Storage as an enabler in managing local resources

Cagliari, 30 May 2019

Abengoa

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Pegasus Microgrids Summer School
Storage as an enabler in managing local resources

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- Why ESS?
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Abengoa Introduction

Abengoa as a company

Abengoa is an international company that applies innovative technology solutions for sustainability in the energy, water and infrastructures sectors.

Technological development continues to be Abengoa’s key competitive advantage in the undertaking of high added value projects. The company continues to develop R&D and Innovation projects, identifying new business areas and acquiring new competences.

Global presence with a recognized position of leadership in main world rankings (ENR, GWI)

+10 GW of installed power and more than 1.8 GW from conventional generation plants under construction

Extensive experience on renewables integration 2.3 GW solar power completed and 232 MW from wind power
Abengoa Introduction

Abengoa as a company

Flexitranstore: BESS stand alone

General Information:
- Technology: BESS (1MW / 2MWh) Lithium Ion
- Application: Flexibility
- Location: Athienou, Cyprus

Abengoa Scope:
- Technology selection (batteries, PCS and auxiliary equipment) and equipment integration in containers
- Development of BESS new control algorithms
- Installation on site and commissioning / start-up
- BESS operation and performance monitoring

Cerro Dominador*: PV+CSP+MS+BESS

General Information:
- Technology: PV (100MW) + CSP (110MW) + MS (17h) + BESS (12MW / 4MWh) Lithium Ion
- Application: Primary Frequency Regulation
- Location: Atacama desert, Chile

Abengoa Scope:
- Technology selection (batteries, PCS and auxiliary equipment) and equipment integration in containers
- Design of algorithms for the Energy Management System
- Installation on site and commissioning / start-up

(*) Cerro Dominador is a Project owned by EIG Global Energy Partners
Applications of Energy Storage

What is a BESS?

A typical architecture of a microgrid with BESS can as follows:

- **Control system**
  - Energy management system
  - Coordinates the operation of the batteries, generation, demand and power converter

- **Batteries**
  - Core of the energy storage system
  - Represents a large share of the costs of the system

- **Generator + Consumer**
  - Prosumers: Generator + Consumer
  - The generation could be RES (PV, Wind...), but also conventional (CHP)

- **Power converter**
  - Bidirectional power converter DC-AC

- **Transformer**
  - Main transformer

- **Switchgear**
  - Microgrid can have a switchgear on the PPC to operate in off-grid mode

- **EMS**
  - Energy Management System

- **PCS**
  - Power Conversion System
Technologies used for Energy Storage

Global Overview

Discharge time at rated power

- Seconds
- Minutes
- Hours

Power levels:
- 1 kW
- 10 kW
- 100 kW
- 1 MW
- 10 MW
- 100 MW
- 1 GW

Technologies:
- Super capacitors
- Flywheels
- NiMH battery
- NiCd battery
- Lead-Acid battery
- Flow batteries (ZnBr, VRB, etc.)
- NaS battery
- NaNiCl2 battery
- Li-ion battery
- Molten salt
- Pumped hydro
- CAES

Metal-air batteries

RENEWABLE ENERGY
Technologies used for Energy Storage

Global Overview

Lithium-ion still dominates the market with 97.5% share of MW in Q3 2018
Lead-acid held 1.7%, while a single vanadium-redox flow battery project took the remaining 0.8%

Quarterly energy storage deployment share by technology (MW %)

Source: Wood MacKenzie Power & Renewables
# Applications of Energy Storage

Why ESS? Energy Storage is a “swiss army knife”

## Needs

1. **Need of peak demand covering**
   - In the least expensive way for final consumers

2. **Need of voltage / frequency regulation**
   - For a smart and more efficient operation of the electric power system

3. **Renewables integration**
   - The increase in non-dispatchable renewable power plants may cause a flexibility crunch in the short term

4. **Requirements of new T&D infrastructure**
   - Due to the increase in maximum power demand and aging infrastructure

