Electrical Vehicles and Charger Stations: State-of-Art

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ABSTRACT

This paper introduces the state-of-art of electrical vehicles, hybrids and charger station currently available. Based at Corredor Verde project, a partnership among SENAI CIMATEC, GESEL, SINAPSIS, UFABC and ABB by 22/2018 ANEEL/COELBA work call aiming the implementation of 17 charger stations between Salvador/BA and Natal/RN cities. It is discussed those technologies challenges along more than 100.000km to be covered by the stations and project´s vehicles. Furthermore, the study and usage of those technologies will permit a new business model study based at electrical network measurements and vehicle behavior over urban and highway scenario, therefore allowing a new scalability perspective about the implementation of this new transport mode in Brazil, where allied with government and industry this new transport mode is also drawing attention from of electrical companies once this mode presents a unknow scenario in terms of impact over the power supply demand, electrical transmission and distribution required to supply it. As main conclusion of this paper it is quote the strong and weak side of currently architectures applied onto vehicles and charger stations, and a briefing regarding the battery's technologies, a stress point of this new transport mode.

Keywords: electrical vehicle, charger stations, corredor verde.

INTRODUCTION

With society's growing concern about the impacts of man on the environment and its consequences for the present and future quality of life, society, as a consumer, has become, day after day, more critical in relation to the origin of consumer products and its environmental and energy impact during its use [1].

Society has been seeking and valuing more and more consumer goods that have a lower environmental impact and, therefore, better social acceptance, and on the other hand eliminating brands and products that do not meet their longings for sustainability.

At the epicenter of this society / consumer behavioral revolution, the automotive industry stands out. With its millions of internal combustion vehicles (VCI) produced year by year; emitting tons of carbon monoxide (CO) and nitrogen oxides (NOx) in the atmosphere in all parts of the planet, promoting harmful effects to health daily in regions of high concentration of vehicles, such as breathing difficulties and globally contributing to the effects of heating global. In this context, the automotive industry, with its high penetration in society's daily life, is increasingly required to present solutions with low environmental impact.

The development and improvement of electric and hybrid vehicles are a response of the automotive industry to this desire of the consumer market and an attempt to adjust to a new reality in society, leaving aside its secular identity in the use of fossil fuel propellants and entering the electric world. In this context, this work aimed to present the state of the art of electric vehicles, hybrids and charging stations currently available.

ELECTRIC VEHICLES

The technology of hybrid and electric cars is an old technological innovation, although there have been important technological advances and despite advances in technologies embedded in modern vehicles and improvement of batteries, in essence the basic concept has not changed. Also called electric vehicles (EV), they use one or more electric motors for traction and propulsion. Unlike conventional vehicles that use internal combustion engines for gasoline, alcohol or diesel, electric cars and trucks use engines powered by electricity, which is stored in batteries or fuel cells.

Electric vehicles have already lived on an equal footing with internal combustion vehicles, but for commercial and political reasons and, above all, the invention of the series production system, have been abandoned. An example to be cited was in 1903 where there were about four thousand cars registered in New York City, 53% of which were steam, 27% gasoline and 20% electric. In 1912, when the electric car fleet in that city reached a peak of 30 thousand units, the number of gasoline cars was already thirty times greater [2].

The environmental aspect is fundamental for the implementation of electric vehicles since, the transport sector is the one that represents 41.9% of the emissions attributed to the energy sector [3]. Electric Vehicle are among several possible vehicle technologies that produce little or no greenhouse gas emissions.

The energy efficiency, thermal efficiency and economic viability of electric vehicles makes it predominate over other options. The various options do not imply, however, an ease in replacing current fossil fuel vehicles. Several factors must be considered, such as: cost of vehicles; availability of electricity and the levels of emissions required to generate it; relationships between the technical and operational aspects of these vehicles and consumer preferences, aspects related to the safety of these vehicles and other economic aspects [3].

Regarding air pollution and the emission of gases that contribute to the greenhouse effect, electric cars and trucks are more environmentally friendly than cars with an internal combustion engine. The use of electricity allows, for example, the development of hybrid propulsion with a lower emission of pollutants and greater efficiency in the use of fuel until a scenario of zero emission with the use of 100% electric systems [3].

