Eco-routing of Electric Vehicles: A Step Towards a Greener Environment

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Abstract: ***The calamitous effect of the industrial revolution has had severe consequences on the environment. The development and use of electric vehicles have become almost a necessary alternative. This paper emphasizes on the use of electric vehicles and their potential in minimizing energy consumption. It also accentuates a fairly new navigation concept known as "eco-routing" of electric vehicles. Electric vehicles have received soaring attention because of the increased focus on environmental issues and sustainable energy. Their merits include low green-house emissions and lower maintenance cost as compared to internal combustion engine vehicles. It has been predicted that if the power used by electric vehicles is produced from renewable energy sources, it will prove to be a true green alternative. .Plugging into renewable energy sources outweighs the cost and short driving ranges for consumers intending to buy electric vehicles. Keeping pace with the technological progression diverse navigation systems are being proposed which aim at reducing the energy consumption and an 'eco-route' seems just the perfect solution.***

Keywords: eco-routing, electric vehicle, energy minimization, range anxiety.

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1. Introduction

The meteoric development of the automotive industry has undoubtedly prompted the progress of human society. The transport sector being one of the largest contributors of greenhouse gases at global level, the increase in automobile emission has become an issue of growing concern for not only city planners, drivers and those related to the automotive industry but for the general population at large. The large number of automobiles, four as well as two wheelers using internal combustion engines (ICE) around the world is posing serious threat to the environment and to human life.Global air pollution has been reported as an important public health problem in most cities of the developing world. The exhaust gases from ICEVs are in fact, a leading contributor to global air pollution. Air pollution, global warming, and the rapid depletion of the Earth's petroleum resources are now problems of paramount concern. An US based assessment shows that a sample Battery Electric Vehicle (BEV) model produces 105,054 pounds of greenhouse gas emissions (CO2 -equivalents) over a full vehicle lifetime, whereas the equivalent ICEV produces 136,521 pounds of greenhouse gas emissions, a 23% advantage in global warming potential for the BEV[1].The development and use of Electric vehicles (EVs) has henceforth become almost a necessary alternative to conventional vehicles. Increasing the share of renewable energy used in the transport sector is seen as an important step to globally reduce greenhouse gas emissions. EVs have been seen as a solution for a long time if the electricity is produced by renewable sources although they still suffers from high battery costs and short range issues. EVs are considered future cars to solve oil dependencies and environmental problems. The idea of EV is not new but its spread has been quite hampered as of now. This is because of few basic reasons like high price, long charging times and limited driving range. Limited range in an electric vehicle may often lead to range anxiety which is considered one of the prime factors that affect acceptance of EVs till date. Extensive research is being carried out on aspects related to EVs and minimization of energy consumption and various new ideas and concepts have been suggested or established as an attempt to bring in an emission-free world.Electric energy is however, not a source of absolutely clean energy with fossil fuel contributing to its production. Thus, energy conservation in case of electric vehicle is a viable engineering problem. Eco- routing of electric vehicles can be seen as a relevant solution to the problem. It is a considerably new roadway navigation concept which uses Global Positioning system (GPS) and identifies the most energy-efficient route for a vehicle to travel between two points and is offered as a way in which drivers can reduce energy consumption. This system can extend the range of electric vehicles by at least 10%[2].The benefits of the eco-routing navigation system go beyond energy and emission savings. The technology can cut down so-called "range anxiety," meaning the driver of an electric vehicle fearing he

or she won't be able to complete a trip without running out of electricity to power the car's battery[3]. A well implemented eco-routing system can be successfully used to minimize energy consumption in EVs.The consumption of energy is probably the most important factor is the design of an optimal eco-routing navigation system. In internal combustion (IC) engines only about 20% of the consumed energy is actually used in moving the vehicle. EVs can function at over 80% efficiency thus reducing the energy demand.

