GRID4EU

INNOVATION FOR ENERGY NETWORKS

Technical Spotlight DEMO6-S1

Spotlight on residential storage implemented in DEMO6

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1. Introduction

1.1 Definitions

Within DEMO6, a **residential storage system** is a storage asset (lithium ion battery, **converter**, monitoring system) connected downstream residential customers **meters.** Residential storage systems are used as **flexibility** for two uses cases: peak demand reduction and PV integration.

1.2 Tags & metadata (Technical Glossary)

Type of solution					
■ Equipment / Hardware / Firmware		☐ Information system		☐ Process	
Manufacturer(s) implied (for equipment or hardware)					
Saft, SMA, SOCOMEC					
Work Stream considered					
■ Active Demand	■ DER	■ Storage	☐ Islanding	☐ MV Innovation	■ LV Innovation
Location / Topology (with regards to distribution grid)					
☐ HV/MV Substation	☐ MV	☐ MV/LV SS	■ LV	■ DER	☐ Meter / ■ Downstream meter
☐ Other Centralized system (calculations, information system)			☐ Other Decentralized system		☐ Other :
Thematic(s)					
☐ Grid Monitoring / state estimation		■ Active demand / DSM		■ DER Integration / increased grid capacity	
☐ Islanding	☐ Anti Islanding protection		☐ Automatic Failure Detection		☐ Remote Grid Operations
☐ Automatic Failure Management / Grid recovery		☐ Automatic Grid topology reconfiguration		☐ Other :	
Use Case(s)					
DEMO 6 ☐ Islanding	■ Peak demand reduction	■ Integrate massive PV production on LV network			■ Encourage resident to adopt smarter habits according to network state
Key figures					
▪ **18** residential storage systems ▪ **4,6 kW / 4 kWh** storage systems					

2. Objective and technical requirements

2.1 Context and objective

On the objectives of DEMO6 is to assess the **effectiveness of electricity storage** in order to reduce imbalances between electricity generation and consumption in an urban district

- **Reduction of demand peaks** in winter
- **Reduction of solar output peaks** in summer

To this purpose, **18** residential producers of solar power were asked to install a system consisting of an **4.6 kW** SMA **converter** and a Saft Li-Ion **4 kWh** battery

Figure 1- Battery installed at customer premises

The **residential power storage system** is designed more specifically to:

- Store the electricity generated by the solar panels of the homes between the hours of 12 AM and 4 PM on the 40 sunniest days in summer (called *"solar days"*).
- Use the electricity stored in the batteries on the 20 peak demand days (coldest winter days) between 6:00 and 8:00 PM to reduce residential peak demand and contribute to reducing CO_2 emissions.
- Store the electricity, apart from *"solar days"* and "*peak days*", when electricity rates are lower (Off-Peak Hours) for later use when the rates are more expensive (Peak Hours), for participants with a **Double Tariff** electricity supply contract **(Off-Peak Hours/ Peak Hours tariff).**[1]
- Store the residential PV generation surplus, apart from *"solar days"* and *"peak days"*, for later use in the evening when solar output decreases, for participants with a **Single Tariff** electricity supply contract **(Base load tariff).**[2]

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[1] Functionality tested in DEMO6 as a somplement to the Uses Cases initially planned in the project.
[2] This functionality, a complement to the Uses Cases initially planned in the project, was tested only partially during the experiment.

Figure 2 - Brochure of the residential storage offer (EDF)

2.2 Control of storage systems

The process of charging and discharging of the batteries installed at the homes of DEMO6 customers is controlled automatically, either remotely by the EDF platform via an "**Energy Box**" connected locally to the **converter**, or locally by this **Energy Box**, apart from *"solar days"* and *"peak days"*.

The *"solar days"* and "peak days" when the system is controlled remotely by EDF are determined on the previous day without requiring any special intervention from the experimenting customers, who are however informed via email or text message about the use of their storage device.

Conversely, the daily automated battery control on "normal" days (i.e. excluding peak days and *"solar days"*) is carried out locally and is fully transparent for the participant.

