# ATELIER TECHNIQUE STOCKAGE

## STRATEGIES DE RECHARGE

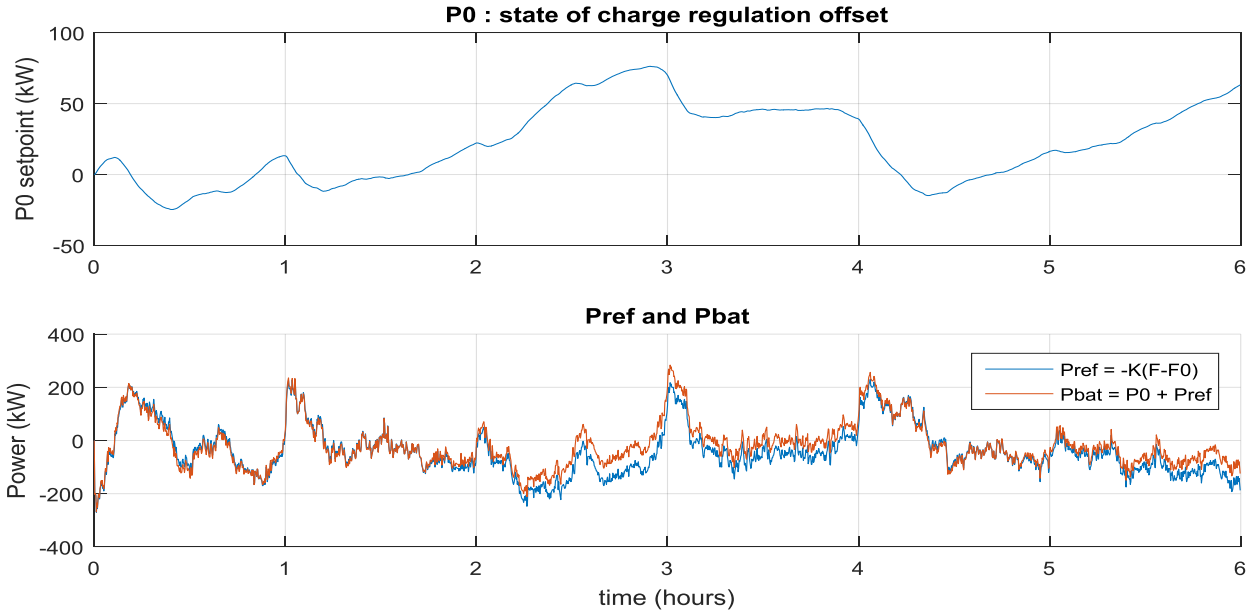
06/04/18



A l'intérieur de la batterie
de 49 MW de  West Burton

# STRATÉGIE DE RECHARGES - PRINCIPE

- **Pour une batterie fournissant de la FCR :**
  - Équation de la puissance pour remplir le service : **$P = -K(F - F_0)$**
    - **MAIS**, des écarts moyens de fréquence longs peuvent faire fortement varier l'état de charge (SoC); le SoC s'éloigne donc de sa valeur de référence (généralement proche de 50%).
    - **Ainsi,** un terme de « **gestion de SoC** » ($P_0$) est rajouté au terme de réglage de fréquence..
  - Équation de la puissance **avec** gestion de SoC : **$P = P_0 - K(F - F_0)$**
  - Le terme $P_0$ se rajoute alors au terme de réglage de fréquence afin de ramener le SoC vers sa référence (50%) quand il s'en éloigne trop.
  - **Attention :** afin de ne pas interférer avec le réglage de fréquence, le terme $P_0$ doit avoir un « effet négligeable » d'un point de vue système. Il doit être par exemple, très lentement variable (comportement d'ordre 1, limitation de rampe…) et/ou borné. **Illustration :**



# STRATÉGIE DE RECHARGE MISE EN PLACE SUR VENTEEA

CIRED

THE VENTEEA 2 MW / 1.3 MWH BATTERY SYSTEM:
AN INDUSTRIAL PILOT TO DEMONSTRATE MULTI-SERVICE OPERATION
OF STORAGE IN DISTRIBUTION GRIDS

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- **Gestion en continu du $P_{SocRef}$** *(dans cet exemple, $P_{FCR,max}$ = +/- 100 kW)*

The VENTEEA TSO1 control algorithm also includes a *SoC* regulation. The example shown in Figure 5 is based on a proportional corrector with a dead band. To have the lowest possible impact on the provision of PFC to the power system, this component of the DESS active power reference is limited (max. ±20 kW in the illustration below) and a ramp rate limit $r_{SoCPFC}$ is applied to clearly separate $P_{SoCref}$ to the main TSO1 control action $P_{refPFC}$.

