POWER STORAGE FOR SMALL SATELLITES: COMPARISON OF NIH2 AND LIION BATTERIES

R. Wenige, M. Schilbach, P.F. Weidner
Diehl & Eagle Picher GmbH, D-90552 Röthenbach, Germany
Tel: +49-911-957-2428, Fax: +49-911-957-2485,
Roger.Wenige@diehl-eagle-picher.com

ABSTRACT

The paper compares the two mainly used technologies for power storage systems in spacecrafts: the mature Nickel-Hydrogen (NiH2) and the new Lithium-Ion (LiIon). A comparison of the power storage system relies on the cell design and active materials for NiH2 and LiIon. Besides the different performance characteristics, the cell chemistry demands different approaches for the entire battery design, structure and interface. As NiH2 is based upon a robust and stable chemistry, a simple battery design is sufficient. NiH2 is not only able to bear deep discharge conditions but additionally it is insensitive against reverse current. Furthermore it is insensitive against over-charge. Its energy principle bases upon the production of internal pressure, which requires stable container material causing higher volume and mass of the entire system. Today NiH2 is the system, where by far the most cycle life data and flight heritage are available.

The LiIon technology is sensitive to overcharge and over-discharge conditions. Therefore a sophisticated battery management system is mandatory. It should include as a minimum protection monitoring versus over-voltage and under-voltage as well as charge control. For highest cycle life and life time expectations, we strongly recommend cell balancing. Due to lighter material and higher energy density, LiIon has lower mass and volume compared to the nickel based battery systems. As there are not yet enough in-orbit data available, LiIon should not be operated in LEO at DOD higher than 30% in order to meet the highest lifetime of the mission requirements.

MAIN SECTION

Small satellites need to use power storage systems with tight space constraints and low weight. Recent developments for increasing energy density of cells and batteries are supporting this demand. The NiH2 technology underwent improvements of its energy density development: Starting from 1.25V independent pressure vessel (IPV) cells to common pressure vessel (CPV) with two cells and 2.5V in one container, the latest design includes the entire battery in one single-pressure vessel (SPV) having 28V. Due to its reduced quantity of components, the SPV design has not only lower mass and decreased cost, but also a reduced internal resistance (e.g. SAR10065 with 50 Ah, 22 cells has 65 mΩ @ 1,000 Hz).
LiIon cells – with typical operating voltage of 3.6V – mean about three times the operating voltage of nickel based systems. This provides the basis for the significantly higher energy density, but also means that fewer cells are required to build up an equivalent battery. For instance, a 28V battery would require 22 NiH2 IPV cells but only eight LiIon cells. As LiIon underlies by far less pressure increase during charging, the cell containers can be made from light weight aluminum. This results in a benefit for energy density by a factor of two to three higher compared to NiH2 cells (table 1).

<table>
<thead>
<tr>
<th>Energy density [Wh/kg]</th>
<th>IPV</th>
<th>CPV</th>
<th>SPV</th>
<th>LiIon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal voltage [V]</td>
<td>1.25</td>
<td>2.5</td>
<td>28</td>
<td>3.6</td>
</tr>
</tbody>
</table>

Table 1: Energy density and voltage comparison of different battery cell types

The lower heat dissipation of LiIon cells during the charging process results in a higher charge efficiency than NiH2, what means a higher charge / discharge ratio as presented in table 2 that also contains the general temperature ranges of both technologies.

<table>
<thead>
<tr>
<th>Temperature ranges</th>
<th>NiH2</th>
<th>LiIon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating temperature</td>
<td>-10° to +25°C</td>
<td>-10° to +35°C</td>
</tr>
<tr>
<td>Non-operating temperature</td>
<td>-15° to +35°C</td>
<td>-20° to +35°C</td>
</tr>
<tr>
<td>Optimum charge temp.</td>
<td>-10° to +10°C</td>
<td>+10° to +25°C</td>
</tr>
<tr>
<td>Optimum discharge temp.</td>
<td>+10° to +25°C</td>
<td>0° to +30°C</td>
</tr>
<tr>
<td>Charge/discharge ratio</td>
<td>1.04</td>
<td>1.005</td>
</tr>
</tbody>
</table>

Table 2: Comparison of temperature conditions for NiH2 and LiIon

![Typical NiH2 discharge characteristics: 81 Ah IPV cell is discharged @ C/2 (41A) under variation of temperature ranging from –14°C to +34°C](image-url)
Typical discharging curves as a function of temperature give evidence for the low temperature constraints of LiIon – with its lowest limit at -10°C - and the limits of NiH2 at high temperature (fig. 1 and 2).

In fig. 3 the different temperature dependency of the capacity is reflected. The LiIon cell with 100Ah, type LSE 100 from GS-Yuasa, was charged with C/10 (10A) and discharged with C/1.5 (67A) until the cut-off voltage of 2.75V. It is compared with a 81Ah IPV NiH2 cell, charged with C/10 (8A) and discharged with C/2 (41A) until the cut-off voltage of 1.00V.

Fig. 3 Capacity versus temperature profile of 100 Ah LiIon and 81 Ah NiH2 cell. Details are described in the text above.
Although the memory effect on NiH2 cells is significantly lower than for NiCd systems, it is still existing and therefore the nickel based electrode systems need special treatment in order to maintain the battery at healthy level: Periodically reconditioning cycles are strongly recommended for long lifetime of NiH2 batteries. Typical calendar life of more than 20 years can be reached by NiH2, i.e. five years ground storage plus 15 years orbital life in GEO. EaglePicher’s heritage on NiH2 is based upon a flight heritage of more than 760 Mio cell hours in space, a manufacturing experience of 30 years, >14,000 cells in orbit and powering about 400 satellites still operating in orbit (February 2005). A summary of data from various cycle life tests on EaglePicher cells is presented in dependence of the depth of discharge (DOD, see fig. 4).

![Fig. 4 Projected life cycle curve of NiH2 cells as a function of DOD](image)

Up to the present day, there are no orbit life data results available from long-term GEO missions by using LiIon batteries. However a great manifold of ground tests for LEO cycling conditions and accelerated GEO conditions are demonstrating their ability for providing the required numbers of cycles and power performance.

After prolonged periods of non-operating or in the case of malfunction, the NiH2 batteries can be woken up and reconditioned without significant loss in capacity. The LiIon batteries, presented here, give evidence that after long term storage without recharging, they retain their capacity at a level for immediate operation. LiIon cells have very low self-discharge rates; typical average in operation is <0.05% a day.

In general our today’s capacity of NiH2 ranges from 4 to 500 Ah compared to the capacity of LiIon batteries from 9 to 350 Ah.

REFERENCES: