Draft for B. Tech. Final Year Project

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State of Health Estimation of LMO/NMC-based Electric Vehicle Lithium-Ion Batteries Using the Incremental Capacity Analysis Technique

ABSTRACT

The implementation of an **accurate but also low computation** demanding SOH estimation algorithm represents **a key challenge** for the BMS in EV applications. In this paper we investigate the suitability of the **incremental capacity analysis (ICA) technique** for **estimating** the **capacity fade** and subsequently the **SOH** of **LMO/NMC-based EV Lithium-ion batteries**. Based on **ageing results** collected during **eleven months of testing**, we were able to **accurately relate the capacity fade of the studied batteries to the evolution of the voltage value**, which corresponds to one of the incremental capacity **(IC) valleys**, obtained using the ICA technique.

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BEEP: A Python library for Battery Evaluation and Early Prediction

Abstract

Battery evaluation and early prediction software package (BEEP) provides an open-source Python-based framework for the **management and processing of high-throughput battery cycling data-streams**. BEEPs features include file-system based organization of raw **cycling data** and **metadata** received from **cell testing equipment**, **validation protocols** that **ensure** the **integrity** of such data, **parsing and structuring of data into Python-objects ready for analytics**, **featurization of structured cycling data to serve** as input for machine-learning, and end-to-end examples that use processed data for **anomaly detection** and **featurized data** to **train early-prediction models for cycle life**. BEEP is developed in response to the software and expertise gap between **cell-level battery testing** and **data-driven battery development**.

Keywords

Battery, **Cycling experiments**, Python, Data management, Machine-learning

Synopsis Article on What is a Battery Management System?

Battery Management System(BMS) is a tech dedicated to the **supervision** of a **battery pack**, which is an assembly of battery cells, electrically organized in a row X column matrix configuration to **enable delivery** of **targeted range** of **voltage and current** for a **duration of time** against expected load scenarios.

The Oversight that a BMS provides usually includes: 1. Monitoring the battery pack 2. Provide protection to battery pack 3. Estimating the battery pack’s operational state 4. Continually optimizing performance of battery pack 5. Reporting Operational Status to external devices

Lithium-Ion rechargeable cells have the highest energy density and the standard choice for battery packs for many consumer products

While they perform superbly, can wreak havoc, if operated outside of a, generally tight **safe operating area(SOA)** with outcomes ranging from **Compromising the battery performance** to outright **dangerous consequences**.

BMS certainly has a challenging job description, and it's overall complexity and oversight outreach may span many disciplines such as electrical, digital, control, thermal and hydraulic

How do battery management systems work?

Battery management systems **do not** have a **fixed or unique set of criteria** that must be adopted. The technology design scope and implemented features generally correlate with:

The **costs, complexity, and size of the battery pack Application of the battery and any safety, lifespan, and warranty concerns**

Certification requirements from **various government regulations** where **costs** and **penalties** are paramount if inadequate functional safety measures are in place

There are many BMS design features, with **battery pack protection management** and **capacity management** being two essential features.

Battery pack protection management has two key arenas: **electrical protection**, which implies **not allowing the battery to be damaged via usage outside its SOA**, and **thermal protection**, which **involves passive and/or active temperature control to maintain or bring the pack into its SOA**

Incremental Capacity Analysis as a State of Health Estimation Method for Lithium-Ion Battery Modules with Series-Connected Cells

Design and Development of Solar Charging System for Electric Vehicles: An Initiative to Achieve Green Campus

ABSTRACT

Renewable energy is a kind of energy that is obtained through different resources such as **sunlight**, **wind energy**, **tides**, **geothermal** etc. It provides **clean energy** that comes from **natural sources** which can be **replenished continuously**. The utilization of more amount of renewable energy will **lower the prices of and demand for fossil fuels**. **Solar photovoltaic energy** is predominantly used for many applications like **heating**, **cooking** and **power generation**. Recent inventions helped in developing vehicles that are driven by solar energy. In this paper, **the design and development of a solar charging system for electric vehicles using a charge controller is discussed**. Implementation of the proposed system will reduce the electricity cost and charging and discharging losses. Also, the proposed solar charging system will be one of the

initiatives taken to achieve Green campus. This paper will demonstrate the system design and performance analysis of a solar-charged electrical vehicle system.

