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# Retrofitting Electric Conversion Kit for Gasoline Vehicles

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***Abstract:***
With an increasing demand of energy-efficient vehicles that can run on renewable energy sources, electric vehicles have gained popularity. But the adoption in Indian market is a challenge due to its high price and lack of infrastructure facility. With more than 10 million vehicles running on the Indian roads alone, converting the existing vehicles into an electric version can be one of the solutions. This study focuses on the development of a method to leverage the number of vehicles to increase the adoption rate of electric vehicles in India at an affordable price range. To design an easy to fit kit which can convert existing car models into an electric car, various components are to be replaced depending on the vehicle parameters and performance requirements. The specifications of all the components used in this conversion depends on the vehicle type thus are needed to be chosen carefully. Reduction in the number of gasoline cars also reduces the pollution rate. It also offers economic benefits to the whole country as it reduces the overall fuel consumption thus reducing the imports.

***Keywords:*** *Battery, EV conversion, Motor, Motor controller.*

## I. INTRODUCTION

Although electric vehicles prove to be an economically and eco-friendly way of transport when compared with the gasoline cars, its high initial cost is the major reason why its adoption is very slow. The fundamental idea is to design an easy to use and install system/kit that can convert a large number (21 lakh passenger vehicles just sold in 2016-17 [1]) of gasoline cars into an electric car, thus reducing the initial high cost of buying an electric vehicle. This option can be viewed as an inexpensive modification that can reduce fuel consumption substantially. This offers an economic benefit to the people as the cost to run an electric car is substantially lesser than that of the regular Petrol/Diesel cars. Pollution rate decreases with reduction in number of gasoline cars. Emissions from electric driving depend most on the fuel type used in the generation of electricity for charging, and range between 0 gCO2/km (using renewables) and 155 gCO2/km (using electricity from an old coal-based plant) [2] compared to 118 gCO2/km for a medium segment car [3].

The cost to install this system is very less when compared to the cost of buying a new electric car, thus increasing the number of electric cars on the road without the addition of new cars. A comparison of various electric cars available in the Indian market is shown in Table- I. Mahindra and Tata are leading players in the electric vehicle segment. The basic components used in an electric car are motors, batteries, motor controllers, cables, etc. Out of these components, the most crucial and expensive components are the motors and the batteries. These components decide the range and performance of the vehicles and are to be selected carefully.

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Table- I: Comparison of available electric vehicles

| Parameters | E2o | E-verito | Tata Tigor Electric | Tata Tiago Electric | E-KUV | Retrofitted kit by e-trio |
|---|---|---|---|---|---|---|
| Price | 6 lakh onwards | 9.5 lakh onwards | 11.5 lakh onwards | 10.5 lakh onwards | 8 lakh onwards | 3.5 lakh kit price |
| Range | 120 km per charge | 110 km per charge | 100 km per charge | 100 km per charge | 120 km per charge | 180 km per charge |
| Charging time | 9 hours | 8 hours | 6 hours | 7 hours | 5 hours | 7 hours |
| Top speed | 90 km/hr | 86 km/hr | 135 km/hr | 135 km/hr | 120 km/hr | 90 km/hr |

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## II. CURRENT SCENARIO IN ELECTRIC VEHICLE INDUSTRY IN INDIA

In recent years, India has taken initiatives towards the promotion of electric vehicles to join the developed nations by increasing the penetration of electric vehicles onto the India roads. Fig. 1 gives us information regarding the distribution of vehicle demographics in India. 79% of all the vehicles on the Indian roads are two-wheelers while small car segments make about 12% of the total [4]. These two categories are major contributors to environmental degradation. Thus require increased adoption rate of electric vehicle in these segments. A Times of India report stated that "According to the transport ministry, nearly 4,00,000 registered electric vehicles run in India with UP at the top with over 1,39,000 registered electric vehicles sold this year" [5].