3. Development and implementation

3.1 Architecture

- **Description of equipments**

The experimental system tested consists of:
- SAFT electrochemical battery (Intensium® Home 4M, 48V/4kWh/4kW)
- SMA SUNNY ISLAND 6.0H **converter**,
- Local control systems consisting of:
  - EDELIA **Energy Box**
  - Radio-transmitters for real-time transfer of data from **Linky smart meters**
- Remote control system (**B2C aggregation platform**) communicating with the local system.

The diagram below shows the various system components:
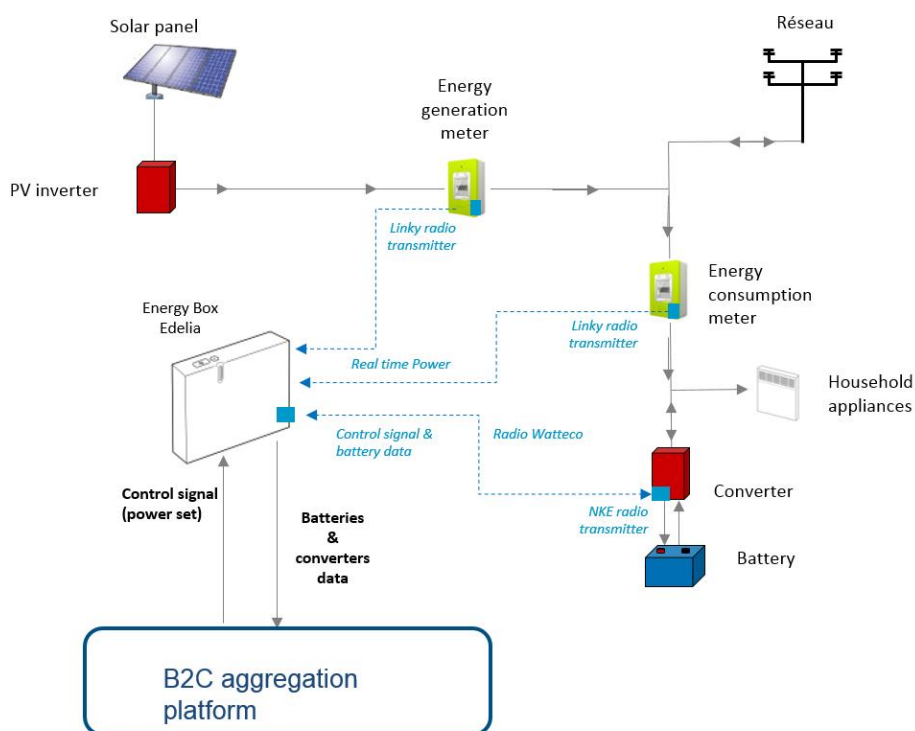
Figure 3 – Residential batteries control system

- **Single line diagram**

The system is equipped with electrical protection devices to ensure its disconnection from the home system in case of over-consumption or power supply cut-off. Furthermore, the **Energy Box** monitors the facilities and in the event of any malfunction transmits instant alerts while measuring all parameters necessary to evaluate the system performance post-event: output efficiency, activated flexibilities, daily charge/discharge cycles.

Figure 4 – Single line diagram

3.2 Main functions

Since the DEMO6 storage system is installed **downstream from the consumption meter**, the batteries are **charged from the power grid**, thereby enabling them to contribute to reducing winter consumption peaks, independently of the power generated by the solar panels (fitted with their own inverter), including at night. Conversely, the stored power must be used **exclusively to supply electrical appliances in the home**, since current regulations do not authorise EDF to buy back the power stored by customers.