2. Basics of electric vehicle

An electric vehicle or electric-drive vehicle is a type a vehicle which uses one or more electric motors for propulsion. Fig.1 illustrates a simple electric vehicle model where a battery is being used to provide electricity to a motor which propels the vehicle. During the mid-19th century, electric vehicles were first designed as the posed a better alternative to fossil fuel-powered cars of that time in terms of comfort and ease of operation[3]. The electricity consumed by electric cars may be generated from a wide range of sources including fossil fuels, nuclear power, and renewable sources or any combination of those.All-electric vehicles (EVs) run on electricity only. Breakthroughs in internal combustion engine and mass production of cheaper gasoline vehicles led to a decline in the use of electric drive vehicles. The internal combustion engine (ICE) has since then been the dominant propulsion method for motor vehicles for almost 100 years, but electric power has remained commonplace in other vehicle types, such as trains and smaller vehicles of all types [4].In India, pollution has almost reached its zenith and a shift to EVs seems the ultimate need of the hour. However, the EV industry in India is still in the blooming phase. As per National Electric Mobility Mission Plan (NEMMP), India plans a major shift to electric vehicle by 2030[5]. It's been touted as the LED moment of transport — the vision of an all-electric passenger car market in India by 2030, greening of the system being the link [6].Electric vehicles may be powered directly by an external power source like a power station or mains supply or by electric energy derived from an external power source stored on-board in battery or supercapacitor.

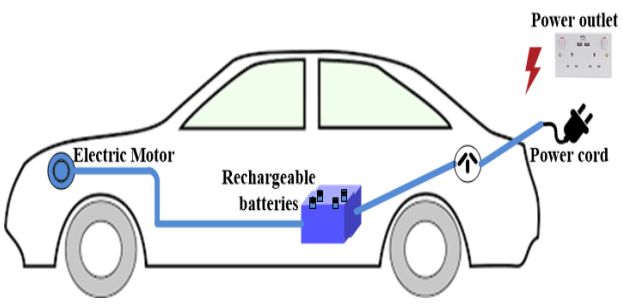

Fig.1 A schematic of an electric vehicle operated by battery

2.1 Advantages of EVs

Electric Vehicles have several advantages over vehicles with internal combustion engines (ICEs):

a. They emit no tailpipe pollutants, although the power plant producing the electricity may emit them.
b. They are energy efficient. Electric vehicles convert about 59%–62% of the electrical energy from the grid to power at the wheels.
c. EVs can prove helpful in driving renewable energy forward by improved battery technology and successful implementation of Vehicle-to-grid system.
d. They help reduce dependency on oil.
e. These vehicles are cheaper to operate.
f. Electric vehicles reduce collective carbon footprint.
g. Electric motors provide quiet, smooth operation and stronger acceleration and require less maintenance than Internal Combustion Engines (ICEs).
h. Motor efficiency is higher as compared to ICEs.

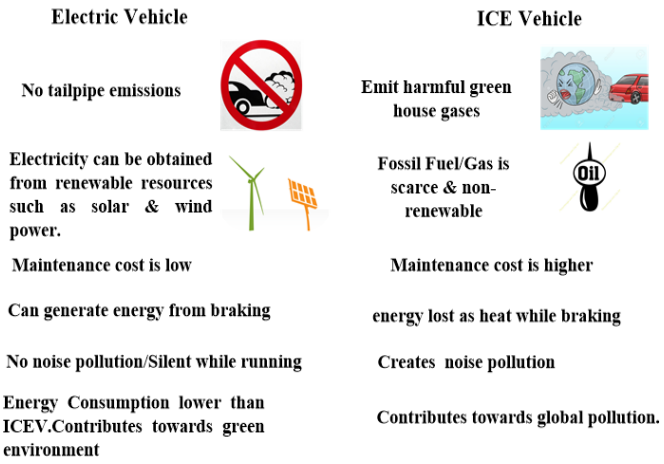

Fig.2. Comparison of ICE and EV

2.2 Range of EV and "Range Anxiety"

The range of an EV can be defined as the driving range of a vehicle using only power from its electric battery pack to traverse a given driving cycle. It is the distance an EV can travel with the energy available. In the case of a battery electric vehicle (BEV), it means the total range per charge. The mass acceptance of EVs is low primarily because of its high price and its limited range. The vehicles face a major problem due to limited range, which occurs because of the low energy density of batteries compared to the fuel of ICE vehicles. Other demerits include long recharge times compared to the relatively fast process of refueling a tank and current paucity of public charging stations. Larger range would mean more energy from batteries which will lead to larger packs being used making the physical dimensions of an EV unfeasible.For EVs, range anxiety is a phenomenon which is till date considered as one of the major barriers to large scale adoption of all-electric cars. It is the apprehension that a vehicle has insufficient range to reach its destination

