Comparison between energy battery and power one for electrical vehicle applications

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Abstract:

In 2009, a presentation was done in PCIM about the experience feedback on electric vehicles of the French car fleet and about the replacement of the initial NiCd battery of an AX vehicle by an iron phosphate Lithium battery with 1600 small cells [1]. Theses cells are power ones. This presentation is a comparison between this power battery and an energy battery in the same format.

The theoretical capacity gain of the energy battery against the power battery is 39 %. However, the theoretical energy density is only 22 % more important because the mass of the energy battery is higher.

The internal resistor of the energy battery is more important than the power battery (around 50% for the tested batteries). During a C/2 discharge, the real energy delivered is approximately equal to the theoretical one. But during a discharge at 1 C or 2 C, the real energy is not as important as the theoretical one because of the internal resistor.

The use of the energy battery is limited for the systems with a low power corresponding to 1 C maximum. A use with a current inferior to 1 C is better. The efficiency is so acceptable. The energy battery can be envisaged for the vehicle with autonomy around 200 km, or higher, where the discharge current is around C / 2.

However their use is outlawed in vehicles needed strong current like the hybrid vehicles. For this kind of vehicles, the power battery is better adapted.

To complete this study, one other study is to do to evaluate the degradations of the performances of the batteries with the temperature. Negative temperature can cause an increase in internal resistor and have an effect in the autonomy and in the life time. The impact should be more important for energy batteries.

I. Introduction

Last year a presentation was done in PCIM about the experience feedback on electric vehicles of the French car fleet. The initial NiCd battery of an AX vehicle was replaced by an iron phosphate Lithium battery with 1600 small cells. These cells are power batteries.

This presentation compares one other kind of battery (energy battery) in the same format in order to observe the differences and to conclude on the better battery for this vehicle. The conclusion will be extended to other kinds of vehicles.

II. Description of the two kinds of battery compared

The two kinds of batteries have exactly the same dimensions and the same shape. There are 26 650 cylindrical batteries (diameter 26 mm, 65 mm long).

The table 1 presents the specified characteristics:

	Power battery	Energy battery
Volume	39 cm² cylindrical	39 cm² cylindrical
Mass	73.5 g	83.5 g
Theoretical capacitance	2.3 Ah	3.2 Ah
Voltage	3.2 V	3.2 V

Table 1

The energy battery has a superior capacitance of 39 %. But because of the mass 14 % higher, the energy density is only 22% more important.

III. Comparison between the real capacitances for different rates of discharge

The different specifications were checked and compared between these two batteries.

	Power battery	Energy battery	Gain
	Real discharge at 0,5 C		
Energy of one cell (Wh)	6,61	9,14	
Energy density (Wh/kg)	90	109	22%
Volumetric energy (Wh/L)	169	234	38%
	Real discharge at 1C		
Energy of one cell (Wh)	6,56	8,76	
Energy density (Wh/kg)	89	105	18%
Volumetric energy (Wh/L)	168	225	34%
	Real discharge at 2 C		
Energy of one cell (Wh)	6,4	8,21	
Energy density (Wh/kg)	87	98	13%
Volumetric energy (Wh/L)	164	211	28%

Table 2

The table 2 presents the theoretical gain about the capacitance, the energy and the mass between these batteries.

The energy density decreases when the discharge current increases. This phenomenon is due to the internal resistor which is stronger in the energy battery. For the power battery, the internal losses are low.

For a 2 C rate, the energy density of the energy battery is only 13% higher than the power one.

The figure 1 and 2 presents the real curves of capacity for the energy battery and the power battery respectively.

