Application Note

Simultaneous Measurement of the Impedance of Battery Modules and Individual Cells

This application note proposes a method for performing acceptance inspections (degradation diagnostics) of lithium-ion batteries, including for recycling, and battery module evaluations more quickly using simultaneous, multipoint AC impedance measurement.

Target

Acceptance inspections of lithium-ion batteries carried out by recycling businesses
Development and evaluation of lithium-ion batteries

Market Movements

As electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) become more popular, it is predicted that lithium-ion batteries removed during repairs and replacements will flood the market. Even batteries that are no longer suitable for use in vehicle applications can be recycled for use in non-vehicle applications such as fixed power supplies and lighting power supplies. In the future, there is likely to be a brisk market for recycled EV batteries that are no longer used in vehicle applications.

Problem

Lithium-ion batteries no longer suitable for use in vehicle applications undergo acceptance inspections by recycling businesses, and the batteries that pass those inspections are used in recycled products. The residual performance of batteries is typically evaluated by means of charge/discharge testing, but that method suffers from a number of issues. Additionally, streamlining the acceptance inspection process itself is a key priority.

- Reliance on charge/discharge testing makes inspections more time consuming, preventing inspection of large numbers of batteries.
- That method provides a reliable means of ascertaining the charge rate of individual cells, but it takes time to disassemble and then reassemble batteries.
- There is no reliable method for diagnosing the degradation of entire modules.

HIOKI

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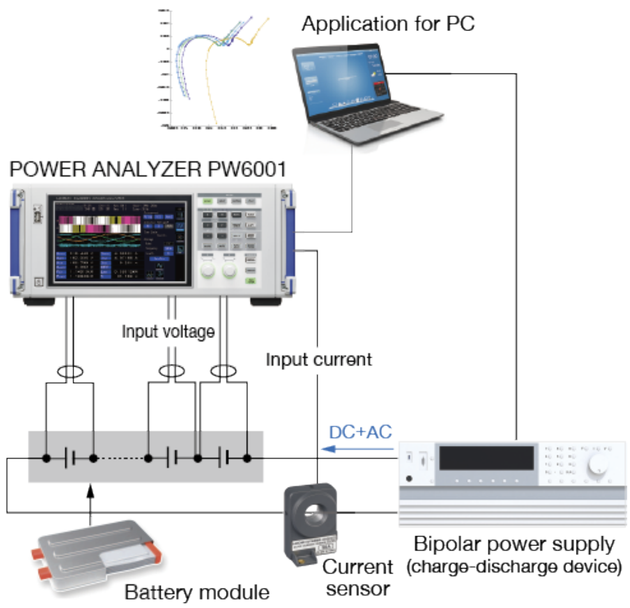
Solutions

One solution is to use a computer application to control a Power Analyzer PW6001 and bipolar power supply. The bipolar power supply is used to apply an AC measurement signal while varying its frequency. The power analyzer is used to measure the real (Rs) and imaginary (X) impedance components based on defined equations. The computer application then renders a Nyquist (Cole-Cole) plot.
Features:
This approach allows AC impedance to be measured while charge/discharge testing is ongoing. Multiple cells and modules can be measured simultaneously, shortening measurement times. A database of Nyquist (Cole-Cole) plots can be developed to provide a yardstick to guide acceptance of batteries for recycling.



Equipment used

POWER ANALYZER	PW6001	HIOKI
Current sensor	Select from options for PW6001	HIOKI
Bipolar power supply		Other company's product

Solutions

Hioki carried out actual tests using modules comprised of 16 groups, each of which consisted of five 18650-type lithium-ion batteries connected in parallel. The groups were connected in series. Rs and X were measured while varying the frequency of the measurement signal from 0.01 Hz to 10 kHz, and a Nyquist (Cole-Cole) plot was rendered based on the results. Voltage was also measured using the BMS voltage detection lines. This approach facilitates easy measurement, even if modules have been packaged together.

