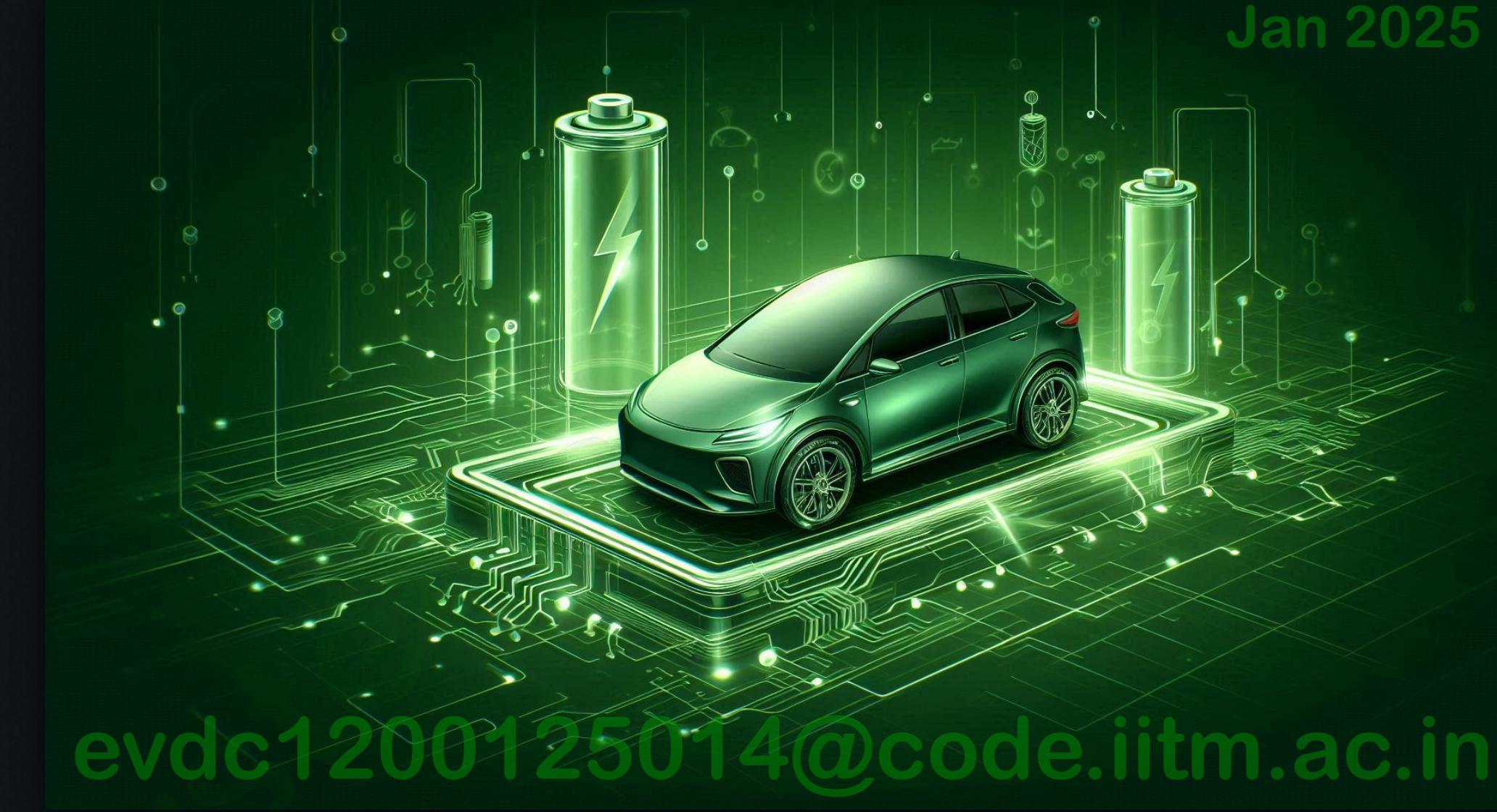


Architectural Design



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AI-Powered EV Battery Fire Prevention System

