Extended Range Electric Vehicle (EREV)

Yatheesha R. B, Anarghya A, Ranjith B. S, Nitish Rao

Abstract-This paper describes the range extension of an electric vehicle. In this project, an Internal Combustion(IC) Engine is coupled to a Permanent Magnet Direct Current (PMDC) Motor and the generated electricity is used to charge the battery when the charge of the battery is very less through a charging circuit. It results in improved range, as the overall distance travelled per charge of the vehicle will increase and thus make it a viable proposition for daily commuting. Increased energy security, as the vehicle will not run on IC engine directly. This leads to lower consumption of fuel.

Keywords – Electric vehicle, Generator, Hybrid vehicle, PMDC motor, Range extension.

I. INTRODUCTION

Extended-range electric vehicles (EREV) or range-extended electric vehicles (REEV) were designed to be run mostly by the battery, but have a petrol or diesel generator to recharge the battery when charge becomes low [1]. However, range extension can be accomplished with either series or parallel hybrid layouts. In a series-hybrid system, the combustion engine drives an electric generator instead of directly driving the wheels. The generator provides power for the driving electric motors by charging batteries [2]. In short, a series-hybrid is a simple vehicle, which is driven only by electric motor traction with a generator set providing the electric power. The Extended Range Electric Vehicle (E-REV) is unique vehicle, where battery and propulsion system are sized such that the engine is never required for operation of the vehicle when energy is available from the battery [3]. As a full-performance electric vehicle, battery, motor and power electronics must be sized for the fullcapability of the vehicle. An E-REV does not need to start the engine for speed or power demands and therefore does not need to be on when battery energy is available [4]. The engine is used only when the battery charge is low and to charge the battery in such cases. Unlike an internal combustion engine, electric motors are highly efficient with exceptionally high power-to-weight ratios providing adequate torque when running over a wide speed range [5]. Internal combustion engines run most efficiently when turning at a constant speed. An engine turning a generator can be designed to run at maximum efficiency at constant speed. Conventional mechanical transmissions add weight, bulk and sap power from the engine with automatic shifting being complex. Unlike conventional transmission mechanism, electric motors are matched to the vehicle with a simple constant-ratio gearbox hence multiple-speed transmission can be eliminated [6].

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II. METHODOLOGY

The following steps were adopted to proceed with the concept of range extension in an electric vehicle.

Step 1: Mounting an IC engine (Petrol/Kerosene run, 3000 rpm, 1.1kW, SUGUNA Manufacturing Company) on the foot board of an electric scooter (EKO COSMIC make).

Step2: Flywheel of IC engine is connected to a PMDC Motor (60V, 5 amps @3000 RPM) and connections are made to the batteries through a charging circuit.

Step3: When the charge indicator shows charge is less, IC engine will be turned ON mechanically and PMDC Motor will produce electricity to maintain the battery level until finding a plug in source.

Step4: Testing the scooter for improved range.

III. LITREATURE SURVEY

A. Energy Consumption per Vehicle

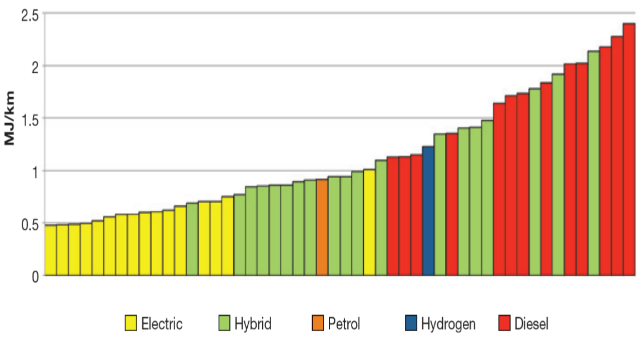

Fig. 1 Energy Consumption per Vehicle

From the above graph, it is clear that the electric vehicles use the least amount of energy, while the hybrids made up the middle range [7]. The diesel engines consumed the most amount of power, followed by the hybrid vehicles owing to their increased weight, and hence lowering their power to weight ratio.

