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TRANSITION OF ICEV TO EV: PROCESS AND EFFICIENCY

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Abstract— In this paper, we suggest a system for effectively transforming the Internal Combustion Engine Vehicle (ICEV) into a Battery Electric Vehicle (BEV), also referred to as retrofitting, while also estimating the total cost of ownership of the BEV in India over a period of time and also its effect on the consumer, as well as the environmental advantages and economic benefits of the BEV over the ICEV.

Keywords— Electric Vehicle, Combustion Engine, Traction battery, TCO, transformation

I. INTRODUCTION

Four technology-driven developments – electrification, shared mobility, connectivity, and autonomous driving – are contributing to this revolution of the automotive industry. Such developments will transform markets and revenue streams, alter connectivity habits and create new opportunities for competitiveness and cooperation. There are a few types of EV technology, the most common being plug-in electric hybrid vehicles (PHEVs), electric range extender vehicles (REEVs), and electric battery vehicles (BEVs). The battery-electric vehicles (BEVs) need new generations of powerful batteries, electric motors and inverters; and they no longer need any of the key technology of conventional cars, such as internal combustion engines and gearboxes. New methods of thermal-management systems need to be created, because there is no longer a heat generating combustion process that can be used for heating or cooling.

Mechanically, EVs are much simpler machines than internal combustion engines vehicles (ICEV), meaning that the cost of service & maintenance is roughly half that of a petrol car. Within time, EVs retain more of their value. In this paper, we propose a method for efficiently turning an ICE vehicle into an electrical one, while also noting the overall cost of ownership in India over the life of the car and the effects it has on the consumer as opposed to the ICEV.

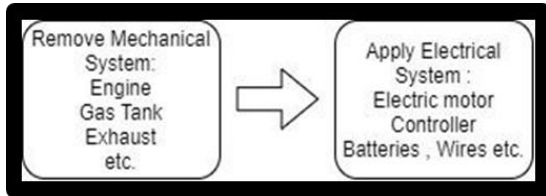
II. HISTORICAL DEVELOPMENT

The electric car is becoming more popular day by day because the prices are dropping constantly and people don't have to waste cash and effort at the gas station. The concept is if we can turn the current combustion cars on the roads into an electric one it would benefit all of us because it would save both the money and the resources/infrastructure required for the fuel. William Morrison invented the first electric car in the U.S. around 1890. Around the turn of the 19th century, electric cars started to become much more common as they were silent, simple to drive, and had many other advantages. Thomas Edison also placed his support behind early electric vehicles, believing in their superiority over other alternatives, and worked to improve better-performing batteries. Henry Ford (who happened to be Edison's close friend) worked with him around 1914 to discuss possibilities for low-cost electric vehicles. However by the 1960s, demand and sales of electric cars declined due to increased combustion or gasoline-powered cars. Yet electric vehicles began to gain popularity as a result of the Oil Crisis of the 1970s. In 2000, Toyota launched the first hybrid vehicle. The whole transition occurred when the silicon valley company Tesla Motors, founded by Elon Musk, started producing electric cars that are fast and useful to all of us. Since 2010, EV's battery costs have dropped significantly and numerous other major car brands are starting to produce their own long-range, highway-enabled vehicles, such as Nissan (Leaf), BMW, VW, etc.

Most governments around the world enact legislation to encourage and promote EVs and phase out combustion engines in the next few decades.

III. SYSTEM DESIGN

The first step in converting a conventional vehicle into an electric car is to strip it of all ICE-related hardware, including the engine, fuel tank, muffler, exhaust, starter, and radiator. The clutch assembly was removed but the existing manual transmission was left in place, although the clutch is no longer needed.



A. Battery –

An electric-vehicle battery (EVB) are rechargeable batteries used to power the electric motors of a battery electric vehicle (BEV) or hybrid electric vehicle (HEV). These batteries are specifically designed for a high ampere-hour (or kilowatt-hour) capacity.

