NATIONAL INSTITUTE OF TECHNOLOGY RAIPUR

DEPARTMENT OF ELECTRICAL ENGINEERING

7TH SEMESTER PROJECT PRESENTATION

ON

REMAINING USEFUL LIFE PREDICTION AND LIFECYCLE OPTIMIZATION OF LITHIUM ION BATTERIES

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WHAT?

An device which can be integrated in BMS of electric vehicles which will provide following features -

1. Will predict when the battery is going to die.
2. Will Find the optimum running cycle for maximum battery life.
3. Will provide all operating characteristics such as voltage, current, SOC etc on an frontend web application.
4. Help in further research and analysis.

WHY?

Existing Batteries are not optimizing their full capacity due to improper usage and lack of data among manufacturers and of awareness among end users.
For example-

1. Charging the battery to full level slowly decreases its maximum life.
2. Fast charging is not an good option always.
3. When an EV is going at cruise it's range can be dramatically increased .
4. When an battery should be replaced is not a very indicative thing.

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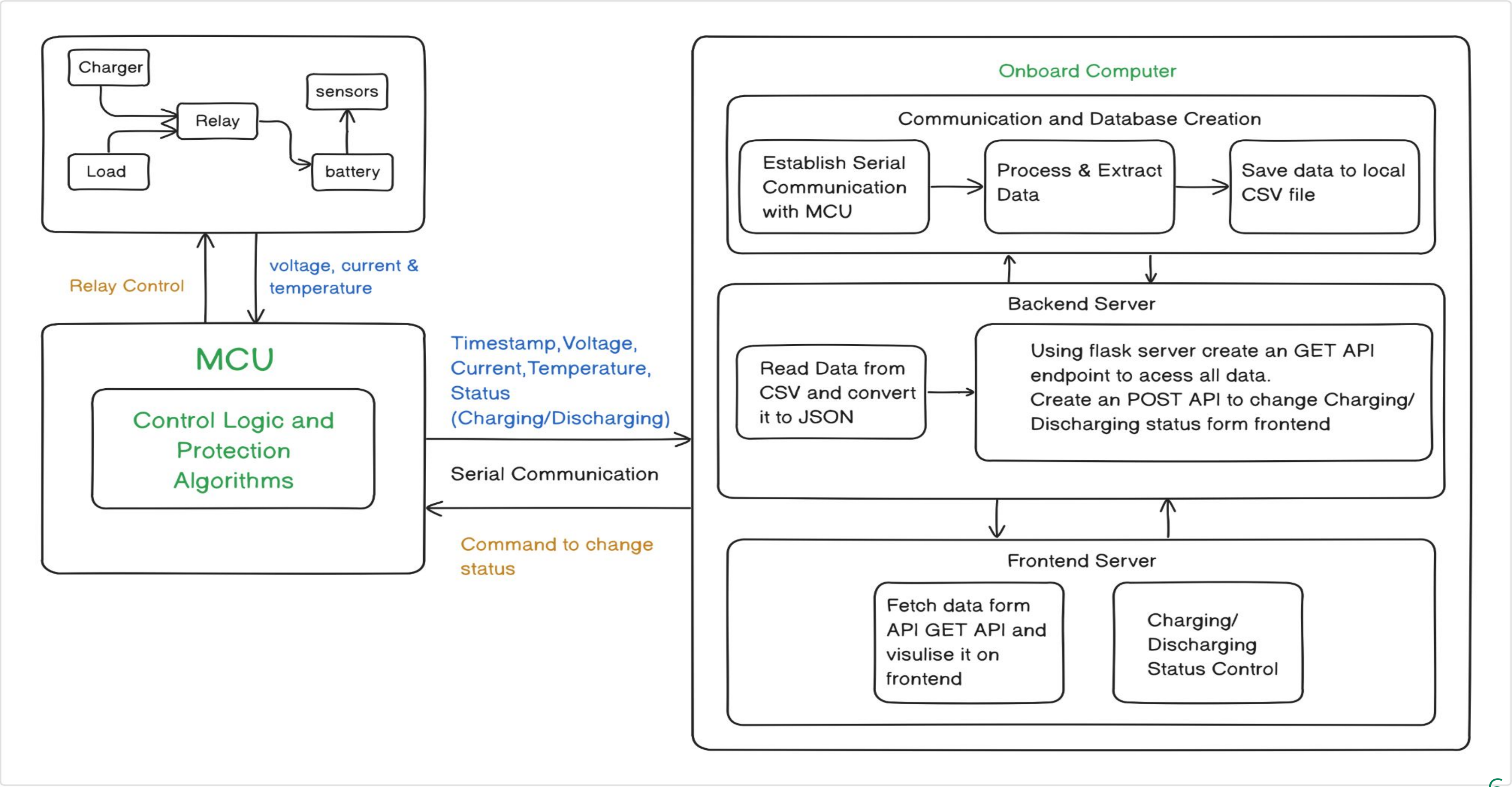
PROJECT FLOW