B. Tank-to-Wheel CO2 Emissions: -

As electric vehicles have no emissions at the exhaust, and hydrogen fuel cell vehicles emit merely water vapour, tank to wheel emissions only have to be calculated for all the ICE and hybrid vehicles [8-10].

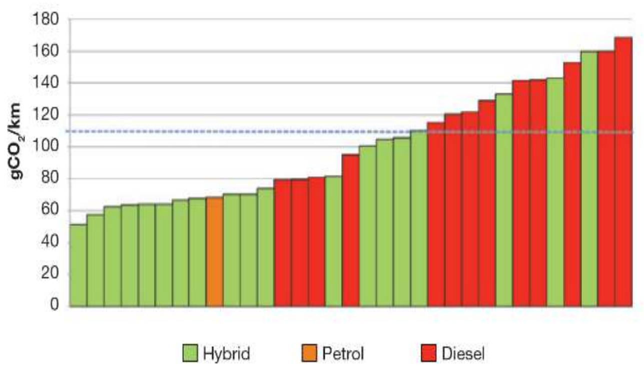

Fig. 2 Tank-to-wheel CO2 emissions

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From the above graph, it is observed that the CO2 emissions produced by hybrid engine and the diesel engine are depended on the category, and the model of the vehicle.

Also, it is observed that although the entry regulations specified a maximum of 110g CO2/km for ICE vehicles as measured by the official European drive cycle, 9 out of 14 ICE entries actually exceeded the threshold despite the fact that the nature of the event encouraged eco-driving.

C. Distance between consecutive charging events v/s Percentage

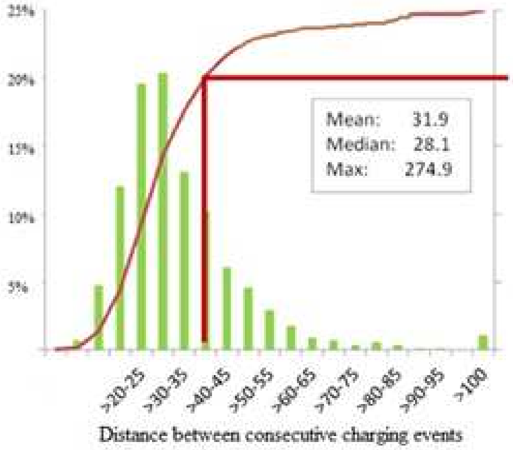


Fig. 3 Distance between Consecutive Charging Events v/s Percentage

It is very important to note that about 32% of Electric vehicles offer a range or distance covered per charge of about 40-45 km. To cover any distance beyond that the Electric vehicle has to be charged once again using a Plug-In source this is the main drawback of the electric vehicle. A range extender in the electric vehicle will ensure an extension in the travelling distance.

- 35 miles (56 km) of each segment would be driven in EV mode if all charging events end with a full battery
- Vehicle's EV mode range is exactly 35 miles (56 km)
- Of course EV mode operation varies based on :

Charging duration, power level, battery state of charge at beginning of charge, driving style, conditions, etc.