and would thus strand the occupants of the vehicle [3]. This anxiety can lead EV owners to drive less .The term "range anxiety" was first reported in the press on September 1, 1997, in the *San Diego Business Journal* by Richard Acello referring to worries of GM EV1 electric car drivers [3]. The range of EVs is dwindled by various factors like uphill drive, speed of the vehicle, weight of the vehicle, strong headwinds, weather, traffic, road conditions and loss in battery capacity. The main strategies to alleviate range anxiety include the development of higher battery capacity at a cost-effective price, accurate navigation and range prediction for long trips.Therefore, effective detection of range is an obvious step forward towards acceptance of EVs.Since lack of information can be a contributing factor, a good navigation system with knowledge of the battery capacity, the remaining distance and the most energy-efficient route can minimize the fear. Using eco-routes will in turn result in consumption of less energy and lesser emissions at large.

3. Energy consumption in electric vehicles

Electrified vehicles are more efficient than ICE ones namely under urban traffic since they have no idling losses, no inefficient clutching at starts (they have good low end torque) and they can recover a portion of the braking energy through regenerative braking . In an EV the energy conversion efficiency of batteries under discharge depends on factors such as the battery State-of-Charge (SOC), the discharge rate, the battery State-of-Health (SOH) or the battery temperature. This temperature is affected by the ambient temperature and also increases during both the charging and discharging processes, even within nominal conditions of voltage and current [7]. However, the problem of the battery temperature increase is more critical during the batteries discharging process, mainly because greater discharge rates might occur and considering that this process is strongly dependent of the driver behavior. Not only are electric vehicles easier and cheaper to maintain, they are also more efficient than the gasoline engine and are therefore cheaper to operate. Literature survey highlights the fact that an EV can travel twice as much distance as compared to an ICEV with same fuel costs.

3.1. Factors affecting energy consumption in an EV

Analysis of the factors that affect the fuel consumption of vehicles is crucial to identify the main factors affecting fuel consumption in electric vehicles. Since the field of electric vehicles is comparatively new, the factors affecting energy consumption is still a topic undergoing research. The obvious factors include battery capacity,vehicle dynamics, and road surface conditions amongst many others. For attaining a greener world, it is critical that energy consumption be minimized. Most internal combustion (IC) vehicles waste up to 80% of the available energy before it even gets to the wheels, and then more through braking which is lost as heat [8]. EVs lend themselves to regenerative braking, which can recoup some of this energy. Researchers have till date reported and proved quite a few factors which are responsible for energy consumption in an EV. The measurement of the energy consumption in an EV is an aspect where tremendous research is being carried on as precise results will lead to accurate prediction of range of the vehicle during a particular trip, range being the prime feature of an EV. The energy consumption of EVs is known to be dependent on many factors that include the following [8]:

a. vehicle parameters, such as coefficient of drag, rolling resistance.
b. driving style and conditions
c. operating conditions, noticeably cold weather, which reduces battery capacity
d. auxiliary power draws, most significantly demisters and cockpit heating,

For an EV, the energy consumption is the integration of the power output at the battery terminals. In other words, it is how much power was consumed per unit distance or unit time.

