AI-Powered Dynamic Battery Energy Storage Ecosystem

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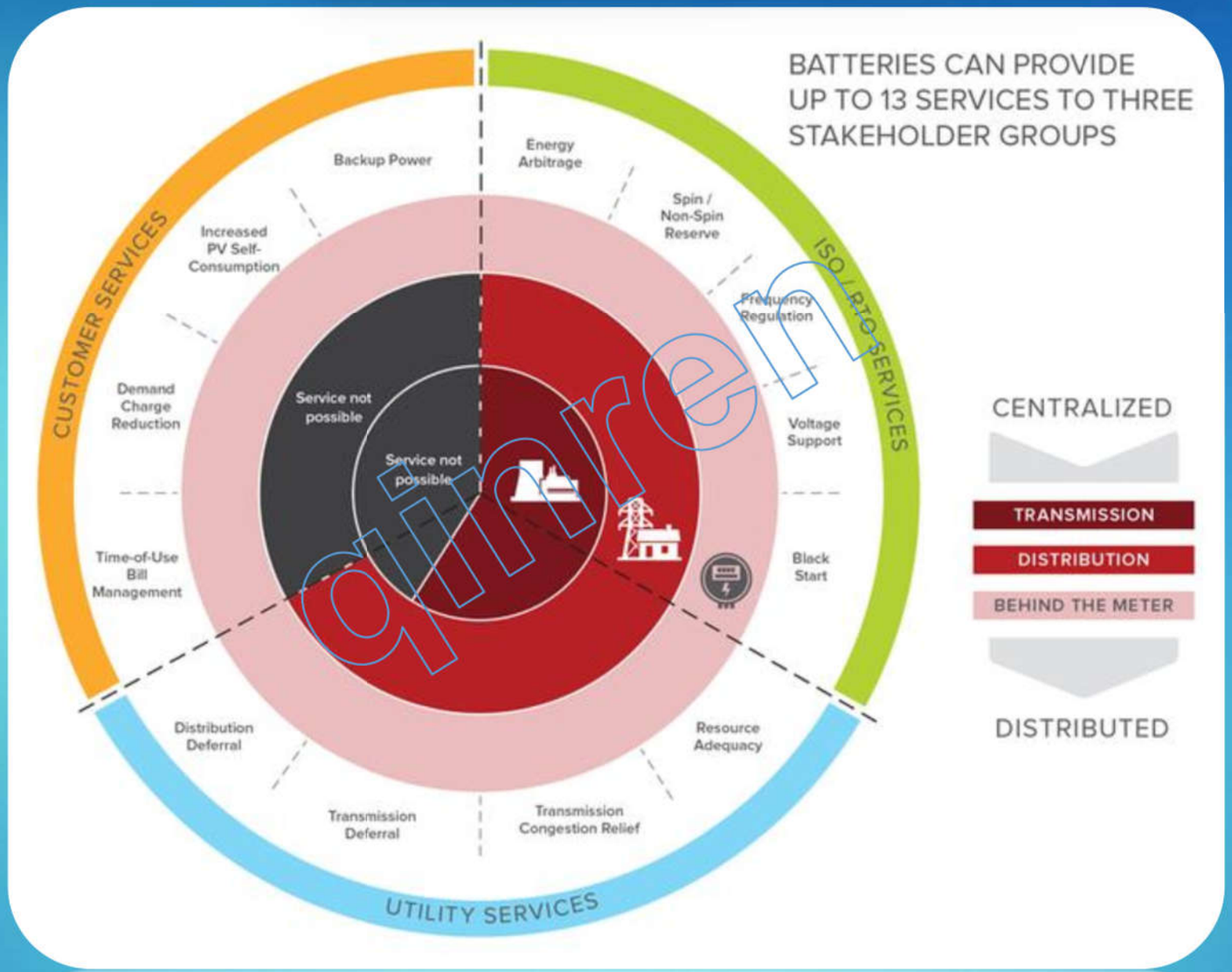
A. Motivation

—— AI-Powered Energy Storage Ecosystem

A1 Energy Storage Services



https://rmi.org/insight/economics-battery-energy-storage/

Current Development:

• Increasing echelon use of dynamic batteries in the residential energy storage system post a key challenge, how to estimate the SOC and SOH of retired BEV dynamics battery modules effectively and accurately. These characteristics of dynamic batteries are influenced by a series of factors related to the historical operating trajectories of dynamic battery modules, such as operating temperature, average driving distance and driver's personal habits. Combing these factors, the battery module usually presents complex non-linearity.

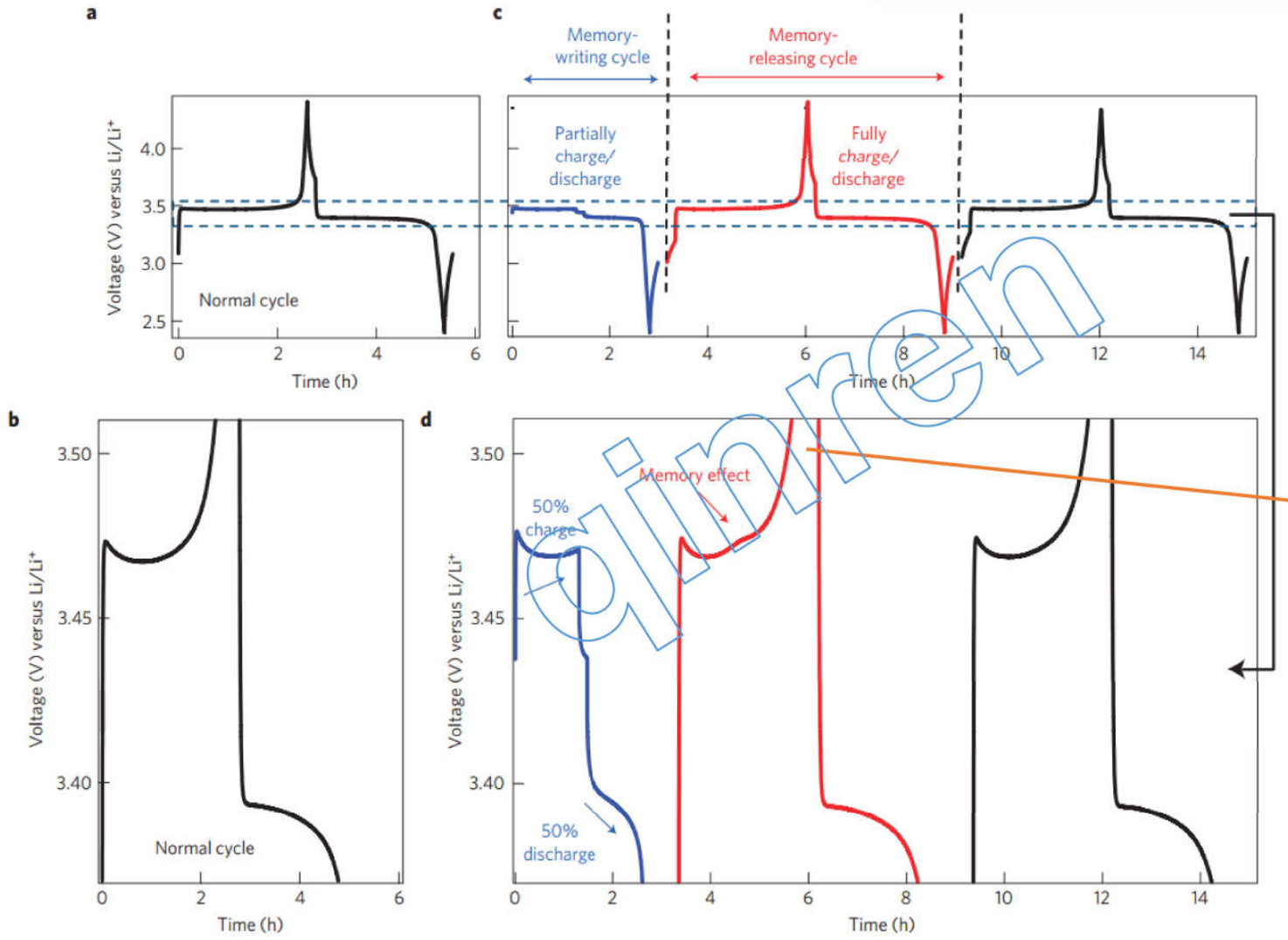
• Meanwhile, it is time-consuming and costly to estimate SOC and RUL for retired dynamic battery modules. A series of factors, such as temperature, load, etc., further level up the difficulty and complexity. Developing new testing models and methods to assess the echelon use of dynamic batteries in a more timely and cost-effective way.

