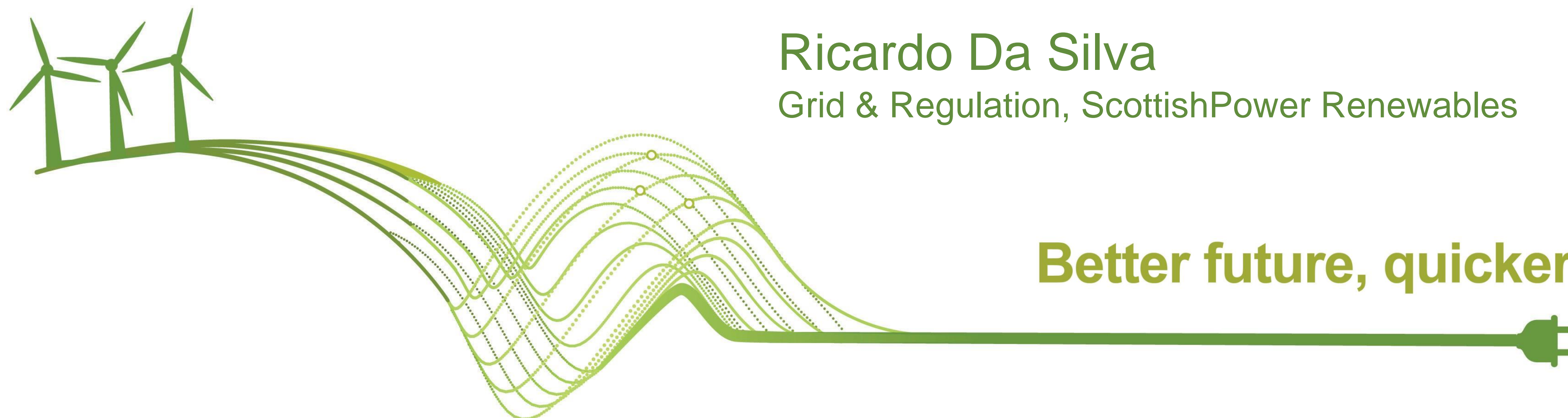




Flexibility From Variable Predictable Low Carbon Technologies

Ricardo Da Silva

Grid & Regulation, ScottishPower Renewables



Better future, quicker

ScottishPower today

100% 1st integrated energy company generating **100% green energy**

Part of the Iberdrola group, **leader in renewable energies**

£6 billion
Investing **£6 billion**
in the UK between
2018 and 2022

2000 MW
Over **2,000 MW**
of wind capacity

5600
5,600 employees,
supporting over
72,000 UK jobs

5M
5M electricity and gas retail
customers spread all over the UK

3.5M
Networks: **3.5M** points of supply
and **110,000 km** of power lines



Better future, quicker



ScottishPower today

We've left carbon generation behind for a renewable future powered by cheaper green energy.

Our focus is on wind energy, smart grids and driving the change to a cleaner, electric future.



Offshore Wind: SPR Overview

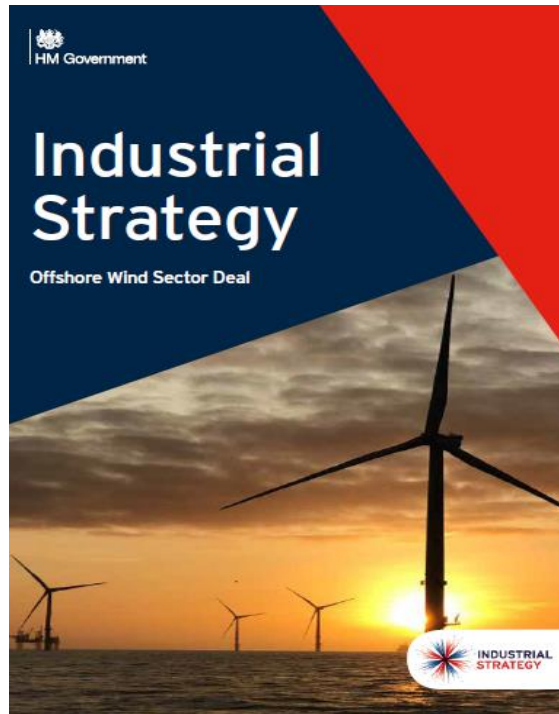
- **Currently operating WoDS and EA1**
- **Working at availability over 97%**
- **Over 1,200 turbines in operation**
- **Operating UK's largest onshore windfarm**
- **Whitelee 539 MW based near Glasgow**
- **Cheapest form of renewable energy**
- **1GW pipeline of projects to 2025**

