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Conversion of IC Engine Driven Bike into Electric Engine Driven Bike

V.Thiyagarajan, V.Sekar

Abstract—India has large two wheelers for personal and private transportation and these two-wheeled vehicles are driven by IC engine. Around 1.3 million vehicles are sold per month. Out of these, 600,000 are motorbikes, 400,000 are scooters, 200,000 are mopeds and 150,000 are 3-wheelers. This gives a total of around 16 million 2 and 3 wheelers sold per year in India. Many of our cities and towns suffer from severe air pollution caused partly by the large number of 2 and 3 wheelers with inefficient and polluting engines. Also few millions of vehicles are scraped every year due to the condemned IC engines which goes for least price value. Rather, if we have a technology to recycle those vehicles for next 10 to 15 years that would enable the users to reuse their vehicles and decrease the massive manufacturing process and import/export of brand new vehicles produces a far greater impact, or carbon footprint, than running an older vehicle for many years. The technology is the conversion process of an internal combustion engine to an electric vehicle powered by batteries comprises many steps from choosing the vehicle, sizing a motor, and the type of batteries. By using an existing vehicle with this conversion technology, you are not only extending the life cycle of that unit, but saving the huge energy input of recycling, new parts production and new manufacturing. This paper takes an old, condemned motor bike of model 1997 and converts into an all-electric engine driven vehicle with a DC motor and lead acid batteries and explains the process of conversion.

Keywords—EV Conversion, Peukert's Effect, Conversion Process, Vehicle Mechanics, Transmission Stages

I. INTRODUCTION

Today there are limited production of electric vehicles (EVs) are available, so converting an existing internal combustion engine (ICE) vehicle to an electric vehicle (EV) might be the best choice available to obtain an EV. A typical EV conversion will achieve a range of 30-60 miles for each charge. Studies have shown that 80% of commuters travel less than 40 miles per day, and 50% of commuters travel 20 miles (or less) per day. An EV conversion can meet those daily driving needs. EVs are a clean, efficient alternative to conventional vehicles. EVs produce zero emissions, are up to 99% cleaner than petrol and diesel vehicles. EV owners enjoy the financial benefits of significantly lower fuel and maintenance expenses. Finally, EVs help reduce our dependence on oil. Use your existing vehicle as the basis of an environmentally friendly and economically viable EV. By removing the IC engine from your existing vehicle you take out the part that has the greatest impact on the environment and your pocket. Not only you are not burning petrol, you have also eliminated the greatest proportion of your servicing costs. EVs don't use oil, don't require periodic tuning and adjustment and having only one moving part, are not prone to damage as are internal combustion engines. An electric drive converted vehicle is a viable and realistic response to commuters in the economy of middle and lower class. Depending on battery choice, electric motor and the donor vehicle you can have a vehicle with sufficient energy per charge to cover anything from daily urban commuting to inter-urban trips. After an EV conversion you are no longer enslaved to the constant upward prices and declining quality of fuel. You need nothing more than a domestic power point to recharge or top up your EV. Indian two wheelers have an average daily commute of less than 40–50 kms. Much of the daily commuters are spent idle, burning fuel yet going nowhere. An EV when stationary is not drawing current draws power when it is required. In addition you are reducing your greenhouse gases too.

A. Steps Involved In Conversion Process

This overview provides a high level framework for performing a conversion.

- Planning the conversion process and driving needs
- Choose the vehicle and study technical factors
- Decide and Look for an EV COMPONENTS for the vehicle you choose
- Remove the IC Engine and its related components, making room for the EV components
- Install the motor, components, Controller, batteries and wiring to be accomplished.
- Testing: Test the battery charger; check the wiring and fuses, connections.

Then take it out for a spin and notice the quiet, smooth ride on the road

Planning the conversion process and driving needs

- The first step in the conversion process *is determining* what kind of bike to convert. Converting an IC engine driven bike in to an electric driven bike can be a rewarding and challenging experience.

For this project a 1986 Model Bajaj – Kawasaki 100 served as the donor bike. The average conversion EV has a realistic range of 50–60 kms range in everyday driving conditions depending on the type of batteries you have and the weight of the vehicle. One or two persons can be travelled. The performance will be almost as equal as the bike when it was with IC engine driven. Have the facilities and necessary tools for conversion.

