

# Retrofit Design Study: Conversion of a Maruti 800 Internal Combustion Engine Vehicle to a Battery Electric Vehicle

Mohammed Misbahuddin Adnan, Aaron Joseph Joji, Mulla Mohammed Faiz Mubarak, Peerjade Sayad Gafoor  
Department of Mechanical (Mechatronics) Engineering, Mahatma Gandhi Institute of Technology, Hyderabad, Telangana, India

Guide: Dr V.V.N. Satya Suresh, Professor, Dept. of Mechanical Engineering, MGIT (Autonomous)

**Abstract** - Rising fuel prices and vehicular pollution in urban India necessitate a transition toward cleaner and more affordable mobility solutions. The purchase of a brand-new Electric Vehicle (EV) remains financially prohibitive for a significant portion of the Indian population, making the retrofit conversion of existing Internal Combustion Engine (ICE) vehicles into EVs a practical alternative. This paper comprises a complete engineering study of the ICE-to-EV conversion of a Maruti 800, one of India's most widely distributed lightweight passenger vehicles. The conversion involves the removal of the petrol powertrain—including the 3-cylinder engine, fuel tank, exhaust system, and radiator—and its replacement with a 10 kW Permanent Magnet Synchronous Motor (PMSM), a 48 V/200 Ah LiFePO<sub>4</sub> battery pack, a motor controller, a Battery Management System (BMS), a DC-DC converter, and a regenerative braking system. Theoretical force and power calculations covering rolling resistance, aerodynamic drag, and gradient forces were performed to size components accurately. These were validated using a MATLAB/Simscape Battery Electric Vehicle (BEV) simulation model configured with vehicle-specific parameters. Simulation results demonstrate electrical efficiency of approximately 10 kWh/100 km, stable battery voltage within 46.5–48.5 V, peak motor torque of 40 Nm within the 48 Nm design limit, and functional regenerative braking. The study establishes a documented, reproducible retrofit methodology applicable to similar low-cost urban EV conversions in developing markets.

*Index Terms* - EV retrofitting, Maruti 800 electric conversion, PMSM motor sizing, LiFePO<sub>4</sub> battery pack, MATLAB Simscape BEV simulation, regenerative braking, urban electric mobility.

## I. INTRODUCTION

The global automotive industry is undergoing one of its most fundamental transitions since the commercialisation of the internal combustion engine. For over a century, ICE vehicles have dominated personal and commercial transport; however, their continued use has generated significant environmental, economic, and energy-security challenges. Governments worldwide are introducing increasingly strict emissions regulations, and consumer awareness around carbon footprint and air quality is growing rapidly.

In India, this transition presents a unique set of challenges. New EVs remain financially inaccessible to a large segment of the middle-class population, with acquisition costs compounded by high battery replacement expenses. Simultaneously, India hosts tens of millions of ageing ICE vehicles—structurally functional but environmentally harmful. Replacing these at scale with new EVs is neither economically viable nor environmentally efficient, since the manufacturing of a new vehicle itself carries a significant carbon footprint. Retrofitting, by contrast, reuses the existing chassis, body, and mechanical sub-systems, eliminating the embodied-carbon cost of new manufacturing while instantly removing tailpipe emissions.

The Maruti 800 was selected as the donor vehicle for this study due to its low kerb weight (~670 kg), simple chassis layout, single-speed-compatible drivetrain architecture, and near-ubiquitous availability in the Indian second-hand market. These characteristics make it an ideal candidate for cost-effective urban EV conversion. The project covers the complete technical workflow: force and power calculations, component selection, system architecture design, and MATLAB simulation-based validation.

The core objectives of this study are: (1) to derive motor power and battery capacity requirements through engineering calculations, (2) to select and specify appropriate EV drivetrain components, (3) to validate design

choices through a multi-parameter BEV simulation, and (4) to assess the cost-effectiveness of the conversion relative to purchasing a new EV. The results establish a replicable, technically rigorous framework for ICE-to-EV conversions of small Indian passenger vehicles.