Research Significance:

- Data-driven and AI-Powered battery management system is very valuable in different application scenarios, particularly the echelon use of BEV dynamic battery modules. The system is able to record and evaluate the real time operating data of dynamic battery modules.
- Our AI system will stream the energy utilization, maintenance and repair of the module in operation with technical and economic benefits and cost reduction.
- In addition, our AI system can evaluate the SOC, SOH and RUL of BEV dynamic battery modules, and rate and even price dynamic battery modules in a timely and economic fashion for the battery trade.

This project is not only an important fundamental research that helps us understand battery-working principles from the AI and data point of view, but also a valuable projects in the applications such as echelon use and AI-Powered energy storage.

A4 Memory Effect in the Lithium-ion Battery

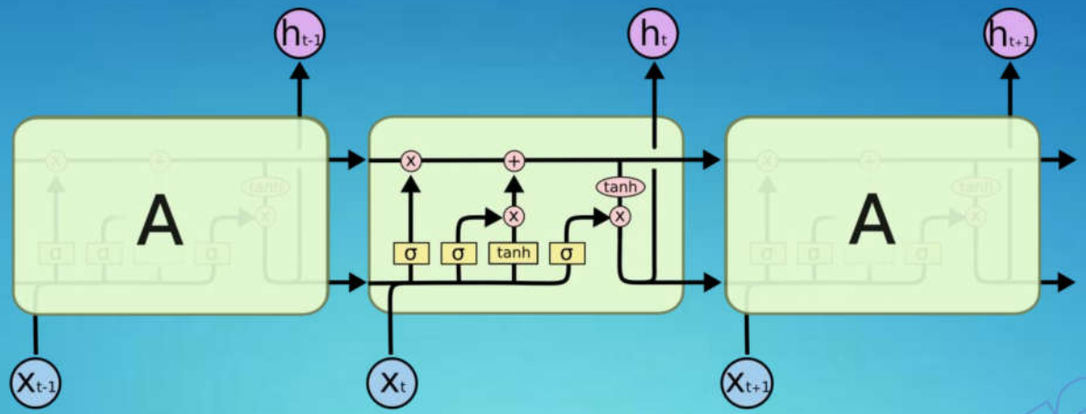


Memory effect in the Lithium-ion Battery – the charging and discharging cycle history will determine the future performance of Lithium-ion battery

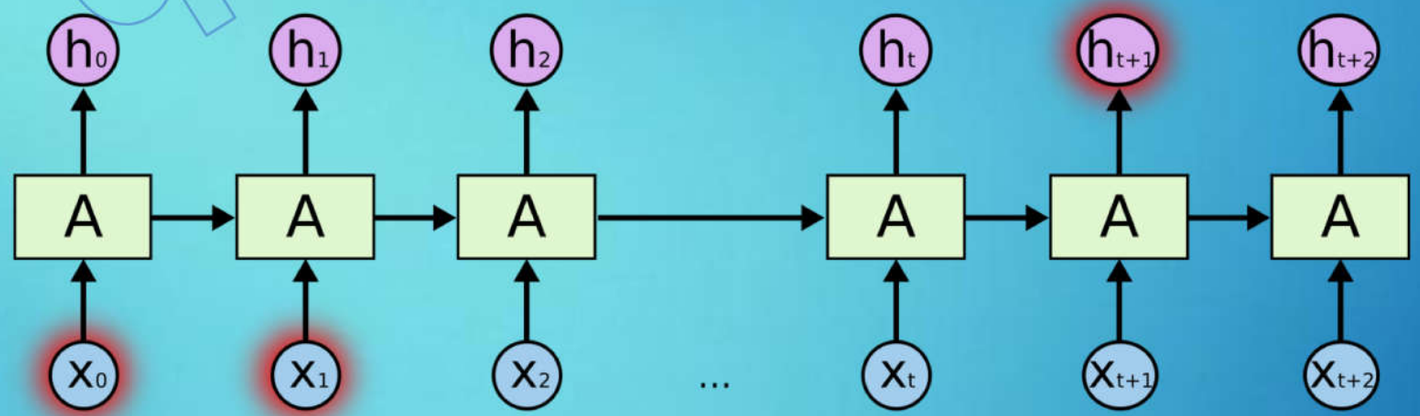
Memory Effect in a Lithium-ion Battery. Nature materials, VOL 12 , JUNE 2013, Page 570

A5

Memory Effect in LSTM



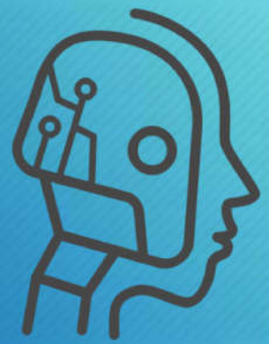
- LSTMs are explicitly designed to deal with the long-term memory dependency problem.
- LSTM and other derivative RNN have advantage to tackle the memory effect of Lithium-ion battery beyond ECM(equivalent circuit model)-free.



A6

Dynamic Model and Application of Battery

Battery Historical Data Collection and Storage



Battery Evaluation based on AI and Big Data

All of these are determined by historical data, data-driven model, electrochemical mechanism and Chemical& Physical processes.