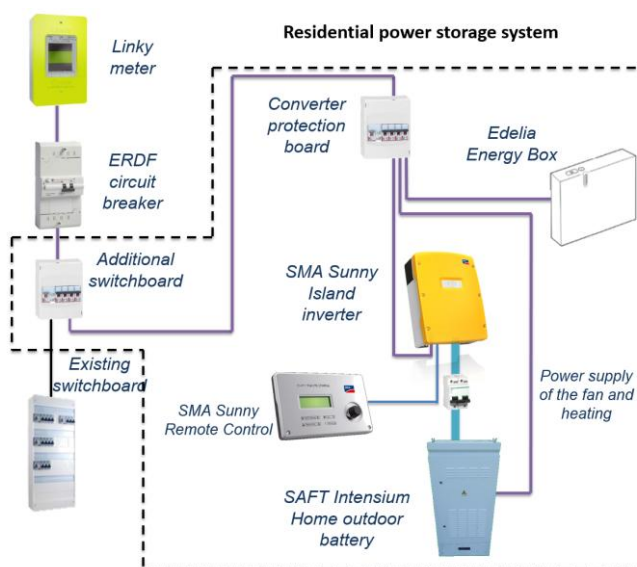Apart from the fact that this system can be used to supply the customers' needs outside of solar production periods,to store low-cost energy at night and re-use it in daytime, this architecture **may be rolled out in the home of non generating consumers**. Ultimately, the batteries controlled by the local or remote system could potentially be the **batteries of electric vehicles** connected to their charger.

The proximity of the storage system to the power generation facilities enables the additional management of battery charging to be **coordinated in real time with the home's PV generation**. Thus the batteries of single-tariff customers could be controlled outside of *"solar days"* in order to store the surplus output during the day and supply the home in the evening. **Self-consumption** would thus reduce power exchanges between the home and the distribution grid.[3]

The same architecture also enables the battery charging process to be adjusted during "*solar hours*" according to the home's instantaneous power output. The upward **flexibility** requests sent on the previous day by the DSO are subject to weather uncertainties, but could therefore be adjusted locally in real time depending on the effective solar output measured at the home level. This function has however not been experimented yet under the DEMO6 trials.

3.3 Deployment

The installation of batteries requires **proper organization and planning** in order to limit the number of visits to the customer's home. The weak point is the **customer's ADSL receiver** that may be subject to various and frequent manipulations.
The daily alert reports require an analysis and sometimes an intervention at the customer's home but access to the facilities is not always authorized immediately (the converter is often installed inside the home).

3.4 Lab tests

Before its experiment with customers, the residential power storage system has been **validated in the laboratory of EDF R & D.** This laboratory has an acquisition system that measures continuously (every 10 seconds) the powers of charging and discharging of the battery and energy exchanges with the network.

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[3] The technical and economic impacts of self-consumption on the electrical system would need to be analysed in order to prevent any windfall effects.

Tests have focused in particular on:
- The reliability of **radio communications,**
- The **trickle charge** to compensate for losses due to consumption of the **converter** and battery.
- The **safety loading** to recharge the battery up to 15% when the SOC falls below the 8% threshold,
- The **non-disjunction of the house** while charging the battery and the non-injection of energy on the network during the discharge of the battery

4. Technical results

The following three strategies are experimented for residential battery management:
- **Default** mode (daily cycle without requests from grid operators),
- **Preparation** mode (charge level to be reached to prepare for upward or downward **flexibility** requested by grid operators),
- **Modulation** mode (charge or discharge power to be applied in response to requests from grid operators).

4.1 Operation in default mode

a) For a **single-tariff non-producing customer**, or a producer without battery servo-control system linked to their power output (case of the first experimental phase), the default operation consists in keeping the battery at a charge level (SOC) around 15%.

