The Use of High Power Lithium Ion Batteries to Support Distributed Generation

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Distributed Generation

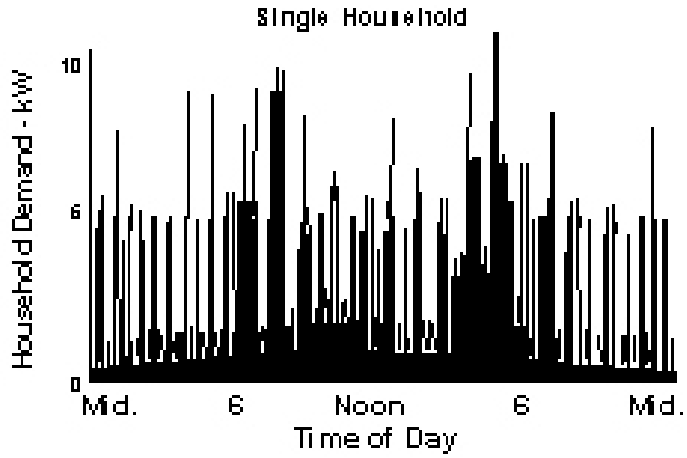
- Predicted move from centralized to ‘personal’ generation
  - Computers
  - Telephone network switching
- Utility benefit – capacity deferral
- Avoidance of T&D costs
- Flexibility
  - Can be configured for low cost
  - Can be configured for high reliability
- Generator types
  - Microturbines
  - Residential fuel cell generators

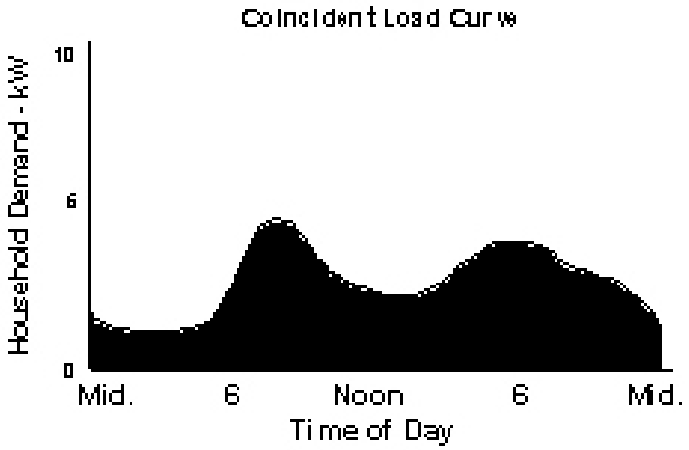
Microturbines

- 25 – 250 kW output
- Majority of installed base is Capstone 30 kW unit
  - 800 out of 1200 units shipped in 2000
  - 300 75 kW units from Honeywell
- High efficiency, but slow response time
  - Approx. 15-second ramping time
  - Requires energy storage for off-grid operation
- Energy storage also used for starting microturbine

Residential Fuel Cell Generators

- Being developed by several companies
  - Mostly PEM fuel cells
- Generator supplying single household sees non-coincident load behavior
  - Not economic to base fuel cell output on peak loads
- Generator output sized for base load
- Energy storage supplies peaks
- Energy storage also used for black starts





Energy Storage Requirements

- **Both microturbines and fuel cell generators benefit from energy storage**
- **Energy storage characteristics**
  - **Peak power capability in 10s of kW**
  - **Total energy delivered <1 kWh**
  - **10s of cycles per day**
- **Other requirements**
  - **Long life**
  - **Low life cycle cost**
  - **Temperature extremes?**
  - **Small volume?**

High Power Lithium Ion

- Originally developed for PNGV program (hybrid EV)
- Batteries supplied for passenger & military vehicles and other defense applications
- Cell capacity up to 30Ah at 3.6V
- Pilot plant production
- Future programs
  - Automotive 42V
  - Hybrid buses
  - Space
  - Directed energy weapons
  - Energy storage

High Power Capability

Temp	% SOC	Max Discharge Power		Max Charge Power
		2 Sec kW/l	18 Sec kW/l	2 Sec W/l
25°C	70%	5.2	3.5	2.0
	50%	4.7	3.2	2.7
	30%	3.8	2.5	3.2
0°C	70%	2.4	1.8	0.8
	50%	2.2	1.6	1.2
	30%	1.5	0.9	1.2

- Energy density is approximately 190 Wh/l
- Compares favorably with VRLA
  - 50-120 Wh/l
  - <1 kW/l at 25°C & 100% SOC

Cold Temperature Performance

- **Cold Cranking**
  - **HP12 can provide 150A/45 sec pulse at –18°C**
- **In-Situ Warming at –40°C by Joule effect**
  - **HP30 capability**
  - **120A after 4 minutes**
  - **200A after 5 minutes**

