Institut de Recerca en Energia de Catalunya
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# Fast response energy storage systems for wind power smoothing

**Barcelona, 9th Barcelona 2014**

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# Overview

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  - Power quality requirements
  - Lab equipment
- **Power smoothing simulations**
  - Ultra-capacitor energy storage devices
  - Fly-wheel based energy storage systems
- **Power smoothing real emulations**
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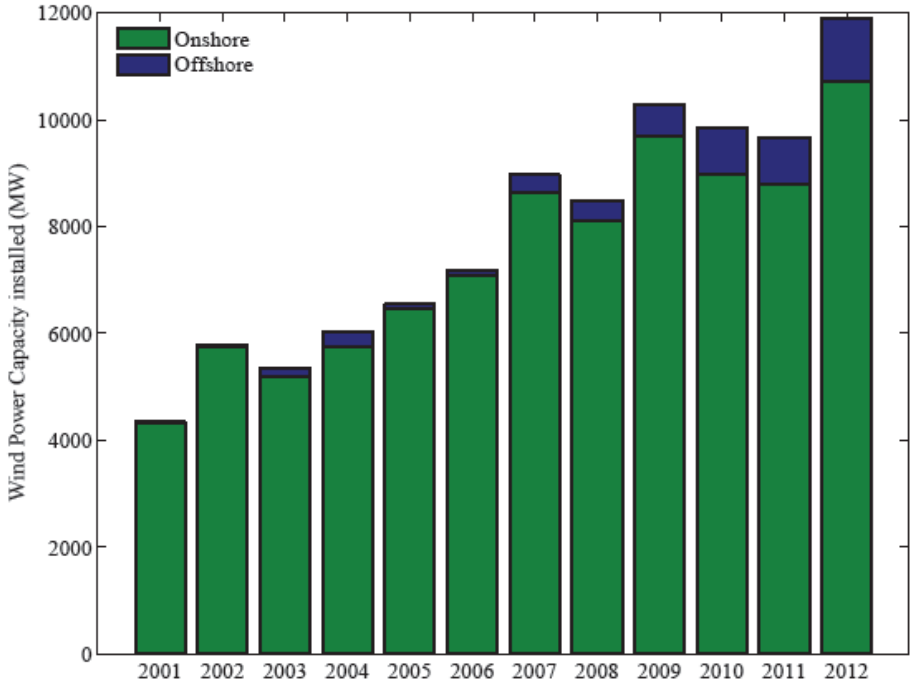
  - Fly-wheel based energy storage systems
- **Conclusions**

# Objectives

The **penetration of distributed renewable generation** sources into both distribution and transmission networks is rapidly **increasing**.

This increase leads to a power generation:

- Highly variable
- Intermitent
- Uncertain



Wind power capacity installed in Europe

These facts imply some problems to consider in the quality of the power generated.

# Objectives

The most relevant power quality problems are:

- Voltage Harmonic Distortion

- **Flicker**

  “Wind fluctuations are directly converted into delivered power fluctuations. Thus, when these wind turbines technologies are connected in a weak or highly wind power generated grid, such variations results in voltage network fluctuations seen by the consumers”.

  This effect could appear at:
  - Fixed-speed wind turbines
  - Variable-speed wind turbine operating in partial-load mode.

  The quality of the power delivered mus comply with international standards as:
  - **IEC-61400-21**
  - **IEEE Std 519**

# Objectives

In order to maximize the power generated and to comply with power quality requirements, extra power devices to smooth power is needed.

