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Conversion of an IC Engine Vehicle to a Battery-Electric Vehicle

Abhishek Mishra[1]*, Biraj Kharel[2], Nabin Mishra[3], Tejraj Tharu[4], Nitesh Kumar Yadav[5]
Department of Mechanical Engineering, Kathmandu University Dhulikhel, Nepal

Abstract:- The gradual increase in carbon emission along with the greenhouse gases results in increased global warming due to the smoke emission from the IC engine vehicles has adversely degraded the environment quality and human health. The global data of 2018 show that road transport accounts for three quarters (74.5%) of the total emissions where passenger vehicles contribute 45.1% and trucks carrying freight contribute 29.4%. Different alternatives have been studied and developed for the reduction of such emissions from the transportation sector. The global world is transitioning towards cleaner means of transportation and it is high time for Nepal to focus on clean transportation technology. Almost 99.9% of the transportation sector of Nepal is dependent on petroleum and diesel-based fuels. In such a scenario, electric vehicles could be one of the alternatives. This paper studies the possibilities of the conversion of IC engine vehicles to battery electric vehicles in the transportation sector. An internal combustion engine Maruti Suzuki 800 car model is selected for conversion into BEV. The internal combustion engine and other related components are removed and replaced by the electric traction motor, battery, and other electrical components with the existing gearbox and transmission system. The components are selected as per the requirements based on the calculations. An electric motor is powered by a lead-acid battery and the electric motor transfers the power up to the wheels that propel the vehicle. A simple model MATLAB/Simulink is developed and tested virtually for analysis and improvement before the actual conversion process. Finally, the vehicle is successfully tested and run on the track without any technical problems. The overall project shows the technical feasibility, an adaptation of new technology, and technology transfer as well as the reuse of an old IC vehicle in the transportation sector in Nepal.

***Keywords**:- IC engine, battery electric vehicle, Maruti Suzuki 800, conversion, traction motor, lead-acid battery*

I. INTRODUCTION

The world is facing a crisis of oil and the price of oil is rising day by day. Even though fossil oil is used in vehicles, it emits the most pollutant chemicals like Sulphur dioxide, carbon monoxide, nitrous oxide, etc. which are hazardous to human health and the environment [1]. But today, even though many alternative forms of vehicle have arrived in the market, the ratio of IC engine vehicles to eco-friendly vehicles is still high. Considering the bad consequences of IC engine vehicles and the hike in gasoline products, many automobile companies have been progressively working on the design, development, and production of alternative eco-friendly electric vehicles. The Battery EV generally consists of a large pack of batteries for energy, an electric AC/DC motor for power, a motor controller to regulate the flow of energy to the motor, and other several subsystems. Considering the similar layout, the Maruti 800 car was converted to an electric car. A total number of six lead acid batteries are used in the car in a series connection. The power train system of a converted car is designed as per the periphery road of Kathmandu University. The power transmission takes place from the battery pack to the electric motor via the Fuse and power controller. Then the power is reached up to the wheels from the electric motor which is coupled with the transmission gearbox fixed at single speed gear. The car propels forward, reverse, and Neutral when the lever of a forward-reverse switch is moved. The conversion process shows the technical feasibility and adaptation of the new technology in the context of Nepal.

The conversion to battery electric vehicle has the following advantages:

- Economically cheaper in the operating phase
- Reused of an old IC vehicle
- Zero Tailpipe Emission and noise pollution
- Erasing the obligation to use a water cooling system [2]

II. METHODOLOGY

A suitable car model Maruti Suzuki 800 was selected for the conversion process because of its light weight and economic feasibility test. Before the conversion of an IC Engine car, an in-depth literature review was done from various research papers and journals, and then the mathematical and numerical calculation was done. A final calculation was made by the project team and components were selected of the required specifications as per the calculation. Then the car was disassembled in the Technical Training Centre (TTC) at Kathmandu University. All the retrofit components were readily available in the Nepali market and then after disassembling subsequent assembling of the electric powertrain was carried out. After all the setup, its power, efficiency, speed discharging, and charging time were tested.

A. Components used

There are major five components that make the electric vehicle run but besides that, there are still more sub-systems that make the system more reliable, efficient, and trustworthy. We have used a Molded Case Circuit Breaker (MCCB) that helps to turn the system off during rest conditions, so that, there would be less chance of short circuit and any damage to the system.