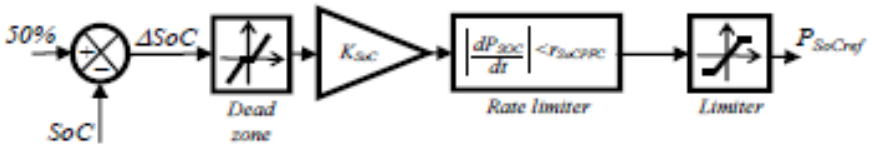



**Figure 5: A simple *SoC* control for PFC.**

A sample result of factory tests is shown in the Figure 6, 7 and 8 below. At the beginning of the test, the *SoC* has reached is reference value of 50 % and $PSoC_{ref}$ is therefore progressively increasing towards 0.

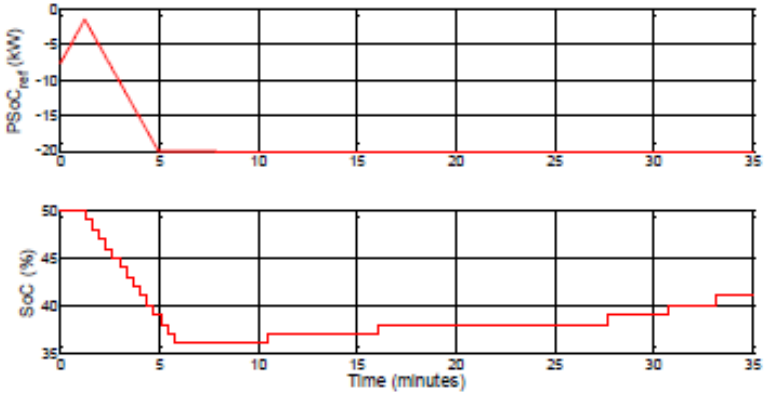



**Figure 6: $P_{SoCref}$ and *SoC* as a function of time.**

A -0.5Hz frequency deviation is then added between $t$ = 1 minutes et $t$ = 6 minutes to the frequency measurement, which immediately results in the full activation of the primary control reserve.

Following the event, the *SoC* is progressively brought back to its reference of 50 %, thus ensuring a high level of availability of the service (Figure 6).

# “IMPACT OF FREQUENCY CONTROL RESERVE PROVISION BY STORAGE SYSTEMS ON POWER SYSTEM OPERATION »

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**Abstract:** Batteries can be used to provide ancillary services, such as primary frequency response. However, their energy capacity is limited. Therefore, set-point adjustments are necessary and the energy for this has still to be provided by power-plants that do not face energy constraints. This paper investigates various aspects of and potential benefits for power system operation and stability, if energy-constraint units are allowed to participate in the ancillary service markets.

The paper is organized as follows: In Section 2, several recharge algorithms are discussed, and the one used in this paper is explained in detail. In Section 3, the simulation setup used to identify system-wide effects of the recharge strategy is described. The use of faster units for primary

*Communication of recharge energy.* All recharge strategies described in Section 2 assume that the required energy is provided by *some other service.* If the energy is not bought explicitly at an energy market, it has to be provided by the secondary control reserves. The amount of energy required might either be communicated *explicitly* by adding the offset to the AGC signal, or secondary control can be triggered *implicitly* via the system frequency.

## 3. SIMULATION SETUP

A simulink model for the synchronous grid of continental Europe is used to analyze the effect of batteries providing primary control reserves on the frequency evolution. Motivated by the available data and the research interest of the authors, the grid is modeled as a two-area system – one area representing the Swiss control area, and the other area representing the remaining European grid.

# "IMPACT OF FREQUENCY CONTROL RESERVE PROVISION BY STORAGE SYSTEMS ON POWER SYSTEM OPERATION »

are within seconds and mHz. Using the frequency data, historic primary control activation and damping by frequency dependent loads can be computed, while the AGC signal leads to secondary control activation and, together with frequency, gives also information about tie-line power. With this information, the power mismatch $\Delta P_{\mathrm{CH}}^{\mathrm{load}}$ can be computed. A similar approach is used to get the power mismatch in the remaining European grid, $\Delta P_{\mathrm{EU}}^{\mathrm{load}}$. We will examine how energy constrained units for primary control affect system frequency and AGC activation, and how much storage capacity is needed. Also, we investigate how the system frequency changes if inertia is reduced.