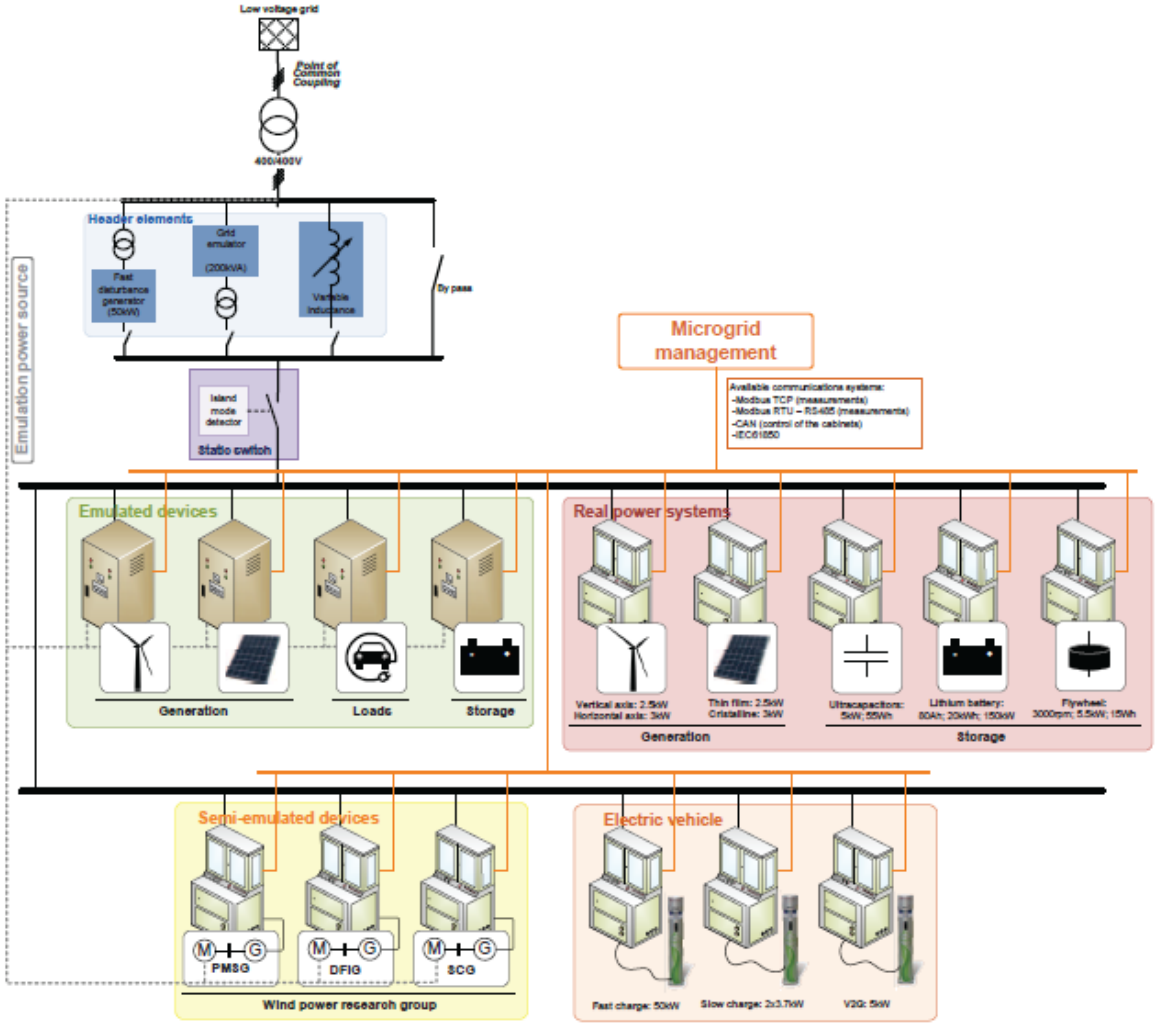
In this work, fast response energy storage devices are considered due to the rapid variability of the wind. The technologies considered are:

- Ultra-capacitors
- Fly-wheel