5. **Consumers empowerment**
   - Electricity consumers can manage their electricity bill and reduce costs associated with less reliable and lower quality power

## Applications

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<tbody>
<tr>
<td>** Residential (BTM)**</td>
<td>~1-10 kW</td>
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<td>** C&amp;I (BTM)**</td>
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<tr>
<td>** Utility-Scale (FTM)**</td>
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</table>

## Energy Storage Sectors

- **Residential (BTM)**: ~1-10 kW
- **C&I (BTM)**: Typ. up to 1 MW
- **Utility-Scale (FTM)**: > 1 MW
Applications of Energy Storage

Energy Storage is a “swiss army knife”

Category 1. Electric Supply (ES)
- Price Arbitrage (PRA)
- Capacity (CAP)

Category 2. Ancillary Services (AS)
- Load Following (LF)
- Frequency Regulation (FR)
- Voltage Regulation (VR)
- Spinning Reserve (SR)

Category 3. Renewable Energy Integration (REI)
- Price Arbitrage (PRA)
- Capacity Firming (CF)

Category 4. Transmission & Distribution (TD)
- Transmission Support (TS)
- Transmission Congestion Relief (TCR)
- T&D Upgrade Deferral (TUD)

Category 5. End User (EU)
- Time of Use (TOU)
- Demand Management (DM)
- Reliability (REL)
- Power Quality (PQ)
Applications of Energy Storage

Energy Storage is a “swiss army knife”

Category 1. Electric Supply (ES)

➢ Price Arbitrage (PRA)

Description
- Focused on Utilities
- Utilities and generators can use the stored energy to buy and sell energy accordingly to the prices in the market

➢ Capacity (CAP)

Description
- Focused on Utilities
- Utilities can manage the energy they can supply, optimizing the grid use
# Applications of Energy Storage

Energy Storage is a “swiss army knife”

## Category 2. Ancillary Services (AS)

<table>
<thead>
<tr>
<th>Description</th>
<th>Utilities can use BESS to restore the frequency to the set point of the grid in case of deviation, absorbing or injecting active power</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Load Following (LF)</strong></td>
<td>Utilities and generators can adjust the power outputs regarding the electricity demand</td>
</tr>
<tr>
<td><strong>Frequency Regulation (FR)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Voltage Regulation (VR)</strong></td>
<td>Utilities can use BESS to restore the voltage level to the set point of the grid in case of deviation, absorbing or injecting reactive power</td>
</tr>
<tr>
<td><strong>Spinning Reserve (SR)</strong></td>
<td>Utilities can use BESS to support the grid in case a generator fail</td>
</tr>
</tbody>
</table>
Applications of Energy Storage
Energy Storage is a “swiss army knife”

Category 3. Renewable Energy Integration (REI)

- Price Arbitrage (PRA)
- Capacity Firming (CF)

Description
- Focused on Utilities, C&I and Residential
- In case of C&I and residential applications, the actor can be considered prosumers.
- Regarding each local or national regulations, prosumers could sell the energy that they will not use to the grid, having profit.

Description
- Focused on Utilities, C&I and Residential
- For utilities, BESS can be used to smooth the ramp rate and eliminate rapid voltage on the grid due to the intermittent power output from RES
- For C&I and residential users, they can use BESS to stabilized the power output and avoid fluctuations in the power supply
Applications of Energy Storage
Energy Storage is a “swiss army knife”

**Category 4. Transmission & Distribution (TD)**

- **Transmission Support (TS)**
  - Description
  - Focused on Utilities
  - Utilities can use the stored energy in BESS for supporting the grid in case of low generation or high demand

- **Transmission Congestion Relief (TCR)**
  - Description
  - Focused on Utilities
  - Utilities can use the stored energy in BESS when the flows of electricity are constrained below desired levels