Batteries for BEV are selected based on their relatively high power to weight ratio, energy density. Smaller and lighter batteries are preferred because they reduce their contribution in the overall load, thereby leading it to improve the performance of the BEV. The most common types used nowadays are the lithium-ion and lithium polymer because of their high energy density compared to their weight. Lithium-ion batteries were initially developed and commercialized for use in laptops and consumer electronics. With their high energy density and long cycle life they have become the leading battery type for use in EVs. The amount of electric charge stored in batteries is measured in ampere hours or in coulombs, with the total energy often measured in kilowatt-hours.

As a secondary storage device to power up the BEV during acceleration, hill climbing and to recover the braking energy Ultracapacitors are used. They store energy in a polarized liquid between an electrode and an electrolyte. Energy storage capacity increases as the liquid's surface area increases. They basically help electrochemical batteries level load power.



Fig. 1. Electric Vehicle Battery

B. Electric Power Controller –The controller is like the brain of a vehicle, its main function is to act as a regulator of electrical energy from batteries and inverters that will be distributed to electric motors. It manages the flow of electrical

energy delivered by the traction battery, controlling the speed of the electric traction motor and the torque it produces.

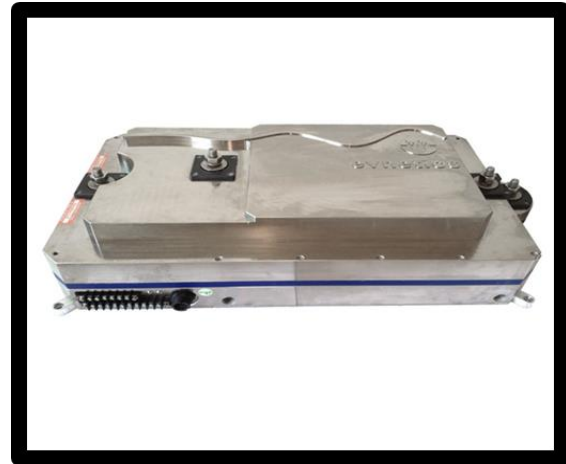


Fig. 2. Electric Power Controller

The controller takes power from the batteries and delivers it to the motor according to the pressure applied on the accelerator pedal. The pedal is hooked to a potentiometer that provides the controller with the signal that indicates the amount of power to be delivered, which basically affects the speed of the car. The controller can deliver zero power when the car is stopped, full power when the accelerator pedal is pushed all the way down, or any amount between.

C. Electric Motor–

An electric motor is an electrical machine that converts electrical energy into mechanical energy. Most electric motors operate through the interaction between the motor's magnetic field and electric current in a wire winding to generate force in the form of torque applied on the motor's shaft. Electric motors can be powered by direct current (DC) sources, such as from batteries, motor vehicles or rectifiers, or by alternating current (AC) sources, such as a power grid, inverters or electrical generators.

Today's automakers use three different types of electric motors in green cars: the BLDC motor, brushed DC motor, and AC induction motor. The BLDC motor has a permanent-magnet rotor surrounded by a wound stator. In an induction motor a 3phase current produces a rotating magnetic field. This results in inducing current on the rotor bars to make it turn. Here the rotor speed always lies behind the RMF speed. The great thing about the induction motor is that its speed depends upon the frequency of the AC power supply so just by varying the frequency of the power supply we will be able to alter the drive wheel speed. Thus control of the car is easy.

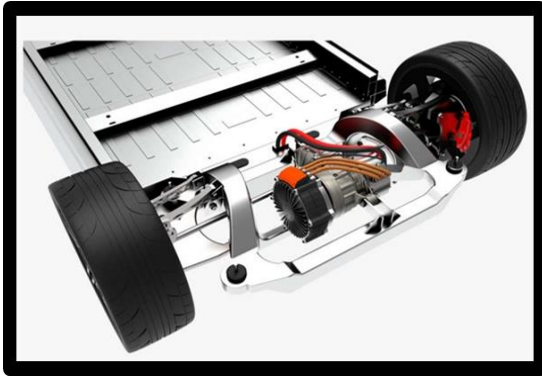


Fig. 3. Electric Motor

Induction motors can work efficiently in any speed range thus no speed varying transmission required in the electric motor.

