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# CRITICAL REVIEW OF THE PERFORMANCE OF THE BATTERY ELECTRIC VEHICLE AVAILABLE ON THE MARKET.

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**Abstract**– The paper analyses the battery electric vehicles available on the market. The data for more than 80 models of such vehicles are collected. The vehicles' performance is compared with different power requirements. The electric motor power, battery capacity and vehicle driving range are analysed to fulfil such requirements. Based on the results of the critical analysis the future possible activities in the field of Battery Electric Vehicles (BEVs) performance improvement are defined.

**Key words**– Battery Electric Vehicles, driving cycle, power required, acceleration performance, battery capacity

## I Introduction

Recent trend toward the zero emission mobility lead to increased number of BEVs in the market over the last 10 years. Accordingly, sales of BEVs in commercial markets have grown. In the world, the number of vehicles with electrified powertrains on the road in 2010 were about 17000 while in 2019 this number has increased to 7.2 mln. The main share of this value comes to China [1]. European countries' BEV market have grown to the second largest overcoming the United States. Fig.1 below shows the world electrified vehicle sales between 2012 and 2019. It is evident that 0.11 mln. electric cars were produced worldwide in 2012 and 4.79 mln. by the end of 2019. Plug-in Hybrid Electric Vehicles (PHEVs) are type of hybrid electric vehicles with possibility to recharge it from external grid. They are characterized by smaller capacity of the battery, which should be enough for 50 km of pure electric range [2].An in-depth analysis of the technical characteristics of BEVs, allow gaining more information about them. Thus, this paper aims to analyse the specifications of the existing BEVs on the market and draw general conclusions to understand the current state-of-the art in sizing the powertrain components. Furthermore, the paper gives an overview about how the existing BEVs are located with respect to main performance requirements. To fulfil the objective, the technical data for more than 80 BEVs were collected from the sources [3] [4] [5] and the manufacturers' websites.

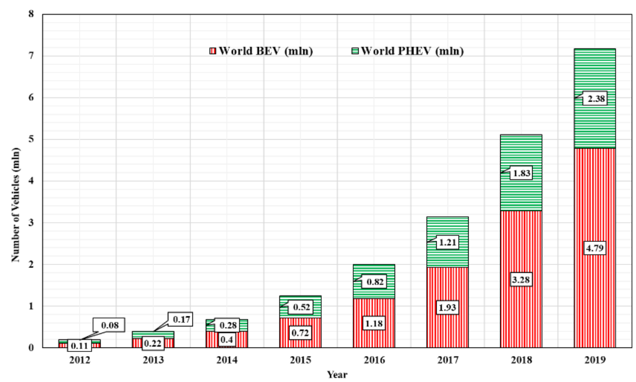


**Fig. 1:** The growth dynamics of the number of electrified vehicles between 2012 - 2019 [1]

## II Critical analysis of the BEVs available in the market

The vehicle performance depends mainly on the power of traction source and the vehicle weight. To determine the category of the vehicles where BEVs are wide spread, the analysis of the BEVs in the weight range of 1000 and 2750 kg were performed. Fig.2 shows that almost 56 percent of BEVs are located in the weight range of 1500 to 2250 kg. These corresponds to C and E categories according to the European car classification [6]. Vehicles in the SUV category make up a large percentage of about 22 percent, as this category holds the highest share in the current new vehicle sales [7].

The maximum power of the traction source of BEVs highlights the transient performance (acceleration, regenerative braking etc.) of such vehicles. Instead, the continuous

