Experience with primary reserve supplied from energy storage system

Philip C. Kjaer, Vestas Wind Systems A/S

ATV: ”Energy storage – a must for successful conversion to green energy”

Monday 28th September 2015 – DTU, Lyngby, DK.

Content

- Motivation
- Application & Installation
- Test Results
- Conclusions & Perspectives

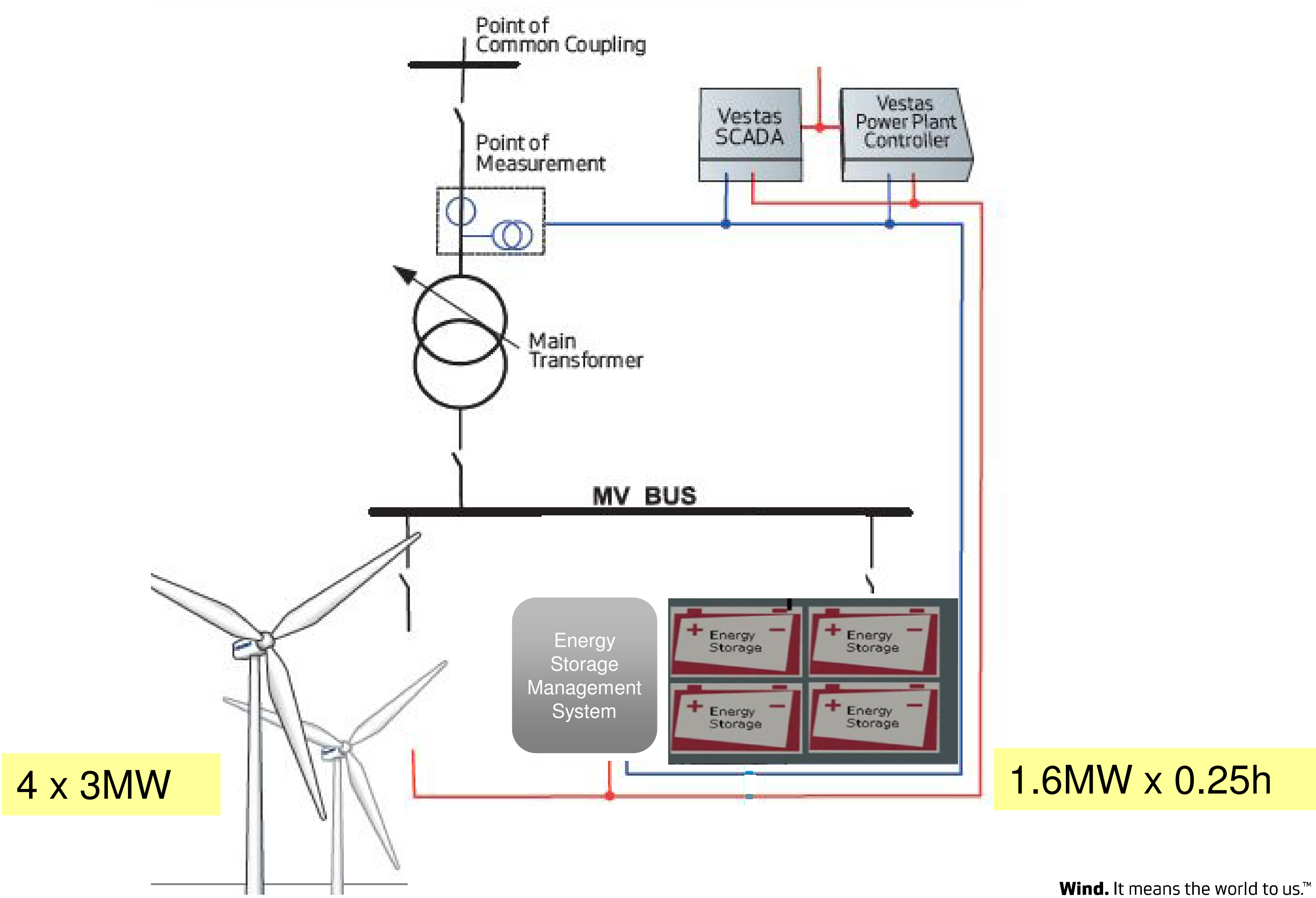
Vestas' research programme on energy storage started in 2010:

Motivation: Identify value-add from wind power + energy storage.

Activities:

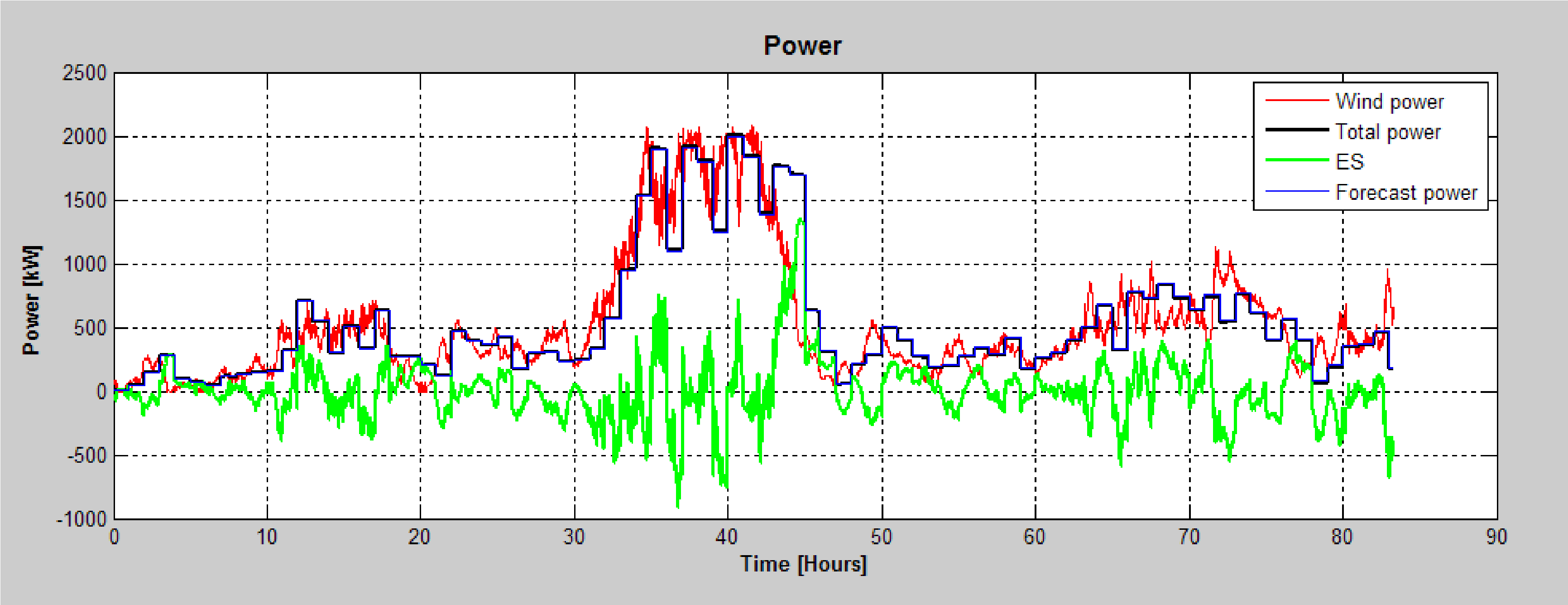
- Identify best match of applications (revenue) and ESS technology.
- Develop competence on optimal control w.r.t. ES life-time and ratings.
- Select & qualify suppliers.
- Verify life-time models.
- Demonstrate integration, functionality and economy.

