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Review Article

Car Parking Regulations Intended for Hybrid and Electric Vehicles

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Abstract

While improvement works for internal combustion engines intended for decreasing exhaust gases which cause on-road vehicles based climate change are going on, the use of alternative fuel and alternative energy resources is on the increase. But there are certain criteria to negotiate for this kind of vehicles to be approved. These are the constraints such as; high initial investment cost for vehicles, limited fuel storage capacities and limited range. In addition to these, the problems such as safety and liability, high fuel filling costs, limited fuel/charging stations, infrastructure (network improvement) investments, developments in current trends mustn't be ignored. In addition to conventional petrol and diesel engines, hybrid and battery electric vehicle practices are becoming widespread in today's cars. Another issue is that cars are parked during 90-95% of the day and parking functions require a number of structural changes. In this context, charging units and safe parking conditions are required to be provided in the parking lots in order to perform the charging operations of battery electric vehicles (BEV), and especially plug-in hybrids (PHEV, ReEV, EREV and RXBEV). In this study, the safety and functional integrity of external plug-in hybrid and electric vehicles and charging units as well as parking lots will be examined.

Keywords: Hybrid vehicles, electric vehicles, car parking, charging unit

1. Introduction

While improvement works for internal combustion engines intended for decreasing exhaust gases which cause on-road vehicles based climate change are going on, the use of alternative fuel and alternative energy resources is on the increase. But there are certain criteria to negotiate for this kind of vehicles to be approved. The constraints such as; high initial investment cost for vehicles, limited fuel storage capacities, limited range, safety and liability, high fuel filling costs, limited fuel/charging stations, infrastructure (network improvement) investments, developments in current trends mustn't be ignored (Romm, 2006).

World's largest car market China, has announced its plan of zero emission recently. With this change of vision, the automotive world has started to shift towards a new tendency. In another respect, countries such as France, Germany, Norway, The UK and Canada have announced that they will introduce certain restrictions on the use of petrol and diesel cars in the near future (AA, 2018).

Today, there are about 1,3 billion vehicles in the world for a population of about 7,65 billion people. That means 169 cars per 1000 people[2] (Demir et al., 2017). Considering the 120-year history of the car, massive trend of hybrid and electric vehicles can be regarded new. Approximately 22-23 years[3] ago, hybrid and electric vehicles began to appear massively on the highway. Today, we are in the days when cars with new generation electric motor, renewable energy, inter-vehicle communication (C2C or V2V) technologies are produced and autonomous driving cars are tested (Demir and Öz, 2018).

The global electric vehicle market has exceeded 2 million in 2016 after exceeding the 1 million limit in 2015. In 2016, more than 750,000 new generation vehicles were sold worldwide. It is estimated that about 3 million hybrid electric (HEV), plug-in hybrid (PHEV), battery electric (BEV) vehicles and hybrid buses (Ebus HEV) and battery electric buses (Ebus BEV) in 2017 can reach **27** million level by 2027 (ICA, 2017).

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[2] The statement of ***"There are approximately 1,250 billion vehicles around the world for a population of 7.5 billion. That means 166 cars per 1000 people."*** has been updated and included in the article.

[3] The first hybrid car is the Toyota Pruis. It was built in 1997 (Toyota, 2018). The first electric vehicle is the EV1 model of the GM. Its production started in 1996, sold by leasing and withdrew in 1999 (Edelstein, 2013).

Cars, without doubt, stay inactive at the same place for longer than people. Because cars spend 90-95% of the day, which is 22-23 hours (Litman, 2006; Yardım, 2009; Demir & Gümüş, 2011), at car parks. These approaches demonstrate the importance of regulated car parks, which are the home of vehicles. In order to charge electric vehicles in car parks, where the charging station is installed, a certain amount of time is required depending on both the battery technology used and the type of charging. Because charging times of the batteries are quite long with the current technology. Another issue is the electrical power drawn during charging. In the new future, there will be inevitable scenarios such as charging 100 cars in one car park at the same time (Demir, 2011). Besides, both long charging times of vehicles and high electrical power drawn during fast charges are the infrastructural issues to be improved. The charging time of the 10 kWh plug-in hybrids (PHEV) at 110 V/15 A can reach up to 8-10 hours but with fast charges at 110 V/50 A or 220 V/30 A it can take less than 2 hours (Mi & Masrur, 2018). As of 2018, battery electric vehicles (BEV) which can offer a range of 300 km, require around 20 minutes of charging and they are expected to take less than 15 minutes to be charged for a range of 400 km in 2020s (ING Economics Department, 2017). The power of the charging units is 50 kW in the 2015s; they will rise to 150 kW in the 2020s and to 250 kW in the 2025s (ABB Group, 2016). Fast charging networks over time will be based on the Combined Charging System (CCS) technology to DC charge up to 350 kW (IRENA, 2017). These values provide insight into the level of improvements to be implemented in the network. In addition, networks need to be configured with smart grid.

