Accelerated Aging of EV batteries based on measured driving profiles

Host Laboratories: Knowledge and Distributed Artificial Intelligence (CIAD) and Femto-ST/Energie/Sharpac

Keywords : Lithium battery, accelerated aging, real driving cycles, driving data acquisition, database creation, data transfer from acquisition to experimentation, user profile

Fields and specialities:
I-8. Techniques of simulation and application
I-17. Control theory and technique
V-1. Prevention and treatment of electric system breakdowns. Economic process
V-4. New technology of high-performance energy economics
VI-3. Sustainable development engineering and lower cost manufacturing

Subject:
Lithium-ion batteries are key elements for sustainable energy use due to the possibility of storing energy with interesting energy densities. Lithium-Ion batteries can be used in mobile, stationary [1] and portable [2,3] applications.
The manufacture of Lithium-Ion batteries involves significant resources and in order to ensure a positive balance sheet on life both from an energy point of view and from a global, ethical and economic point of view, it is necessary to find ways to use, reuse and recycle Lithium-Ion batteries in an optimized way. During use the battery degrades due to multiple effects [4]. However, it can be concluded that there are two kinds of aging, calendar aging and use aging. This aging can influence the performance of a battery in two ways: either it decreases the capacity or the maximum power that can be delivered. The permissible aging varies considerably depending on its application. For example, for an application in electric vehicles a decrease in energy capacity to 70-80% of its initial value indicates the end of use [1, 5, 6].
Currently, the maximum lifetime envisaged for a Lithium-Ion battery is expected to reach 30 years, considering a first automotive life and a second stationary life [1]. However, the stresses in the first and second life and consequently the aging patterns can vary widely. Thus, the aging of a battery pack is particularly dependent on its use during its first life as an automotive traction battery. It is therefore important to be able to analyze precisely the use made in the first life to be able to predict its future aging in order to (1) choose the most suitable use for his second life (2) advise / help drivers in their driving and their recharging habit so as to prolong the duration of automobile use and to optimize the duration of use as stationary storage. Consequently, it is both crucial and difficult to establish a complete knowledge base making it possible to identify typical usage profiles (recharging / driving) and therefore to be able to precisely predict the future behavior of a Lithium-Ion battery.
In addition, the first real life feedback from electric vehicle batteries and portable batteries shows that aging is less pronounced than expected [2,3].
Finally, if the most widespread modes of use are known and well identified, it will be important to have their impact on aging in order to improve lifespan. Two ways exist for this, either to design the batteries to meet little aging in the most used areas or to imagine approaches or driving assistance systems (ADAS) to encourage drivers to avoid areas of use. Favorable to premature aging. These two approaches can be applied in a complementary way.

Planned works:
The object of the proposed thesis is to create an experimental database in order to study the dominant parameters during aging. Consequently, it is essential to carry out the tests in an accelerated manner in order to limit test times.

Although temperature and current were identified as the parameters that allow accelerated aging, their influence has not yet been sufficiently tested to establish reliable and scientifically recognized test protocols [7].
The proposed doctoral thesis aims to contribute to both the study of the accelerated aging of Lithium-Ion batteries and the means of data acquisition, storage and transmission of real driving while respecting the private data of drivers. In addition, one aspect that will be addressed is the appropriate choice of driving cycles, since the most well-known (homologation) cycles are not necessarily the most realistic. Thus, it is legitimate to question the realism and the representativeness of a real cycle. For this, all cycles will be analyzed in order to identify typical profiles in order to extract the associated cycles of use in order to study in more detail the aging encountered during this cycle [9,10]. In order to reduce aging in these areas, two means will be studied; design the batteries to meet low aging in the most used areas or imagine approaches to encourage drivers to avoid particularly aging areas of use. These two approaches can be applied in a complementary way.
For this thesis, an existing electric vehicle is to be equipped with an acquisition system whose parameters to be recorded remain to be defined (cf. Figure 1). They will contain battery data (current, voltage, temperature), but also cycle data (speed, altitude, height difference) of use and charging strategies. The analysis of other parameters, such as engine load, energy recovery... will also be studied. This data will be stored in the vehicle and then synchronized to a database for systematic analysis.

Figure 1: The EV which will be used during the PhD

This EV usage data will then be used in two ways. First, they will be used in a raw way to replay the real life of the batteries as faithfully as possible and at the same time they will be analyzed to extract typical profiles and associated duty cycles [9, 10]. This dual approach should allow a first step in identifying good practices in terms of battery aging use.

The two types of data will then be read by a battery test bench (if possible with an associated climatic chamber) equipped with batteries comparable to those of the vehicle the real battery cycles measured are replayed in a loop on the battery test bench [11, 12]. In order to accelerate aging, the thesis will focus on cyclic aging because calendar aging is already studied in detail [8] and will take advantage of the fact that the vehicle is on average used for one hour per day and when stationary. for twenty-three hours a day. By respecting the limits of relaxation and temperature variation, an aging acceleration factor of between ten and twenty is expected.