*Normal operation.* Results detailing the sensitivity to parameters battery quota $\beta$, averaging period $a$ and delay $d$ are given in Table 2. For each simulation run, the amount of positive control energy $E_{\mathrm{CH}}^{\mathrm{pos}}$ and negative control energy $E_{\mathrm{CH}}^{\mathrm{neg}}$ requested by secondary control services in Switzerland is given. Additionally shown is the resulting required storage capacity of the battery $\Delta$SoC, which is the difference between the maximal and minimal SoC reached, as well as the maximum offset power $\Delta P^{\mathrm{off}}$ and total battery power $\Delta P^{\mathrm{bat}}$. Latter defines the power capacity requirements of the battery. Note, that the highest primary control reserve activation in the simulation period was at 0.78 p.u..

Table 2. Sensitivity of battery and AGC usage on design parameters. Results of one-year simulation. Colourings highlight correlation between parameters and outcome.

| Parameters | | | | AGC,CH | | Battery response | | |
|---|---|---|---|---|---|---|---|---|
| $\beta$ [s] | offset | $a$ [s] | $d$ [s] | $E_{\mathrm{CH}}^{\mathrm{pos}}$ [GW h] | $E_{\mathrm{CH}}^{\mathrm{neg}}$ [GW h] | $\Delta$ SoC [min] | $\|P^{\mathrm{off}}\|_\infty$ [p.u.] | $\|P^{\mathrm{bat}}\|_\infty$ [p.u.] |
| 0 | - | - | - | 317.1 | -506.2 | – | – | – |
| 0.5 | yes | 900 | 900 | 317.7 | -509.9 | 22.91 | 0.61 | 0.91 |
| 1 | yes | 900 | 900 | 318.5 | -513.9 | 22.91 | 0.61 | 0.91 |
| 1 | no | 900 | 900 | 318.2 | -513.7 | 22.94 | 0.61 | 0.91 |
| 1 | yes | 600 | 900 | 319.0 | −514.3 | 20.81 | 0.64 | 0.93 |
| 1 | yes | 300 | 900 | 319.9 | −515.1 | 18.87 | 0.66 | 0.91 |
| 1 | yes | 900 | 600 | 319.5 | −515.0 | 18.49 | 0.61 | 0.92 |
| 1 | yes | 900 | 300 | 320.8 | −516.6 | 14.03 | 0.61 | 0.92 |
| 1 | yes | 900 | 0 | 321.3 | −517.7 | 8.85 | 0.61 | 0.84 |

Parameter $a$ defines the averaging period, increasing $a$ reduces the ramp rate of the offset, and thus the ramp rate required by the second-tier service providing the recharge energy. $d$ is a delay, which might be useful if the power is bought at intra-day markets, or if a power plant is to be started up to provide the offset energy. $P^{\mathrm{loss}}$ are the losses

$\beta$ governs what share of the primary control reserves are provided by batteries.

Replacing traditional primary control reserves with batteries leads to a slight increase of energy requested from secondary control reserves, but this is on the order of 1 % of the total energy cycled. In this respect, there is no

# BATTERIE DE EKZ EN SUISSE : RECHARGE EN CONTINUE AUTORISÉE PAR SWISS GRID

**Primary control reserves provision with battery energy storage systems in the largest European ancillary services cooperation**

CIGRE 2016

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The Zurich 1 MW BESS depicted in Figure 2 was commissioned in March 2012. It has a rated power of 1.1 MW and an energy capacity of 580 kWh, of which 250 kWh are usable at peak power in order to limit battery degradation (see Table 1 for key properties) [10].

The battery system prequalified for the provision of PCR in July 2014 according to the requirements of the Swiss TSO. Since then, the battery unit participated continuously in the Swiss market as well as in the newly formed joint PCR market, winning tenders for 41 weekly bid periods as of 31.12.2015.

The employed approach for controlling the SoC of the Zurich 1 MW BESS is a moving average strategy [8] according to:

For the Zurich 1 MW BESS an averaging period $a$ of 15 minutes (180 steps, with a step duration of 5 s) was chosen to ensure a slow recharging behavior, and a simple power-dependent efficiency model was used to calculate the losses. According to the peak power capability of 1.3 MW, $P_{off}$ is limited to ±0.3 MW to make sure the BESS can provide 1 MW of PCR power at all times.

The needed recharging energy is sourced from secondary frequency control. It was verified in [11] by means of simulations that this control strategy performs well during contingencies, does not put secondary control reserves under undue stress, and increases energy demand from secondary reserves by only 1–2% over the course of one full year of operation. Under the real life conditions of the