BATTERY CHARGE AND DISCHARGE STRATEGIES IN TERMS OF ENTROPY PRODUCTION

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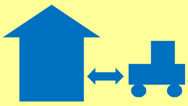
INTRODUCTION

- Electric vehicles (Evs) will be common soon to fight against climate change.
- Several considerations on electric grid performance will have to be taken into account to satisfy security and stability at reasonable economic performance.
- Vehicle batteries have been proposed to be used as energy backups to improve peak shaving of the grid: Vehicle to Grid V2G



Vehicle to grid (V2G)

- However, battery users could undergo an accelerated degradation of bateries, which would result in an increased cost.

AIM

We aim to characterize the relationship between energy and economic efficiency in terms of entropy considering battery ageing and related costs.

METHODOLOGY

We use experimental data of a battery cell and we define a simplified electric model $R_s + R_{CT}//C_1$. Parameter evolution with ageing is available.

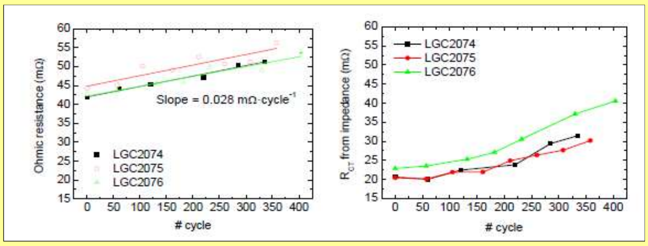


Figure 1: Cycling evolution of Rs and RCT for three Li-ion NMC 2,8 Ah cells (LG ICR18650 C2)

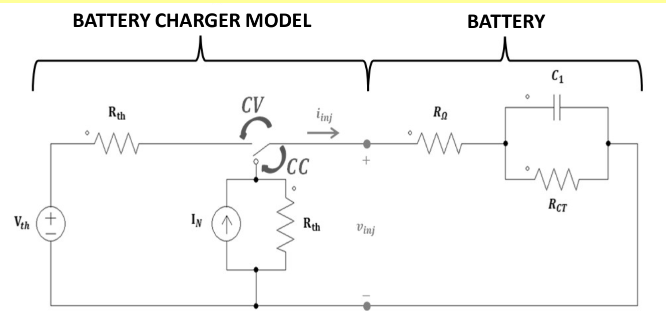
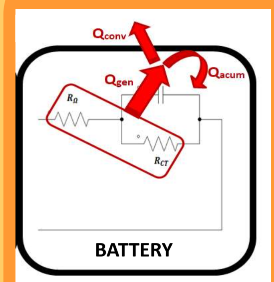


Figure 2: Normally, battery charge is carried out at constant current – constant voltage. The change CC-CV takes place at the maximum voltage. We simulate different change points (β) as a funtion of battery State of Charge (SoC) and compare different charge/discharge ratios and profiles to obtain the best charge/discharge efficiency.

ENERGY, ENTROPY AND ECONOMIC ANALYSIS



Energy

When the battery is operating dissipates heat due to Joule effect and electrochemical reactions Q_{gen}.

This heat:

- partially heats up the cell Q_{acum}
- is partially delivered to the environament through convection Q_{conv}.

Entropy

Entropy is computed from heat generation and battery and environament temperatures $dS = \frac{dQ}{T}$

Economic approach: we consider the cost of buying the electric energy from the grid and the cost of selling the stored energy to the grid.

Buying cost		Selling cost
Energy term [€/kWh]	Power term [€/kW day]	Energy term [€/kWh]
0.07818987	0.13220231	0.06359318

$$\text{Economic efficiency}[\%] = \frac{\text{Benefit}_{total}}{\text{Cost}_{total}} \cdot 100 =$$

$$= \frac{\text{E}_{\text{delivered}_{ch}} \cdot \text{Energy cost}_{sell} \cdot 100}{\text{E}_{\text{consumed\_total}_{ch}} \cdot \text{Energy cost}_{buy} + \max(\text{P}_{\text{consumed}_{car}}) \cdot \text{Power cost}_{buy}}$$