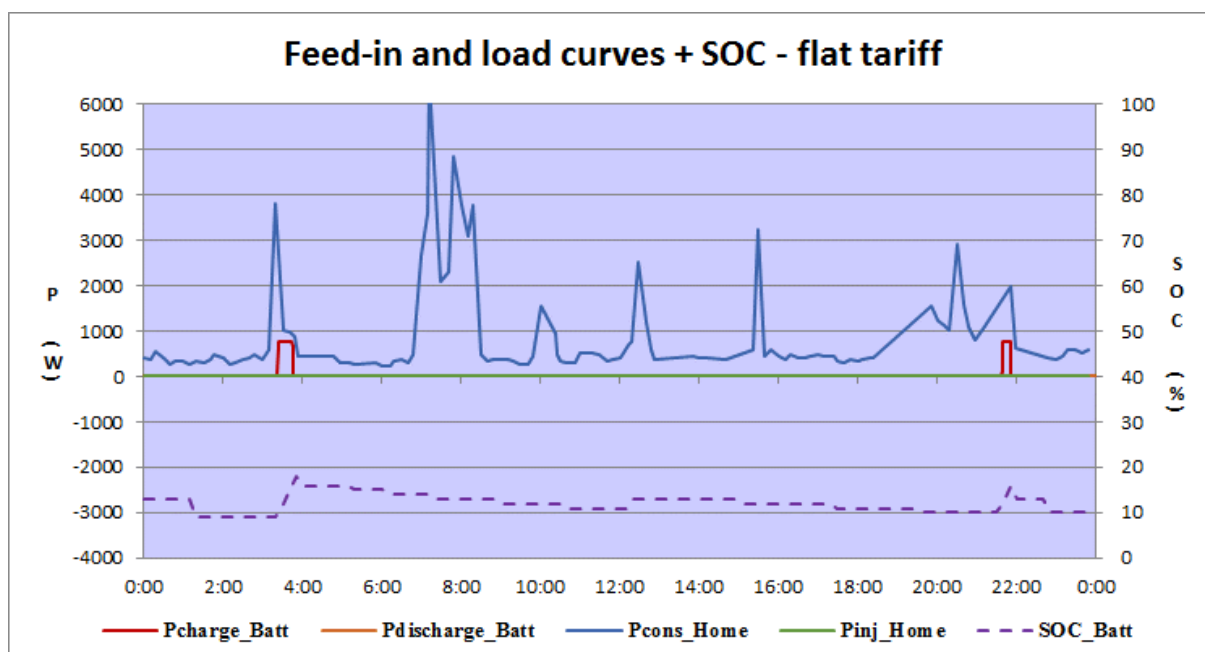The graph below shows the periodic trickle (or float) charges designed to compensate for the system's auto-discharge.

Figure 5 – Example of trickle charges over one day (red curve)

The trickle charge is triggered here twice a day in order to compensate for load losses from the **converter** and battery.

b) For a **single-tariff producing customer** equipped with a battery servo-control system linked to their power output (case of the second experimental phase), the daily default cycle consists in starting to charge the battery at sunrise in order to absorb any potential surplus output from the home, and then reinjecting the stored power in late afternoon (after 4:00 PM) to maximise the customer's auto-consumption, up to a minimum SOC of 15% expected at midnight, as shown on the diagram below.
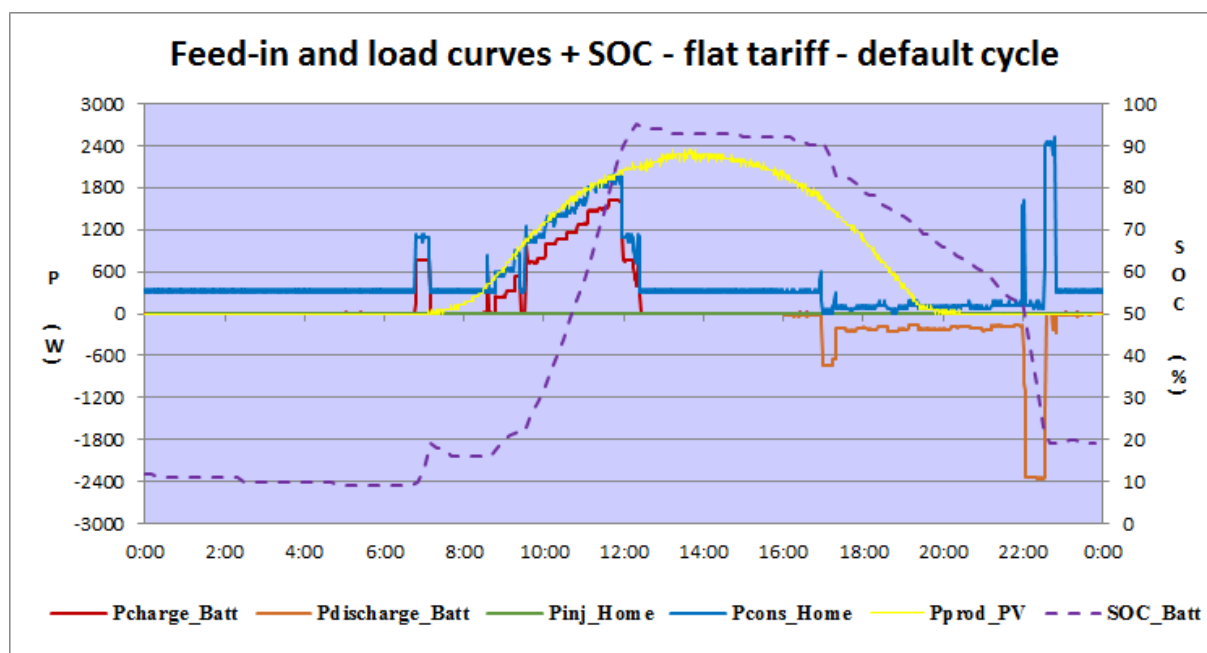

