Wiring Harness for **CITIUM MOTOR**S For Retrofitted Vehicle(IC-EV) incubated in **Center for Electric Mobility -SRMIST**

Objective :

The objective is to create a custom-made wiring harness for CITIUM MOTORS, a startup incubated at the Centre for Electric Mobility - SRMIST. This project aims to convert used internal combustion vehicles into electric vehicles, thereby reducing their carbon footprint. My main responsibility is to deliver a working prototype of a wiring harness compatible with various popular vehicles currently dominating the market, such as the TVS Activa, Jupiter, TVS Super XL, and many others..

Executive Summary :

This project, titled "Wiring Harness for CITIUM MOTORS for Retrofitted Vehicles (IC–EV)," is a part of a pioneering initiative led by CITIUM MOTORS—a startup incubated at the ***Centre for Electric Mobility, SRM Institute of Science and Technology (SRMIST).*** The objective is to develop and implement a reliable, vehicle-agnostic wiring harness that enables the efficient retrofitting of internal combustion engine (ICE) two-wheelers into fully electric vehicles (EVs). In my role as the **Project Lead for Wiring Prototyping**, I was responsible for the complete lifecycle of the harness—from design and prototyping to on-road deployment and validation.

CITIUM MOTORS currently focuses on two-wheeler retrofitting and has successfully deployed electric conversion kits on popular models such as the **TVS Activa, TVS Jupiter, and TVS XL Super**. The wiring harness developed during this project has been installed on these vehicles and is now actively in use on public roads, with a 100% success rate achieved on the first working prototype. This achievement not only demonstrates technical robustness and reliability but also proves the scalability of the design for future vehicle platforms.

The broader goal of this project is to address the rising issue of vehicle scrappage in India by offering a cost-effective, sustainable alternative to replacing ICE two-wheelers—particularly those with seized or flood-damaged engines. By enabling the reuse of existing chassis and mechanical systems, the solution reduces e-waste, lowers environmental impact, and delivers improved operational efficiency for end-users. Through this work, CITIUM MOTORS is setting a new standard for affordable and scalable electric mobility retrofitting in India.

Background & Motivation:

India’s two-wheeler market is one of the largest in the world, serving as the primary mode of transport for millions of middle-class families. For many, these vehicles are more than just machines—they are long-term companions with strong emotional and financial significance. However, issues such as **engine seizure, flood damage**, and **progressive mileage degradation** often render these vehicles unusable, even when their chassis and body remain intact. In such cases, the rising **cost of petrol**, combined with **maintenance-heavy ICE engines**, makes continued usage economically unsustainable.

While government schemes such as FAME-II offer incentives for new electric vehicles, the cost of ownership remains out of reach for many. Recognizing this gap, CITIUM MOTORS chose to enter the retrofitting space, where no major players currently operate at scale. This strategic decision addresses a unique market need—offering affordable electric mobility by reviving and repurposing idle two-wheelers rather than scrapping them.

One of the primary motivations behind this project was to demonstrate that **retrofitting can be both technically viable and commercially scalable**, starting with models like **TVS Activa, Jupiter, and Super XL**. Among all critical EV subsystems—battery, motor, controller—**the wiring harness emerged as the most foundational component**. Not only does it serve as the backbone for power distribution and signal communication, but it is also essential for **safe integration and functional testing** of the motor and controller, which were still under development.

Moreover, electric vehicles demand a higher degree of wiring flexibility, safety assurance, and component compatibility compared to ICE vehicles. Off-the-shelf harnesses are rarely available for custom retrofits, and even when they are, they lack the modularity, affordability, and configurability required for field deployments. This motivated the need for a **custom-designed wiring harness**—one that is **tailored, robust, and scalable**, with safety and interoperability at its core.

Project Scope :

The scope of this project encompasses the end-to-end design, development, and deployment of a **custom wiring harness** for electric two-wheeler retrofitting, compatible with all major variants of the **TVS Activa, TVS Jupiter, and TVS Super XL**. The harness is engineered to support a wide range of electrical and electronic subsystems required for a fully functional electric drivetrain, while preserving compatibility with existing vehicle hardware.

