Case Study: Saft Lithium-ion vs. Nickel-Hydrogen:

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Customer Profile: Leading GEO Commercial Satellite Manufacturer

The Challenge

As space technology develops, there is a demand for more powerful and lower weight battery systems. The role of satellite batteries is to provide power to the satellite when it is eclipsed from the sun, for several missions such as Low Earth Orbit (LEO) or Geosynchronous Orbit (GEO) applications. Moreover, batteries for high-tech space applications face a particularly tough life; for example, more than 15 years are requested as a nominal lifetime for such GEO systems. They must deliver additional guarantees of reliability, performance and durability.

How do you improve upon conventional energy storage capability such as nickel-hydrogen (Ni-H2) batteries used for at least the past 20 years onboard satellites? Saft has the answer: based on the extensive work performed on the technology for applications such as electric vehicles, now lithium-ion (Li-ion) batteries are replacing Ni-H2 onboard satellites.

The Solution

Until the recent past, geostationary communication satellites used the Ni-H2 technology. The size of these satellites, and consequently the power demand during eclipses, has been continuously growing since the 1980s. By the early 1990s, the average satellite weight was two tons for a power demand in the range of 2 to 3 kW. Today, the average weight is at least five tons for a 10 kW power demand or more.

In 2006, and leading into 2007, satellite manufacturers have planned to build 15 to 30 kW satellites. For example, Alphabus is the next generation satellite under development in Europe (with power up to 25 kW).

Ni-H2 battery technology for a 20 kW satellite weighs at least 700 kg. The complete battery will soon reach the critical weight. Considering the expensive launch price of each kilogram into GEO orbit, the battery is a strategic and key component. Moreover, the use of Ni-H2 batteries is limited to the range of 14 to 16 kW due to the high thermal dissipation.
Significant research on Li-ion technology began in 1996 and was done under the Stentor technology project, including several major European agencies and customers. This demonstrated the ability to use Li-ion on GEO satellites using a Saft Li-ion battery. In fact, since Stentor was the first to even consider the use of Li-ion, it focused on the numerous advantages of Li-ion for evaluation, compared to Ni-H2.

This work led to the insertion of Li-ion technology on true commercial telecommunication satellites. W3A and Amazonas launches in 2004 marked the beginning of the new battery technology era for GEO communication satellites.

Li-ion is considered the best-adapted battery technology due to its various advantages over the two other space technologies: nickel-cadmium (Ni-Cd) and Ni-H2.

The main advantage of Li-ion is the weight reduction of the battery system due to higher specific energy. The specific energy of Li-ion is higher than 125 Wh/kg, whereas the maximum achieved with Ni-H2 is 60 Wh/kg. At the battery level, the weight is reduced by at least 40 percent. More than 350 kg weight saving is expected on a 20 kW satellite.

The second advantage is also a weight saving linked to the lower thermal dissipation and higher Faradic efficiency of the Li-ion compared to the Ni-H2. These characteristics impact the solar panel and radiator sizes. An additional five to ten percent of the weight can be saved.

Additionally, the self-discharge of Li-ion is very low compared to Ni-H2: 0.03 percent of capacity loss per day compared to 10 percent. The management of the state of charge (SOC) on a satellite during integration, launch pad operations and solstice period is easier (battery charge on the
launcher before launch is not mandatory as it is with Ni-H2 batteries). Ni-H2 battery self-discharge (30 times higher than Li-ion) imposes recharge of the battery up to the final countdown. This recharge operation performed under the fuse cap is a critical phase of the launch mainly because of the thermal management of the battery.

Furthermore, the memory effect observed in Ni-Cd and Ni-H2, which affects the cycling performance of such batteries, does not exist with Li-ion. So, in-orbit management can be simplified because using Li-ion can cut out the reconditioning operation necessary for Ni-H2.

Another major advantage of Li-ion is the direct relationship between the battery SOC and the OCV. This characteristic induces two functionalities of the battery. The voltage is used as a precise energy gauge, which allows the state of charge of the Li-ion battery to be known exactly at any time of the mission. In Ni-H2, strain gauges on the pressure vessel are used (as the cell H2 pressure increases with the charge) to indicate only a rough order of the state of charge.

<table>
<thead>
<tr>
<th></th>
<th>NiCd</th>
<th>NH2</th>
<th>Li-ion</th>
<th>System Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Density (Wh/kg)</td>
<td>30</td>
<td>60</td>
<td>125</td>
<td>Weight Saving</td>
</tr>
<tr>
<td>Energy Efficiency %</td>
<td>72</td>
<td>70</td>
<td>96</td>
<td>Reduction of charge Power : solar panel</td>
</tr>
<tr>
<td>Thermal Power (Scale : 1-10)</td>
<td>8</td>
<td>10</td>
<td>3</td>
<td>Reduction of radiator, heat pipes sizes</td>
</tr>
<tr>
<td>Self Discharge %/month</td>
<td>10</td>
<td>80</td>
<td>1</td>
<td>No trickle and simple management at Launch pad</td>
</tr>
<tr>
<td>Temperature Range °C</td>
<td>0 to 40</td>
<td>-15 to 20</td>
<td>10 to 35</td>
<td>Management at ambient</td>
</tr>
<tr>
<td>Memory Effect</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No reconditioning</td>
</tr>
<tr>
<td>Energy Gauge/Monitor</td>
<td>No</td>
<td>Pressure</td>
<td>Voltage</td>
<td>Better observability of State Of Charge</td>
</tr>
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<td>Charge Management</td>
<td>CC</td>
<td>CC</td>
<td>CC/CV+</td>
<td>Balancing system needed</td>
</tr>
<tr>
<td>Modularity</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>One Cell Design, Ability to put cells in parallel</td>
</tr>
</tbody>
</table>

The Advantages and Drawbacks of the Li-ion Technology Versus the Two Current Ones Li-ion cells can be directly assembled in parallel giving high battery modularity in terms of capacity, using one cell size. The only attention needed for Li-ion systems is the need for a more sophisticated electronic system for battery management, instead of using a “brutal” overcharge management used by nickel systems. The numerous advantages of Li-ion compared to the two current nickel technologies (Ni-H2 and Ni-Cd) have led to an increasing number of satellite projects adopting Li-ion batteries as the baseline power source. All satellite manufacturers have already adapted their platforms to the characteristics of this new electrochemical couple.

To assess this last point, Saft has been in the last three years, selected by the main satellite primes to supply Li-ion batteries for their satellites in replacement of the previous Ni-H2 technology. Today,
more than 45 satellites have base-lined power systems using Li-ion instead of Ni-H2. More than 35 are big GEO commercial satellites.

Saft is working mainly with the leading GEO commercial satellite manufacturers (in Europe, U.S., Asia and Russia) to install this technology onboard their platforms. It must be highlighted that the recent platforms have been designed to adapt this new battery technology from both the pure battery capability and system management points of view.

Currently, six GEO satellites and two LEO satellites have been launched with Li-ion batteries. The most recent are Hot Bird 8, manufactured by EADS Astrium; Koreasat 5 and Syracuse 3B, manufactured by Alcatel Alenia Space.

Conclusion

The benefits that flow from installing Li-ion bring significant advantages over traditional solutions such as Ni-H2. Major industries acknowledge these benefits and have turned to Saft’s expertise and extensive experience in space to adopt Li-ion batteries for their space programs. Saft is a world leading supplier and manufacturer of space batteries for a wide range of applications such as GEO, LEO, MEO, probes and launchers. In addition, Saft is the only space battery supplier who can offer all three battery technologies and demonstrates vast experience in the space battery business, dating back to the 1960s.

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