LIFEMIT

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Abstract**—**

LIFEMIT project deals with Energy management, storage systems within the frame of hybrid and electric motorization. It deals more particularly with deployments of lithium-ion batteries in heavy vehicle application. It supports the development of tools and demonstrates how virtual prototyping and a system approach lower the risk for lithium-ion batteries development.

The partnership includes: Nexter, military vehicles manufacturer; Saft, a world specialist in the design and manufacture of high-tech batteries for industry; Eigsi - L3E , laboratory experts in electric and renewable energy; GREEN-ENSEM-INPL, laboratory experts in electronics and power electronics; and the IMS laboratory, more particularly for its expertise in electronics.

The first result is obtained by the development and the experimental validation of an embedded algorithm which sharply increases practical lithium-ion battery power without accelerating its ageing. The second main result is the demonstration that virtual prototyping associated with system architecture analysis are powerful tools for battery design, especially for large lithium-ion battery systems.

Keywords-component: digital mock-up, virtual prototyping, battery, lithium-ion, ageing, battery integration, system, real time, embedded, algorithm

I. Introduction

LIFEMIT project deals with Energy management, storage systems within the frame of hybrid and electric motorization. It deals more particularly with deployments of lithium-ion batteries in heavy vehicle application. It supports the development of tools, and demonstrates how virtual prototyping associated with a system approach makes lower the risk for lithium-ion batteries development.

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In the first section, we will speak about virtual prototyping applied to lithium-ion battery for sizing purpose. We will focus on the different characteristics that battery models have to fulfill to get real design tool. In a second chapter, we will investigate Saft Charge and Discharge management algorithm which optimizes battery rated power. The third chapter will deal with experimental validation of this battery management. The last chapter will show how the risk analysis drives the system battery architecture. Then we will conclude on the project outputs, project which ends by April of 2011.

II. Virtual Prototyping Applied to Lithium-Ion Battery

Battery models widely used for integration purpose are based on equivalent electrical circuitry. Such models, schematically represented by the figure 1, can integrate battery thermal models, which are seen as black box by the system integrators.

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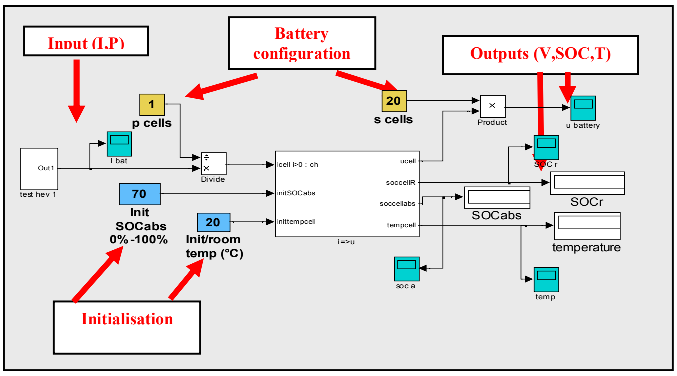


Figure 1: Standard battery model

These models allow virtual battery integration; nevertheless it does not integrate enough information about battery ageing to allow a system design. Ageing prediction depends on many factors: temperature, State Of Charge (SOC), current intensity, voltage, and their combinations. In this project, we use for the dynamic simulation, values of maximum current allowed in discharge and more critically in charge to reach the lifetime target. These values are output of the model as depicted in figure 2.

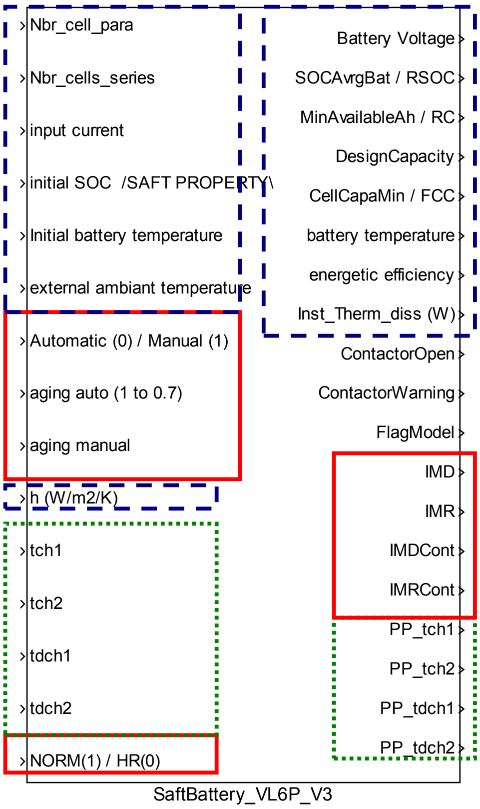
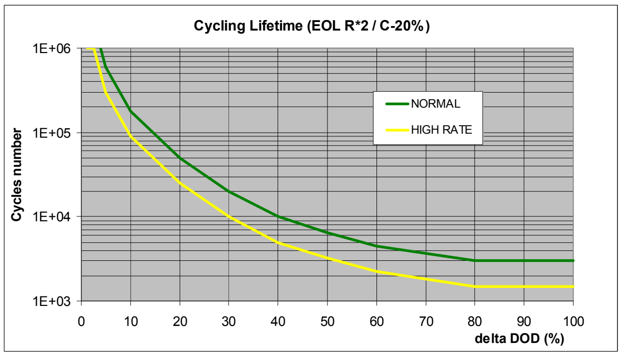