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Table 1: Components of a converted vehicle

S.N.	Components
1	DC Motor
2	Lead Acid Battery
3	Forward/Reverse Switch
4	Motor Controller
5	MCCB
6	Potentiometer

B. Maruti Suzuki 800 car

A car that was used for more than 25 years was selected Which was still in running condition though the tire was inflated. Some components including the rear brake and light were damaged was were replaced furtherby.

Fig. 1: Maruti Suzuki 800 car for conversion

C. Disassembling of car

All components of cars such as its Three-cylinder engine, alternator, auxiliary battery, and even seats were taken out from the car for further assembling of other electrical components. The 1st image shows the frontal parts that are removed, whereas 2nd image shows the rear portion that was removed.

Fig. 2: Frontal part of the disassembled car

Fig. 3: Rear part of the disassembled car

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D. Design and Calculations

The theoretical calculations were done before selecting the required components. Generally, major parameters such as Power, torque, and Forces were calculated using all the below equations, and some standard values were assumed following some research journals given in Table 2.

The curb weight of the car was 650 kg before the removal of the engine and after removal, it was 560 kg and after adding the electric powertrain it rose to 805 kg due to the heavy weight of the battery. So, the total gross weight was 1155 kg after adding the weight of 5 passengers with an average weight of 70kg each given in Table 3 [3]. Based on this weight the calculation was carried out.

Table 2: Assumption parameters

S.N.	Parameters	Value	unit
1	Coefficient of Drag (Cd)	0.4	N/A
2	Density of air (d)	1.225	Kg/m3
3	Velocity(v)	30	Km/hr.
4	Acceleration time(Ta)	6	Sec
5	Coefficient of Rolling Resistance (Crr)	0.01	N/A
6	Acceleration (a)	1.388	m/s2

Table 3: Parts and their weight [3]

S.N.	Parameters	Value	unit
1	Curb Weight of the car	650	Kg
2	Weight of payload	350	Kg
3	Weight of motor	40	Kg
4	Weight of battery	200	Kg
5	Wight of engine	90	Kg
6	Weight of controller	5	Kg
	Total Weight	1155	Kg

E. Calculations

- *Aerodynamic Drag Force*

The drag force is given by

$$\text{Drag Force } (F_d) = 1/2 *Cd*A*d*v^2 = 1/2*0.4*1.225*2.0232*(8.33)^2 = 34.39\text{N}$$

- *Rolling Resistance force*

The rolling resistance force is given by

$$\text{Rolling Resistance Force}(F_{rr}) = C_{rr}*M*g = 0.01*1155*9.81 = 113.3055\text{N}$$

- *Accelerating force*

The acceleration force is given as,

$$\text{Accelerating Force(Fa)} = M*a = 1155*1.388 = 1603.14\text{N}$$

The project aims to run on a smooth road with zero gradient so, the gradient force is kept Zero.

- *Total Tractive Force and Power*

$$\text{Tractive Force}(F_t) = F_d+F_{rr}+F_a = 34.39+113.3055+1603.14 = 1750.83\text{N}$$

$$\text{Total Power (P)} = F*v = 1750.83*8.33 = 14584.41\text{watts}$$

- *Total Nominal Power*

$$\text{Force(Fn)} = Fd+Frr = 34.39+113.3055 = 147.69\text{N}$$

$$\text{Nominal Power (Pn)} = F*v = 147.69*8.33 = 1230.3\text{watts}$$

The Maximum power required to drive a vehicle was 14584.41 watts. So, the motor with a peak power of 16kw was selected.

- *Battery Selection*

Battery with 72 volts and 100Ah was selected and the total watt-hour of the battery is given by,

$$\text{Battery capacity (Wh)} = \text{Voltage (V)*Ampere hour (Ah)} = 72*100 = 7200\text{wh}$$

Since, the power of the battery is enough to power the motor, which is higher than nominal power so, this specification was used.