Wind Power Plant with Energy Storage



Lem Kær
substation & energy storage system

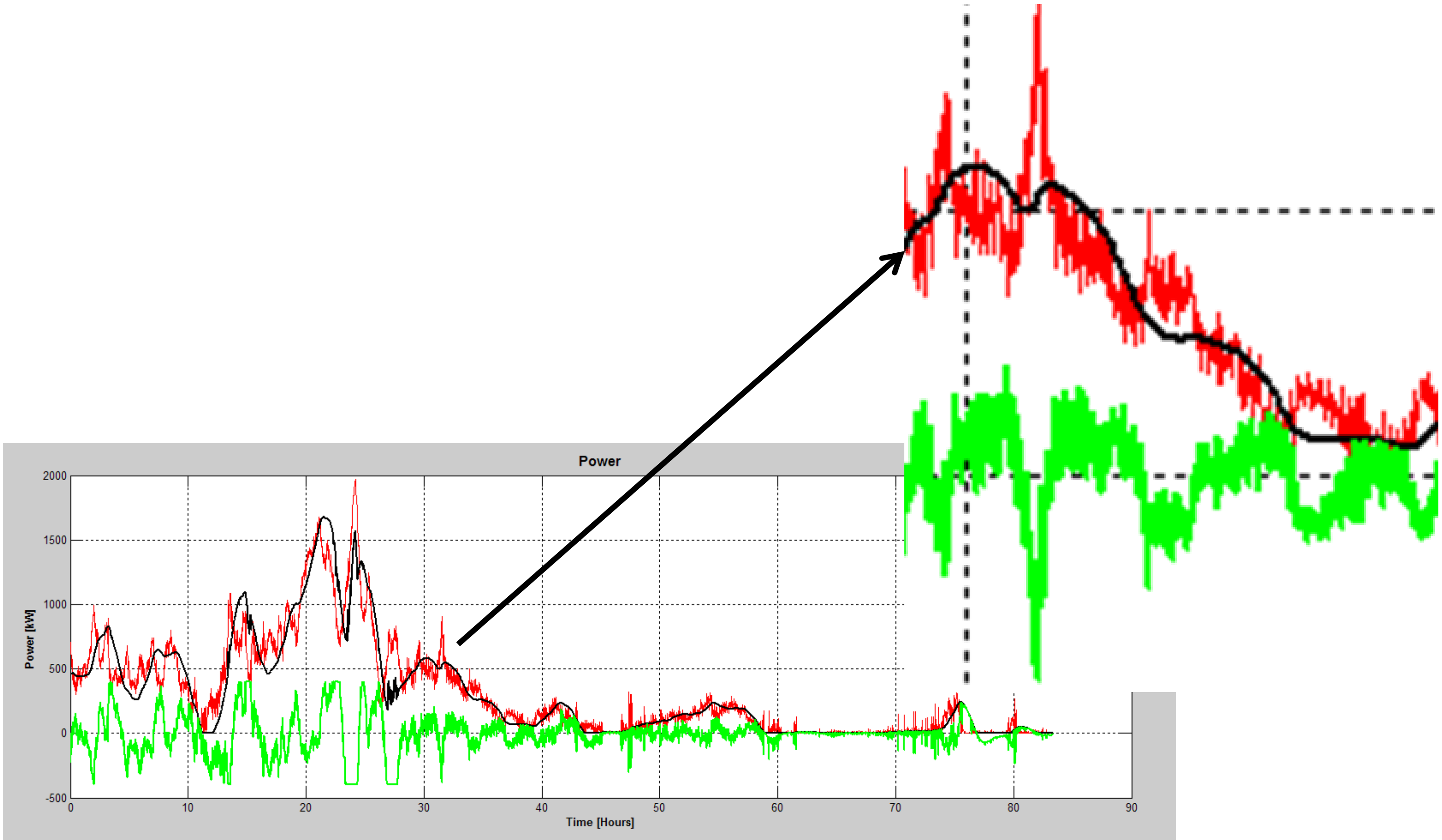
Forecast Error Reduction



Idea: Reduce financial penalties for not meeting generation commitment.

Reality: Aggregation of several wind plants over a geographical spread allows similar gains.

Ramp Rate reduction / power smoothening (dP/dt control)



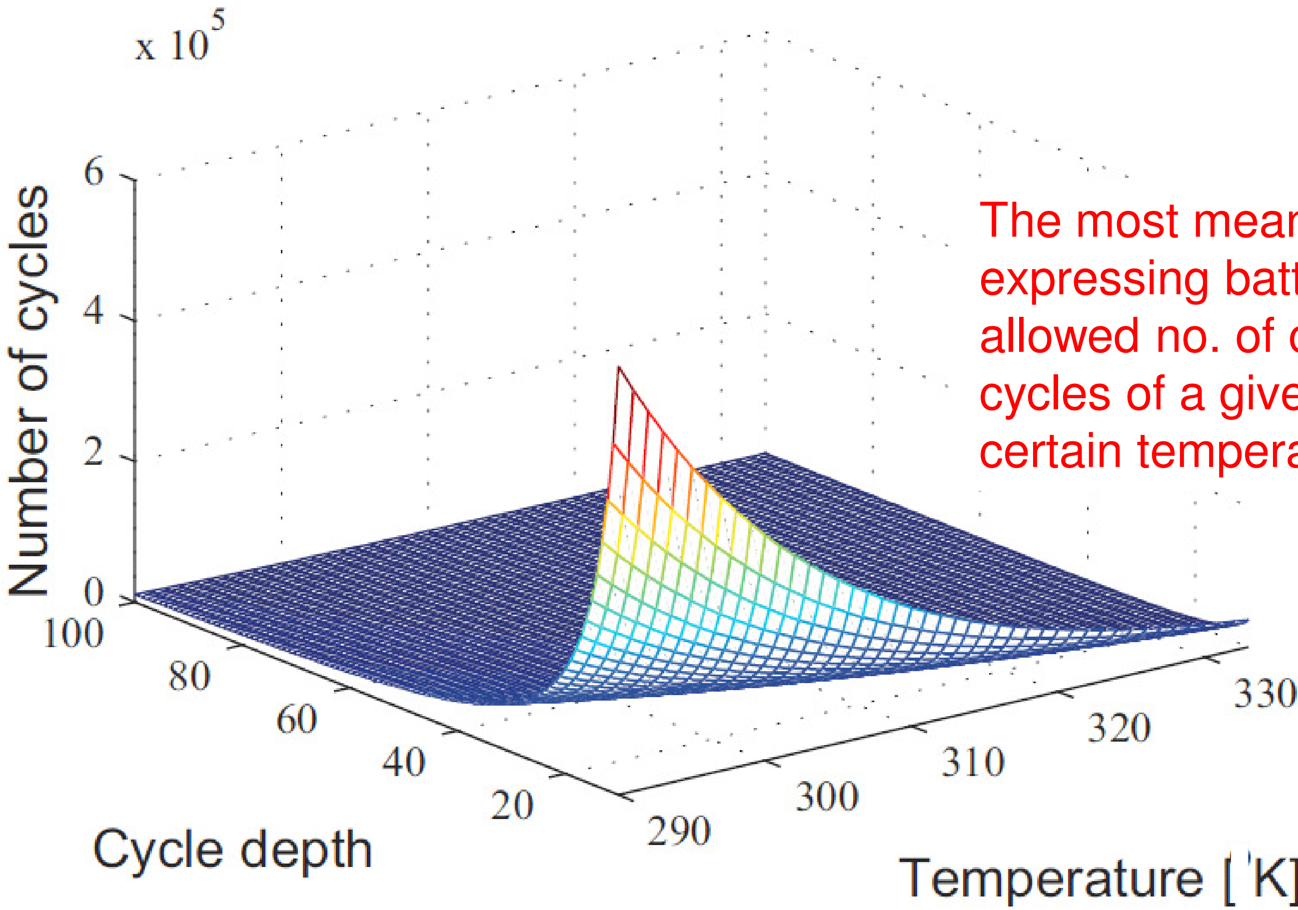
Idea: For power quality in weak networks, keep output variations from the combined Wind/ESS plant below a threshold.

Reality: no payment for service; fast wear-out.

Cost: storage life-time

Modelling:

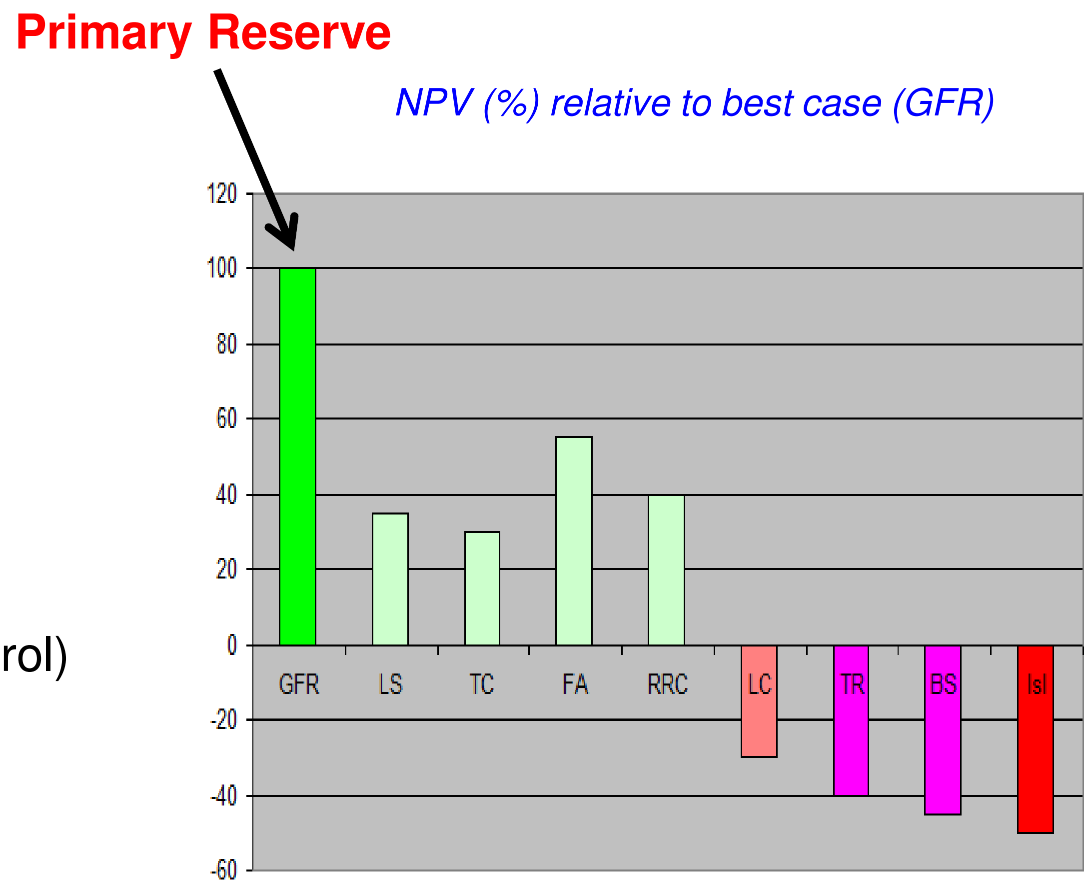
- Determine ESS ratings to warrant life-time for a given mission profile
- CAPEX (MW & MWh ratings + fixed cost)
- OPEX (efficiency + capacity degradation + standby + replacements + availability)



The most meaningful single number expressing battery lifetime is the allowed no. of charge/discharge cycles of a given charge depth at a certain temperature.