## II. LITERATURE REVIEW

It was observed that EV retrofitting has attracted growing academic and commercial interest globally. In advanced markets, conversion initially gained traction among classic car enthusiasts; in developing nations such as India, the motivation is more pragmatic—reducing pollution and extending the economic life of existing vehicles [3]. A 2023 report by the Global Green Growth Institute (GGGI) estimates that retrofitting can reduce lifecycle greenhouse gas emissions by 35–60% compared to continued ICE vehicle operation, directly aligning with India's Nationally Determined Contributions under the Paris Agreement [3].

A widely cited Indian case study (Team-BHP, 2020) documented the conversion of a Maruti 800 using a 19 kW BLDC motor, a 13.2 kWh Winston LiFePO<sub>4</sub> pack, and a Curtis programmable controller, achieving a range of 120 km and a top speed of 80–85 km/h [1]. This benchmark confirms that a lightweight ICE platform can yield a functionally competitive urban EV without factory-level tooling. Mechatronic Trading (2023) has further demonstrated commercial viability by offering standardised retrofit kits for the Maruti 800 and Tata Nano, indicating the emergence of a scalable Indian retrofit market [2].

On the technical side, Eydgahi and Long (2011) note that retaining the existing gearbox during conversion simplifies integration and provides torque multiplication at low speeds [4]. Modern PMSM motors with Field-Oriented Control (FOC) offer superior torque density and efficiency relative to induction motors, making them the preferred choice for compact city-car conversions [5]. Hoeft (2021) highlights that retrofitting eliminates the need to manufacture an entirely new vehicle, reducing embedded material emissions and supporting circular economy principles [6].

Key technical challenges identified in the literature include thermal management of motor and battery systems, battery packaging constraints in chassis not designed for prismatic cells, high-voltage electrical safety, and regulatory ambiguity in the Indian homologation framework [5][6][7]. Economic analyses consistently show that retrofit costs are 30–60% lower than new EV purchase costs, with fleet operators recovering investment within 18–30 months through fuel savings [7]. These findings collectively substantiate the technical feasibility and economic relevance of the approach adopted in this study.

## III. METHODOLOGY

### A. Vehicle Architecture and Component Mapping

The Maruti 800 (original kerb weight: 670 kg) was selected as the donor platform. The ICE powertrain components identified for removal totalled approximately 170 kg, including the 3-cylinder petrol engine, fuel tank, exhaust system, radiator, air intake, carburettor, clutch, and associated wiring. EV components added to the chassis—motor, battery pack, controller, DC-DC converter, BMS, and wiring harness—contributed approximately 100 kg. With five passengers at 70 kg each, the total effective vehicle mass used in all calculations was 950 kg. Table I summarises the component mapping.

TABLE I: ICE-to-EV Component Mapping

Removed ICE Component	Added EV Component
Engine (3-cyl petrol)	10 kW PMSM Electric Motor
Fuel Tank	48 V / 200 Ah LiFePO <sub>4</sub> Battery Pack (10.24 kWh)
Radiator & Cooling System	Motor Controller + Liquid Cooling Kit
Exhaust System	Motor Mount + High-Voltage Wiring Harness

Alternator

DC-DC Converter (48 V → 12 V, 50 A)

### B. Theoretical Force and Power Calculations

Three primary resistive forces were derived to establish motor power requirements at a target cruise speed of 60 km/h (16.67 m/s).

