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Study on Evaluation Method of Aging Degree of Lithium-ion Batteries

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Collaborative Innovation Center of Electric Vehicles in Beijing


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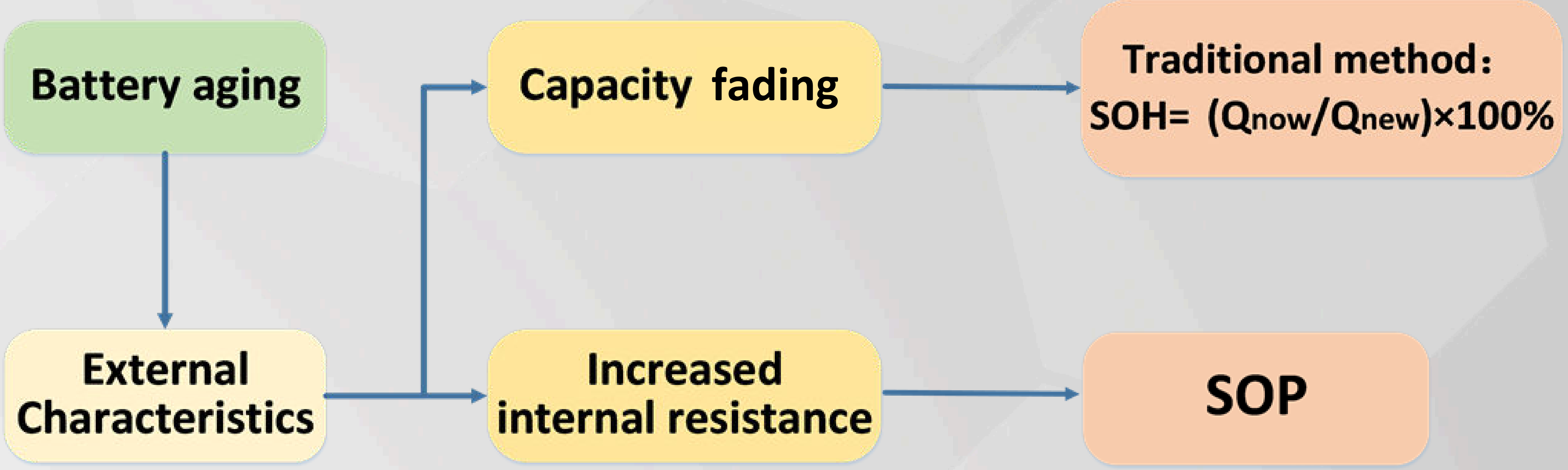
Problem



Target

"P"---Battery power

Can it evaluate battery aging?

What is the relationship between "P" and internal characteristics of batteries?