In this study, charging units and safe parking conditions to be deployed in the parking spaces for charging of plug-in hybrids (PHEV, ReEV, EREV and RXBEV) and battery electric vehicles (BEV); the safety and functional aspects of the trio of these vehicles, charging units and the car park will be addressed.

2. Plug-In Hybrid and Battery Electric Vehicles

In this section, plug-in hybrid and battery electric vehicles (PHEV and BEV) will be mentioned.

2.1. Hybrid Electric Vehicles (HEV)

According to the definition given by the technical committee of the International Electrotechnical Commission; hybrid electric vehicle (HEV) is defined as a vehicle in which energy is supplied from two or more energy sources and at least one of these energy sources provides electrical energy (Demir, 2011). Currently liquid or gas fossil fuels are used in HEVs. System efficiency is increased by the electric motor; fuel consumption is reduced by recovering the kinetic energy during braking by the recovery braking system and also it is possible to arrange the torque and speed of the internal combustion engine (ICE) under normal conditions during normal driving. ICE can tolerate the range disadvantages of battery electric vehicles by providing a long range to the vehicle (Mi & Masrur, 2018). HEVs are categorized as; series, parallel, series-parallel[4] and complex according to power transmission configuration; micro, mild, full/strong, plug-in (PHEV) and extended range (EREV) hybrids according to the degree of hybridization (Table 1).

Table 1: *Comparison of HEVs according to the degree of hybridization*

	Micro Hybrid	Mild Hybrid			Full Hybrid	Plug-in Hybrid	Battery Electric
Electrical power (kW)	2-4	10-15	<21	15-21	25-60	40-110	60>
Voltage level (V)	12	48	48	<160	150-350	<360	<450
Only electric range - km	0	0			5-10	<50	200-480[5]
Estimated CO_2 benefit %	5-6	7-12			15-20	>20	100

(Ref: Blessing, 2014; x-engineer.org, 2017; ING Economics Department, 2017; IRENA, 2017; Demir & Öz, 2018)

PHEVs[6] can be driven by traction batteries in the vehicle and allow the range of the vehicle to be increased. The limited range problem, which is one of the main reasons why BEVs are not preferred, is solved by gasoline or diesel engines in PHEVs. For this reason, PHEVs are also referred to as extended range electric vehicles in some studies. Blended PHEVs have become more popular both due to reduced system cost - smaller electric motor, smaller battery pack and lower battery power ratios- as well as fuel economy optimized for different driving conditions. When compared to the extended range hybrid vehicles (hybrid with range extender – RXBEV, range extended electric vehicle – ReEV or EREV), blended PHEVs generally use parallel and complex configurations. In these configurations, both the ICE and the electric motor can drive the wheels directly (Mi & Masrur, 2018).

[4] Hybrid electric vehicles are categorized as series, parallel and series-parallel according to power transmission configuration, and categorized as series, parallel and complex in some sources. Thus, in the literature, sometimes ‘complex’ or ‘combined’ expressions can be used instead of ‘serial-parallel’. An example of this is the Toyota Prius (Demir & Öz, 2018).

[5] Today, the range of middle-class battery electric vehicles is about 200 km. This situation is expected to reach 350 km by 2030 (Clean Energy Ministerial, 2017). However, vehicles with higher range are available today. These vehicles are stated to have a range of ≥250 km (Hülshorst et al., 2017) and 200 - 300 km (ING Economics Department, 2017). It is also stated that the average battery storage energy in PHEVs will be 30 kWh and 60 kWh in BEVs in 2030 (IRENA, 2017).

[6] Plug-in Hybrid Electric Vehicle (PHEV) will be called “external rechargeable hybrid vehicle” in this study (Demir & Öz, 2018).

The battery used in the PHEVs has a higher capacity than the battery of the full hybrid vehicle. Since it is equipped with a more advanced battery, thermal management has a more complex monitoring system to control system loads and other parameters. In this type of vehicles, the task of the selected ICE is basically to charge the battery while driving, so it can be stated that the electric motor is the primary drive element. Compared to conventional vehicles with ICEs, these vehicles can provide 40-50% fuel economy (Sayın, 2011). Thanks to its large batteries, more braking energy can be recovered and provides flexibility for the engine to operate under optimal conditions. However, electric drive for all driving conditions sometimes does not benefit from the limited energy use of the battery. However, electric drive for all driving conditions sometimes does not benefit from the limited energy use of the battery (Mi & Masrur, 2018).