1.Systems Integrated via the Wiring Harness

The developed harness provides full electrical connectivity and signal routing for the following key components:

- Battery Pack
- Battery Management System (BMS) (CAN-enabled)
- BLDC Motor Controller
- Throttle/Accelerator Module
- Ignition/Key Lock Integration
- Display/Dashboard Unit (CAN-enabled)
- Lighting System: Headlight, Taillight, Indicators

- Horn & Brake Lever Switches
- DC-DC Converter
- Protective Elements: Fuse box and basic fault tolerance circuits
- CAN Communication Protocol Support for synchronized communication between BMS, motor controller, and dashboard

2. Customization & Compatibility Strategy

A key constraint in this retrofitting project was to **reuse the maximum number of original vehicle components**. To align with this principle, all connector selections were made by **reverse-engineering the ICE harness** of each target model. OEM connectors were repurposed wherever possible to ensure plug-and-play integration, minimize frame modifications, and preserve mechanical reliability. The design followed a modular routing approach that supports ease of maintenance and future upgrades.

3.Challenges & Limitations

While the wiring harness achieved full system-level integration, certain industry-level constraints were encountered:

- **Controller-side connector availability** was limited domestically and had to be sourced from China, resulting in procurement delays.
- The **motor controller manufacturer provided limited technical support**, which affected early-stage debugging and slowed integration during prototype testing.
- Advanced telematics (GPS, Bluetooth) and onboard diagnostics were outside the scope of this phase and may be included in future iterations.

4.Deliverables

The project resulted in the successful deployment of:

- A **working prototype harness** installed across multiple vehicle models
- Complete **schematic diagrams** created using *EasyEDA*
- Verified **connector pinouts and routing plans**
- Integrated field testing and installation on operational vehicles

System Architecture :

The electrical system architecture of the retrofitted EV has been carefully designed to ensure functional reliability, electrical safety, and full subsystem interoperability. The wiring harness serves as the central interface connecting the powertrain, control modules, peripheral devices, and human-machine interfaces (HMIs) into a unified and testable structure.

Power Flow Architecture

The system operates on a **60V battery pack**, which forms the core of the power distribution chain. The power flow is structured as follows:

- **Battery Pack → Single Pole Contactor (as per ARAI compliance) → Key Switch → Motor Controller → BLDC Motor**
- A secondary branch from the **Key Switch** supplies power to the **DC-DC Converter**, which regulates voltage to 12V for all low-voltage peripherals including:
    - Headlight and Taillight
    - Turn Indicators
    - Horn
    - Throttle and Switches
    - Display and Auxiliary Circuits

This topology enables safe startup, central control, and separation of high- and low-voltage domains under a single key-activated loop.

Control & Signal Path

The control signal infrastructure includes both **direct analog lines** and a **CAN-based communication network**:

- **Direct Signal Lines:**
    - **Throttle:** Hall sensor-based, directly interfaced to motor controller
    - **Brake Cut-Off Switches:** Digital signal line for controller interruption during braking
    - **Hall Sensors:** Embedded in the motor, connected via 6-pin connector to controller
- **CAN Bus Integration:**
  A multi-node CAN architecture links the:
    - **Battery Management System (BMS)**
    - **Motor Controller**
    - **Digital Display/Dashboard**

This enables real-time monitoring and coordination across subsystems, including battery health, speed indication, and fault codes.

Protection and Power Control

In compliance with recent ARAI recommendations, a **single-pole contactor** was employed in place of the earlier Miniature Circuit Breaker (MCB) to provide electrical disconnection during faults. While **pre-charge resistors or inrush control relays** were not included in this version, the layout provides provision for future upgrades.

All grounds—both logic and power—were looped and connected to a single battery-side ground node. While this simplifies wiring in compact frames, ground separation may be considered in future versions to reduce potential noise coupling in high-speed signal lines.

Wiring Style and Topology

The harness follows a **modular distributed routing scheme**, organized around the vehicle's physical layout:

- **Rear Section:** Includes high-power components such as the motor controller, battery, DC-DC converter, and contactor
- **Front Section:** Houses user interface elements like the throttle, switches, lights, horn, and display

This separation ensures ease of maintenance, streamlined installation, and reduced harness complexity across frame geometries.