Ensuring a Fire-Free, Secure & Sustainable EV Future

Sudarshana Karkala

EV.Engineer, AI-Driven Battery Safety

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AI-Powered EV Battery Fire Prevention System

The Problem

EV Battery Fires are a Major Concern

- Frequent thermal runaway incidents leading to fire hazards.
- Lack of real-time battery health monitoring & risk alerts.
- Fleet operators & EV owners suffer from unexpected breakdowns and expensive battery replacements.
- Regulatory pressure (AIS-156) for stricter safety measures.

Example : Bangalore has seen a 300% increase in EV fire incidents in 2023-24.

Project / Module Details

AI-Powered EV Battery Fire Prevention System

- Battery Temperature Monitoring System
- Battery Voltage & Current Analysis
- State of Charge (SOC) Estimation
- EV Battery Health Prediction
- Real-Time Battery Monitoring with IoT
- Intrusion Detection in Battery Management System (BMS)

The Solution

Leverages AI & Machine Learning to predict battery failures before thermal runaway.

Real-Time Monitoring of critical parameters:

- Temperature fluctuations
- Voltage imbalances
- Cell inconsistencies

AI-Driven Predictive Analytics for early detection of anomalies.

Automated Preventive Actions:

- Controlled discharge to prevent overheating
- Active cooling mechanisms (liquid/air cooling)
- Emergency shutdown & alerts

Seamless BMS Integration:

- Works with existing Battery Management Systems
- Adds AI-powered safety layer

Cloud-Based Analytics & OTA Updates:

- Continuous learning from real-world battery failures
- Over-the-Air (OTA) updates for AI model improvements

1. Battery Temperature Monitoring System

Goal: Read temperature data, analyse trends, and detect overheating.

Concepts: File handling, NumPy, Pandas, Matplotlib

Tasks:

- Read a CSV file containing battery temperature data
- Calculate average, max, and min temperatures
- Plot a temperature trend graph using Matplotlib
- Detect overheating conditions (e.g., alert if temp > 60°C)

Outcome: Basic battery monitoring using Python

3. State of Charge (SOC) Estimation

Goal: Estimate battery SOC using voltage and current data.

Concepts: Numerical computing, Basic Machine Learning

Tasks:

- Load historical battery data (Voltage, Current, SOC)
- Train a simple regression model to predict SOC
- Validate results using test data
- Display real-time SOC values for a given input

Outcome: SOC estimation using Python

2. Battery Voltage & Current Analysis

Goal: Analyse voltage & current data to detect anomalies..

Concepts: Pandas, Data Visualisation, Time-Series Analysis

Tasks:

- Load battery voltage & current datasets
- Identify voltage drops and current spikes
- Plot Voltage vs. Time & Current vs. Time
- Set a rule: Alert if voltage drops below a threshold

Outcome: Detect battery performance issues

4. EV Battery Health Prediction

Goal: Use AI to predict battery degradation over time.

