Energy storage for wind power plants

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Introduction

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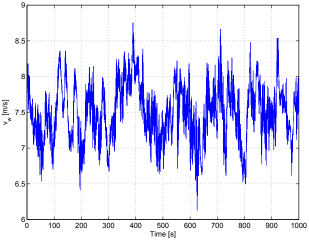
Wind is variable and non-controllable

- Due to the stochastic nature of wind, the electrical power generated by wind power plants is neither constant non controllable.
- This affects the **network planning** as the expected generation level depends on non reliable wind forecasts. Also it affects the **power quality** as the fast fluctuations of wind power can cause harmonics and flicker emissions.



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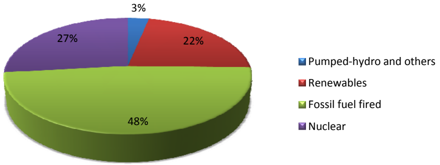
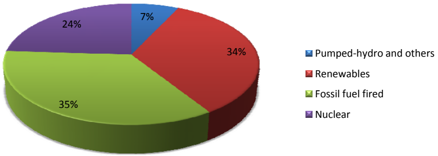
Introduction

European electricity mix

Electricity generation EU-27 (2012)



Electricity generation EU-27 (2020)



Increase of renewables share & Replacement of controllable generators

Stringent requirements for grid connection of renewables (mandatory capabilities, ancillary services, power quality issues...)

The electrical system of the future needs to be FLEXIBLE

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Introduction

Flexibility: a key aspect for the future electrical networks

Flexibility

- Power transmission systems
- Demand side management
- Energy storage systems
- Back up capacity
- Regulatory framework

All these aspects will determine the requirements and the scenario for the grid integration of renewables

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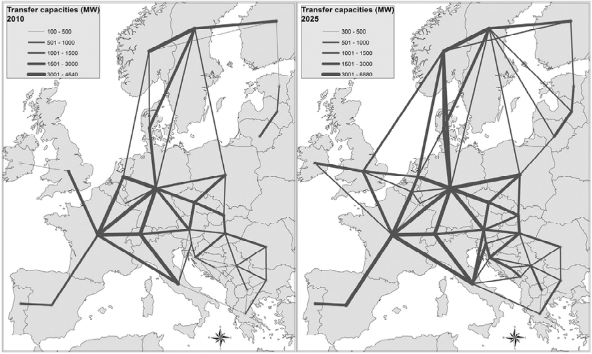
Flexibility: a key aspect for the future electrical networks



Example: scheduled reinforcement of power transmission lines for 2025 [Source: Eurelectric].

Introduction

Flexibility: a key aspect for the future electrical networks

- The proper **regulatory framework** is principal for the integration of renewables
- In this sense, there is a trend towards the integration of European electrical markets
- Also, towards the reduction of the time operating basis of the electrical market: reduction of forecasting errors
- Portfolio approach

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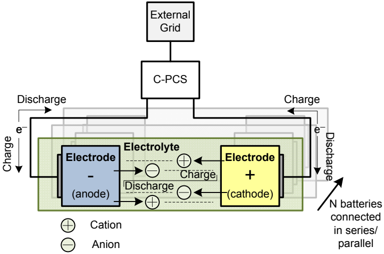
Flexibility: a key aspect for the future electrical networks

- **Energy storage systems (EESs)** are also providers of flexibility.
- They may play an important role in wind power applications by enhancing the controllability of the output of wind power plants and providing ancillary services to the power system and thus, enabling an increased penetration of wind power in the system.



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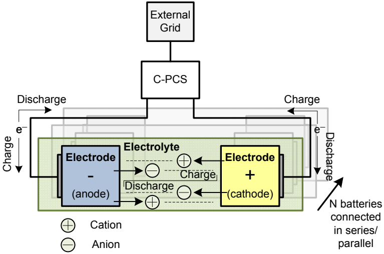

Review of energy storage technologies for wind power applications

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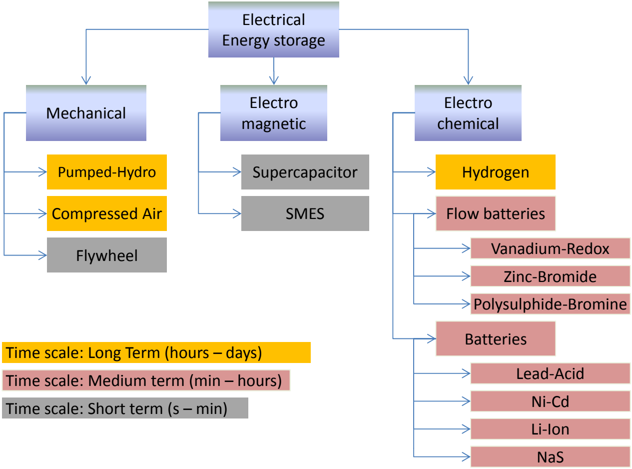
Catalogue of energy storage technologies