DATA GENERATION AND PREPARATION → DATA TRANSPORTATION → MACHINE LEARNING

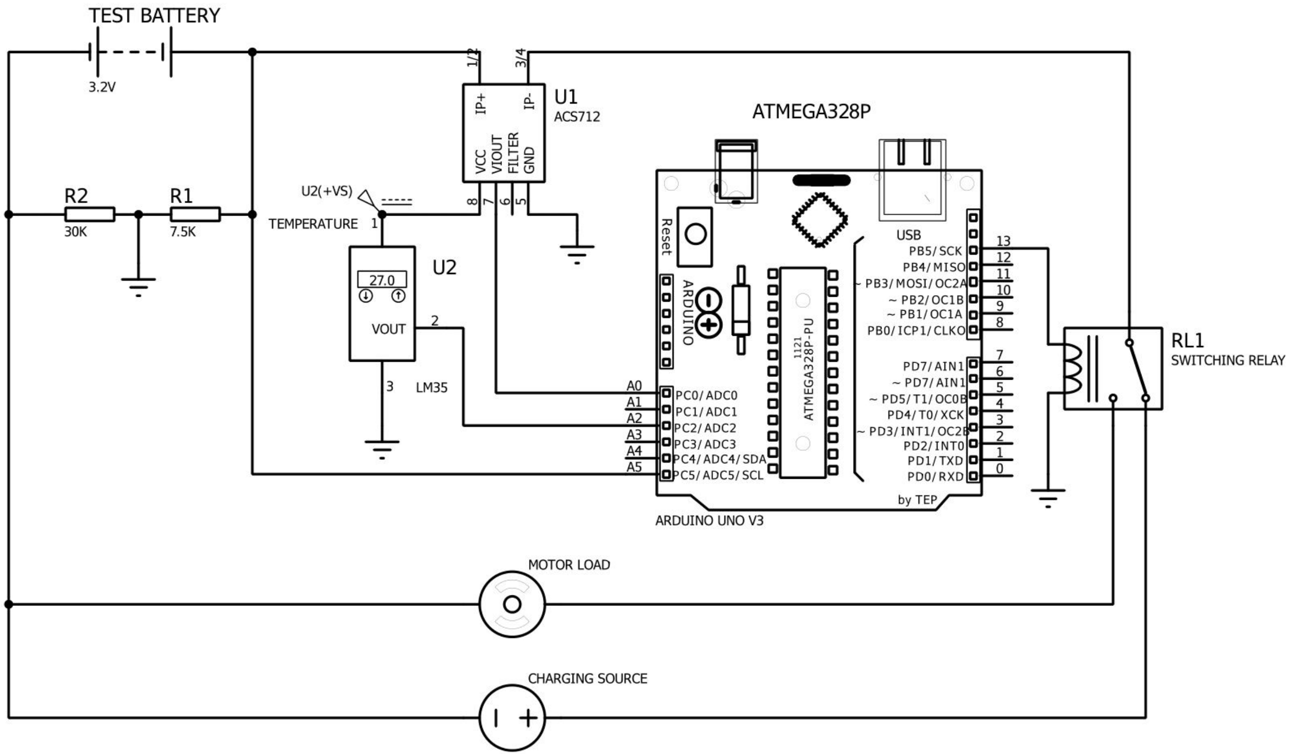
METHODOLOGY

Figure 1



Charger
sensors
Relay
Load
battery
Relay Control
voltage, current & temperature
MCU
Control Logic and Protection Algorithms
Timestamp,Voltage, Current,Temperature, Status (Charging/Discharging)
Serial Communication
Command to change status
Onboard Computer
Communication and Database Creation
Establish Serial Communication with MCU
Process & Extract Data
Save data to local CSV file
Backend Server
Read Data from CSV and convert it to JSON
Using flask server create an GET API endpoint to acess all data.
Create an POST API to change Charging/ Discharging status form frontend
Frontend Server
Fetch data form API GET API and visulise it on frontend
Charging/ Discharging Status Control

