SIEMENS
Ingenuity for life

Automotive

IFP Energies nouvelles

Enhancing lifetime battery modeling for longer-life green vehicles

Product

Simcenter

Business challenges

Develop battery aging simulation functionalities

Strengthen positioning of Simcenter Amesim as a best-in-class modeling and simulation platform

Keys to success

Encapsulate fundamental physical phenomena

Operate simulation platform efficiently

Analyze electrochemical energy storage system behavior

Results

Built easy-to-use, high-fidelity aging models

Obtained reliable aging simulation results

Analyzed 10 years of battery behavior in a few hours

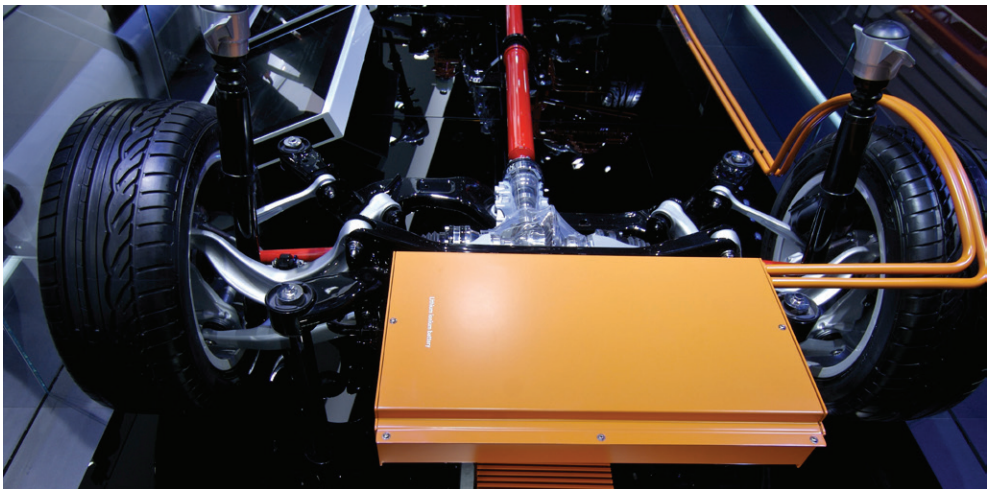
Greener, more reliable and cost-efficient technologies

Reducing carbon dioxide (CO_2) emissions is a major challenge facing the world's automakers. To address this issue, manufacturers have developed new technologies such as hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV) and pure electric vehicles (EV).

The success of these technologies hinges on the efficiency of energy storage systems such as batteries and ultra-capacitors. These components are expensive, and it is difficult for original equipment manufacturers (OEMs) and battery manufacturers to master and guarantee electric storage systems for more than eight years. Today, battery durability is one of the biggest problems facing the auto industry.

The fact that there are many different battery chemical technologies and aging mechanisms makes this problem even more complex. Degradation mechanisms vary greatly according to the type of chemical technology considered. Types include lithium nickel cobalt aluminum oxide (NCA), lithium iron phosphate (LFP), lithium nickel manganese cobalt oxide (NMC) and lithium titanate (LTO).

There are two different aging modes: cycling and calendar. Cycling corresponds to the battery usage when a car is moving, while calendar corresponds to when a car is parked. This cycling and calendar distribution is not the same for a passenger car as a bus or a truck. For instance, the cycling mode percentage is much higher for trucks compared to passenger cars.



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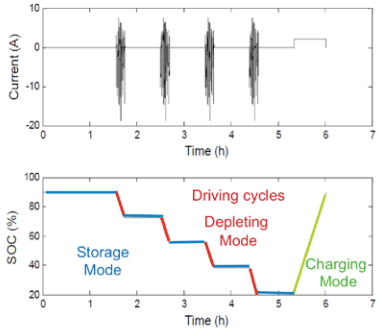
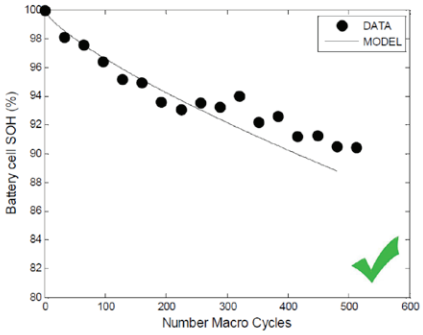
Eric Prada, Ph.D.
Electrochemical R&D Engineer
IFPEN Electrochemistry and Materials Department