Figure 6 – Default cycle for a single tariff producing customer

When the home's solar output increases (yellow line), the battery is charging (red line) since the consumption demand (blue line) is lower than the output generated. In this example, the battery is fully charged at 12:00 noon. It only starts discharging intermittently after 4:00 PM since the customer's consumption (probably absent from the home until then) remains low until the hot water tank is activated, thereby providing for the battery discharge between 10:00 and 11:00 PM.

It should be noted that the total power demand of the home (blue line) is virtually null during the battery discharging periods (self-consumption of the stored solar power).

c) The graph below corresponds to the daily default cycle of a **double-tariff customer**; it shows the charging process in Off-Peak Hours starting at 0:00 (red line) and the discharge in Peak Hours starting at 6:00 AM (orange line). The discharge is modulated to supply the home's uses, with a relatively fluctuating consumption as shown in this example.
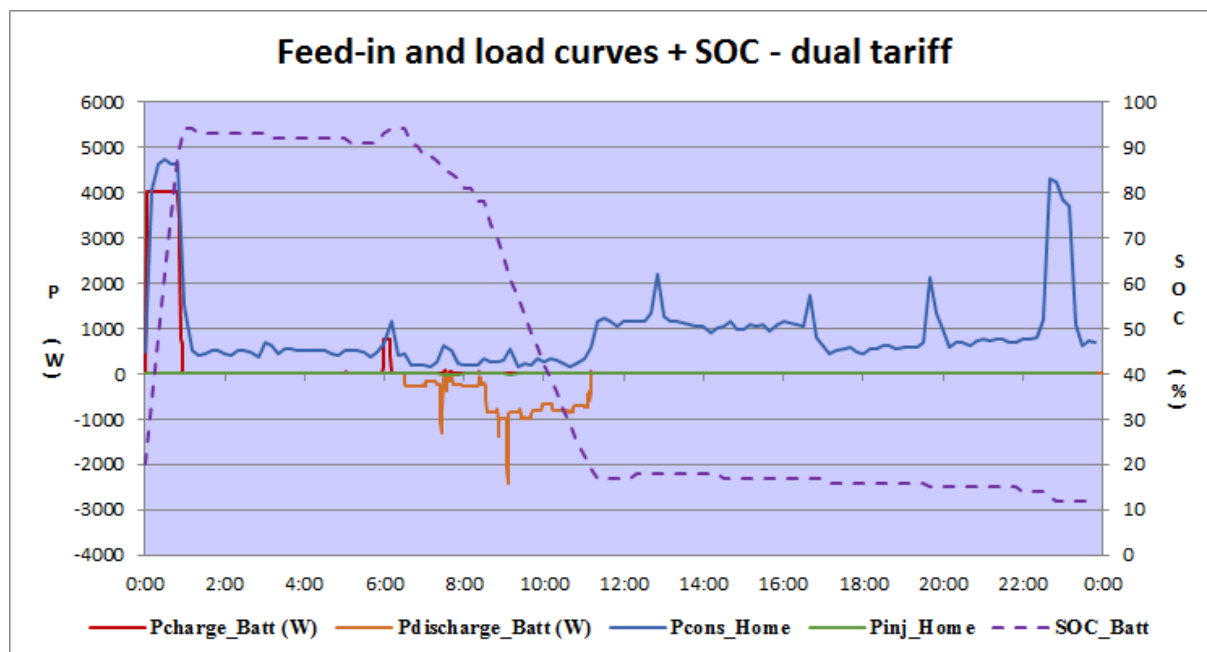
Figure 7 – Default cycle of double tariff customer

