同行专家业内评价意见书编号: 20240858141

附件1

浙江工程师学院（浙江大学工程师学院）同行专家业内评价意见书

姓名： 居铃泠

学号： 22160026

申报工程师职称专业类别（领域）： 能源动力

浙江工程师学院（浙江大学工程师学院）制

2024年04月01日

一、个人申报

（一）基本情况【围绕《浙江工程师学院（浙江大学工程师学院）工程类专业学位研究生工程师职称评审参考指标》，结合该专业类别(领域)工程师职称评审相关标准，举例说明】

1.对本专业基础理论知识和专业技术知识掌握情况
熟练掌握本专业基础理论知识和专业技术知识，本科时期平均学分绩点为4.90/5.00，平均学分绩点专业排名6/216。其中，电路、电力系统稳态分析、电力系统保护与控制、现代控制理论、电机学、电力电子技术、高电压技术等课程成绩均为90分以上，对应的实验课程及课程设计成绩均为优秀，能够在掌握本专业基础理论知识和专业技术知识的基础上灵活应用相关知识、进行实践。
2.工程实践的经历
2022年07月-
2023年07月于苏州时代新安能源科技有限公司进行专业实践，专业实践成绩为90分、考核为优秀，实践报告《电化学储能电池状态监测研究》被评为2022年浙江省专业学位研究生优秀实践成果、浙江大学专业学位研究生优秀实践成果一等奖。
3.在实际工作中综合运用所学知识解决复杂工程问题的案例（不少于1000字）
（1）工程问题背景
目前的电化学储能电池安全性评估算法大多采用电气量和温度建立电池状态估计模型，基于数据驱动方法实现电池内部的荷电状态和老化状态的估计，但这种估计方法仅基于电、热等参数进行电池检测，不能充分挖掘电池老化的电化学状态。应结合电池储能系统应用的技术特点，选择合适的数据分析平台，扩增电池关键参量信息源，增加对电池内部电化学特征数据的采集与挖掘，进而设计、优化合适的评估算法。
（2）项目主要内容
《电化学储能电池状态监测研究》项目研究内容如下：
①研究基于X射线、红外、超声图像的储能电池非侵入式特征提取方法，研制储能电池非侵入式检测装置
②提出考虑储能电池电化学机理与经验模型的安全性评估指标
③构建基于数据驱动的储能电池安全状态评估模型
本人承担研究内容1、研究内容2的X射线CT相关研究，同时部分参与研究内容3，研制完成储能电池X射线CT非侵入式检测装置一台，确定储能电池非侵入式安全性评估指标，提出基于X射线CT非侵入式检测技术的储能电池老化诊断方法，提出一种基于重新定义最大-
最小边界的锂离子电池OCV-SOC曲线标定方法。形成SCI期刊论文《Degradation diagnosis of lithium-ion batteries considering internal gas
evolution》（本人一作，发表），《Open circuit voltage state of charge curve calibration by redefining max-min bounds for lithium-ion
batteries》（本人一作，发表），《Data-driven state-of-health estimation for lithium-ion battery based on aging
features》（本人二作，发表），获得第一届高校电气电子工程创新大赛全国赛三等奖。
（3）意义
①项目可实现非侵入式提取储能电池安全特征参数，实现多源数据融合的储能电池安全状态评估，可应用于储能系统中，提升电化学储能系统运行的安全性；
②项目可有效减小低电流OCV测试实验获取OCV-
SOC曲线的放电容量与最大可用容量的不一致性影响，使得OCV-
SOC曲线的SOC范围更接近实际值，提升了锂离子电池SOC估计精度。
（4）应用价值或社会影响力
首先，我在专业实践中取得的成果具有一定的经济效益。我搭建了储能电池X射线CT非侵入

式检测装置，提出了基于X射线CT的储能电池老化诊断方法。这种老化诊断方法具有准确、可靠等特点，能够对储能电池的老化程度和安全性进行评估，为企业提供了可靠的数据支持和决策依据。通过该技术的应用，企业可以及时发现储能电池的老化问题，采取相应的维护和替换措施，从而降低维修和更换成本。

其次，我的专业实践成果可以在储能电池领域产生积极的社会效益。储能电池技术在能源存储和电动车辆等领域具有重要的应用前景，而安全性和老化问题是制约其广泛应用的关键因素。通过我提出的储能电池非侵入式安全性评估指标和老化诊断方法，可以为储能电池提供科学的评估和监测手段，促进储能电池技术的发展和推广，推动清洁能源的应用和碳减排目标的实现。