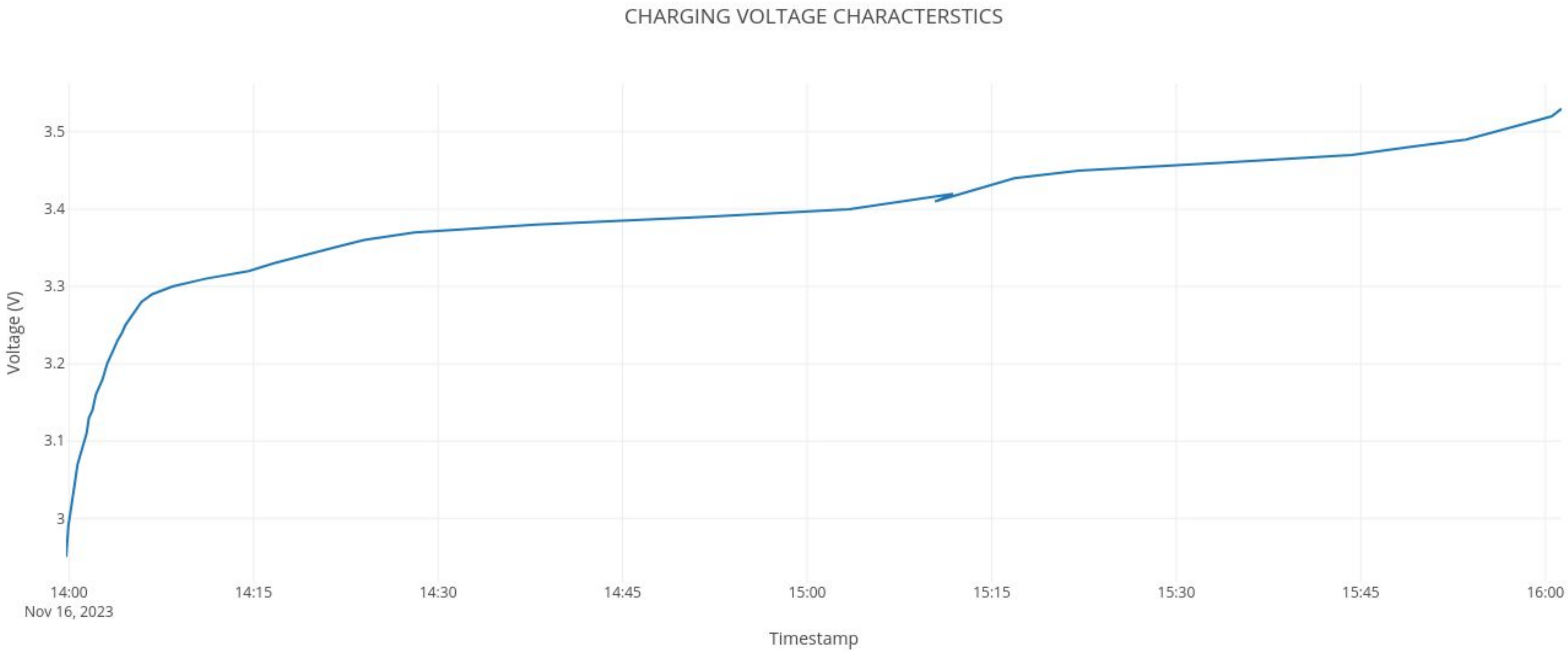
CIRCUIT ARRANGEMENT



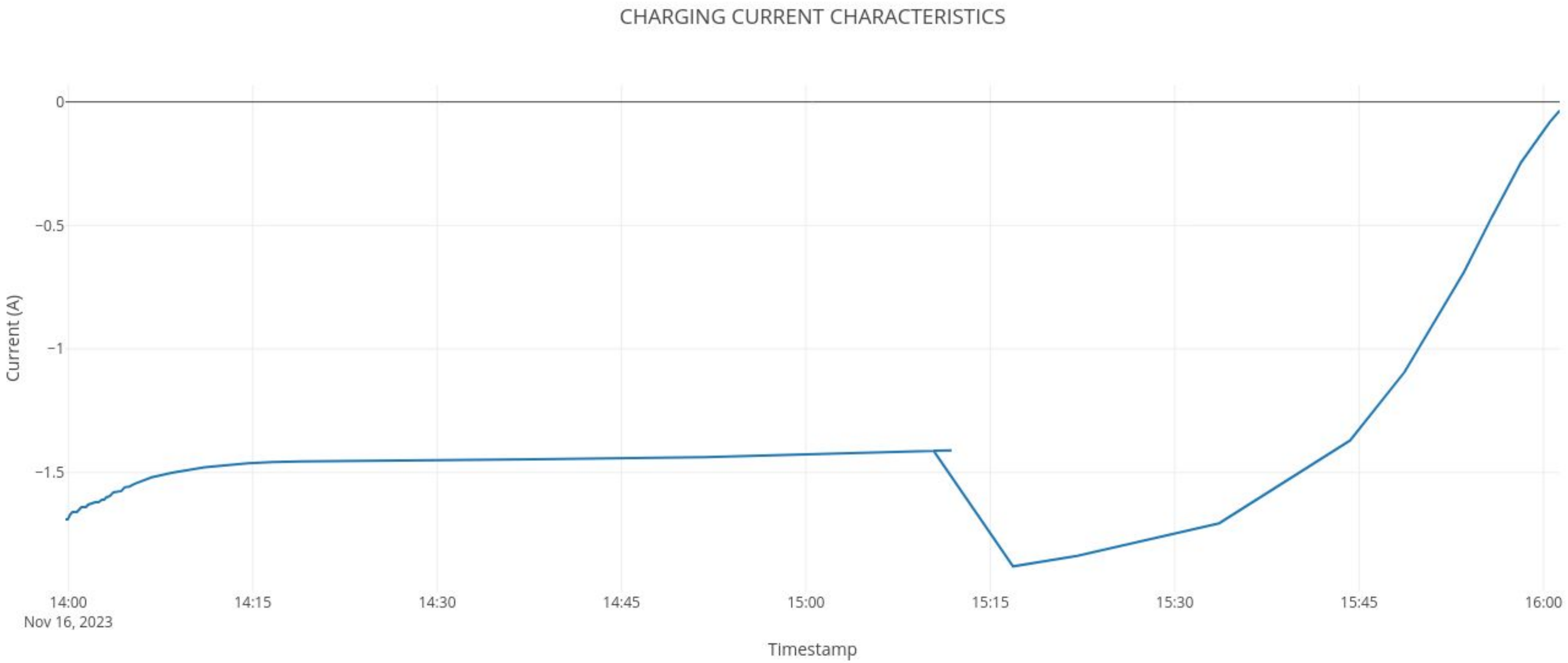
THE FIRMWARE

- Over Charge protection of the battery.
- Automated Cutoff of charging if battery is critically low.
- Over Current protection of the hardware.
- Receiving Commands from frontend application to change its charging/ discharging state.
- Extraction and calculation of sensor data for onboard analog to digital converter.
- Encapsulation of all data in a format which can be forwarded for further processing.
- Establishing a serial communication with raspberry pi.