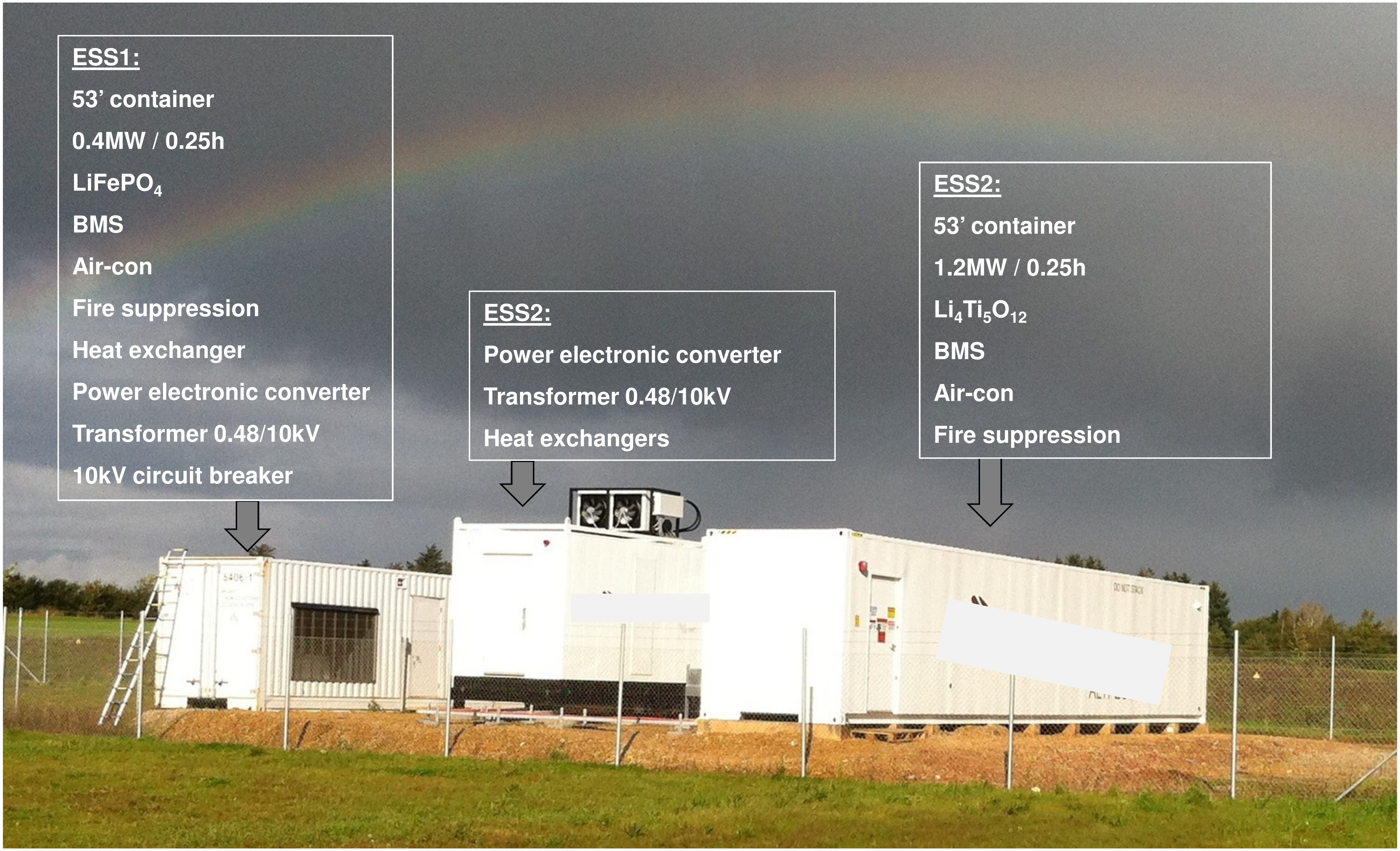
The potential services a Wind Power Plant augmented by embedded Energy Storage can provide

- Ancillary services
  - Primary Reserves
  - Secondary Reserves
  - Tertiary Reserves
  - Black Start
- Load Shifting – Energy Arbitrage
- Transmission Curtailment
- Forecast Error Reduction
- Ramp Rate reduction (dp/dt control)
- Voltage Control
- Islanding
- *(Transmission deferral)*

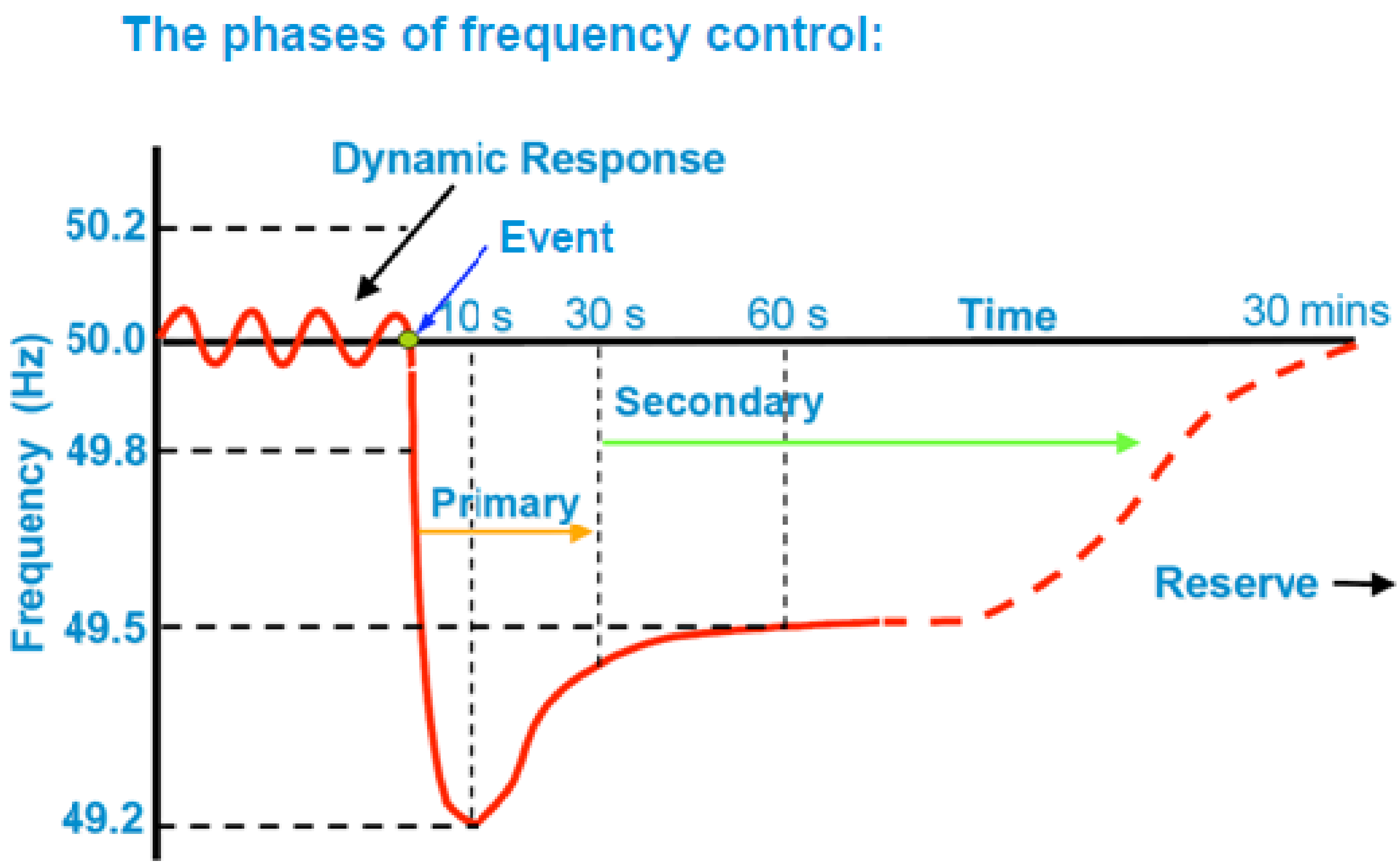


Results from a 2009 Vestas study on a 66MW wind plant in three different locations (electricity markets).