（5）为企业（行业）解决的实际问题

①部分解决了储能电池老化机理解耦困难、难以诊断的问题，从机理角度提升了电池的老化诊断效果；

②部分解决了低电流OCV测试实验获取OCV-SOC曲线的放电容量与最大可用容量的不一致问题，提升了锂离子电池SOC估计精度。

（二）取得的业绩（代表作）【限填3项，须提交证明原件（包括发表的论文、出版的著作、专利证书、获奖证书、科技项目立项文件或合同、企业证明等）供核实，并提供复印件一份】					
1. 公开成果代表作【论文发表、专利成果、软件著作权、标准规范与行业工法制定、著作编写、科技成果获奖、学位论文等】					
成果名称	成果类别 [含论文、授权专利（含发明专利申请）、软件著作权、标准、工法、著作、获奖、学位论文等]	发表时间/授权或申请时间等	刊物名称/专利授权或申请号等	本人排名/总人数	备注
Degradation diagnosis of lithium-ion batteries considering internal gas evolution	TOP期刊	2023年06月24日	Journal of Energy Storage	1/4	SCI期刊收录
Open circuit voltage - state of charge curve calibration by redefining max - min bounds for lithium-ion batteries	TOP期刊	2023年12月22日	Journal of Energy Storage	1/4	SCI期刊收录
基于容量边界修正的锂离子电池 OCV-SOC 曲线标定方法	发明专利申请	2023年11月03日	申请号：202311457090.2	1/5	

2.其他代表作【主持或参与的课题研究项目、科技成果应用转化推广、企业技术难题解决方案、自主研发设计的产品或样机、技术报告、设计图纸、软课题研究报告、可行性研究报告、规划设计方案、施工或调试报告、工程实验、技术培训教材、推动行业发展中发挥的作用及取得的经济社会效益等】

<table>
<tr><td colspan="2">（三）在校期间课程、专业实践训练及学位论文相关情况</td></tr>
<tr><td>课程成绩情况</td><td>按课程学分核算的平均成绩： 84 分</td></tr>
<tr><td>专业实践训练时间及考核情况(具有三年及以上工作经历的不作要求)</td><td>累计时间： 1 年（要求1年及以上）
考核成绩： 90 分（要求80分及以上）</td></tr>
<tr><td colspan="2">本人承诺</td></tr>
<tr><td colspan="2">个人声明：本人上述所填资料均为真实有效，如有虚假，愿承担一切责任，特此声明！

申报人签名： 居铃泠</td></tr>
</table>

22160026

二、日常表现考核评价及申报材料审核公示结果

日常表现考核评价	非定向生由德育导师考核评价、定向生由所在工作单位考核评价： ☑优秀 □良好 □合格 □不合格 德育导师/定向生所在工作单位分管领导签字（公章）： 年 月 日
申报材料审核公示	根据评审条件，工程师学院已对申报人员进行材料审核（学位课程成绩、专业实践训练时间及考核、学位论文、代表作等情况），并将符合要求的申报材料在学院网站公示不少于5个工作日，具体公示结果如下： □通过 □不通过（具体原因： ） 工程师学院教学管理办**公室**审核签字（公章）： 年 月 日

浙 江 大 学 研 究 生 院

攻读硕士学位研究生成绩表

学号：22160026	姓名：居铃泠	性别：女	学院：工程师学院	专业：电气工程	学制：2.5年
毕业时最低应获：24.0学分	已获得：27.0学分			入学年月：2021-09	毕业年月：2024-03
学位证书号：1033532024602129			毕业证书号：103351202402600355		授予学位：能源动力硕士

学习时间	课程名称	备注	学分	成绩	课程性质	学习时间	课程名称	备注	学分	成绩	课程性质
2021-2022学年秋季学期	储能材料		2.0	82	专业学位课	2021-2022学年秋冬季学期	研究生论文写作指导		1.0	95	专业学位课
2021-2022学年秋季学期	储能原理		2.0	85	专业学位课	2021-2022学年春季学期	储能器件与装备		2.0	93	专业学位课
2021-2022学年秋季学期	智能配电网技术		2.0	85	专业学位课	2021-2022学年春季学期	研究生英语基础技能		1.0	免修	公共学位课
2021-2022学年秋季学期	新能源发电与控制技术		2.0	79	专业学位课	2021-2022学年夏季学期	自然辩证法概论		1.0	89	公共学位课
2021-2022学年秋季学期	电力系统运行与控制		2.0	93	专业选修课	2021-2022学年春夏季学期	研究生英语		2.0	92	公共学位课
2021-2022学年秋冬季学期	中国特色社会主义理论与实践研究		2.0	90	公共学位课	2021-2022学年夏季学期	储能系统及应用		2.0	95	专业学位课
2021-2022学年冬季学期	工程伦理		2.0	87	公共学位课	2022-2023学年秋季学期	创新创业实践训练		2.0	通过	跨专业课
2021-2022学年冬季学期	工程中的有限元方法		2.0	83	专业选修课						