Continuing to explore opportunities for investment in new offshore wind globally



Better future, quicker

Background



BEIS Offshore Wind Sector Deal 2019
30GW Offshore Capacity by 2030
CCC's Net Zero Report
75GW Offshore Capacity by 2050

New Systems

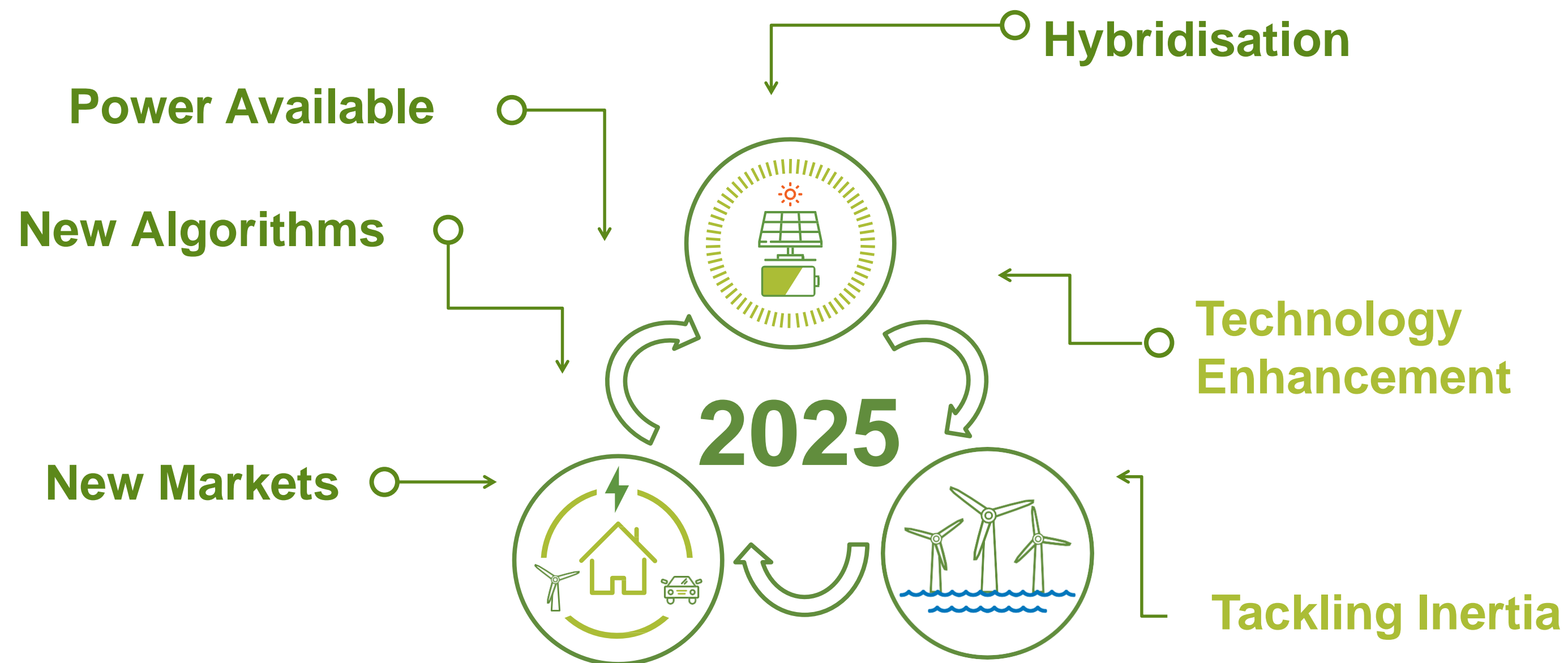
New Products

New Services

100% Zero Carbon Operation



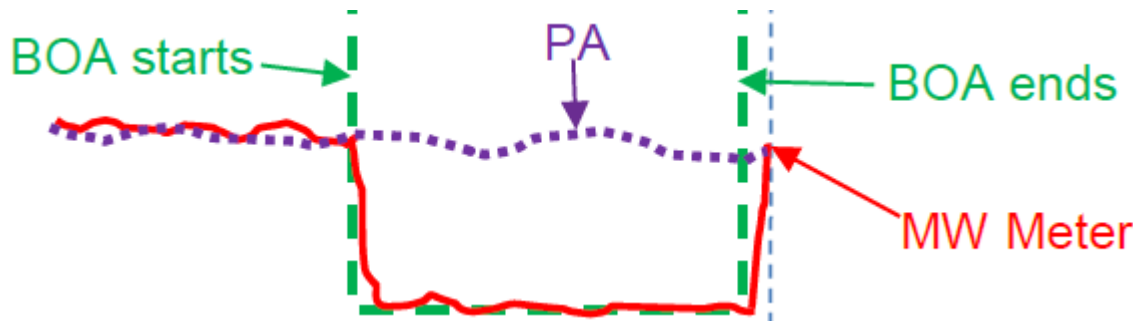
Beyond Good Intentions



Key Enablers

Power Available

Headroom
FR BM RP
CMP314



Solution	Estimated Cost	RoCoF	Sync Torque/Power (Voltage Stability/Ref)	Prevent Voltage Collapse	Prevent Sub-Sync Osc. / SG Compatible	Hi Freq Stability	RMS Modelling	Fault Level	Post Fault Over Volts	Harmonic & Imbalance	System Level Maturity	Notes	Key
Constrain Asynchronous Generation	Hgh	I	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Proven	These technologies are or have the potential to be Grid Forming / Option 1	Doesn't No Resolve Issue
Synchronous Compensation	High	I	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Proven		P Potential I Improves
VSM	Medium	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	P	Modelled	Has the potential to contribute but relies on the above Solutions	Yes Resolves Issue
VSM0H	Low	No	Yes	Yes	No	P	P	P	Yes	P	Modelled		
Synthetic Inertia	Medium	Yes	No	No	P	No	No	No	No	No	Modelled		
Other NG Projects	Low	Yes	P	Yes	No	No	No	P	P	No	Theoretical		
Timescale (Based on work by SOF team)			Now	2019	2019	Now	2020	Now	Now	2025	2025		