INTRODUCTION

The demand for energy is increasing due to the increase in population and the economic conditions of many countries. Recent research works reported that fossil fuels have **limitations such as global warming, limited resources and economical issues**. The **energy crisis is expected in the near future** and the **utilization of renewable energy is to be explored to the maximum possible extent to overcome the problems that arise out from fossil fuels**. Many researchers suggested the use of renewable energies considering many environmental aspects. Renewable energy such as solar energy can be an effective alternative in terms of its availability, cost-effectiveness and environmental friendliness.

CONCLUSION AND FUTURE SCOPE

The **development of the Solar Charging system for electrical vehicles** project comprised of various disciplines like electrical, electronics, and mechanical engineering technologies. This paper attempted to provide a framework for the design and development of a solar charging system which would provide an opportunity for the students to learn the theoretical aspects and hands-on experience of **utilizing solar energy**. The **proposed solar charging system will be one of the initiatives taken to achieve a Green campus**. The design considerations and calculation for various components are presented in detail. The **economic analysis** of the proposed system reveals that the **payback period** of the project is *3.5 years*. It is clearly evident from Table 3 that the **proposed solar-based vehicle charging system is better than the existing electrical charging system** both in terms of **operation and economical aspects**. Researchers work on this project get a basic idea of the design and building of Solar PV systems for several useful applications such as **electrical vehicle system**.

Based on the proposed project, many new works will be developed to design an efficient system for further applications. The performance analysis of the solar-charged vehicle system will be carried out to enhance the efficiency of the **pilot project**. As a measure to **reduce the carbon footprint** to achieve energy sustainability, this project will be further enhanced. In addition to this solar charging system, an effort will be made to operate all battery-operated vehicles available on the campus to utilize solar energy by establishing more charging stations. This initiative will encourage energy sustainability on campus and inspire the various stakeholders such as students, faculty and staff to use public transportation and electric vehicles that are charged by solar energy.

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Computer modelling of electrical power systems

Electrical power systems

What the hell is a **steady and dynamic** state of electrical power systems?

Prereqs

- power system theory
- matrix analysis
- neumerical techniques

computational and transmission system developments **FACTS** & **HVDC** links General purpose single phase load flow program

Neuton fast decoupled algorithm power system in dynamic states electronagmetic transients with reference to the EMPT method power electronic components electromechanical models

Chapter-1(Introduction)

FORTRAN based power system computer progarams implemented to run on mainframes

HVDC && FACTS technologies *modern power transmission and distribution systems are A.C. right?*

EMTP -> Electro Magnetic Transient Programs RTDS -> Real Time Digital Simulation

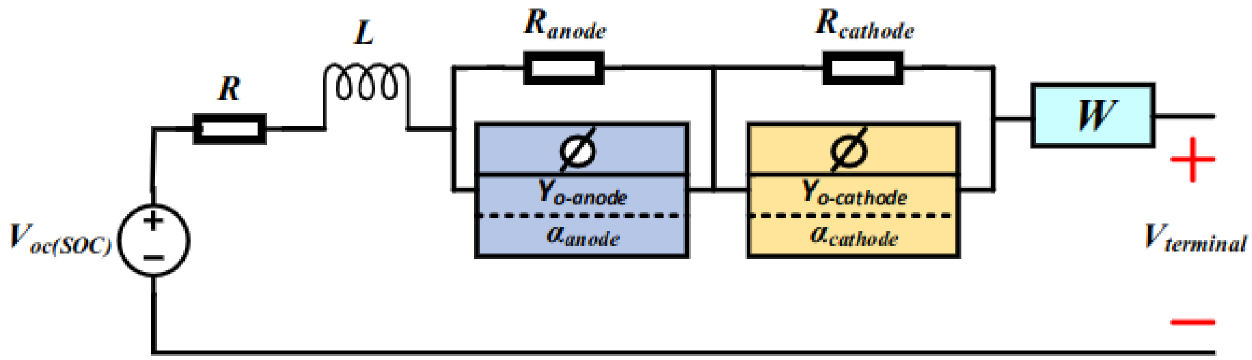
- **HIGH VOLTAGE DIRECT CURRENT** => HVDC
- **FLEXIBLE ALTERNATING CURRENT TRANSMISSION SYSTEMS** => FACTS