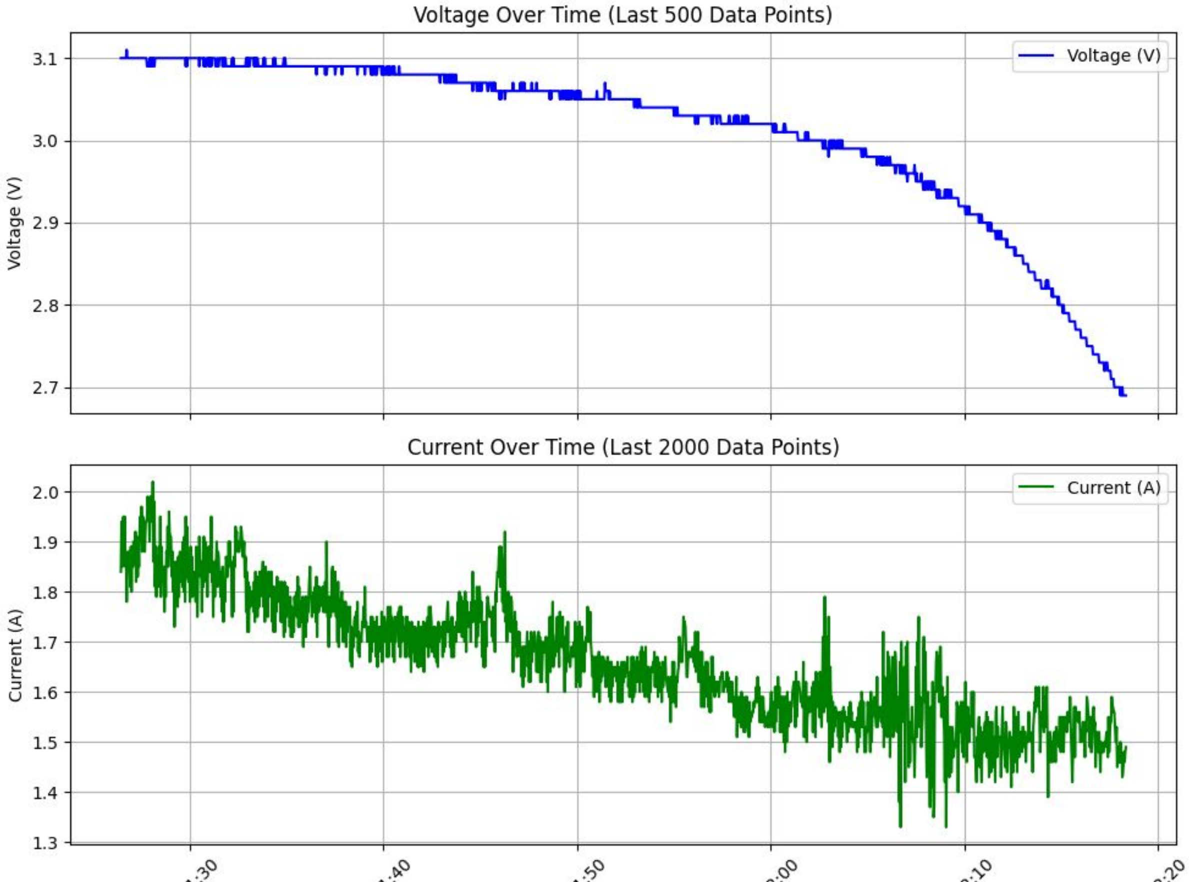
CHARGING VOLTAGE CHARACTERISTICS



CHARGING CURRENT CHARACTERISTICS



DISCHARGING VOLTAGE AND CURRENT CHARACTERISTICS



STATE OF CHARGE

- The state of charge (SoC) of cells is defined as the available capacity in ampere-hours (Ah) expressed as a percentage of its rated capacity.

