RoCoF Alternative Solutions Project Industry Workshop

21st November 2014

Agenda

Item	Time	Speaker
Tea/Coffee	09.00	
Introduction and Welcome • Overview of RoCoF issue • RoCoF Alternative Solutions Project overview	09.30	Robbie Aherne
Regulatory Authorities Update	10:00	RAs
Potential Alternative Solutions • TSOs' list of potential alternative solutions • Presentations from industry • Discussion	10:15	Eoin Kennedy TBC All
Phase 1 Assessment Methodology • Proposed Phase 1 assessment methodology • Discussion	11.45	Eoin Kennedy All
Next Steps and Timelines	12.30	Robbie Aherne
AOB	12.50	All
Close / Networking Lunch	13:00	

RoCoF Overview

Robbie Aherne

EIRGRID

semo
Single Electricity Market Operator

SONI
System Operator for Northern Ireland

DS3 – Shaping the System of the Future

Grid Code

Performance Monitoring

DSM

System Services

ROCOF

Frequency

Voltage

Renewable Data

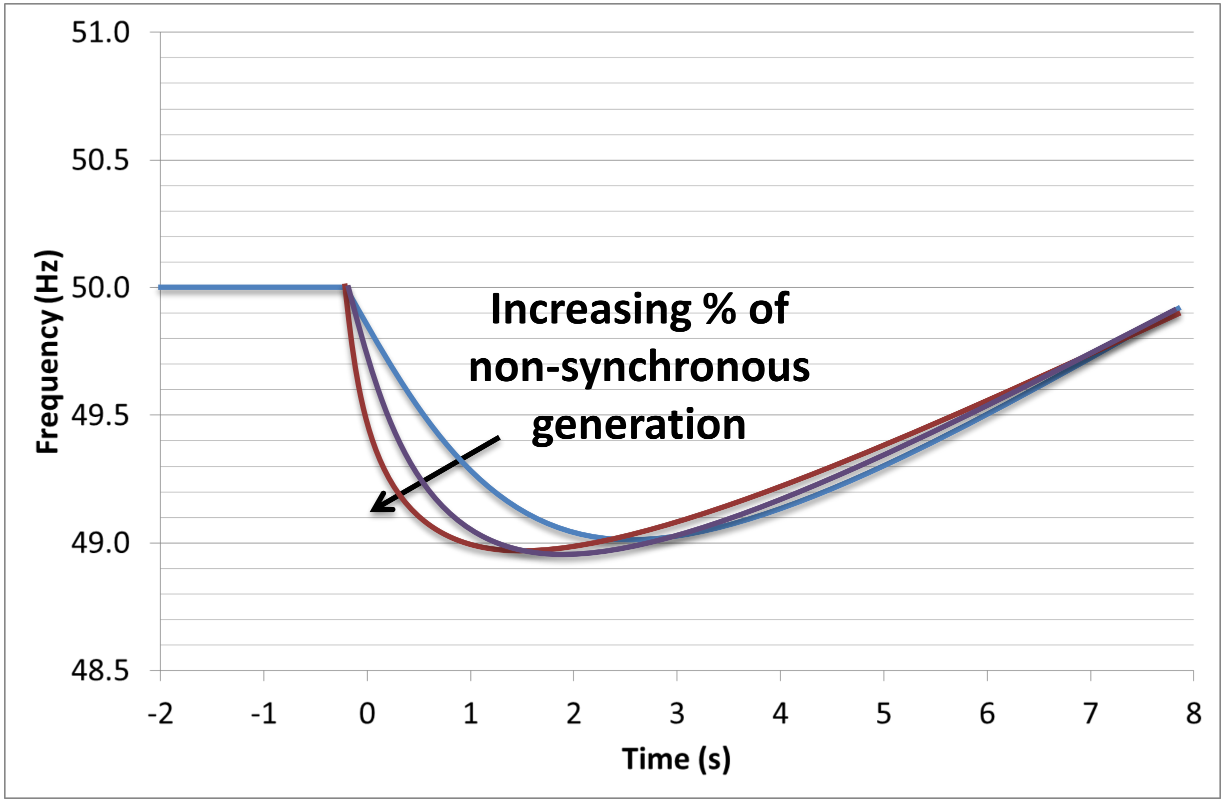
WSAT

Control Centre Tools

Model Dev. & Studies

EIRGRID semo SONI

RoCoF Concept



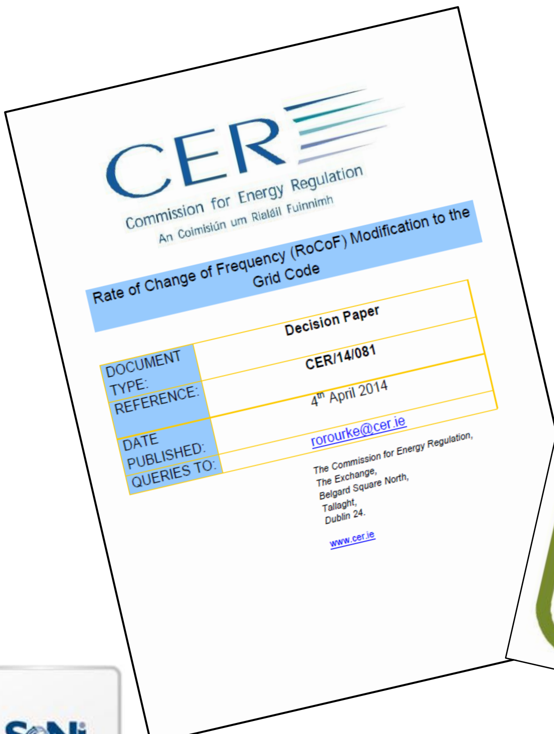
RoCoF

- CER decision paper April 2014
- UR decision paper May 2014

Generator Studies Project

TSO-DSO Implementation Project

Alternative Solutions Project



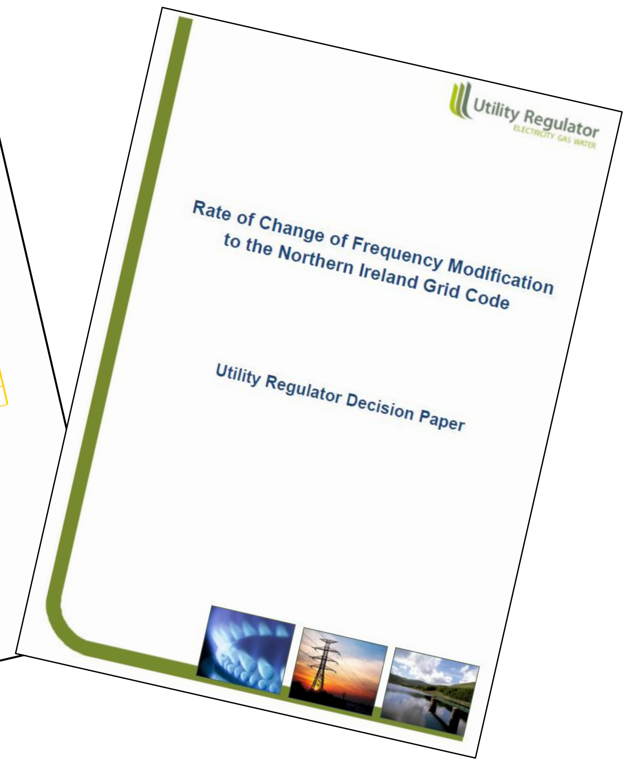
CER
Commission for Energy Regulation
An Coimisiún um Rialáil Fuinnimh

Rate of Change of Frequency (RoCoF) Modification to the Grid Code

DOCUMENT TYPE:	Decision Paper
REFERENCE:	CER/14/081
DATE PUBLISHED:	4th April 2014
QUERIES TO:	rorourke@cer.ie

The Commission for Energy Regulation,
The Exchange,
Belgard Square North,
Tallaght,
Dublin 24.