D. Components of Extended – Range Electric Vehicle

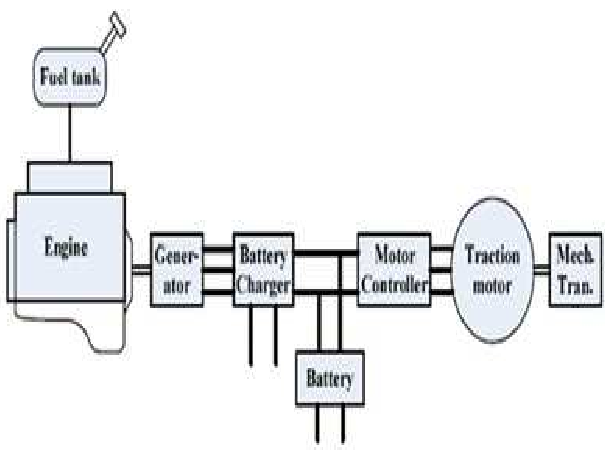


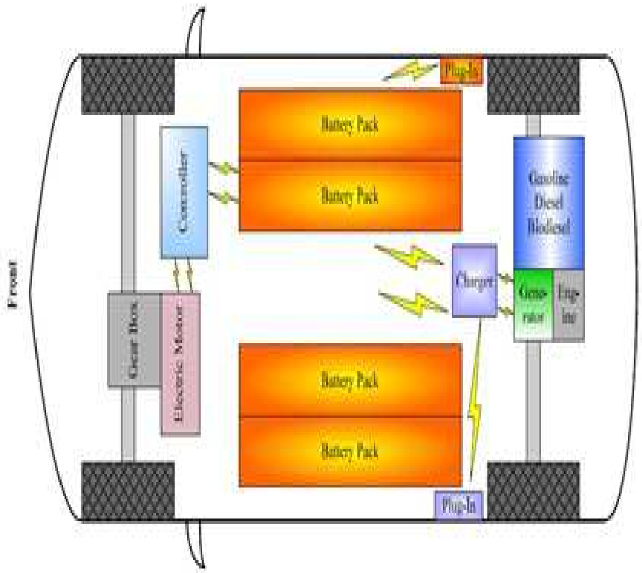
Fig. 4Components of E-REV

There are two operation modes: the pure EV and the range extended EV. For daily short-distance travel, the EV operates in pure battery EV mode without the range extender. The range extender can be assembling on the EV for a long distance travel. A system operating strategy is such that the Range Extender is to be activated during estimated low battery State-of-Charge (SOC) and operates until a desired SOC has been achieved. The generator set is controlled with constant speed and its output is constant voltage and Frequency, such as 220V, 50Hz. The output of the generator set is connected to the interface of the charger. Unlike a conventional generator set, this generator set provides rated output by controlling the output current of the charger. This ensures that the generator set works at the highest efficient point and has a low emission. The battery can also be charged by the charger with a household outlet or fast charged at charging station.

E. System Configuration

There are two electric drive system solutions: four wheel hub motor drive system and single motor drive system.

Fig. 5 Layout of the Four Wheel Drive System



F. Engine configuration

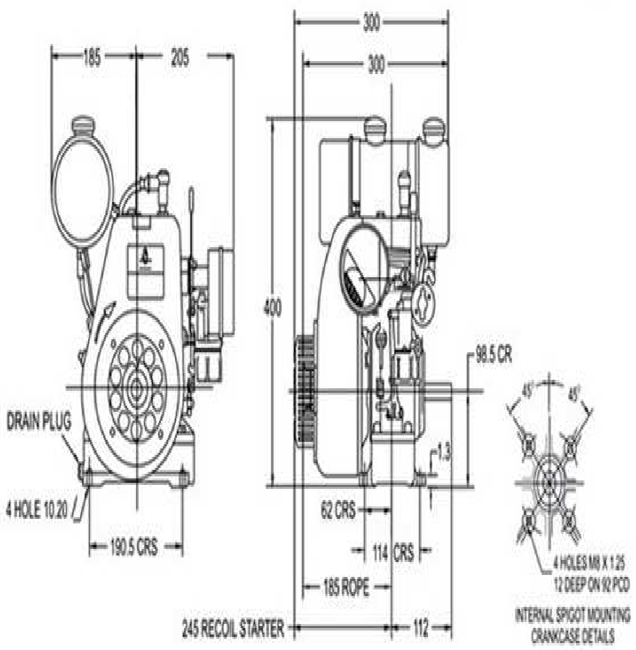


Fig. 6Installation Drawing of IC Engine

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IV. EXPERIMENTAL PLAN

Stage: 1

Procurement of electric scooter, IC engine and PMDC motor in working condition.

Fig. 7Eko Cosmic-I Model, 2004 Make

A. Description of the Electric Scooter

This electric scooter was manufactured by Eko Cosmic Vehicles. This vehicle has a top speed of 40 km/hr. and autonomy of approximately 40 - 50 km on a single charge. This product requires registration to drive but do not require driving license. EKO COSMIC Electric Bike is powered by a rear wheel hub motor and has a sealed rechargeable Lead-acid battery pack. The batteries have a life of 12,000 – 15,000 km. Recharging the batteries takes about 4 - 6 hours.