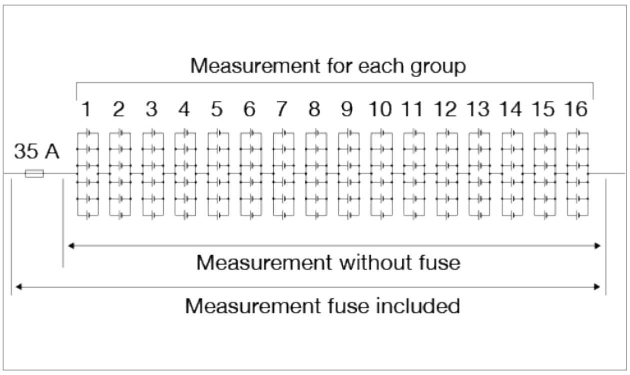


Fig.1 Module used for the experiment

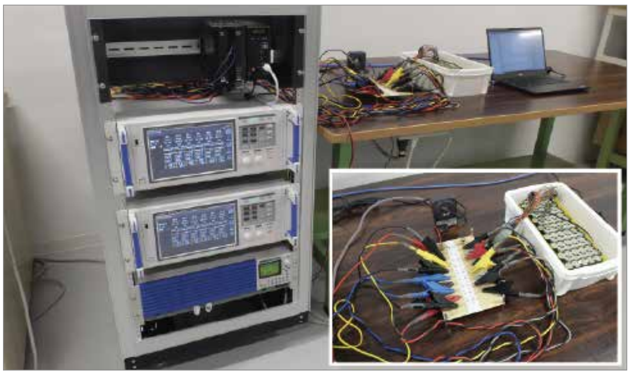


Fig.2 Module and equipments used for the experiment

Measurement data

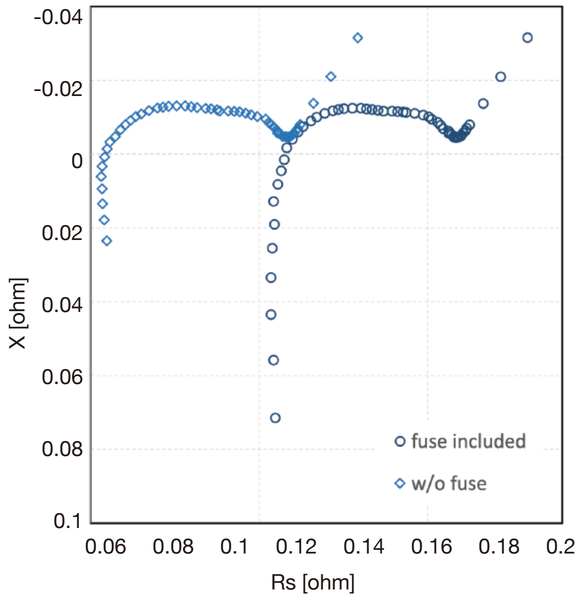


Fig.3 Comparison between fuse included and without fuse

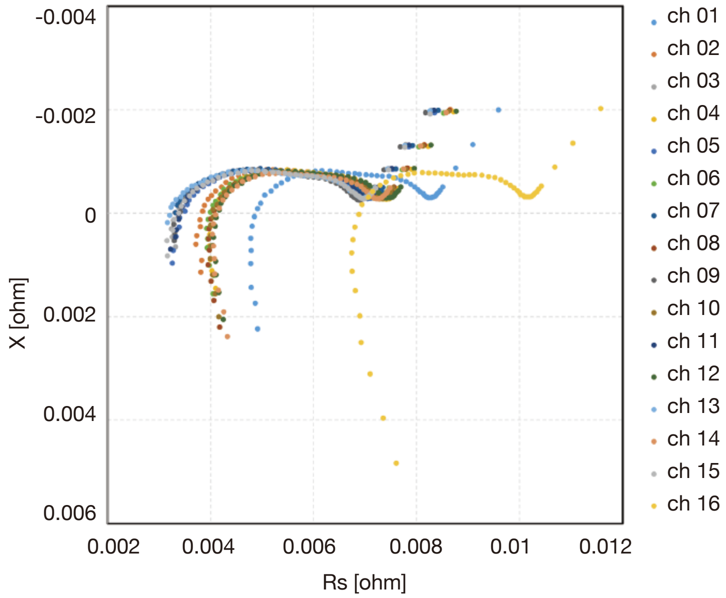


Fig.4 Comparison of each group

First, this figure illustrates the results of making measurements with and without a fuse. When the fuse is included, the waveform moves to the right by the amount of the fuse's resistance. In this way, stable measurement is possible even when there are elements connected in series with the battery module (for example, a fuse or FET).

Fig. 4 illustrates measurement results for each of the 16 parallel-connected groups.

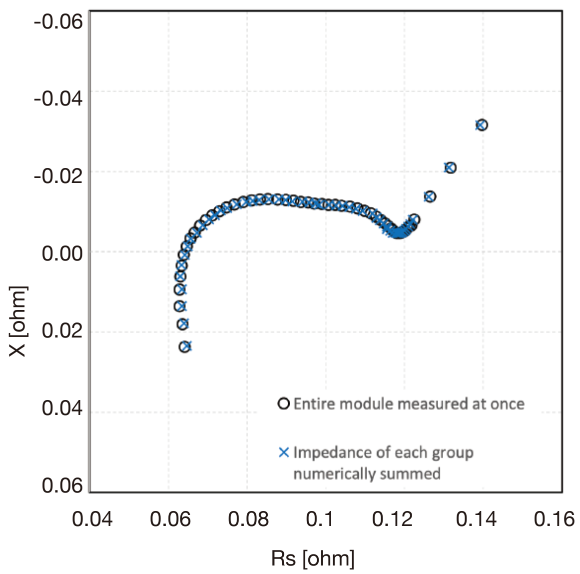


Fig.5 Comparison between no fuse and 16 groups total

This figure plots the results of adding the measurement results for the 16 groups and the overall values as measured without the fuse. The two waveforms roughly match, indicating that the setup was able to make measurements in a stable manner.

Measurement data

Hioki prepared a video portraying Rs and X measurement performed while sweeping the frequency from 0.1 Hz to 10 kHz and of the resulting Nyquist (Cole-Cole) plot. *The recording was made at triple speed.

“Simultaneous Measurement of the Impedance of Battery Modules and Individual Cells”
https://youtu.be/6ix27mdJE1E

Information

Hioki offers a broad range of solutions for battery R&D and production lines as a leading manufacturer of battery measuring instruments. The company is committed to contributing to the realization of a society in which electric vehicles can be utilized more broadly by providing measurement solutions for battery reuse and recycling.
Diagnosing battery degradation requires the study not only of advanced measurement technologies, but also techniques for accumulating and analyzing data. HIOKI E.E. Corporation will continue to provide degradation diagnostic solutions while meeting individual customers’ requirements.
Please have interested customers contact Hioki.

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