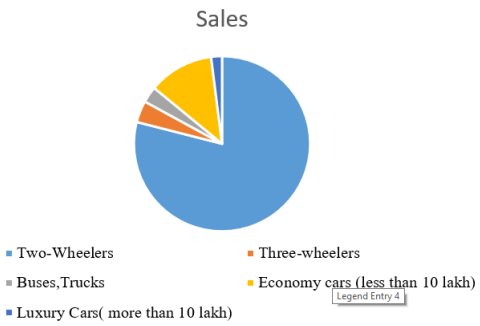


Fig. 1. Vehicle distribution in India [4]

## III. DESIGN FACTORS FOR EV CONVERSION

The design of an Electric Vehicle (EV) conversion kit depends upon the car that is to be converted, parameters like weight, size, performance requirement and overall shape of the car. The electric motor selected for driving a vehicle must have the ability to provide sufficient power and torque to overcome the force due to load and other opposing forces acting on the vehicle [7],[8]. This power has to be provided by the motor thus it is necessary to know all the forces which are shown in fig. 2 where V is vehicle speed and Mv is the total mass of the vehicle. Parameters of Maruti Suzuki Wagon-R 2015 model are shown in Table- II and Table-III gives us the calculations to find the total force acting on it.

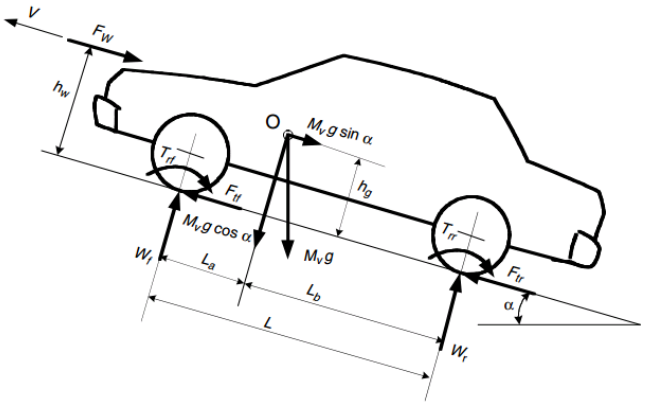


Fig. 1. Forces acting on a vehicle [6]

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Table- II: Parameters of Maruti Suzuki Wagon-R (sample)

| **Length** | **Width** | **Height** | **Total Mass capacity *(M)*** | **Drag coefficient *(C)*** | **Front area *(A)*** | **Velocity *(V)*** | **Rolling coefficient *(Crr)*** | **Gradient angle *(θ)*** | **Air density** |
|---|---|---|---|---|---|---|---|---|---|
| mm | mm | mm | kg | - | $m^2$ | m/s | - | degree | $Kg/m^2$ |
| 3495 | 1495 | 1660 | 1500 | 0.3 | 2.4 | 22.22 | 0.09 | 15 | 1 |

Table- III: Force calculation on Maruti Suzuki Wagon-R

| **Forces** | **Formula** | **On WagonR (N)** |
|---|---|---|
| **Drag** | $D = 0.5\ X\ C\ X\ A\ X\ V^2$ | 177.742 |
| **Rolling Friction** | $F_r = C_{rr}\ X\ M\ X\ g$ | 1324.35 |
| **Gradient Force** | $G = M\ X\ G\ X\ \sin\theta$ | 3808.242 |

The selection of the motor has to be done by considering all these forces. The performance, range and passenger capacity of the vehicle determines various components requirements. It is also important to know the weight distribution of the vehicle to create a balanced system while installing the electric systems. All the components of electric kit are to be assembled in such a way that it does not disturb the aesthetics and dynamics of the vehicle.

## IV. PROCEDURE OF EV CONVERSION

Conversion of vehicles into the electric vehicle can be done in many different ways depending on the vehicle design and performance requirements. The flow chart shown in fig. 3 explains the complete conversion process.

