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Test Procedures and Measurements for Recharge Evaluation of Battery Electric Vehicles in Power Concessionaires in Brazil

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Abstract

This text focuses test procedures and measurements carried out with a battery electric vehicle. In fact, it is part of a pioneering research in Brazil whose the main objective was to elaborate a battery recharge test methodology for performance evaluation of EVS. It is considered an important step for future electric vehicle utilization in the scope of concessionaires transport activities as well of their customers. During the research it was verified that the proposed test procedures and the specified instruments are adequate.

Keywords: energetic efficiency, state of charge, battery recharge, linear regression, electric vehicles

1 Introduction

The transport based solely on conventional Otto and Diesel cycles, even with renewable fuels, is gradually ceasing to be the most appropriate for a better efficiency and less environmental impacts. Electric vehicles could contribute to a more sustainable scenario in Brazil, since its energy matrix is suited to this technology by huge presence of hydroelectric generation [1,2]. Those considerations contributed towards the creation of the Brazilian Electric Vehicle Association – ABVE in August 2006. It is important to highlight the growing concern worldwide with atmospheric emissions caused by transport activities that are mostly powered by fossil fuels. The damage from air pollution and imbalances produced by the so-called greenhouse gases, which have inter-linkages with climate change explain this situation considered by several scientific institutions. In that sense there was a change of paradigm with regard to vehicular propulsion systems. The gradual penetration of electric vehicles is a consequence that needs research and studies, especially on electric energy supply. It is important to mention recent projects of massive introduction of electric vehicles are underway because the risks of investments in this area are better understood. This scenario provides initiatives from the electric power companies with regard to social and environmental responsibility, through the use and promotion of clean transportation. In the economic aspect, it is possible to predict reductions in operating expenses of their fleets, highlighting that the cost of recharging of electric vehicles in this case is attractive. In addition, the development of new business for this emerging market segment will result in additional revenues, due to recharge the batteries. This also applies to hybrid electric vehicles that could charge their batteries in the power grid, the so-called "plug-in hybrid electric vehicles”.

These arguments stimulated Ampla Energy Services Inc. to establish in September, 2006 a partnership with Rio de Janeiro State University – UERJ through its Electric Vehicles Studies Group – GRUVE to conduct a research project. This project was the first about road electric vehicles approved on the research & development program supervised by Electric Energy National Agency – ANEEL. Ampla supplies energy to 66 municipalities in the state of Rio de Janeiro,

covering 73% of its territory with an area of 31,784 km^2 serving to 2.2 million customers.
The project goal was to develop a testing methodology for assessing the performance of battery electric vehicles in order to meet the conditions for their use both within the companies transport services and by their clients who will become users of these automobiles.
Important activities were developed during the research:
- Implementation of the Vehicular Propulsion Systems and Electrochemical Sources Laboratory at UERJ as showed in Figure 1.
- Purchase of an electric vehicle to check the feasibility of carrying out the tests with the specified instruments.
- Test Execution and technical reports preparation.

Figure1: Vehicular Propulsion Systems and Electrochemical Sources Laboratory at UERJ

The research has established procedures to characterize energetic, environmental and economic parameters in order to demonstrate the benefits of adoption of this technology by the company.
Additional studies were carried out for the identification of cultural, technological and institutional barriers in order to develop the electric vehicle technology in Brazil.
The high taxes burden on the production, selling and licensing of electric vehicles is the most serious obstacles identified. As a matter of fact they are more expensive in comparison with the taxes for internal combustion vehicles.
Of course it constitutes a contradiction that has started to be modified recently by the Brazilian Congress because the automotive law is outdated and do not consider the benefits of electric vehicles utilization.

2 Vehicle description and test instrumentation

It was utilized an electric "Palio Week End" provided through the agreement signed between Itaipu Binational (Brazilian and Paraguayan electric generation company) and Fiat, as well KWO and MES-DEA, both in Switzerland. Figure 2 below shows the electric vehicle in a recharge station at Ampla headquarter in the city of Niterói.