Energy Storage installation

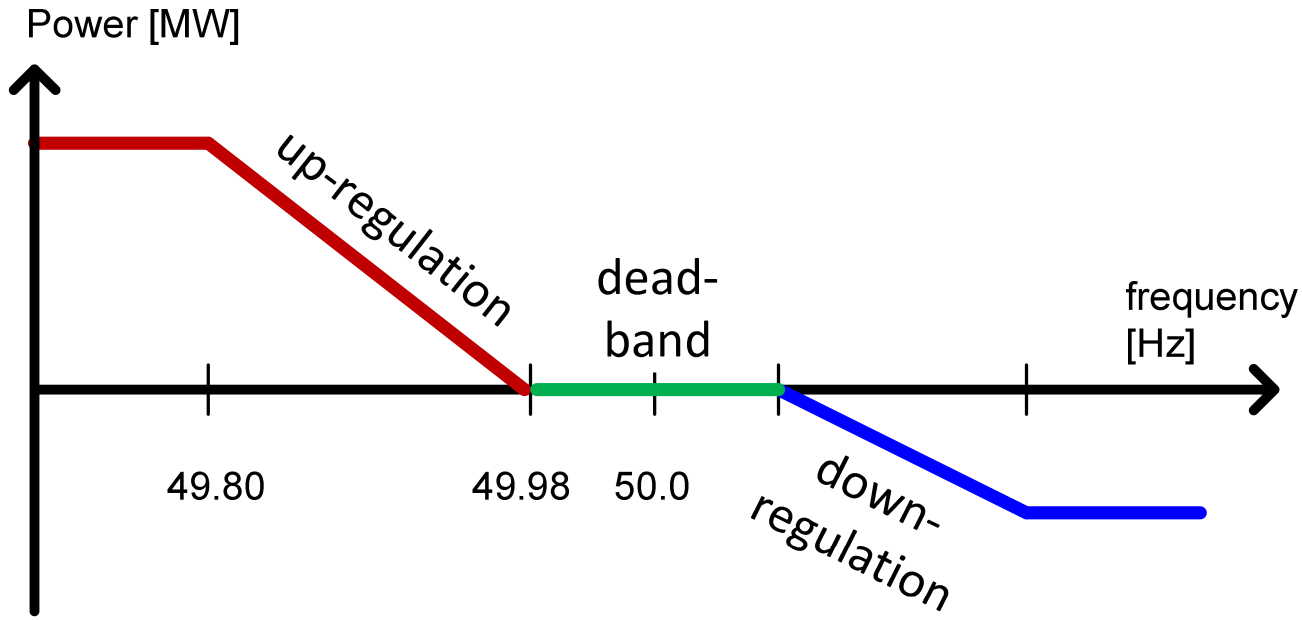


Power System Stability



Source: NationalGrid, U.K.

Frequency support. Primary reserve.



The Danish TSO, Energinet.dk, defines the primary reserve product as:

- “Regulation must be supplied at a frequency deviation of up to +/- 200 mHz relative to the reference frequency of 50 Hz. This will normally mean in the 49.8-50.2 Hz range. A deadband of +/- 20 mHz is permitted. The reserve must as a minimum be supplied linearly and be fully activated within 30 seconds in the event of a frequency deviation of +/- 200 mHz.”
- “……… be able to deliver a constant level of active power (dicharge) for 15 minutes. After another 15 minutes it should be able to repeat the delivery.”

- Auctions take place at 15h00 the day before delivery, and bids are supplied in 6 blocks of 4 hours each.

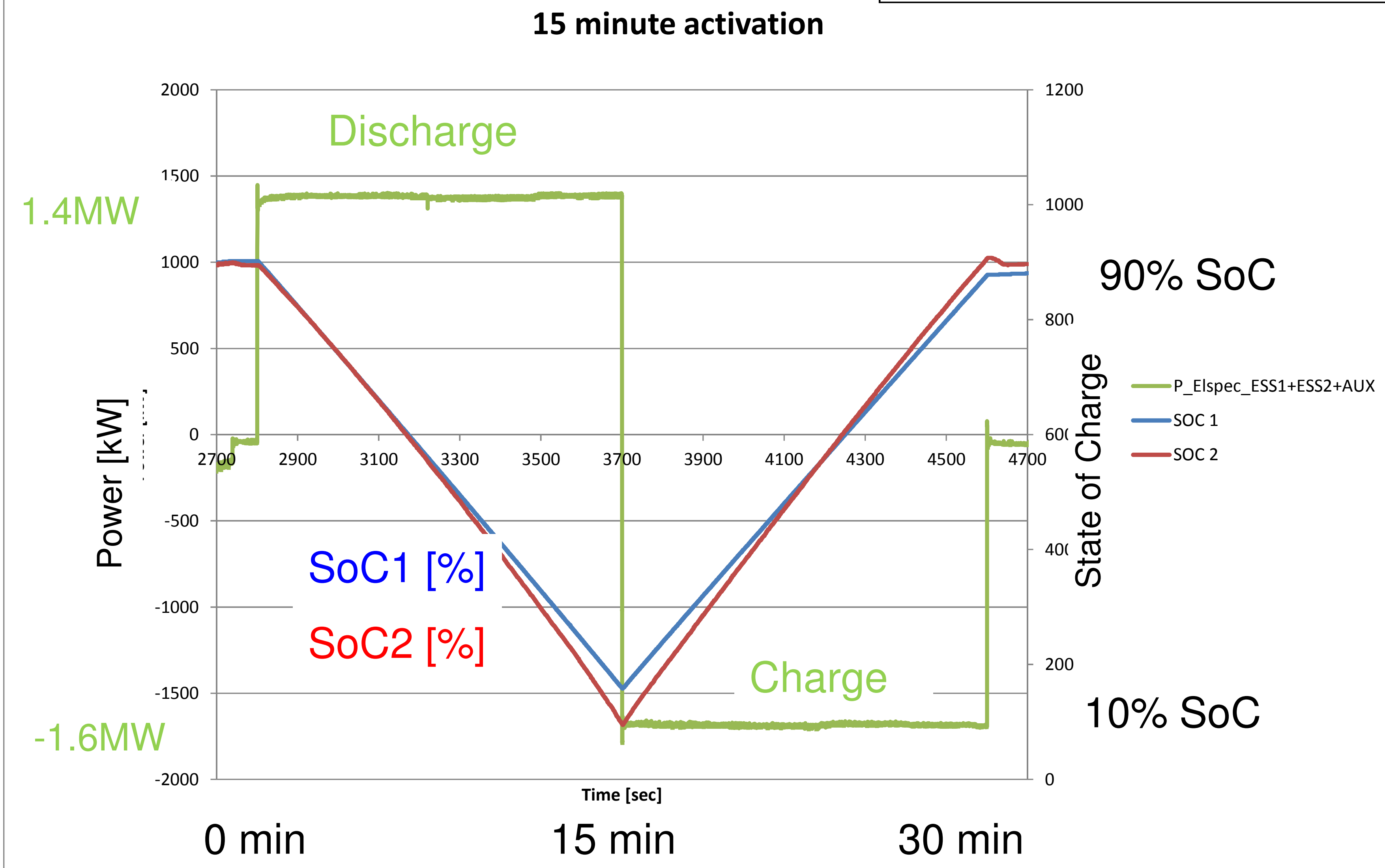
- Upwards and downwards regulation (under- and over-frequency, respectively) are separate, ie. asymmetrical bids are permitted.

- For an ESS **“up-regulation-only”** provider, currently no requirements exist to the level and direction of the power flow when not delivering upwards regulation.