Figure 2: Battery model including ageing properties.

The blue squares gather the standard inputs / outputs of a thermo-electrical model. The red square gather the input/output of ageing. The battery age can be input in "manual" or "automatic" modes. The level of stress which can sustain the battery is precise with the "NORmal" or "High Rate" modes. According to the mode, the cycling battery lifetime is given in figure 3.



SAFT VL cells battery cylelife.

The maximum current intensity related to the mode chosen is provided by the IMR/IMD outputs.

The green squares gather the Power Prediction inputs/outputs. It provides the constant maximum power for a given duration so that the current doesn't exceed IMRIMD "ageing limit" values during this duration

This simulation method integrating electric, thermal and ageing behavior of Saft batteries allows fast sizing of a battery system in its environment.

The maximum current in discharge (IMD) and in charge (IMR) will be described in the following chapter. Such models, integrated in SIMVEH [1] Nexter vehicle models, allowed many simulations for electric and hybrid vehicles. The figure 4 depicts an illustration of an electric configuration with high power VL30P, and high energy VL45E Saft cells in vehicle electric mode.

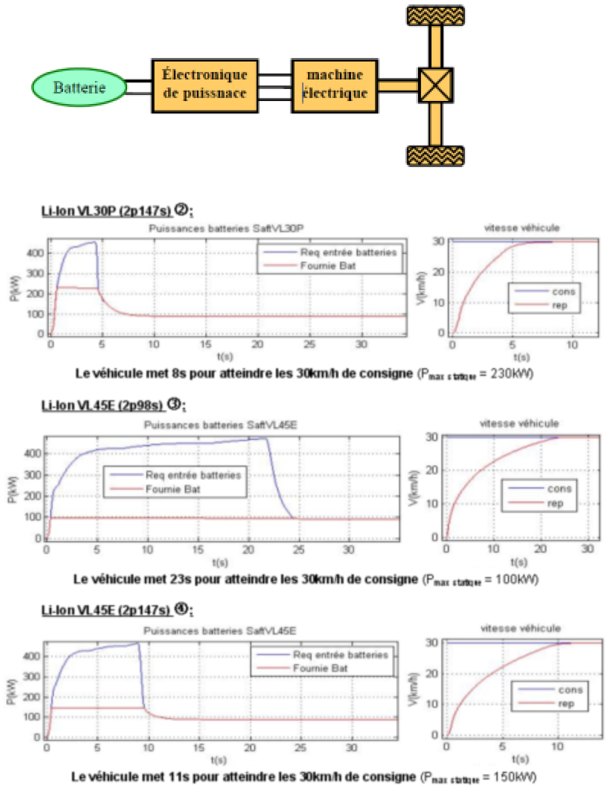


Figure 4: System virtual prototyping

III. BATTERY CHARGE AND DISCHARGE MANAGEMENT (IMRIMD) ALGORITHM

It is well-known that high charge intensity, especially at low temperature can lead to lithium plating inside lithium-ion batteries and as a consequence, it can sharply decrease the battery lifetime. Lithium-ion batteries are specified for a maximum charge current. This maximum charge current is critical to recover energy during braking phase for example. Moreover, most of the time, regenerative applications charge only partially the battery. It is also known, at least experimentally, that short pulse charge can be conducted at higher currents than full battery charge. Saft developed an algorithm which integrates these different characteristics to provide, on real time the maximum current which can be used without degradation of the battery [2]. It is based on an over-capacity you fill or you empty depending on the real time value of the current, see figure 5.