Figure 2: Recharging station at Ampla Energy Services Inc headquarter in the city of Niterói

The electric vehicle components such as motor, inverter, dc-dc converter, battery and its charger are manufactured by MES-DEA. The other parts as chassis, body and accessories are provided by Fiat. This car is equipped with a special three-phase asynchronous motor with 15 kW of power rating and a nominal torque of 50 Nm. The battery is a high temperature sodium-nickel chloride Zebra type, 253 V, 76 Ah and 165 kg.
A committee coordinated by Itaipu Binational that participate electrical power companies, researching centers, universities and Fiat are making efforts for improving the vehicle technical characteristics.
Forms and tables were developed to register traveled distances as well temperature, state of charge and voltage of the battery.
In addition it was designed a bench by LSPV/UERJ for connecting the vehicle to the power grid as showed in Figure 3. This figure also shows the basic instrumentation to study the battery recharging process through a MARH–21 energy analyzer, manufactured by RMS in Brazil. With MARH-21 it is possible to record network supply voltage, current, active, reactive and apparent power, harmonic components and total harmonic distortion of voltage and current, power factor and energy consumption. These data can be stored and observed by a computer graphic interface during the test.

Figure 3: Instrumentation and connections bench for analyzing battery recharge process at LSPV/UERJ

3 Methodology and application of the tests

The methodology for assessing the performance of electric vehicles has considered two conditions: the battery discharging process, when the vehicle is in motion followed by a recharging process when it is parked. It was observed in the first condition the behavior of acceleration, braking, drivability and autonomy. The routes were established taking into account slopes, load to be carried, distance and state of charge. It is important to mention that the battery recharge tests offers a valuable set of results as the electric energy consumption, power factor, harmonic behavior of voltage and current as well the refueling cost. Additionally, it was possible to estimate emissions avoided and the fuel saved in comparison to a similar internal combustion vehicle.

Table 1 – Results from Short Distance Tests

Weight (kg)	Recharge time Δt (minutes)	Distance Δkm (km)	ΔSOC (%)
169,50	237	20,0	23,9
224,05	281	23,7	28,2
153,55	38	2,1	3,5
153,55	54	4,1	5,7
153,55	72	5,9	8,9
236,00	18	3,0	1,5
236,00	50	4,0	5,7
236,00	74	6,0	9,1
155,05	57	4,0	6,8

Some results from short distance routes with huge slopes are shown in Table 1 whose last column indicates the battery state of charge variation [3, 4]. With these tests it is possible to apply a linear regression model for these variables in order to know for example the relationship between the state of charge reduction and distance as it is showed in Figure 4.

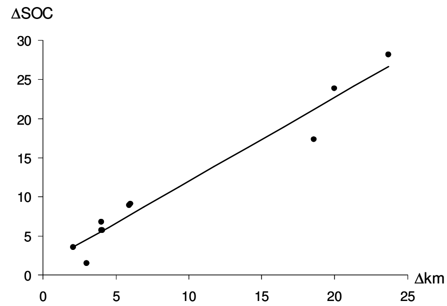

Figure 4: State of charge versus trip distance

Equation 1 below which corresponds the graph in Figure 4 reveals that for each kilometer there is 1,15% state of charge reduction. It also shows the great influence of the huge slopes in those routes because the estimated autonomy of this vehicle for more favorable conditions is about 110 km.

$$\Delta SOC = 1{,}1538 \Delta km \quad (1)$$

In Figure 5 it is possible to observe the network supply voltage and charge current behaviors recorded in May 16, 2008 with RMS energy analyzer at LSPV/UERJ in accordance with the third line of Table 1. The current is almost constant at the beginning of recharge process and after decreases. The opposite has occurred with voltage.

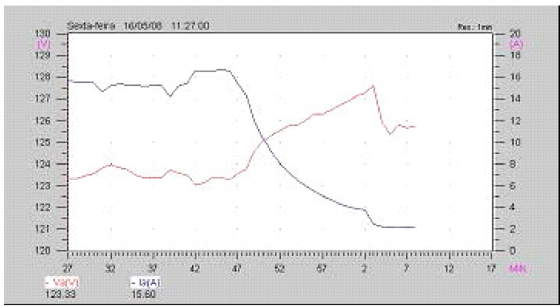

Figure 5: Voltage and current behaviors during the vehicle recharging

Instantaneously samples of voltage and current of this test are presented in Figures 6 and 7. The bar graphs illustrate the harmonic components percentage that can inform if the energy quality and the recharging rectifier are in accordance with existing standards.