www.cer.ie



Utility Regulator
ELECTRICITY GAS WATER

Rate of Change of Frequency Modification to the Northern Ireland Grid Code

Utility Regulator Decision Paper

Generator Categorisation

- TSOs' assessment of prioritisation based on:
  - Run hours (existing/forecast)
  - Constrained-on
  - Priority dispatch

- Generator Capability studies to begin shortly

Alternative Solutions Project

- Joint project by TSOs
- Communication with industry via DS3 Advisory Council and website/email

Phase 1 (5 months)

- Range of theoretical options assessed at a high level via weighted scoring matrix approach
- Subset of viable options (2 to 3) selected for Phase 2 analysis

Phase 2 (13 months)

- More detailed review of the viable options from Phase 1
- Analysis focused on technical and economic aspects of each option

RoCoF Implementation Project

Generator Studies Project

TSO-DSO Implementation Project

Consumer cost

Alternative Solutions Project

Consumer cost

- Determine realistic alternative solutions to the RoCoF issue

- Techno-economic study not a procurement exercise

EirGrid

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Regulatory Authorities Update

Rate of Change of Frequency: Regulatory Update

RoCoF Alternative Solutions Workshop

21st November, Dundalk

Robert O'Rourke

Commission for Energy Regulation
An Coimisiún um Rialáil Fuinnimh

Background

- CER Decision (CER/14/081) published 4th April 2014
  - Extensive discussion at Grid Code (and working group)
  - Independent review by CER's consultants
  - Public Consultation
- Implementation of the new RoCoF standard in principle following completion of the generator studies
  - 18 – 36 month study period
  - RoCoF alternative solutions project required
  - TSO/DSO Implementation project

Context

- CER consider increasing the RoCoF standard to 1Hz/s a crucial step towards Ireland's 2020 RES targets
- Required to increase SNSP to 75%
- Technical challenge for generators to confirm compliance
  - Detailed studies must be undertaken
- CER must balance;
  - the importance of implementing RoCoF quickly;
  - the consumer interest; and
  - the safety and security of the system

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RoCoF Implementation Project Framework

Modification

- Approved in principle
- Effective after confirmation from studies
- 18-36 Month timeline

Implementation

- Generator studies; Independent co-ordination
- TSO-DSO implementation project
- TSO led alternative solutions project

Financial Arrangements

- No Cost recovery for study
- GPI to be phased in after 18 months
- Payments (e.g. HAS) to be developed

Where the alternative solutions project fits in

- All three RoCoF projects are important for the implementation of RoCoF
- The Generator Studies are the priority
  - If generators cannot comply RoCoF implementation is highly unlikely
  - This will remain the CER's main focus
- The Alternative Solutions Project
  - Any viable outcome is likely to be complementary to complete (or almost complete) generator compliance
  - Will assist the CER assessment of the reports in 18 months
  - The CER has <u>not</u> committed to approving any procurement through this process

Next Steps

- Formal start of the RoCoF Implementation Project is today
  - 21st November 2014
- Trilateral meetings taking place between Generators, EirGrid, and the CER next week
- The CER has appointed a technical advisor to co-ordinate the project
- Project plans will be published once finalised and regular updates will be provided to industry

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Questions

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Potential Alternative Solutions

Eoin Kennedy

Alternative Solutions

Issue

- Increase in non-synchronous generation with resulting decrease in system synchronous inertia

Possible solutions

- New or modified plant to provide:
  - Synchronous inertia at lower MW output levels than existing plant, and/or
  - Rapid MW response that may reduce the RoCoF