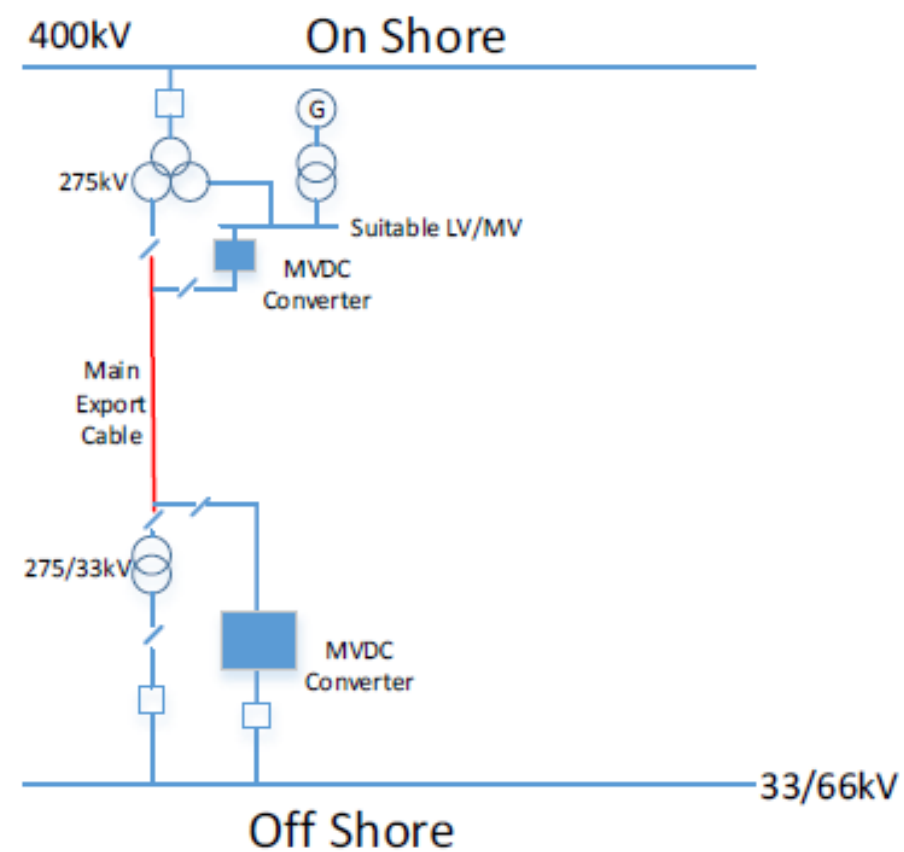
VSM
Grid forming
GC100

New Algorithms

Key Enablers

Hybridisation

Storage
Hydrogen
Synch Condenser
Super Capacitors



Frequency
response
Inertia
Restoration

New Markets

Recent VSM Trials

Storage
Solar
