COMPARATIVE ANALYSIS OF THE PERFORMANCE OF BATTERY ELECTRIC VEHICLES AND CONVENTIONAL INTERNAL COMBUSTION ENGINE VEHICLES

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Abstract: Comparative analysis of the performance of battery electric vehicle (BEV) and conventional internal combustion engine vehicles illustrates broadly difference of on working principles that our choice leads to which one of the vehicles is more convenient and eco-friendly. The parameters of both types of vehicles will be considered comparatively by their current structural state which helps to distinguish improved sphere on manufactured new model. In addition, the performance of the electric machine (EM) and internal combustion engine (ICE) is analyzed that the comparison of relevant parameters as well as the discussion of advantages and disadvantages will be provided.

Keywords: Battery electric vehicles (BEV), internal combustion engine (ICE), electric machine (EM).

1. Introduction

Nowadays the use of BEV (figure 2) increases globally over ICE-based vehicle (figure 1) by what, rate of the comfort of BEV is accepted experimentally well by drivers and also, harm to the environment is diminished by decrease of the amount of vehicle emission. The EU has set out several objectives, whether short-term or long-term and from that, the first set of regulations was introduced in 2009 following a voluntary commitment by the car industry to reduce the average CO2 emissions of vehicles. As electric cars give pollution-free, noise-free and high performance, it is

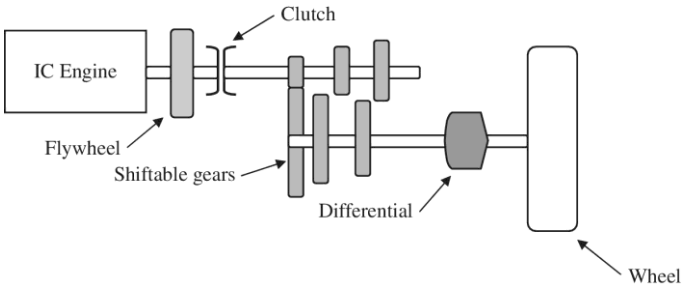

Figure 1: Structure of ICE-based vehicle

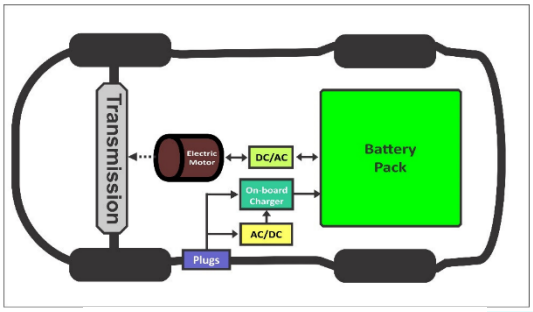

Figure 2: Structure of BEV

expected that the electric vehicle can capture the market and make the ICE counterpart obsolete by 2025 [2]. The technology behind the induction motor, inverter and lithium-Ion power source, and synchronized wheel mechanism make the electric cars work with better performance.[1],[2]

BEV selling rises comparatively at high rate over ICE-based vehicle, however BEV has several drawbacks compared to ICE-based vehicle. For case, with a relatively low travel range, some drivers prefer to use ICE-based vehicle. In addition, in some countries, charging stations are not fully organized yet, which creates issues, concerning large distances. In other case, recharging time impedes to use of BEV by long waiting time than the refilling time of ICE-based vehicles. However, the recharging time of both fast and conventional type of BEV reduces gradually by time. In the next section, the performance of ICE-based vehicle and BEV will be analyzed by comparing their characteristics specifically. In the third section, ICE and EM are

reviewed by analyzing working principles comparatively. In the last section, we will conclude comparative analysis of performance of ICE-based vehicle and BEV by considering the improvement of the performance of vehicles.

2. Comparative analysis of the performance of BEV and ICE-based vehicle

Capacity of energy (energy density) should be evaluated primarily in vehicles; in case of ICE-based vehicle, the energy density of diesel or petrol fuel is higher than the chemical energy inside the battery packs of BEV at 10 times of batteries. Compared to liquid fuels, most current battery technologies have much lower specific energy, and this often impacts the maximum all-electric range of the vehicles. The most common battery types in modern electric vehicles are Lithium-Ion and lithium polymer, because of their high energy density compared to their weight [3]. Other types of rechargeable batteries that were used in electric vehicles are lead-acid ("flooded", deep-cycle, and valve regulated lead acid), nickel-cadmium, nickel-metal hydride, and, less commonly, zinc–air, and sodium nickel chloride ("zebra"). The amount of electricity (i.e. electric charge) stored in batteries is measured in ampere-hours or coulombs, with the total energy often measured in kilowatt-hours.[3]

Most electric vehicles are structured with lithium-ion batteries (Li-Ions or LIBs) that lithium-Ion batteries have a higher energy density, longer life span, and higher power density than most other practical batteries. Complicating factors include safety, durability, thermal breakdown, and cost. The energy density of lithium-ion batteries currently used in electric vehicles is 100-180 Wh/Kg and the cost of cells is in the order of $400/kWh [3]. In addition, refilling time is essential point, so that drivers should continue on their way without spending time for refilling. The recharging time by AC 220 V is nearly 12 hours and AC fast charge is approximately 3-4 hours, which is clearly established that BEV hasn't reached yet the refueling time of ICE vehicles. But from the other side, the low location of battery packs results in lower location of center of gravity, which yields in better stability during

maneuvering. Moreover, BEV differs from ICEV with its high torque at low speeds, which results good dynamic behavior (acceleration) from low speeds.