Rolling Resistance ( $F_r$ ): Derived from the deformation torque model,  $F_r = \mu_r \cdot m \cdot g$ , where  $\mu_r = 0.0156$  (speed-dependent coefficient),  $m = 950$  kg, and  $g = 9.81$  m/s<sup>2</sup>. On a flat road:

$$F_r = 0.0156 \times 950 \times 9.81 = 145.3 \text{ N}$$

Aerodynamic Drag ( $F_d$ ): From the standard fluid-mechanics drag formulation,  $F_d = \frac{1}{2} \rho C_d A_f V^2$ , where  $\rho = 1.136$  kg/m<sup>3</sup> (air density at 38°C, Hyderabad summer),  $C_d = 0.34$ ,  $A_f = 1.70$  m<sup>2</sup> (EcoModder-corrected frontal area),  $V = 16.67$  m/s:

$$F_d = 0.5 \times 1.136 \times 0.34 \times 1.70 \times (16.67)^2 = 91.3 \text{ N}$$

Gradient Force ( $F_g$ ):  $F_g = m \cdot g \cdot \sin\theta$ . For a 5° slope:  $F_g = 950 \times 9.81 \times \sin 5^\circ = 812$  N. Gradient force was excluded from battery energy calculations since the vehicle does not operate continuously on a gradient.

Total flat-road tractive force:  $F_t = F_r + F_d = 236.6$  N. Required wheel power at 60 km/h:  $P_{\text{wheel}} = 236.6 \times 16.67 = 3,943$  W. Accounting for drivetrain efficiency ( $\eta_{dt} = 0.88$ ) and motor efficiency ( $\eta_{\text{motor}} = 0.90$ ):  $P_{\text{electrical}} = 3943 / (0.88 \times 0.90) = 4.97$  kW continuous. A 10kW-rated PMSM was selected to provide a 2× peak-to-continuous margin for acceleration and gradient climbing. Required battery energy for 100 km range:  $E = P_{\text{electrical}} \times (100/60) = 5.17 \times 1.667 \approx 8.62$  kWh. The selected 10.24 kWh pack provides approximately 18% margin over this requirement.

### C. Component Specifications

The following components were specified based on the calculations above and matched to commercially available hardware from Indian EV suppliers:

- Motor: 10 kW PMSM, 48 V, rated speed 4600 RPM, peak torque 48 Nm, efficiency 88–92%, mass 24 kg.
- Battery: Yukinova LiFePO<sub>4</sub>, 51.2 V nominal, 200 Ah, 10.24 kWh, BMS included, cycle life 4000–6000, mass 105 kg.
- Controller: Programmable motor controller with regenerative braking capability, matched to 48 V bus.
- DC-DC Converter: 40–90 V input, 12 V/30 A output, ~95% efficiency, aluminium heat-sink cooled.
- Charger: Smart charger, 58.4 V/30 A output, 7.5 h full-charge time, >88% efficiency.
- Gear Reducer: Single-speed, gear ratio 7.0, drivetrain efficiency 88%.

Total estimated conversion cost: ₹3,64,300 (approx. USD 4,370), including battery, motor, cooling, braking vacuum pump, charger, and fabrication.

### D. MATLAB/Simscape BEV Simulation

To validate the theoretical calculations, a complete Battery Electric Vehicle simulation was implemented in MATLAB R2023a using the Simscape BEV template. The model was configured with Maruti 800-specific parameters via the BEV\_MASTER.m script, which initialises all subsystems, defines the drive cycle, configures the solver, and executes the simulation in a single run.

The High-Voltage Battery subsystem was modelled as a 48 V DC voltage source with internal resistance  $R_{int} = 0.005$  Ω, nominal capacity 200 Ah, and initial SOC = 100%. A bidirectional current path enables regenerative charging. The Motor Drive Unit (MDU) was specified with peak torque 48 Nm, peak power 12 kW (with 20% overrating margin), rotor inertia 0.002 kg·m<sup>2</sup>, and combined motor-and-driver efficiency 88% at 3500 RPM/40 Nm. A PI speed controller with  $K_p = 0.8$ ,  $K_i = 0.2$  and torque saturation limits of ±48 Nm was used. The single-speed reducer was set to a gear ratio of 7.0 with  $\eta = 0.88$ .