Features of the electric scooter

- Power Consumption: One Unit (for complete charge).
- Safe speed and easy to drive.
- Low maintenance cost.
- 2 seater vehicle (The vehicle is designed to carry a maximum payload of 130 kg.)

Specifications of Electric Scooter

Table I.Electric Scooter Specification

Contents	Features
Range	40-50 Km
Top speed	40Km/hr
Charging Time	4-6 hours
Brakes	4 meter braking distance
Motor type	Permanent magnet synchronous motor
Motor driving power	500W
Battery	Sealed lead acid, 12V 17Ah in series

B. Greaves MK 12 Engine

Fig. 8 Greaves MK 12 Engine

In the project, the MK 12 Engine, Greaves make was used. It is 1.1kW, @3000RPM engine which is more than sufficient to charge the batteries through the charging circuit. And the specifications of the engine are given in the table 4.2. As the power of PMDC Motor is 500 W, then the Engine power should be greater than 500W. Its consumption is 0.5 litres for travelling a distance of 40Km by charging batteries.

Table II. Engine Specifications

Model	MK-12
Fuel	Petrol(Start)/Kerosene(Run)
No. of cylinders	1
Bore X Stroke (mm)	55 X 50
Total Displacement (cc)	120
Continuous HP	2 HP/1.5 HP@ 3400 rpm
Max. Torque (Nm)	5.8 @ 2800 rpm
No Load Min RPM	1700
No Load Max RPM	4000
Compression Ratio	5.6/4.36
Weight (kg)	17
Ignition Timing	24^0 BTDC
Ignition System	C.B. (Electronic Optional)
Spark Plug	Micro W 95T1/M45Z8
Fuel Capacity (litres)	2.5/2+0.5 (Petrol)
Lubrication Method	Splash Type
Engine Oil	20 W 40
Sump Capacity (ml)	570
Governor Type	Centrifugal Fly
Starting Method	Rope and Pulley
Direction of Rotation	Anticlockwise @ Drive End

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C. PMDC Motor

Fig. 9 Permanent Magnet DC Motor

These types of motor are essentially simple in construction. As the magnetic field strength of a permanent magnet is fixed it cannot be controlled externally, field control of this type of dc motor cannot be possible. Thus permanent magnet dc motor is used where there is no need of speed control of motor by means of controlling its field.

Stage2:

1. Flywheel of IC engine is connected to a PMDC Motor (60V, 5 amps @3000 RPM) through a belt drive and the whole setup is mounted on the floorboard of the electric scooter with suitable clamping.
2. The power developed at the flywheel was coupled to the PMDC Motor (60V, 5 amps at 3000 RPM) through the V – Belt drive and a rated power output of 300 W (60V x 5amps).
3. The connections were given to the batteries through a charging circuit which helps in developing the required current levels.
4. Here there is a need to charge 4 x 12V series connected batteries which require 1.2 x 48 which is equal to 57.6V and hence we made use of 60V PMDC Motor. And this is because of voltage drop on application of load.

12V Battery – Max. Voltage for Charge is 14.5 Volts Charging Current – Maximum charging current should not exceed 10% of Maximum A/H capacity of Battery.

The battery used here is 12V / 60AH Battery.

Maximum Charging Current = 60/10 = 6 Amps.

Maximum Charging Voltage V = 2.35 V /Cell x 6

= 14.10 V

This means for four batteries,

= 14.10 x 4

= 56 V.

A. Design of V – Belt Drive

For power transmission between two shafts, the drive pulley operates at 3000 RPM,

Drive Pulley Diameter = 90 mm, Driven Pulley Diameter = 90mm,

Power of Engine = 1.1 kW

Power to be transmitted = 0.5kW.