说明：1. 研究生课程按三种方法计分：百分制，两级制（通过、不通过），五级制（优、良、中、及格、不及格）。

2. 备注中“*”表示重修课程。

学院成绩校核章：

成绩校核人：张梦依

打印日期：2024-04-02

浙江大学研究生院（60）成绩校核章

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Research papers

Degradation diagnosis of lithium-ion batteries considering internal gas evolution

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Keywords:
Degradation diagnosis
Lithium-ion battery
Electrolyte decomposition
Internal gas evolution
X-ray computed tomography

ABSTRACT

Degradation diagnosis is essential for the safety of lithium-ion batteries. However, there lacks a method to provide detailed information about battery degradation mechanisms comprehensively. As an important product of electrolyte decomposition, internal gas evolution is rarely involved in degradation diagnosis. In this paper, internal gas evolution is evaluated based on X-ray computed tomography (CT), and used for degradation diagnosis by combination with internal resistances. Internal resistances are identified based on the equivalent circuit model (ECM) to describe different degradation mechanisms. Region of interest (ROI) volume of the tomogram, which reflects internal gas volume, is extracted to describe electrolyte decomposition using an X-ray CT. The proposed method is verified based on accelerated aging experiments and evaluation experiments of two batteries at different C-rates, whose results show that the tested batteries have different primary degradation mechanisms due to different degradation paths. It is recommended that the replacement of lithium-ion batteries adhere to the criteria of internal resistance and ROI volume change rates. The proposed method considers internal gas evolution and thus improves the effect of the degradation diagnosis in terms of degradation mechanisms.

1. Introduction

Lithium-ion batteries are widely used in energy storage systems nowadays for their high energy density, high efficiency and long life [1,2]. However, ensuring the safety of lithium-ion batteries remains a challenge [3]. As a result, a sequence of accidents have been happening worldwide [4]. Battery degradation can give rise to complicated side reactions which may lead to thermal runaway or explosion, so it is important to figure out whether the battery is in a safe state in advance. Although battery status such as state-of-health (SOH) [5,6] and state-of-charge (SOC) [7,8] are estimated, how batteries degrade is not clearly revealed in the battery management system (BMS) [9] so that there may be lurking risks which cannot be discovered by existing measurements and estimations. A degradation feature can be defined as a measurable characteristic or property that changes over time as the battery undergoes degradation. It is selected based on sensitivity to degradation, ease of measurement and the degradation mechanisms that it reveals. To prevent lurking risks, detailed degradation features should be extracted to disclose and evaluate primary battery degradation mechanisms as a supplement to existing BMS functions. By setting proper upper limits to the features, the battery tester can replace the battery timely, and thus safety problems caused by battery degradation can be prevented in advance.

In the literature, battery degradation is usually diagnosed based on either the thermodynamic or the kinetic phenomenon of the battery [10]. The thermodynamic diagnostic methods utilize the relationship between voltage and capacity under the equilibrium condition, while the kinetic diagnostic methods are based on kinetic processes for different timescales [10]. Incremental capacity (IC) curve [11], differential voltage (DV) curve [11], pseudo open circuit voltage (pOCV) curve [12] and electrochemical impedance spectroscopy (EIS) [13] are widely used in degradation diagnosis. However, in order to reach the equilibrium condition or detect low-frequency parameters, the aforementioned methods are too time-consuming despite the precision. Equivalent circuit model (ECM)-based methods [14,15] simplifies the EIS method by identifying internal resistances instead of measuring AC impedance via different frequencies [14]. However, the identified parameters are only applied in SOH estimation and have not been used as features for degradation diagnosis. Some degradation features can be extracted from ECMs to reflect certain degradation mechanisms.

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第 1 条，共 2 条

标题: Degradation diagnosis of lithium-ion batteries considering internal gas evolution

作者: Ju, LL(Ju, Lingling);Li, XN(Li, Xining);Geng, GC(Geng, Guangchao);Jiang, QY(Jiang, Quanyuan);

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Edition	JCR® 类别	类别中的排序	JCR 分区
SCI	ENERGY & FUELS	**19/115**	**Q1**

第 2 条，共 2 条

标题: Data-driven state-of-health estimation for lithium-ion battery based on aging features

作者: Li, XN(Li, Xining);Ju, LL(Ju, Lingling);Geng, GC(Geng, Guangchao);Jiang, QY(Jiang, Quanyuan);

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SCI	THERMODYNAMICS	**3/62**	**Q1**

注：

1. **期刊影响因子及分区情况最新数据以 JCR 数据库最新数据为准。**
2. **以上检索结果来自 CALIS 查收查引系统。**
3. **以上检索结果均得到委托人及被检索作者的确认。**

教育部科技查新工作站（Z09）

检索人（签章）：阙忱忱

2023 年 9 月 4 日

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Research papers

Open circuit voltage - state of charge curve calibration by redefining max–min bounds for lithium-ion batteries