The drive cycle was defined as a smooth 100-second sigmoid velocity profile, accelerating from rest to 60 km/h over 30 seconds, holding cruise for 35 seconds, then decelerating to rest. The sigmoid formulation— $v(t) = \max(\text{rise} + \text{fall} - 60, 0)$ —was chosen over piecewise-linear profiles to eliminate derivative discontinuities that

cause integrator instability in stiff solvers. The ode15s variable-order solver was used with maximum step size 0.05 s, RelTol =  $1 \times 10^{-4}$ , AbsTol =  $1 \times 10^{-5}$ .

## IV. RESULTS AND DISCUSSION

### A. Battery Performance

Fig. 1 presents the five battery performance signals recorded on the HV Battery scope over the 100-second drive cycle.

**Battery Current:** During the initial acceleration phase ( $t = 0-20$  s), current peaked at approximately 300 A as the motor demanded maximum torque to accelerate the 950 kg vehicle from rest. During steady-state cruise at 60 km/h ( $t = 30-65$  s), current stabilised at 100–150 A, consistent with the theoretical flat-road electrical power draw of  $\sim 5.17$  kW at 48 V ( $\approx 108$  A). At  $t = 65-90$  s (deceleration), current reversed to  $-80$  A, confirming functional regenerative braking with the motor operating as a generator.

**Battery Voltage:** Terminal voltage sag during peak acceleration was  $\Delta V = I_{\text{peak}} \times R_{\text{int}} = 300 \times 0.005 = 1.5$  V, reducing terminal voltage to 46.5 V—less than 4% below the 48 V nominal, indicating the pack is not overstressed. Voltage recovered to  $\sim 48$  V during cruise and rose to  $\sim 48.5$  V during regenerative braking, consistent with open-circuit voltage recovery behaviour in lithium-ion cells.

**State of Charge:** Starting at 200 Ah (100% SOC), the pack depleted to approximately 197.8 Ah by  $t = 65$  s—a discharge of 2.2 Ah over the  $\sim 0.9$  km drive segment. Extrapolating this discharge rate yields an energy consumption of approximately  $2.2 \text{ Ah} \times 48 \text{ V} = 105.6 \text{ Wh}$  per km, or  $\sim 6.4$  kWh/100 km for the cruise-only portion. A small SOC recovery is visible during the regenerative braking phase, confirming energy recuperation.

**Electrical Efficiency:** The integrated efficiency metric (kWh/100 km) settled at approximately 10 kWh/100 km by  $t = 100$  s. This is within 16% of the hand-calculated flat-road value of 8.62 kWh/100 km. The difference is physically attributable to acceleration energy costs and full drivetrain loss modelling, both of which are absent from the steady-state hand calculation. This agreement constitutes strong validation of the component sizing methodology.

**Battery Temperature:** The Basic-fidelity Simscape battery subsystem uses a constant-temperature output; no thermal rise was modelled. Analytically, at 300 A peak with  $R_{\text{int}} = 0.005 \Omega$ , resistive heating is  $P = I^2 R = 450 \text{ W}$ . Over 100 seconds with a thermal mass of 1600 J/K, this implies  $\Delta T \approx 28 \text{ K}$ —a practically significant rise that would require active thermal management in physical implementation.

### B. Vehicle and Drivetrain Performance

Fig. 2 presents the five vehicle performance signals from the Vehicle scope.

**Vehicle Speed Tracking:** The reference and actual speed traces were nearly indistinguishable throughout the drive cycle, demonstrating that the PI controller is well-tuned for the 950 kg vehicle mass. The vehicle reached 60 km/h in approximately 30 seconds, consistent with the sigmoid drive cycle design.

**Motor Speed:** At 60 km/h cruise speed, the calculated motor speed is  $\omega_{\text{motor}} = (60/3.6)/0.272 \times 7.0 \approx 4300$  RPM. The simulation scope confirmed a peak of approximately 4000–4300 RPM, within the designed operating band of 3000–5000 RPM, validating the gear ratio selection.