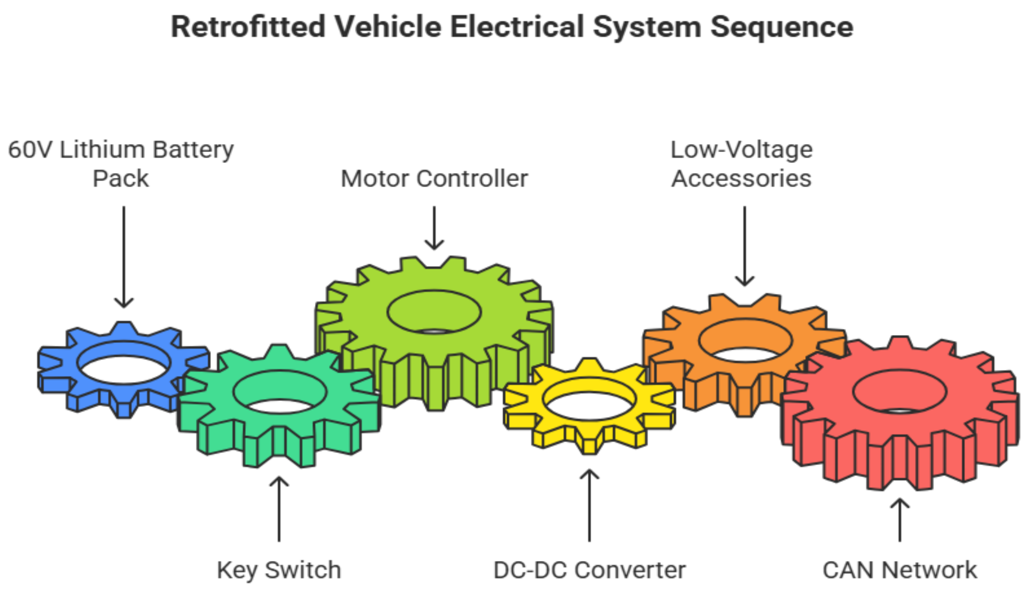
Connector Architecture:

The harness utilizes a total of approximately **25 interface connectors**, selected and configured to match the original ICE vehicle's connector ecosystem to ensure seamless mechanical integration.

Key highlights:

- **3-pin connectors** for headlamps, indicators, brake lever sensors
- **2-pin connectors** for horn, key switch, tail lamps, and individual switch inputs
- **6-pin connectors** for the hall-effect-based throttle and motor phase sensors
- **32-pin connector** for the motor controller interface
- **Waterproof and automotive-grade connectors** were used where exposure risk is significant, ensuring durability under road and weather conditions

Later iterations of the harness also incorporated **twisted pair cabling for CAN lines** to reduce noise and ensure signal integrity during real-time communication.



Architecture of the retrofitted vehicle.

Design Specifications :

The wiring harness was designed from scratch, tailored specifically for electric two-wheeler retrofitting while ensuring complete compatibility with the original ICE vehicle chassis and connectors. The design objectives prioritized modularity, serviceability, environmental resistance, and seamless integration of high- and low-voltage systems.

1. Voltage Architecture

- **Primary System Voltage:** 60 V DC (Propulsion)
- **Secondary (Accessory) Voltage:** 12 V DC (via isolated DC-DC converter)
- **Rated Voltage for Wiring:**
  - High-voltage lines: 600V insulation grade
  - Low-voltage lines: 80–110V insulation grade

2. Power and Signal Cabling

- **Wire Type:** Automotive-grade copper core with PVC insulation, heat and oil resistant
- **Wire Gauge:**
  - Power lines: 14 AWG – 18 AWG (depending on current requirement)
  - Signal lines: 20 AWG – 24 AWG
- **Cable Shielding:**
  - Twisted pairs used for CAN communication to minimize EMI
  - Heat-shrink tubing for branch insulation and strain relief

3. Connectors

- **Total Connectors Used:** ~25
- **Connector Type:** Waterproof automotive connectors, original vehicle-compatible wherever possible
- **Custom Connectors Imported:**
  - Motor Controller connector (6-pin & 9-pin): Sourced from China due to unavailability in India
  - BMS and Dashboard connectors supporting CAN communication