Their capability have been validated through simulation and lab experimentation.

# Laboratory equipment

At IREC, there is a complete microgrid system for testing:

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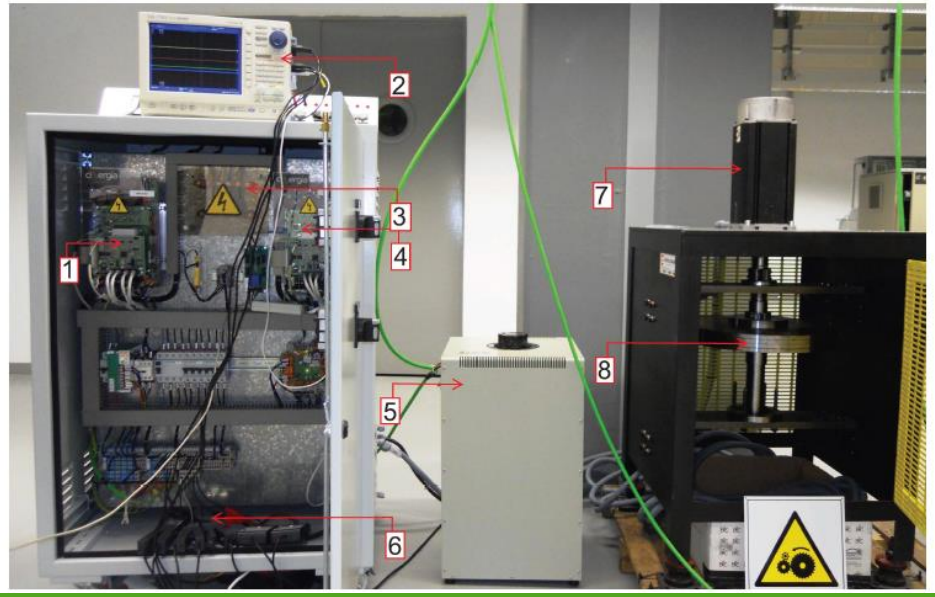
# Laboratory equipment