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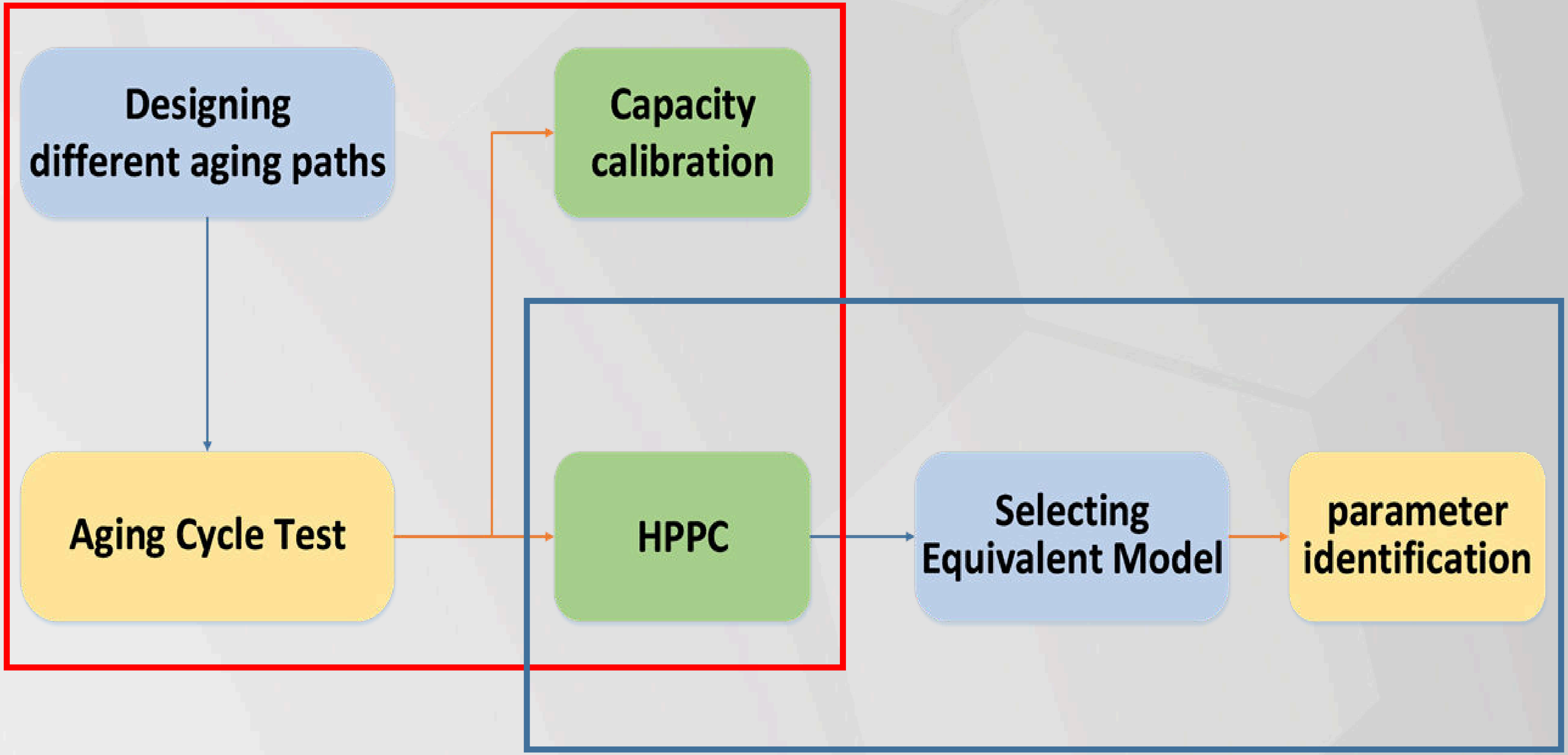
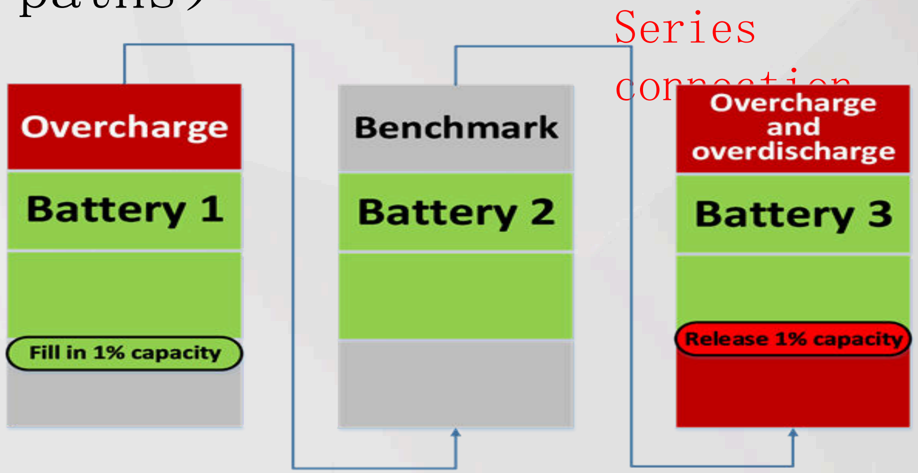
01.Introduction

Research ideas



02.Experimental design and data analysis

Aging Cycle Test (Three aging paths)



- **Step 1:**

1C , CCCV , Charging, No.2 battery→3.6V;
Recharge,I < 1/20C, static for 0.5 hours;