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Review of energy storage technologies for wind power applications

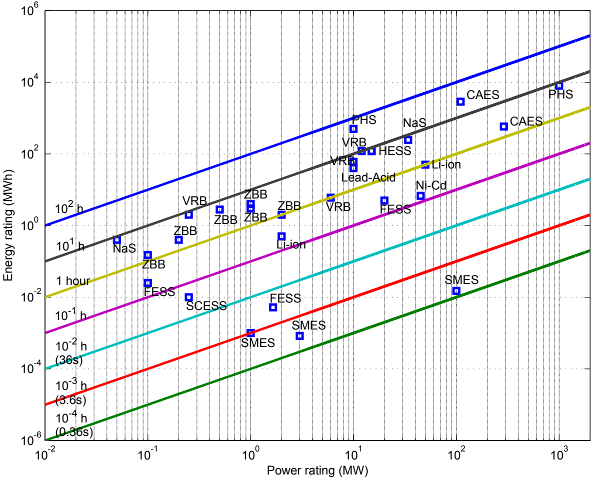

Figure : Discharge time at rated power of several energy storage systems

Review of energy storage technologies for wind power applications

Among the conclusions of the review...

- ESSs can provide numerous services for the grid integration of wind power.
- There can be identified applications where ESS are required to inject or absorb power for less than a minute, as in power smoothing of wind turbines; or long-term storage applications, such as those related to load following or seasonal storage.

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Review of energy storage technologies for wind power applications

	Full power duration of storage	Pumped Hydro	Hydrogen	Compressed Air	Vanadium Redox	Zinc Bromine	Polysulphide Bromide	Sodium Sulphur	Lead Acid	Nickel Cadmium	Lithium Ion	SMES	Flywheel	Supercapacitor
Fluctuation suppression	≥ 1 min				v	v	v	v		v	v	v	v	v
Low Voltage Ride Through					v	v	v	v	v	v	v	v	v	v
Voltage control					v	v	v	v	v	v	v	v	v	v
Oscillation damping			v		v	v	v	v	v	v	v	v	v	v
Spinning reserve	≥30 min	v	v	v	v	v	v	v	v	v	v	v	v	
Load following	1-10 h	v	v	v	v	v	v	v	v	v	v			
Peak shaving		v	v	v	v	v	v	v	v	v	v			
Transmission curtailment	5-12 h	v	v	v	v	v	v	v						
Time shifting		v	v	v	v	v	v	v						
Unit commitment	h-days	v	v	v										
Seasonal storage	≥120 days	v	v	v										

Figure : Applications of ESSs in wind power. Source [1]

Category I: Short term storage needs

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The applications within this category are:

- Suppression of the fast fluctuations of the power output of the wind power plant,
- support under low voltage ride through situations,
- voltage control support to the connection point of WPPs,
- improve the stability of power systems with high penetration of wind energy against disturbances.

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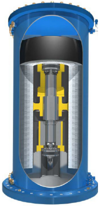
Category I: Short term storage needs

Defining characteristics for EESs

- High ramp power rates,
- high cyclability,
- limited energy and power capacities.



Suitable EESs

- Batteries and flow batteries,
- and specially supercapacitors, flywheels and SMES.

Category I: Short term storage needs

Example: use of flywheels for wind power smoothing

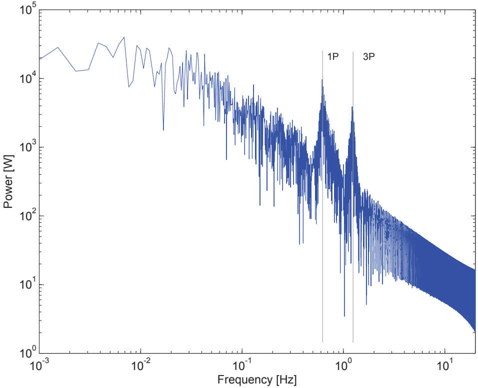


Figure : Frequency power spectrum of a WT. Source [4]

Fast wind power fluctuations can cause **fast voltage variations** affecting the **power quality** levels. In particular, high **flicker** levels can be noted due to cyclic perturbations to the rotational torque (rotating sampling effect) and other factors.