The SOC (charge level) purple curve reaches a maximum level on completion of the initial charge (at 1:00 AM) and at the end of the trickle charge (around 6:00 AM). After the discharge stops (at 11.30 am), losses lead to a low but gradual decrease in the SOC level until the controlled recharge process starts again at 0:00.

Lastly, the light-blue line shows the total power consumption of the home with two consumption peaks: at 0:00 during the battery's fast charge, and at 10:30 PM when the hot water tank is activated. We can also see on this curve the consumption reduction during the battery discharge.

4.2 Operation in preparation mode and activation of flexibilities

The period of preparation and later activation of batteries in peak hours (6:00 -8:00 PM) is detailed in the graph shown below.
The red line represents the preparation power curve (charge from 0:00 to 1:30 AM), followed by maintenance charging of the battery (at 1:00 PM).
The orange line shows the battery discharge into the customer's household appliances between 6:00 and 8:00 PM according to the set-up point (1350 W). At the end of the request (8:00 PM) the battery completes its discharge following the default cycle.
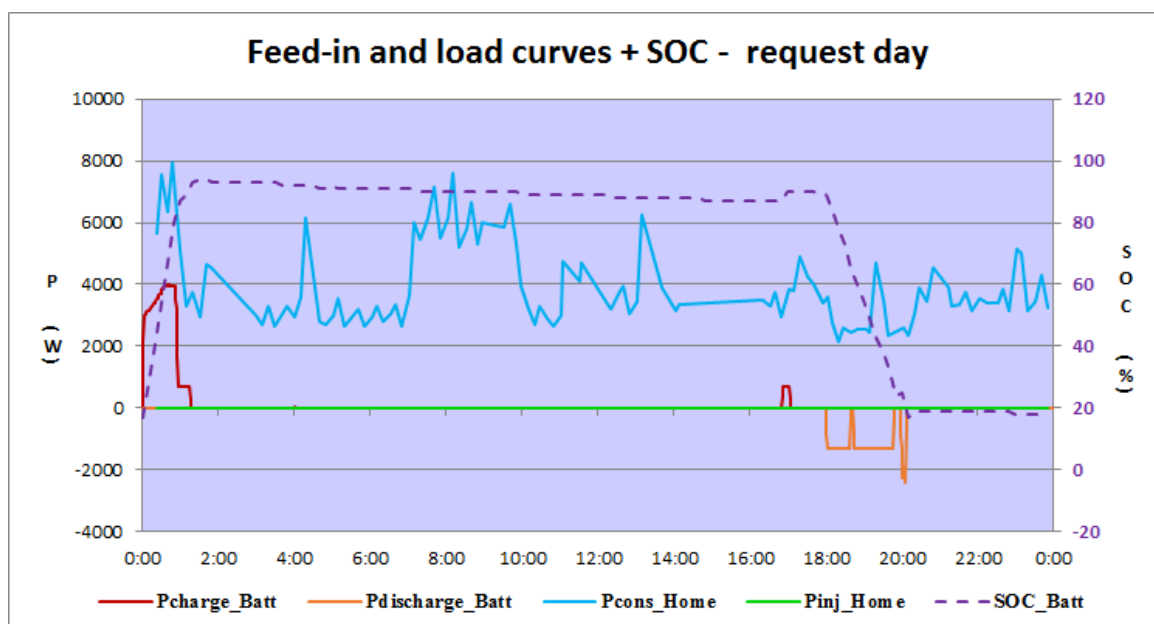
Figure 8 – Feed in, load and SOC level curves for a request day during winter