D. Inverter–

An inverter is a device that converts DC power from the battery into the AC power required by an electric vehicle motor. The inverter can change the speed at which the motor rotates by adjusting the frequency of the alternating current. It can also increase or decrease the power or torque of the motor by adjusting the amplitude of the signal. In addition to this, the inverter on an electric car also has a function to change the AC current when regenerative braking to DC current and then used to recharge the battery. The type of inverter used in some electric car models is called the bi-directional inverter category.



Fig. 4. Inverter

E. Battery Charger–The battery charger converts the AC power available on our electricity network to DC power stored in a battery. It controls the voltage level of the battery cells by adjusting the rate of charge. It will also monitor the cell temperatures and control the charge to help keep the battery healthy.



Fig. 5. Electric Charging Setup

A charging cable for standard charging is supplied with and stored in the vehicle. It's used for charging at home or at standard public charge points. A fast charge point will have its own cable.

There are 2 types of electric car chargers:

On-board charger: the charger is located and installed in the car.

Off-board charger: the charger is not located or not installed in the car.

E. Other Components–

DC/DC Converter (G): This is one of the electric car part that converts higher-voltage DC power from the traction battery pack to the lower-voltage DC power needed to run the vehicle accessories and recharge the auxiliary battery. It is quite important as some accessories may get damaged by using the high-voltage power.

Thermal System – Cooling: This system maintains a proper operating temperature range of the engine, electric motor, power electronics, and other components. There are basically 3 common battery thermal management methods used today i.e Convection to air either passively or forced. Cooling by flooding the battery with a dielectric oil which is then pumped out to a heat exchanger system.

IV. WORKING OF AN ELECTRIC CAR

The power house of any electric car is its auxiliary battery which serves as a “fuel tank”. The power to the induction motor is provided by the battery pack itself, which consists of lithium ion batteries in tubes packed within the vehicle.

When you push on the gas pedal, the signal is transferred to the controller by a cable from the pedal which is connected to two potentiometers. This signal tells the controller how much power to deliver to the electric car's motor. Generally, there are two potentiometers for safety's sake. The controller reads both potentiometers and makes sure that their signals are equal. The controller does not operate until both the signals are equal. This arrangement is installed to guard against a situation where a potentiometer fails in the full-on position. The controller reads the setting of the accelerator pedal from the potentiometers and regulates the power accordingly. This



gives the car acceleration. The controller is placed in between to control and regulate the supply of electricity given to the various functions in the car such as motor, air conditioning and all other equipment. This battery also powers all of the electronic devices in the car, just like the battery in a gas-powered car does.

AC motors and controllers often have a regenerative feature. During braking, the motor turns into a generator and delivers power back to the batteries. Since electric vehicles use an electric motor, the driver can take advantage of the motor's momentum when pressure is applied on the brakes. An electric car uses the forward momentum of the motor to recharge the battery, unlike fuel-powered cars which convert all the potential energy in the motor into heat. This process is called regenerative braking.

The shifter for the manual transmission was replaced with a switch, disguised as an automatic transmission shifter, to control forward mode and reverse mode.

Also an inverter is placed to convert the DC voltage of the battery into 3 phase AC supply to the induction motor.

I. OWNERSHIP COST Analysis

The following part presents the comparison of the operating prices of electric cars to those that operate on fuel. The cost of driving an BEV can be contrasted directly with the comparable operating costs of a ICEV.

The Internal combustion engines (ICE) are very inefficient as a consequence of laws of thermodynamics. The ICE produces mechanical work by burning the fuel. During the combustion process, the fuel is oxidised and it releases heat which is in turn transferred partly into the mechanical energy. A great deal of energy produced by ICE is wasted.

1 litre of petrol/gasoline contains approximately 8.9kWh of energy. The ICEs have mostly an efficiency of around 20%, though the diesel engines have an efficiency of 38%-40%. Some have even figured out how to get it around 50%.

