Galvanostatic Cycling with Potential limitation 4: Low Earth Orbit (LEO) battery satellite protocol

I – INTRODUCTION

The aim of this paper is to describe an application for the GCPL 4 protocol in the field of battery testing. This protocol is available with EC-lab software and can be used with all our instruments.

This galvanostatic cycling protocol has a different timing from the previous GCPL protocol, in that the total duration of every sequence is defined, independently, from the fact that at a given time during the step, the maximum potential can be reached and the instrument turns from the initial galvanostatic mode to a constant potential one.

By way of comparison, in GCPL and GCPL-3, the initial galvanostatic mode run for a maximum time (*t1*) and if a potential limit (WE-RE in GCPL, WE-CE in GCPL-3) is reached in that time, the duration of the constant potential mode that follows is either set to a given time (tm) or limited by the condition for the redox current to be lower than a given value. In GCPL-2, if a potential limit is reached on the galvanostatic sequence, the system switches to the next step without any constant potential sequence.

II – EXPERIMENTAL PART

After a full charge (not shown here) the battery was first discharged down to 3.0 V with a constant potential period until the discharge current (Fig. 1) was less than 5 mA (Step 1, for about 3 hours). This was carried out in order to measure the effective capacity of this aged battery. One hour open circuit period was then set, to follow the open circuit voltage (OCV) of the discharged battery.

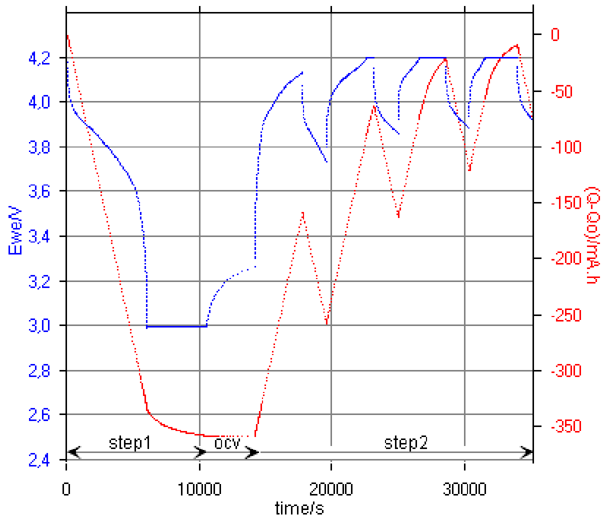

Figure 1: E_{we} and (Q-Q_0) evolution versus time at the beginning of the experiment.

Then the "LEO" cycling was started (Steps 2 and 3, Fig. 2) for a total of 21 cycles. No rest periods were set during this period of cycling, according to the fact that in the real application, the battery turns from charge to discharge as soon as the satellite goes from sun (that charges the battery) to darkness.

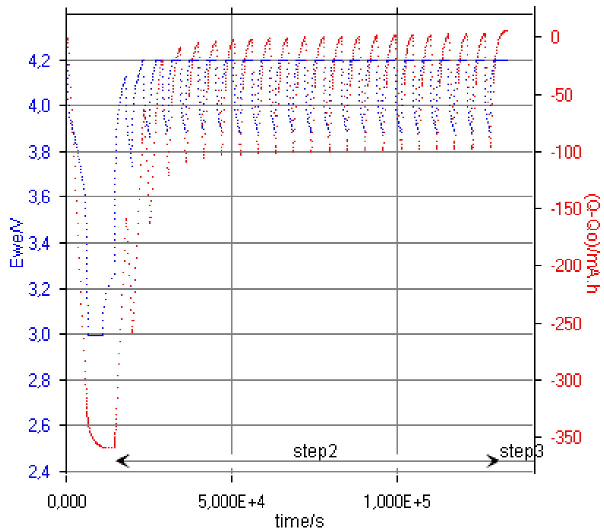

Figure 2: E_{we} and (Q-Q_0) evolution *vs*. time.

A final charge period with a constant potential duration fixed by a charge current lower than 5 mA was performed, in order to check how much the battery could be charged in this condition, compared to the standard one during the "LEO" periods. A long final OCV was set to determine the equilibrium potential of the charged battery.

III – RESULTS AND DISCUSSION

Fig. 1 shows the time dependence of the potential (E_{we}) and of the total charge (Q-Q_0) from the beginning of the experiment. The initial deep discharge (step 1, down to 3 V) appears to take about 3 h and the effective battery capacity is close to 360 mA.h. Thus, the galvanostatic charge/discharge conditions (200 mA) are slightly larger than a C/2 regime, and the 5 mA limit current in the deep initial discharge and final charge corresponds to a C/72 regime, *i.e* close to reaching total discharge/charge. After the 1h rest period the OCV is 3.27 V, but not at equilibrium yet.

Then the LEO cycling starts. On first charge (200 mA for 1h, with 4.2 V limit) the potential limit was not reached, due to the fact that it started from a deeply discharged state. In the following discharge (-200 mA for 0.5 h) the potential decayed from 4.08 to 3.74 V under current.

Then on the second charge/discharge cycle the 4.2V charge limit was reached for a short time, and the potential decayed from 4.16 to 3.86 V.

On a longer time scale (Fig. 2) one can see that the charge/discharge of the battery is close to its dynamic equilibrium on the fourth cycle, the discharge occurring in the 4.17 V- 3.89 V window.

The slight increase of the total charge with cycling corresponds to the fact that the battery comes closer and closer to its maximum charge, as also illustrated by the final charge, in which the constant potential period was not limited by the total duration of the charge period, but by a final 5 mA charge current. Then after a 24 hours rest period the OCV appears to be 4.16 V, which corresponds to the equilibrated fully charged battery.

IV – CONCLUSION

In this application note, we have shown the specificities of the GCPL4 technique where the total duration of a sequence is fixed regardless of whether the limits during CC and CV steps are reached or not.

An application example is shown, the Low Earth Orbit battery satellite protocol, where the battery will enter charge or discharge periodically.