Type - A V-belt is selected. [11]

Velocity = $\frac{\pi * d1 * n1}{60} = \frac{\pi * 90 * 3000}{60}$ =14.1372 m/s = V_1=V_2

Power Capacity:

N* = V $[\frac{0.45}{V^{0.09}} - \frac{19.62}{de} - \frac{0.765V^2}{10^4}]$

$d_e = d_p \times F_b$ = 90mm

N* = 1.7143 kW.

Number of V- Belts:

i = $N * \frac{F_a}{N} * F_c * F_d$

i = 1

Pitch Length:

L = $2 * C + \frac{\pi}{2}$[D+d]+$\frac{[D-d]^2}{4C}$

L = $2 * 250 + \frac{\pi}{2}$[90+90]+$\frac{[90-90]^2}{4*250}$

L = 500 mm

C_{max} = 2[d_1 + d_2] = 360 mm

C_{min} = 055[d_1 + d_2] + T = 107mm

Select C = 250mm.

Selection of V – Belt:

Cross Section symbol A,

Nominal Top Width = W = 13mm,

Nominal Thickness = T = 8mm.

Stage3:

- When the charge level comes down to a very low level, then it is indicated by the charge dial. Then, the engine is switched on mechanically.
- The power developed from the engine generates electricity through the PMDC motor and charges the batteries through the Charging Circuit.
- Our charging circuit charges the batteries at 3 Amps.

A. Charging Circuit

Pulse Width Modulation Charging Circuit (PWM)

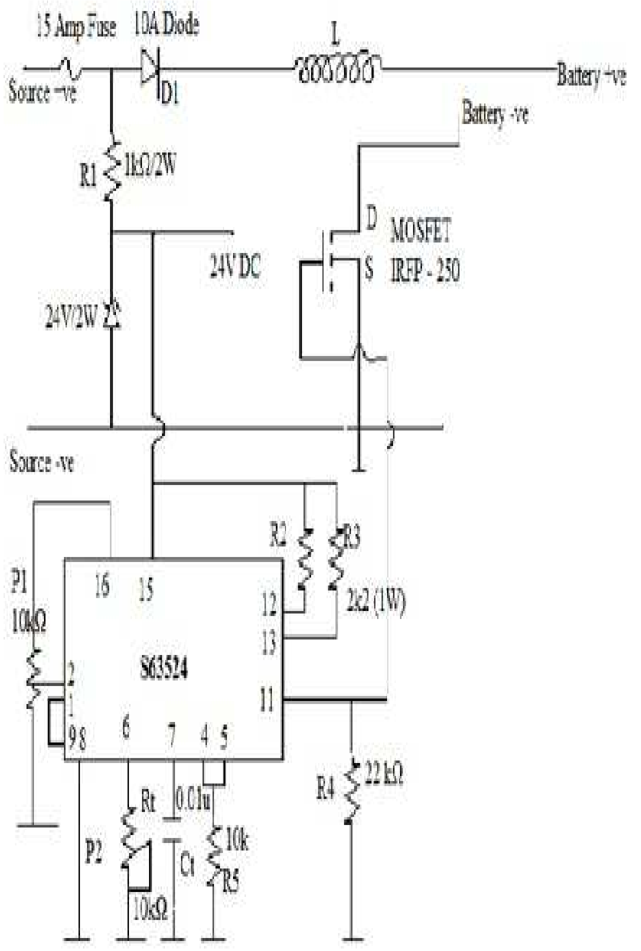

Fig. 10 Block Diagram of Charging Circuit

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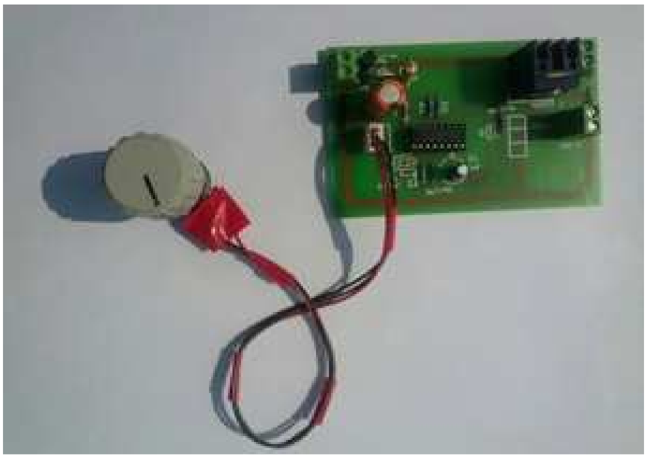

Fig. 11 Charging Circuit

When the charge level in the charge indicator shows less, then the Engine is switched on mechanically. The power developed from the engine generates electricity through the PMDC motorand charges the batteries through the Charging Circuit.