Operating Costs-

Calculation based on the assumption that both the BEV & ICEV travel 50kms a day for 24 days in a month.

ICEV:-

Considering a car with an ICE having an efficiency of 20% and the average mileage of 5L/110km (i.e. 15kmpL). So to just move the car, the energy required would be:-

$$\Rightarrow \left\{ (8.92 \text{ kWh}) \times \frac{10 \text{ L}}{150 \text{ km}} \right\} \times (20\% \text{ eff}) \cong \frac{17.8 \text{ kWh}}{150 \text{ km}}$$

At a cost of ₹87/ L of gasoline, mileage of 15kmpL costs: \Rightarrow

$$\left(\frac{₹ 87}{1 \text{ L}} \times \frac{10 \text{ L}}{150 \text{ km}} \right) \cong \frac{₹ 870}{150 \text{ km}}$$

Therefore, average consumption of gasoline per day = 3.33 L (for 50km)

\Rightarrow Cost of operating **per day** = ₹ 87 x 3.33 L = ₹ 289.7

Calculating the cost for **24 days** (1200km) = ₹ 289.7 x 24days

$$= ₹ 6953 \cong ₹ 7000$$

$$\therefore \text{Cost for 1 year (14,400km)} = ₹ 289.7 \times 24 \text{ days} \times 12 \cong ₹ 7000 \times 12 = ₹ 84,000$$

$$\therefore \text{cost for 8 years (1,15,200km)} = ₹ 289.7 \times 24 \text{ days} \times 12 \text{ months} \times 8 \text{ years} \cong ₹ 84,000 \times 8 = ₹ 6,72,000$$

BEV:-

Considering the electric version of the same car having an charge/discharge efficiency of 81%. The energy required to move this version would be:-

$$\Rightarrow \left(\frac{17.8 \text{ kWh}}{150 \text{ km}} \right) / 80\% \text{ eff} \cong \frac{21.9 \text{ kWh}}{150 \text{ km}}$$

At a cost of electricity at Rs 4.67 / kWh, driving for 150km would cost:

$$\Rightarrow \frac{₹ 21.9}{150 \text{ km}} \times ₹ 4.67 \approx \frac{₹ 102.6}{150 \text{ km}}$$

Therefore, average consumption of electricity per day = 7.3 kWh (for 50km)

\Rightarrow Cost of operating **per day** = ₹ 4.67 x 7.3 kWh = ₹ 34

Calculating the cost for **24 days** (1200km) = ₹ 34 x 24 days = ₹ 816 \cong ₹ 820

\therefore Cost for **1 year** (14,400km) = ₹ 34 x 24 days x 12months \cong ₹ 820 x 12months = ₹ 9840

\therefore Operating cost for **8 years** (1,15,200km) = ₹ 34 x 24 days x 12months x 8 years \cong ₹ 9840 x 8 = ₹ 78,720

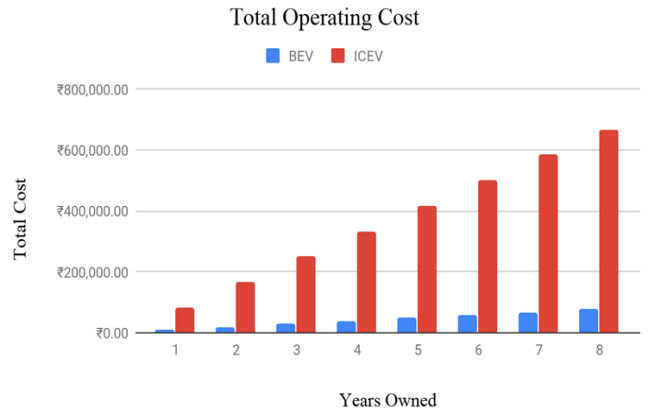


Fig. 6. Graph of Operating Cost comparison of BEV & ICEV

Maintenance Charges-

Mid Sized ICEV:-

Considering only the miscellaneous charges as maintenance charges of the ICEVs in the first 2 years as the servicing is provided by the manufactures, which then increases gradually annually.