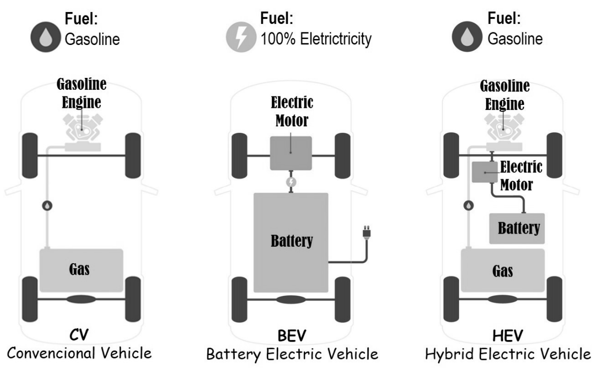

Figure 1 - Electric Vehicle vs. Internal Combustion Engine [4]

In Figure 1 we have a comparison between conventional internal combustion cars (ICE) and Electric Vehicle (EV).

The differences between a vehicle with ICE and a EV are large. To start the evaluation, in an ICE the system mixes air and fuel causing an explosion, activates a piston that in turn activates a crank and consequently makes the engine turn. In the electric motor (EM) there is no burning or explosion, it works with a set of coils that works with the inversion of magnetic fields and this dynamic makes the axis always rotate [5].

In the ICE the acceleration happens with a throttle that allows a bigger entry of air to combine the fuel and cause a bigger explosion, thus giving more power to the engine. In EM the control is given through the amount of energy that is sent to the motor. The higher the frequency, the faster the motor spins and the lower the frequency, the slower it spins [5].

Another noticeable difference between ICE and EM is that the combustion engine needs a transmission system, the transmission, to take the vehicle out of inertia. The EM has the ability to move the vehicle at low speed without the need to reduce gears. The electric motor car uses the gearbox only to reach higher speeds [5].

To improve energy efficiency, some electric models take advantage of the car's mechanical forces to recharge the batteries. In ICE, when you step on the brake, all energy is dissipated as heat in the brake and this energy is lost. In the ME it is possible for the motor itself to become a generator and do the reverse cycle, that is, the energy feeds the batteries to be used again, it is not possible to recover everything, but it does recover a good part [5].

At the end of the sixties and the beginning of the seventies, when the combustion car was considered one of the main sources of air pollution in large cities, public opinion started to turn to environmental problems and electric cars started to attract attention again. large automakers. The 1973 oil crisis highlighted the need to develop and improve technologies that were not dependent on oil. However, it was only in the late 1980s and with the intention of reducing pollution in large cities, that attention was once again turned to electric vehicles. From then on, the concept of sustainable development gained strength and the industry's focus began to focus on solutions for using alternative energy sources and the development of new transport and mobility technologies [2].

Given this scenario, the development and commercialization of electric cars was seen as a very important alternative for sustainability.

EVs are automobiles powered by one or more electric motors, they can be classified in some categories. The main types of electric vehicles are:

• Battery Electric Vehicles (BEV)

• Hybrid Electric Vehicles (HEV)

• Plug-in Hybrid Electric Vehicles (PHEV)

BATTERY ELECTRIC VEHICLES

The BEV has a system in which the electric motor is the only source of propulsion. Large batteries can be recharged through regenerative braking and connection to the mains. Since BEV has an architecture where the propulsion system is completely electric, the driving range (distance it can travel) is based on the capacity of the battery. BEV has excellent benefits, such as zero emission and better vehicle performance compared to (HEV), which can be charged with low-cost electricity produced by any type of plant, including renewable energy [6,7].

However, despite these advantages, BEVs also face major challenges. Storing electricity (batteries) is still expensive and charging takes relatively long. Thus, like conventional vehicle engines, advanced batteries in electric vehicles are designed for relatively long service life, but eventually wear out. The Nissan Leaf battery, for example, is guaranteed for 8 years or 160,000 km, whichever comes first [8].

Despite EVs practically zeroing out the emission of pollutants during running-in, the environmental impact of their batteries must be considered, especially in their manufacturing and end of life disposal processes.

The development and technological advancement of battery-powered cars are linked to the development of batteries as they give the electric vehicle a differential in terms of autonomy in relation to its fossil competitors.

The Electric motor, the power electronics, the battery and charging systems are the most critical technologies for EVs. These components undergo major changes and improvements throughout the vehicle development process [1].

The popularization of EV is highly dependent on technological advances for batteries, since vehicle autonomy is directly affected by its charging capacity, recharge and useful life [6].

In addition to the aspects highlighted above, the popularization of EVs depends on their final sales value to the consumer, that is, if compared to combustion vehicles, the sales values practiced for electric vehicles are higher; batteries being one of the great villains for this price difference, justifying, therefore, the significant expense of car manufacturers in developing new technologies applied to batteries.

With the new research and new investments, an improvement in the energy efficiency of the batteries is expected to be between 70% to 75% between 2020 and 2022 when compared to the batteries currently used. Also highlighting the potential to triple energy efficiency and reduce the cost per KW by 70% in 2030 [9].