Power discharge variations between 6:00 and 8:00 PM will depend on:

- the **flexibility** profile requested on the previous day by the grid operator,
- the combination of the various flexibilities optimised by the **B2C aggregator** (EDF) on the previous day,
- the actual power consumptions and outputs of the home, which may end up limiting the discharge planned on the previous day by the **B2C aggregator** (real-time activation of the local **Energy Box** automated system)

The graph below shows the operation of **flexibility** activation in summer between 12:00 noon and 4:00 PM
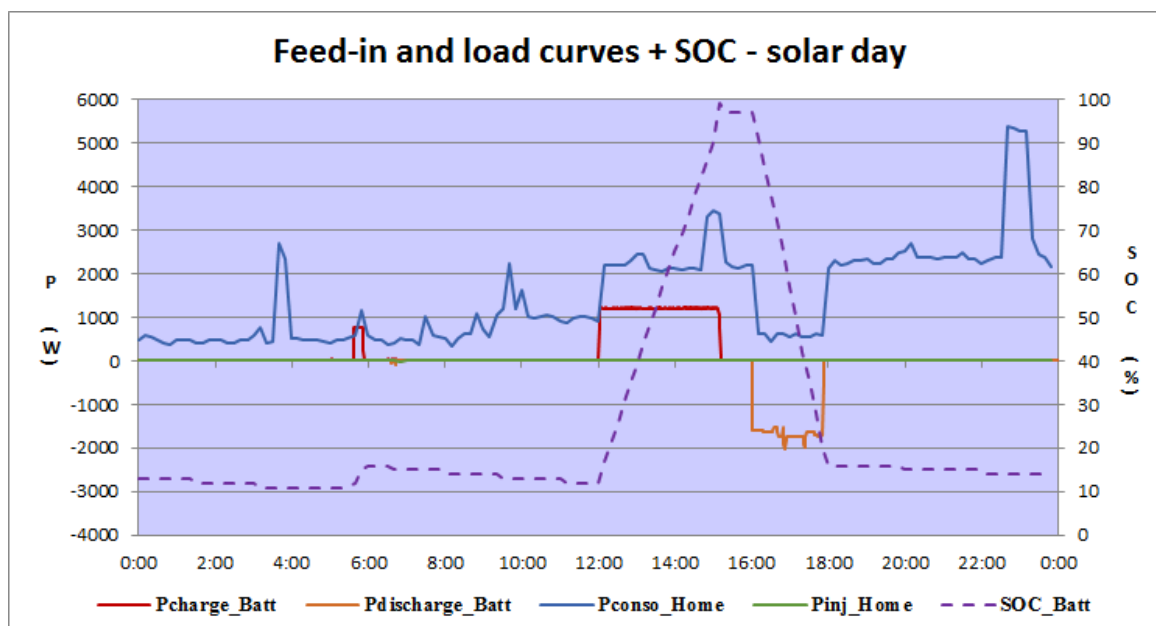

Figure 9 - Example of daily power curves (charge in red, discharge in orange) and SOC of the battery (purple)

4.3 Output efficiency

The graph below shows the mean and maximum **efficiency rates**, with maximum rates corresponding to the efficiency recorded on request days.

It may be noted that the efficiency of the battery/**converter** system (excluding auxiliaries) varies from one installation to another and from one day to another on the same installation, since the efficiency is closely linked to the charge/discharge cycle and to the power consumed by the customer's electrical uses.

The mean efficiency rate (excluding auxiliaries) recorded for all installations during the summer trial was approximately 67%.

