

Galvanostatic Cycling with Potential limitation 4: Low Earth Orbit battery satellite protocol.

Available instruments with GCPL 4

Instrument	MPG	VMP	VMP2	BiStat
Used			×	
Alternative	×	×		×

OVERVIEW

This aim of this paper is to describe an application of 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.

INTRODUCTION

This galvanostatic cycling protocol has a timing different from the previous GCPL protocol, in the way 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 reach and the instrument turns from the initial galvanostatic mode to a constant potential one.

For comparison, in GCPL and GCPL-3 the initial galvanostatic mode run for a maximum time (t_1) 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 (t_m) or limited by the condition for the redox current to be lower than a given value. In GCPL-2, if a limit potential is reached on the galvanostatic sequence, the system switch to the next step without any constant potential sequence.

EXPERIMENTAL PART

For the experiment conditions used in EC-Lab software, see the [.mpl file](#).

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 was less than 5 mA (Step 1, for about 3 hours). This was done in order to measure the effective capacity of this aged battery. One hour open circuit period was set then, to get an idea of the open circuit voltage (OCV) of the discharged battery.

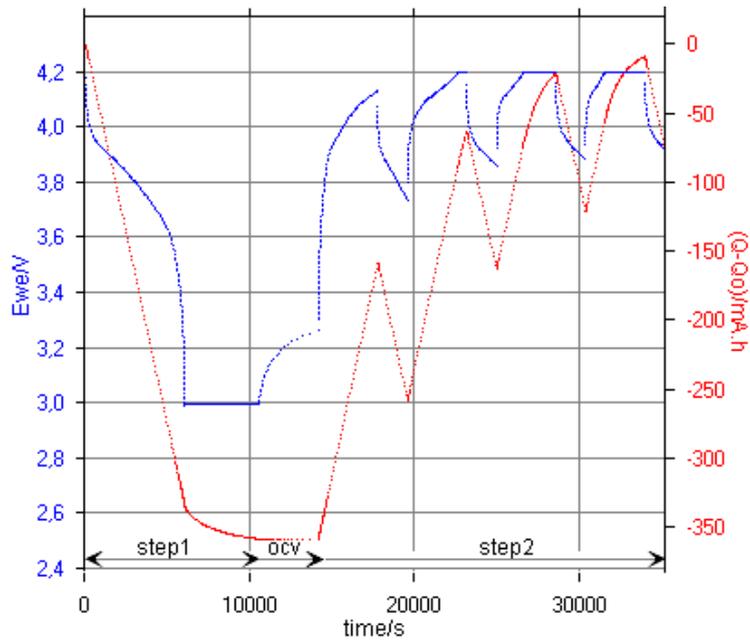


Fig. 1: Ewe and $(Q-Q_0)$ evolution versus time at the beginning of the experiment.

Then the "LEO" cycling was started (Steps 2 and 3) for a total of 21 cycles. No rest periods were set in this cycling, in agreement to the

fact that in the real application the battery turns from charge to discharge as soon as the satellite goes from sun to darkness.

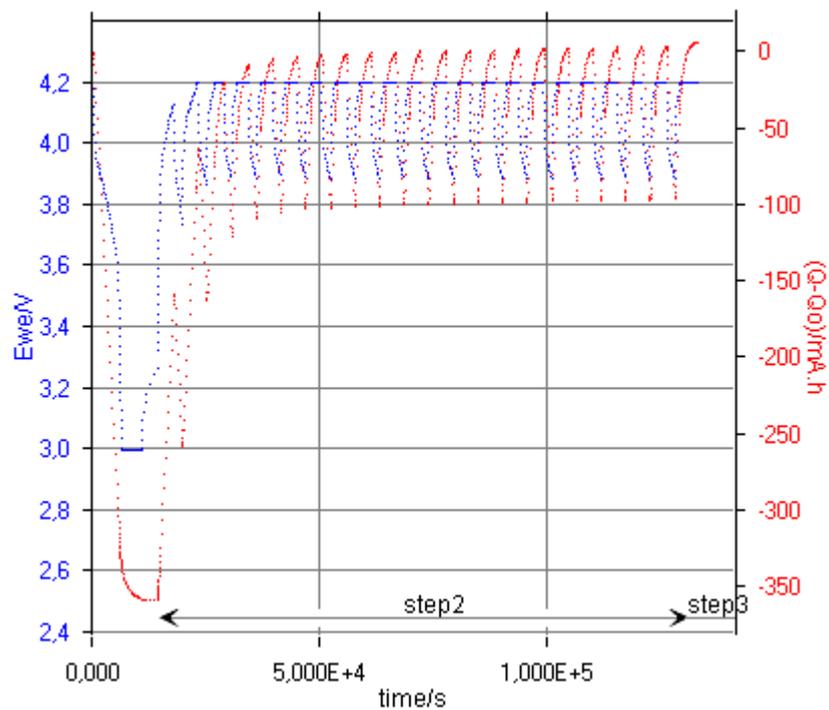


Fig. 2: Ewe and $(Q-Q_0)$ evolution versus time for all the experiment.

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.

RESULTS AND DISCUSSION

In fig.1 are reported 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.

Looking 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 correspond 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.