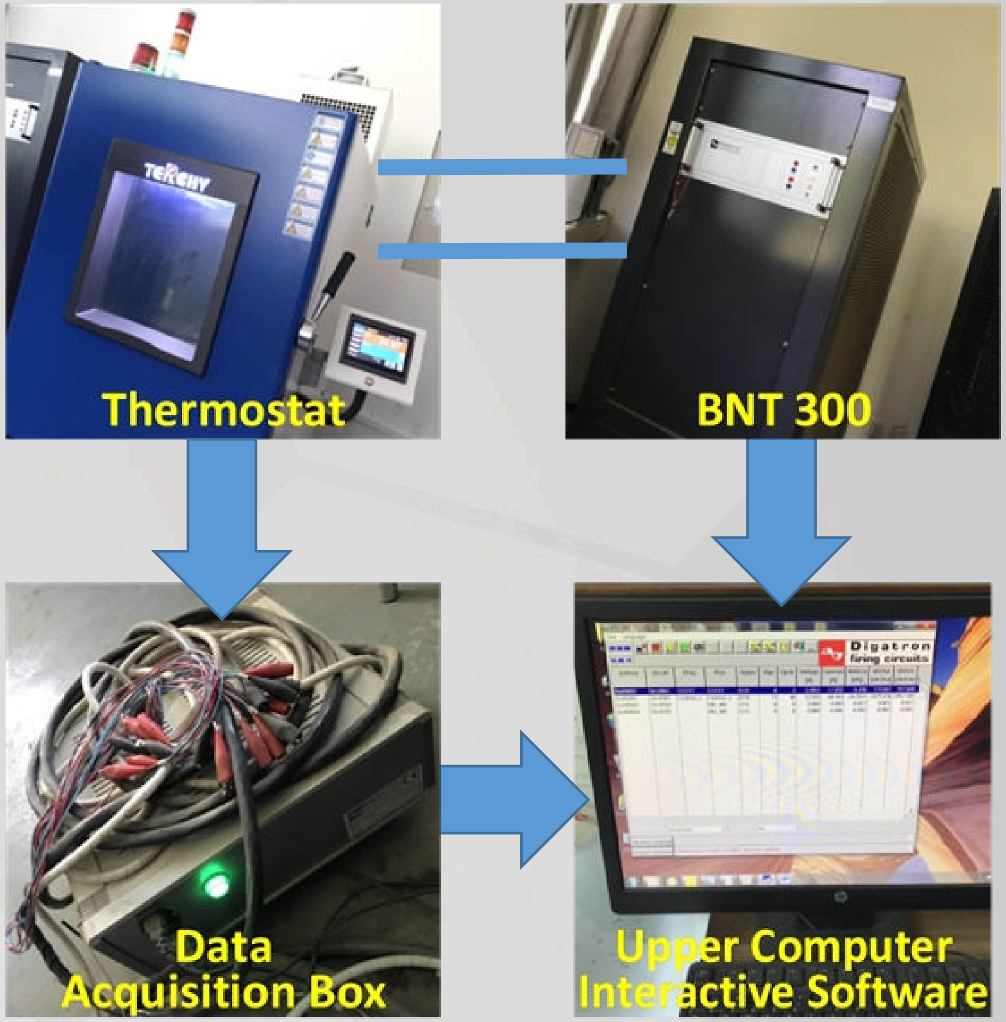
- **Step 2:**

1C , Discharging , No. 2 battery →2.8V, static for 30 min;
C/3, No. 2 battery →2.8V,static for 30 min;

- **Step3:**

Repeat the above steps.

Build an experimental platform



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02.Experimental design and data analysis

Cell & Procedure

Cell

- Lithium-ion batteries
- Cell capacity: 60Ah
- Nominal voltage: 3.2V
- Discharge cut-off voltage: 2.8V
- Charging cut-off voltage: 3.6V