SOC

SOH

Battery **Rating** System based on Historical Data and Model

Battery **Pricing** based on SOC/SOH Estimation

Battery Assets **Trading** based on Power Battery Pricing

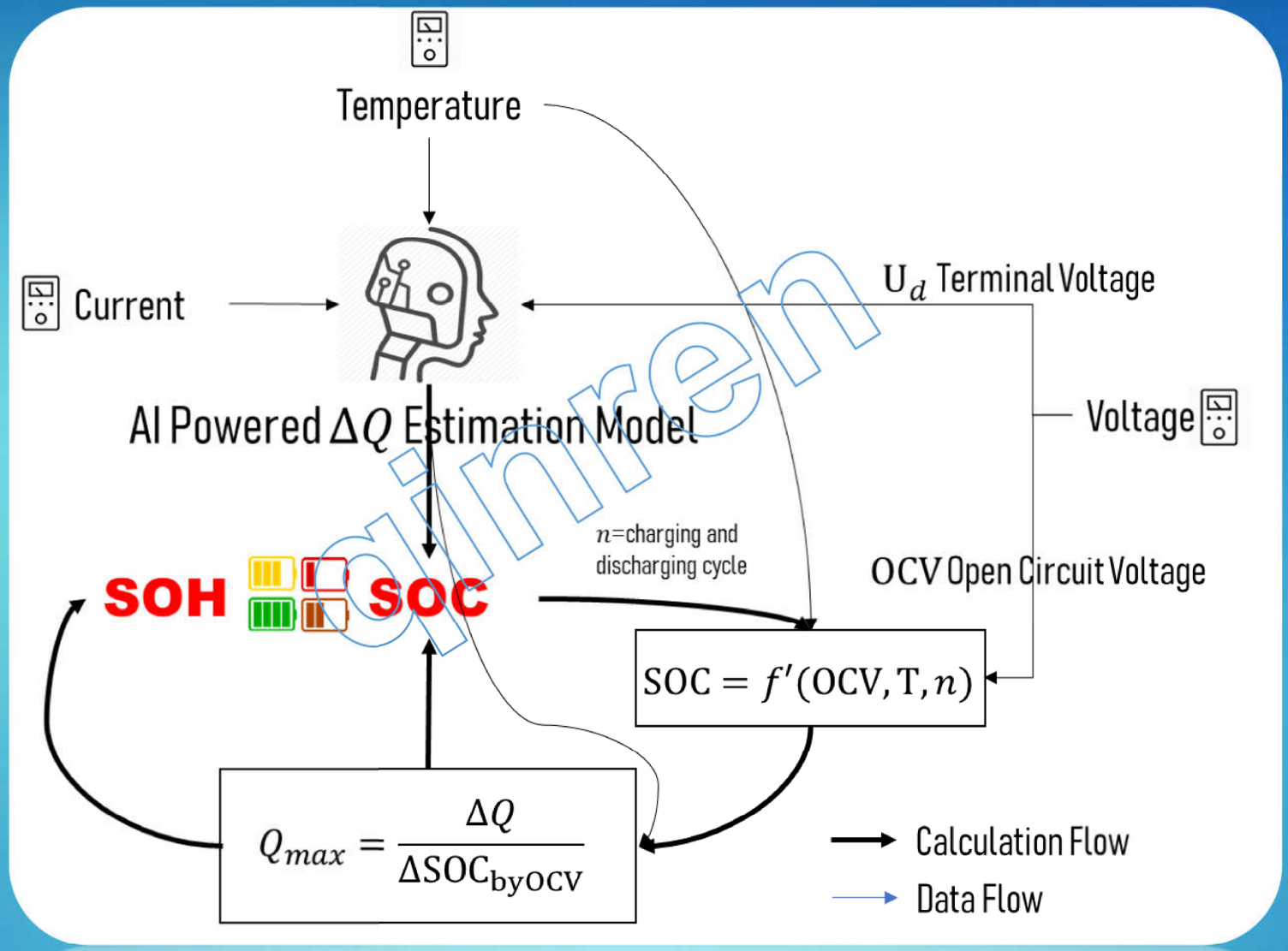
Energy Storage System **Operating** based on SOC Prediction