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The converted vehicle will meet the following performance specifications, such that it is desirable for the largest number of customers. The success metrics almost certainly is 200 kg pay load, 45kmph in speed, 60kms average riding range, around 5hours of charging and so on….

Choose the vehicle and study technical factors

The basic idea of what need to do a conversion, the next step is choosing a body style and chassis. For a family commuter with a range of 50 Kms or more consider a light compact used bike that has enough space to accommodate one or two persons. Choose a bike without rust.

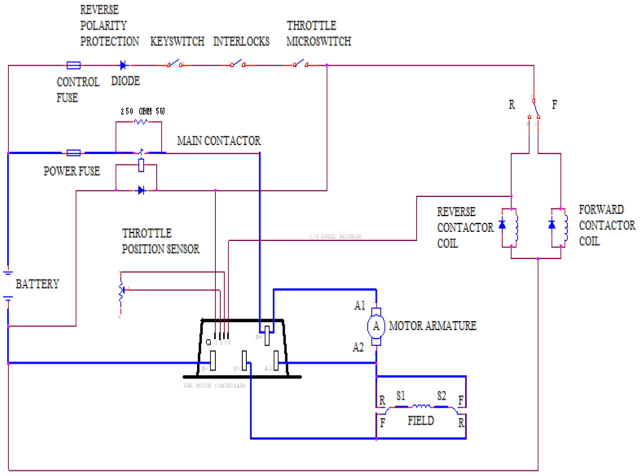

Fig. 1 Wiring block diagram of converted EV – 12v system

Fig 1 shows the complete wiring cum block diagram of the vehicle's electrical system which is converted in to electrically driven. It has interlocking mechanism like the motor stops whenever the mechanical brake applied to the rear wheel.

Decide and Look for an EV COMPONENTS for the vehicle you choose

An advanced brushed DC series-wound motor for driving the bike. 12-volt lead acid batteries are used in this application because they have more energy density which is necessary for range. Deep cycle batteries can also be used since; it has high power long life large format high specific energy traction batteries such as LiFePO4. The DC motor controller regulates current going to the motor. It is a solid-state device that uses a pulse width modulator (PWM) that sends short bursts of current to the motor at a rate of 15 kHz. Potentiometer around the capacity of 5K ohm throttle between the controller and the accelerator, similar to the way a sewing machine pedal works. The pot box's lever arm is attached to the existing accelerator cable. An electric DC operated relay (main contactor) that serves the same purpose as the ignition switch in a gas car. When the key is turned to the start position, the contactor closes the circuit to allow current to flow to the controller. A circuit breaker is to be incorporated as a safety device that shuts down power for servicing or during an emergency. The circuit breaker is installed under the covering and can be switched both off and on from the driver's left or right handle bars with an extension or cable. The main fuse protects the system from high voltage spikes. A fuse should be installed at each battery box or group of batteries. A shunt is placed in series within the wiring as a means to connect meters. Shunts are available in different sizes for both high and low power configurations. A charger interlock relay that keeps the circuit open so nobody will inadvertently drive off with the charge cord plugged into the car. The DC/DC converter is similar in function to a gas car's alternator. It charges the 12 volt accessory battery by chopping voltage from the main battery pack down to 13.5 volts. Make sure you have access to the proper tools and supplies, and a place to do the conversion.

Remove the IC Engine and its related components, making room for the EV components

Dismantling IC Engine and its Components like Petrol tank, tail pipe to be removed carefully. Care must be taken to mark electrical connections. Nuts and bolts to ensure that parts which will be reused can be properly identified and placed. Switches, lighting accessories and horns not to be dismantled and they can be enabled by an auxiliary battery. Lightings may be replaced by bright LED lights.