Testing

- Every 100 cycles
- Capacity Test
- Hybrid Pulse Power Charaterzation Test

130*36*190（mm）

Formula for calculating 10 seconds power

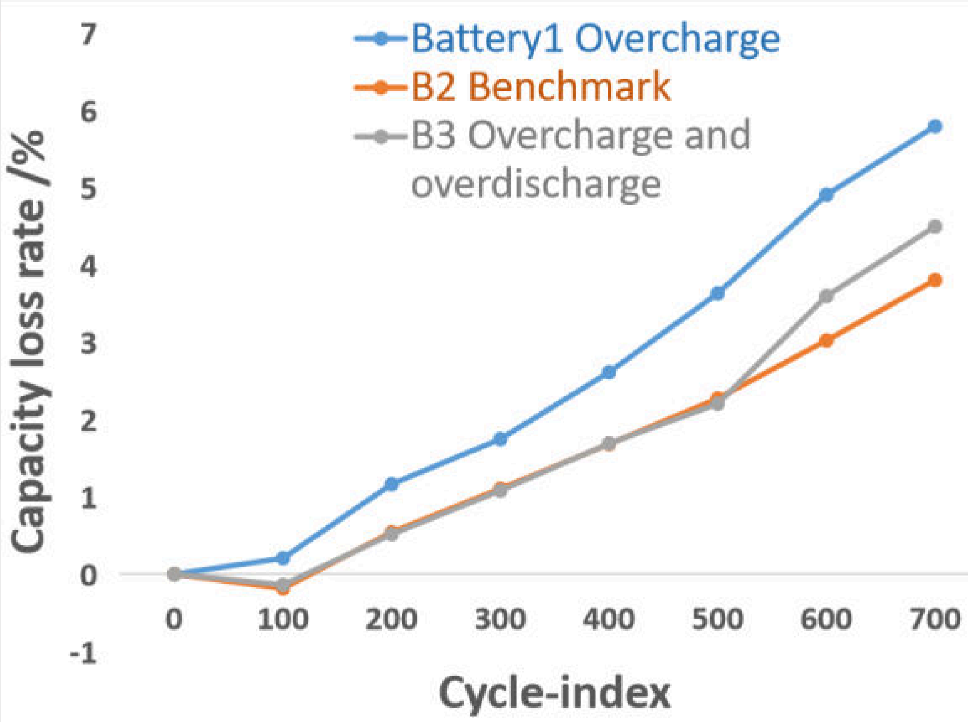
$$P_{DCH} = \frac{V_{MIN}(OCV_{DCH} - V_{MIN})}{R_{DCH}}, \qquad R_{DCH} = \frac{OCV_{DCH} - V_{10S}}{I_{DCH}}$$

$$P_{CH} = \frac{V_{MAX}(V_{MAX} - OCV_{CH})}{R_{CH}}, \qquad R_{CH} = \frac{V_{10S} - OCV_{CH}}{I_{CH}}$$

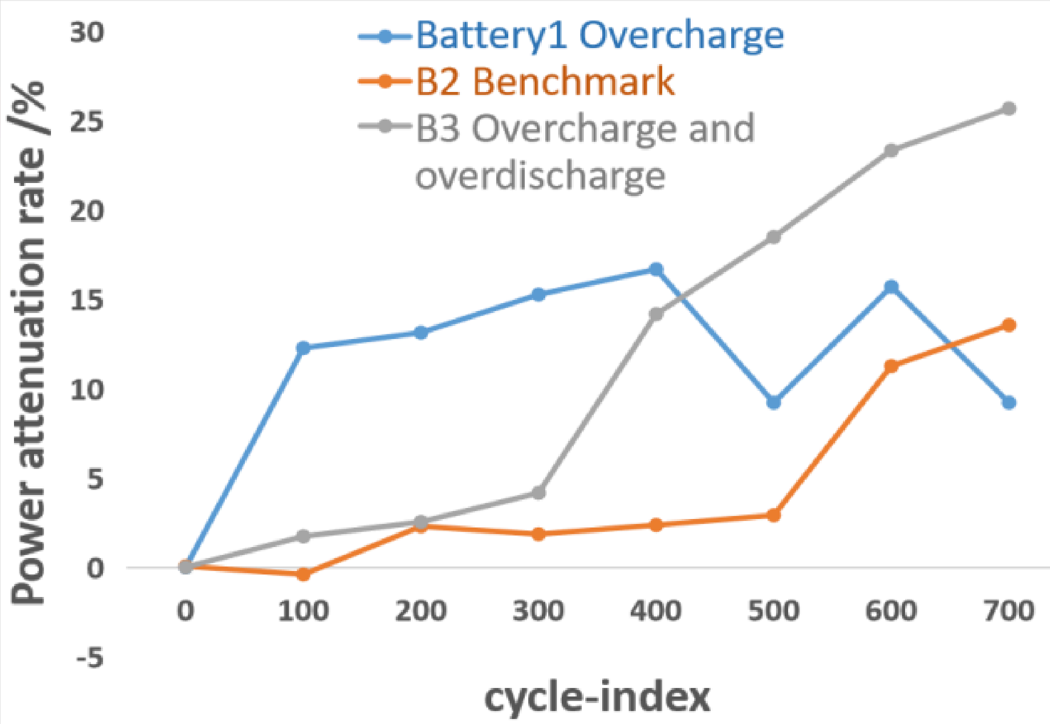
02.Experimental design and data analysis