Once this characterization of aging has been carried out, it will be a question of confirming or invalidating the classification of profiles and the identification of profiles of virtuous use. These results will then make it possible to offer driving assistance systems that are either passive (by informing the driver of good practices and possible areas for improvement) or active by acting on the vehicle's actuators to force the user to adopt a " good attitude.

The following diagram shows the different stages of the process (cf. Figure 2):

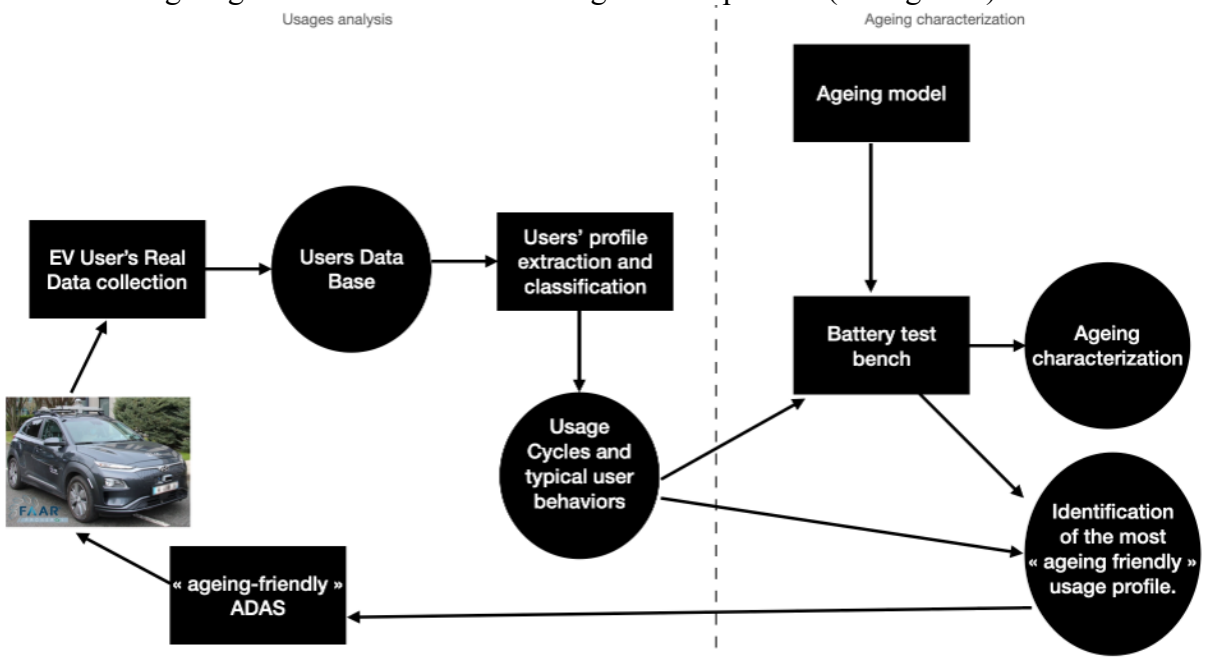

Figure 2: The different stages of the process

At the end of the thesis, the work can be used to create an experimental database among other things to create digital models, to create test protocols that can one day participate in the standardization of aging tests for Lithium batteries. Ion and to define battery usage data that should be backed up to collect events contributing to aging. Another aspect will be to create incentives for drivers to avoid particularly aging battery operating points.

Planned deliverables include:
• M6: Preliminary bibliographic report
• M9: Implementation of data acquisition
• M12: Launch of the trials campaign
• M12: national, international or summer school conference
• M18: Automated data acquisition interface, battery test bench
• M21: scientific article on data acquisition linked to experimentation
• M30: scientific article which presents the results of battery aging
• M36: thesis defense

Références :

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Candidate Profile:
The candidate must have training (engineering degree or master of science) in the field of energy or IT or nearby (electric vehicles, electrical engineering, on-board systems, etc.). A first experience in the field of lithium-ion accumulators is an advantage. As the subject includes different scientific fields (electrical engineering, computer engineering, SHS), a willingness to address interdisciplinary research work is important. The work carried out in the internationally oriented laboratory requires a good command of English.
The proposed thesis work requires great autonomy, great motivation, and work discipline. Good interpersonal skills are essential. As the work integrates experimental aspects, an aptitude in this field and initial experiences will be a plus.

Supervisor(s) :

Thesis supervisor: ***Dr.*** **Daniela CHRENKO (MdC-HdR)** - Femto-ST / Energie / Sharpac: experiences in the field of first and second life battery applications, and the definition of mobile and stationary uses
Thesis supervision: ***Pr.*** **Franck GECHTER** - CIAD: expertise in the fields of artificial intelligence, autonomous vehicles and ADAS