PHEV duty cycle at 45°C

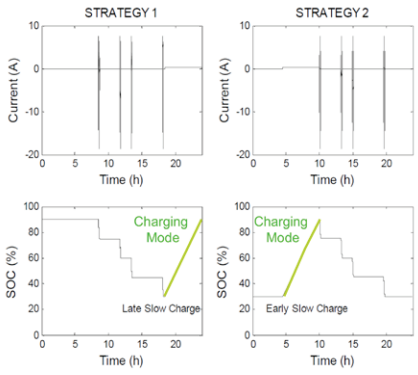


Simulation vs. experiments



The PHEV battery aging model takes into account daily driving, parking and recharge cycles.

To design reliable, safe and cost-efficient energy storage solutions, it is critical for manufacturers to have an in-depth understanding of battery systems' electrothermal behavior. Aging phenomena cause an increase in the internal resistance and a reduction of the capacity of the battery, leading to power and energy loss in the storage system. During vehicle usage, these losses are responsible for poor battery performance and autonomy degradation. Many stress factors, including temperature, current intensity and state-ofcharge (SOC), can impact the storage systems' degradation rate. Taking all these phenomena into account in the preliminary specifications phases is a difficult challenge. This is where mechatronic system simulation has a decisive role to play by helping to provide an appropriate solution.



Unlike classic usage in which the PHEV Li-ion battery is recharged at the end of the daily mission, "just-intime" charging allows for reducing battery degradation phenomena.

Long-standing partners, new challenges

Ten years ago, Siemens PLM Software started cooperating with IFP Energies nouvelles (IFPEN), a research and innovation center with strong expertise in the fields of energy, transport and environment. As a part of its innovative transport activity, IFPEN designs and enhances technological solutions to reduce vehicle fuel consumption and environmental impact.

In 2008, IFPEN started working on electric storage systems issues. Following six years of powertrain simulation partnership, many IFPEN research and development (R&D) specialists have become proficient in using Simcenter Amesim™ software, part of the Simcenter™ portfolio. Moreover, IFPEN knew that Simcenter Amesim was becoming the standard for many industry players.

The choice of partner was evident, and the initial scope of cooperation between Siemens PLM Software and IFPEN was extended to battery issues. As a result, Siemens PLM Software and IFPEN co-developed the electric storage library, now available within Simcenter Amesim software, a powerful and versatile multi-domain simulation platform.

Electric storage library

The first shared achievements included in the electric storage library are focused on Lithium-ion (Li-ion) and nickel-metal

hydride (Ni-MH) batteries as well as ultra-capacitors. The library consists of either generic or validated (calibrated) electro-thermal models allowing for rapid and easy simulation.

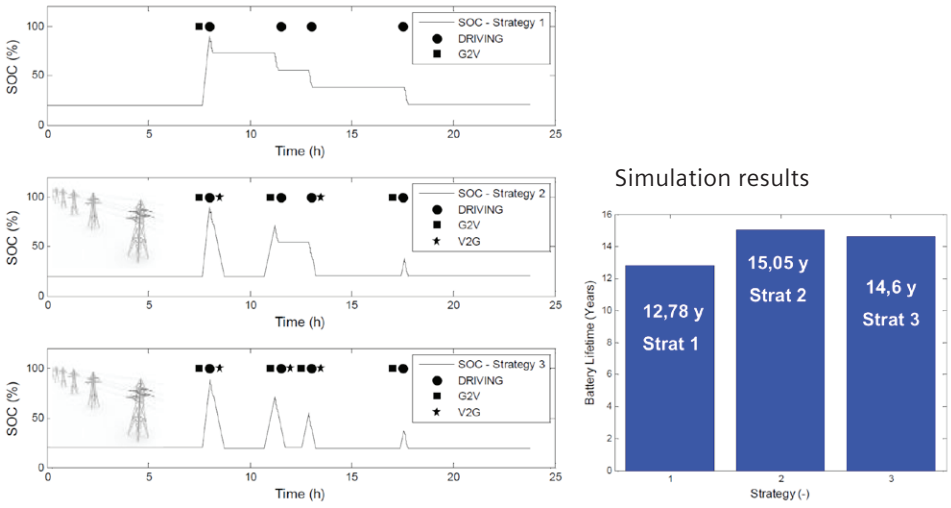
To calibrate models, experimental tests were mainly performed at the IFPEN battery test bench facilities. As an alternative, users can quickly calibrate empirical equivalent circuit models with their own experimental data thanks to the battery assistant tool developed by Siemens PLM Software and available in the electric storage library.