Test results

Danish TSO ENERGINET.DK Primary Reserve approval test

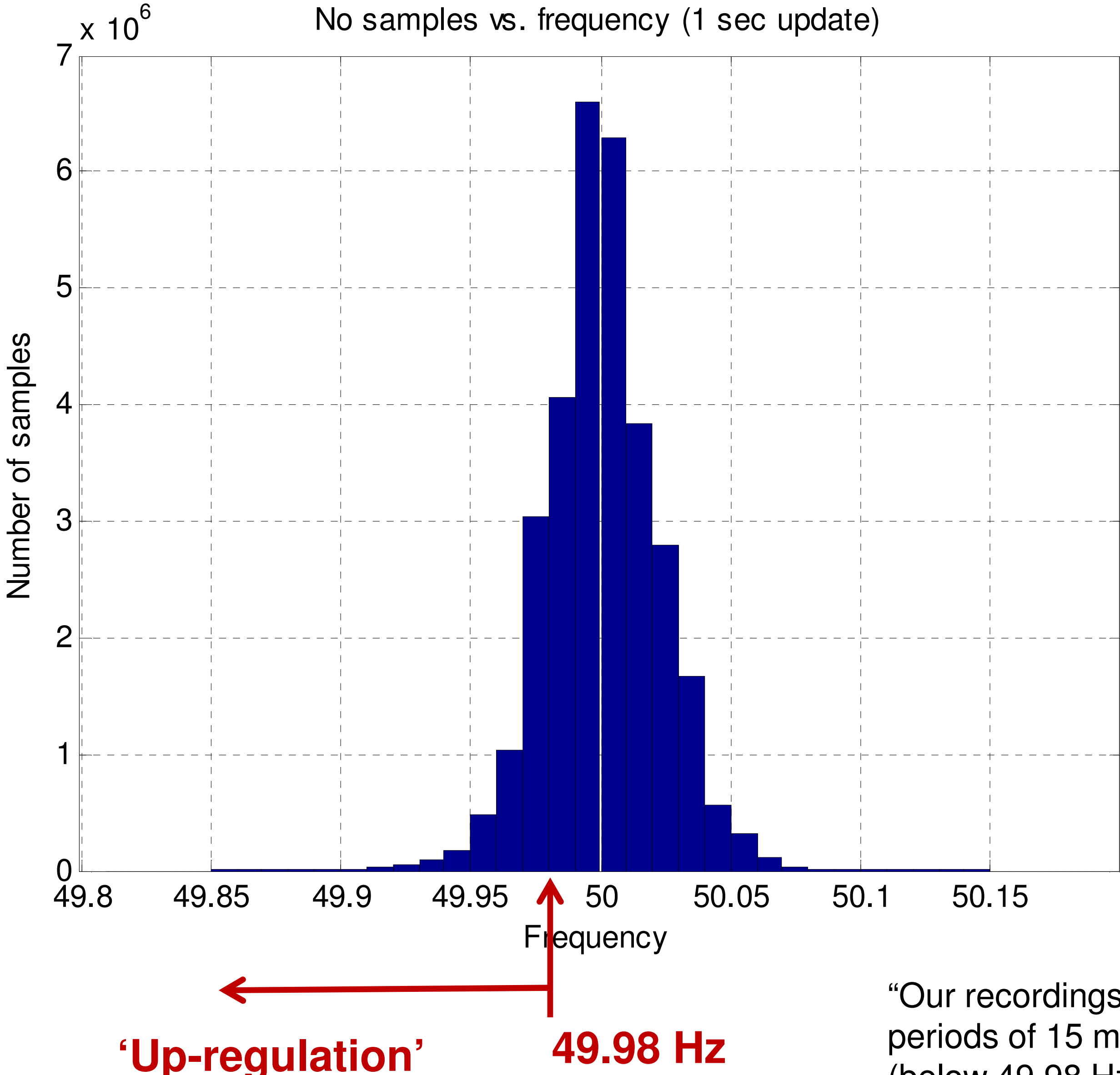
>85% round-trip efficiency



Wind. It means the world to us.