B. Core Module: State of Battery Predictive Analytics based on AI

—— AI-Powered SOC/SOH Predictive Analytics

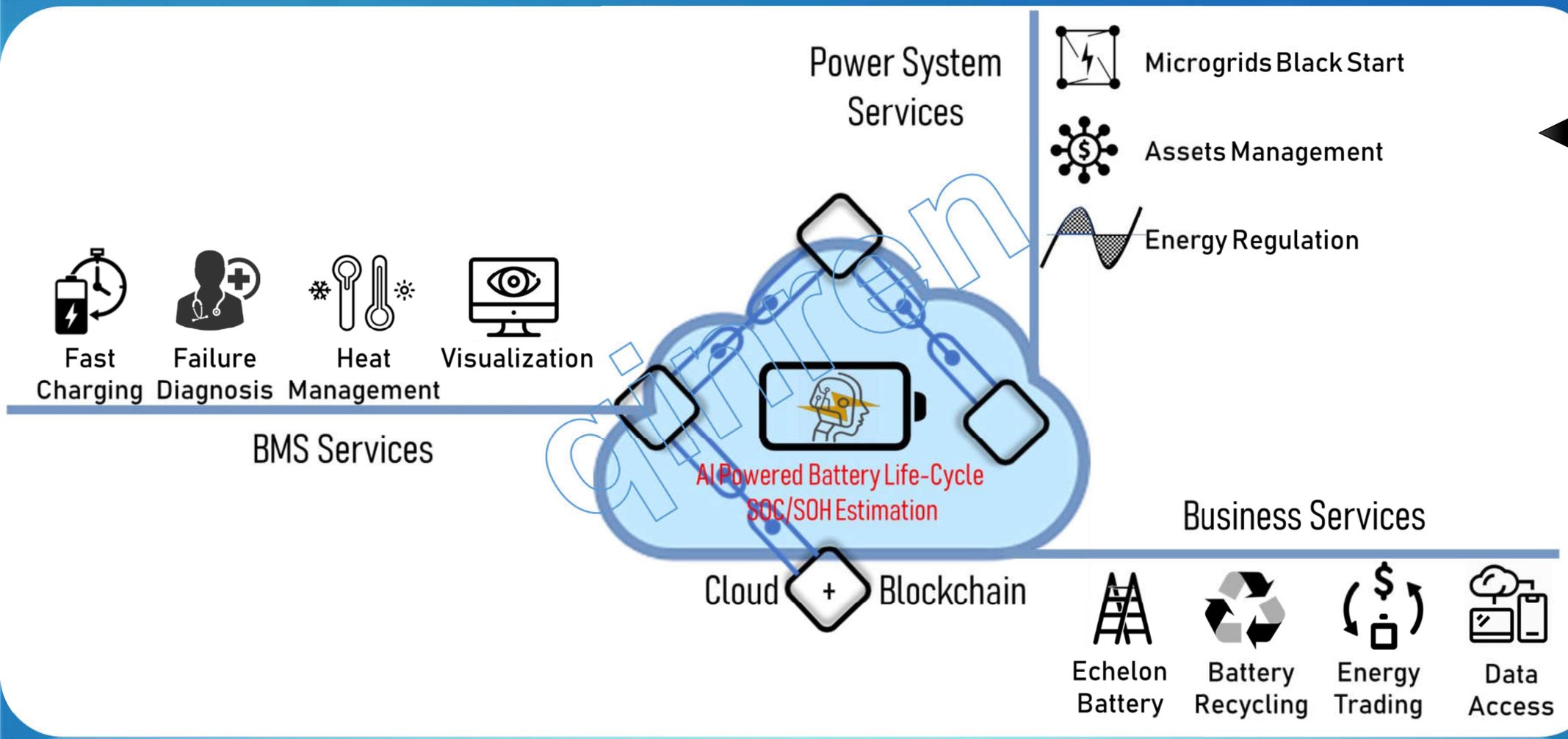
B1

AI-Powered SOC/SOH Predictive Analytics



B2

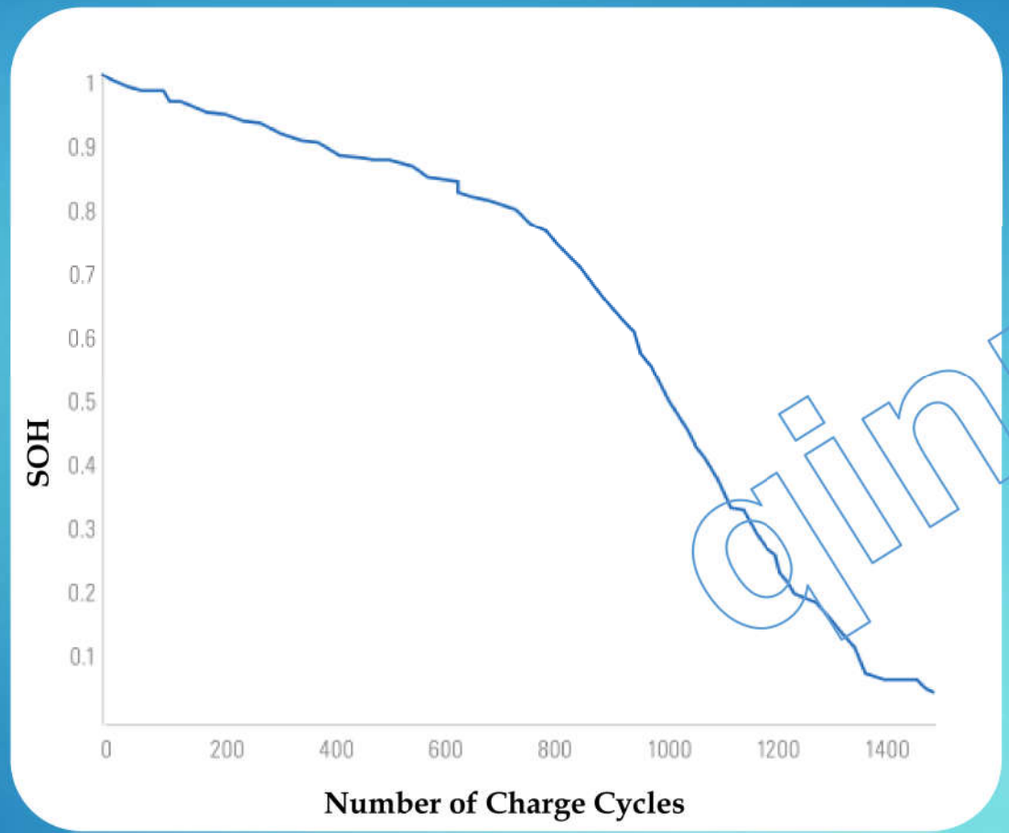
Dynamic Battery Data-Driven Ecosystem



C. Life-Cycle Data of Energy Storage System

—— Artificial Intelligence + Blockchain

Why do we need statistical modeling?



SOH vs. Charge Cycles

1. The dependence of battery states on the historical operational time series data requires statistical understanding.
2. The data-driven AI-powered abnormal behavior detection and prediction requires the reliable statistical modeling of battery time series data.
3. The SOC/SOH forecasting interpretation requires the incorporation of the theoretical description of battery material degrade and internal physical and chemical changes

C2

Package of Historical Data

Blockchain-base Data Authorization: Data authorization on who to use and how to use.

Distributed Computation: AI-Powered Prediction Analytics in the distributed fashion.

Data Reliability: Blockchain-based system and structure to guarantee the authenticity of data sources and data security.

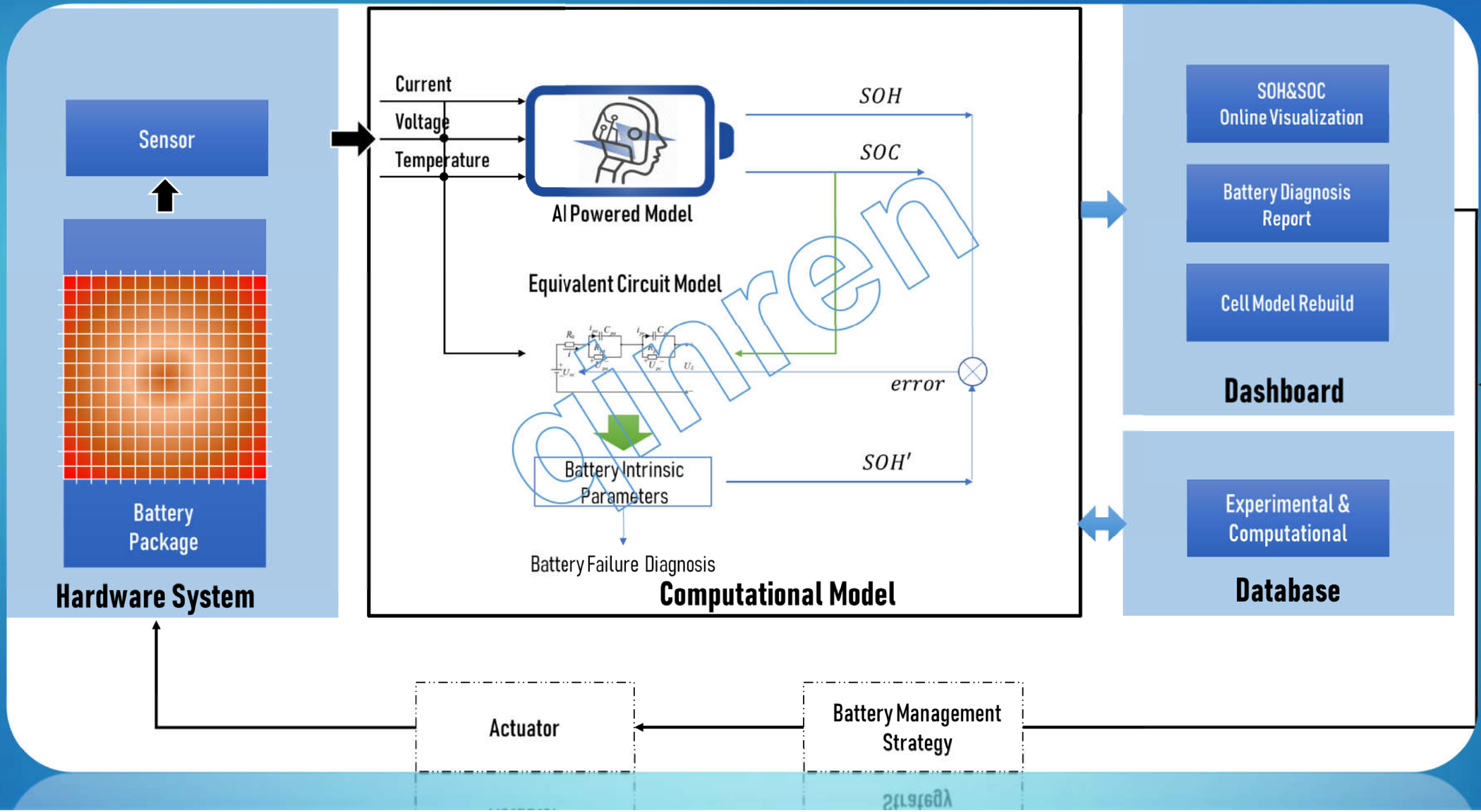
Encapsulation: Data encapsulation according to algorithms and services.