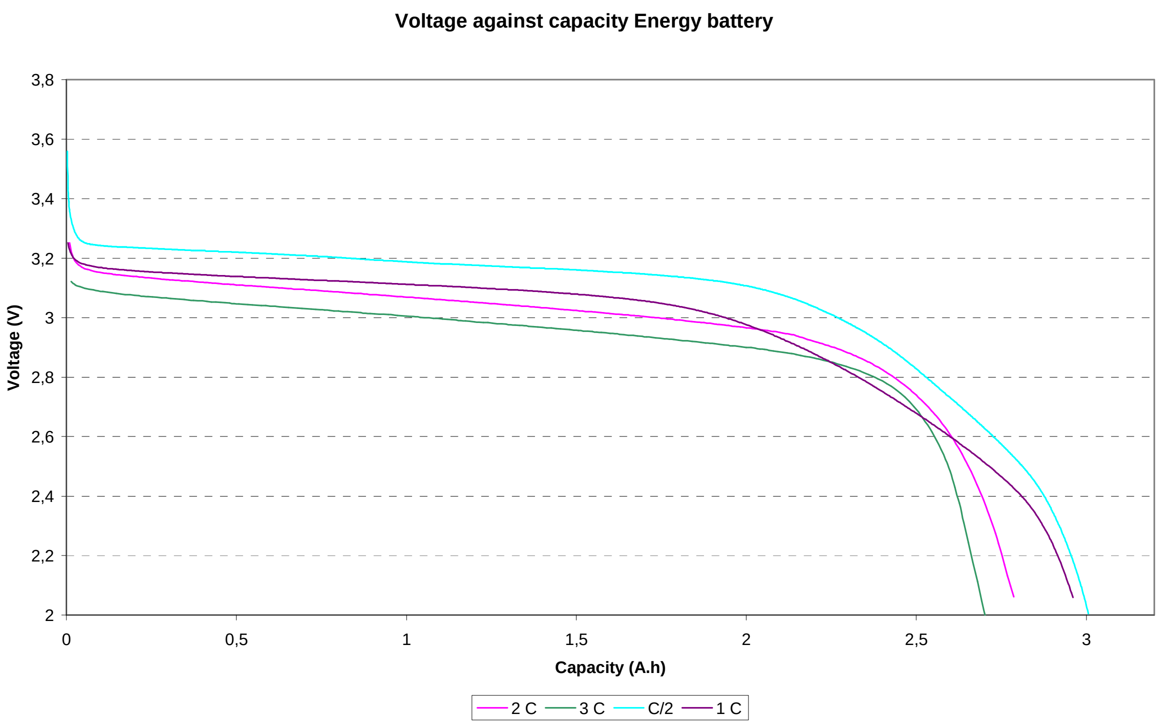

Figure 1 : Energy battery: voltage against capacity for several currents

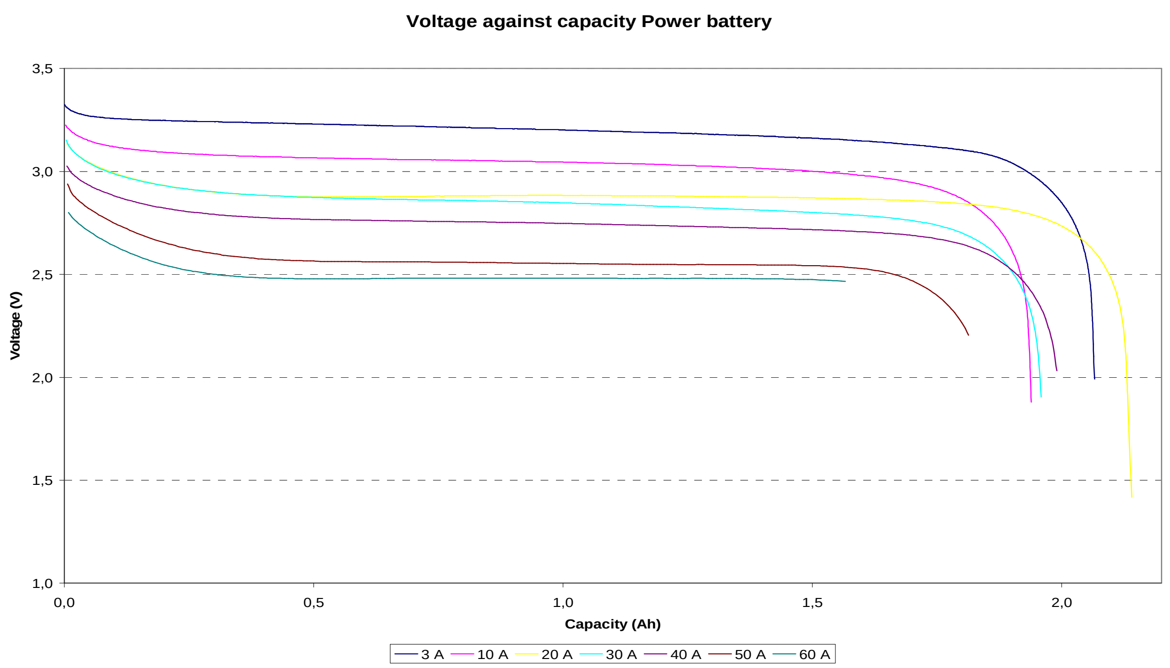

Figure 2 : Power battery: voltage against capacity for several currents

IV. Internal resistors

The internal resistor of a battery is a very important characteristic because it is this parameter which defines a great part of the level of thermal lost energy of the battery. To measure this resistor, we discharge the batteries from the total capacity to the minimal with a fixe current of 3 A, and some brief discharges