CHALLENGES OF STORAGE

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AGENDA

1. FRENCH POWER SYSTEMS : A NEED FOR MORE FLEXIBILITY
2. POSSIBLE ROLES OF STORAGE IN FRANCE
3. STORAGE TECHNOLOGIES OVERVIEW
4. CONCLUSION
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The French energy mix includes more and more renewable

- Wind and photovoltaic power development had slowed in recent years but began trending higher again in 2014.
- France is now home to almost:
  - 10,000 MW of wind power
  - 6,000 MW of photovoltaic capacity

Source: RTE
INCREASING SHARE OF INTERMITTENT RENEWABLES PRESENTS NEW CHALLENGES

- Total generation in France reached 540.6 TWh in 2014
  - Nuclear represents the main part (77 %)
  - Intermittent renewable energies account for a larger of the French generation in 2014:

<table>
<thead>
<tr>
<th>Energy produced</th>
<th>TWh</th>
<th>Change 2014/2013</th>
<th>Share of generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydropower</td>
<td>68.2</td>
<td>-9.7%</td>
<td>12.6%</td>
</tr>
<tr>
<td>Wind power</td>
<td>17.0</td>
<td>+6.7%</td>
<td>3.1%</td>
</tr>
<tr>
<td>Photovoltaic</td>
<td>5.9</td>
<td>+27.2%</td>
<td>1.1%</td>
</tr>
</tbody>
</table>

- Challenge for the national energy supply / demand balance

- 95 % of the intermittent renewables are connected to the distribution grid
  - Challenge for the integration in the local grids
A GROWING NEED FOR LOCAL, NATIONAL AND … INTERNATIONAL FLEXIBILITY

- French POWER systems: a need for more flexibility is deeply connected to the other European power systems

  as a consequence, France is strongly exposed to the evolution of their generation mixes

  *The French balance is also dependent on the intermittent generation abroad, particularly the German wind and solar generations*

- A **common approach** on the way to deal with the need for flexibility may be profitable

![Coverage of consumption with photovoltaic power](image)

![Comparison of trends in exchange balance on Franco-German border and wind and photovoltaic generation in Germany](image)

*Source: RTE*
TO COPE WITH VARIABILITY OF INTERMITTENT RES: NEW NEEDS FOR FLEXIBILITY

- To characterize variability, daily maximum output of intermittent generation can be compared over many scenarios:
  - Ex: EC Roadmap towards 2050 (High RES), 60% of RES at 2030, of which 40% of wind and PV (700 GW). *The figure below uses 30 historical climate scenarios (1 day, 30 points)*

Variability has always existed (demand) and some solutions proved to be competitive: hydro storage, PHS, flexible thermal generation, interconnections,… Storage with high duration capacity could play an increasing role.

*Wind & PV forecast generation in 2030 based on historical profiles*
FRENCH ISLANDS’ POWER SYSTEMS HAVE ALSO TO FACE BIG CHANGES

- In the French island systems, wind and photovoltaic power development is quite important too.

- Need to monitor the instantaneous intermittent renewable power because, beyond a certain threshold (set at 30% by ministerial order), the lack of inertia of the generation mix weaken the system.

Localization of the French islands managed by EDF SEI

Power production on a typical day during the austral winter in the “Réunion” island

Source: EDF-SEI
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STORAGE COULD PLAY AN INCREASING ROLE IN A MORE FLEXIBLE POWER SYSTEM

- The technical and economical progress of some storage technologies could give it a more and more important role in the power system management.

- But storage is a solution to bring more flexibility to the system, but it is one solution among others:
  - Grid development
  - Very flexible power plants
  - Demand side management

- Storage has two challenges to take up:
  - Economical challenge: to find profitable business models
  - Technical challenge: to identify the services to the system
STORAGE CAN GIVE SERVICES AT DIFFERENT LEVELS OF THE GRIDS

- Frequency Regulation - MW
- Frequency Regulation - MW
- Frequency Regulation - MW
- Frequency Regulation - kW
STORAGE AND FREQUENCY REGULATION IN ISLANDS

- In island systems, the very prompt response of storage is interesting to provide “dynamic frequency control support”
  - Even with enough primary reserve, a loss of a group in isolated systems can lead to load shedding (Primary Reserve not available fast enough)
  - Requires a short response time (<1s) and a discharge duration of a few 10s