The main technical challenges for the development of the electric storage library were to choose the right level of energy storage system models for end users. "We had to design and work on different modeling approaches that allow for easy and fast simulation, while still encapsulating the details of fundamental physical phenomena to ensure reliable simulation results," says Eric Prada, electrochemical R&D engineer, electrochemistry and materials department at IFPEN.

"Our current challenge is to gain insight into electrochemical energy storage systems behavior and develop predictive and reliable mathematical models enabling engineers to rapidly build, specify and optimize energy solutions," Prada says. "For instance, they can be used for energy storage sizing to meet power and energy performances of a targeted application for battery management systems functional design and usages strategies optimization."

As a part of its cooperation with Siemens PLM Software, the IFPEN team has recently developed different modeling approaches to simulate battery degradation phenomena. IFPEN designed a dynamic electrochemical aging model able to predict the loss of autonomy degradation for a specific Li-ion battery technology (LiFePO4/graphite). IFPEN's advanced electrochemical and analytical testing facilities made it possible to calibrate electrochemical models by measuring the main geometrical, electrical and physico-chemical cell parameters. Then those predictive models were validated on a wide database built up on the basis of in-house cell tests and test results available in the literature.

Thanks to these studies, 10 years of battery behavior can be analyzed in only a few hours. This validated model can be used to analyze the impact of usage strategies for the vehicle (monitoring the SOC for the PHEV) or for the vehicle-to-grid (V2G)



Providing a limited number of connections, V2G technology increases PHEV battery's lifetime.

Solutions/Services

Simcenter Amesim
www.siemens.com/plm/simcenter-amesim

Customer's primary business

IFP Energies nouvelles (IFPEN) is a public research, innovation and training center that provides industries and the public with efficient, economical, clean and sustainable technologies to address major 21st-century challenges: climate change and environmental impacts, energy diversification and water resource management.
www.ifpenergiesnouvelles.com

Customer location

Rueil-Malmaison
France

technology. "The Simcenter Amesim Electric Storage library is of great help to renewable energy and automotive industries players," says Prada. "This allows design engineers to make the right technical and economical choices in the right time schedule."

Outlook on effective storage systems modeling

The upcoming developments of the Simcenter Amesim Electric Storage library will provide engineers with models for other Li-ion technologies, in particular lithium iron phosphate (LFP) and nickel manganese cobalt (NMC) high-power and highenergy systems. Medium term, further developments will provide high value-added, physics-based models from the electrode materials and cell specification to the full battery pack design.

The battery modeling market is fast-growing and competitive. Today, some competitors of Siemens PLM Software offer solutions for the multi-dimensional design of battery systems, with a particular focus on thermal issues. These tools enable design engineers to fine-tune battery design, but they are often time-consuming and do not allow for aging modeling. In contrast to competitors' computational fluid dynamics (CFD) battery codes, Simcenter Amesim, with its electric storage library, will be extremely attractive because it will provide a multi-domain, time-efficient aging modeling solution.

"I strongly believe that Simcenter Amesim will become a best-in-class battery modeling and simulation platform within the next two or three years," says Prada. "Our development roadmap is well-phased and will provide strong results."

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