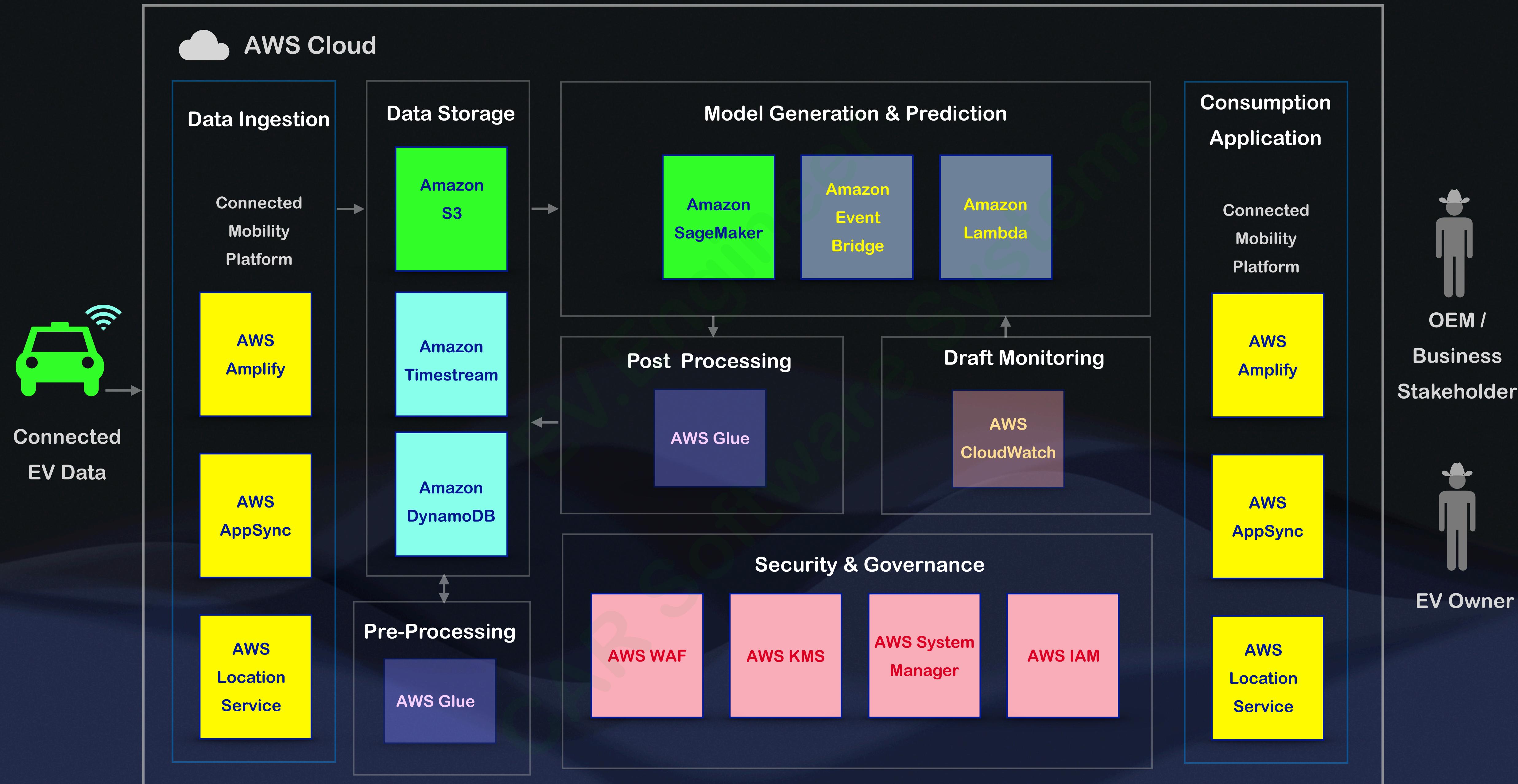
Concepts: Machine Learning, Data Science

Tasks:

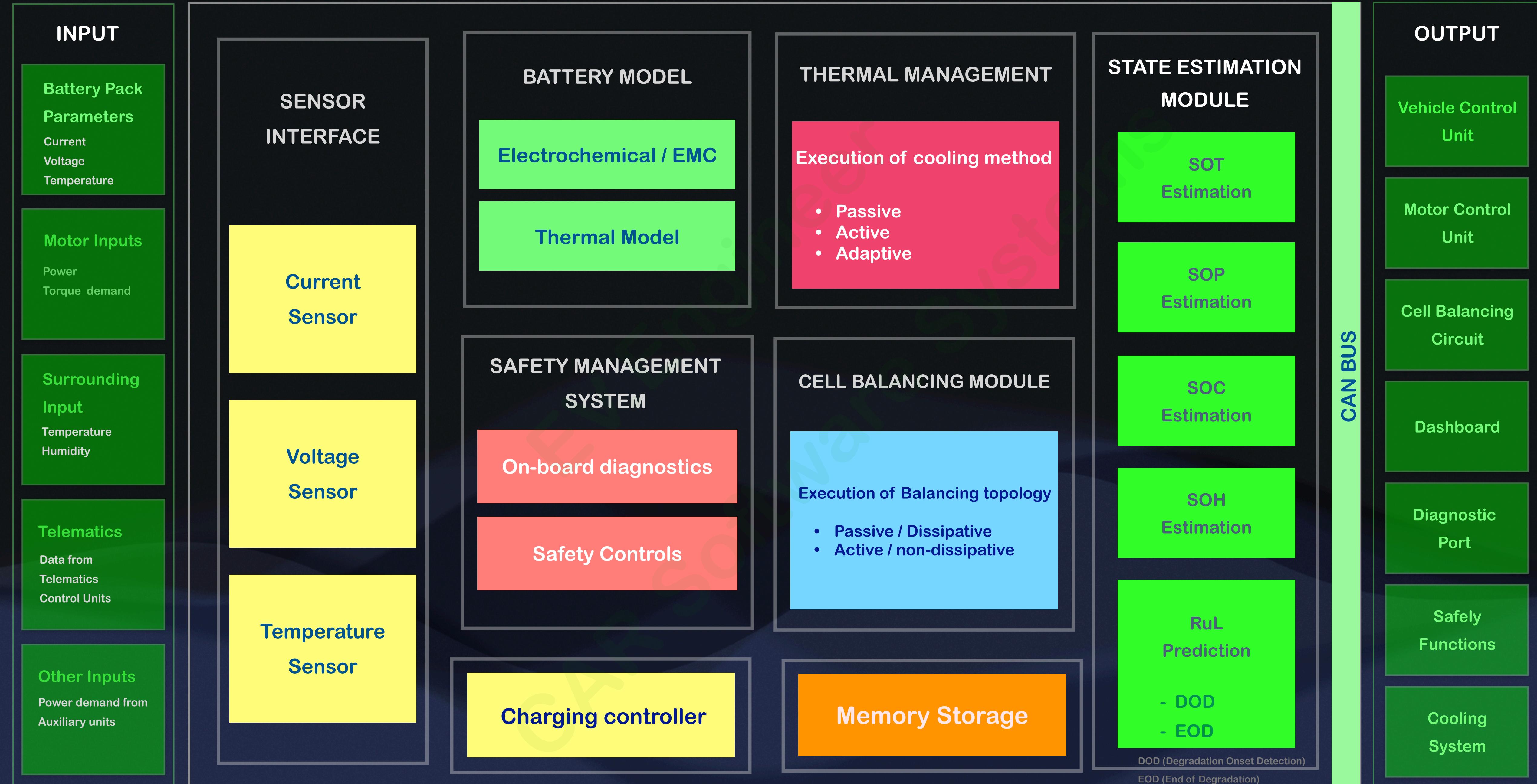
- Load battery charge-discharge cycle data
- Identify patterns in battery degradation
- Train an ML model (Scikit-learn) to predict Remaining Useful Life
- Visualise predictions with graphs

Outcome: AI-based battery health prediction

Cloud Architectural Design



Architecture of EV Battery Management Systems



AI-Powered EV Battery Fire Prevention System



Intrusion Detection in Battery Management System

Collect Battery Data Logs (or Use Sample Data)

Analyse Normal vs. Anomalous Data

Implement an Anomaly Detection Model

Real-Time Intrusion Detection Simulation

Secure Battery Data with Encryption

Potential Cyber Threats:

Spoofing Attack: Fake voltage readings injected

Man-in-the-Middle Attack: soc data modified

Malware in BMS: Unauthorised data manipulation

5. Intrusion Detection in Battery Management System

Goal : Detect anomalous activities in an EV Battery Management System using Python. (Hacking attempts, data tampering, or unauthorised access)