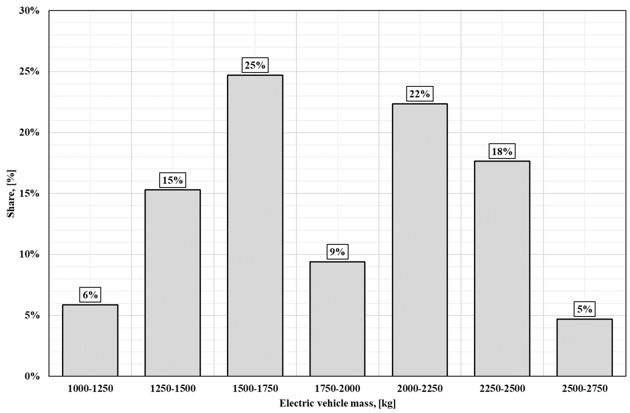


**Fig. 2:** The weight distribution of BEVs available on the market

power indicates the vehicle steady-state performance such as maximum or constant speed, gradeability and others. Therefore, based on the data collected the maximum power of the electric motors of the BEVs were arranged in Fig.3. It shows that the most of the available BEVs have the electric motors in the range of 100-400 kW. Almost 70 percent of BEVs in the market have the electric motor power in this range. This means the particular design of the electric motors and their inverters are required to satisfy the required electric motor power output. This could be the main reason why the permanent magnet electric motors are widely used in BEVs use to high power outputs for a given geometrical dimensions [8]. BEVs with power below 50 kW and above 600 kW are rarely used. These high-power BEVs mainly belong to Tesla models. Another important indicator is the specific power that is calculated as a ratio between maximum power and the vehicle weight. Higher specific power indicates the better acceleration and overtaking performance of the vehicle.

Fig.4 shows the distribution of the specific powers for

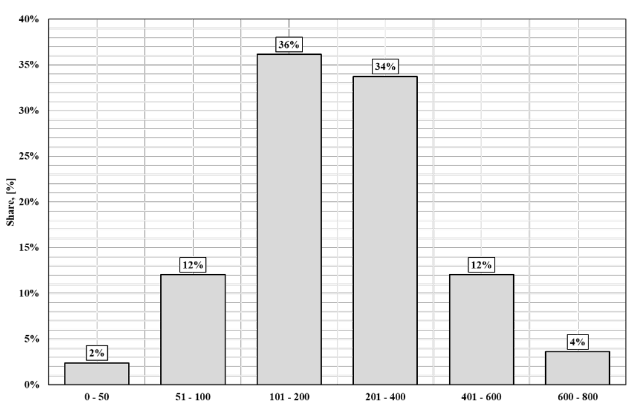


**Fig. 3:** The distribution of BEVs electric motor power

the considered BEVs. The most common specific power has been found to be in the range of 50 - 150 W/kg and it accounts for almost 75 percent of all BEVs. The specific power required to accelerate to 100 km/h from a standstill in 12 s is around 40-50 W/kg [9].

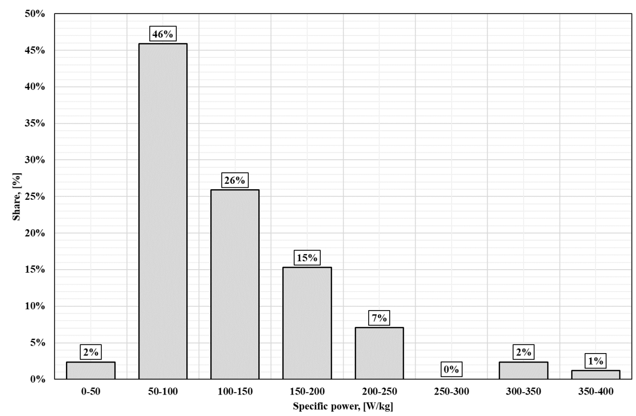


**Fig. 4:** The distribution of BEVs electric motor's specific power

This means that the BEVs currently available on the market have acceleration performance superior to the minimum acceleration requirement set by Partnership for a New Generation of Vehicles [10]. As the share of BEVs on the roads increases, the city traffic will consist of mixed performance vehicles (conventional and BEVs). Therefore, the performance of the BEVs has to meet minimum requirements set to conventional vehicles. In this work, the following performance requirements are considered: acceleration time to reach 100 km/h, maximum speed, overtaking performance and gradeability. As it was mentioned before, the main performance requirements sued in the paper are listed in PNGV. The analysis of technical characteristics of considered BEVs are summarized as a plot of total power available at the wheels vs. vehicle weight (Fig.5).