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Example: use of flywheels for wind power smoothing

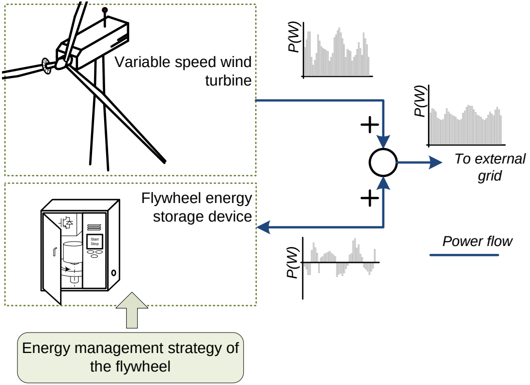

Figure : Conceptual diagram for wind power smoothing with flywheels. Source: [4]

Category I: Short term storage needs

Example: use of flywheels for wind power smoothing

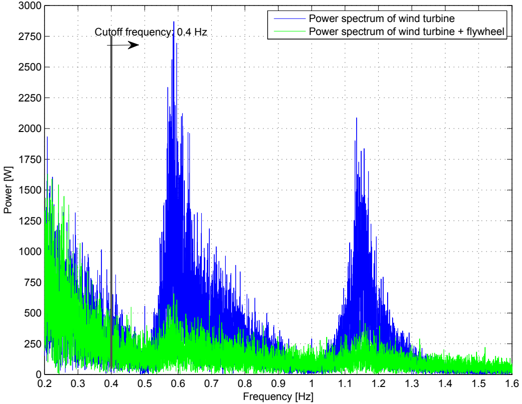

Figure : Spectrum of the power injected to the grid, with and without including storage support. The mean wind speed is 7 m/s, wind turbulence is 0.05 pu. Source: [4]

Category I: Short term storage needs

Example: support during shortcircuits and severe voltage drops

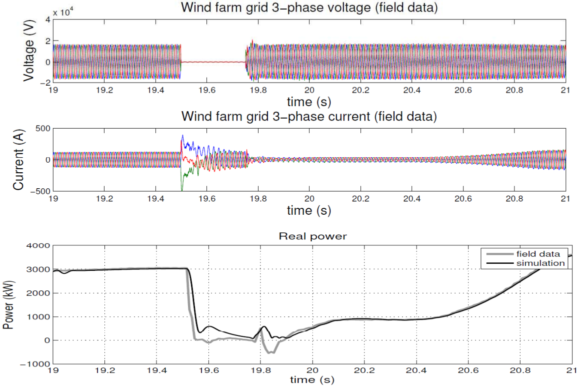

Fig. 8. Test 1. Active power. V=0 pu, t=250 ms, 3-phase voltage drop

Figure : Behaviour of a wind turbine during a shortcircuit in its PCC

Category II: Mid term storage needs

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These applications require the EESs to continuously regulate power for the time frame comprised between **a few minutes up to 10 hours**

The applications within this category are:

- System frequency control support.
- Load following. In this service, storage technologies can help wind power plants in meeting their output target.
- Peak shaving of the typical mountain and valley shape of the load curve.

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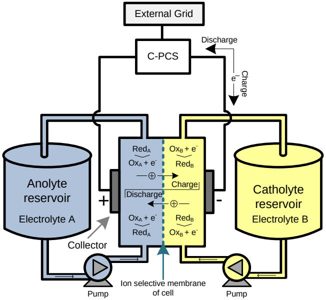
Category II: Mid term storage needs

Defining characteristics for EESs

- Relatively high ramp power rates,
- relatively short time responses (<1s),
- relatively high energy and power capacities,
- very low self-discharge rates.

Suitable EESs

- Flywheels (for primary frequency support),
- and specially batteries, flow batteries, hydrogen-based technologies, CAES and PHS.



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Category II: Mid term storage needs

Example: 34 MW NaS batteries for 51 MW WPP in Futumata (Japan) in 2010 for transforming the wind power facilities into a baseload electricity source.

Figure : 17 sets of 2 MW NaS batteries [2]

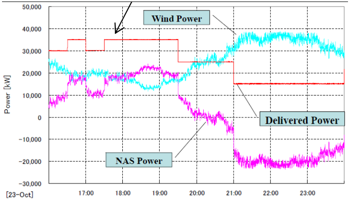

Figure : Power exchanged with the network [2]

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Category III: Long term storage needs

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These applications require the EESs to regulate high power levels for **several hours up to several days**

The applications within this category are:

- Transmission curtailment (due to issues related to the capacity of transmission lines or stability issues).
- Unit commitment. To reduce uncertainties regarding mesoscale variations of the wind.
- Seasonal storage. To deal with large seasonal variations in the generation or consumption levels.

