Rejuvenation of Fuel Cells

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Reducing degradation of fuel cells is of critical importance for their commercialisation. A series of long-term tests were performed in the SAPPHIRE project to study the phenomenon in μCHP systems. The tests highlighted a regenerative effect of shut-downs that led to lower voltage degradation, or even voltage recovery, over several thousand hours of operation.

SAPPHIRE Experimental Campaign

The SAPPHIRE consortium planned a test campaign on μCHP PEMFC systems, which was executed by partner Dantherm Power (today Ballard Power Systems Europe). The objective of the experimental campaign was to test two μCHP systems in nominal conditions for **3000 hours** of operation each, to provide a baseline for system degradation. Two stacks that had already been operated in a field trial for 5000 hours were selected to remove break-in effects.

Data logging was tasked to industrial PCs integrated in the μCHP systems. These PCs were however unable to handle the large amount of data logging due to limitations in their communication capacity over USB, which eventually led to repeated, erratic and unpredictable **emergency shut-downs** of both systems. One of the systems (#1) had sensibly more frequent emergency shut-downs than the other (#2): system #1 failed on average about every two days, system #2 every two weeks.

After the data logs were analysed, it was found that both systems exhibited very low degradation rates: compared to Dantherm Power's nominal rate of **2 μV/h**, system #2 had a tenfold improvement: **0.2 μV/h**. System #1 even showed a marked voltage rejuvenation, **−4 μV/h**.