The points indicated as BEV are collected data points of total electric motor power. The lines Z60-8 and Z60-12 represent power values required to accelerate from 0 to 60 mph (96 km/h) in 8 and 12 s, respectively. The line Vmax = 137 km/h shows the power required to drive the vehicle with given weight at maximum speed of 85 mph (137 km/h). The line WLTC represents a maximum power values required to accomplish a WLTC homologation cycle. It can be indication of the power required in daily usage of the vehicles. Fig.5 shows that the most of the considered BEVs have enough power to accelerate to 96 km/h in less than 8 s.

The electric motor maximum powers can satisfy the power

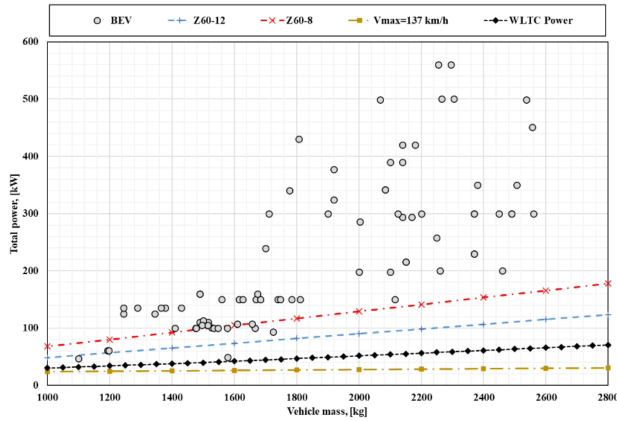


**Fig. 5:** The data points for electric motor total power vs. BEV weights

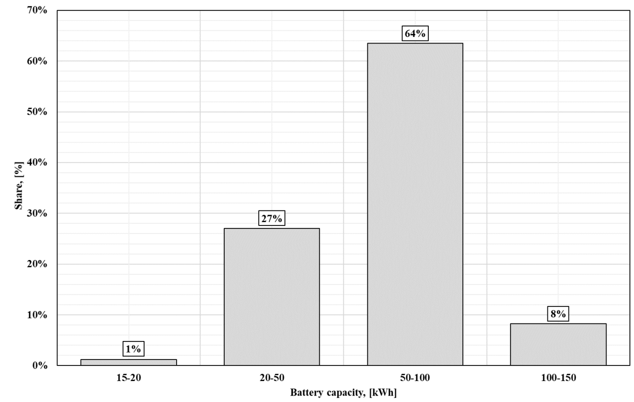


**Fig. 7:** Distribution of battery capacity of BEVs available on the market

requirement of WLTC driving cycle. As can be seen from the graph, the power of all the BEVs analysed are sufficient to reach a maximum speed of 137 km/h. It should be noted that the most of the BEVs have the electric motors that are oversized in terms of power. In daily usage, most of the time these vehicles do not utilize all the rated power they have. It is known that the electric motors have lower efficiency at low torque regions.

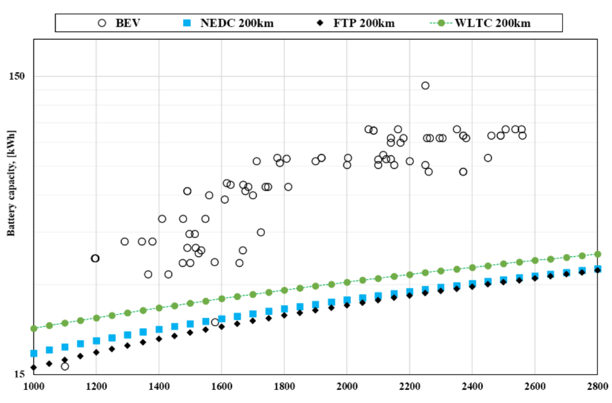


**Fig. 6:** Battery capacity analysis for the BEVs available on the market

Therefore, this oversizing of the electric motor could result in higher losses during the daily driving scenarios. The driving range of BEVs depends on the battery capacity as it is only source of energy in such vehicles. Therefore, the battery capacities were analysed. Fig.6 shows a dependency of the battery capacity of existing vehicles from the vehicle weight.

