The future has arrived, are we ready for EV?

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Abstract. With the invention of petroleum in 1859, R & D of internal combustion (IC) engine powered vehicle commenced and the first gasoline powered automobiles hit the market of Germany in 1876. Two major problems are associated with petroleum powered automobiles; these are chemical and noise pollution. These are causing tremendous damage to the nature and its habitat. Also the petroleum reserve is fast depleting. Hence all the eyes were focused towards non-petroleum bases automobile. Automobile with alternate fuels, engine with improved efficiency were tried but keeping the health of our planet in mind, maximum thrust of research is aim to run the automobile using green energy. Solar energy, the most popular green energy, found suitable in light transport like rickshaw and three wheelers because of low energy density. EV may be the solution of future transportation system. It offers zero emission and reduces noise pollution. Cost of purchase of EV is more, though its less running cost. The technology, especially the energy storing technology is yet to be matured. Overall cost of EV will come down within affordability with the technology. EV will be popular over conventional vehicle and it appears to be the viable solution in near future.

Keywords: Automobiles, EV, HEV, Pollution, Charging

1.0 Introduction

One of the main differences between the plants and animals is that the animals can move from one place to another. The speed of move may vary from species to species; like snail’s pace and the pace of leopard. The speed of walk of a young adult person is 4.5 to 6.5 km/hr [1] which may be much faster than the snail but inadequate to meet the requirements. This reason necessitated man to walk day in and day out to move from place to place. Another associated problem of human is its load carrying capacity, which is limited to 20 to 25 kg for a person weighing around 50 kg [2]. This capacity decreases with the increase of the person’s weight, for self weight above 70 kg, the load carrying capacity falls below 20 kg. Use of animals for the purpose of faster movement was being used by us since the time immemorial. It was with the invention of wheel around 3500 BC [3] that the revolutionary change to move faster with load took birth in the form of animal cart. However, in order to enhance mobility and load carrying capacity, the society remained indebted to surface transport; both rail and road transport. Consequent to invention of steam engine by Thomas Newcomen in 1712 and its subsequent up-gradation by a Scottish inventor, mechanical engineer and chemist James Watt, more than the transportation system, the world witnessed the industrial revolution [4]. With the invention of petroleum, it opened a new horizon to think about internal combustion engine and the automobile industry was about to commence its journey. The age old problems of slow movement and limited load carrying capacity of mankind got an answer when the first automobile rolled out of the factory in USA in 1886 [5]. It gain huge popularity and by 1920, automobile became part of life, with additional advantage of creating job opportunity in auto industry and its ancillary sectors. These industries played an important role to improve the economy of USA [6].

1.1 Early automobiles

Though the first oil exploration was credited to Colonel Edwin Drake [7] an American businessman, who successfully drilled oil well in 1859, the cars of early 1900 were electrical motor driven. Earlier in 1769, some of them were powered by bulky and low efficiency steam engines. This is because, the initial use of petroleum was to light lamps. The situation changed with the invention of electric bulb by Thomas Alfa Edition and the first gasoline powered automobiles hit the market of Germany in
1876. Ten years later, [8] commercial production with IC engine fitted in it and gained popularity due to easy availability of refilling stations. Production of diesel car started in France in 1933 with the introduction famous brand Citroën's Rosalie. The Mercedes-Benz and the Hanomag Rekord were available in the market in 1936.

1.2 Problems with Conventional Automobiles

Two major problems associated with petroleum fuelled automobiles are chemical pollution due to emission of toxic gases through the engine exhaust and noise pollution caused by the engine and other associated moving parts.

1.2.1 Chemical Pollution: The engine exhaust emits volatile organic compounds, oxides of nitrogen, lead oxides and carbon monoxides. These harmful chemicals mix with ambient air and the atmosphere gets polluted leading to much short term and long term adverse effects on natural ecosystems. Formation of smog, depletion of ozone layer, greenhouse effect, global warming etc are some of the unwanted effect on the atmosphere. The resultant condition adversely affects health of natural habitats, agricultural productivity and changes the climatic conditions [9]. Vehicle types and pollutant for emissions from common petrol engines [10] and diesel engines [11] with fuel combinations is given in Table 1.

| Engine type       | Fuel Type | Vehicle type           | Major emissions                  |
|-------------------|-----------|------------------------|----------------------------------|
| Petrol Engine     | Petrol    | Cars, buses (some trucks) | HC, CO, NOx, Pb & particulate   |
| Diesel Engine     | Diesel    | Lorries, trucks tractors (some buses & cars) | NOx, SOx, HC, CO, Soot and particulates |
| Two-stroke Engine | Petrol    | Motor cycles           | HC, CO, NOx, Pb & particulates   |