Emulators

Ultra-capacitors

Fly-wheel

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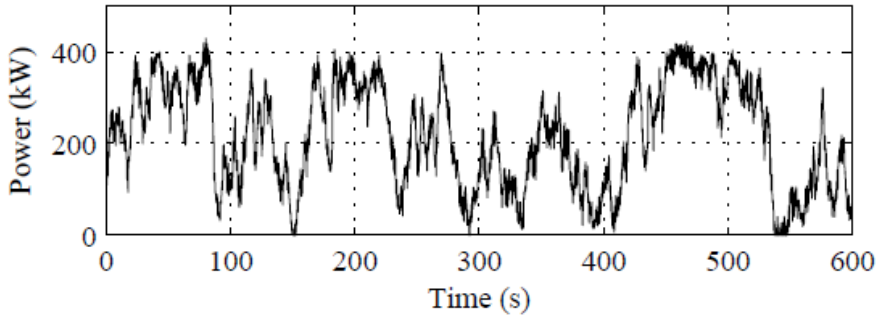
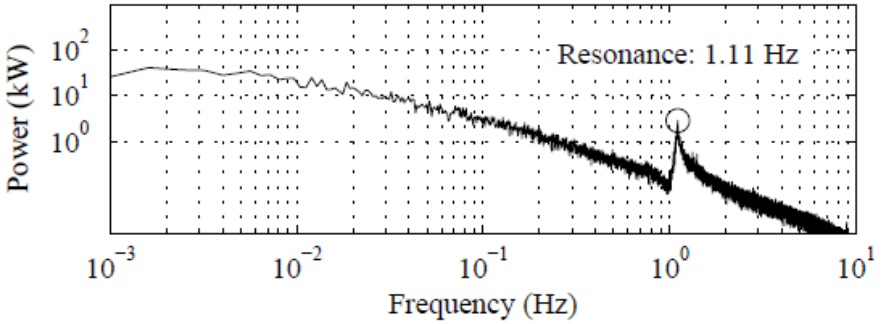
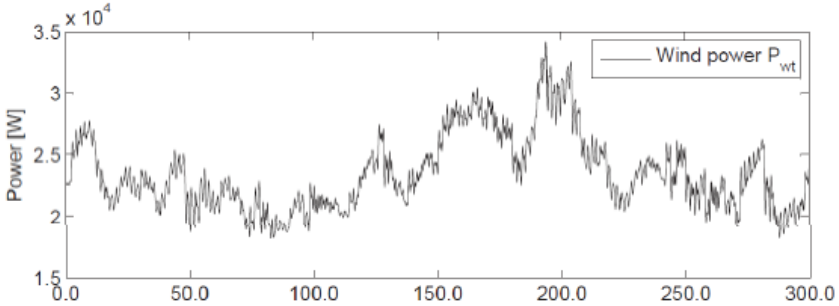
# Wind profiles considered

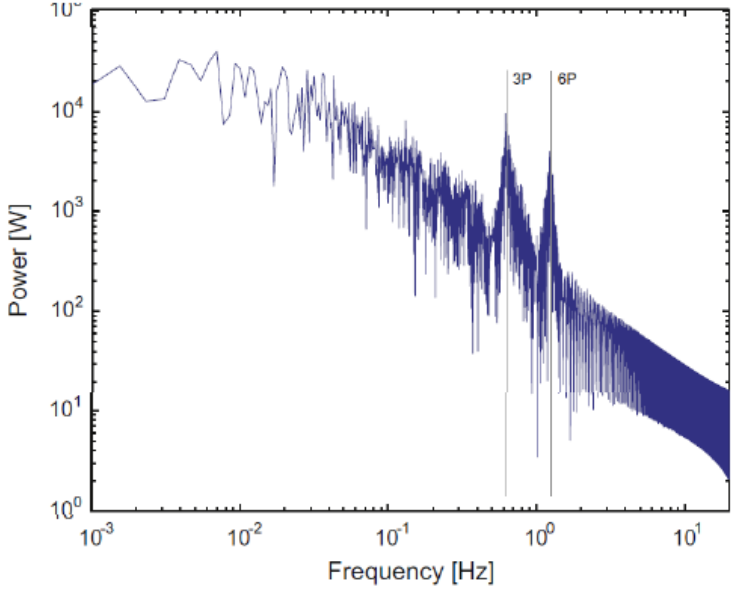
Power delivered by the wind turbine and their frequency response