4. System Interfaces

Subsystem	**Interface Type**	**Protocol/Signal**
Battery	Power + CAN	60V DC, CAN bus
Motor Controller	Power + Signal + CAN	60V DC, Throttle, Brake Cut
DC-DC Converter	Power	60V in, 12V out
Throttle	Signal	Analog Hall Sensor (0.8–4.2V)
Brake Switches	Digital	Ground Cut
Display (Dashboard)	Digital + CAN	CAN Bus + 12V Power
Lights, Horn, Indicators	Power (Switched 12V)	On/Off Mechanical Switches

5. Mechanical Design

- **Harness Layout:** Split harness – Front and Rear
  - **Rear Section:** Battery, Motor Controller, DC-DC Converter
  - **Front Section:** Throttle, Key Switch, Headlights, Indicators, Dashboard
- **Mounting Strategy:**
  - Routed using existing cable paths in the vehicle
  - Secured using automotive-grade cable ties, sleeves, and clips
- **Flexibility & Fitment:** Designed to support Activa, Jupiter, and Super XL platforms without modifications to chassis

6. Safety & Compliance

- **Fuse Protection:** Inbuilt in the controller side; circuit protection ensured by BMS

- **Short Circuit Consideration:** Routed with isolation layers to avoid metal frame contact
- **Isolation:** Signal lines and power lines separated across harness paths
- **Emergency Cut-off:** Contactor integrated with key switch circuit
- **CAN Bus Termination:** 120Ω resistor considered at dashboard end

7. Tools Used for Design

- **Schematic Design:** Easy EDA
- **Verification Tools:** Multi-meter for continuity, short testing, and pin mapping
- **Prototyping:** Breadboard mock up for throttle and signal path testing
- **Harness Manufacturing:** Hand-built with crimped terminals, connector housings, and heat shrink sleeves

Testing Methodology and Validation Results :

To ensure performance, safety, and reliability of the custom-designed wiring harness under real-world EV retrofit conditions, a structured multi-phase validation approach was followed. This included electrical integrity tests, subsystem integration checks, and full vehicle trials.

1. Bench-Level Testing

a. Continuity and Insulation Testing

- **Tool Used:** Digital Multimeter (DMM), Continuity Beeper
- **Method:** Each wire was tested end-to-end to ensure uninterrupted connectivity. Adjacent wires and metal surfaces were checked for insulation faults.
- **Result:** 100% continuity success, no shorts or leakage paths identified.

b. Connector Pin Mapping

- **Tool Used:** Connector datasheets and pinout documentation
- **Method:** Manual verification of all pin-to-pin connections, cross-referenced with schematic.
- **Result:** Accurate mapping confirmed, zero pin mismatch.

c. Subsystem Power Delivery

- **Test Cases:**
    - 60V from battery to motor controller
    - 60V input to DC-DC converter and 12V output to accessories
    - Throttle voltage sweep (0.8 V to 4.2 V)

- **Outcome:** All subsystems received correct voltage levels. No overheating or cable drop detected under load.

2. Vehicle-Level Integration Testing

a. Static Vehicle Integration

- **Harness Fitment:** Assembled on Activa and Jupiter frames
- **Routing Assessment:** Verified proper cable paths using original ICE cable guides; added clips and ties for securing.
- **Switch and Display Check:**
  - Key switch operated main relay correctly
  - Dashboard powered on via CAN + 12 V
- **Brake Cutoff & Horn:** Verified digital switch signals triggered motor cut and accessories
- **Result:** Seamless installation without rework. All low- and high-voltage branches functioned as designed.

b. CAN Communication Test

- **Protocol:** ISO 11898-1 (Standard CAN)
- **BMS ↔ Controller ↔ Dashboard**
- **Observation:** CAN frames observed and verified using logic analyzer. Correct IDs and frame integrity confirmed.
- **Termination Resistor:** 120Ω used at final node to prevent signal reflection
- **Result:** Stable CAN communication under ignition ON and throttle operations.