were done at 20 A. The ratio of the voltage difference by the current difference is the internal resistance value.

This work is done for several points all over the discharge.

The figure 3 shows the points done for the two kinds of battery.

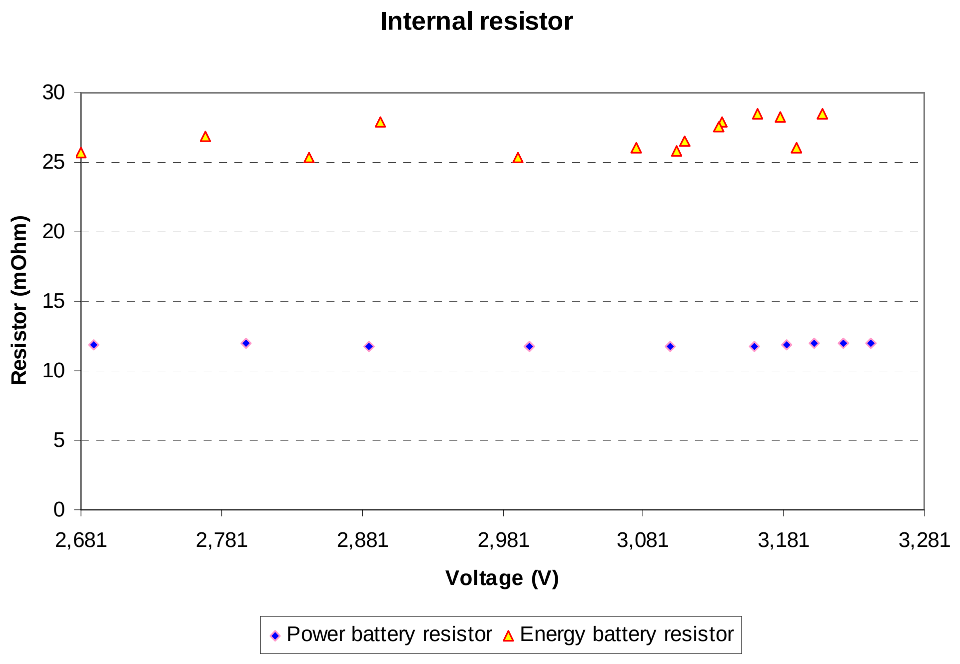

Figure 3 : Internal resistor comparison

The internal resistor is sensibly stable during the discharge. The mean resistor of the energy battery is 27 mOhm and only 12 mOhm for the power battery.

These resistors include the resistors of the connections which are around 3 mOhm for each battery.