Ultra-capacitors case study




Fly-wheel case study

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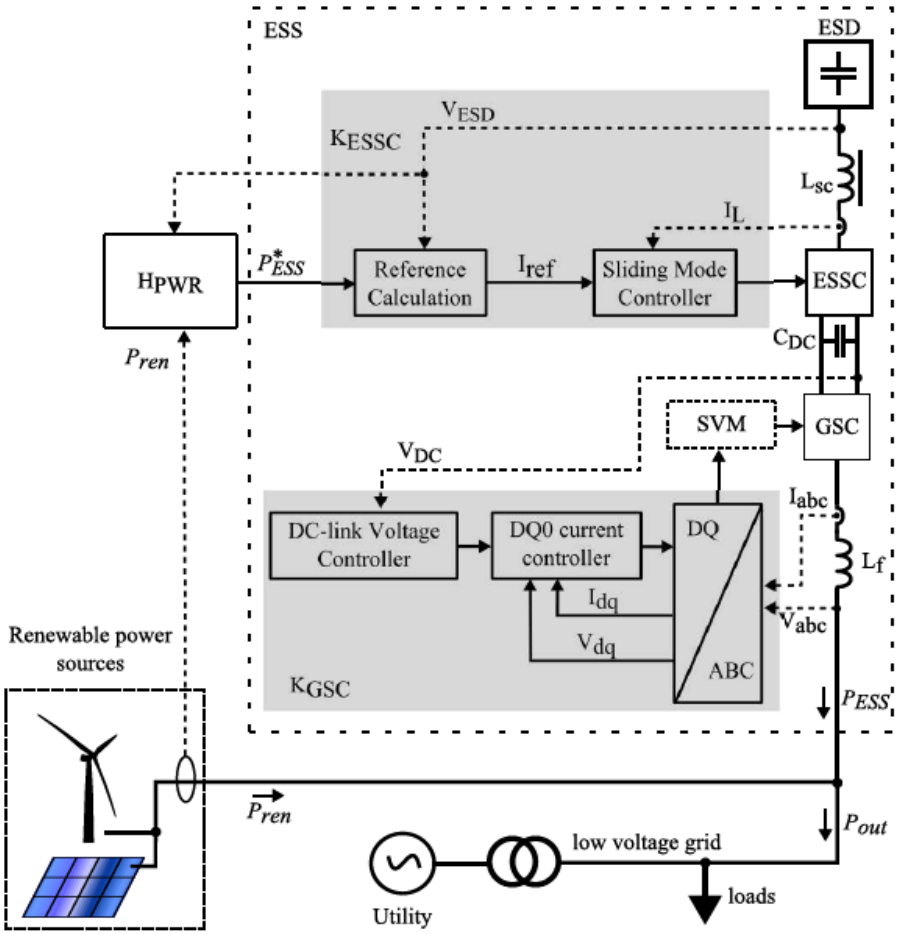
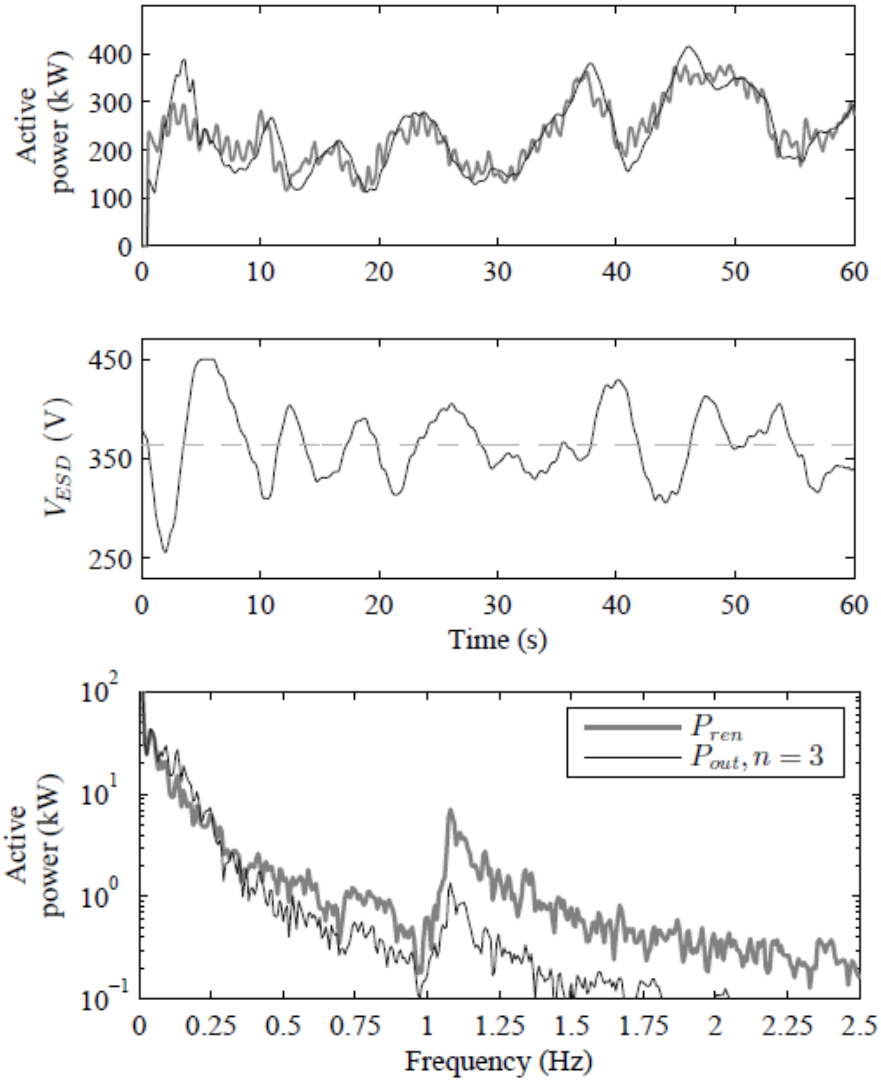
# Simulation results – Ultracapacitors case

