatively inexpensive materials (nickel, carbon, KOH)

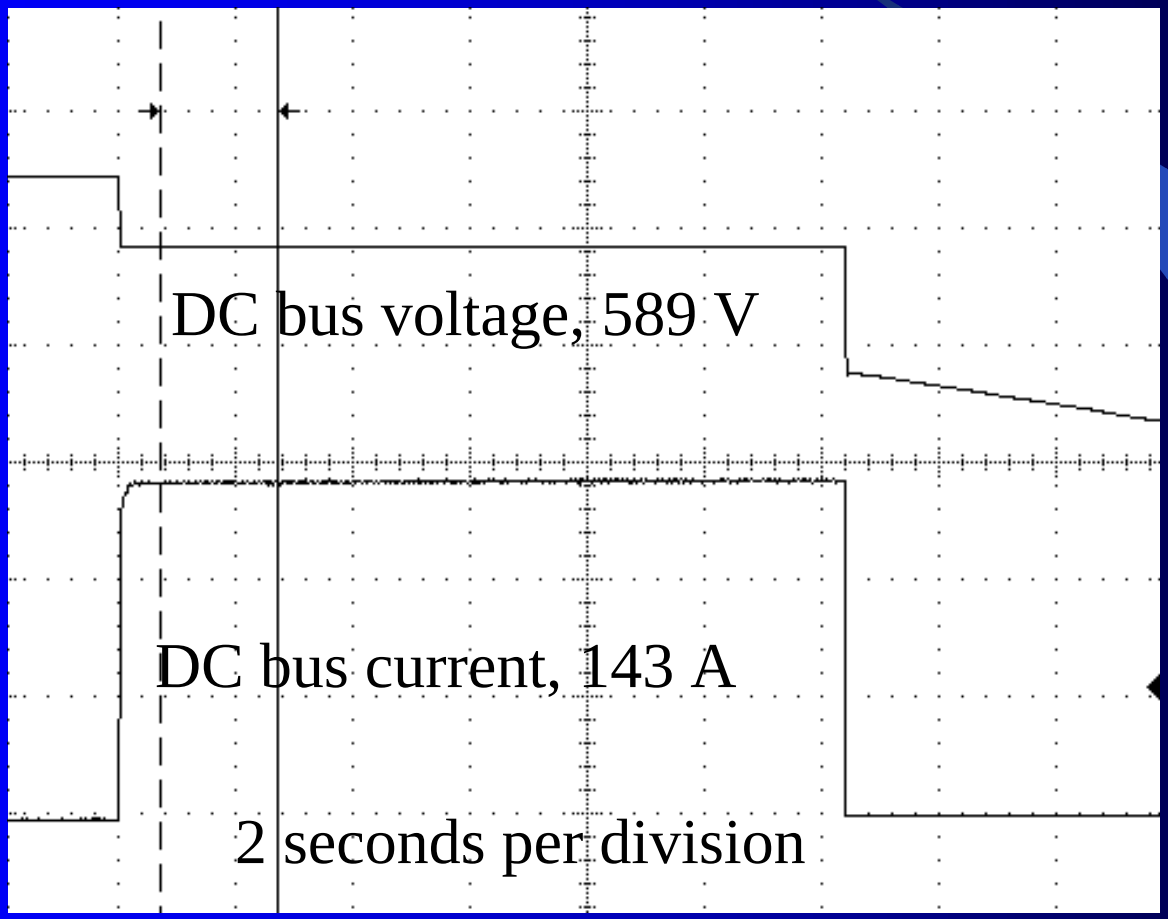
Demonstration

- EPRI PEAC has installed and demonstrated an ultracapacitor-based system.
- 100 kW for 10 seconds (1 MJ).

RTS-100 Specifications

- Power – 100 kW
- Energy – 1 MJ
- DC bus voltage – 400-230 V
- DC output voltage 585 VDC (adj. To 600)
- The system makes use of power electronics to maintain constant power to the adjustable speed drive.
- Recharge time is 100 seconds.

RTS-100 Performance Chart



Multi-Megawatt System - Preliminary Specification

Average power	3 MW
Energy delivered	9.5 MJ
Discharge time	3 seconds
Peak Power	7.1 MW
# of strings/# of cells per string	10/420
Volume	2-4 m^3 (1-2 refrigerators)

Next Steps

- Several parameters need further investigation:
  - Maximum storage
  - Maximum power
  - Optimum float voltage
  - Type and number of cells
  - Optimum bus voltage
  - Operating life
  - Efficiency
  - Leveling System
  - Long term reliability

Summary

- Asymmetrical ultracapacitors have been proven effective in applications other than as memory backup for computers.
- EPRI PEAC is currently in the process of gathering more information about the design and application of systems sized for multi-megawatt applications.
- Preliminary analysis indicate good performance, small footprint, and high reliability

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