Another factor of great impact on EVs is the question of battery life, since it is vitally important in financial terms since they represent between 20% and 25% of the vehicle's value [9]. Thus, a short service life means a high cost of exchange in addition to a frequency of replacement and disposal that raises serious concerns in the environmental issue since the proper disposal of batteries at the end of their useful life is a major issue to be resolved.

Some automakers have already announced the construction of factories to analyze, reuse and recycle used batteries from their electric cars. Some initiatives are for the complete recycling of other partial components of these batteries [10].

Batteries for Electric Vehicles

Despite the great importance of batteries and massive investments that the development and improvement of them has been attracting, their development dates back to 1859, being the first rechargeable lead-acid batteries invented by Gaston Planté and later transformed into a marketable product by Camille Alphonse Faure by around the year 1881 [6]. Figure 2 shows the battery development timeline.

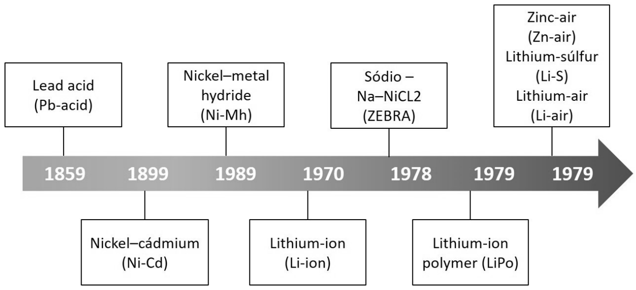

Figure 2 - Development timeline of EV battery [6]

From the 1970s, with the invention of lithium batteries, there was an acceleration in the development of new battery technologies. The lithium battery is used in electric vehicles, cell phones and notebooks.

Invented in 1859 by the French physicist Gaston Planté, lead-acid batteries were the first batteries for commercial use. As for the chemical process in lead-acid batteries, this occurs through the combination of lead and acid electrodes, used to generate electricity and has a density of 35Wh / kg. The lead-acid battery is a mature and inexpensive technology. However, some disadvantages can be seen in lead-acid batteries, such as low energy density, that is, low storage capacity, their weight and requires routine inspection of the level of electrolytes (battery water) in addition to causing damage to the environment. environment when they are not disposed of properly [6].

With the advancement of studies and technology, the lead-acid battery has been replaced by a nickel-based battery, such as nickel-cadmium (Ni-Cd) and nickel-metal hydride (Ni-MH) in order to reduce weight in 100% electric vehicles [11].

Nickel batteries use a relatively mature technology and have a higher energy capacity compared to the lead-acid battery. Until the past decade, the majority of EV used a Nickel-based battery, mainly Ni-MH. The density of Ni-Cd batteries is 50-80Wh / kg and Ni-Mh batteries are 70-95Wh / kg. [6]. However, there are disadvantages of this type of battery such as: low charge and discharge efficiency, high self discharge rate, low performance in cold weather and memory effect.

Nickel-hydride cylindrical batteries differ from nickel-cadmium batteries only in the cathode which is a Metal Hydride. The memory effect proved that Ni-Cd batteries are not suitable for application in VE as they require high charge and discharge rates. In addition, the Ni-Cd battery has high rates of toxicity in its components, making it as well as lead-acid batteries harmful to the environment. Ni-MH batteries, on the other hand, stand out negatively in the time to complete the recharge cycle and for discharging even when not in use [6].

Called thermal batteries, the nickel-sodium (Na – NiCL2) battery technology, which uses NaCl, is part of a class of batteries also known as the molten salt battery. These batteries became known in 1978, during the ZEBRA (Zeolite Battery Research Africa) program, in South Africa. They have a high energy density of 70-95 Wh / Kg [6].

The ZEBRA battery needs to work at temperatures ranging from 270 to 350 oC, this requires that the battery is constantly being powered from a charge source because, if it does not, it will take one to two days for the batteries to charge again . This time is necessary for the battery to warm up. The external temperature of the ZEBRA battery is between 5 and 10 oC above the ambient temperature [29]. The extreme operating temperature has become one of its biggest negative points, since there is a greater complexity in its thermal and safety management [6].

The Nickel-Sodium Battery uses abundant raw materials in its composition (nickel, iron, aluminum oxide and sodium chloride - table salt), which are relatively low-cost and easy to recycle.

Lithium-Ion Batteries are the state of the art batteries used in electric vehicles. The lithium-based battery is one of the most promising technologies in the area, as it has a high energy/power density, is light, financially more accessible, with less toxicity and capable of accepting fast charges and recharges with reduced loss of efficiency. However, current lithium-based battery packs also have their limitations, especially in a malfunction scenario where there is a risk of fire and explosion [12].

