Characterizing Lithium Iron Nano-Phosphate Cells

Michael Sparks*, Daniel Muffoletto†, and Dr. Jennifer Zirnheld‡
Energy Systems Institute - University at Buffalo
*Presenter †Graduate Student Advisor ‡Faculty Advisor

Introduction
The focus of this research is to investigate and apply various characterization methods on A123 Lithium Iron Nano-Phosphate cells to build comparisons and conclusions hinting at what their real world performances might be like. Four cells were chosen numbered as follows: 1, 2, 3, and 8. Each cell was discharged at 10 A, 25 A, and 40 A. Their internal resistance and its inherent effect on temperature and cell voltage will be investigated.

Methods
A. The DC Load Test
This involves shorting out the battery using a predetermined resistor and using the measured results along with the known parameters to determine the pure ohmic resistance of the cell.

B. Equivalent Series Resistance (ESR)
ESR is the measurement of a cell’s internal resistance at a fixed frequency. A test signal is applied to the cell, and the cell’s response is measured to determine the resistance.

C. Electrochemical Impedance Spectroscopy (EIS)
Unlike ESR which is a fixed frequency measurement, EIS involves measuring the frequency response of the cell over a wide range of frequencies. This method is useful for determining specific values for a complex equivalent circuit [1] as shown in Fig. 3.

Results

![Complex Equivalent Circuit](image)

Fig. 3. Complex equivalent circuit of a lithium iron nano-phosphate cell based on Randles circuit with Warburg impedance shown as Zw [2].

![Equivalent Series Resistance During Discharge](image)

Fig. 4. Accumulated resistance data from the A123 cells discharged at different rates.

![Cell Temperature During Discharge](image)

Fig. 5. The A123 cell’s temperature fluctuations during each discharge.

![Cell Voltage During Discharge](image)

Fig. 6. Summary of all discharges showing the relationship between higher current draws and lower final capacity ratings.

<table>
<thead>
<tr>
<th>Cell</th>
<th>Discharge Current</th>
<th>10 A</th>
<th>25 A</th>
<th>40 A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ESR (mΩ)</td>
<td>Max Temp (ºF)</td>
<td>Capacity (Ah)</td>
<td>ESR (mΩ)</td>
</tr>
<tr>
<td>1</td>
<td>-</td>
<td>-</td>
<td>10.3</td>
<td>49</td>
</tr>
<tr>
<td>2</td>
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<td>3</td>
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<td>10.0</td>
</tr>
<tr>
<td>8</td>
<td>14.3</td>
<td>32</td>
<td>2.10</td>
<td>12.5</td>
</tr>
</tbody>
</table>

Conclusion
There is a linear relationship between cell temperature and ampere hours based on the cell’s heat transfer characteristics. The slope of this relationship is based on the rate of discharge, with lower current, longer discharges having better efficiency in terms of total energy output. With higher current discharges, the battery’s ability to produce electrical power decreases, and a greater ratio of this energy is dissipated as heat.

References

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