- Additionally, evaluating the state of health (SOH) of a battery becomes significant, representing the battery's capacity to store and deliver electrical energy in comparison to a new battery.

METHODS FOR SOC ESTIMATION

- VOLTAGE CURRENT METHOD
- COULOMB COUNTING METHOD
- KALMAN FILTERING METHOD
- MACHINE LEARNING

COULOMB COUNTING METHOD

The Coulomb counting method is based on the principle that the total charge that flows into or out of a battery is equal to the integral of the current with respect to time. In simple terms, it involves measuring the current flowing into or out of a battery over time and integrating these values to estimate the total charge passed through the battery.

$$\mathbf{SOC}\ (\boldsymbol{t}) = \mathbf{SOC}\ (\boldsymbol{t} - 1) + \boldsymbol{I}\ (\boldsymbol{t})\boldsymbol{n}\Delta\mathbf{t}$$

ALGORITHM

1. Store instantaneous current value.
2. Calculate the time interval between two consecutive values (it should be smaller than 10s).
3. Calculate the area swept by the current curve during this duration.
4. Add this to an memory variable. This will be our incoming/outgoing charge.

REAL TIME DATA DISPLAY

DATA PREPROCESSING

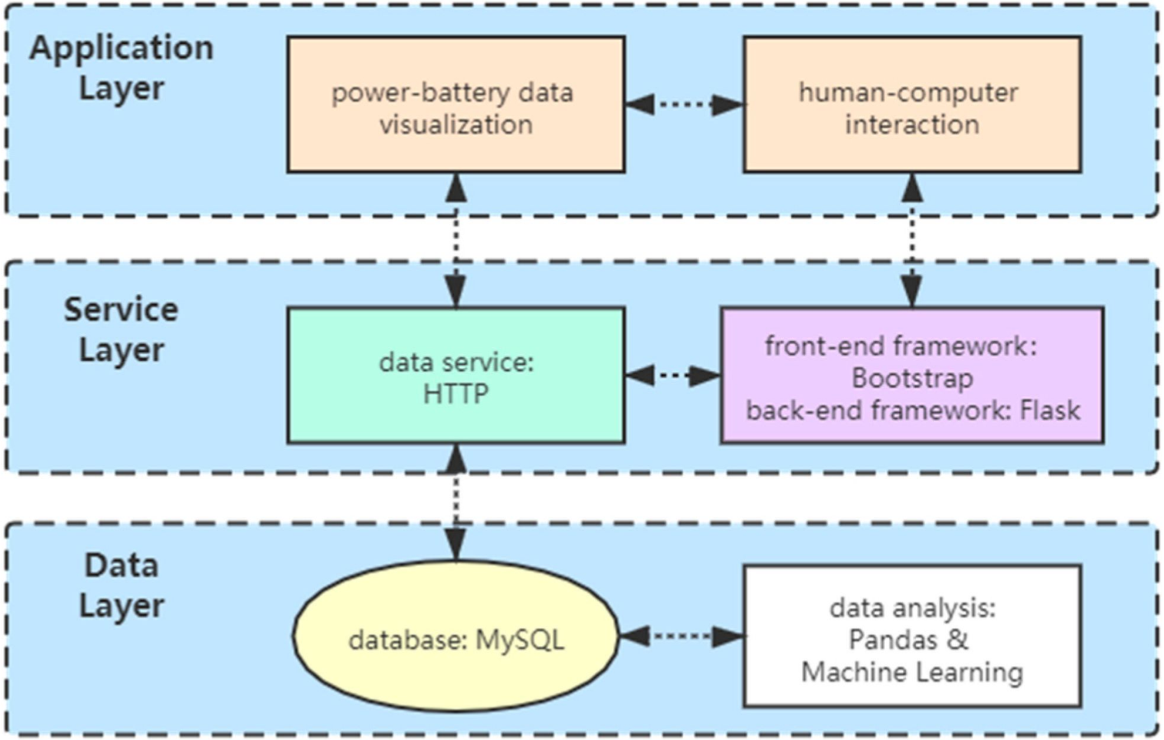
DATA STORAGE

SYSTEM DESIGN

DATA STORAGE

- A complete data analysis platform should set up a corresponding database, which is conducive to the realization of data centralized management and interface sharing, data security, repair faults, and system development easily .
- The MySQL with open-sources and high-performance that can provide safe and reliable data storage support for a web platform, as well as improving data independence, is employed in this work.