Possible Phase 1 Options

Initial TSO list of potential solutions

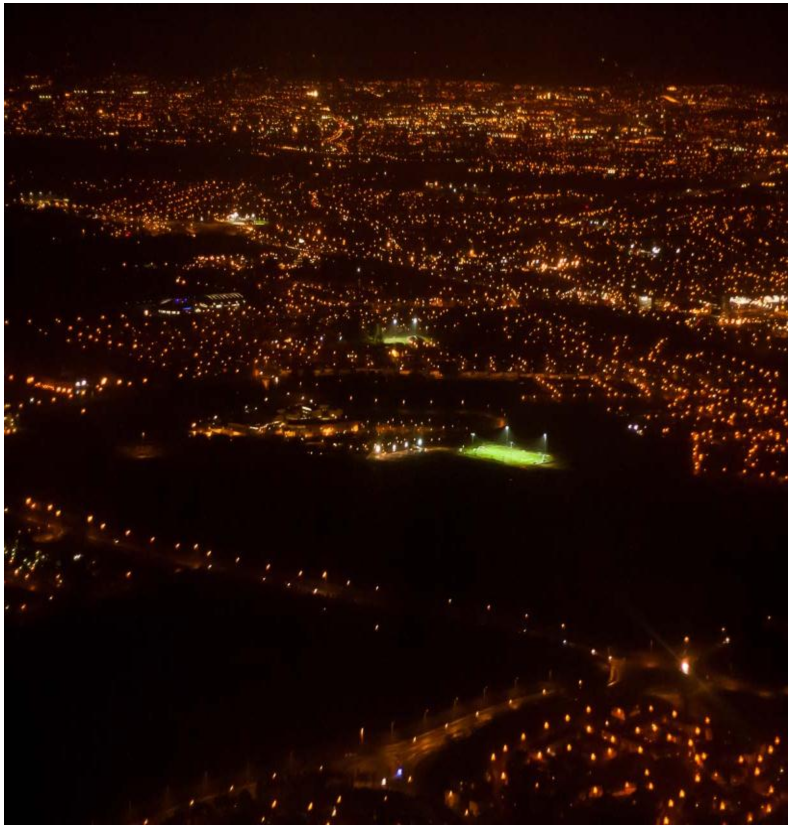
Operational Strategy	Infrastructure Investment
1. Operational measures 2. Load management 3. “Parking” of machines	4. Installation of synchronous compensators 5. Use of synthetic inertial response from devices with power electronics e.g. HVDC, wind and batteries 6. Storage 7. Reduction in the minimum MW generation thresholds of conventional generation 8. Construction of AC interconnectors to Great Britain 9. Combination of technologies

1. Operational Measures

- Reduction in the size of the largest single infeed
- Manage the system with a small number of non-RoCoF compliant generators