04. AI-Powered Battery Management System

1. Failure Diagnosis
2. Visualization
3. Database
4. Fast Charging

D1

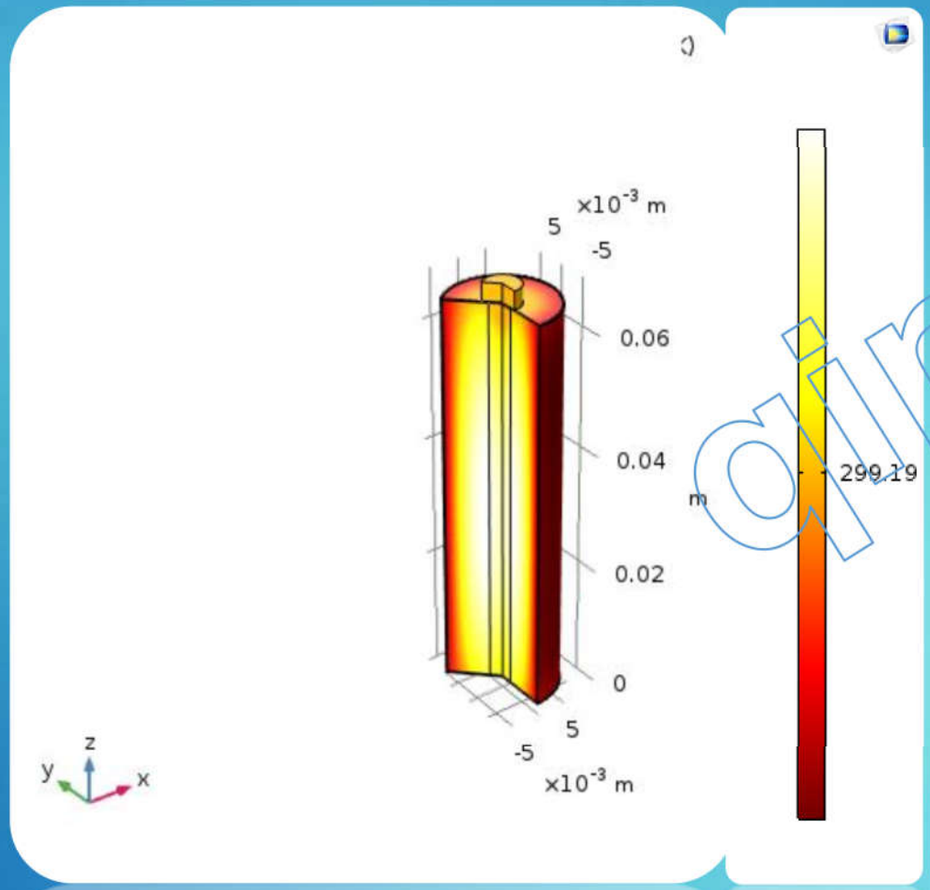
AI-Powered BMS



D2

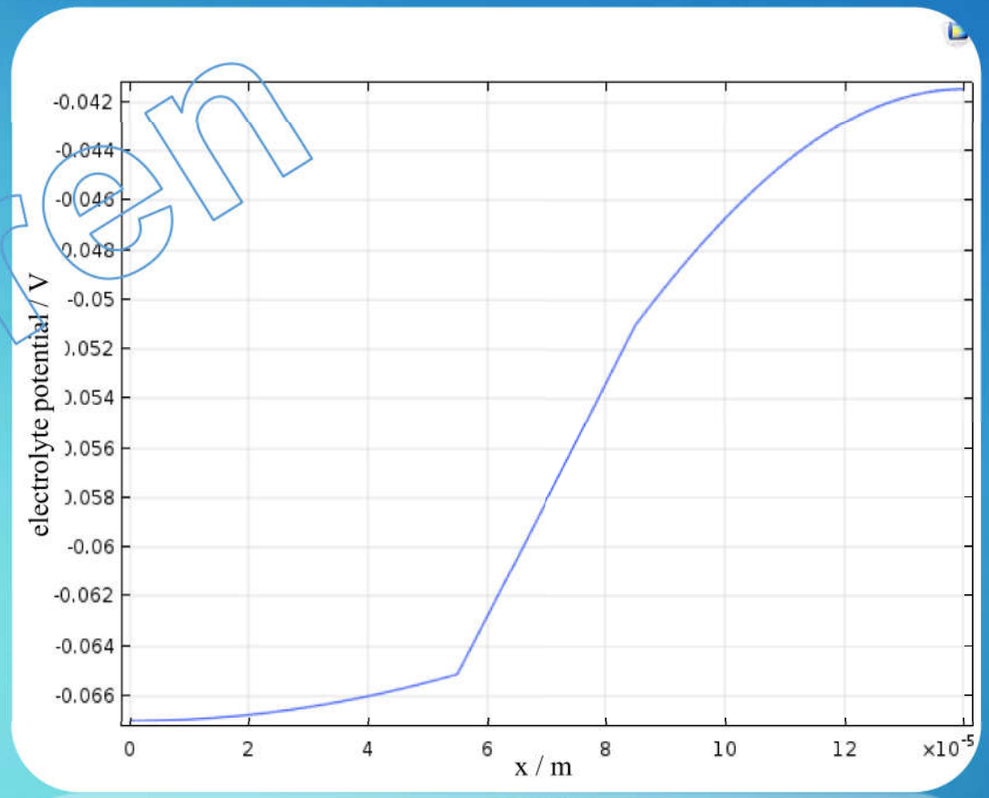
Electrochemical Mechanism and Time Series Data

COMSOL: Electrochemical Simulation Model



Temperature spatial distribution of battery cell at a time

Simulink: Electric Vehicle Simulation Model



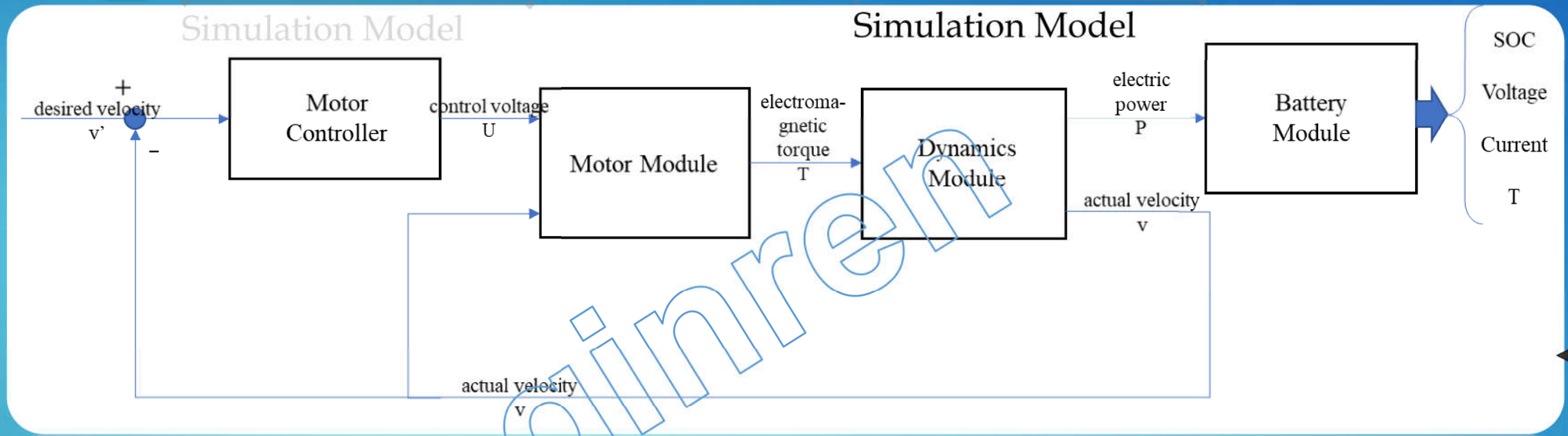
Local distribution of one-dimensional electrolyte potential