Concepts Used:

- Log Analysis & Data Forensics
- Anomaly Detection (Machine Learning)
- Cybersecurity Threat Detection

Project Overview

The Battery Management System (BMS) logs critical parameters:

- Voltage, Current, Temperature
- State of Charge (SOC), State of Health (SOH)
- Communication logs (CAN messages)

Potential Cyber Threats:

- **Spoofing Attack:** Fake voltage readings injected
- **Man-in-the-Middle Attack:** SOC data modified
- **Malware in BMS:** Unauthorised data manipulation

Expected Outcomes

- Build a Battery Intrusion Detection System (IDS)
- Detect cyber attacks on BMS data
- Train an ML model to differentiate between normal and attack conditions
- Secure BMS communication with encryption (Advanced)

STEP 1 : Collect Battery Data Logs (or Use Sample Data)

- Use a CSV file containing battery logs with timestamps
- Add a column for intrusion detection labels (Normal / Attack)

STEP 2 : Analyse Normal vs. Anomalous Data

- Load the dataset using Pandas
- Visualise voltage/current variations using Matplotlib
- Identify unexpected spikes, drops, or inconsistent SOC values

STEP 3 : Implement an Anomaly Detection Model

- Use Scikit-Learn to train an ML model for intrusion detection
- Algorithms: Isolation Forest, Random Forest, or Logistic Regression
- Train model on normal vs. attack data samples
- Detect real-time anomalies from live battery logs

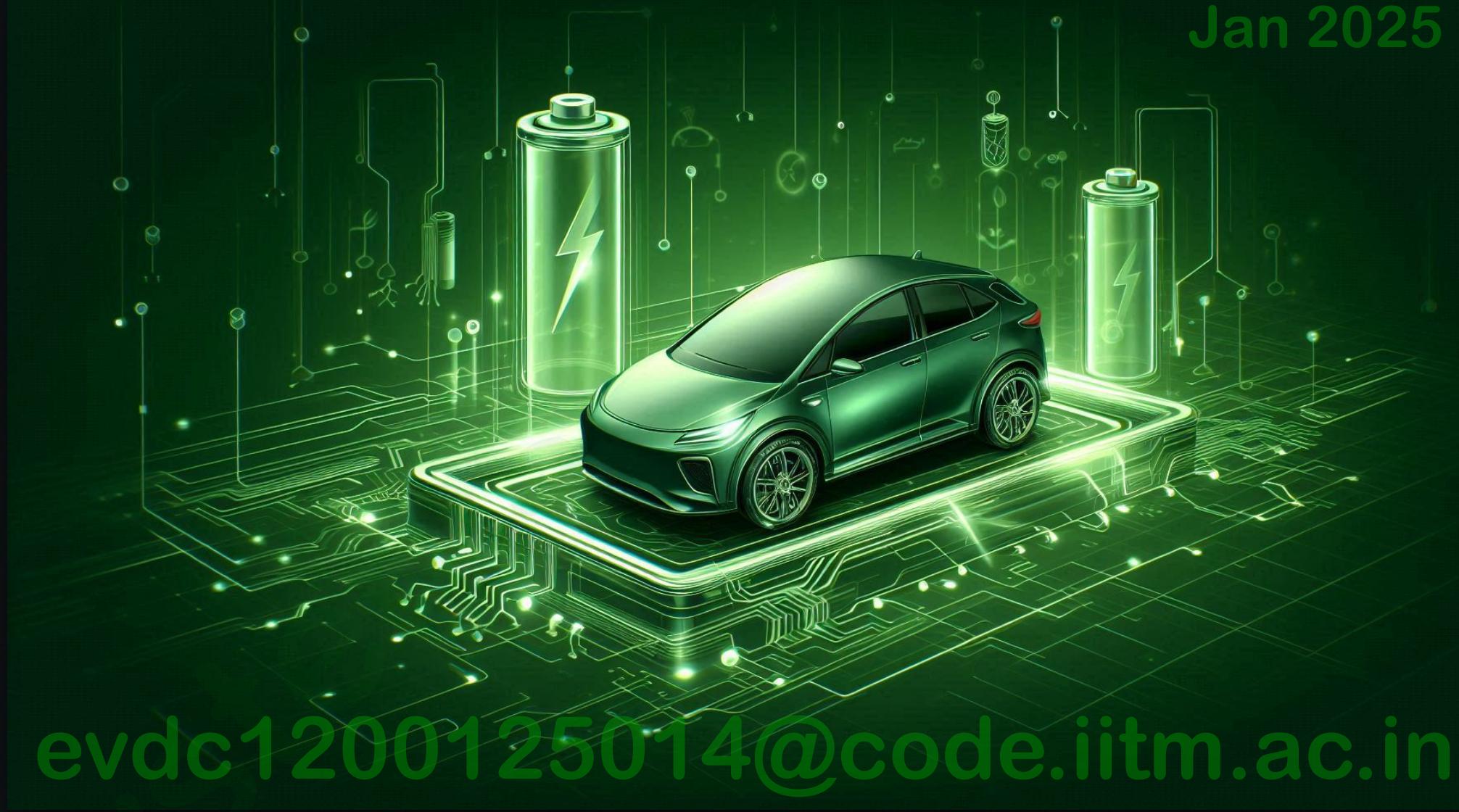
STEP 4 : Real-Time Intrusion Detection Simulation