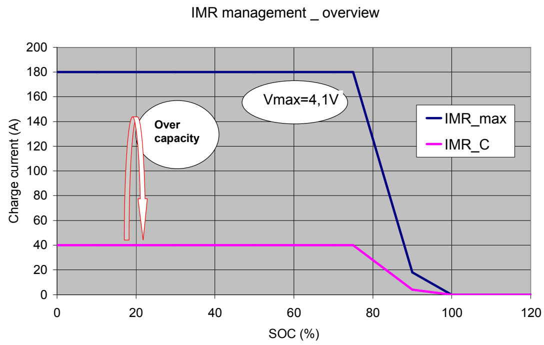


Figure 5: Charge dynamic management.

The algorithm allows passing high dynamic cycles without battery degradation. Analyze can be perform by comparing maximum current allowed (IMRIMD) to the current, or power specification. An illustration is given in figure 6.

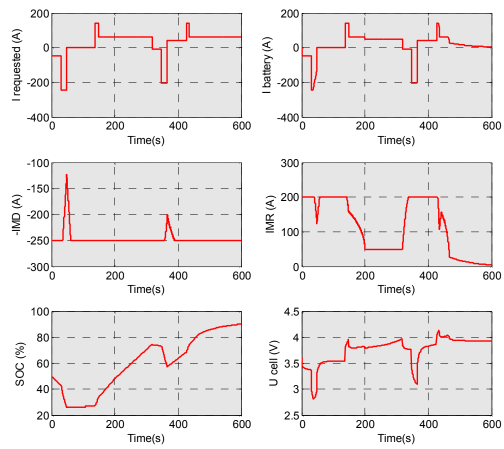


Figure 6: Algorithm dynamics.

The validation of the high pulse power capability of Saft cells with its associated algorithm is demonstrated by experimental validations presented here after.

IV. EXPERIMENTAL VALIDATION

To assess impact of IMRIMD algorithm on ageing, Eigsi performs a specific test to follow the maximum current given by IMRIMD on one test bench. In a second test bench, a more traditional cycling test is performed according to Saft cell maximum current allowed. Figure 7 shows the “standard” cycling and figure 8 the “dynamic” high power cycling for Saft VL30P cells.

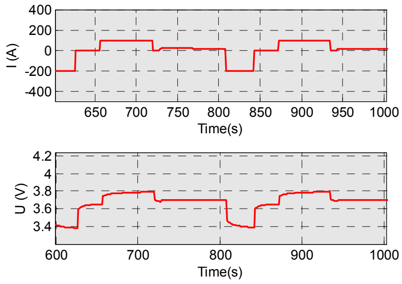


Figure 7: Cycling at maximum continuous current

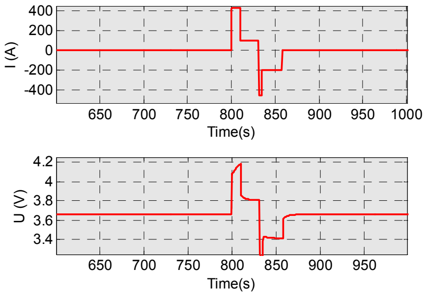


Figure 8: Cycling according to IMRIMD

During the test, cell temperature is kept the same for the two benches. The zoom, see figure 9, on the IMRIMD high power algorithm shows that charge is performed at 400A for 6% of Depth of discharge (DOD) variation, that is to say close to 1.5 kW/kg during 12s. During the pulse, power capability is 4 times higher than continuous specification.

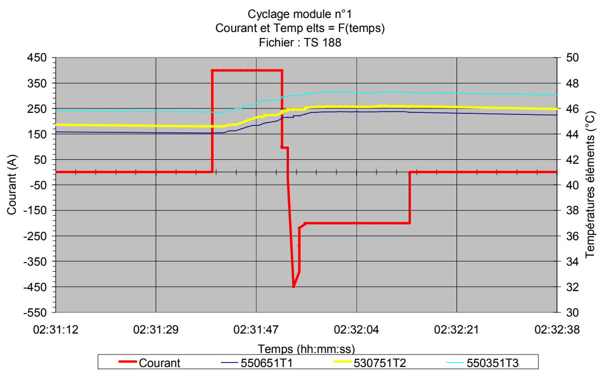


Figure 9: Zoom on the electrical test.

The cells have performed more than 40 000 cycles with slight ageing. Figure 10 presents internal resistance and capacity evolutions according to the continuous current profile, and according to IMRIMD pulse profile.

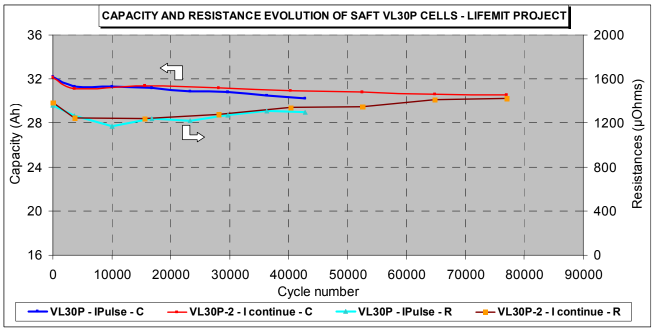


Figure 10: Resistance and capacity evolutions during the cycling tests.