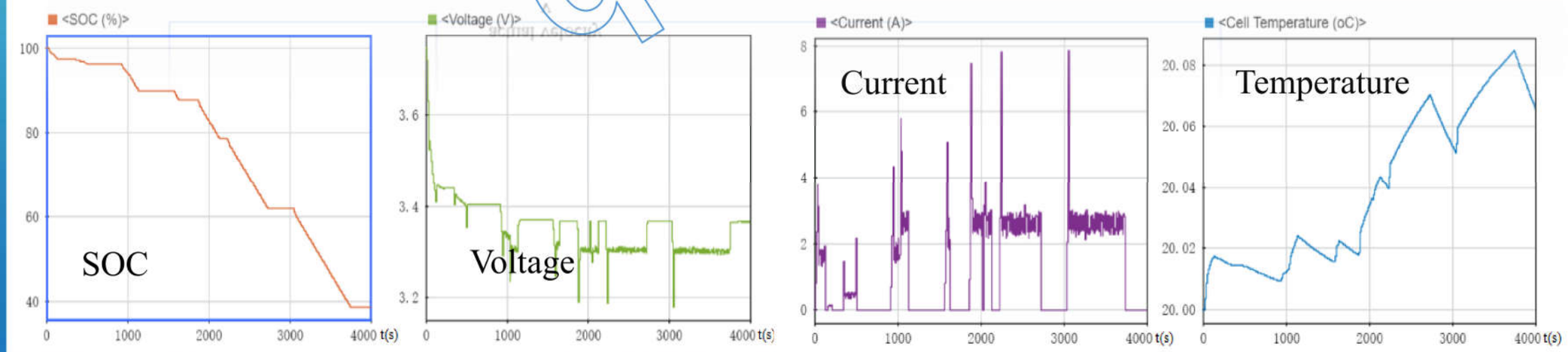
D3

Simulation and Time Series Data

COMSOL: Electrochemical Simulation Model

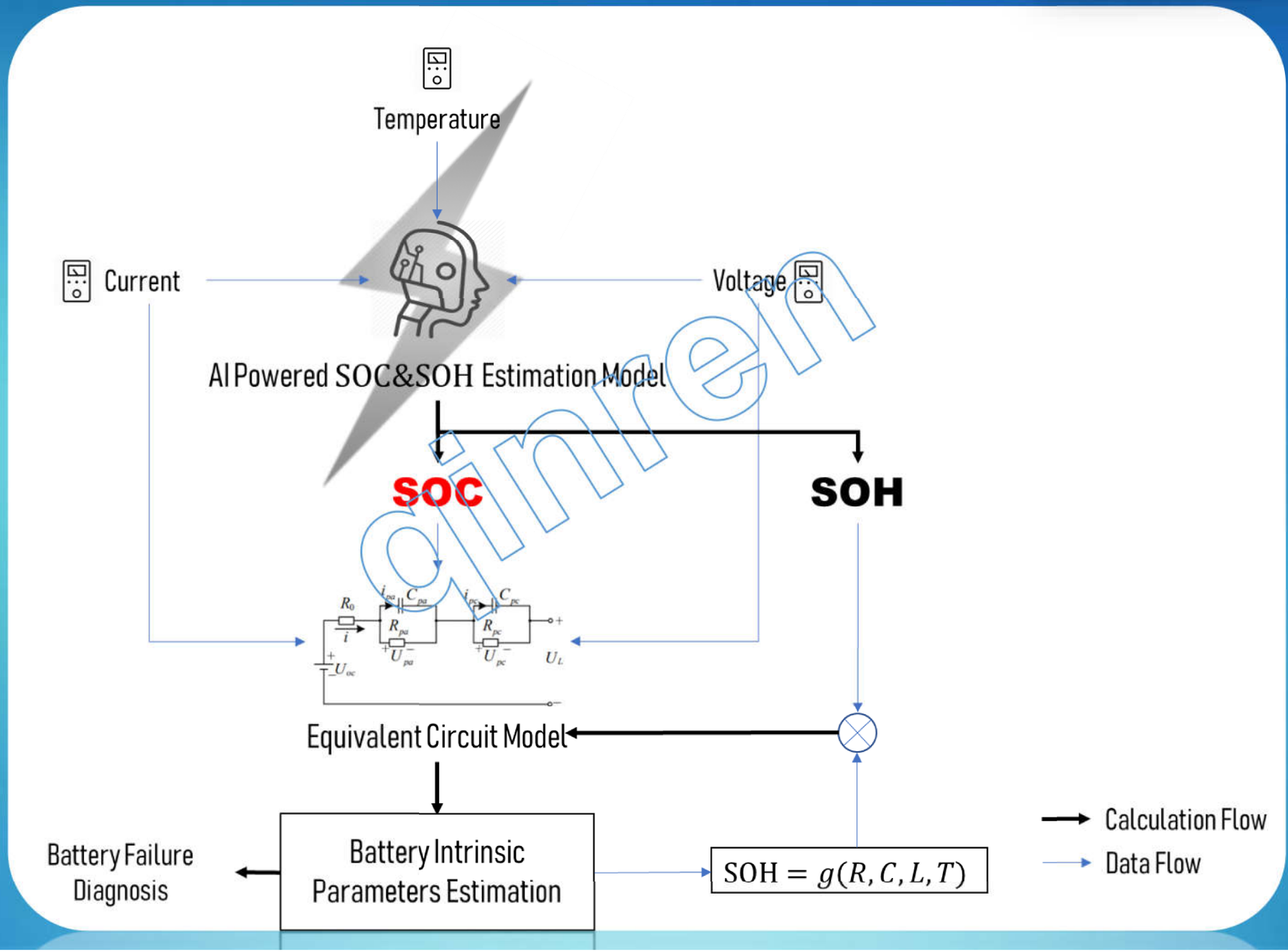
Simulink: Electric Vehicle Simulation Model





D4

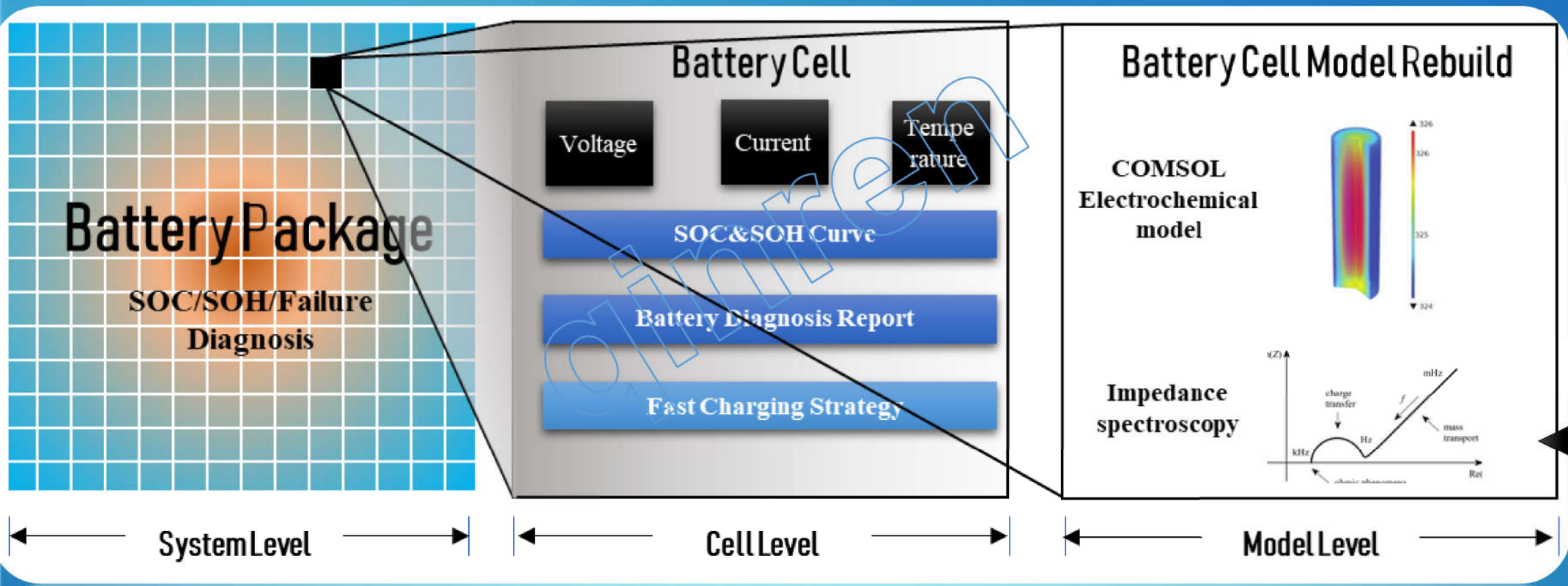
Data-driven AI Failure Diagnosis in couple with Simulation