Okay, I'm looking to gain understanding on Battery Management Systems Current book that I'm reading is **Computer Modelling of Electrical Power Systems** You have to stop reading this book because

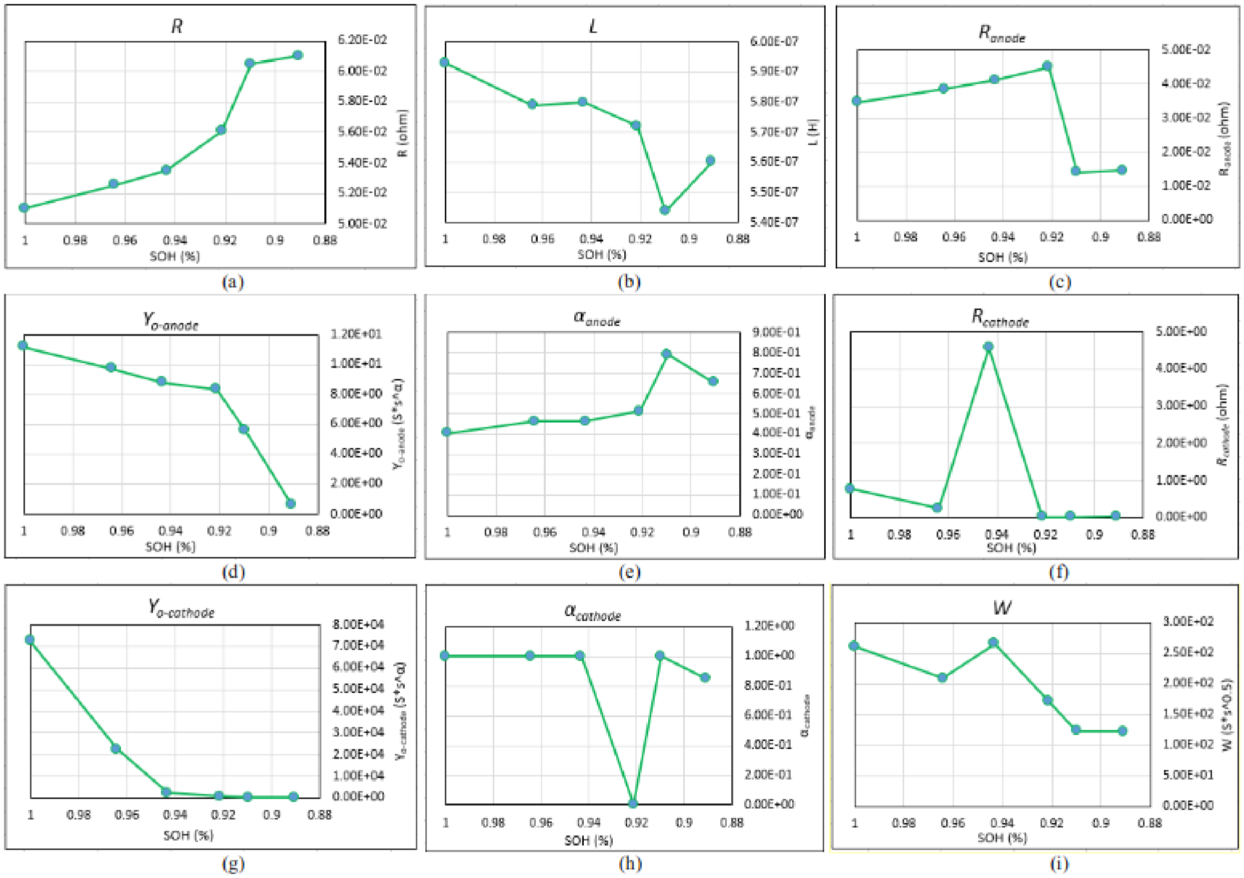
1. It doesn't have any thing on BMS
2. It contains topics on **Load Flow** and **Transmission Systems Modelling**
3. It contains topics like **FACTS** & **HVDC** transmission, which, Right now, I don't give a flying fuck.