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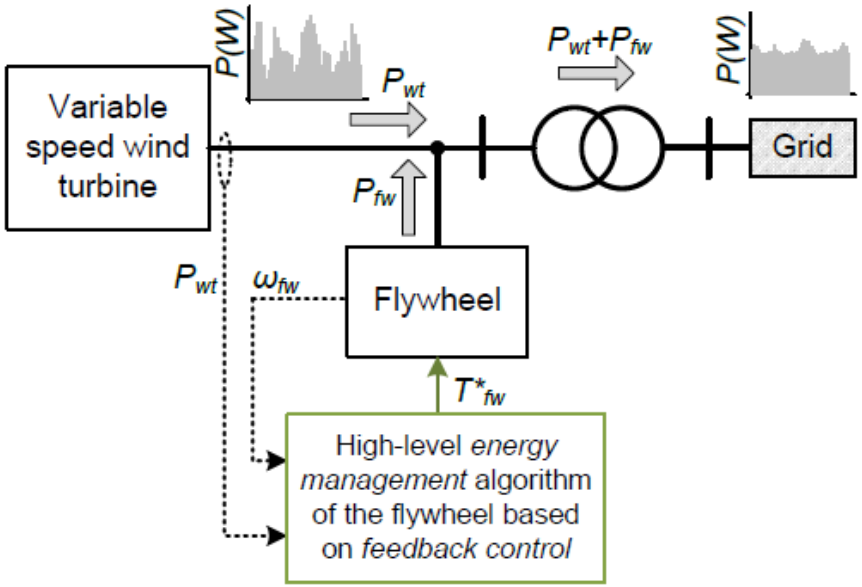
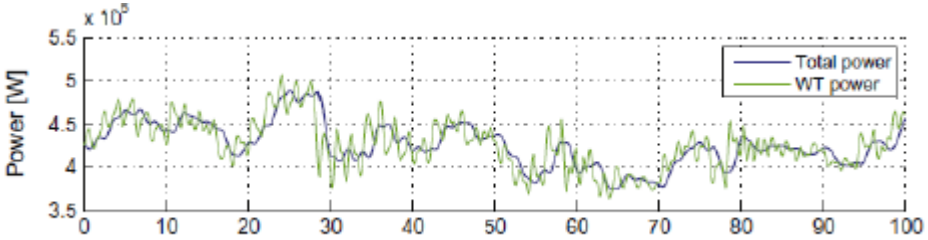
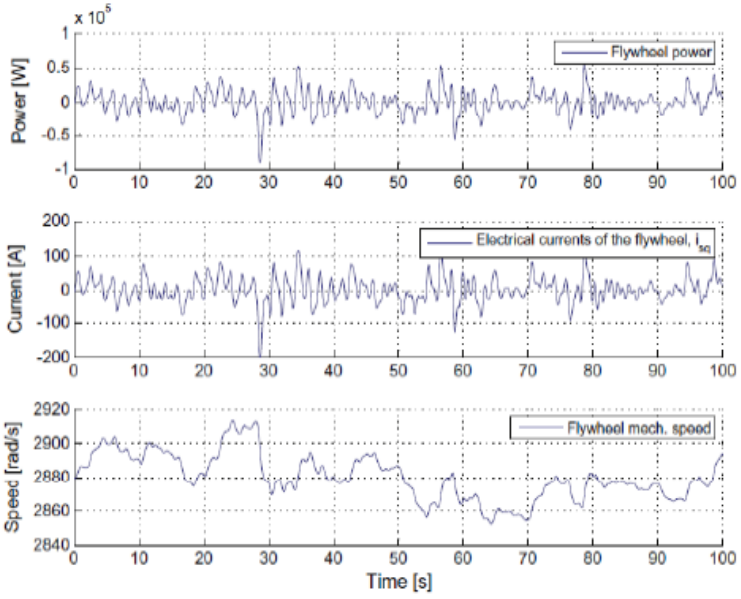
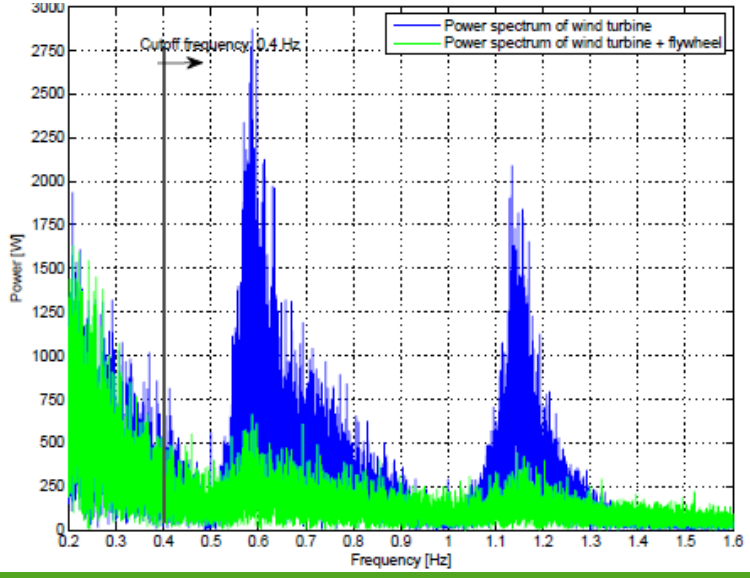
# Simulation results – Flywheel case