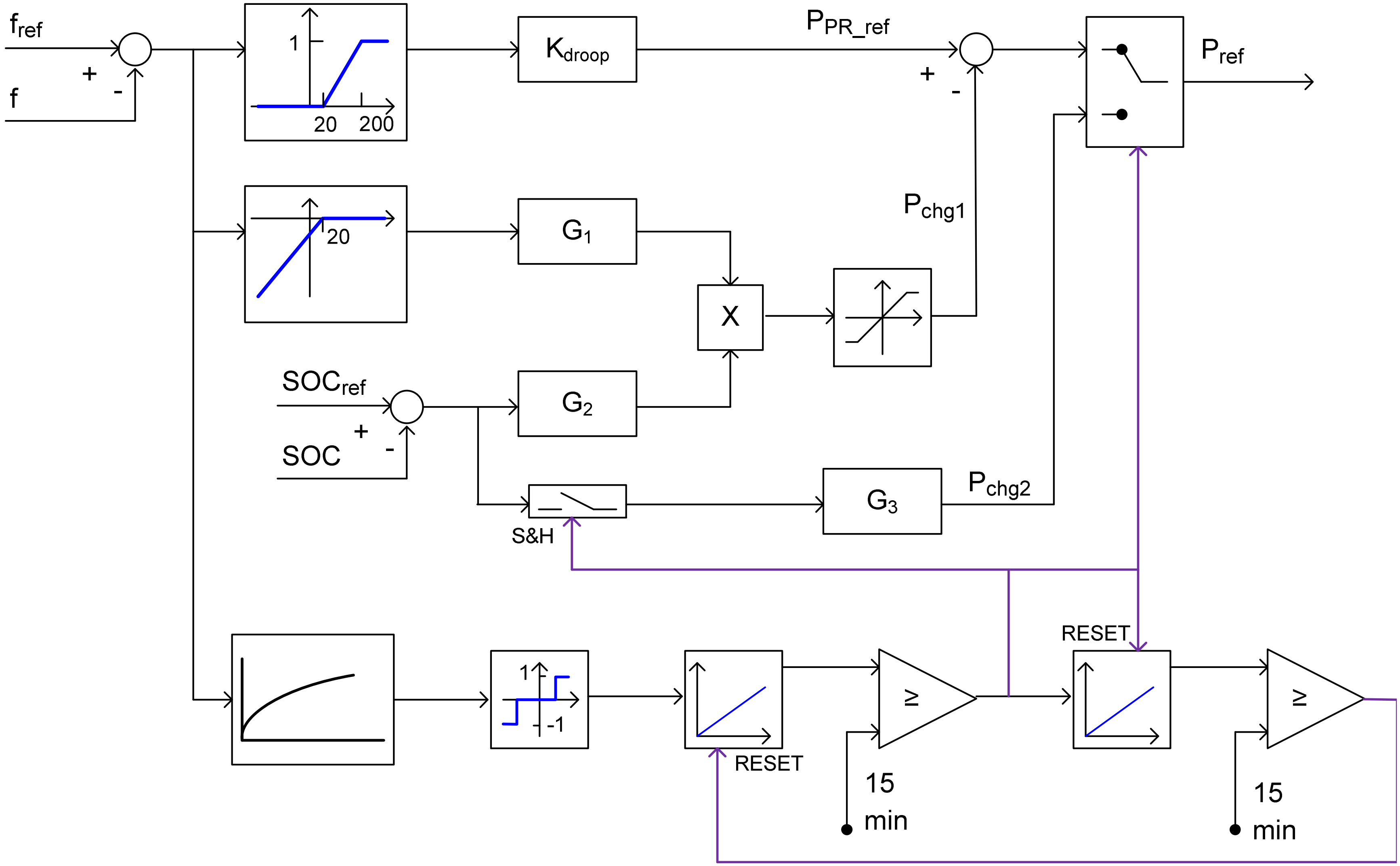
Frequency recordings

Jan 1st 2013 – May 31st 2015

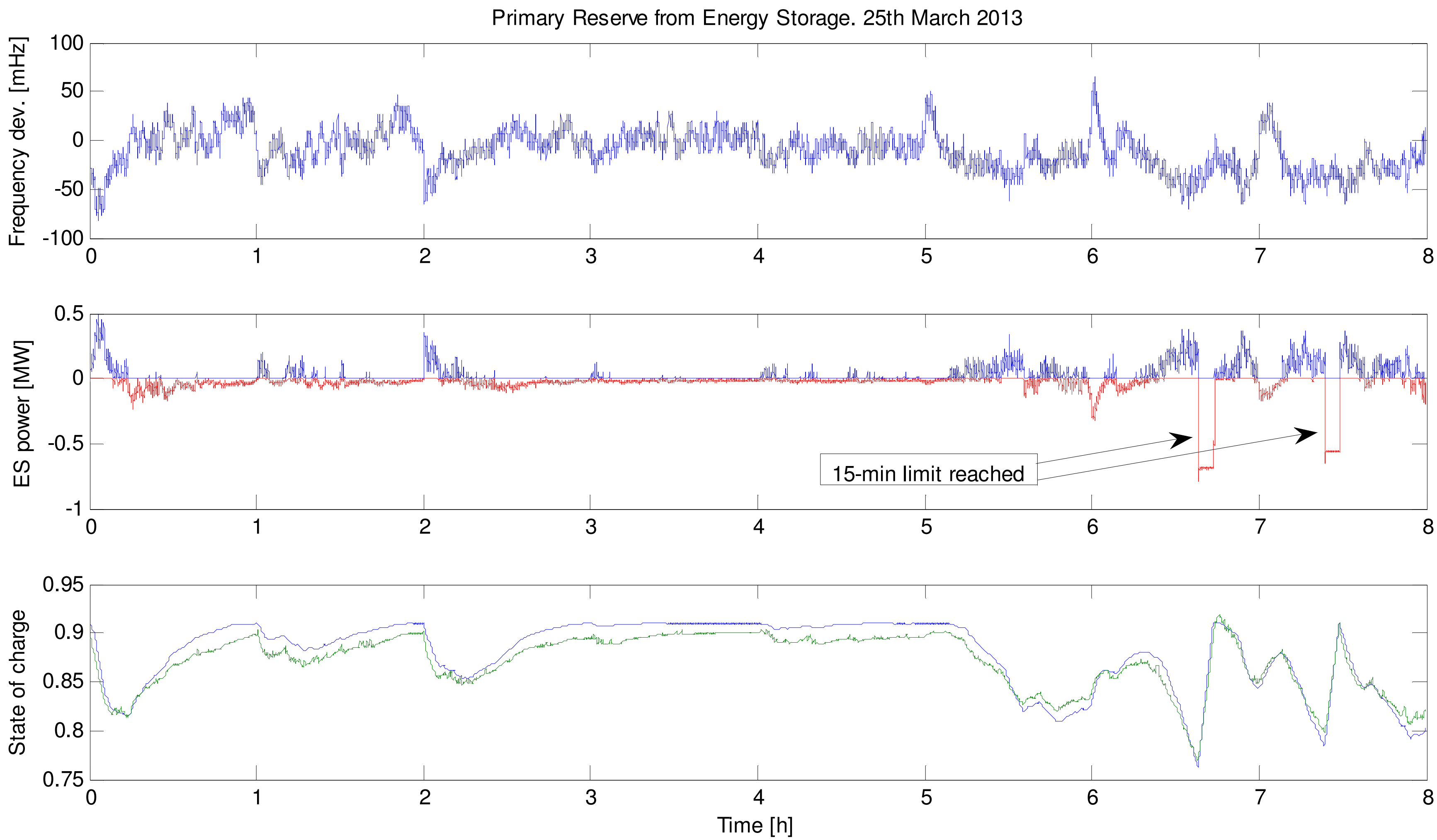


"Our recordings have shown that continuous periods of 15 minutes of under-frequency (below 49.98 Hz) only occur in average 50 times per month (ie. <2%)."