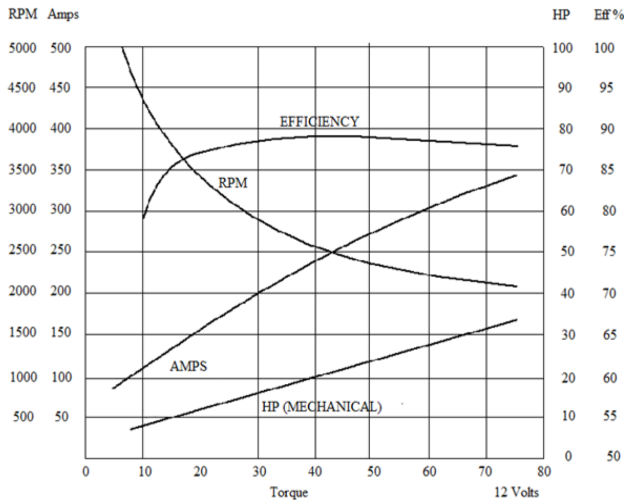

Fig. 2 Overall characteristics of Electric vehicle's attributes on 12 V systems

Fig. 2 shows the overall characteristics of electric vehicle conversion like Torque versus RPM & Amps in left side of the graph and Torque versus HP & Efficiency in right side of the graph. Install the motor, components, Controller, batteries and wiring to be accomplished. EVs require very few parts so installing the components is relatively simple. Ideally, the components should be placed close together to keep wire lengths short. The controller requires sufficient cooling to work properly so it should be placed in the airstream or mounted on a heat sink with a thermal joint compound for heat conduction. The pot box should be mounted on a sturdy surface and the accelerator cable should be routed in such a way so as to prevent kinks or pinching. Since there is a slight spark when the contactor closes it should be placed below the top level of the batteries. Each component should be kept away from water splash.

The motor is mounted in the space in such a way to connect straight to the rear wheel sprocket. The first step of the motor assembly is attaching the motor holder into the chassis. The holder in the assembly is drilled and

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set screws holes so the screws will hold the assembly holder and seat the motor properly. Blow out any metal shavings and screw the set screws in place. Two set screws are used for each hole, one on top of the other. Position the motor so the terminals are easily accessible once the motor is mounted in the bike. Next, position the motor by adjusting the adjust-bolt which is welded with the motor case so that the belt will be tightened and motor sprocket is aligned straight to rear wheel sprocket. Make sure all the bolts and nuts are tightened to the correct specifications.

As shown in the wiring diagram, there are four basic systems in an electric bike: *the propulsion system, 12 volt system, charging system and the displays and controls*. The propulsion system uses high voltage to power the electric motor, in this case 12volt/128ah. The auxiliary 12 volt system powers the accessories such as lights, horns and relays. The onboard charging system uses 220 VAC household current rectified to DC power to charge the batteries. The measuring instruments are used as same as with the petrol bike. Nothing replaced with new instruments like speed meter, rpm meter. In addition to that battery monitor to be incorporated as the new one. Digital voltmeter and ammeter may be incorporated for the further study purpose. Heavy duty lugs is used for connections between motor and main batteries. 400 amp fuse is placed in the circuit. To prevent corrosion a thin layer of Noalux is applied on each battery terminal

On the 12 volt side, 16 gauge wiring is used throughout the vehicle, except the wiring for the 12 volt battery which is heavier. The existing ignition wire, 12 volt accessories, contactor and components are wired to a terminal strip. When the ignition key is turned to start the car, the contactor closes the circuit in the propulsion system. Although the circuit is closed, current will not flow to the motor until the acceleration given.

Also wired into the car is a charger interlock which is a safety relay that opens the contactor while the car is charging. This prevents the car from being driven off while the car is still plugged into the charger. The charger is an onboard transformer less unit with built in GFI (ground fault interruption). Input wiring includes 10 gauge household wires that are wired from the charger to a 220 VAC outlet under the rear bumper of the bike. Output wiring includes a positive lead from the charger to the top of the battery pack and a negative lead from the charger to the bottom of the battery pack. The charger has a built in ammeter so amperage can be adjusted according to the available current at the charging location. This means the car can be charged anywhere where there is available electricity.