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Category III: Long term storage needs

Defining characteristics for EESs

- Very high energy and power capacities,
- virtually zero self-discharge rates.

Suitable EESs

- Hydrogen-based storage technologies,
- PHS,
- CAES.

Figure : Turlough Hill (Ireland)

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Category III: Long term storage needs

Example: Hydrogen production using wind power

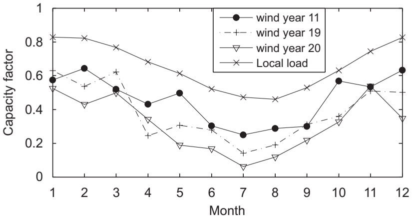

Figure : Seasonal wind power variation. Source: [3]

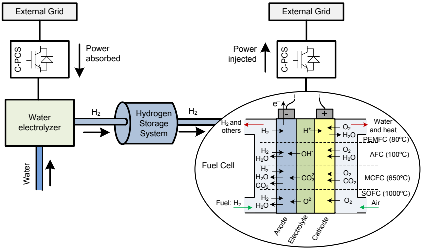

Figure : Regenerative fuel cell. Source: [1]

Hydrogen can be produced, stored and then used for electricity production in fuel cells.

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Category III: Long term storage needs

Example: Long term storage for avoiding wind curtailment

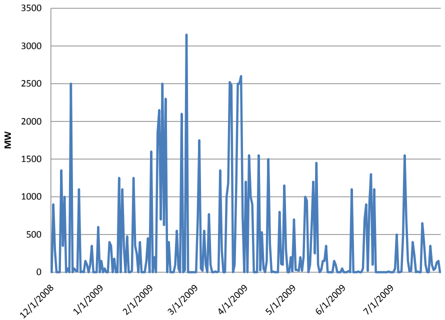

Figure : Example of a wind power curtailment profile during 2 months

The wind power sector in Spain **lost 90 Million Euro in 2012** due to wind power curtailment.

Conclusions

Conclusions (1/3)

- Nowadays, there is a tremendous effort in improving the capabilities and efficiencies of the available storage technologies, as well as reducing their capital costs. The aim is to make ESS economically suitable for the use in stationary applications and, therefore, allow higher penetration ratios of renewable energies in the system.
- High power ramp rates of some systems such as SMES, flywheels or supercapacitors allow their use for power smoothing of wind turbines, favouring the mitigation of the voltage and frequency variations at the connection point of the WPP.
- ESS with high energy and power capacities can be used as well for improving the predictability of the output of wind power plants, involving technical benefits that favour the incorporation of wind power in the network, and also economic benefits owing to penalty reductions in forecasting errors and reduction of wind power curtailment, for instance.

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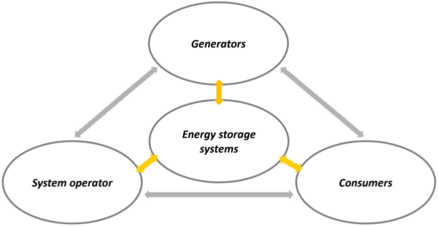
Conclusions (2/2)

- In spite of the numerous technical benefits ESSs can provide to the electrical network in general...
- Who is willing to pay for the storage devices?
- Who should be the storage operator?
- How the services provided by the storage devices are going to be economically valued?
- The answers to these questions need implication of all actors of the electrical network.



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Questions?

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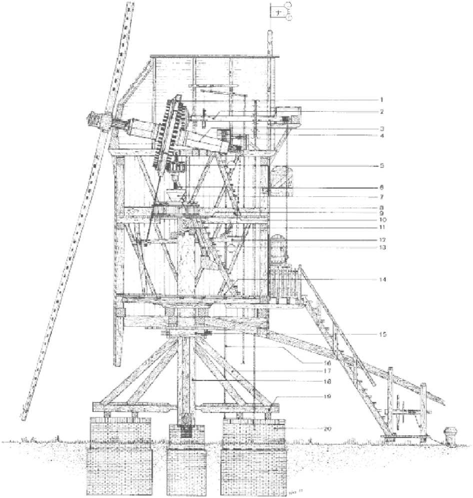

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