- *Battery Charging time*

The charger used for charging the batteries was the aftermarket charger it charged the batteries at constant 20A and the equation used for the charging time is given by,

$$\text{Charging time (t)} = \text{Ampere hour (Ah)/Ampere (A)} = 100/20 = 5\text{ hours}$$

F. Component Selections

➢ Lead Acid Battery

Battery is the main component that serves as a source of energy to propel the car either forward or reverse direction. The Lead Acid battery was chosen due to its low economic cost and ease of availability in the Local Market. The total number of batteries chosen were six each with 12V and a current rating of 100Ah to power the electric DC motor which accounts for a total of 72V connected in a series connection.

Fig. 4: Lead-Acid Battery

➢ *DC Motor*

The motor is used for driving the wheels through the axle shaft or connected directly through the wheels. But, here axle shaft is used through a transaxle where the motor is coupled to its original gearbox transmission. The Brush DC motor (model-k91-4003) is used in the car which was previously used in SAFA tempo. It is a single-shaft DC motor with 72-144V and 8-22hp. The available maximum torque was 38.5Nm at the speed of 3000RPM.

Fig. 5: Electric DC Motor

➢ *Motor Controller*

The motor controller is used for regulating and maintaining the proper current and voltage to the motor so that it ensures smooth and reliable operation conditions. The controller is selected so that it perfectly matches the motor and the battery. The selected controller is of model Curtis PMC 1209-6401 with the operating voltage and current range of 48-72V and 400A respectively.

Fig. 6: Motor Controller

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➢ *Potentiometer*

The potentiometer is also called throttle which is used for controlling the speed of the motor which eventually controls the velocity of a car. It draws current from the main lead-acid battery which is connected via the motor controller. The below figure shows the throttle used in the car which is a common type of throttle used generally in most of the converted electric cars compatible with the motor and controller.

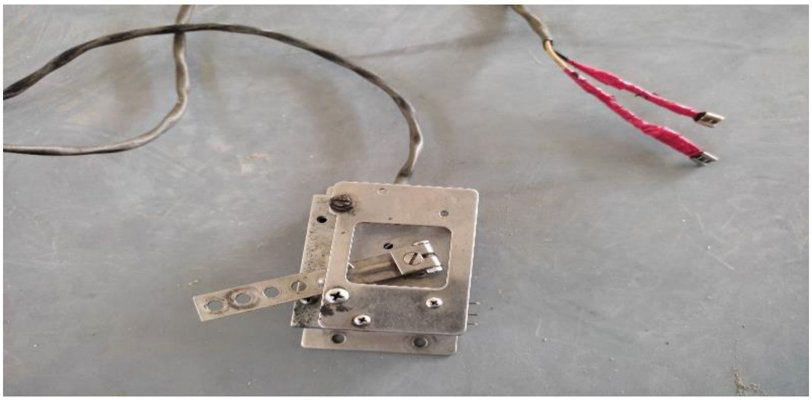

Fig. 7: Potentiometer

➢ *Molded case Circuit Breaker (MCCB)*

MCCB is generally used in the industry for cutting the circuit in case of a high flow of current or short circuit. Because of the high current flowing through the DC lead acid battery, MCCB is connected between the battery and the power controller to stop the overflow of the current. When excessive current is passed from the battery then the MCCB cuts off the current flowing to the system and provides safety.

Fig. 8: Molded Case Circuit Breaker (MCCB) [4]

➢ Forward-Reverse Switch

The forward or reverse switch connects or disconnects the power supply or load, which can make the motor forward or reverse. If we want to make the car go in reverse, we can easily change the direction by pulling the lever of the FR switch.

Fig. 9: Forward-Reverse Switch

➢ *GPS Module*

A GPS module is used in the vehicle which is powered by the auxiliary battery. This GPS module tracks the velocity of the vehicle and the distance traveled by the vehicle.

Fig. 10: GPS Module [5]

G. *Mathematical Modelling*

The simulation of the vehicle model is done in MATLAB Simulink using the Simscape blocks related to the vehicle modeling. The overall vehicle modeling is shown in Figure 10 below. In the designed EV main components are the Battery, Drive Cycle, controller, DC motor, vehicle body, and Transmission system. The drive cycle is the input data like how a human drives the actual vehicle here WLTC drive cycle is introduced to make the designed vehicle give the output and how it reacts to the drive cycle. The main objective of designing the mathematical model is to estimate the state of charge (SoC), distance traveled by the vehicle, and the speed of the vehicle. There is the SoC block that estimates the amount of the battery used, and the velocity of the vehicle and the distance traveled are also recorded in the model [6].