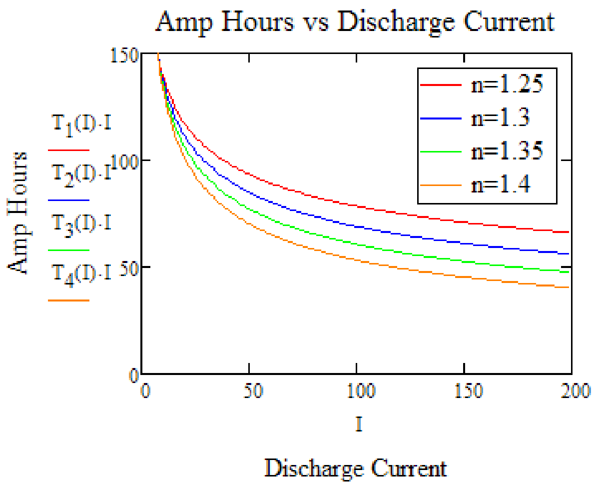

Fig. 3 Amp hours affected by Peukert's Effect

Fig 3 shows amp hours affected by Peukert's effect and it is a method for indicating battery pack status is by measuring the current drawn out of them. The fundamental obstacle to this technique is Peukert's Effect. The capacity of a battery decreases as the rate of discharge increases. A deep cycle lead acid battery is rated in amp hours but the discharge rate should also be displayed. The lead acid batteries used here are 128ah.Where T is the time the battery will last at the discharge rate I. N is the Peukert's coefficient that ranges from 1.2 to 1.4 in flooded lead acid batteries.

Test the battery charger; check the wiring and fuses, connections

We've finally got the bike together, or almost together, and it's time for a road test. Before heading out, the battery charger is tested and the batteries are charged. The 12 volt system, propulsion wiring, fuses, and battery terminal connections are inspected one last time. Turn the key to the start position. Instead of the usual "er-er-er-vrooom" you'll hear the contactor click then silence. Release the brake, Accelerate the bike twists the accelerator and off you go. The first thing you'll notice is how quiet the bike is. This will make it easy to spot any unusual noises or vibrations. The bike should brake and accelerate smoothly. Don't be surprised if your bike's range is shorter on the first run than expected. The batteries usually need about 40 charges before they meet optimum range.

II. GUIDELINES AND SAFETY

1. Always shut off the power when servicing the bike.
2. Dissipate the capacitors from the controller before servicing the controller or propulsion system. Even though the controller is off the capacitors may still be alive. A light bulb works well as a dissipation device.
3. When servicing the drive train always keep the drive wheels off the ground with proper jack stands.
4. Keep loose hair, jewellery or clothing away from spinning motor shafts.
5. Always wear proper eye protection when working with power tools and handling batteries. Deep-cycle batteries

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contain caustic acid which may splash or spill when they are moved or handled.

6. Wear protective clothing when carrying or moving batteries. Acid could spill and burn a hole through any clothing it contacts.
7. Wear steel toed boots when carrying or moving batteries. Batteries can weigh up to 80 pounds and can cause serious injury if they fall.
8. Wear heavy gloves when moving or carrying batteries. Use protective rubber or latex gloves when checking or watering batteries.
9. Always provide proper ventilation when charging batteries. A small spark can cause a fire if hydrogen gas accumulates in an enclosed area.
10. Never inhale the fumes when watering the batteries.
11. Tape the ends of wrenches when tightening battery terminals. A loose wrench can come in contact with battery terminals and cause a short.
12. Never ground the propulsion batteries.

III. VEHICLE MECHANICS FUNDAMENTAL

The design of any vehicle movement must follow the law of physics. Following Newton's second law, the forward motion of a vehicle can be expressed as:

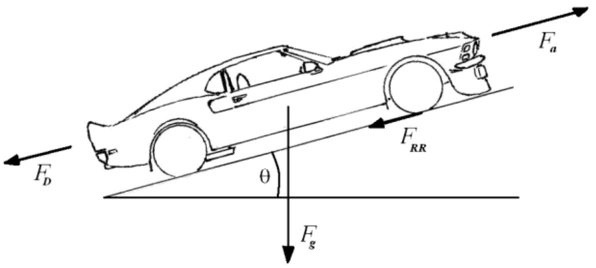

Fig 4. Equation of motion

Where

F_D → The drag force due to air resistance [aerodynamic drag]

F_{RR} → The force due to rolling resistance of the tyres on the road.

F_a → The force due to acceleration

F_g → The force due to gravity

IV. MAIN TECHNICAL SPECIFICATIONS

- All Vehicle Gross Weight: 50kgs
- Rated Load: 150kgs
- Overall Dimensions:
- Maximum Speed: 45km/h
- Travel Range on Full Charge: 45km, >70km with extended range power pack
- Slope Climbing Capacity (degrees): 20
- Rated Power: 1448W
- Rated Average Speed: 30km/h
- Rated Voltage: 12V
- Rated Efficiency: 70 %
- Charging Time: 4-8 hrs
- Motor Type : 12V Brushed DC series-wound
- Battery Type: 12V/32Ah x 4 SMF - Lead Acid