V. Charge and discharge curves

The charge and the discharge curves permit to see the evolution of the voltage during the time and to see the stability of the batteries. In this test, the temperature is also measuring to detect the impact of the current on the temperature.

In order to be exactly in the same condition for the two batteries, they were assembly in series and so the current in the two batteries is strictly the same.

The figure 4 shows the voltage and the temperature of the two batteries for two charge and discharge cycles. The current is 1 C for the energy battery and 1.4 C for the power battery.

Of course, the power battery (red curve) is full before the energy battery (pink curve) because his capacity is only 2.3 Ah against 3.2 Ah for the energy battery.

This curve (figure 4) shows that the temperature of the energy battery is more important than the power battery. The maximum elevation of temperature is around 10 ℃ for the energy battery against only 4 ℃ for the power battery. Moreover, the voltage of the energy battery is more important during the charge and less important during the discharge than the power battery.

The figure 5 is exactly the same work, but with a current of 2 C for the energy battery and 2.8 C for the power battery. The figure 5 shows a very high temperature in the energy battery. The maximum temperature reaches 45 ℃ and the maximum specified temperature is 60 ℃. The energy battery can't bear a charge and discharge current more than 2 C or 3 C because of the temperature rises.

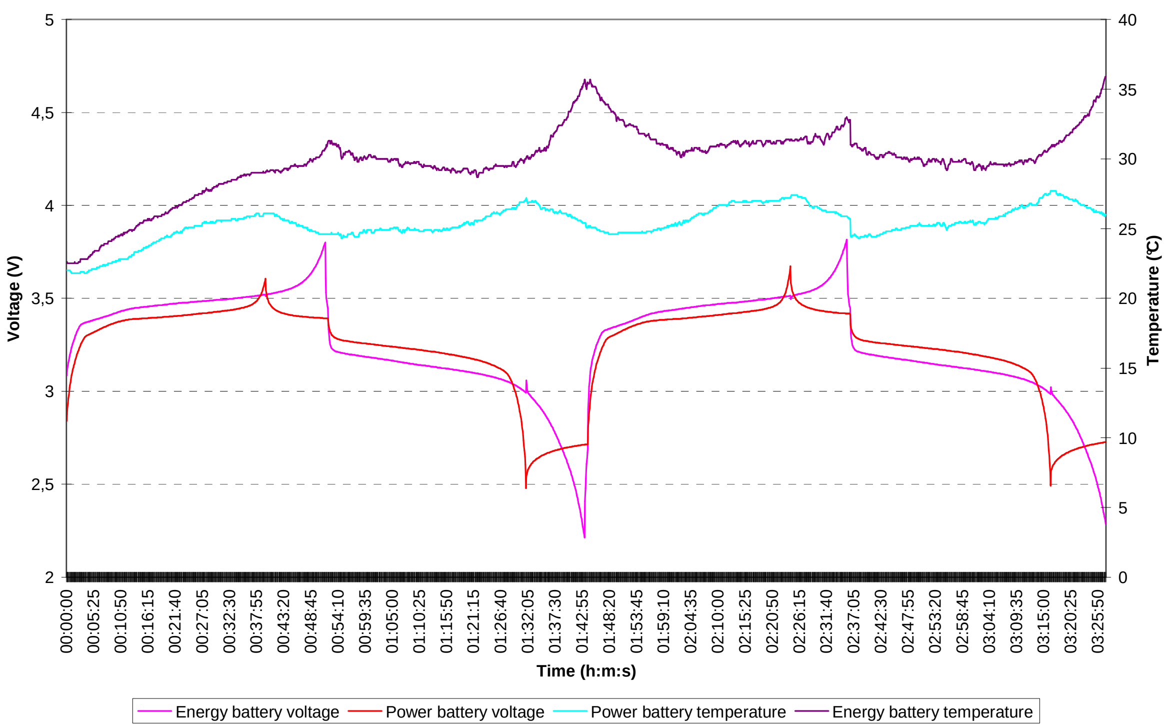

Figure 4 : Voltage and temperature curves comparison for a 1 C and 1.4 C current

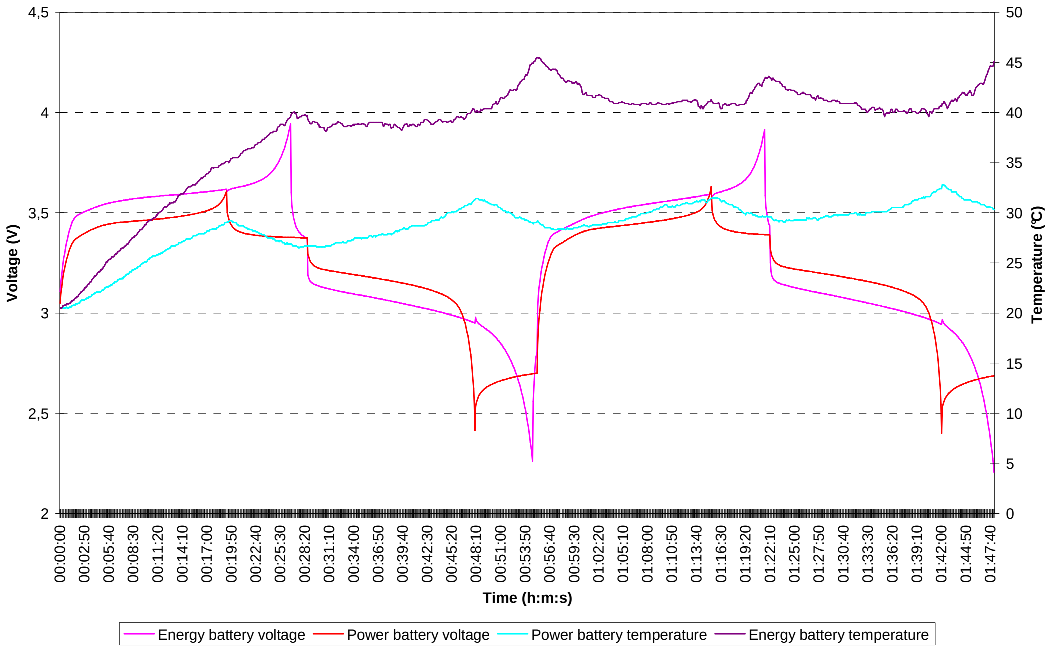

Figure 5 : Voltage and temperature curve comparison for a 2 C and 2.8 C current

In order to highlight this voltage difference, a curve of hysteresis (figure 6) is done for a current of 1 C for the energy battery and 1.4 C for the power battery.

The red curve is the voltage during the charge of the power battery and the pink curve is the voltage during its discharge. And by the same way, the light blue is the voltage during the charge of the energy battery, and the dark blue is the voltage during his discharge.

The red and pink curves are smaller because of the smaller capacity of the power battery.

The hysteresis effect is small for the power battery and very important for the energy battery.

This hysteresis effect traduces directly the internal energy losses, and the temperature rise.