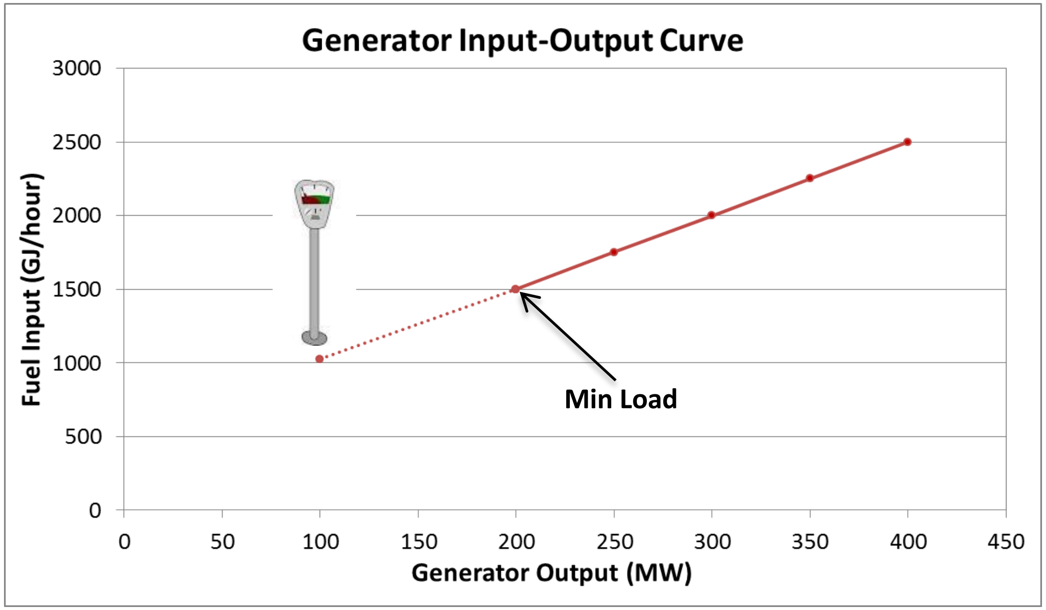
2. Load Management

- Some load management measures could potentially be employed to provide fast MW response to a frequency dip, for example:
  - Demand side response
  - Short Term Active Response (STAR)



3. “Parking” of Machines

- It may be possible to operate synchronous generators at MW output levels lower than minimum load
- Provides same level of inertia as at higher output levels and greater headroom for non-synchronous generation
- Operating at low outputs has impact on efficiency, emissions and ability to provide system services



4. Synchronous Compensators

- Also referred to as synchronous condensers
- Traditionally designed and used to control network voltages rather than to provide synchronous inertia
- May be potential to adapt to provide more inertia

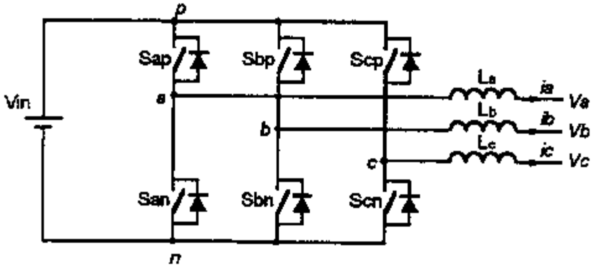
5. Synthetic Inertial Response

- Various technologies connected to the grid via power electronic devices have potential to provide fast MW response

Wind Turbines

HVDC Interconnectors

Batteries



6. Storage

- Multiple technologies developed or under development

- Some provide inertia and others may provide “synthetic inertia”

Electrical
- Capacitors
- Ultra-capacitors
- Superconducting magnetic energy storage

Mechanical
- Pumped hydro
- Compressed Air Energy Storage (CAES)
- Flywheels

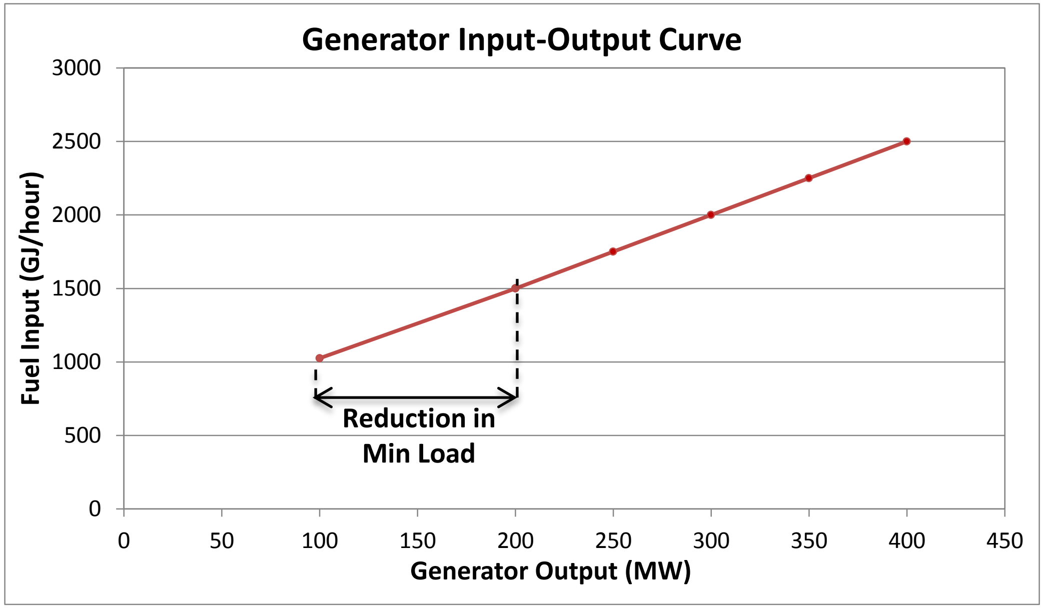
Electro-chemical
- Batteries
- Flow batteries