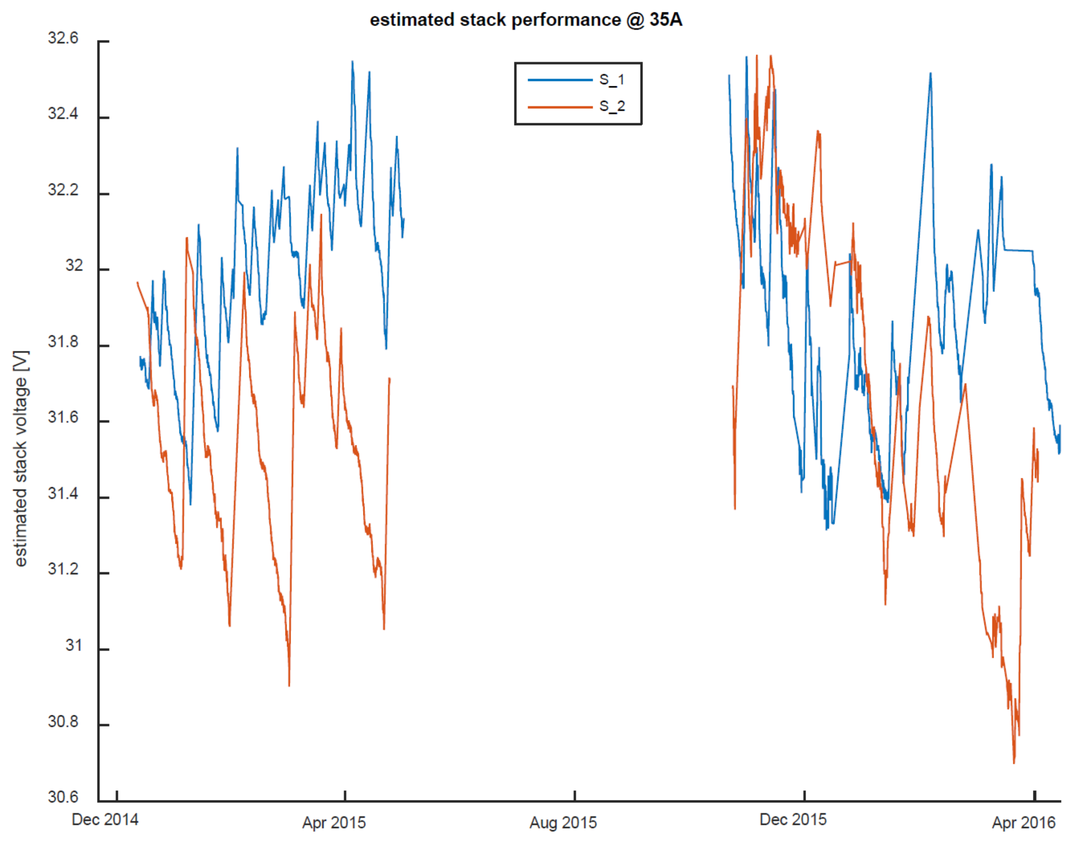

Figure 1: *Stack performances through the two test campaigns.*

In figure 1, the performance of the two systems is represented as the estimated voltage at the nominal current of 35 A; the first half of the data is the initial 3000-hour baseline test with random shut-downs, whereas the second half is a second test, run to confirm the effect of shut-downs on voltage.

Reproducibility of Regeneration

After the analysis of the data of the first batch, a second test campaign was planned to confirm whether the shut-downs were the cause of the improved degradation performance. The systems were fitted with external loggers to correct the issue of random emergency shut-downs. System #1 would be then operated nominally, whereas system #2 would be subject to regular **shut-downs for the first 1000 hours**, after which it would be operated nominally.

As shown in figure 1, system #2 has indeed an initial **rapid increase in performance** in correspondence to the period during which shut-downs were scheduled, which is later replaced by a slow degradation. System #1, instead, shows degradation until February 2016, when a series of unintentional faults occurred, which induced shut-downs and thereby another increase in performance. The performance of system #1 is analysed in detail in figure 2 below.

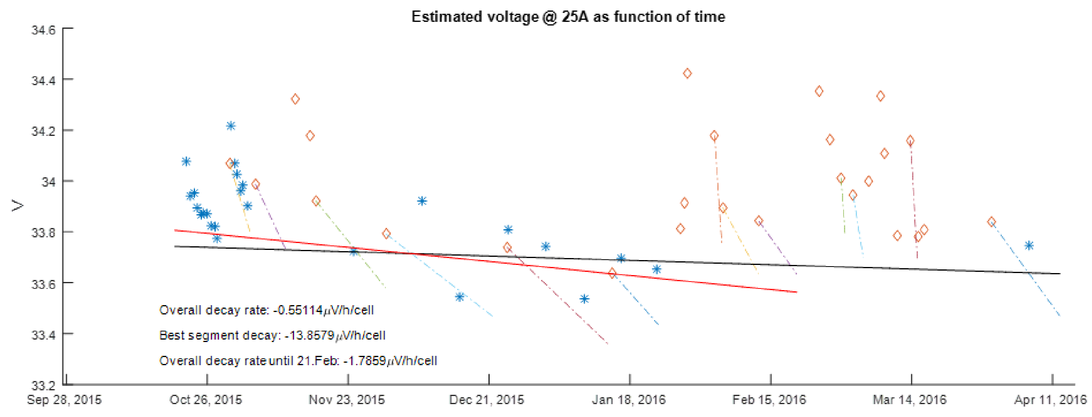

Figure 2: *System #1's performance in the second campaign. Every diamond ◇ is a start-up, followed by a dashed line of continuous operation. Every asterisk ∗ is a measurement on a polarisation curve.*

Ongoing Study in GIANTLEAP

The possibility of reducing degradation by appropriate shut-down procedures has far-reaching implications for automotive fuel cells, where shut-downs are usually associated to *increased* degradation.

To investigate the potential for automotive applications, the GIANTLEAP project (which shares half of its partners with SAPPHIRE) will perform shut-down/start-up experiments on automotive stacks. A public deliverable on **experimental protocols** is in publication.

Caveats

While it has been experimentally proven that appropriately performed shut-downs can improve voltage performance, the exact mechanism of this phenomenon has not yet been identified, even though it is likely related to the **cathodic catalyst layer**.

In particular, it is not known whether this is sustainable for longer times than in the experiments, or whether this approach could promote other degradation pathways, e.g. membrane degradation.

Acknowledgement

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