2.2. Battery Electric Vehicles (BEV)

In BEVs, the wheel is only driven by the electric motor. And the power supplied to the electric motor is provided by energy storage systems. Therefore, since no fuel is consumed in BEVs, no emission is released and these vehicles are called ***"zero emission vehicles from battery to wheel"***. In particular, as renewable energy input increases in electrical energy production, environmentalism from the well to the battery is also improved. In addition, these vehicles have very low noise emissions as well as fuel and maintenance costs compared to ICEs. As there aren't many moving elements, they do not need to adjustment or oil change (Ünlü et al., 2003).

The BEVs are driven by at least one electric motor. Electric vehicles can be configured as front-wheel drive, rear-wheel drive or 4-wheel drive. Basically, it can be defined in two main concepts. It is possible to drive electric motors from the wheel hub and drive only one electric motor in the central power transmission (VW Academy, 2013). Electric motor, in the drive structure of the central electric motor, drives gearbox, axles (in some applications also cardan shafts) and wheels. Differential is used on each drive axle. In addition, reduction requirements in BEVs are provided by reduction gears.

An important factor that prevents the spread of BEVs is the vehicle performance. Batteries that drive vehicles are quite heavy and they limit the range of the vehicle. While conventional vehicles travel approximately 550-800 kilometers with a full tank, BEVs offer an average range of 150-250 km after charging. Another obstacle is the filling times of the tank. While the tank of the conventional vehicle can be filled in 1-2 minutes; BEVs require about half an hour for fast charging, 3-4 hours for medium-speed charging and about 5-12 hours for slow charge (Demir & Başeğmez, 2018).

3. Charging Units and Deployment Principles

Battery technology and charging infrastructure are the main determinants of the development of PHEV and BEVs. The charging process can be basically classified as slow, normal, fast and ultra-fast charging. Also, wireless charging has also been developing in recent years. Charging time of 10 kWh plug-in hybrids (PHEV) at 110 V/15 A can reach approximately 8-10 hours and this time can be shorter than 2 hours with fast charges at 110 V/50 A or 220 V/30 A (Mi & Masrur, 2018). As of 2018, battery electric vehicles (BEV), which can offer a range of 300 km, take around 20 minutes to be charged and they are expected to take less than 15 minutes to be charged for a range of 400 km in the 2020s (ING Economics Department, 2017). The power of the charging units is 50 kW in the 2015s; they will rise to 150 kW in the 2020s and to 250 kW in the 2025s (ABB Group, 2016). Fast charging networks over time will be based on the Combined Charging System (CCS) technology to DC charge up to 350 kW (IRENA, 2017). By using DC electricity, the vehicle charging times can be reduced to as low as 15 minutes. Table 2 shows the EVSE charge levels, Figure 1 shows the AC and DC charging units and Figure 2 shows the deployment of public charging stations.

Table 2: EVSE charge levels (Platte River, 2017)

EVSE Type	Power Requirement	Panel Service	Approx. Equipment Cost
Level 1	1.8 kW	15-20 Amp	$250 +
Level 2	6.6 kW	30-80 Amp	$500-2000* +
DCFC	50+ kW	120+ Amp	$6,500+