- **T&D Upgrade Deferral (TUD)**
  - Description
  - Focused on Utilities, but also interesting for C&I and microgrids
  - Microgrids and energy communities can use BESS to avoid new investment in infrastructure
## Applications of Energy Storage

Energy Storage is a “swiss army knife”

### Category 5. End User (EU)

<table>
<thead>
<tr>
<th>Description</th>
<th>Time of Use (TOU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Focused on Residential and C&amp;I</td>
<td></td>
</tr>
<tr>
<td>- Residential users can use the BESS to manage their energy, using it for peak pricing periods and reduce the bill</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Demand management (DM)</th>
</tr>
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<tbody>
<tr>
<td>- Focused on Residential and C&amp;I</td>
<td></td>
</tr>
<tr>
<td>- Users can use the energy from the BESS to cover their own needs in energy supply, avoiding the supply from grid in peak periods, where price are higher and quality and stability can be worse</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Reliability (REL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Focused on Residential and C&amp;I</td>
<td></td>
</tr>
<tr>
<td>- Users have available a source of energy from BESS, that can avoid outages and improve energy supply quality</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Power Quality (PQ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Focused on Residential and C&amp;I</td>
<td></td>
</tr>
<tr>
<td>- This application is especially useful in remote areas, where the energy supply from the network is bad</td>
<td></td>
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</tbody>
</table>
Applications of Energy Storage

Energy Storage is a “swiss army knife”

So, in summary, Energy Storage provides the capabilities to...

➢ Make a better usage of local resources

➢ Increase the penetration of renewables through improved grid control

➢ Reduce/remove investments on T&D infrastructure

➢ Reduce price volatility, decreasing consumers costs

➢ Improve grid resiliency and power quality, reducing service outages
Energy Storage Costs Overview

How much is the real cost?

Battery cost are going down significantly and the trend is expected to continue, but...

- Values shown below are volume-weighted average (volume of EV batteries is much, much higher than volume of stationary batteries)
- There are (and will be) “turbulences” (high increases in demand, bottlenecks in the supply of raw materials (lithium ore, metals, etc.) similar to what happened with PV panels in the past

Source: BNEF, March 2019. [https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/](https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/)
Energy Storage Costs Overview
How much is the real cost?

BESS (Battery Energy Storage Systems) are not just batteries!

• **Scale matters!** The bigger your project is, the cheaper the batteries are (and the opposite). This is specially important in C&I sector, where project-dependent costs could be higher than in Grid sector.

• PCS costs will also decrease in future (but not at the same rate than batteries) because it is the same technology than used in PV.

• Rest of items do not have much more room to improve because they are standard industrial equipment (Balance of Plant) or project-dependent costs (EPC).

Source: BNEF $/KWh for a 100MW/4hr system. Note: PCS: Power control system, EMS: Energy management system.
Energy Storage Costs Overview
How much is the real cost?

BESS in the domestic market

<table>
<thead>
<tr>
<th>Brand</th>
<th>Usable Capacity (kWh)</th>
<th>Cost</th>
<th>Battery Material</th>
<th>Warranty</th>
<th>Life Cycles</th>
<th>Depth of Discharge (DoD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tesla Powerwall</td>
<td>13.5 kWh</td>
<td>From £5,500</td>
<td>Lithium-ion</td>
<td>10 years</td>
<td>Unlimited*</td>
<td>100%</td>
</tr>
<tr>
<td>SolaX 3.3</td>
<td>3.5 kWh</td>
<td>From £4,010</td>
<td>Lithium-ion</td>
<td>10 years</td>
<td>6,000</td>
<td>95%</td>
</tr>
<tr>
<td>LG Chem RESU 6.5</td>
<td>6.5 kWh</td>
<td>From £3,043</td>
<td>Lithium-ion</td>
<td>10 years</td>
<td>6,000</td>
<td>90%</td>
</tr>
<tr>
<td>Powervault G200</td>
<td>4 kWh</td>
<td>From £4,677</td>
<td>Lithium-ion</td>
<td>10 years</td>
<td>&gt; 4,000</td>
<td>90%</td>
</tr>
<tr>
<td></td>
<td>4 kWh</td>
<td>From £2,000</td>
<td>Lead-acid</td>
<td>5 years</td>
<td>&gt; 1,800</td>
<td>70%</td>
</tr>
</tbody>
</table>