- In the simulation below, load shedding is avoided with a storage capacity of 5-10 MW, a total of primary frequency reserve of 20-25 MW and a peak demand of 250 MW

Example of frequency evolution in case of a loss of group

Source EDF R&D Delille G, et al., « Dynamic frequency control support », IEEE oct 2010
STORAGE AND FREQUENCY REGULATION IN CONTINENTAL EUROPE

- In Europe, “frequency regulation” is regularly referred to as one of the most promising opportunities for storage development but…
  - The market is …
    - … limited: 3000 MW in Europe
    - … 600/700 MW in France
    - … uncertain: very different regulations depending on the country
    - … competitive: storage compete or complement to other existing and proven solutions
  - Demonstration is still needed
    - Experimentation launched with a 1 MW / 30 minutes Li-ion battery on the “Concept Grid” of EDF R&D

- In the United States, some specific regulations have been settled for “frequency regulation”
  - “Power for Performance” has been created for very effective “frequency regulations”
    - Very reactive flywheels and batteries are eligible
STORAGE CAN GIVE SERVICES AT DIFFERENT LEVELS OF THE GRIDS

- Generation support - MWh
- Arbitrage - MWh
- Frequency Regulation - MW
- Grid constraints - MWh
- Arbitrage - kWh
- Frequency Regulation - kW
- Grid constraints - MWh
- Frequency Regulation - MW
- Arbitrage - MWh
- Curtailment minimisation - MWh
GRID INVESTMENT DUE TO NEW PV GENERATION (REINFORCEMENT POSTPONED OR AVOIDED)

- This service is a case by case analysis: each feeder is specific.
- However, some research suggest storage is not the only option:
  - Not the most economical option (but no mutualization considered).
  - The storage may be a temporary solution to manage grid constraints but the grid development remains the most appropriate solution in the long term.

Net Present Cost (NPC) of different solutions vs. rated power of the new PV plant

Source: Delille et al, CIRED 2013
STORAGE CAN GIVE SERVICES AT DIFFERENT LEVELS OF THE GRIDS

- Generation support - MWh
- Arbitrage - MWh
- Frequency Regulation - MW
- EHV / HV
- Grid constraints - MWh
- MV
- Arbitrage - kWh
- Frequency Regulation - kW
- Arbitrage - MWh
- Frequency Regulation - MW
- Grid constraints - MWh
- LV
- Curtailment minimisation - MWh
- EHV / HV
- Grid constraints - MWh
IS MUTUALISATION OF A STORAGE DEVICE FOR VARIOUS SERVICES FEASIBLE?

- The key is to limit simultaneous request
  - Not all services can be well provided by a same device (see Delille, PhD thesis 2010)
  - If services are well picked, simultaneous request can be limited
    - *Example*: voltage smoothing, outages reduction from a DSO perspective and Arbitrage

- There seem to be possibilities for mutualize a storage device among services
  - But there is generally one main service – the other services add less value
    - Most interesting services: grid investment deferral and reserve => residential ES the best option?
  - More analyses are needed
    - What if the residential customer uses the storage for his benefits first?

*Based on Loevenbruck, CIRED 2013*
STORAGE CAN GIVE SERVICES AT DIFFERENT LEVELS OF THE GRIDS

Generation support - MWh

Frequency Regulation - MW

Grid constraints - MWh

Arbitrage - MWh

Frequency Regulation - kW

Grid constraints - MWh

Arbitrage - kWh

Frequency Regulation - MW

Curtailment minimisation - MWh

Arbitrage - MWh

Which challenges for residential generation and storage?
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STORAGE TECHNOLOGIES OVERVIEW

Power

< Seconds

Seconds

Minutes

Hours

Energy

Flywheels

Batteries

CAES*

H2

PHS**

Thermal storage

*CAES : Compressed Air Energy Storage

**PHS : Pumped Hydro Storage
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CONCLUSION

- To assess the storage markets we need:
  - to understand the applications, their potential and their associated revenues
  - to establish the merit orders of the technological solutions

- The context is very important:
  - interconnected system vs. isolated system
  - existing generation mixes
  - development of demand-response

- To be profitable, storage devices will have to propose different services to different actors

- The future transport mutation towards electric mobility and the emergence of smart grids could place batteries in the heart of the future power system
Thank you