Lithium batteries have several configurations such as: Lithium-Ion-Cobalt; Lithium-Ion-Manganese; Lithium-Ion-(Phosphate) Iron (Magnesium); Lithium-Ion- (Nano) Phosphate; Lithium-Ion-Titanium Oxide (LTO - Lithium Titanium Oxide); Lithium Polymer; Lithium Air.

Among the various technologies the most used for application in electric vehicles are the Lithium-Ion- (Nano) Phosphate, Lithium-Ion-Titanium Oxide and Lithium Polymer batteries [13].

HYBRID ELECTRIC VEHICLES

The HEV proposal is an intermediate solution between conventional combustion-propelled vehicles, ICE, and purely electric vehicles. Despite the fact that HEV are more expensive than conventional ones, they are still much cheaper than BEV.

In recent years, the industry has accelerated the development of hybrid electric motors. This trend is observed in all segments of the transport industry and particularly in the automobile industry. Several factors motivated these changes, among them are the environmental objectives, market strategies, fuel costs including the scarcity of natural resources. Seeking to meet these needs and using new technologies, a hybrid vehicle was developed that could use combustion engines in conjunction with electric engines, thus creating HVEs [7].

HEV have two types of engines and have a mechanism that reduces fuel consumption, generating less pollutants and, at the same time, is more powerful than BEV. As it is a combination of the two types of engines, they have individually smaller volume/size than conventional combustion engines. Hybrid vehicles do not have cables for connection to the power grid. The battery is recharged from the combustion engine itself and from mechanisms such as regenerative braking. In HEVs it is necessary to fill the vehicle with fuel. Basically the difference between the HEV and the PHEV is in the electrical components that are even bigger (such as the engine, alternator and battery), and make it possible to operate entirely in electric mode with the battery being able to be recharged directly into the network [7].

There are different configurations of hybrid systems for electric vehicles. As for architecture they can be Series, Parallel and Series-Parallel. As for the level of hybridization, they can be Micro, Moderate or Complete. The size of the combustion engine will depend on the level of hybridization. The larger the electric motor, the alternator and the battery, the smaller the combustion engine. In Figure 3 we have a series HEV [7]

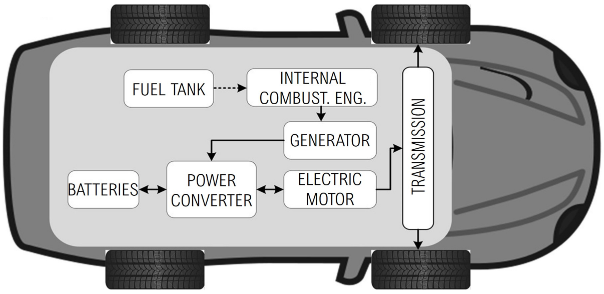

Figure 3 - Hybrid Electric Vehicles (HEV) Series [6]

PLUG-IN HYBRID ELECTRIC VEHICLES

Similar to HEV, PHEV can be configured in series, parallel and series-parallel, however, it has an external electrical charging plug, larger electrical components (more robust electric motor and battery) and a full-size combustion engine reduced [14].

PHEV has a longer autonomy compared to HEV, due to the activation of its fully electric mode, which allows the vehicle to run on battery autonomy before the combustion engine is activated. Thus, it emphasizes the various modes of operation in a PH, includinEVg the battery only mode (only the battery supplies power), the engine only mode (only the combustion engine drives the vehicle), combined mode (both the combustion engine how much the battery provides the necessary energy) and energy division mode (the energy of the combustion engine is divided to drive the vehicle and charge the battery) [14].

The possible modes of operation in PHEV depend directly on the components used, the application and the vehicle topology. In Figure 4 we have a PHEV in series.

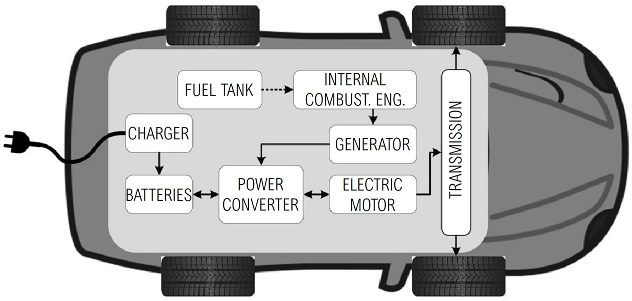

Figure 4 - Plug-in Hybrid Electric Vehicles (PHEV) Series [6]

ELECTRIC VEHICLE CHARGING STATIONS

ADVENT OF ELECTRICAL CHARGERS – The first electric vehicles were developed during the 1830's decade. Initially they were powered for non-rechargeable cells, however at the beginning of the 20th century the vehicles became rechargeable. As a result, electric cars achieved a historical mark of 1/3 of the number of cars sold in United States [15,16].