**G-Force:** Peak acceleration G-force was  $+0.05g$  ( $\approx 0.49 \text{ m/s}^2$ ), appropriate for a 10kW motor propelling a 950 kg vehicle in urban conditions. Deceleration G-force reached  $-0.10g$ , reflecting smooth regenerative braking. The deceleration force corresponds to  $F_{\text{dec}} = 0.10 \times 9.81 \times 950 = 931 \text{ N}$ , within the motor's regenerative torque capability.

**Motor Torque:** During acceleration, the commanded torque peaked at approximately 40 Nm—within the 48 Nm saturation limit, with no windup or instability observed. Cruise torque was 10–15 Nm, precisely sufficient to overcome rolling resistance and aerodynamic drag at 60 km/h. Deceleration torque was  $-20$  Nm, confirming active regeneration.

### C. Comparison of Theoretical and Simulation Results

TABLE II: Theoretical vs Simulation Performance Comparison

Parameter	Theoretical	Simulation
Flat-road motor power (kW)	4.97	~5.0 (cruise current $\times$ 48 V)
Battery energy for 100 km (kWh)	8.62	~10 (incl. accel.)
Motor speed at 60 km/h (RPM)	4300	4000–4300
Peak motor torque (Nm)	$\leq 48$	40 (peak commanded)
Voltage sag at peak current (V)	1.5 (calc.)	1.5 (46.5 V observed)

### D. Limitations

Several limitations were identified. First, the Basic-fidelity Simscape battery and motor subsystems use constant-temperature outputs, meaning thermal dynamics—potentially the most critical safety consideration in a physical build—are not captured in the simulation. Higher-fidelity Simscape subsystems (BatteryHV\_refsub\_SystemSimple or equivalent) are required for thermal validation. Second, the drive cycle is a simplified flat-road sigmoid profile and does not represent real Indian road conditions, including speed breakers, variable gradients, and stop-and-go urban traffic. Third, the simulation is one-dimensional; lateral vehicle dynamics, road camber, and steering forces are not modelled. Fourth, the 48 V system architecture, while commercially common for small retrofits, imposes high current demands (300 A peak) that require robust BMS current limiting and appropriately rated high-current connectors and cabling.

## V. CONCLUSION

This paper has presented a complete engineering study of the ICE-to-EV retrofit conversion of a Maruti 800, integrating theoretical force and power calculations, component specification, system architecture design, and MATLAB/Simscape simulation-based validation. The study demonstrates that retrofitting a small Indian passenger vehicle into a functional urban EV is technically feasible using commercially available components at a total cost of approximately ₹3,64,300—substantially lower than the acquisition cost of a new entry-level EV.

Key findings include: (1) a 10 kW PMSM motor and 10.24 kWh LiFePO<sub>4</sub> battery pack are correctly sized for a 950 kg converted vehicle operating at urban speeds up to 60 km/h; (2) the simulation-predicted electrical efficiency of 10 kWh/100 km validates the theoretical estimate of 8.62 kWh/100 km within a 16% margin, with the difference fully explained by acceleration energy and drivetrain losses; (3) battery voltage remained stable within 46.5–48.5 V throughout the drive cycle, confirming adequate pack sizing; (4) regenerative braking is functional, recovering energy at up to  $-80$  A during deceleration; and (5) motor speed, torque, and G-force profiles are all physically consistent with design targets.

The methodology used in this study—combining force analysis, component selection logic, and multi-parameter BEV simulation—is directly replicable for similar small-vehicle retrofit projects. Future work should address: (1) physical prototyping and real-road validation, (2) higher-fidelity thermal modelling of motor and battery subsystems, (3) advanced BMS integration and high-voltage safety validation, (4) Indian homologation and regulatory compliance pathways, and (5) integration of second-life battery packs to further reduce conversion cost. With continued refinement, this retrofit model represents a scalable, sustainable, and economically viable pathway toward widespread EV adoption in India's urban mobility ecosystem.

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