E. Cloud-Based Battery State Visualization

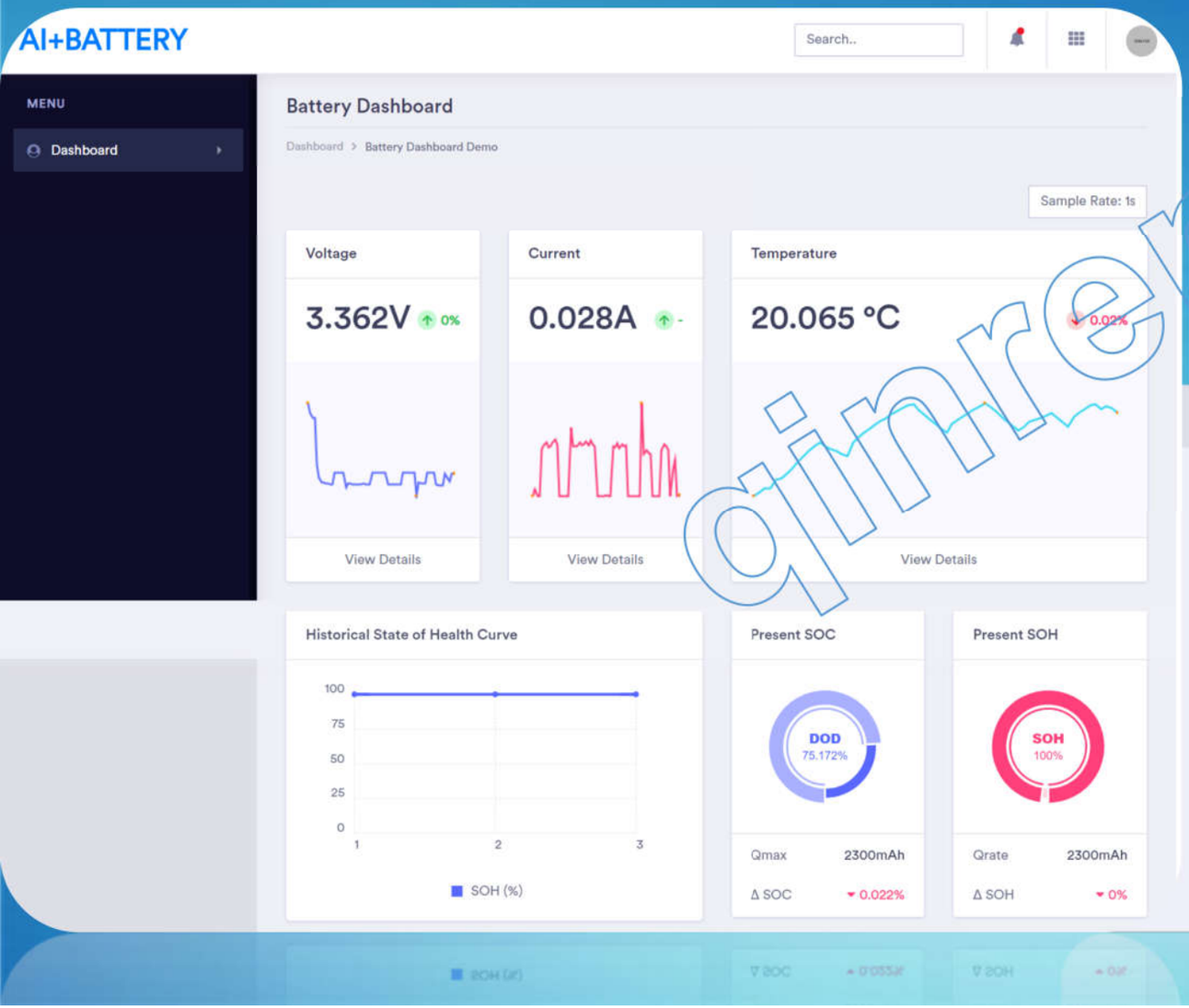
E1

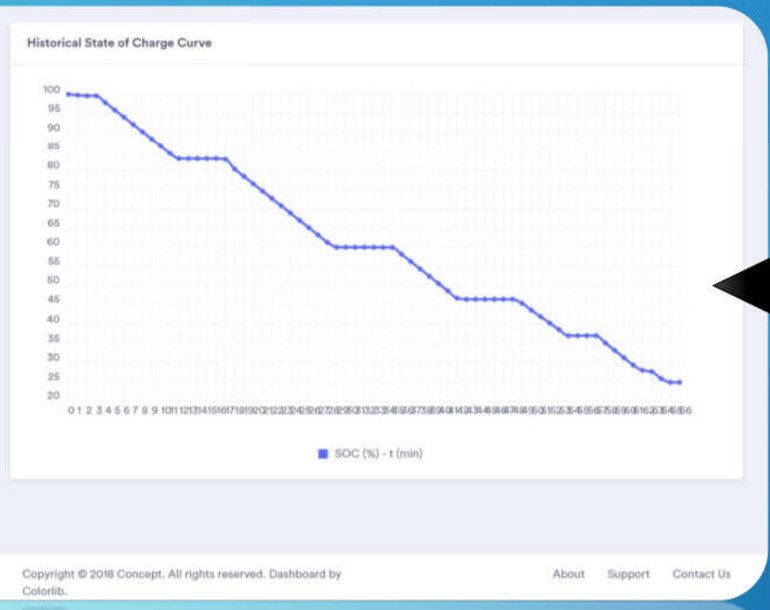
Cloud Visualization Dashboard



E2 Cloud Visualization Dashboard

Demo: http://qinren.tech/battery/index.html





F. Echelon Use of Storage Battery

F1

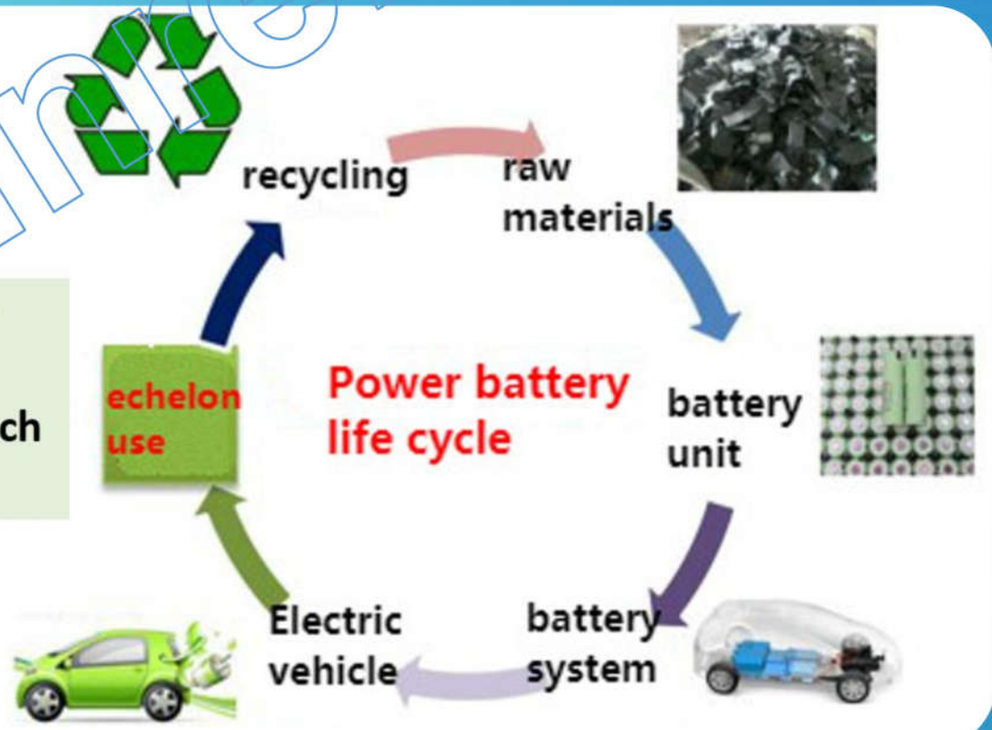
Echelon Use of Battery

The number of retired BEV dynamic batteries is huge and the trend grows explosive.

- It is expected that the annual amount of retired BEV dynamic batteries in China will reach **340,000** tons by 2024. From 2014 to 2024, the total amount of retired lithium-ion dynamic batteries will reach **1 million** tons.

- The statistics of State Grid Corporation's Science and Technology Department (Smart Grid Department) shows that State Grid Corporation will produce more than **100 MWh** of retired dynamic lithium-ion batteries by the end of 2015. Currently, there are more than **400 MWh** dynamic lithium-ion batteries deployed in electric vehicles. In the next few years, nearly **100 MW** dynamic lithium-ion batteries will retire from electric vehicles every year.

- **Residual value assessment**
- **SOH estimation methods**
- **Battery characteristics research**
- **Echelon use research**



F2 The Importance of Life-Cycle Battery Data

Echelon Utilization of Lithium-ion Battery Module

Nowadays, LionSmart and Munich University of Technology are developing a server-based battery management system (BMS), which can record and estimate the real-time data of BEV dynamic battery module in operation. Although this system comes with cost, the server can be used for the maintenance and repair of battery module with the historical data, and provide the clues about the SOH/SOC of retired BEV dynamic battery modules, which makes the screening process of battery modules for the echelon use more timely and economical. In addition, TUV SUD continues to work on the development of other test models and methods for evaluating the SOH and quality of retired battery modules. We expect that these new test models and methods will speed up the evaluation and screening processes, and furthermore reduce cost and save test time.

1. Remaining Useful Life (RUL) Prediction

The life cycle of Lithium-ion dynamic battery can be estimated according to RUL, which refers to the number of charging-recharging cycles that the quality of battery decreases to a threshold in the certain condition of charging and discharging.

The prediction methods of RUL includes the following three ones:

- The method based on Physical failure/aging model
- The data-driven method
- The hybrid method

2. Discrete Integration Technology

Under different local environments and working conditions, due to the different consumption rates of batteries, the aging decay rates of retired batteries from the same batteries are different.

How to integrate and utilize the batch of dynamic batteries with different diversity degrees from different sources and furthermore make them work together more efficiently as a system is a problem that needs to be solved urgently.

Battery rating indicators include:

- Maximum capacity
- Equivalent Resistance Spectrum
- Pulse discharge voltage

3. Lithium-ion Electric Core Performance Evaluation