The process of recharging was carried out exclusively in the car dealers, where the battery could be loaded on board or removed and taken to the "battery room". The first residential chargers appeared in the beginning of the 20th century. They could have a direct or alternated current (AC) input, depending on the power supply of each residence, and a direct current (CC) output [15,16].

The first residential chargers worked at different voltage and current levels, varying with the model and brand of the equipment. Consumers could also order custom chargers according to their specific battery model. DC connectors had a unique pattern with only one internal pin which worked as a positive terminal and the external area of the connector worked as a negative terminal [15].

In spite of the quick development of vehicles and chargers, from 1910 electrical cars began to lose market for combustion-powered cars. The large production of these vehicles was led by Ford with the famous Ford T in 1913 and resulted in the decreasing of the prices offered for the cars with combustion engine. As a consequence, electrical cars became less competitive, losing its market share [16].

Furthermore, a fall in oil prices raised the population's access to combustion-powered cars what confirmed its place as a dominant force in industry of the following century [16].

At the end of the 20th century, the concerning about global warming and the necessity to mitigate greenhouse gases had contributed to make governments in several developed countries invest in research and developments of electric vehicles [29]. In this context, electric cars appeared again in global stage with the hybrid model Toyota Prius, which was released in 1997 and sooner became a sale success. The first Plug-in cars, which means models that can be charged by plugging it into a socket, began to be produced in large scale in 2008 by the Chinese manufacturer BYD. After that, from 2010 the main world automakers started to produce and release their own electric vehicles [17].

The modern electric chargers appeared also from 2010 with several technologies, different ways of charging and connector patterns. They can vary according to the manufacturer, type of charge, model and region of operation. DC chargers have become a trend in the world due to their capability to provide faster and faster loads to the battery [17].

TYPES OF CHARGERS – Plug-in chargers are divided in levels by their power and time of charging [18]:

Level 1: Simple chargers that use the internal AC/DC conversion circuits of the car. For these types the car is plugged directly into a socket.

Level 2: Chargers able to charge 7 times faster than the Level 1 equipment. However, they demand a more complex electrical installation.

Level 3: More advanced equipment which can charge a vehicle in few minutes.

There are also chargers superior than level 3, which are classified as XFC (Extreme Fast Charging). These chargers have power greater than 400kW, but they are still in a research stage and are not found commercially [19]. Table 1 presents a short briefing of the existing chargers.

Table 1 - Types of electric chargers [19]

Type	Voltage Level	Maximum Power (kW)	Time of charging
Level 1 (Slow)	120 VAC	3.7	10-15 h
Level 2 (Slow)	220 VAC	3.7-22	3,5-7 h
Level 3 (Fast)	3-Ø 480 VAC	22-43.5	10-30 min
	200-600 VDC	<200	
		<150	
XFC	>800 VDC	>400	~ Time for fill a car with gasoline

In addition to these types of chargers, there are also chargers by magnetic induction that don't need a wire connecting the car and the charging system. These chargers are still in a stage of dissemination of results but for the next years they should increase their market share, due to the easy installation and loading process [19].

TYPES OF CONNECTORS – The electric car industry have not achieved an agreement about a universal model of connector in alternated or direct current. For this reason, there are several possibilities in market, which are defined according to the region and power level of the charger.

For example, in North America and Europe it's more used the CCS type while in Japan the CHAdeMO is preferred. In China, the country with the biggest market for electric vehicles, the GB/T type is the chosen one. Besides that, there are specific connectors from Tesla, which are used around all the world [19].

Figure 5 summarizes 8 different connectors types. J1772 Type 1, IEC62196-2 Type 2 and GB/T are AC models and the other topologies presented are DC connectors.