The maintenance charges included are:-

Serviceing charges per year = ₹ 10,000/yr

Battery change (every 2 years)= ₹ 5000

Other Miscellaneous Charges= ₹ 3000/yr

Total maintenance cost = ₹ 15,500/year

BEV:-

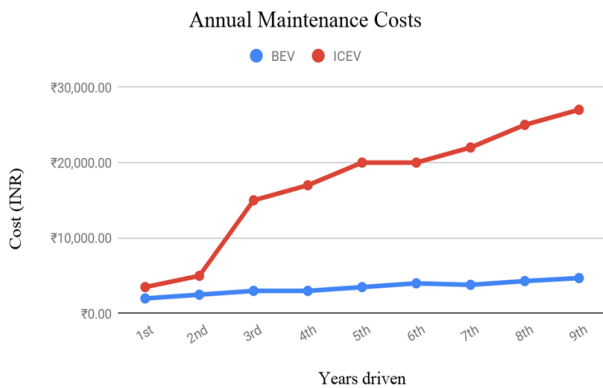


The maintenance charges of the BEV are negligible as compared to the ICEV as no parts require regular oiling or replacement and therefore are difficult to quantify. But some studies suggest that the maintenance charges of EVs can be up to 70% less than a regular ICEV.

Since BEVs have less moving components, they face less temperature stress and do not need oil and filter replacements. Also, due to the possibility to recuperate energy whilst braking, the braking pads will last longer. For PHEVs and BEVs, the replacement cost of the traction battery is one of the biggest concerns of EV shoppers. Some analysts have made assumptions that the traction battery may not need replacement during the useful life of the vehicle while others assume the manufacturer's warranty of 100,00 miles sufficiently characterizes the expected battery lifetime because for an average driver 100,000 miles is approximately equates to around 12 years.

The maintenance services included are brake fluid test, balancing, cabin air filtering, wheel balancing and thermal cooling check ups. Major maintenance charges include tyre replacement and battery replacement (if necessary) which

| kms | TCO BEV | TCO ICEV |
|----------|--|---------------|
| 1st year | ₹1,084,325.00 | ₹774,785.00 |
| 2nd year | ₹21,844.00 | ₹171,872.00 |
| 3rd year | ₹32,016.00 | ₹265,308.00 |
| 4th year | ₹41,688.00 | ₹350,744.00 |
| 5th year | ₹51,860.00 | ₹437,180.00 |
| 6th year | ₹62,032.00 | ₹520,616.00 |
| 7th year | ₹71,504.00 | ₹606,052.00 |
| 8th year | ₹81,676.00 | ₹692,488.00 |
| Total | ₹14.46 lakhs | ₹38.19 lakhs |
| | Cost of EV vehicle | ₹10,72,653.00 |
| | Cost of Combustion Version of same vehicle | ₹6,87,849.00 |



have been excluded from the computations.

Fig. 7. Graph of Annual Maintenance Costs In BEV and ICEV

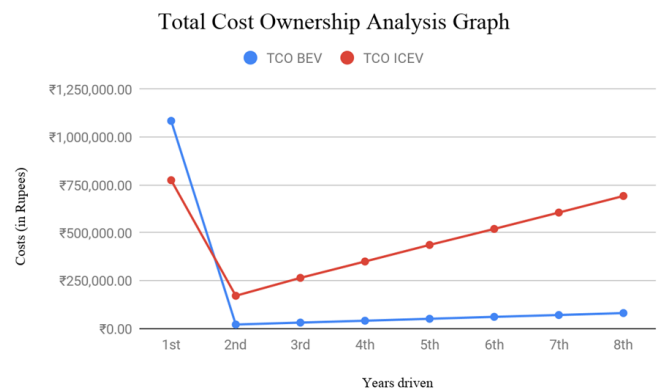
According to the chart above, initial maintenance charges are very low as the servicing of ICEVs as well as BEVs are done by the manufacturers. The cost shoots up for ICEVs continuously every year.