Charging controller

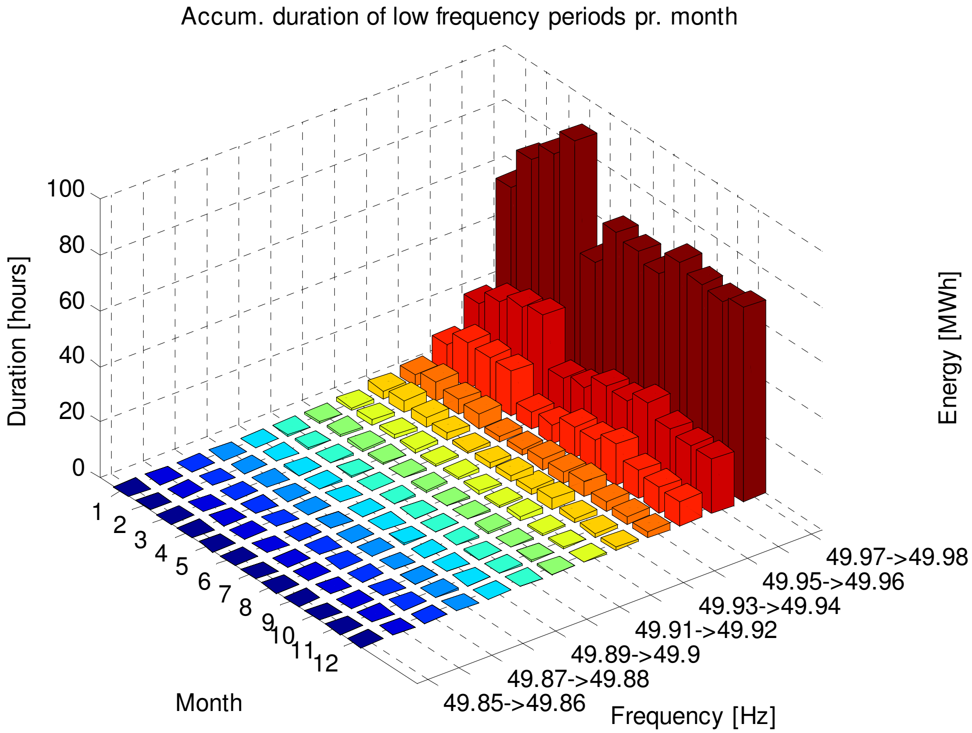


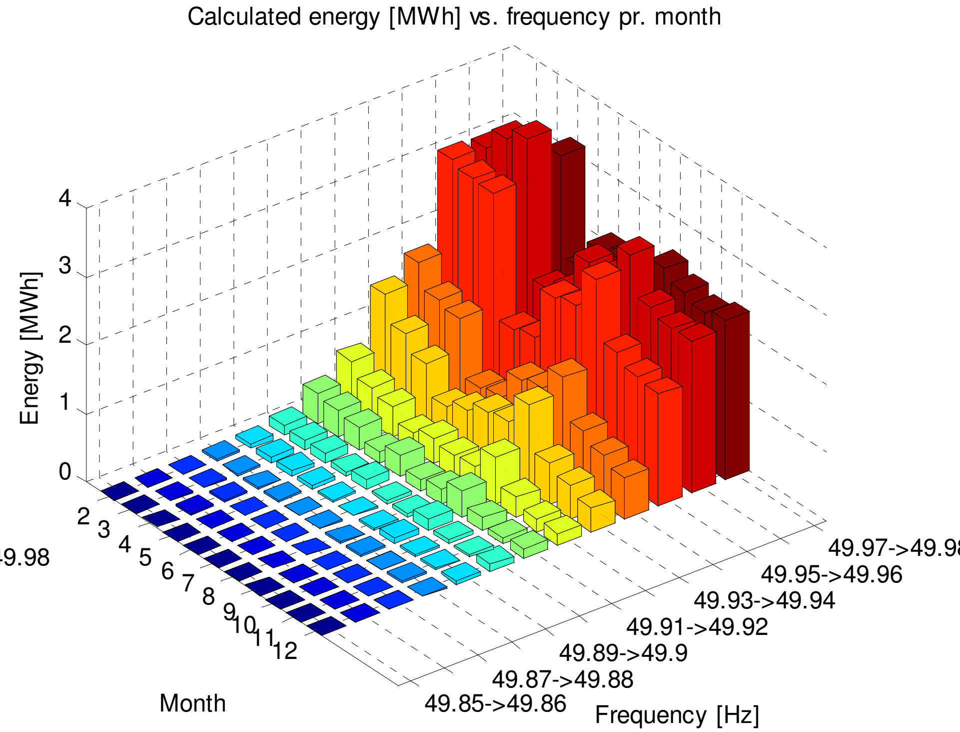
Data recorded at site



Data recorded at site

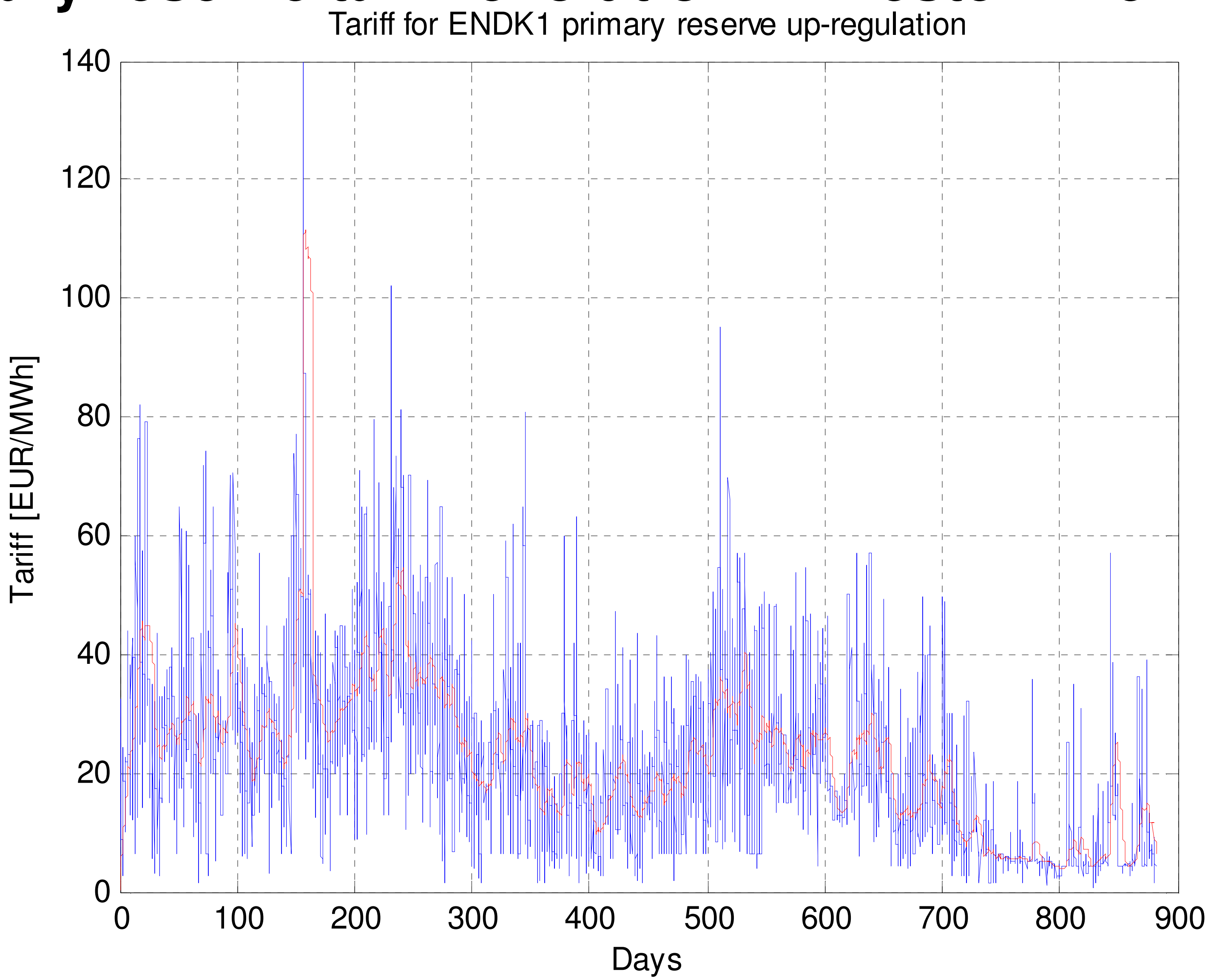
Recordings from 2013-2014





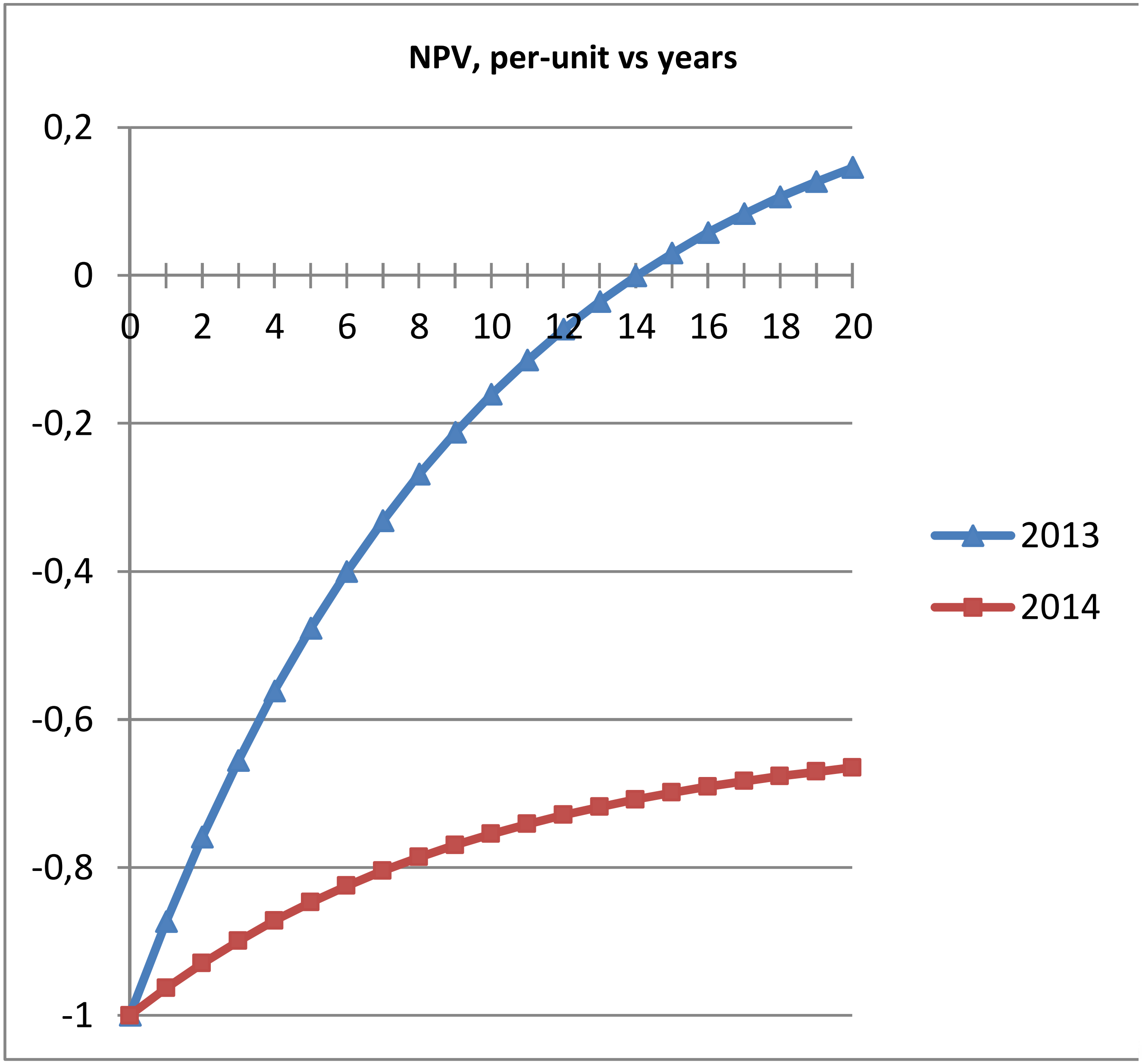
Discharged during upward regulation	0.32 MWh/day
Charged	0.60 MWh/day
Absorbed for auxiliary power consumption	0.35 MWh/day
Duration of frequency below 49.98Hz	16%
Under-frequency energy demand	0.35 MWh/day

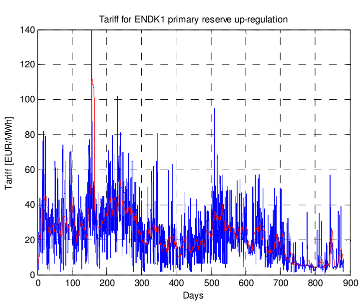
Primary reserve tariff evolution in Western Denmark