Evaluation of Electrical Circuit Model Parameter variations under different state-of-health conditions for Litihium-ion battery.

- ECM parameter variation
- different state-of-health conditions



Model component	Description
$V_{oc(SOC)}$	Open circuit voltage of battery. It varies with the SOC value of battery.
R	Series resistor which mainly models the resistance of electrolyte and current collector of battery.
L	Inductive component which models the porous nature of battery electrodes [12].
R_{anode}	Resistance parameter to characterize the behavior of double layer effect occurring close to anode electrode. It is responsible for one of two semi-circles in the EIS [21].
$Y_{o\text{-}anode}$	Capacitance parameter of CPE for anode electrode. It is responsible for one of two semi-circles in the EIS.
α_{anode}	Fractional phase element coefficient of CPE for anode electrode.
$R_{cathode}$	Resistance parameter to characterize the behavior of double layer effect occurring close to cathode electrode. It is responsible for one of two semi-circles in the EIS.
$Y_{o\text{-}cathode}$	Capacitance parameter of CPE for cathode electrode. It is responsible for one of two semi-circles in the EIS.
$\alpha_{cathode}$	Fractional phase element coefficient of CPE for cathode electrode.
W	Warburg impedance which models diffusion process occurring in low frequency region of EIS.



keywords

ageing, capacity fade, EIS

Questions

what are computationally economical methods for determining SoH of a BMS which are Accurate as well?

First of all, State of Health is not a term related to BMS. BMS computes the **State of Health** for a **battery pack**. **State of Health is a property of a battery pack** like this one

Or, this one

Now, the question is, what are the algorithms to BMS uses to calculate State of Health of a battery pack? ### What are the most common methods used for determining SoH of a BMS?

Figure 1: EV Battery Pack

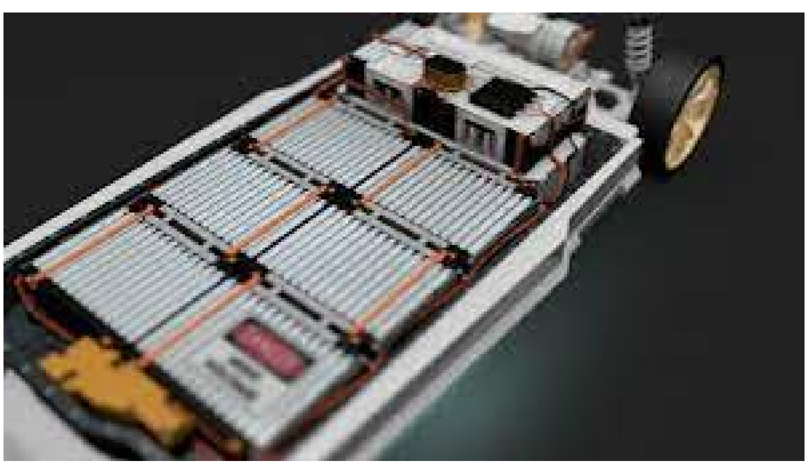


Figure 2: EV Battery Pack

How can we use such methods to determing SoH of a BMS for a real world EV?

Okay, ICA(Incremental Capacity Analysis) is a method for determining SoH, which is, both, computationally economical as well as pretty much accurate?

ICA can further be used for Capacity Fade?

What the hell is capacity fade anyway?

What are the most common types of batteries used in Modern EVs? In the paper which I'm reading, they discussed LMO and NMC based batteries

What are ageing results?

What are capacity fade of a battery?