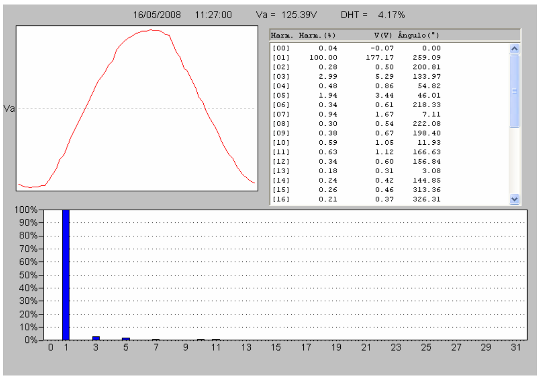

Figure 6 - Sample of battery recharging grid voltage and corresponding harmonic components

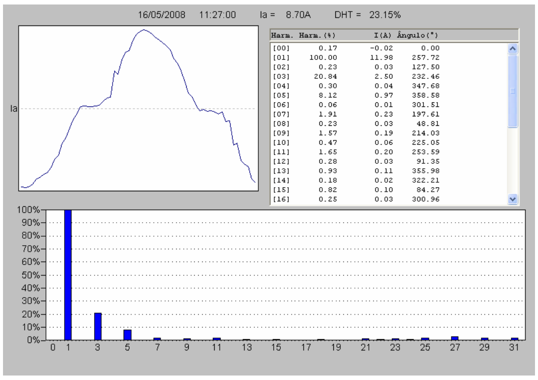

Figure 7 - Sample of battery recharging grid current and corresponding harmonic components

A more complete behavior of the harmonic components is given by THD (total harmonic distortion) calculations [5]. They are presented in the graph of Figure 8 for voltage and current that is represented by the top curve.

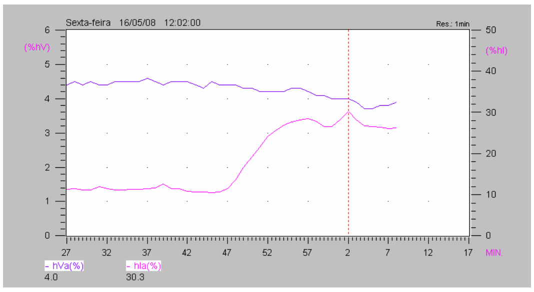

Figure 8 – THD of voltage and current supply

In Table 2 are indicated the registered maximum and minimum values of total harmonic distortion of voltage and current in the test of Figure 8. These values are expressed as percentages of the fundamental components of voltage and current. Tables 2 and 3 furnish the values of the main harmonic components of voltage and current.

Table 2 - Voltage Main Harmonic Components Values (% of V_1)

2nd	3rd	5th	7th	9th	11th	13th
0,28	2,99	1,94	0,94	0,38	0,63	0,18

Table 3 - Current Main Harmonic Components Values (% of I_1)

2nd	3rd	5th	7th	9th	11th	13th
0,23	20,84	8,12	1,91	1,57	1,65	0,93

The energy consumption during this recharging process was 0,908 kWh and 0,143 kVArh. This methodology previews other data to be registered as the state of charge evolution, battery and ambient temperature as well the recharging DC current and voltage.

4 Conclusions

The proposed methodology presents adequate measurements procedures and instrumentation for evaluating battery EV performance.

It is possible to predict in a medium term after a more dense penetration of electric vehicles in Brazilian market an improvement for their load factors since much of the battery recharge process occurs at night. Revenues are expected in consequence of increasing in energy sales. In addition operating costs can be decreased in transportation services with the utilization of electric vehicles fleets, especially if the battery recharge is done in these companies with their own electric energy.

This study has demonstrated the possibility of using electric vehicles by Brazilian power concessionaires as well by their customers for transportation of cargo and people principally in urban areas. It is necessary more researches for increasing the autonomy and diminishing the recharging time.

There is an urgent need for public policies in Brazil because the high taxes imposed to the EVS production and commercialization act as a barrier for a better technological development.

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