Figure 11 shows the output velocity to the input velocity graph of the vehicle which shows how the vehicle is responding to the Drive Cycle. The blue line represents the velocity from the drive cycle and the yellow line represents the output velocity from the vehicle. WLTC drive cycle is used to perform the simulation with a simulation time of 1776 seconds.

Then in the following figures, when the WLTC cycle is used, the max. speed gain by the vehicle is 35km/hr. which is in line with the velocity profile of the drive cycle. Initially, the simulation was performed with 98% battery, and the state of charge of the battery after 8.49% being used is 89.59%. the distance cover by the vehicle in 1776sec (30min) simulation time nearly equals 6.9km. at a constant speed, the steady current of 83A was drawn.

The State of charge of the lead acid battery and the current withdrawn by the motor concerning time are shown in Figure 12 and Figure 13 respectively. As time goes on, the battery gets drained from its initial condition (98%) and loses its power. The current vs time graph illustrates the fluctuations of current concerning the dynamic demands of the driving scenario.

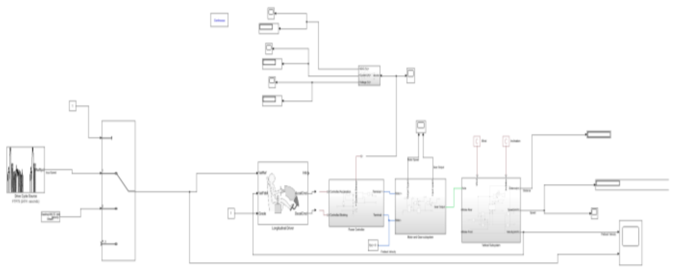

Fig. 11: Simulink model of car

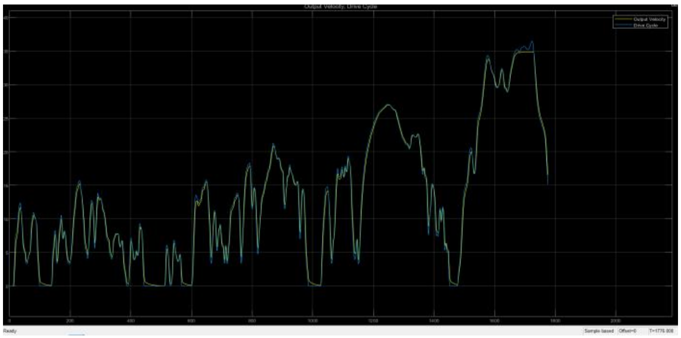

Fig. 12: Output velocity to the input velocity graph

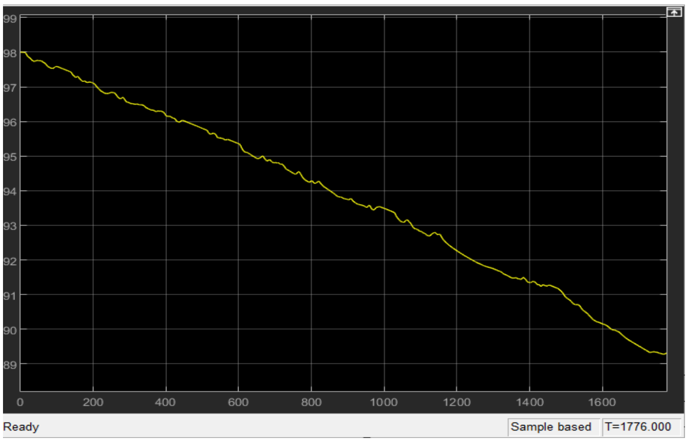

Fig. 13: State of charge vs Time graph

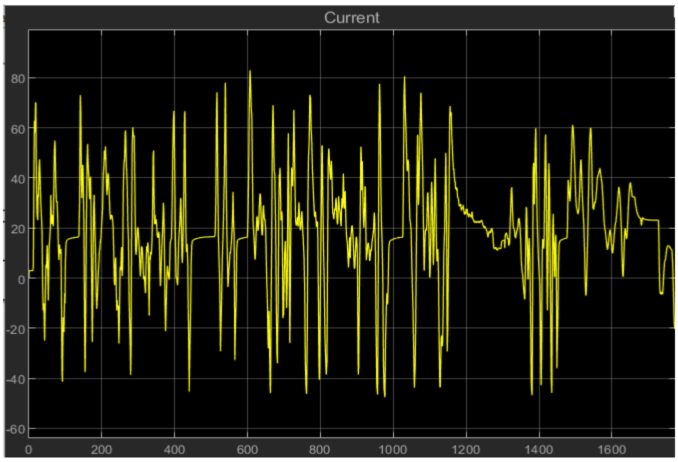

Fig. 14: Current vs Time graph

H. Schematic Layout

After the selection of the car and electric components, the schematic layout is prepared about how the Electric powertrain system is integrated with a vehicle. It was proposed to have all its Lead-Acid batteries in the trunk hood, while the Motor, F-R switch, and controller were placed in the frontal part. Moreover, the transmission gearbox was located where it was before set in a fixed second gear and coupled with the help of a coupler to the motor.

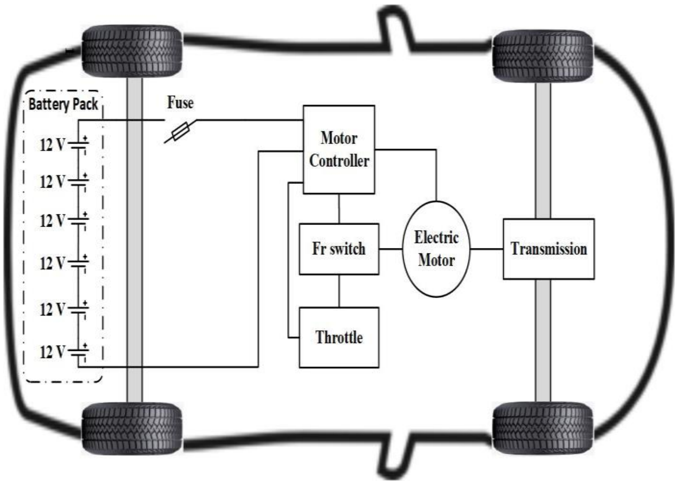

Fig. 15: General layout of an electric system component in a car

I. Assembling of the electric power train