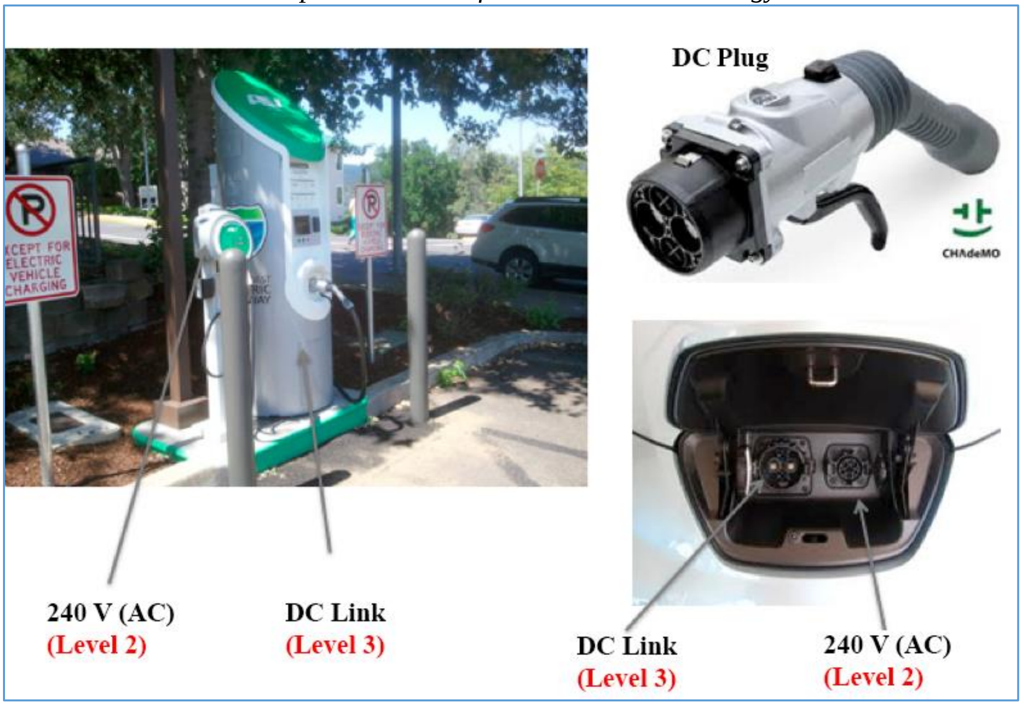

Figure 1. AC and DC charging units (Kintner, 2013)

Figure 2. Public charging stations (Kintner, 2013)

4. Car Parking Regulations Intended for PHEVs and BEVs

Basically the future of PHEV and BEV market will be determined by satisfactory solutions to the issues such as; battery technologies and replacements, chargers (charging current: AC and DC applications with slow, medium, fast and ultra-fast charging), parking/installation locations where the device will be deployed, intelligent network management and electricity supply, pricing of charging services, incentive legislation to ensure healthy conduct of all these procedures (Demir, 2011-a; Gurbetci et al., 2014). The long charging times of PHEVs and BEVs have also brought about the application of battery exchange. Some manufacturers try to overcome this problem with “quick drop” battery exchange stations (Doğu, 2011).

One of the most important issues affecting the future of PHEVs and BEVs is undoubtedly bringing the qualifications of paid or free car parks to a level that meet the needs of these vehicles.. For this;

- Dedicated spaces,
- Choosing a suitable area with minimum pedestrian traffic,
- Choosing slow, medium and fast charging units based on the location and condition of the car park (centrality, suitability for multiple-use, mobility, income level) and proximity to transfer points,
- Making necessary arrangements for disabled drivers to use these units[7],
- Horizontal and vertical markings,
- Protection of charging units from rain, flood and natural disasters,
- Providing valet service,
- Illumination of the area where the unit is placed,
- Banquettes to protect the unit,
- Providing the shortest working distance,
- Taking ergonomic and easy to use measures,
- Measures against cold and freeze in surface parking,
- Taking necessary measures against the threat of vandalism,
- Providing ventilation requirements when necessary,
- Matters and services such as provision of reasonable limits and appropriate pricing options must be provided for the pricing of charging and the car park that will be used during charging.

Also;

- Transfer of information such as charging units and usage status to traffic density map and geographic information systems,
- Calculation of effective utilization rates of charging units,
- Determining the maintenance costs of charging unit and equipment,
- Subjects such as gathering information for insurance work against faults and failures will also play a key role in the efficient use of the charger (Gurbetci et al., 2014).

Costs arising from air pollution are on the increase. When the cost of health expenses, losses due to deaths, building damages, expenses for nature and biosphere, cost of pollution caused by noise pollution, cost of damage caused by noise, cost of measures taken to reduce the risk of climate change, cost of damages caused by increasing temperature and energy taxes , annual taxes on established infrastructure facilities (Aybar, 2010) are considered, vehicles such as PHEV and BEV seem to be the mandatory choice of our world.

5. Conclusions

Day by day, costs arising from air pollution are on the increase. When the cost of health expenses, losses due to deaths, building damages, expenses for nature and biosphere, cost of pollution caused by noise pollution, cost of damage caused by noise, cost of measures taken to reduce the risk of climate change, cost of damages caused by increasing temperature and energy taxes , annual taxes on established infrastructure facilities are considered, vehicles such as PHEV and BEV are the mandatory choice of our world. In order for the business model of these vehicles to be profitable, it is necessary to build an infrastructure for these vehicles, such as charging, car park, network, pricing; and correspondingly, both providing necessary commercial facility and applicable legal regulations will be encouraging.

Abbreviations

BEV	Battery Electric Vehicle
C2C	Car to Car Communication
HEV	Hybrid Electric Vehicle
ICA	International Copper Association
ICE	Internal Combustion Engine
PHEV	Plug-in Hybrid Electric Vehicle
ReEV/EREV	Range Extended Electric Vehicle – Extended Range Electric Vehicle
RXBEV	Hybrid with Range Extender
V2V	Vehicle to Vehicle Communication

[7] Access to charging stations and connection equipment must be considered to enable disabled drivers to charge their electric vehicles. For this purpose, the electric vehicle attachment equipment should not be positioned higher than 120 cm and lower than 60 cm from the parking surface (Anonymous, 2009).

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