Jan 1st 2013 **May 31st 2015**

Net present value of green field investment



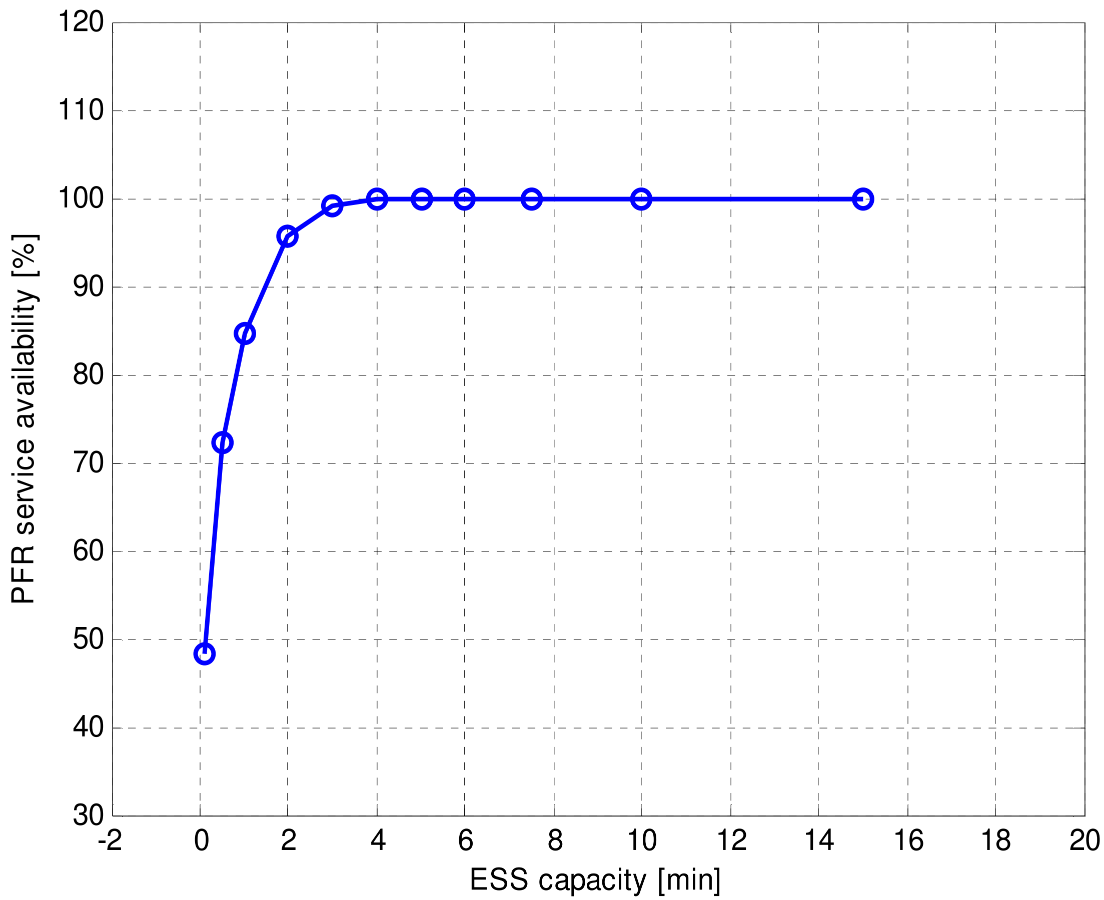


us.™

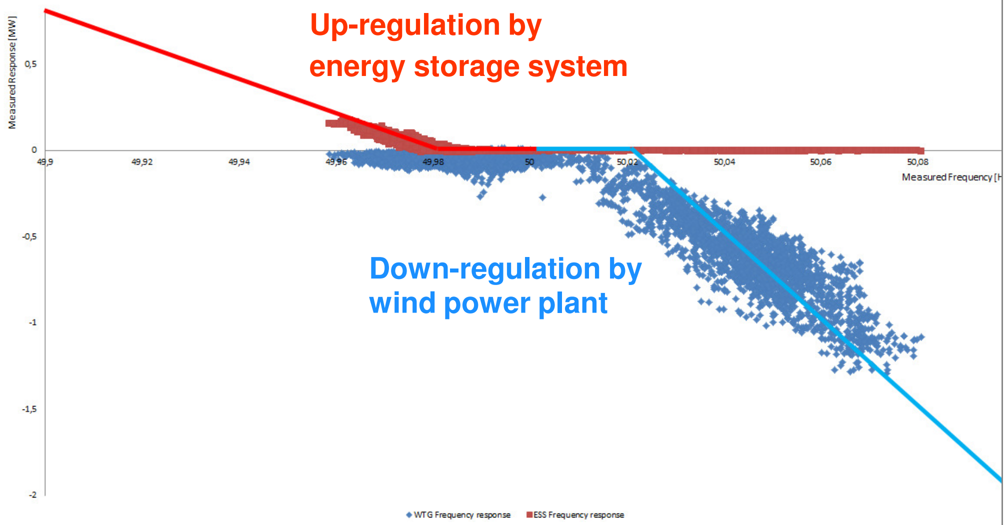
Simulation power/energy ratio for primary reserve

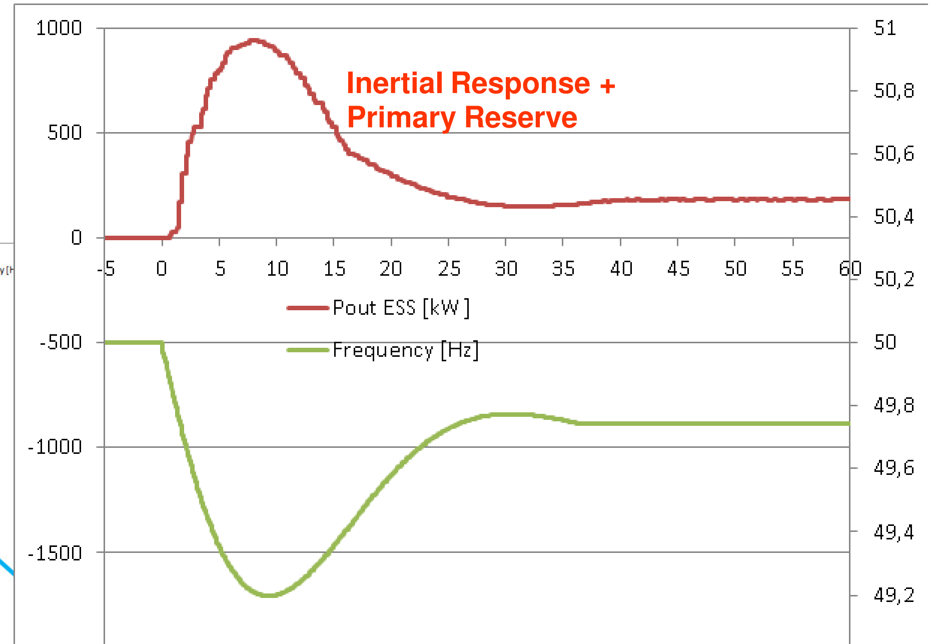
Simulations are based on 1 year grid frequency data (2012).

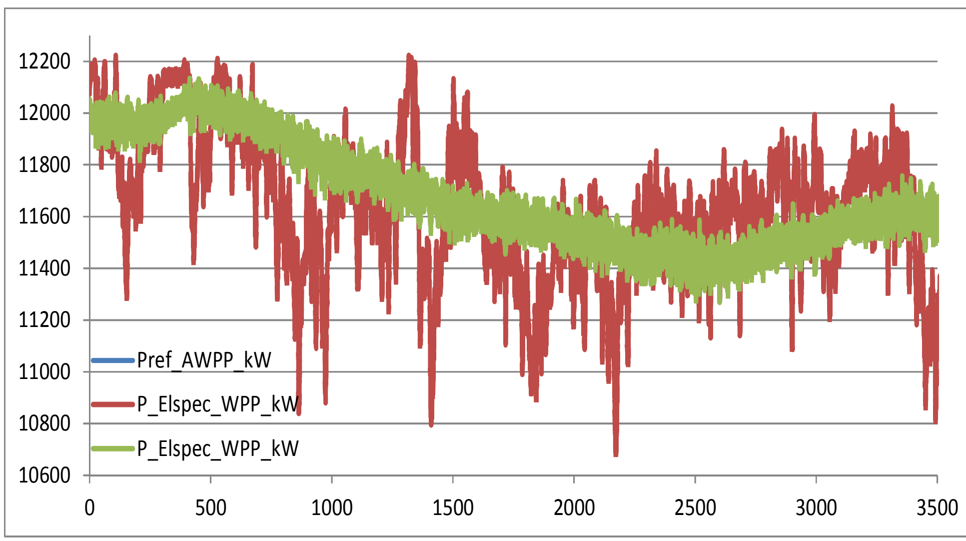
ESS Capacity (discharge time with ESS full power)	PFR_{AVA} [%]
15 min discharge time	100,00
10 min discharge time	100,00
7.5 min discharge time	100,00
6 min discharge time	100,00
5 min discharge time	99.94
4 min discharge time	99.82
3 min discharge time	99.06
2 min discharge time	95.70
1 min discharge time	84.63
0.5 min discharge time	72.26
0.1min discharge time	48.39



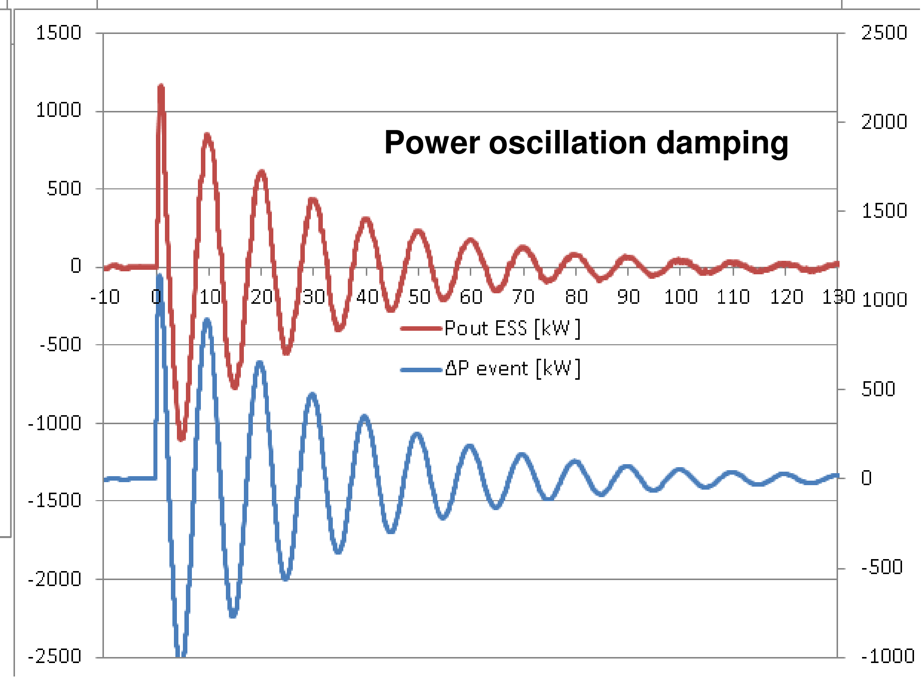
Wind power plant + energy storage applications







Power smoothening



From 2012-13: www.ewea.org + www.twenties-project.eu

Conclusions and Perspectives

1. The TSO has approved storage units for primary reserve market participation.
2. Apparently the only installation of its kind in Scandinavia. Commercial operation for 3 years.
3. The 15-minute constant power discharge effectively sizes the capacity. Only used for up-regulation.
4. The observed network frequency excursions are very modest ➔ Low utilisation of storage (2%).
5. Effective full-cycle efficiency is 50% (30% incl. aux power losses).
6. Specific algorithm developed and approved for control of storage charging.
7. If symmetric bids are required, SoC controller must be adapted (and business case erodes).
8. Recent reserve power tariff reduction erodes business case.
9. Storage cost reduction required and expected.
10. Installed storage capacity may be reduced if requirements were matched to actual frequency excursions. This would increase utilisation rate. Main circuit efficiency should then be optimised.
11. Blending other ancillary services may increase earnings.

Thanks to:

Energi Danmark

ENERGINET/DK

DANISH TECHNOLOGICAL INSTITUTE

Vestas

Wind. It means the world to us.™

DONG energy

The Danish National Advanced Technology Foundation

AALBORG UNIVERSITY DENMARK


Vestas
Wind. It means the world to us.™
Thank you for your attention.
DO NOT STACK
ALTI-ESS