Among the other advantages of BEV, essential part is zero tank-to-wheel emissions, but conversely to BEV, different types of emission gas are released from ICEV, that are CO (Carbon monoxide), HC (unburned hydrocarbon), NO_X (Nitrogen Oxide), PM (particulate matter). Elimination or at least reduction of CO_2 emissions can be done in two ways: either by increasing the efficiency of internal combustion engines or by switching to other fuels and propulsion. Demand and sales of electric cars in the EU increased by 51% at the turn of 2016 and 2017 [4]. Even though the number of registered electric cars becomes larger every year, they still represent only a small percentage of the market. An important factor to mention is that the production and disposal of electric cars put a much greater impact on the environment compared to conventional cars.[1]

The travel range of ICE-based vehicle is relatively higher at 1.25 times with a full tank (approximately 500 km) than BEV. From Heating, Ventilation and Air conditioning (HVAC), compartment heating is realized through the waste heat of the engine in ICE-based vehicle, but in BEV, compartment heating is realized using the energy of the batteries. The performance of BEV is highly dependent on environmental condition, so that ambient temperature can cause degradation of execution. Another advantage is that the braking system works as regeneration of energy during deceleration phases, a battery can be charged by generator which converts mechanical power to electrical. When the brake is pressed or the electric car is decelerated, the motor becomes an alternator and produces power, which is sent back to the battery.[3]

3. Analysis of ICE and EM

The efficiency of vehicles is considered significantly that ICE efficiency (approximately maximum efficiency for gasoline is 35% and for diesel is 40%) is very low compared to the efficiency of EM (about 95% maximum efficiency. The

speed of the induction motor is directly proportional to the supply frequency, so just by varying the supply frequency with help of a variable frequency drive, the speed of the induction motor can be easily varied. This simple fact makes electric car speed control easy and reliable at high-speed ranges (0-22000 rpm) compared to BEV (800-7500 rpm).

Torque is a measure of how much rotational force can be produced, whereas power is a measure of how hard an engine has to work to produce the rotational force.

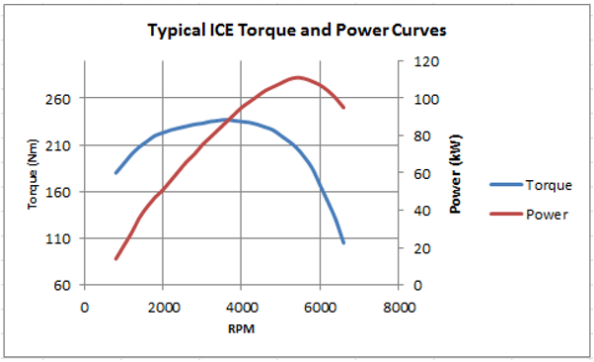

Figure 3: Torque versus Speed characteristics of ICE vehicle

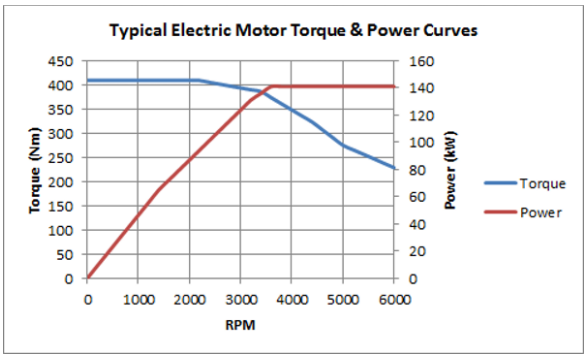

Figure 4: Torque versus Speed characteristics of BEV

As shown below, the power and torque characteristics of a combustion engine are represented in Figures 3 and 4.

In contrast, an electric motor provides full torque from zero kilometers an hour, with a linear relationship between how fast the motor is spinning and the power required. Concerning to given characteristics, it is concluded that BEV moves extremely fast at accelerating because of EM has ability to push load very quickly.[3] And also, ICE can face NVH (Noise, Vibration, Harshness) problems, however, the ICE has high reliability than EM with applying it for more than 130 years.

4. Conclusion

The danger to the environment will be huge if the usage of fossil fuels for propulsion is not reduced. Nowadays, there are some examples of zero-emission vehicles, even though they have low reliability, among which battery electric vehicles are good examples. BEV can make some inconveniences for drivers, however, by

modernization of BEV, problems will find solutions gradually. For example, nowadays every produced new model of BEV improves its recharging time as much as possible differently in effective quantity by comparing to last model. In five to 10 years, though, far faster charging might be possible, because companies are developing new lithium-ion battery materials, as well as new "solid-state" batteries, which are more stable at faster charging speeds. Moreover, they could place recharge rates of 20 minutes or less within reach. [6]

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