SYSTEM DESIGN



REAL TIME DATA DISPLAY

Battery Performance Monitoring	→ SOH, SOC, SOS
Optimizing Battery Usage	→ Load management , Energy Efficiency
Predictive Maintenance	→ Fault Detection,Maintenance Scheduling
Battery Management System	→ Balancing, Temperature Control, Performance Improvement

Predictive Maintenance

Why?	Cost Reduction	Increased Equipment Lifespan	Enhanced safety
How?	Data Collection	Data Analysis	Predictive Models
Advantages	Reduced Downtime	Cost Savings	Improved Safety

REMAINING USEFUL LIFE (RUL)

Why?

- Proactive Maintenance Planning
- Optimizing Asset Management
- Cost Savings

Threats

- Data Collection
- Model Development
- Monitoring And Prediction
- Decision Support

RUL ESTIMATION OF LI-ION BATTERIES

Factors Influencing

- Cycling Aging
- Operating Conditions
- Capacity Fading

Advantages

- Optimized Maintenance Strategies
- Improved Reliability
- Environmental Impact

LIFE CYCLE OPTIMIZATION OF LI-ION BATTERIES

Material Selection

- Raw Materials
- Recyclability

Manufacturing Process

- Energy Efficiency
- Reduced Waste

End-of-Life Considerations

- Recycling Programs
- Second-Life Applications

Environmental-Impact Assessment

- Life Cycle Assessment (LCA)
- Carbon Footprint Reduction

DATASET OVERVIEW

- The Hawaii Natural Energy Institute examined 14 batteries at specified weather conditions. From that source dataset, we created features that showcase the voltage and current behavior over each cycle. Those features can be used to predict the remaining useful life (RUL) of the batteries. The dataset contains the

```
df.head()
```

	Cycle_Index	Discharge Time (s)	Decrement 3.6-3.4V (s)	Max. Voltage Dischar. (V)	Min. Voltage Charg. (V)	Time at 4.15V (s)	Time constant current (s)	Charging time (s)	RU
0	1	2595.30	1151.488500	3.670	3.211	5460.001	6755.01	10777.82	11
1	2	7408.64	1172.512500	4.246	3.220	5508.992	6762.02	10500.35	11
2	3	7393.76	1112.992000	4.249	3.224	5508.993	6762.02	10420.38	11
3	4	7385.50	1080.320667	4.250	3.225	5502.016	6762.02	10322.81	11
4	6	65022.75	29813.487000	4.290	3.398	5480.992	53213.54	56699.65	11

MODELS USED FOR RUL PREDICTION

EXTRA TREES REGRESSOR

RANDOM FOREST REGRESSION

EXTREME GRADIENT BOOSTING

SUPPORT VECTOR REGRESSOR

MODELS USED FOR RUL PREDICTION

LINEAR REGRESSION

LASSO REGRESSION

RIDGE REGRESSION

ELASTIC NET

CONCLUSION

- The comparative study of machine learning models suggested that XGBoost model is excellent for RUL estimation.

- Quality dataset for research and analysis was generated.

- New ways to optimize the battery cycle were implemented

FUTURE SCOPES

- The device can be printed on small pcb with a more specialized and compact microprocessor and microcontrollers.
- The device can be **incorporated in BMS** of an electric vehicle. It can be an added advantage increasing the range of the EV significantly.
- **An user recommender system** can be expanded upon this project which will enable the users to get insights and commands to guide them towards better usage of their battery.
- **Smart Grid Integration :** By communicating with the grid, the device can participate in demand response programs, helping to manage peak loads and contributing to a more sustainable and resilient energy infrastructure.