Converters
Super Capacitors

Dersalloch Windfarm 69MW
Inertial response provided
within 50ms

Frequency
response
Inertia
Restoration

New Markets

Better future, quicker

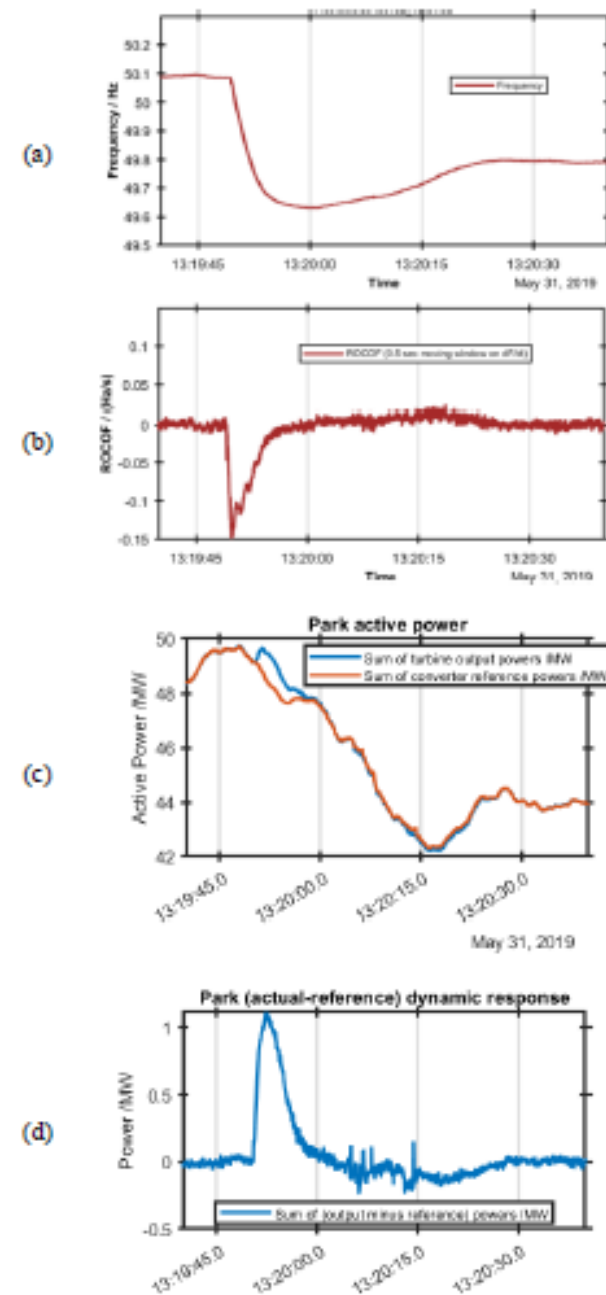