Ageing Result

Capacity test



HPPC



$$\text{Capacity loss rate} = 1 - \frac{Q_{NOW}}{Q_{NEW}} \times 100\%$$

02.Experimental design and data analysis

How to deal with

?: Normalization

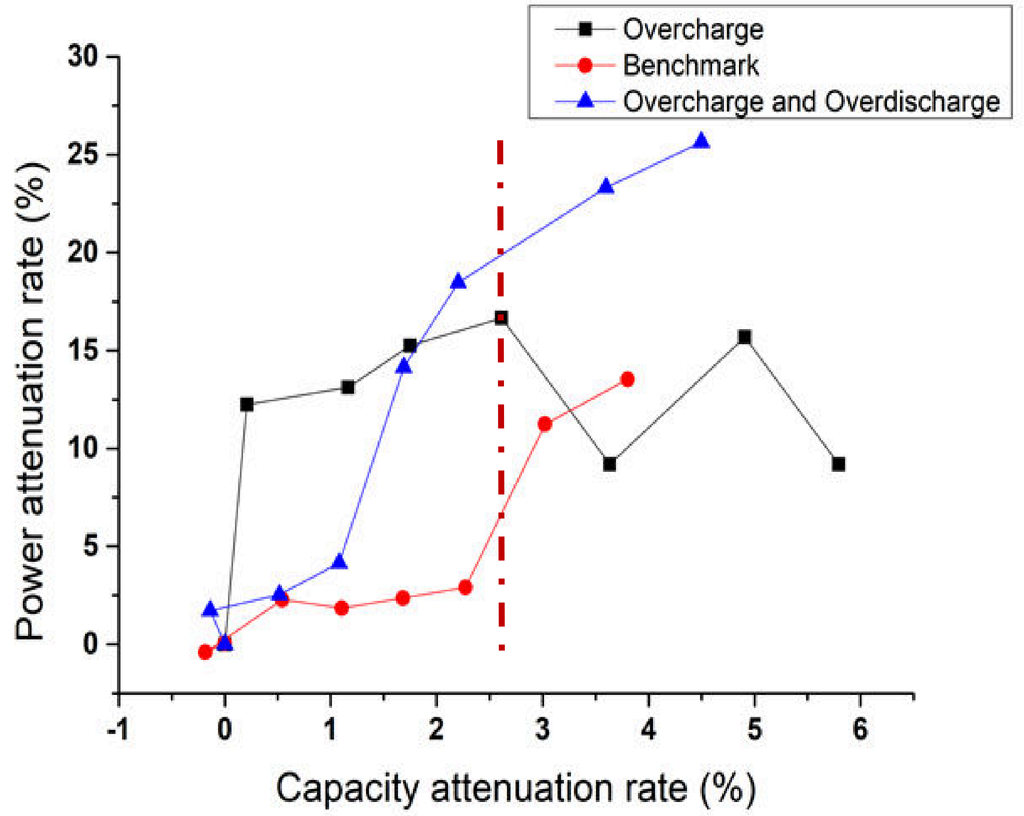
what do we observe?

Power loss varies with the same capacity loss.

Conclusion?

It is not perfect to evaluate battery life only by residual capacity in tradition.
It also needs comprehensive evaluation from the power point of view.