4. Eco-routing of electric vehicles

Eco-routing is a navigation method typically guided by Global Positioning System (GPS) which, unlike a conventional GPS-based navigation system, identifies the most energy-efficient route which need not necessarily be the shortest or the fastest route as it takes into account various factors such as real time traffic information, weight of the car, weather conditions and location-specific attributes including road type, road grade and speed limits along with the distance and time considerations[9]. Eco-routing, while promising a reduction in fuel consumption and greenhouse gas emissions and consequent reduction in carbon footprint for a fossil fuel-powered car, for an electric car provides means to lessen "range anxiety" by helping the driver determine a suitable route through which the range of distance up to the destination can be covered by the available charge in the battery [3].

As per Literature review, studies have shown that a vehicle navigation tool they created can cut electric vehicle energy use up to 51 percent. In the recent past, there has been an escalation of GPS-guided navigation systems that assist drivers on which routes to take, which in most cases defines the route taking the least time [9]. However, shortest distance doesn't always minimize energy consumption, more so because there are various conditions that are to be taken into account during a trip from one place to another. An eco-routing system in electric vehicles takes into account speed limits and even real-time traffic conditions. Recent research shows that prevalent navigation systems are based on

algorithms which take into account factors like real-time traffic, weather conditions, weight of the vehicle and few other location-specific attributes. But traveling at high speeds for longer distances may result in higher energy consumption and emissions compared to a more direct route at lower speeds. This is due to factors such as stronger aerodynamic drag force at higher speeds and steep road grades [2]. Therefore, the objective of this research is to build an eco-routing navigation system algorithm which would take into account all important factors including the road grade, road surface conditions, aerodynamic drag, etc. and which would be able to guide drivers with the most energy efficient route while taking a trip.

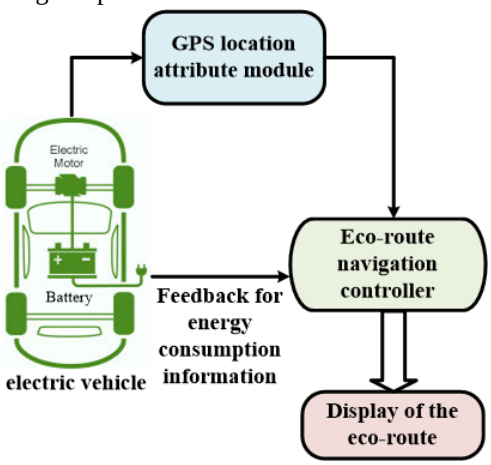

Fig.4.Schematic showing working of a simple eco-routing navigation system.

The concept of eco-routing in EVs has been depicted in Fig.4.A simple model includes inputs from a vehicle user describing the source and the desired destination. The system consists of a GPS module which updates information of the latitudes and longitudes of the source and destination thereby providing route information to the eco-route controller. It also provides elevation data as well as other road information necessary for calculation of required energy to complete the particular trip. The navigation controller then takes feedback from the battery of the EV as to whether that amount of power is available for completion of the trip. Complex calculations of data allow the controller to display the eco-route, meaning the route that will consume the least energy for that trip.

4.1. Need for eco-routing

The increase in emissions is a growing concern for all. Eco-routing, being a considerably new concept claims that its usage can reduce energy consumption as well as emissions. Research has shown that a vehicle navigation tool they created can cut electric vehicle energy use up to 51 percent [9]. This process can help in minimization of energy consumption in EVs.The benefits of eco-routing are manifold. Research shows that eco-routing navigation systems can potentially reduce fuel consumption and greenhouse gas emissions from conventional fossil fuel-powered vehicles by five percent to 15 percent. For electric vehicles however, the merits of the eco-routing navigation system go beyond energy and emission savings. The range of electric vehicles is an important factor. Eco-routing is capable of reducing the so-called "range anxiety," meaning it lessens the electric vehicle driver's fear of not being able to complete a trip without running out of electricity to power the car's battery.