Average energy losses are estimated to **1,2 kWh per day and installation** and are due to the consumptions of the different components: battery (BMM power: 10 W), the **converter** (26 W in operational mode) and auxiliaries.
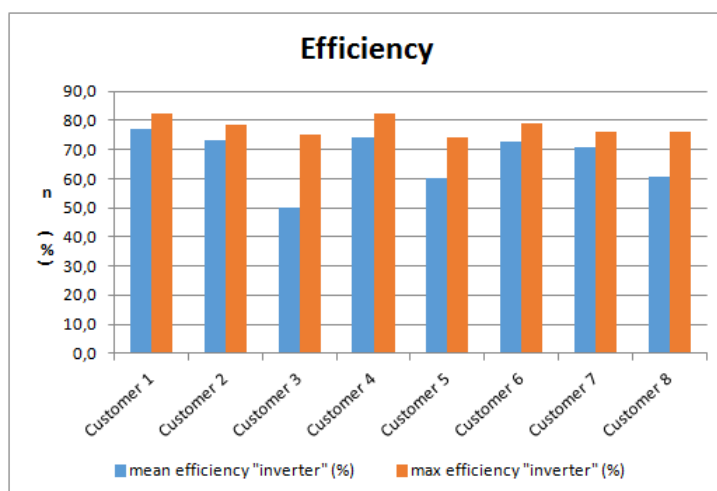

Figure 10 – Mean and maximum efficiency rates on recorded requested day (summer 2015)

The maximum 82% rate was obtained over a short cycle, for a charging load of 1200 W during 3 hours and discharge at a power constantly above 1000 W within less than 3 hours.

Minimum value for client 3 has been observed on a day of very low consumption.

Taking into account losses in auxiliary devices (box, sensors, battery ventilation…), the efficiency drops by 4 points down to 78% in the best case and down to 63% on average.

5. Conclusion and key messages

- The DEMO6 residential storage system is installed downstream from the **power supply meter** in order to maximise its use, including at night and potentially in the homes of simple (non-producing) consumers.
- The controlling system is distributed into 2 levels: EDF's **B2C aggregation** platform which schedules the activation sequences on the previous day, and the **Energy Box** which adjusts

in real time the charging/discharging instructions according to the local requirements (power consumption and generation of the home).

- Three control strategies are implemented: daily default cycles or charge level maintenance, preparation for flexibilities, activation of flexibilities upon request from the grid operators.
- The maximum efficiency of the system, including command and control auxiliary devices is **approximately 78%** (82% excluding auxiliaries), but drops down to 63% (67% excluding auxiliaries) on average over the entire period of effective battery operation (excluding servicing or technical testing when the efficiency may be downgraded). These values can be linked to the fact that configurations are experimental and not optimised[4].

6. Appendix

6.1 To go further

Document	Topic
dD6.7	Technical results *(§3.6)*
dD6.8	Sociological studies
dD6.9.2	Key Performance Indicators (KPI) *(§2.2 and 2.3)*
dD6.9.3	Key messages *(§2.5)*
Technical Spotlight S10	Peak demand reduction flexibilities
Technical Spotlight S11	Residential flexibilities involved in PV integration

6.2 Glossary

Term	Definition
B2C Aggregator	This platform offers the system operators (ERDF and RTE) some upward or downward power flexibility options to help them respond to grid constraints. Potential flexibilities from residential premises reside in the control over various devices downstream from the meter and information displayed to the experimental users to turn them into agents of such flexibilities.
Converter	A power converter system associated with a battery is power electronics device acting as bidirectional voltage converter (AC <-> DC) and charger for the battery.
Double tariff	Regulated tariff for customers with a subscribed power below 36 kVA. The clients have 8 hours at off-peak rate during the night, and pay on on-peak rate during the day. In July 2015, the price is 16,00 c€/kWh (on-peak) and 11,14 c€/kWh (off-peak)
Energy Box	The Energy Box is a gateway that provides communication of the battery with the aggregation B2C platform. The box Energy also provides local management of energy storage based on consumption and solar generation of the house.
Flexibility	A flexibility is a mean to modify (increase or decrease) a load curve, at client or network level
Linky meter	Linky is a communicating meter, which means that it can receive and send data without the need for the physical presence of a technician. Installed in end-consumer's properties and linked to a supervision centre, it is in constant interaction with the network. This is what makes it "intelligent".
Single tariff	Regulated tariff for customers with a subscribed power below 36 kVA. In July 2015, the price is fix: 14.67 c€/kWh

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[4] An average 71% roundtrip efficiency has been computed on 40 complete cycles