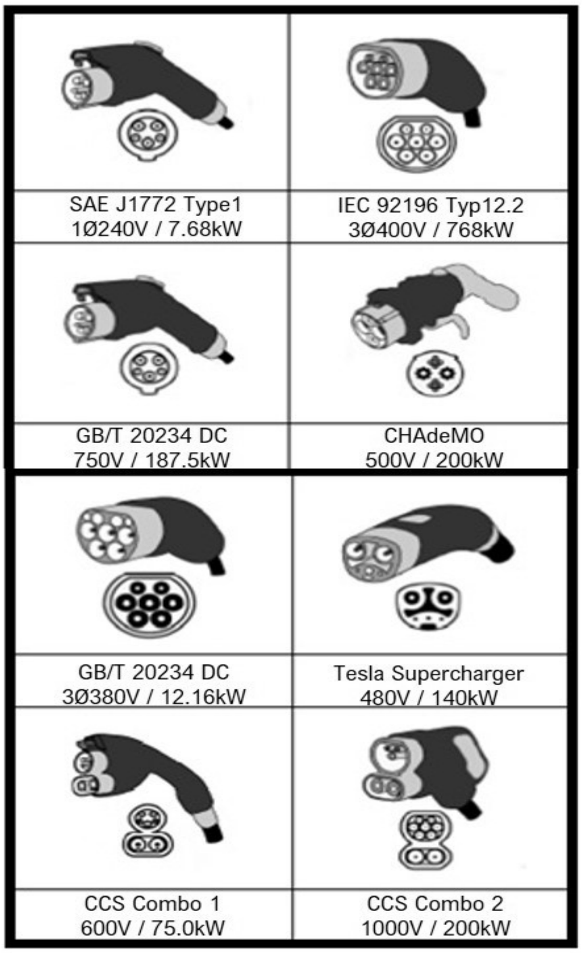

Figure 5 - Different connectors models

Although DC fast charging connectors represents 67% of plug-in electric vehicles sold in the world, there is still a market dispute between the existing patterns for DC models. GB/T has a major participation with 37% of the number of chargers, even serving only Chinese market, according to InsideEVs [20].

CHAdeMO shares the second place with Tesla connectors, representing each one a parcel of 22% of the connectors used in the world. However, CHAdeMO has been losing space in international sales, being limited to only 2 Japanese factories: Nissan and Mitsubishi [20].

The CCS model has a market representation of only 13%, but it has the higher growth expectation for next years. CCS Type 2 became a standard not only in Europe, but also in many countries around the world and even Tesla began to adopt this pattern in new vehicles used outside of North America. AC 3-phase type 2 charger corresponds to the remaining 6% with a tendency of drop for next years, because the technology of fast charging using AC current is getting obsoleted [20].

COMERCIAL CHARGERS – There are many options and models for vehicle charging. Residential chargers are the most used, because the period of charging at night is usually enough to attend consumer's necessity that often uses electric car only in urban streets. There is also a model of charger recommended to public spaces such as supermarkets and malls, and another model which provides a faster charging, allowing the user to drive for long roads, as these chargers have a shorter period of loading the car's battery [21].

Residential Chargers (levels 1 and 2)

Residential chargers do not require a high power level due to the long time available for the charging process, which usually happens during the whole night. Therefore, level 1 and 2 equipment are the most appropriated to be used at home.

With Level 1 chargers, cars can be plugged directly in 127V or 220V sockets in 1-phase systems and the power required vary between 2,2kW and 4,4kW. They are classified as slow chargers because they can take until 18 hours to achieve complete loading [21,22].

There are also Wallboxs, level 2 chargers, available in single-phase and three-phase versions with power that vary between 3kW and 22kW in AC mode. Several models of Wallbox can be found in Brazil, some of them are sold by car dealers and others are provided together with the car when sold, one example of this case is the Nissan Leaf model [8]. The time for total loading using a charger of 7,2kW of power is about 7 hours, while a 22kW charger needs approximately 2 hours and a half to achieve total loading [21,22].

Chargers used in commercial areas (level 2)

In places as center malls and supermarkets, level 2 chargers are used because they need a higher power than level 1 ones, as they need to load car's battery while consumers are shopping. This kind of charger has more functionalities that allow the use in public spaces, such as multiple outputs, a control system to reloading, access to remote connection, other else. Their power usually varies between 7.2kW and 43kW in AC mode [19,20].

Fast loading chargers – Electric Charging Station (level 3 and XFC)

Level 3 chargers appeared due to the necessity of faster loading in a shorter time, approximating the time to load a car's battery with the time to fill a car by gasoline. For this, it was developed technologies for charging in a direct current way that make possible the delivery of energy in higher power levels [19].

The charging stations are able to provide an output power of 50kW DC what reaches 80% of car's battery charge in approximately 30 minutes. The most part of the stations has an AC output to be used in vehicles that do not have the necessary technology to charge in direct current. Extreme fast chargers are able to work with power level greater than 50kW. As an example, the Tritium charger deliveries 350kW, what make possible to reach 80% of battery load in 10 minutes [22].