- Simulate incoming battery data (live stream using Python)
- Detect unauthorised activities and trigger alerts
- Implement logging system to save security breach attempts

STEP 5 : Secure Battery Data with Encryption

- Use AES Encryption (Python pycryptodome module)
- Encrypt critical BMS data before transmission \
- Ensure only authorised systems can decrypt it

Business Plan



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Example : Bangalore has seen a 300% increase in EV fire incidents in 2023-24.

The Solution

AI - Powered Thermal Runaway Early Warning System (TREWS)

- Predicts & prevents battery overheating & fire risks using real-time analytics.
- AI-driven thermal modelling detects early failure patterns.
- Smart charging optimisation prevents excessive heat buildup.
- Instant alerts via SMS, WhatsApp, Fleet Dashboards for preemptive action.
- Cybersecurity integration to prevent data tampering & enhance safety.

Vision Statement

"To revolutionise EV Battery safety with AI-powered predictive technology, ensuring a fire-free, secure, and sustainable electric mobility future."

Mission Statement

"We are building AI-driven early warning systems that predict and prevent EV Battery Thermal runaway, ensuring a fire-free and secure electric mobility future.

Our solution reduces risks, enhances battery longevity, and provides real-time safety insights for fleet operators, service centers, and manufacturers—creating a scalable, high-impact business model in the growing EV industry."

Core Values

- **Innovation** – We push boundaries in AI and predictive analytics to enhance EV safety.
- **Quality** – Delivering accurate, reliable, and high-performance safety solutions.
- **Safety & Security** – Protecting lives and assets by preventing battery failures before they happen.
- **Customer-Centricity** – Focused on solving real-world EV battery safety challenges for fleet operators, service centers, and manufacturers.
- **Team Empowerment** – Fostering a culture of excellence, collaboration, and continuous learning.
- **Sustainability** – Promoting a cleaner, greener future by improving EV battery efficiency and longevity.

Market Opportunity

EV Market Growth in India (2024-2030):

- **4M+ EVs on Indian roads by 2025** → Rising demand for predictive safety solutions.
- **\$2B+ TAM in EV battery analytics & predictive safety by 2027**
- **EV Two-Wheeler Market CAGR 49%** → 90% of growth from fleet & delivery startups.
- **Battery Fire Incidents Increased by 300% (2023-24)** → Regulatory compliance & safety demands.
- **Total Addressable Market : \$2B+ EV Battery Analytics Industry by 2027.**

Primary Target

- **Bangalore's EV Battery Service Centers & Fleets** → Rapid Expansion to Other Cities.