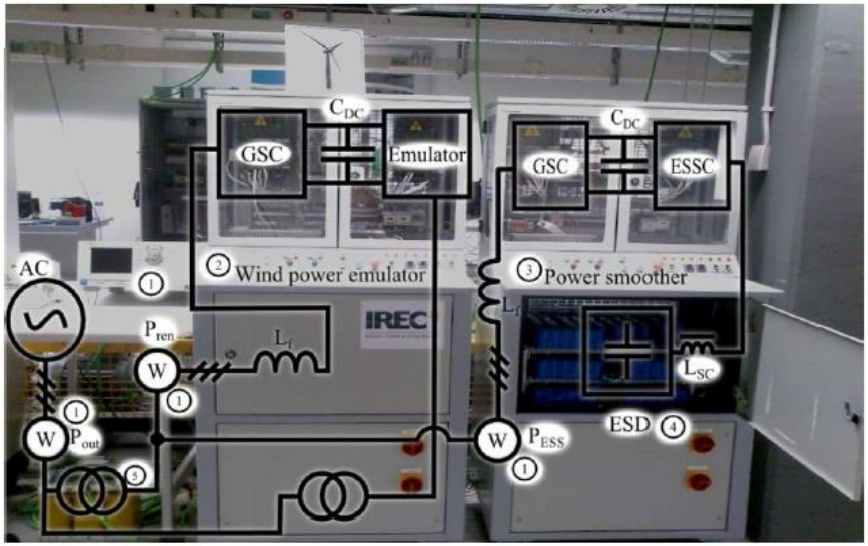


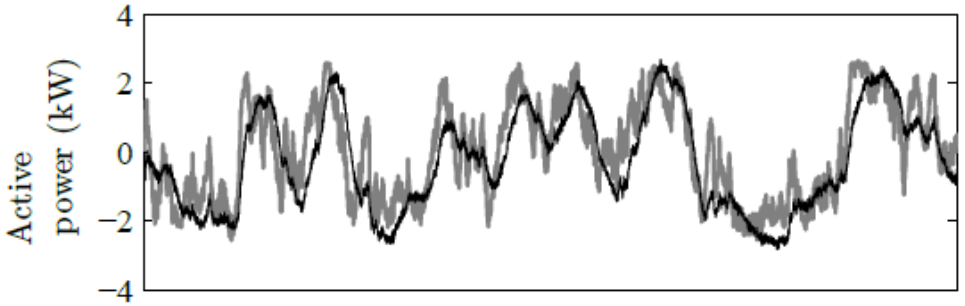



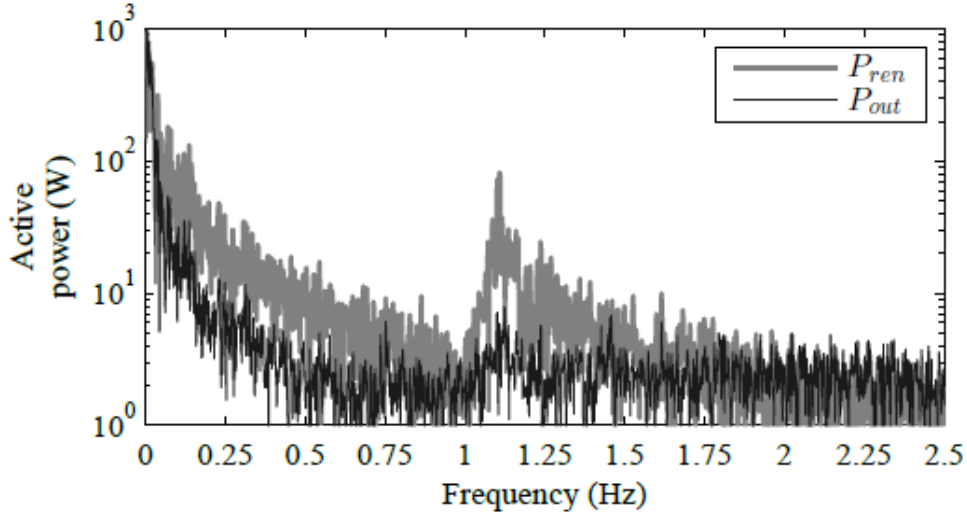



# Experimental results – Ultracapacitors case

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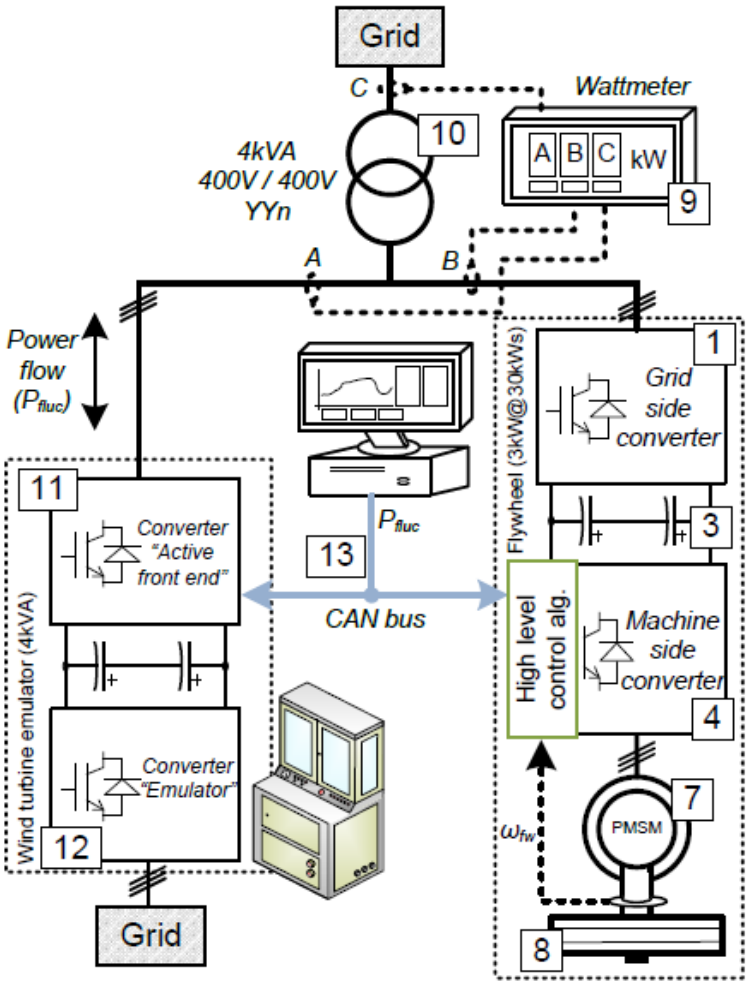
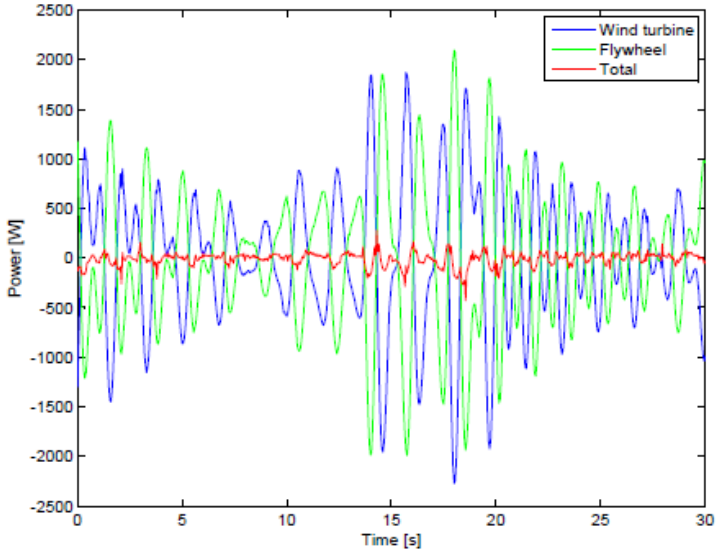
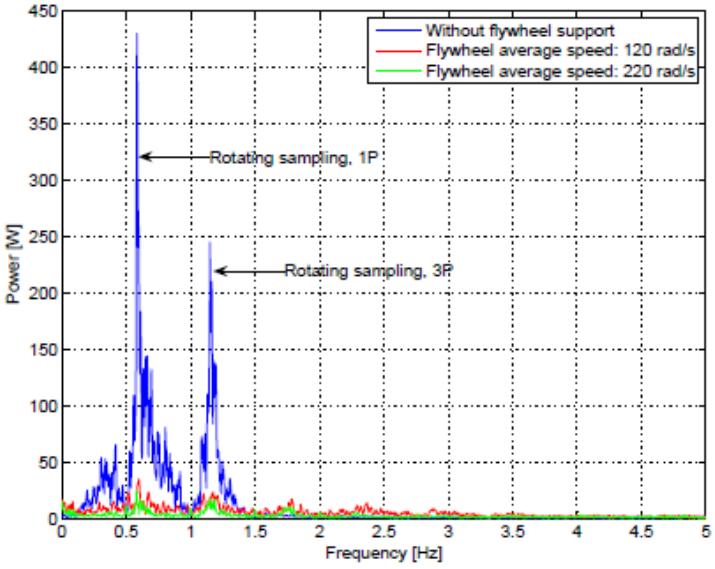
# Experimental results – Flywheel case

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# Conclusions

This work has highlighted an important issue of power quality for distributed system operators (DSOs) as flicker.

This work has demonstrated through both simulation and experimental results that the use of energy storage devices, basically ultra-capacitors and fly-wheels, can contribute to the enhancement of power quality delivered by the wind farms (any topology), reducing the flicker effect.

This work has been developed under the project: **KIC-Smart Power**

**Publications :**

Díaz-Gonzalez, F. et al. “Energy management of ywheel-based energy storage device for wind power smoothing" Applied Energy, vol. 110 pp. 207-219, 2013

Díaz-Gonzalez, F. et al. “Control of a Flywheel Energy Storage System for Power Smoothing in Wind Power Plants" IEEE Transactions on Energy Conversion, Online, 2013

Pegueroles-Queralt, J. et al. “A Power smoothing system based on supercapacitors for renewable distributed generation" Under Second review, IEEE Transactions on Industrial Electronics, 2013

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# Thank you for your attention!

# Questions?