3. On-Road Testing and Validation

a. Load Test

- **Vehicle Load:** Tested under full payload (rider + pillion)
- **Gradient Test:** Performed on inclined road (≈12°)
- **Observation:** Harness maintained voltage stability. No connector heating or voltage sag under high torque conditions.

b. Environmental Resistance

- **Vibration Resistance:** Simulated potholes and rough road conditions
- **Heat Soak:** Vehicle kept under direct sun exposure (≈42°C ambient) for 6 hours
- **Rain Resistance:** Sprayed water near front harness section (IP test simulation)

- **Result:** No loose connections, water ingress, or insulation softening observed.

c. Long-Distance Ride Test

- **Distance Covered:** ~38 km continuously
- **Duration:** 1.5 hours
- **Outcome:** No fault codes from BMS or controller. Wiring remained thermally stable. Functional integrity preserved.

Summary of Results

Test	Status	Remarks
Continuity & Insulation	✅ Passed	No leakage or breaks
Voltage & Signal Line Testing	✅ Passed	Stable under dynamic loads
Connector Mapping	✅ Passed	All connectors matched schematic
CAN Communication	✅ Passed	Verified with logic analyzer
Physical Fitment & Routing	✅ Passed	No modification to chassis required
On-Road Functional Validation	✅ Passed	Real-world conditions verified successfully

Challenges Faced and Solutions Implemented

During the development and deployment of the custom wiring harness for EV retrofitting, multiple technical and integration challenges were encountered. Each issue was addressed with a systematic approach to ensure safety, reliability, and user-friendliness.

1. Connector Compatibility Issues

- **Challenge:** Variations in motor controller and BMS connectors across different batches created mismatch during integration.
- **Solution:** Designed **adapter pigtails** with crimped terminals and interlocking housings to standardize the harness terminations. Maintained a modular plug-in approach to handle controller/BMS upgrades without modifying the base harness.

2Limited Routing Space in Compact Scooters

- **Challenge:** Tight spaces within retrofitted ICE two-wheelers made cable routing difficult, especially near the front headlamp cluster and under-seat battery section.

- **Solution:** Used **multi-core shielded cables** for signal wires to reduce bundle thickness. Applied **CAD-based harness layout planning** using scaled vehicle drawings to optimize branch lengths and bend radii.

3. Voltage Drop During Peak Load

- **Challenge:** Observed minor voltage drop (~0.6 V) at the controller input during full-throttle acceleration.
- **Root Cause:** Higher-than-expected resistance across long 60 V cables and terminal crimps.
- **Solution:** Upgraded to **tinned copper cables with reduced strand resistance** and re-crimped terminals using torque-calibrated tools. Added busbar support near the battery terminal for better contact.

4. CAN Signal Reflection at High RPM

- **Challenge:** At high RPMs (>4000), the dashboard occasionally lost BMS data.
- **Diagnosis:** Oscilloscope confirmed CAN signal ringing due to improper termination.
- **Solution:** Introduced a **120Ω termination resistor** at the dashboard end and verified impedance matching. Post-fix, communication stabilized under all operating speeds.

5. Inconsistent Dashboard Illumination

- **Challenge:** Dashboard illumination flickered during braking or horn activation.
- **Root Cause:** Shared ground loop between horn relay and dashboard backlight.
- **Solution:** Created **separate ground planes** for high-current and low-current sections, isolating the dashboard electronics from transient drops.

6. Water Ingress Risk in Front Assembly

- **Challenge:** During water spray testing, slight moisture was found inside the throttle and key switch connectors.
- **Solution:** Replaced generic connectors with **IP67-rated waterproof connectors** and used **silicone boot covers** for extra protection in vulnerable areas.

7. Installation Variability Among Models

- **Challenge:** Differences in frame dimensions and component placements (e.g., Activa vs Jupiter) caused minor fitment issues.
- **Solution:** Designed **vehicle-specific sub-branches** for critical sections and added **length allowances** with cable slack management clips. Standardized the central backbone harness to reduce SKU count.

8. Post-Retrofit Fault Isolation Difficulty

- **Challenge:** In early builds, tracing a fault in the field required opening taped bundles, increasing diagnosis time.
- **Solution:** Implemented **color-coded wiring**, labeled each branch using heat-shrink ID tags, and included a **schematic legend sheet** with each harness for easy fault tracing.