Fig. 2. Response to IFA trip with windpark H = 4 s. (a) SPR 33kV PQ analyser frequency. (b) SPR 33 kV PQ analyser ROCOF (c) Park output power and reference (d) Park output power minus reference

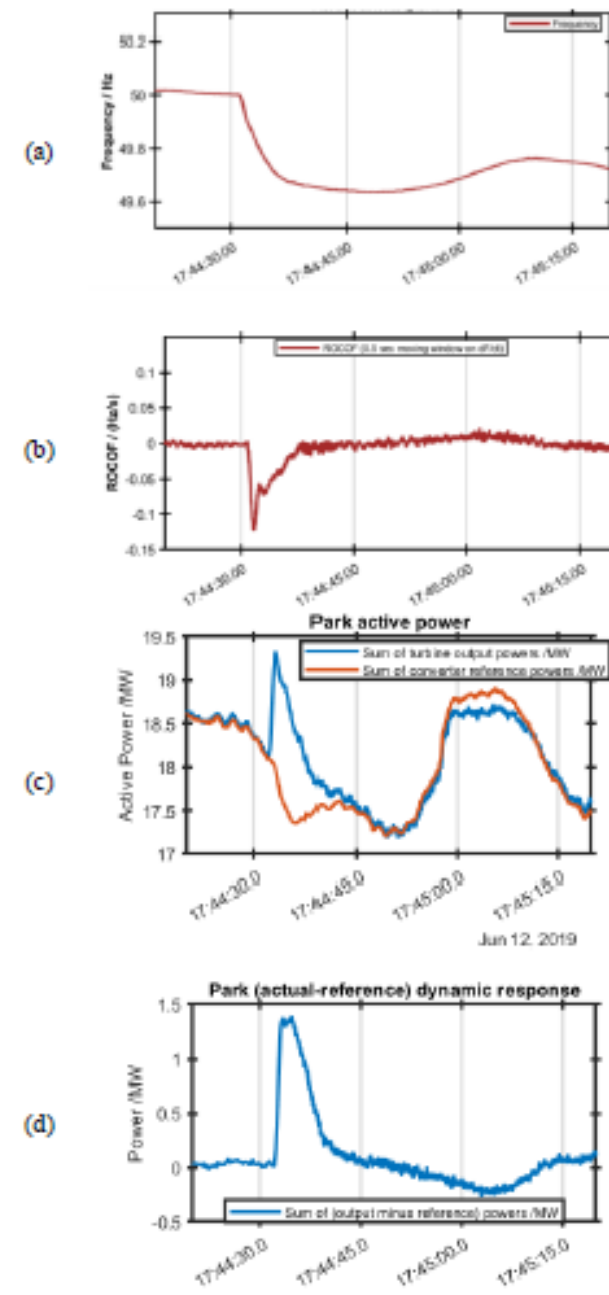
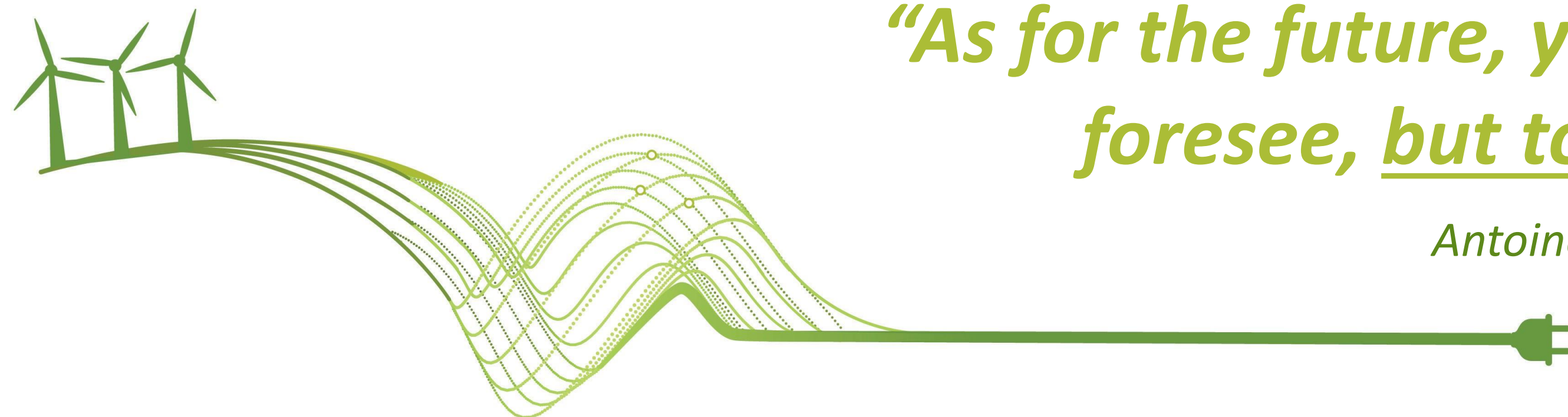