1.2.2 Noise Pollution: It is caused by automobiles is primarily because of running of IC engine, frictional noise due to rolling of whets on the road surface. Another source of noise is uncontrolled honking of horn. Automobile noise is a growing public health concern for children, young and old people. This is more acute in urban areas where the traffic density is very high. Prolonged exposure to noise affect concentration, slip disturbance, high blood pressure, increased risk of hypertension and heart disease [12]. Depending upon the level and duration noise, its effect on our health can be broadly categorized into four group as given in Table 2 [13].

| Category | Effect                  | Health Problem                                      |
|----------|-------------------------|------------------------------------------------------|
| I        | Physical effects        | Hearing defects                                      |
| II       | Physiological effects   | High blood pressure, irregularity of heart rhythm and ulcers |
| III      | Psychological effects   | Sleeplessness and going to sleep late, irritability and stress |
| IV       | Effects on work performance | Reduction of productivity and misunderstanding what is heard |

For average human beings, noise level of 85 dB is considered as a safe level by hearing health professionals. [14]. Permissible noise level in residential areas as per WHO specification is 50 dB(A) [15]. According to Govt. norms the noise range for horns has been fixed between 93 dB(A) and 112 dB(A). [16]. In spite of strict pollution norms, it has not been possible to control the adverse effects due to huge vehicle density.

1.3 Consideration of Alternate Source of Power
Alternate to conventional automobiles Research for alternative to conventional automobiles are on which would not threat this planet with chemical and noise pollution. Another reason to look for alternatives is that the oil reserve is fast depleting. It is estimated that annual global consumption rate of crude oil is excess of 11 billion tones. At this rate the global oil reserve will last for another 50 years or so [17]. Automobile with alternate fuels, improves engine have received some attention as potential options [18]. However, keeping the health of our planet in mind, maximum thrust of research is aim to run the automobile using green energy with particular reference to solar energy. But there is a mismatch between solar energy available \textit{vis-a-vis} energy required to run the vehicle: former being lesser than the later, solar cars are limited to light transport like rickshaw and three wheelers. Another option gaining popularity is electric vehicle (EV), probably the best answer against chemical and noise pollutions and also achievable solution against limited oil reserve.

It is observed that that EV is generally noiseless while it is running at a speed below 25 km/hr. Since we are not used to zero noise in actual road condition, it becomes very dangerous for the visually impaired pedestrians and slow movers like bicycles and rickshaws because they fail to recognize that an EV is behind them. This has resulted to add some noise while the EV is moving at slow speed to alert these movers. Toyota Corporation Japan has incorporated the audible warning system which may increase with the increase speed of EV. It was suggested that the noise level should be alarming but below the annoying level [19].

2.0 The Electric Vehicle

In IC Engine, the energy is developed using petroleum only. However, electricity is generated by generator/alternator which can run from a diversified source of energy. Moreover, limited oil reserve has forced every country to move beyond conventional IC engine driven vehicle and many countries have set time frame [20]. The UK has announced that it will stop selling of conventional cars in the year 2040 in order to achieve the target of zero emission road environments by 2050. Paris, however wants to achieve the both the targets ten years before UK. Scotland plans to stop selling IC engine vehicles by 2032. The Scandinavian countries have introduces green tax system [21] to encourage the citizens to go for environment friendly transport in place of fossil fueled system. Austria and Netherlands planned to impose ban against IC engine cars by 2025 and 2030 respectively. China is only the major country yet to set any deadline against banning of conventional cars. However, they are working to set a time line and it may be declare the dead line any time soon. In USA, sale of EV is growing at rapid pace as the tax credit ranging between $ 2500 - $ 7500 is being give to the customers against the purchase of each new [22] EV. In India, the Ministry of Heavy Industries and the [23] NITI Aayog are working together to ensure that by the year 2030, only EVs are available for the Indian roads. The sale of EV has picked up especially for the two wheels segments. However, with present demand of EV which is only one out of 400 conventional vehicles, India has a long way to go to achieve its deadline of 2030.