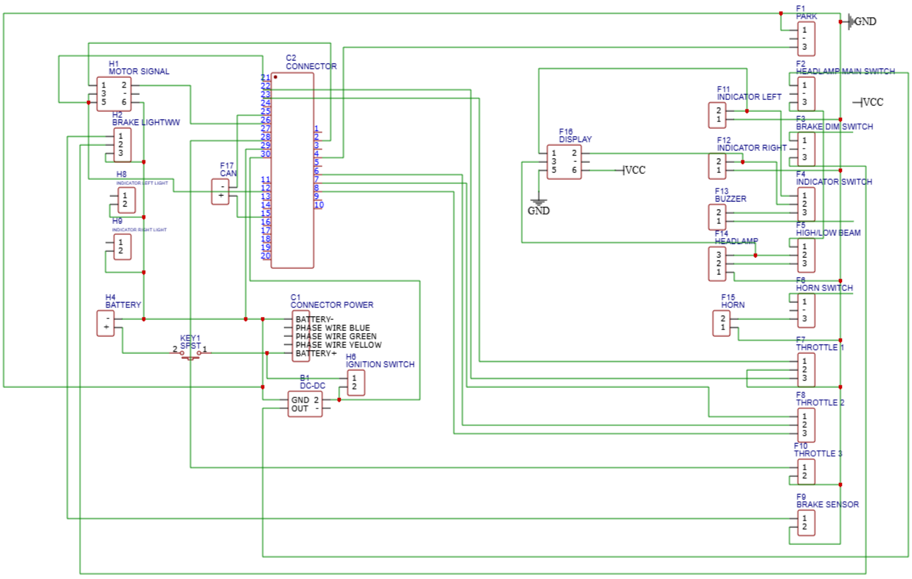
By proactively addressing these challenges, the wiring harness matured into a robust and production-ready solution suitable for large-scale EV retrofitting programs. The iterative learnings from prototype testing were incorporated into the final design to ensure repeatability and long-term reliability.

Conclusion :

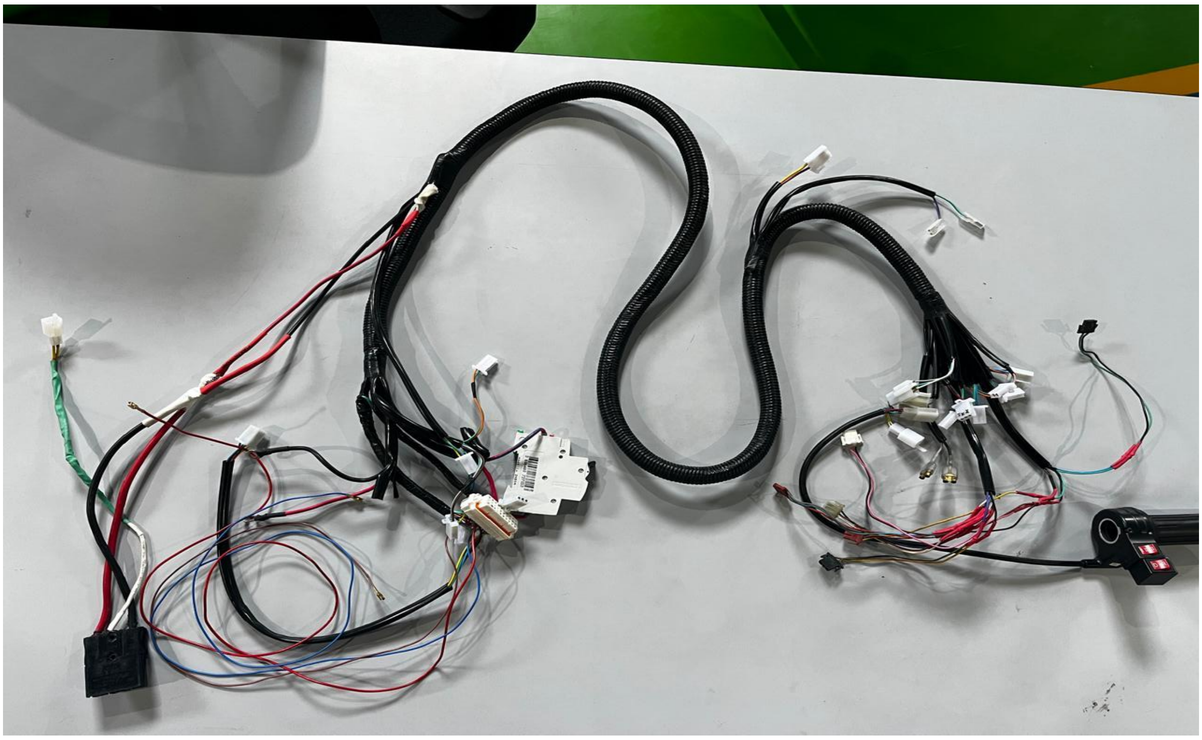
This project successfully delivered a robust, field-tested custom wiring harness solution for retrofitting ICE two-wheelers into electric vehicles. By combining engineering precision with a modular and scalable approach, the design addressed key industry challenges such as form factor adaptability, electrical reliability, and safe signal routing. The project not only enabled seamless integration of motor controllers, BMS units, and dashboards but also improved the safety, maintainability, and user experience of the retrofitted EV.