- <u>Battery:</u>
- 4Nos x 12v/32ah [in parallel] = 12v/128ah [1536 watt hrs]
- DOD: @80% 128ah x [80 / 100] =12v/102ah[1224watt hrs]
-
- <u>Motor:</u>
- 12vdc/2200w/4000rpm/Series-wound/continuous duty
-
- ***Calculations Overview:***
-
- <u>CASE 1 Single Stage Transmission</u>
-
- Motor shaft sprocket radius = 4cm
- Circumference = 2πr [2 x 3.14 x 4]
- C_1 = 25.12cm
- Drive wheel sprocket radius = 12cm
- Circumference = 2πr [2 x 3.14 x 12]
- C_2 = 75.36cm
- Gear Ratio:
- C_1 / C_2 = 25.12 / 75.36 =1:3 → Gear Ratio
-
- <u>Torque Calculations:</u>
-
- Torque= 60P / 2πN
- P = Power in watts → 1224 watts
- N = Speed in rpm → 4000 rpm
- N = for 1:3 gear ration the speed N is 4000rpm/3
- = 1333 rpm
- = [60 x 1224] / [2 x 3.14 x 1333]
-
- **<u>Torque = 8.73Nm</u>**
-
- <u>Speed Calculations:</u>
-
- Rear Wheel Diameter = 30.51 cm
- Rear Wheel Circumference = 2πr [2 x 3.14 x 30.51]
- = 191.61 cm or 1.91 meter
- Formula for Speed = [Circumference x rpm x 60] / 1000
- = [1.91 x 1333.3 x 60] / 1000
- = 153.23 km/hr [Max. Speed]
-
- **<u>CASE 2 Double Stage Transmissions</u>**
-
- Motor shaft sprocket radius = 4cm
- Circumference = 2πr [2 x 3.14 x 4]
- C_1 = 25.12cm
- Middle shaft sprocket radius [input] = 11cm
- Circumference = 2πr [2 x 3.14 x 11]
- C_2 = 69.08cm
- Middle shaft sprocket radius [output = 2.7cm
- Circumference = 2πr [2 x 3.14 x 2.7]
- C_3 = 16.95cm
- Drive wheel sprocket radius = 12cm
- Circumference = 2πr [2 x 3.14 x 12]
- C_4 = 75.36cm

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❖ <u>Gear Ratio:</u>
❖ C_1 / C_2 = 25.12 / 69.08 =1:2.75 → Gear Ratio Stage 1
❖ C_3 / C_4 = 16.95 / 75.36 =1:4.07 → Gear Ratio Stage 2
❖ Total gear ratio [C_1 / C_2]: [C_3 / C_4]=1:11
❖ <u>Torque Calculations:</u>
❖ Torque = $60P / 2\pi N$
❖ P = Power in watts → 1224 watts
❖ N = Speed in rpm → 4000 rpm
❖ N = for 1:11 gear ration the speed N is 4000rpm/11
❖ = 363 rpm
❖ = [60 x 1224] / [2 x 3.14 x 363]
❖
❖ **<u>Torque = 32.23Nm</u>**
❖
❖ <u>Speed Calculations:</u>
❖
❖ Rear Wheel Diameter =30.51 cm
❖ Rear Wheel Circumference = $2\pi r$ [2 x 3.14 x 30.51]
❖ = 191.61 cm or 1.91 meter
❖
❖ Formula for Speed = [Circumference x rpm x 60] / 1000
❖ = [1.91 x 363 x 60] / 1000
❖ = 41.59 km/hr [Max. Speed]

V. CONCLUSIONS

Converting Internal Combustion Engine driven bike in to an Electric engine, lot of benefits enjoyed by the low-income people. This project can be simple and successful. It has been studied in the villages and town and it showed that 98 percent of all trips are less than 50 kilometres per day; most people do all their driving locally and take only a few long trips. One hundred kilometres and longer trips are only 17 percent of total kilometres driven. As stated by General Motors' own surveys in the early 1990s (taken from a sampling of two wheelers in USA) indicated that: Most people don't drive very far. More than 40 percent of all trips were less than 10 kilometres. Only 8 percent of all trips were more than 30 kilometres. Nearly 85 percent of the two wheelers drove less than 50 kilometres per day. A smooth, proficient EV conversion provides fulfilling, inexpensive and environmentally friendly transportation.

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