Electric Core performance assessment includes RUL assessment (refer to the previous slide), safety assessment and reliability assessment.

The main detection contents include:

- Whether the shape of battery pack changes
- Whether lithium dendrite forms inside batteries
- Reliability of Connectors, Protective Layers and Insulation Layers
- Change of DC Internal Resistance
- Variation of Voltage Difference

F6

Battery In-cloud Database

1. Core R&D and Production Database

Retain the initial design and production information and the parameters of battery electric cores.

2. Battery Pack Development and Production Data System

Retain the parameters of battery electric cores in the assembly process.

3. In-Vehicle Monitoring Data System of BEV Battery Packs (Life Cycle Data)

The monitoring system collecting the real-time data of BEV battery packs in operation will help relevant businesses manage, monitor and inspect BEV dynamic battery modules. At the same time, the system will provide data support in battery predictive analytics, such the SOC, SOC and RUL prediction of retired dynamic batteries.

F7 Application of Battery Data in Echelon Use

Technical Feasibility: Whether the retired batteries still hold commercial values as commodities for the echelon use according it safety, RUL and charging-discharging performance of retired dynamic batteries

Standard Feasibility: Decides what standards dynamic batteries should satisfy for the further echelon uses for different industrial applications since different industries has different standards for the battery pack size, voltage class, and capacity.

Economic Feasibility: Decide if the echelon use of retired dynamic batteries have the price advantage as commodities, at least, the cost of re-screening and re-assembling the retired dynamic batteries

At present, what is urgently needed is an integrated service system for the echelon use market of dynamic batteries

What the system can offer includes:

- **Data Platform**: Design and optimize secure and efficient in-cloud distributed database of BEV dynamics battery cells/packs
- **Analysis Platform**: Realize in-cloud visualization and virtualization of energy storage batteries based on the AI-powered predictive analytics and the further applications in the IoT system.
- **Trading Platform**: Design standardized trading mechanism based on the reliable manufacture and operation data and asset evaluation system

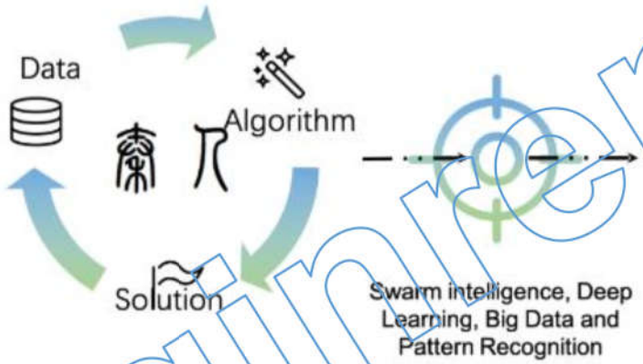
Demand ⟷ Applicability **Blockchain**

AI-Related Energy Storage Startups

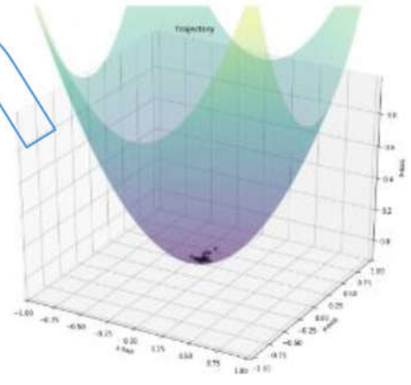
Team — qinren.tech

Army of Physicists, Electrical Engineers and More

Our members focus on optimize machine learning models and data analysis
We have strong finance, electrical engineering and computer science background



Swarm intelligence, Deep Learning, Big Data and Pattern Recognition



Xin Chen, Associate Professor, Team Leader.

Yuxuan Sui, Housing Market and Pridictive Analytics.

Siyu Chen, Python Crawler and Data Visualization.

Yadong Zhang, Time Series Prediction Method, Financial Market Dynamics and Trading Algorithm.

Chenye Zou, Predictive Models of Battery State of Charge and Fast Charging Strategy.

Huo Long, Complex System Analysis of Power System Robustness and Stablity.

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Thanks!