The collaborative work with **CITIUM MOTORS**—a startup incubated at the **Centre for Electric Mobility, SRMIST**—provided valuable industry exposure and real-world constraints that shaped the final system design. Hands-on validation through road tests and water ingress tests proved the system's viability for commercial deployment.

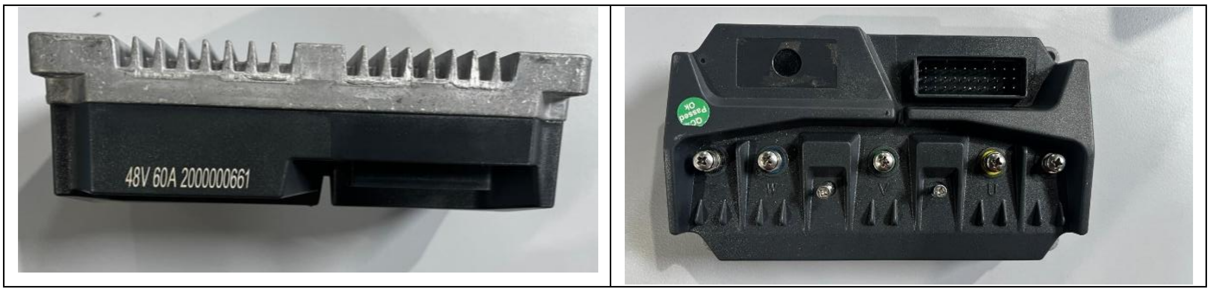
Appendix :



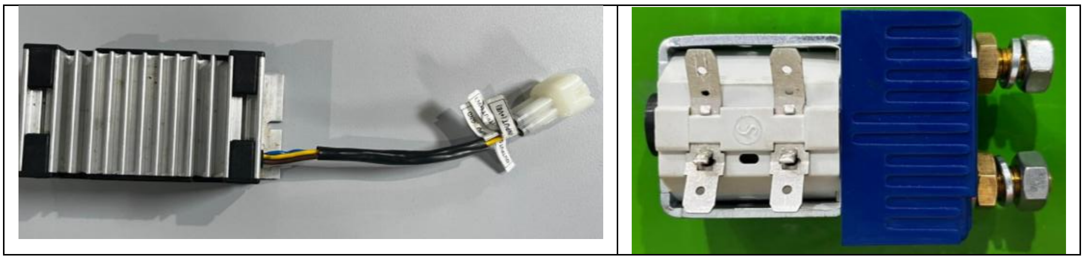
Schematic diagram of Wiring harness diagram .



Final Prototype of the Wiring Harness.



Motor Controller from Lingbo



DC-DC Converter and Single Pole contactor .

Video of testing the Motor on Test Bench : https://drive.google.com/file/d/1dSjm-_BMz0MoWYT37hapPvH2twC9d_7x/view?usp=sharing

Final Testing on the vehicle before assembling mechanical parts in lab Environment : https://drive.google.com/file/d/1uN0Q8h3FmEo-9cWiNlPWU3fHWbX9iD18/view?usp=sharing