4.2. Present Scenario

An "eco-routing" navigation system mainly takes into consideration real-time traffic information, weight of the car, weather conditions, and few location specific features like road type and road grade, etc. Literature survey shows that in the last decade, there has been an escalation of GPS-guided navigation systems that assist drivers on which routes to take. Most models have been designed as an attempt to minimize the distance travelled by the vehicle. However, shortest distance doesn't always minimize energy consumption and emissions because of factors such as heavily congested roadway sections. Newer generation eco-routing navigation systems are being developed taking into account speed profiles, weather conditions and even real-time traffic conditions and provide drivers the shortest-duration routes, which may have vehicles travel longer distances, albeit on less congested roadways. However, traveling at high speeds for longer distances may result in higher energy consumption and emissions compared to a more direct route at lower speeds. This is due to factors such as stronger aerodynamic drag force at higher speeds and steep road grades. Also, till date most of these systems are proprietary and not available publicly.

An accurate and detailed eco-routing system shall be able to calculate the energy consumption of a particular EV during a specified trip, whether there is enough charge available to complete the desired trip and also point out the route in which EV will consume the least energy during that trip.

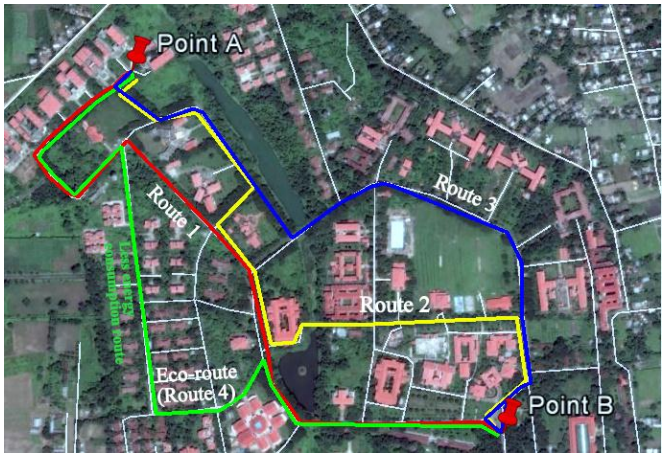

Fig.3. Diagram showing various route choices along including an eco-route.

Fig.3. illustrates how an eco-routing navigation system can predict the route which will consume the least amount of energy during a specified trip when there is more than one route available to reach the desired destination. It is important to highlight here that an eco-routing system takes into account all the factors which contribute in energy consumption of a vehicle and predicts a route which not always is the shortest route. But, the eco-route is of major importance to EV users because such a route helps in increasing the range of an EV.

4.3. Major Challenges

Existing navigation systems are mostly based on speed profiles and traffic information. It has also been observed that the eco-navigation systems which are currently being used by EVs are licensed versions and thus not easily accessible for experimentation purposes. Study shows that an efficient navigation system is dependent on various factors all of which are not considered for evaluation. Literature review has shown that Eco-routing strategy may also cause significant negative impacts at the network level if fully implemented. It may be highlighted Ahn et al. in 2012 presented that Eco-routing does not always reduce travel time. Taking a less congested route, the driver may at times drive at far higher speeds which would, in turn, increase energy consumption.

Cost is another factor which poses a challenge to the development of efficient routing systems. Prevalent navigation systems have their algorithms based on various factors but an important, almost necessary factor of road grade has still been ignored. Road grade has significant impact on the energy consumption of an EV. Higher road grades will result in more consumption of energy .Therefore, developing an eco-routing navigation algorithm by analysing all vital factors including road grade and road surface conditions and which is considerably cheap and user-friendly might serve as a solution to range anxiety. Also, the eco-route if devoid of road grade and all like factors which increase energy consumption shall definitely help in lowering the energy consumed during a trip.

5. Conclusion

Electric vehicle is an immediate and necessary option, especially for places high in population which results into higher traffic on roads. EV use will cut down on the harmful green-house emissions that cause pollution and also provide ways for minimization of energy. Minimizing energy consumption is an arising issue now-a-days. This paper presents a perspective on how EV use can effectively cut down energy consumption. It introduces the concept of eco-routing. The development of an efficient, user-friendly eco-routing system shall definitely aid in minimizing energy consumption and thereby contribute in lessening global pollution and building a greener world.Small environment changes will make a difference. Electric Vehicles can save thousands of rupees in fuel costs. They can really help save our environment. The future lies in our hands to build a better safer world.

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