Fig. 12 Assembled Generator on Scooter

Stage4:

In this stage experiments on Gasoline scooter, Conventional Electric scooter, and our Extended – Range Electric Scooter were conducted.

Test distance – 80km

Vehicles used are,

1. Gasoline scooter – TVS Wego
2. Conventional electric scooter
3. Extended range electric scooter

1. It can be seen from the real world testing of electric scooter (without E-REV) on road which runs around 40 Km from one complete charge which will consume 1 unit of electricity. Hence occurred cost is about Rs 5 for travelling 40 km (taking 1unit= Rs 5). Further it can't travel beyond 40 km. For conventional gasoline powered scooter for which we have taken TVS Wego (110 cc) as a reference and the distance, cost occurred are calculated. For driving the same 40 km distance, it has takenRs 64 (taking 50 km as its mileage and cost of one litre of gasoline as Rs 80.90)

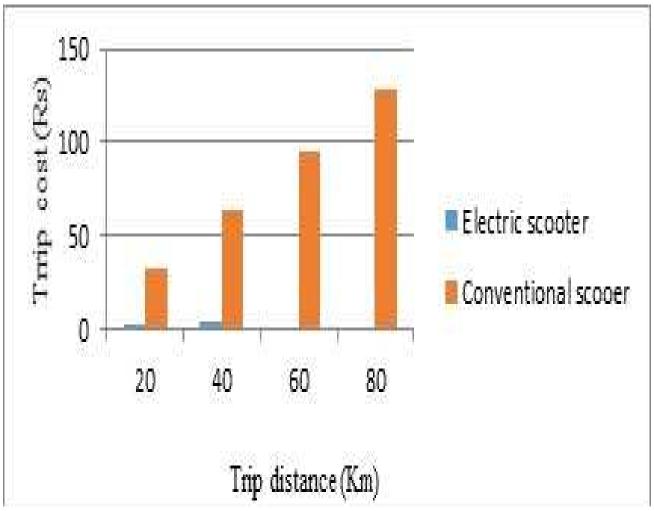

Fig. 13 Trip distance v/s Trip Cost

2. So from our Range Extender concept, it is possible to travel beyond 40 km with least amount of petrol consumption. In the testing, until charge became low, range extender (generator set) unit was never used. So when charge level becomes low, i.e.,when the scooter cannot run on the batteries and it will be around 40 km for single charge as per the testing, the range extender unit is switched ON to continue travelling to 80 Km, which consumed only 0.5 litre of gasoline and the overall cost is 45 Rs (5 Rs as a soul electric vehicle and 40 Rs as a Range extender vehicle)