Total Cost Ownership

The total cost of ownership is the purchase price of the asset plus the operating cost and the maintenance charges incurred over the span of years favourably over the lifespan of the asset.

The table below has the sum of annual operating charges and the annual maintenance charges with the cost price of the asset being added to the 1st year.

The line graph below shows the Total Cost Ownership of owning an BEV over ICEV. So it can be clearly seen that the initial cost of acquiring an ICEV is way less than that of EV, but over time the ICEVs tend to be over cross their initial cost due to expensive operating and maintenance costs. Whereas, BEVs are highly expensive to buy but tend to give value for money as its operating and maintenance charges are not that costly. Over its whole life the total costs of BEVs do not cross



its initial cost.

Fig. 8. Total cost ownership analysis graph Of BEV and ICEV

V. IMPACTS OF USING EVs OVER ICEVs

From an economic perspective, BEVs enjoy some distinct advantages. Firstly the electricity cost associated with operating an EV over a specific distance is significantly lower



than gasoline cost to operate a comparable ICEV for the same distance. Second, as calculated above BEVs cost less to maintain, owing to simplicity of the battery-electric motor system and a lot less moving parts as compared to regular maintenance requirements of operating an ICE.

The initial investment for BEVs is very high relative to other cars due to the high cost of the battery packs, but the automobile battery technology has advanced quickly since the new generation of BEVs came into the market, with the price per kilowatt-hour (kWh) of lithium-ion battery packs falling from \$700 in 2010 to just \$156 in 2018, which is further expected to fall to \$100/kWh). For the 2020 Mid-Size Passenger Sedan, the overall expense of owning the BEV is 14.46 lakh relative to 38.19 lakh for the ICEV — a 62% expense benefit over the ICEV, without any government subsidies or incentives. The cost differential between BEVs and ICEVs will narrow for new vehicles by 2025. If BEVs are to truly become a success in India, it will be crucial for manufacturers to reduce the initial heavy cost burden a BEV poses for the average consumer. Ultimately, the high underlying cost of BEVs and the shortage of charging points is a limiting factor in their future market penetration of BEVs in the automotive market. One can further minimize harmful air pollution caused by exhaust emissions by choosing to drive an EV. An EV has zero exhaust emissions. If the recharging of EV can be achieved by using renewable energies, greenhouse gas emissions can be reduced much more. For instance, recharging the EV from the solar photovoltaic system during the day rather than from the grid or buying Green Power from one's electricity retailer. Then, even though the EV is recharged from the grid, greenhouse gas emissions will be reduced.

Some other advantages of choosing EVs over ICEVs are that reduced toxic exhaust emissions is beneficial for the Air Quality Index of the driving area. Better air quality will lead to fewer health problems which in turn reduces the healthcare costs significantly. Engines are also cleaner than petrol / diesel engines, which ensures less noise pollution. Recent studies have shown that a variety of EV features can improve safety, for instance, the EVs tend to have a lower centre of gravity that makes them less likely to turn over. These can also have a smaller chance of large fires or accidents, and the structure and reliability of EVs can make them safer in a crash.

VI. CONCLUSION

Cars powered by internal combustion engines have been the technical approach that dominated the car industry and influenced the way transport systems have become internationally structured. This paper presents the conversion methods of a traditional Internal Combustion Engine vehicle into an Electric Vehicle. It also lists the main constitutive elements that were removed from ICEV and integrated into the BEV. The paper also mentions the total cost of ownership and benefits of owning a BEV over a period of time, even though BEVs have few disadvantages regarding its cost and

ease of charging points, the BEV technology will improve such that TCO will decline and driving range will improve. These improvements will benefit the consumer and increase the Global Warming Potential (GWP) differential relative to ICEVs.

However, despite the increasing need to decarbonize the global economy, alternative drivetrain solutions are now gaining strategic advantages, and businesses need to change. Hybrid and fully-electric powertrains draw substantial investment, and so do new mobility technologies and facilities on the transport and energy grid interfaces.

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