Target Customers & Business Model

Target Customers

- **EV Battery Service Centres** – Main focus for early adoption & pilot testing.
- **Fleet Operators** – Require predictive battery health insights.
- **Battery Swapping Networks** – Need real-time monitoring for multiple batteries.
- **EV OEMs & Dealerships** – Long-term partnerships for factory-level integration.

Business Model

- **Service Center Subscription** : ₹2,999 - ₹9,999 per month (for battery analytics & fire prevention insights)
- **Add-on Services for EV Owners (via Service Centres)** : Freemium model (basic free, premium ₹499/year)
- **API Licensing for EV OEMs & Battery Swapping Companies**.

Goal

- **Secure 3-5 pilot customers in Bangalore → Scale Nationwide.**

Competitive Landscape

Competitor	Solution	Weakness
Ola Electric	Internal battery monitoring	No AI-based thermal runaway prediction
Ather Energy	BMS safety system	No external predictive analytics
ION Energy	AI analytics for OEMs	Not available for individual EV owners
Log9 Materials	Battery R&D & safety focus	No real-time user alerts
EV Doctor	AI-powered battery diagnostics & monitoring	Primarily targets service centres; limited end-user focus
Our Solution	AI-powered real-time battery fire prevention system	First with proactive early warning & smart alert system
	Key Differentiators : Predictive AI Smart Alerts Cybersecurity Scalable SaaS.	

Roadmap & Execution Plan

Short-Term (0-1 Year):

- Secure partnerships with 3+ major battery service centers in Bangalore for pilot testing.
- Deploy AI-based predictive analytics as a service for EV battery inspections.
- Collect real-world data & refine AI model accuracy.

Medium-Term (1-3 Years):

- Scale to 50+ service centers across major Indian cities.
- Expand to battery swapping companies & fleet operators.
- Integrate with OEMs for factory-level safety compliance.

Long-Term (3-5 Years):

- Become India's #1 AI-driven EV battery safety platform.
- Expand beyond 2-wheeler to 4-wheelers & public transport.
- Standardise AI-driven battery diagnostics across all EV service centers

Risk Management

- **Dependence on Data Availability** – AI accuracy depends on access to high-quality battery telemetry data from service centers & fleets.
- **Service Center Adoption Barrier** – Some traditional service centers may resist adopting AI-based predictive solutions due to a lack of familiarity.
- **Integration with Existing BMS Systems** – Many EVs have built-in BMS; we need to demonstrate the added value of our AI analytics.
- **Cybersecurity Risks** – Handling critical battery safety data makes the system a potential target for hacking or tampering.
- **Real-Time Processing Costs** – Running AI-driven analytics at scale requires cloud infrastructure, balancing costs while keeping subscriptions affordable.

Mitigation Strategies

- Partner with leading fleet operators & service centers to improve data collection.
- Provide training & easy-to-use interfaces for service centers.
- Highlight differentiation from BMS by offering early risk detection & alerts.
- Implement strong encryption & cybersecurity protocols to protect data.
- Optimise cloud-based architecture to balance cost efficiency & performance.