It's worth to mention that Level 3 chargers have a better performance when the battery is under 80% of loading, because after that there is a big drop in the speed of loading process. For this cases, it's more advantageous to use a level 2 equipment to charge the remain 20%, as the loading speed is almost the same of a fast charge [24].

Figure 6 illustrates this case of speed drop showing that the between 70% - 80% of battery, the power of recharge starts to decrease fatly. The drop is even more realized when vehicle's battery achieves almost 90%. This phenomenon is explained by the fact that as battery gets fuller, more slowly the process of charging happens. Then, it's possible to conclude that fast charging above 80 – 90% of battery's load is less useful considering that the loading gets more and more slowly [25].

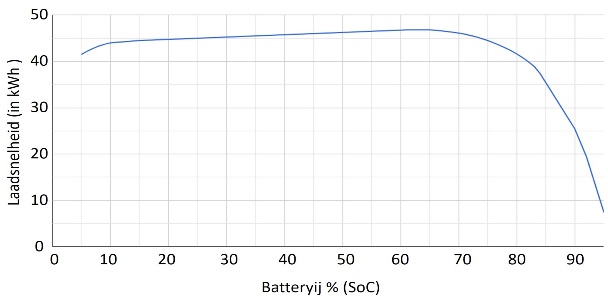

Figure 6 - Charge curve for a loading of 50kW [25]

It's important to note that each vehicle has its own charge curve, defined according to the type of battery used by the manufacturer.

Among the existing models of charging station, it should be highlighted the Terra 54 produced by ABB, illustrated by Figure 7. This model will be used in the project "Corredor Verde" and it has the following specifications presented in Table 2, Table 3, Table 4 e Table 5

Figure 7 - Terra 54 [26,27,28]

Table 2 - Input Data of Terra 54 [26, 27, 28]

Input Data	
Connection	3F + 1N + 1T
Voltage	400 V
Frequency	50 / 60 Hz
Nominal Current	125 A
Power factor	> 0,96

Table 3D - C Output Data of Terra 54 [26, 27, 28]

Output Data		
Unity	CCS	CCS HV
Power	50 kW	50 kW
Voltage	200 - 500 V	200 - 950 V
Maximum Current	125 +/- 5 % A	125 +/- 5 % A
Cable Length	3,9 m	3,9 m

Table 4 DC - Output Data of Terra 54 (b) [26, 27, 28]

Output Data		
Unity	CHAdeMO	CHAdeMO HV
Power	50 kW	50 kW
Voltage	200 - 500 V	200 - 950 V
Maximum Current	120 A	120 A
Cable Length	3,9 m	3,9 m

Table 5 - AC Output Data of Terra 54 [26, 27, 28

Output Data		
Unity	AC Type 2 Socket	AC Type 2 Cable
Power	22 kW	22 / 43 kW
Voltage	400 +/- 10% V	400 +/- 10% V
Maximum Current	3 x 32 A	3 x 32 A / 3 x 64 A
Cable Length	-	3,9 m

To conclude, the market of electric vehicles is becoming a reality and getting stronger worldwide. The growing fleet of these cars brought the need to create different charging methods to attend specific consumers demand.

Another important issue is the appearance of chargers with higher power level with the aim to increase the speed of loading and bringing more convenience to vehicle's owner. However, the power demanded from the electrical system has also a tendency to be even greater, highlighting the need to have special care in the infrastructure of electric installation, so the stability of the power system is not affected. It's necessary also investments that aim to improve the technology used in vehicle's battery to support high levels of voltage and current.

Nationally, in Brazil, this market is still incipient due to the high cost of these vehicles and to the low incentive from the government in the electric mobility sector. In addition, the lack of public chargers in the country makes unfeasible long road trips as vehicle's owners do not have place to make a quick recharging in the battery

Finally, the commercial market of electric vehicles was expanded in the country in 2019 with prices more attractive, what shows that each day more vehicles and chargers are going to occupy a bigger part of Brazilian streets and roads for next years.

CORREDOR VERDE SCENERY

The project aims to create a green corridor in the Northeast (stretch between Salvador / BA and Natal / RN), containing 11 charging stations on the highway (50 kW) and 6 more stations in urban shopping malls (22 kW). The project also aims to evaluate a new business model for companies in the electric sector through the operation of electric vehicle charging stations, in addition to bringing a vision of scalability in the use of electric vehicles in Brazil. In addition, the performance of the 04 electric cars in the northeast region will be evaluated, comparing them with 02 plug-in hybrid vehicles and 02 combustion vehicles. The project will be carried out by a group of institutions composed of **SENAI CIMATEC, GESEL, SINAPSIS, UFABC AND ABB,** whose responsibilities are detailed throughout this document.