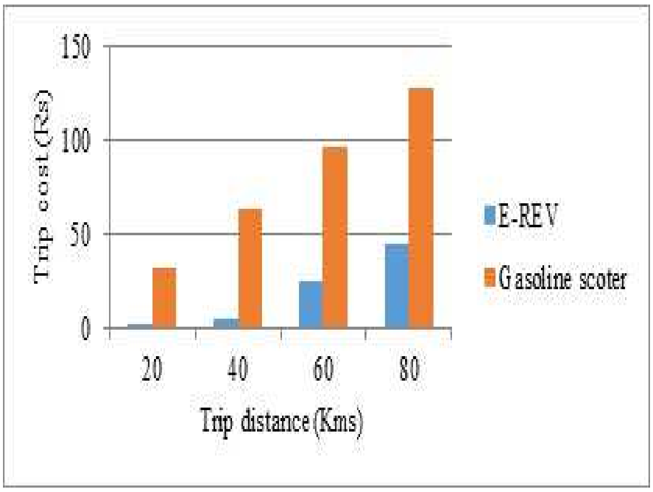

Fig. 14 Trip distance v/s Trip cost

As an Extended-Range electric vehicle, the overall fuel consumption is very less compared to that of conventional gasoline type of vehicle. Up to 35-40 Km. of distance there will be no fuel consumption because, vehicle will act as pure electric scooter. But to travel beyond 40 Km. range extender will come into picture causing fuel consumption. So if there is a need to travel further 40 Km. it will consume only 0.5 litre of gasoline fuel. Thus, only 0.5 litre of fuel is consumed to travel a distance of 80 Km. (40 Km as a pure electric scooter + 40 Km as an E-REV). So this process is continued until finding a plug-in source to charge the batteries. Thus overall energy security will be increased. Whereas in conventional gasoline powered scooter, it will consume around 1.6 litre of gasoline fuel to travel the same 80 Km. of distance. Thus it will increase the energy scarcity.

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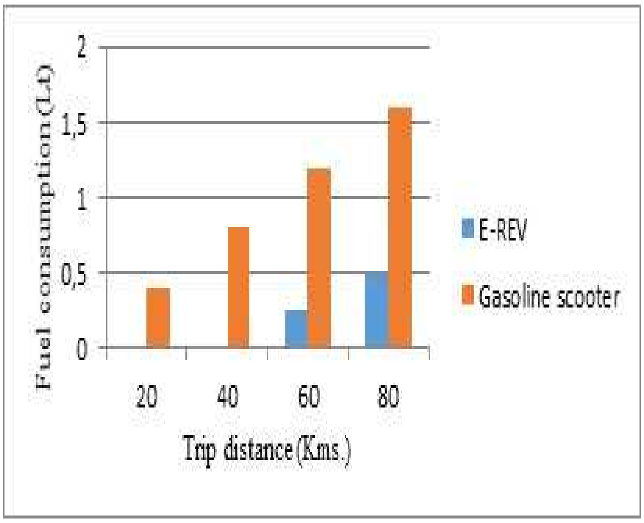

Fig. 15 Trip Distance v/s Fuel

Table III. Cost of travelling for different vehicles

Test vehicle	Distance travelled	Cost in Rs
TVS Wego	**80km**	**130**
Conventional Electric scooter	**40km + 40km**	**10**
Extended – range electric scooter	**80km**	**45**

And the main advantage here in Extended – Range Electric Scooter is,

- Firstly cost reduction as it took only 45Rs to travel 80km for which Gasoline Scooter took about 130Rs.
- Secondly increased energy security meaning, the use of electric scooters to travel 80km in a single charge using Range Extender.
- Third, reduced emissions due to the use of Electric scooters for first 40km with zero emissions.[12]

V. RESULTS AND DISCUSSIONS

Based on the tests carried out to extend the range of the electric scooter within the scope of this investigation the following conclusions have been drawn: -

1) Initially the Electric scooter runs on Battery charge completely and when the charge is low, the IC engine runs the scooter by charging the batteries simultaneously.
2) The range of electric scooter is effectively increased by using IC Engine – PMDC setup through the charging circuit.
3) The range of Extended – Range Electric Vehicle (E-REV) is comparatively more than the conventional Electric vehicles.
4) On conducting tests with varying some of the parameters observations made is that when input current (amps) to the charging circuit increases, the time taken to charge the batteries decreases.
5) On the basis of comparison between the results obtained of Extended – Range Electric Vehicle (E-REV) and conventional Electric Scooter it is clear that the distance covered per charge is comparatively more for E-REV.
6) Cost of Gasoline Scooter to travel 80km is 130 Rs.
7) Cost of Conventional Scooter requires 2 charges for which its use in real world is limited.
8) Using Extended – Range Electric Scooter a travel 80km in 45Rs is possible.First 40km at the cost of Electricity this is 5 Rs then IC Engine - PMDC Motor setup which costs 40 Rs, for next 40km.

VI. ACKNOWLEDGMENT

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