Fig. 3. Response to IFA trip with windpark H = 7.5 s. (a) SPR 33kV PQ analyser frequency. (b) SPR 33 kV PQ analyser ROCOF (c) Park output power and reference (d) Park output power minus reference

Our Role

“As for the future, your task is not to foresee, but to enable it”

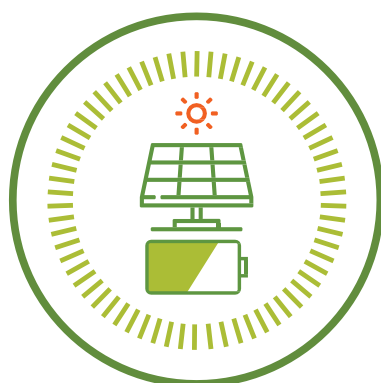
Antoine de Saint Exupéry



SPR – PPA



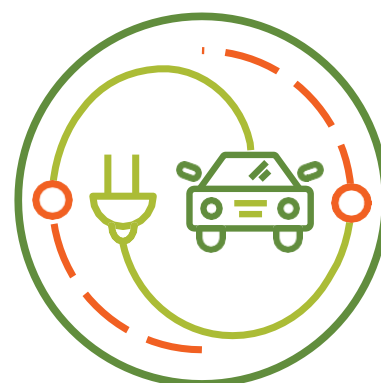
SPR – New
Tech Delivery



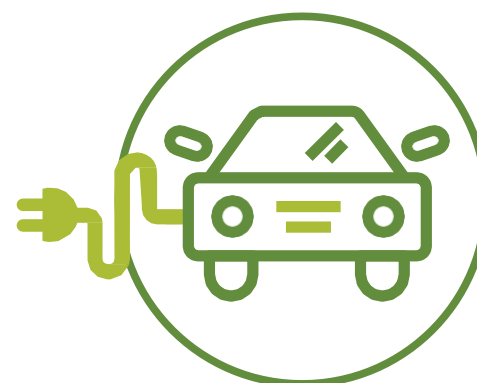
SPEN – Network
of the Future



SPEN – Project
Charge



Retail – EV's



SPR – Offshore



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