For companies in the energy sector, it is strategic to follow the market for electric vehicles, which has a growing trend in Brazil and, therefore, demands a position from the companies responsible for generating, transmitting and distributing the energy that feeds such vehicles. In regulatory terms, the current standard allows the definition of the price of kWh by the operator of the recharge system and, even, the performance of companies outside their respective concession areas. This requires a study on ways of charging the user that make the business feasible for operators, as well as models for installing charging stations in states outside the distribution concession area, anticipating possible regulatory changes. As Neoenergia has a distribution concession in 3 of the main states in the Northeast, the company has a lot of synergy with the operation of charging stations on highways, connecting large capitals and favoring the diffusion of electric vehicles in the Northeast.

Among some characteristics of the Green Corridor project, we can highlight the potential for impact where, within its scope of operation, its coverage will reach approximately 66% of the states of northeastern Brazil, allowing, therefore, the robust study of a new business model and vehicle evaluation and charging stations to be used in the development of the project, thus enabling the assessment of impacts on the electrical network of this new automotive modal..

CHALLENGES OF THE CORREDOR VERDE SCENERY

Brazil, a country of continental dimensions, presents unique peculiarities regarding the extension of its territory, both longitudinally and latitudinally, and allied to a road network primarily for roads.

The distances to be overcome between large urban centers or interstate tourism pockets are a relevant issue, when we talk about the insertion of the electric modal to cover these distances, coupled with the poor quality of the road infrastructure to its users, especially in the northeast region, object of implementation of the Green Corridor.

The project, as already discussed in previous topics, has the challenge of covering approximately 1,200 km of highway between Salvador / BA and Natal / RN and with 11 fast charging stations to cover the entire round trip. In a simple account, 11 charging stations would be enough to have 1 charging station every 110km - range of autonomy totally within the technical specifications of electric vehicles available in the Brazilian market today.

However, the reality is more severe. Through a field survey, where a project team covered the entire distance to and from the route covered by the Green Corridor project, all points of interest that had the minimum stopping conditions for recharging and resting were registered along the route. for project drivers. Through this survey, the use of the Inter-City Charging Station Deployment methodology was established to assist in the definition of the installation of charging stations based on the identification of the Installation Potential (IP) of a charging station [30]. This methodology is based on the following formula:

$$IP_j = a_1 \cdot x_{1,j} + a_2 \cdot x_{2,j} +$$

Where:

• X1: Average daily volume (VMD) of vehicles on the roads;

• X2: Classification of the infrastructures of each supply point;

• X3: Evaluation of the distance between two supply points;

• a1: Weight of variable X1;

• a2: Weight of variable X2;

• a3: Weight of variable X3.

Where, the points of interest for the installation of the stations, previously visited by the project team that carried out the entire round trip in the planned itinerary of the project, were classified and quantified as follows, in order to corroborate with the variable x2 of the formula 1 and in accordance with that defined in [31]:

• Minimum - basic items from a gas station + parking + small convenience store and bathroom;

• Medium - basic items + restaurants, snack bars and some type of additional service (pharmacies, supermarkets, etc.);

• Superior - medium items + accommodation (hotel, inn, etc.)

It was noted during the field survey, not only the low quality of the available infrastructure, true “black holes” of basic infrastructure, which makes the theoretical km for each station impractical.

The distances between loading points have become a logistical challenge, thus forcing vehicle autonomies to their specification limit taking into account safety factors against the influence of temperature, which, as previously mentioned, is one of the most impacting external factors in charging and discharging the vehicle battery and setting restrictions on the maximum speed on the road.

Continuous monitoring will be carried out using hardware and software specially developed within the scope of the project to collect vehicle data and charging stations along the estimated 70,000 km of travel.

FINAL CONSIDERATIONS

With the Green Corridor project, it will be possible to analyze the behavior of hybrid and electric vehicles compared to combustion vehicles. It may also serve as a basis for defining the business model or type of charge and the cost of implementation. The means of tax incentives can also be studied. As well as the changes in the electrification networks that will need to be made, that is, the restructuring of the electric network.

In addition, the project will provide subsidies for the analysis of administrative, technical and financial management and various aspects such as: electricity consumption of each vehicle, battery status (time in use, number of charge cycles performed, level of remaining charge, and maintenance schedule).

It is also worth mentioning that the project will provide the development of applications that communicate with the system database, to provide information to users of charging stations. This will allow the vehicle's electricity consumption to be remotely consulted, as well as an estimate of the remaining charging time can be made.

In addition, determining the position available via the vehicle's GPS would allow the nearest charging stations to be found.

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