Cold Temperature Performance

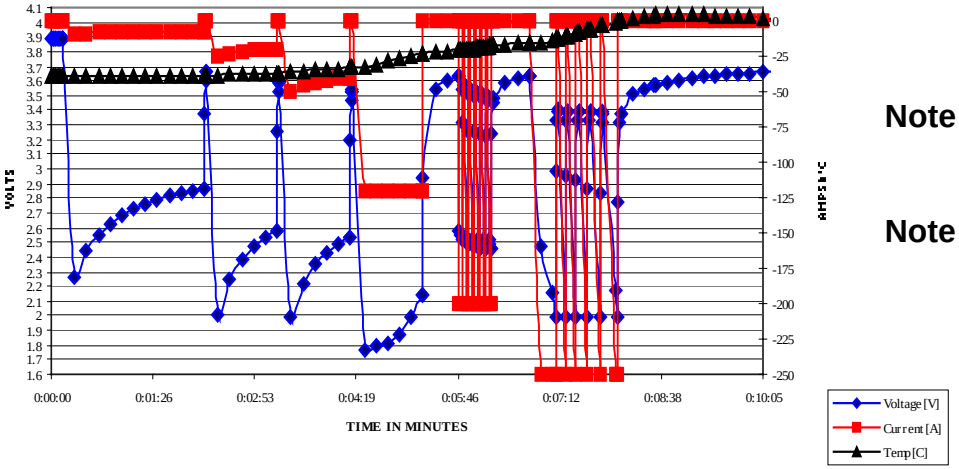
Cranking Capability at –18ºC, Current Pulse 150A

Cell SOC	100%	85%	70%	55%
Pulse - seconds	45	45	45	37
Minimum Voltage (V) end of pulse	2.67	2.55	2.42	2.10

Note 1: Rest time between pulse is 10 minutes. (Shorter rest would have resulted in improved performance because of cell internal warming.)

Note 2: Recent change in electrochemistry should result in improved cold temperature performance.

Warm-up Test at –40ºC with HP30 Cell

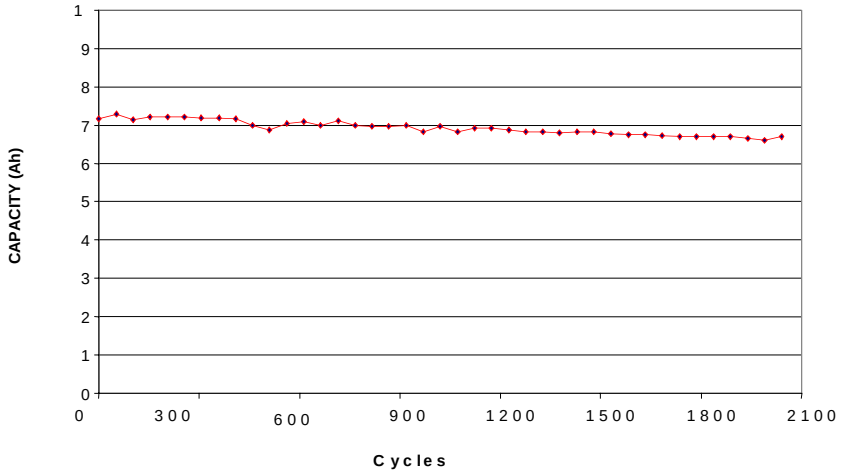


Note 1: Loads: 20W/2 min., 50W/1 min, 100W/1 min, 120A/1 min., 200A/3 sec. & 250A/30 sec.)

Note 2: Temperature of Chamber: -40ºC; Cell Temperature –39.1ºC to +8.5ºC

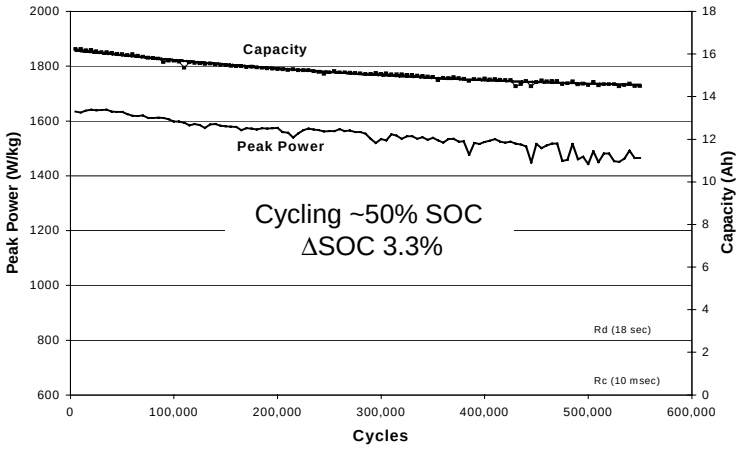
Cycle Life & Calendar Life

HP Cell Performance
100% DOD Cycle



Actual: 2000 cycles
Projection: >5000 cycles

HP Cell Performance
Shallow Cycle



Projection: >1,000,000 cycles

- **Calendar Life: more than 10 years for HEV application (Projection based on hot climate temperature profile)**
- **High temperature testing has shown that reduction in high power capability with age is slower than rate of energy loss**

Future Outlook

- **Pilot production for high power cells almost operational**
  - **High energy cells produced at pilot level for over one year**
- **Industrial production expected in 2-3 years**
- **Ongoing development work on higher power versions**

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Summary

- Distributed generation is poised for rapid growth
- Distributed storage goes hand-in-hand
- In the short term, most units will be sold with lead-acid batteries
- High power lithium ion comes closest to meeting technical requirements of these applications
- Technology expected to be highly competitive

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