After the Disassembling process, the electric powertrain components such as the motor, battery, controller, potentiometer, auxiliary battery, etc. were installed in the evacuated car. For mounting the motor and controller, a resting platform of mild steel was made by machining and welding, whereas for mounting the battery, the frame bracket was made after its static analysis by keeping the load of the battery in the rear portion.

Fig. 16: Motor and other parts installed under the bonnet

Fig. 17: Battery system installed under the hood

III. RESULT AND DISCUSSIONS

After the fabrication and installation of the Electric Drivetrain, the electric car was tested on zero gradient road. Parameters such as real-time range, maximum velocity, discharge rate, and charging time were observed. The maximum velocity that the car attained was around 45km/hr. But it was driven generally at a constant speed of 30km/hr. The range it has was 35-40km driving on a plain road for a single charge. The initial torque is very high compared with the torque produced after increasing the speed of a car. The car can propel forward and backward smoothly in both directions.

The use of lead acid batteries has increased weight by a significant amount which could be improved by replacing it with Li-ion batteries which would drastically reduce the weight of the car and more range and power of the car will be gained. Also, the C.G. of the vehicle has shifted from its original position to more on the rear side. There is a high probable chance to understeer and the slip in the frontal wheels of a car. Replacing it with smaller batteries would also help with slippage of wheels and prevent understeering.

IV. CONCLUSION

The IC engine car was successfully converted to a battery-electric vehicle with good performance. However, the vehicle performance was greatly influenced by several factors such as battery type and size, motor power, and vehicle type. Due to the bulk size of the lead acid battery, the gross weight of the vehicle was increased and more load was observed at the rear side of the car. The more powerful motor could be used for better performance of the car. Implementing this project has shown the technical feasibility and implementing further, it could be fruitful and beneficial in terms of economics, fuel cost saving, and reuse of similar old vehicles.

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