The overall scenario is of course quite encouraging and continuously tilting towards EV because of awareness program raised by all the countries for a greener planet. The data in Table 3 [24] shows that the demand of EV is increasing exponentially with every passing year.

| Year | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|------|------|------|------|------|------|------|------|
| No. of EV in Million | 0.11 | 0.22 | 0.4 | 0.72 | 1.18 | 1.93 | 3.27 |

By extrapolating data beyond the year 2018, as shown in the plot in Fig. 1, the number of EV in the years 2019 and 2020 is showing tremendous increase up to 5.57 and 8.12 million respectively.
3.0 Variants of EV
In its simplest form EV contains a motor which is the power pack to drive it. The motor may be AC or DC motor, which run using electricity from a battery bank. The motor speed is controlled by a controller. The motor together with the battery bank and controller replaces the IC engine and fuel system. In pure form of EV, called Battery Electric Vehicle (BEV), the battery bank is charged from external power source, called charging station. The second variant is Hybrid Electric Vehicle (HEV). As the name suggests, it has twin facility of running in electricity as well as using IC Engine [25]. The battery in this case is charged through two sources of energy. First source of energy is generated by the onboard IC Engine coupled with a generator. The second method is by capturing the energy, which otherwise would have been lost due to application of brake. In this case the electric motor is made to function as a generator and charge the system. This is called regenerative braking. There is another variant of EV called Plug-in Hybrid Electric Vehicle (PHEV) which provides twin facility of charging the battery from a charging station [26], as well as by its on-board IC engine coupled with a generator.

4.0 Additional Advantages of EV
In addition to zero emission and noiseless operation, EV offers some more additional advantages which are much desired requirements of users. These are very high pick up, very low running cost and maintenance cost. Technically, it has simple power train with forward and reverse gear eliminating the gear box of a conventional car. It is estimated that for a range of 600 km, running cost of EV is only 30 to 33% of that of gasoline vehicle [27]. Energy conversion from chemical energy to mechanical work for IC Engine vehicle is 29 - 32 % for gasoline engine and 34 – 36 % for diesel engine [28] remaining energy is lost due to heat loss, noise, friction etc. For EV 85 to 90% energy of the battery is converted to mechanical work at the wheel [29].

5.0 Challenges with EV
All types of EV have higher initial cost as compare to its conventional counterpart. This is the one of the reasons that EV is unable to climb the preference chart of potential customers. It is observed that EV is more cost effective if the complete lifecycle of the vehicle is considered instead of initial cost. Comparing Tata Nexon EV and Maruti Suzuki Swift DZire (Diesel) it is noted price parity comes between the two in the 7th or 8th year of life. Maintenance and service costs of EV being lower,
further years of running, EV works out to be cheaper [30]. To popularize EV, various tax exemptions is given by the Governments for initial purchase.

5.1 Charging Station: Very few charging stations are available at the road side. Average range of electric car being around 300 to 400 km, users are more worried about its next recharge rather than enjoying the drive. Few states of US and Canada has established alternative fuel data centre [31] which provides the locations, hours of operation, and type of charging equipment available etc.

5.2 Charging time: Generally considerable time is required to charge the battery resulting long idle time for the users. It is observed that for an electric car having a battery capacity of 60 kWh, the charging time from zero to full is eight hours by a 7kW charging station [32]. Penn State University of USA has developed EV battery with high energy storing capacity but low charging time. It is reported that the battery which provides a [33] range of 480 km need only 10 minutes to achieve full charge. However, using fast charger the charging time can be reduced considerably. One of the solutions of long waiting time can be use of ‘cooking gas cylinder refilling principle’. This is to deposit the exhaust battery and in exchange pick up a charged battery. For this there is a requirement of common specifications by all the battery manufactures for same type of EV.

5.3 Range: Current generation of EVs offer appreciable range with fully charged battery. Hyundai Kona offers a range of around 450 km with its 39 kWh lithium-ion battery [34]. MG ZS EV and Tata Nexon EVs have the single charge range of 340 km and 310 km respectively.

6.0 Conclusion
There is a paradigm shift of technology from conventional (petroleum fuelled) automobile to EV. Potential customers will take time to absorb this shift of technology and accept the new driving system. In one hand, EV offers zero emission, zero noise pollution and low operational cost which satisfy the environmentalists, on the other hand to delight the car lovers, in addition to all essential features; it offers a very high pick up with smooth ride. For example, popular electric car of SUV category MG ZS has been designed to accelerate from 0-100 km/h in 8.5s. However, high procurement cost, not so good support system like inadequate charging stations, long charging time, limited range of operation etc are the present challenges faced by the owners. Hence there is an urgent need to consider these aspects and provide solutions. It is accepted that the human mind is not open to welcome any new technology quickly without comparing the support system with the existing one. Hence, instead of looking toward additional features, the mind looks into the impending problems it may have to surmount as new owner. So the designers have a challenging task to make the support system owner friendly. EV has the scope to be controlled by AI, and the work is on in this regard. The technology, especially the energy storing technology is yet to be matured. As the technology is absorbed at the commercial production level, overall cost of EV will come down within affordability. There is no denying that EV is here to stay and this is the solution of future transportation system. Hence, the future has arrived to migrate to EV from the conventional vehicle and presently it appears to be the viable solution to the existing transportation system.

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