Variation of power loss and ampere-hour loss under different aging paths



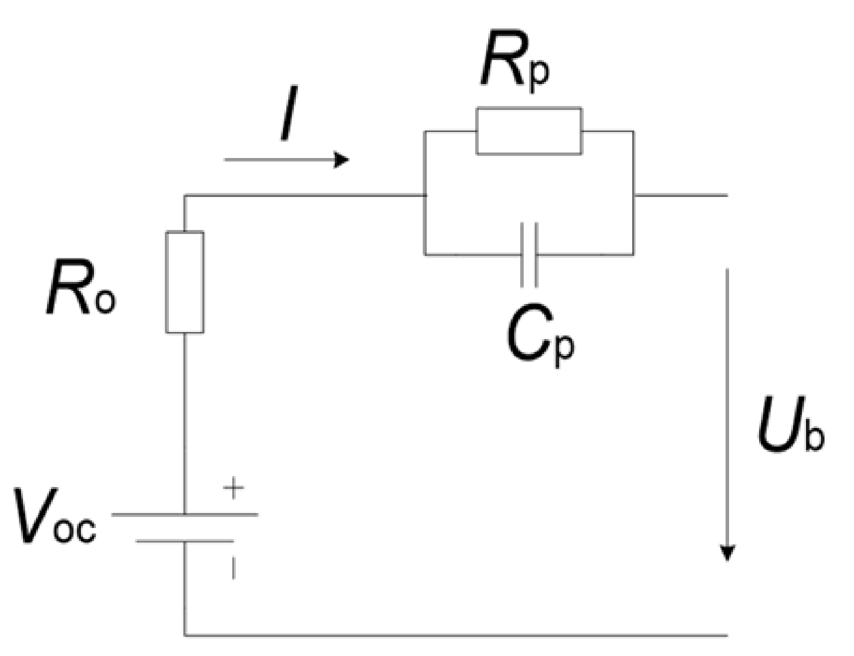
02.Experimental design and data analysis

Target

·Looking for the causes of battery power decline

Model

First-order RC circuit structure



Model parameter

R_0: ohmic resistance

R_p: Polarization internal resistance

Model input: I

Model output: $U = -U_b + V_{oc}$

$V_{oc} = U_b + IR_o + U_p$

Model equation: $\dot{U}_p = -\frac{U_p}{C_p R_p} + \frac{I}{C_p}$

02.Experimental design and data analysis

Parameter identification

Input current → Equivalent circuit model → Outpu t → $U = -U_b + V_{oc}$ → Laplace transform →

$U(s) = I(s)G(s)$ → $G(s) = R_o + \frac{R_p}{1 + R_p C_p s}$ → Linear discrete → Difference equation

$$U(k) = -\alpha_1 U(k-1) + \beta_0 I(k) + \beta_1 I(k-1)$$

$$R_o = \frac{\beta_0 - \beta_1}{1 - \alpha_1} \quad R_p = \frac{2(\beta_1 - \alpha_1 \beta_0)}{1 - \alpha_1^2} \quad C_p = \frac{T(1-\alpha_1)^2}{4(\beta_1 - \alpha_1 \beta_0)}$$

02.Experimental design and data analysis

Fitting accuracy

10 seconds power

Internal parameters

Matlab →

Curve fitting

$$f(x) = p1 \cdot x + p2$$

Parameter identification results

	R_0	R_P	C_P
Barrery1	0.978	0.563	0.007
Battery2	0.885	0.568	0.275
Battery3	0.907	0.54	0.335

02.Experimental design and data analysis

Power attenuation&parameter

$$P_{DCH} = \frac{V_{MIN}(OCV_{DCH} - V_{MIN})}{R_{DCH}}$$

Discharge internal resistance（R_{DCH}）?

Expression of total internal resistance

$$R = R_0 + R_P(1 - e^{-\frac{t}{\tau}}), \tau = R_P \cdot C_P$$

Discharge power expression

$$P_{DCH} = \frac{V_{MIN}(OCV_{DCH} - V_{MIN})}{R_0 + R_P(1 - e^{-\frac{t}{\tau}})}$$