Investment & Funding Requirements

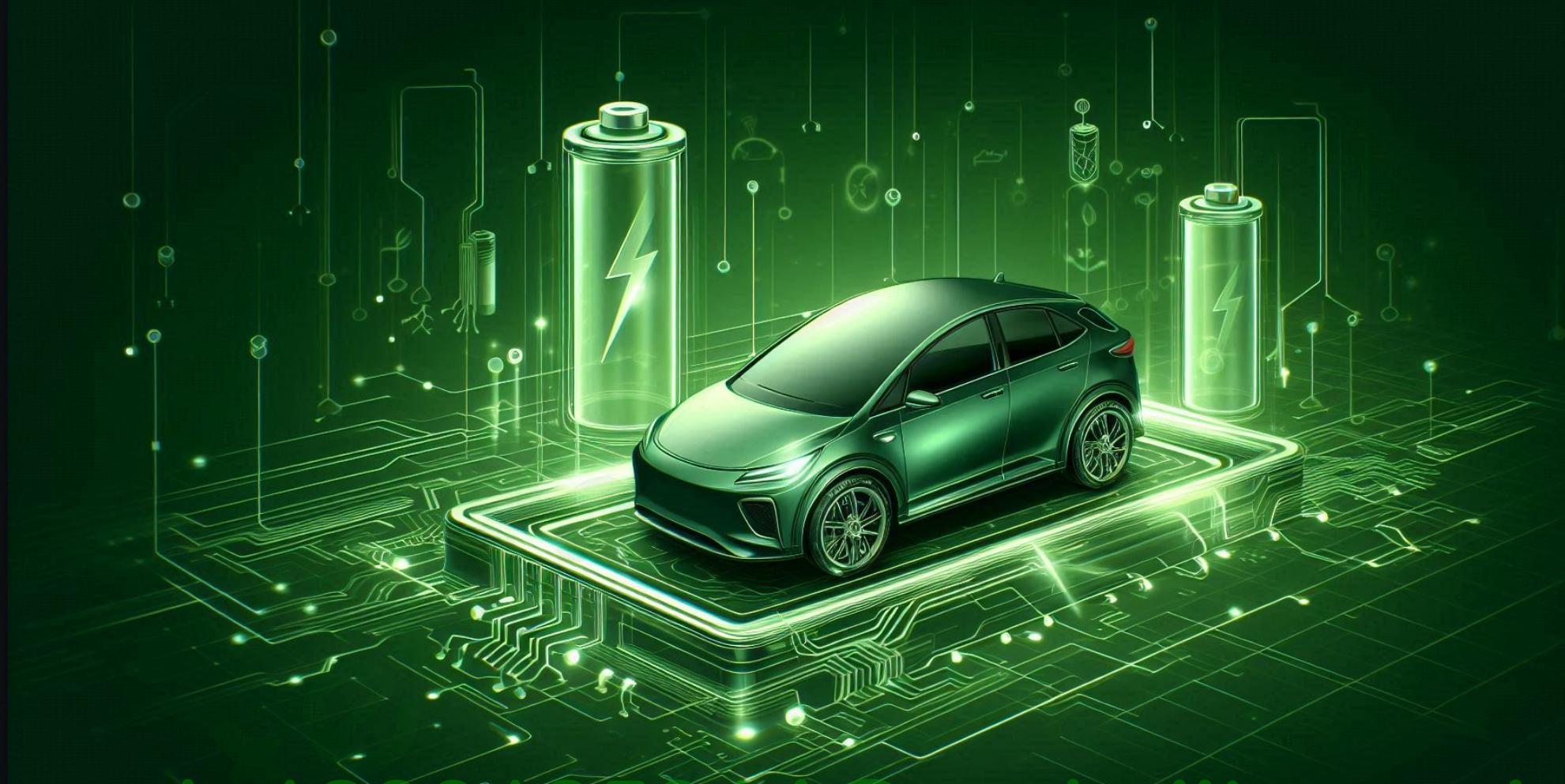
- Develop & test AI models with real-world data
- Build the web platform & API integrations.
- Launch pilot programs with fleet operators & service centers.
- Scale cybersecurity & cloud infrastructure.

Potential Investors & Grants

- Micelio Fund, Blume Ventures, Indian Angel Network.
- Government Grants: FAME India, Startup India, NITI Aayog.
- Corporate Collaborations: EV battery makers, fleet operators, OEMs.

Goal

- Secure first funding → Build MVP → Achieve Product-Market Fit → Scale Nationwide.



Join Us in Creating a Fire-Free EV Future!

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Looking for Strategic Partners, Pilot Customers & Investors.

Thank you

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