It is evident that as the mass of vehicle increases the battery capacity increase, as well. Three lines indicate the battery capacities required to fulfil the required driving range on different homologation cycles. In this analysis, driving range of 200 km and such homologation cycles as FTP, NEDC, and WLTC are considered. Fig.6 shows that most of the BEVs can run more than 200 km. As it can be seen from the figure, the battery capacity should be at least 30 kWh to accomplish this driving range depending on the vehicle weight. Fig.7 summarizes that the existing BEVs have a battery capacity in the range of 50-100 kWh. The share of these range accounts for almost 65 percent of the total available BEVs on the market.

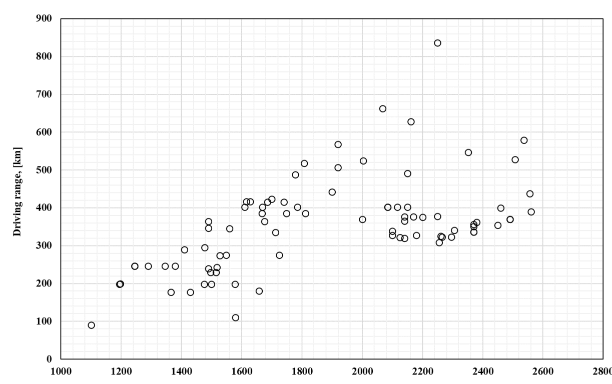


**Fig. 8:** Driving range analysis for the BEVs

The technical specifications include the data for the driving range, which is shown in Fig.8. Moreover, the figure shows that the majority of the BEVs can have driving range more than 200 km as it was predicted from the battery capacity installed on them (Fig.6). Fig.9 shows the distribution of the driving range for the considered BEVs. Almost 87 percent of existing BEVs have a driving range more than 200 km. However, more than half (57 percent) of the vehicles have a driving range of 200-400 km. One of the main advantages of the BEVs over conventional petrol fuelled vehicle is the possibility of recharging it at home or during the parking. This gives additional freedom in reducing the capacity of the battery, as most of the daily travels do not exceed 200 km.

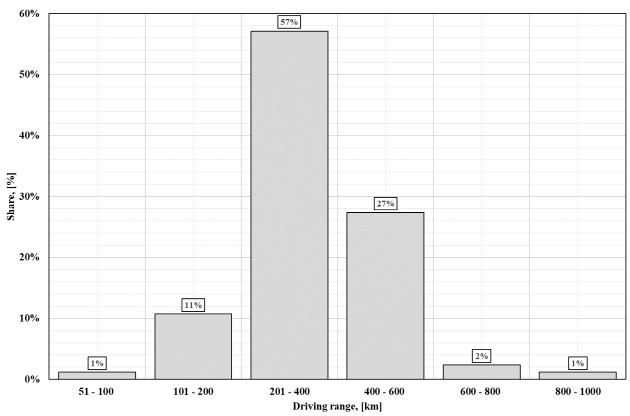


**Fig. 9:** Driving range distribution of BEVs

## III CONCLUSIONS AND FUTURE WORK

This paper present analysis of BEVs available on the market, by collecting the technical data for more than 80 BEVs. As the share of BEVs on the roads increases, the city traffic will consist of mixed performance vehicles (conventional and BEVs). Therefore, the performance of the BEVs has to meet minimum requirements set to conventional vehicles. It was found that almost 75 percent of electric motor specific power of existing BEVs are in the range of 50-150 W/kg, which is enough to satisfy the minimum acceleration requirement. It should be noted that the most of the BEVs have the electric motors that are oversized in terms of power. In daily usage, most of the time these vehicles do not utilize all the rated power they have. It is known that the electric motors have lower efficiency at low torque regions. Therefore, this oversizing of the electric motor could result in higher losses during the daily driving scenarios. It would be interesting to understand the influence of having the same total rated power but with two or more electric motors. This might allow using two smaller electric motors with the feature of deactivation of one when low torque is needed. One of the main advantages of the BEVs over conventional petrol fuelled vehicle is the possibility of recharging it at home or during the parking. Therefore, the influence of sizing the battery based on daily trip length could be investigated.

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