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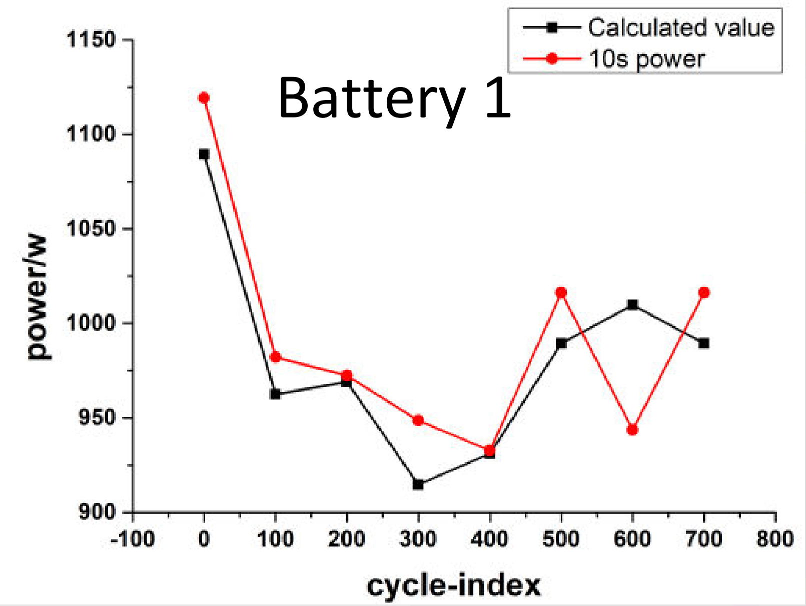
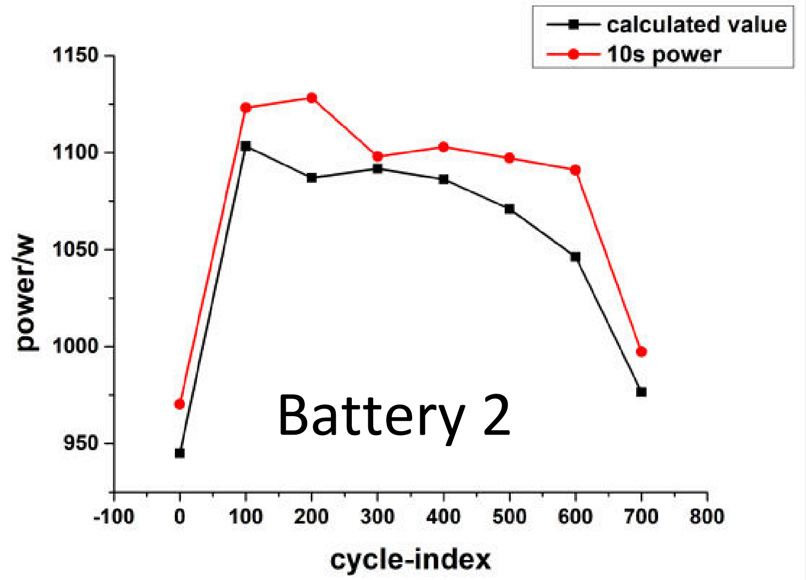
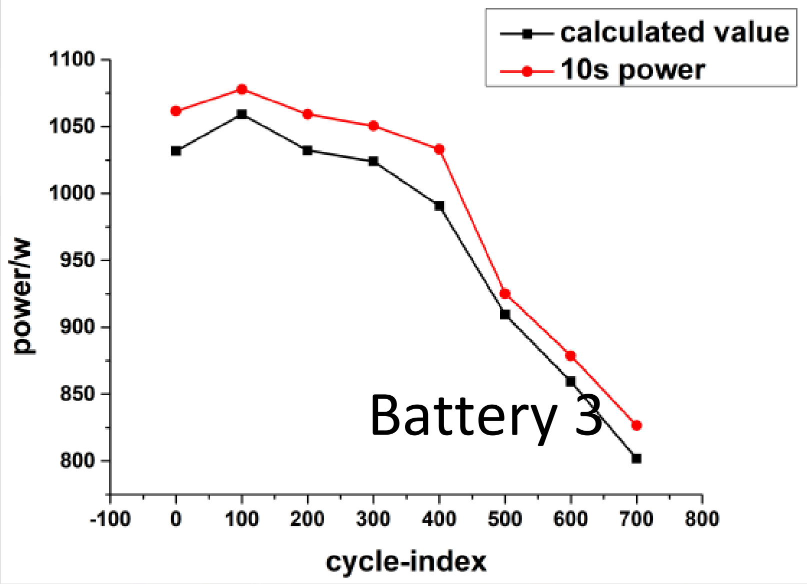
02.Experimental design and data analysis



$P_{\text{calculated value}}$ <10s power

Error result <4.3%





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02.Experimental design and data analysis

Results

- The correlation between **R0** and power of each monomer is the highest, and **RP** is the second.
- Model validation

Discharge power expression

$$P_{DCH} = \frac{V_{MIN}(OCV_{DCH} - V_{MIN})}{R_0 + R_P(1 - e^{-\frac{t}{\tau}})}$$

03.Conclusion and prospect

Summary of results

- Under different aging paths, when the battery capacity declines uniformly, the power declines differently.
- Power fading is positively correlated with internal resistance, and is most correlated with ohmic internal resistance.
- An aging assessment method based on power degradation should be established.

03.Conclusion and prospect

Follow-up work

- Continue the experiment, Searching for Quantitative Decline Relations between Internal Resistance and Power, Capacity and Power .
- Cell → Battery Pack