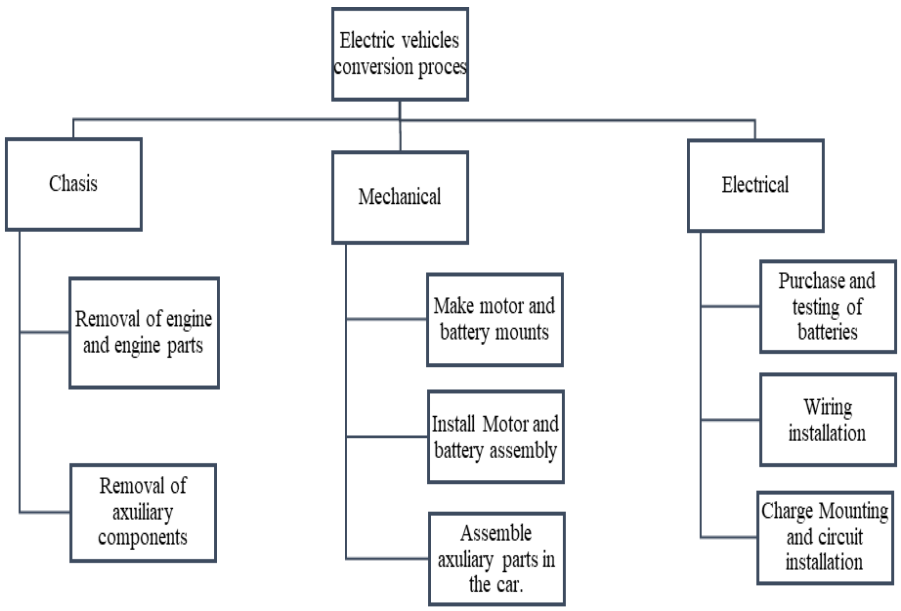


Fig. 2. Conversion Process Flow chart [9, 10]

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## V. COMPONENTS OF EV CONVERSION KIT

Motor, motor controller, batteries and some auxiliary systems are used in the conversion process.

### A. Motor

Motors are the components that drive the vehicles. They are the most important components of an electric car. Motor is more efficient than an internal combustion engine due to minimum moving parts thus requires very less maintenance. Electric motors used in the electric vehicle should have important attributes like simple design, high specific power, low maintenance cost, and good control [11]. Table IV shows a comparison between two majorly used motor types.

Table- IV: Comparison between DC series and BLDC motor [12]

| Parameters | DC series Motor | BLDC Motor |
|---|---|---|
| Power to weight ratio rating (1-5) | 2.5 | 4.5 |
| Peak efficiency | 85-90 % | >95% |
| Cost of Motor for 10kw (approx.) | Rs 40,000 – Rs 50,000 | Rs 60,000 – Rs 70,000 |

The specification of the motor to be selected depends upon the vehicles to be converted and the performance required. For the conversion of a small hatchback, a 72V DC series motor can work sufficiently well and can provide a decent performance apt for a city commute [11].

### B. Motor Controller

The motor controller controls the flow of power from the battery to the motor using a microprocessor and various feedback systems that monitor the operation of the system [9]. The controller to be chosen has to have high performance, highly reliable and economically feasible and thus a solid-state motor controller is used. The motor controller varies the amount of current and voltage supplied to the motor which controls the speed of the motor, this is the reason that the throttle response in case of electric vehicles is better than an IC engine.

Currently PWM (Pulse Width Modulation) D.C motor controllers are used as they are easily available in the market and easier to install and also affordable for EV conversion. The controller to be selected should be of enough capacity to withstand the current load on it. Thus a 72V Curtis controller which is based on MOSFET technology is preferred for this application as they are easy to install and has the capacity to withstand large current inputs [13,14]. The average cost of a 72V DC motor controller with armature current of 275-500 A is about Rs 30,000 [13].

### C. Batteries

Electric batteries are the power sources in any electric car and determine the range of the electric vehicle. Compact, lightweight and efficient batteries are preferred while designing any electric vehicle. The main parameters that determine the power output of the battery are shown in Table -V [9]. As cost is an important aspect to be considered for the conversion of the vehicle, the choice of the battery that is to be used has to be chosen carefully. Being one of the expensive parts it is important to choose the battery with longer life. The life length of a battery is dependent on several complex and interacting mechanisms relating to cell chemistry combined with storage and charging and discharging conditions such as temperature, cycle depth, and different forms of chemical degradation [15].