Lingling Ju [a,c], Pan Long [b,c], Guangchao Geng [b,c,*], Quanyuan Jiang [b,c]

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ARTICLE INFO

Keywords:
Open circuit voltage
State of charge
Lithium-ion batteries
Low-current OCV test
Adaptive square-root unscented Kalman filter

ABSTRACT

The relationship between open circuit voltage (OCV) and state of charge (SoC) is essential for SoC estimation of lithium-ion batteries, which can be secured by either low-current OCV test or incremental OCV test, with incremental OCV test demonstrating better results. Nevertheless, low current always leads to a discharge capacity that is inconsistent with maximum available capacity, which is a key parameter in SoC estimation. Therefore, the resultant OCV-SoC curve fails to provide a consistent SoC range and thus affects SoC estimation. In this paper, OCV-SoC curves obtained from low-current OCV tests are calibrated by redefining max–min bounds to improve SoC estimation accuracy. Max–min bounds of SoC are redefined by measuring, calculating and resetting upper and lower cut-off voltages of the OCV-SoC curve. Based on second-order RC model, model parameters are identified online and adaptive square-root unscented Kalman filter (ASRUKF) algorithm is introduced to perform SoC estimation, which is proved to be precise and adaptive. The calibrated OCV-SoC curve achieves an overall better SoC estimation performance than that obtained from the low-current OCV test and incremental OCV test, which is validated by experiments of $LiNiMnCoO_2$ (NMC) batteries at 0 °C and 25 °C.

1. Introduction

Electric vehicles (EV) are gradually substituting fuel vehicles worldwide due to their higher energy efficiency, lower operating cost and less environmental impact [1–3]. Lithium-ion battery is one of the mainstream batteries applied in EVs [4] for high energy density, low self-discharge rate and longevity [5]. In order to ensure safe operation of lithium-ion batteries, battery management system (BMS) monitors major battery parameters such as voltage, current and temperature in real time. Based on the measurements, essential indices are estimated to evaluate the state of the batteries comprehensively. State of charge (SoC) is one of the indices, which is important for battery safety, efficiency and longevity [6–8]. However, the estimated SoC value can be influenced by many factors such as temperature [9–11] and working environment [12,13], making accurate SoC estimation a challenging task. Therefore, a precise and adaptive SoC estimation is in significant demand.

In the literature, frequently-used SoC estimation methods mainly include coulomb counting method [14–16], data-driven method [17–22] and model-based method [4,6,23–25]. The coulomb counting method is known for its simplicity, but its performance is affected by measurement accuracy and setting of initial value [26]. The data-driven methods can learn the battery behavior properly, but it requires a large amount of training data and strong computing power [14]. The model-based methods can avoid the aforementioned demerits properly, thus it can perform SoC estimation in a precise and adaptive way with less requirement of computing efforts. Following a model based method, a model is chosen firstly to describe the electrochemical behavior of a battery. One of the commonly used models is equivalent circuit model (ECM) [27]. Then the model parameters are determined and SoC estimation is conducted. Kalman filter (KF) and the derivative-based algorithms are the most widely used model-based SoC estimation algorithms, followed by other filters and observers [28]. The square-root unscented Kalman filter (SRUKF) algorithm [29,30] is capable of conducting SoC estimation with high accuracy and short convergence time.

The relationship between open circuit voltage (OCV) and SoC is often described by OCV-SoC curves, which is essential for SoC estimation [31,32]. The accurate measurement of the OCV-SoC curves plays an important role in battery SoC estimation. There are two common OCV tests for OCV-SoC curve acquirement: low-current OCV test and incremental OCV test [33]. In the literature, the two OCV

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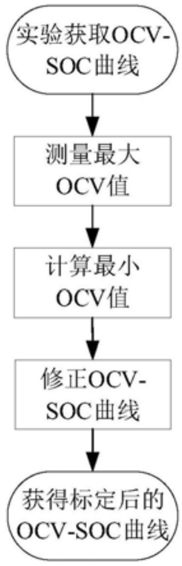
(54)发明名称

基于容量边界修正的锂离子电池OCV-SOC曲线标定方法

(57)摘要

本发明公开了一种基于容量边界修正的锂离子电池OCV-SOC曲线标定方法。本发明采用的技术方案为:通过低电流OCV测试实验获取锂离子电池的OCV-SOC曲线,通过最大可用容量测试获取最大、最小OCV值,利用最大、最小OCV值裁剪OCV-SOC曲线,最后重新定义SOC范围以获得标定后的OCV-SOC曲线。本发明的有益效果是:充分利用锂离子电池容量测试数据,有效减小低电流OCV测试实验获取OCV-SOC曲线的放电容量与最大可用容量的不一致性影响,使得OCV-SOC曲线的SOC范围更接近实际值,提升了锂离子电池SOC估计精度。



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