Ageing with pulse and continuous profiles are similar. The test still goes on to assess an ageing slope.

A second test will be performed to assess impact of undulations on the whole battery system. The test bench developed by GREEN laboratory is finished and results will be provided during the congress. Figure 11 shows the tests bench.

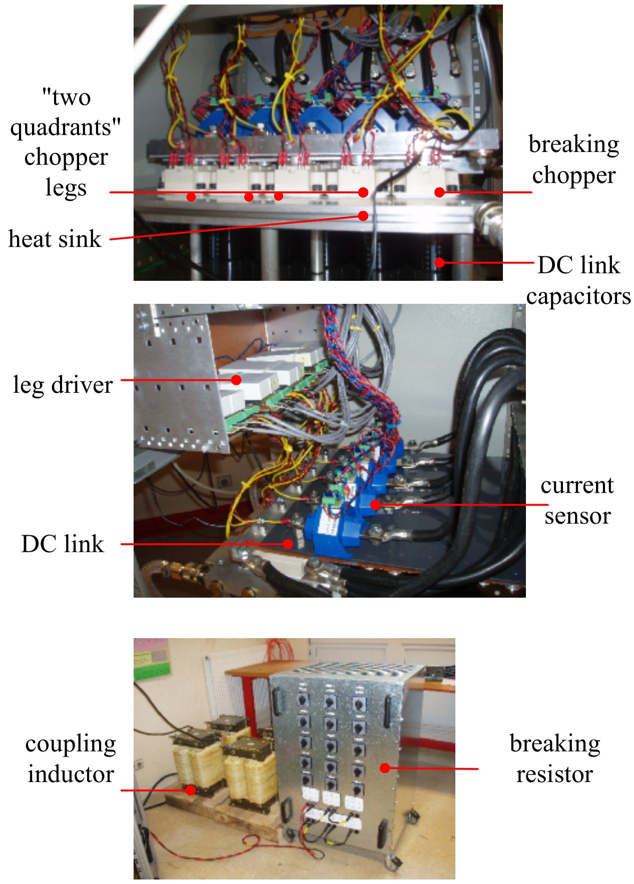


Figure 11: Test bench for specific power electronics tests

V. Battery Architecture

Battery architecture depends on many parameters, in which we can have thermal management, mechanical constraints and environment, electrical specification and whatever the type, Interface constraints. Illustration of vehicle targeted is given in figure 12.

Figure 12: Final system.

Not only does the system's development be driven by the cost, but also by the battery system availability and safety.

Battery architecture for Nexter vehicle was developed through a RAMS (reliability, Availability, Maintainability, Safety) analysis. Figure 13 presents a synoptic of this activity

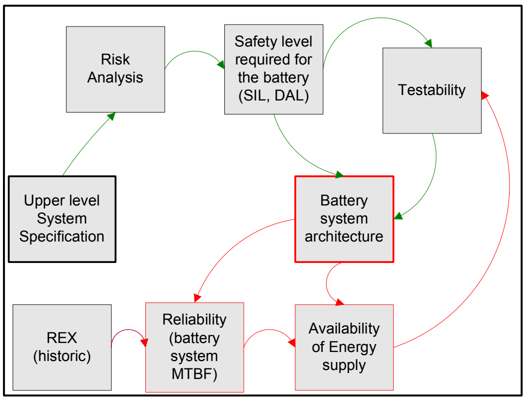


Figure 13 RAMS analysis overview.

Finally, virtual prototyping associated with system architecture analysis are powerful tools for battery design, especially for large lithium-ion batteries. The final mechanical battery concept is given in the figure 14.

Figure 14: Virtual battery design

VI. Conclusions

LIFEMIT project allows developing advanced batteries digital mock-up which integrates impacts of solicitations on its ageing. It shows that virtual batteries are efficient for battery sizing, for system optimization, for end user learning of the new storage technology, and finally the technology deployment. Innovative test benches have been developed in the frame of this project to test battery systems. It has to be noticed that a patent filing is in progress between Saft and IMS to lower battery electronic consumption. These results will be consolidated by the end of the projects, in April 2011.

Acknowledgment

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References

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[2] G. Barrailh, S. Benjamin, and P. Desprez, "Battery with charge and discharge management," European Patent EP 2 048 735