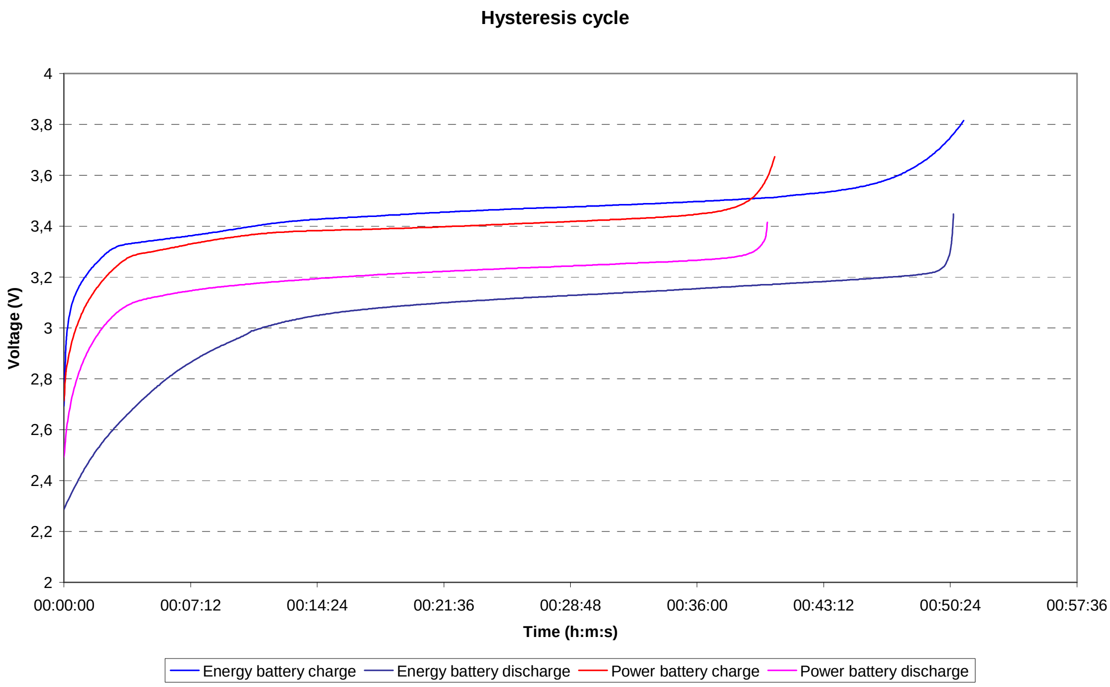

Figure 6 : Voltage hysteresis comparison

AX	Power battery	Energy battery	Energy battery	Power battery
Number of cell	1600	1600	2200	2200
Energy (kWh)	10,5	14	20	14,4
Autonomy (km)	110	147	210	151
Mass of the battery (kg)	138	154	212	190
Total mass of vehicle (kg)	810	826	884	862
Ratio mass battery/mass vehicle	17%	19%	24%	22%

Table 3

Last year, the replacement of the initial NiCd battery of an AX vehicle by 1600 small LiFePO4 batteries was presented. According to the results of this presentation, energy batteries are well adapted for 200 km range with C/2 discharge rate.

The table 3 compares the performances for 1600 and 2200 cells for our AX demonstrator.

If the 1600 actual power cells are replaced by 1600 energy cells, the autonomy goes up from 110 km to 147 km. If we used 2200 energy cells, the autonomy is 210 km against 151 km for 2200 power cells.

The global mass variation is acceptable and is always less than 900 kg.

VI. Conclusion

In this presentation, to kinds of batteries are tested and compared. The two kinds of battery are power and energy batteries.

The theoretical capacity gain of the energy battery against the power battery is 39 %. But the theoretical energy density is only 22 % because the mass of the energy battery is higher.

During a discharge at C/2, the real gain is around the theoretical gain. However, during a discharge at 1 C or 2 C, the gain is not as important as the theoretical gain because of the internal resistor and additional hysteresis losses.

The use of energy battery is well adapted for systems with a current less than 1 C discharge rate. The efficiency is so acceptable with low current.
For the vehicle with high current, superior at 1 C, the power battery is better.

The power battery is well adapted for electrical vehicles with autonomy less than 100 km which need a continuous discharge current more than C (100 km done at 100 km/h, so total discharge in one hour). The energy battery can be used for vehicles with autonomy like 200 km or more, where the continuous discharge current is around C/2.

All of these tests are done for an ambient temperature. It is necessary to study the degradation of the performances and the autonomy where the temperature is negative because of the internal resistor increase. This impact should be more important on energy battery, because the internal resistance and the hysteresis losses are higher.

VII. References

[1] Bruno Béranger, Daniel Chatroux, Eric Fernandez, Sébastien Fiette: Experience feedback on electric vehicles of the French car fleet – battery impact PCIM2009 Nüremberg