SIMULATION RESULTS

Operation performance

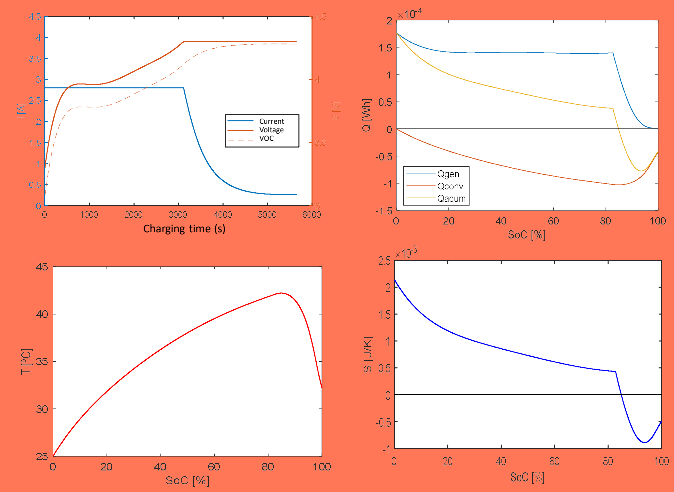


Figure 3: Current, voltage, temperature and entropy due to Q_{acum} typical profiles for a charge process

Efficiency performance

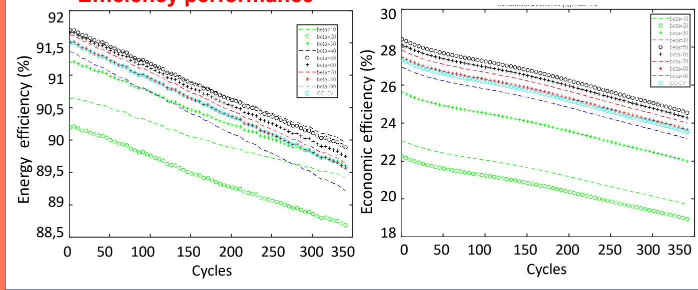


Figure 4: Energy efficiency and economic efficiency for different β. We find that optimal processes depend on the charge rate, and β.

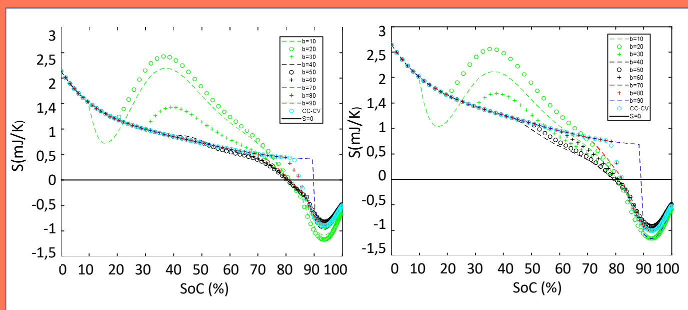


Figure 5: Entropy generation during charge as a function of SoC and of β. We find that the optimal charge path is the smoothest one.

	Efficiency [%]					
β (%)	C/2		1C		3C/2	
Escenari	Energy	Economic	Energy	Economic	Energy	Economic
10	91.873	23.432	90.017	21.370	87.317	18.125
20	92.105	24.427	89.427	20.569	86.185	16.652
30	93.263	28.154	90.392	23.785	87.137	18.674
40	93.940	29.906	**90.806**	26.185	**87.452**	**19.723**
50	94.275	31.212	90.786	**26.471**	87.276	19.538
60	94.520	32.979	90.697	26.185	87.088	19.325
70	94.720	35.807	90.624	25.901	86.996	19.120
80	**94.795**	38.608	90.533	25.537	86.869	18.848
90	94.780	**38.696**	90.285	25.041	86.345	18.455
CC-CV	94.700	33.853	90.531	25.415	86.981	18.949

We compare the best efficiency in terms of energy and economic performance for different charge rates and β. The best approach does not fit the Standard CC-CV method.

CONCLUSIONS

1) We evaluated V2G in terms of energy, entropy and economy.
2) Entropy plays an interesting role to find the best path to operate batteries.

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