- A relevant information for domestic BESS is the price of equipment
- It is necessary to have into account not only the battery costs, but also installation and inverter

- Depending on the Tariff-in-feed, energy consumption from grid or regulation, return time can vary and make interesting or not the inversion in domestic batteries

Source: Greenmatch (last update on April 2019). https://www.greenmatch.co.uk/blog/2018/07/solar-battery-storage-system-cost
Applications of Energy Storage

Energy Storage for Communities

One of the most important concepts for the development of microgrids and energy communities is the “Behind the Meter” (BTM) idea

- A BTM generation system is a renewable or conventional energy generating facility that produces power on site
- As the power is being generated on site, not produced on the side of the grid, it is referred to as ‘behind the meter’
- In the same way, energy storage systems can be installed and used on site. This type of unit can store energy generated by a BTM generation system, such as solar PV, Combined Heat Power (CHP) unit, or a wind turbine, and then release it when it is needed. For example, at night when a solar PV plant is not generating.
- Any excess energy, from the generation or storage systems can be fed back into the grid, helping to balance supply and demand and generating additional revenue in the process
- Revenues or compensation depends on regional or national regulation
Applications of Energy Storage
Forecast of future BESS deployments

BTM usage is expected to capture the greatest share of future BESS deployments

Cases Studies
Self-sufficient communities

Successful case: Feldheim, an energy self-sufficient village

- Since 1997, Feldheim has become a self-sufficient community
- Wind turbines, PV installations and a biogas plant generate more than 140,000 MWh/year
- Energy Storage devices compensate the fluctuations of the wind and solar plants
- Feldheim has their own grid. That saves costs and provides independence to the grids of conventional utilities
- *Feldheim* inhabitants electricity bills are 30% lower and heat bills are 10% lower
Successful case: La Rambla del agua, an recovered self-sufficient village

- La Rambla del Agua is a small village, that since 60s was in fact abandoned
- La Rambla is a very remoted area village, in mountain
- 10 kW PV + BESS, with lead batteries for 44 homes and public lighting
- Neighbors manage their own consumption
- La Rambla, as community, has become prosumer, being independent from the grid
Cases Studies
Self-sufficient communities

PEGASUS pilots can become self-sufficient communities

• University of Cyprus (UCY) pilot includes a BESS in their equipment

• Saint Julien en Quint (AURAEE) has evaluated energy storage to operate on island mode and improve quality of energy supply

• Mega Evydrio (CRES) has also analyzed energy storage for island mode operation with different BESS sizes

• Sport Park Ruse (Energap), Gozo Island and Preko Island pilots have also modelled and analyzed the implementation of energy storage
Case Studies
European demonstration projects

Flexitranstore(*): BESS for flexibility

• Several pilot demonstrators with BESS
• Abengoa is developing a 1MW / 2 MWh Lithium-ion BESS
• To be installed in Athienou, Cyprus in H2 2019
• BESS will help, with a sophisticated control system, to provide stability to the grid
• Substation has a high RES penetration and high fluctuation on energy demand due to seasons variation (summer vs winter)

(*) Flexitranstore is a project founded from European Union's Horizon 2020 programme under GA No 774407
Case Studies
European demonstration projects

Tilos: BESS for Island

- Integration of BESS + Wind + PV in Tilos Island
- RES provide energy for the entire island
- Reduction of CO2 and economic benefit, due to reduction of Diesel generators (approximately 70% expected)
- Energy supply independent from mainland
Thank you
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