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Table- V: Specifications for battery selection [9]

| Battery Type | Nominal Cell Voltage (volts) | Operating Temp Range (°C) | Life Cycle | Theoretical Spec Energy (wh/lb) | 3Hr Rate Spec Energy (wh/lb) | Energy Density (kwh/cu ft) | Specific Power30 sec pulse (watts/lb) | Power Density 30 sec pulse (kw/ cu ft) |
|---|---|---|---|---|---|---|---|---|
| Lead Acid | 2.1 | 35-70 | 600 | 79.5 | 15.9 | 2.55 | 72.7 | 8.50 |
| Nickel Cadmium | 1.25 | 30-50 | 2000 | 99.1 | 25.0 | 3.40 | 86.4 | 9.35 |
| Nickel Metal Hydride | 1.4 | 20-60 | 600 | 84.1 | 29.5 | 4.96 | 68.2 | 11.33 |
| Nickel Zinc | 1.6 | 40-65 | 250 | 155.0 | 27.3 | 2.83 | 59.1 | 2.83 |
| Nickel Iron | 1.25 | 40-80 | 800 | 121.4 | 22.7 | 3.40 | 52.3 | 6.51 |
| Sodium Sulfur | 2.08 | 300-400 | 350 | 345.5 | 38.6 | 3.26 | 54.5 | 5.10 |
| Sodium Nickel Chloride | 2.59 | 250-350 | 1000 | 360.0 | 59.1 | 4.81 | 76.3 | 6.37 |
| Zinc Bromine | 1.8 | 0-45 | 500 | 194.5 | 31.8 | 1.98 | 38.6 | 3.26 |
| Zinc Air | 1.62 | 25-65 | 70 | 595.5 | 59.1 | 1.84 | 22.7 | 1.84 |
| Lithium Iron Disulfide | 1.66 | 400-450 | 500 | 295.5 | 75.0 | 6.80 | 107.5 | 1.56 |
| Lithium Polymer | 3.5 | 0-100 | 300 | 248.2 | 72.7 | 7.36 | 90.9 | 5.95 |

Another parameter that is important for the choice of electric vehicles is the number of batteries to be used. The number depends on the battery pack capacity required keeping in mind the space availability and allowable weight that can be added to the vehicle. All these parameters are to be taken into consideration while developing the battery pack. Table- VI compares different types of batteries available in the market currently to create a battery pack of 72V.

Table- V: Battery cost comparison [16]

| Parameters | Lead-Acid Battery | Li-Ion Battery |
|---|---|---|
| **Voltage** | 12 | 3.7V |
| **Ampere-Hour** | 100 | 2.5Ah |
| **Price per piece (approx.)** | Rs 8000 | Rs 100 |
| **Number of cells required (approx.)** | 12 | 1500 cells |
| **Total Cost of battery pack (approx.)** | Rs 96,000 | Rs 1,50,000 |
| **Battery pack capacity** | 14.4 kwh | 13.5 kwh |

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Due to lighter weight, compact size and higher energy density and efficiency, Li-ion batteries are better for the EV application but they tend to be very expensive. With time, the cost of Li-Ion batteries will decrease and could find its application for EV conversion. Lead-acid batteries are not the ideal batteries for EV conversion as they are very bulky and require a large space but could be considered due affordable price range. The removal of the engine and other components compensates the weight of the batteries.

### D. Auxiliary Systems

Many other auxiliary systems are required to be installed into the vehicle to make it commercially useful. These systems may already be present in the gasoline car but may need some modification to work with the new system. An extra battery needs to be added to operate other electrical subsystems like air-conditioning, head and tail lamps, radio systems [17]. An extra pump is required to run the power steering system which was previously operated by the engine. Appropriate cooling is to be provided to the battery compartment to avoid overheating of the battery and the motor. These systems increase the efficiency of the kit and improve the performance and comfort of the vehicle.

## VI. CONCLUSION

The above methodology can be implemented to convert any vehicle into an electric vehicle. Depending on the vehicle to be converted, the components may change but the basic pattern remains the same. Conversion of vehicles into an electric version can prove to be a way that may improve the environmental condition of the nation. This affordable option can increase the adoption rate of the electric vehicle thus reducing the dependence on fossil fuels. Such a conversion kit can make it easy for middle-class people to adopt an electric car without increasing their expenses or compromising on the performance of the vehicle. But to implement electric vehicles in India, some infrastructure like electric charging station network is still required. With an increase in electric vehicles, the electricity consumption would also increase thus it is required to develop technology to harness renewable energy and generate electricity in ways that are environmentally friendly and economically feasible. The kit too would need to be upgraded to improve the technology to improve the performance parameters of the vehicle. Thus converting existing vehicles into an electric version can prove to be a great option for the future of transportation in India.

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