Chemical
- Hydrogen

Thermal
- Hot water/steam/oil
- Molten salt

7. Reduction in Min MW Thresholds

- Permanent reduction in the minimum load threshold of conventional generators
- Efficiency is reduced
- Generator maintains ability to provide system services at reduced MW output levels

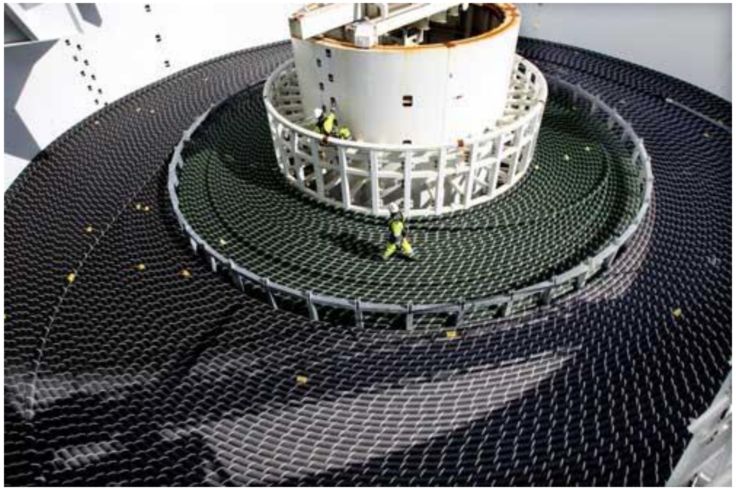


8. AC Interconnection to GB

- Currently connected to GB via two HVDC interconnectors

- AC interconnection could result in a stronger system from a frequency response perspective due to much higher inertia levels on the combined system

- Technical challenges



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Industry Presentations

RoCoF Alternative Solutions Project

21/11/2014

Lumcloon Project Overview

Environment	Fully consented 300MW CCGT, old Ferbane Power Station
Grid	Connection offer, no constraint issues, midlands location
Planning	Full planning, strong community support
Design	Designed for high-wind Irish System, multi-unit flexible robust design

Lumcloon Project Overview

Environment

Grid

Planning

Design

Shovel-Ready Project with well considered design for high-wind renewable system and market

Technically robust project, deliverable 18 months from financial close

RoCoF Alternative Solution

- Prevent RoCoF exceeding current standard
- High inertial grid support at very low MW output
- Facilitated by multi-turbine design
  - 4 x SGT 800
  - 1 x SST 900
- Many different configurations of oversizing generation/flywheel, offsetting other ramping capability

Low MW Synchronous Rich Output when you Need It

	MW Output Range	Steam Turbine	Gas Turbine 1	Gas Turbine 2	Gas Turbine 3	Gas Turbine 4
Staging (most efficient)	38MW to 295 MW	Always on	Always on	Off / On with increasing MW output	Off / On with increasing MW output	Off / On with increasing MW output
Flexible 1 (more flexible, less efficiency)	38MW to 295 MW	Always on	Always on	Idling / On with increasing MW output	Idling / On with increasing MW output	Idling / On with increasing MW output
Flexible 2 (negative min-gen, least efficiency)	Minus 15MW to 295MW	Always on	Compression / On with increasing MW output	Compression / On with increasing MW output	Compression / On with increasing MW output	Compression / On with increasing MW output

Can change mode depending on the needs of the system in that half-hour

RoCoF Alternative Solution Evaluation

- Mature technology

- Able to withstand ramping and take wide-swings in non-synchronous generation

- Standard operation under current Grid Code rules
  - Within-day mode change welcomed

- Fully consented, Gate 3 offer, design well progressed
  - Potential for refinement

- Independent studies have shown €40m savings to consumer in energy costs

- Can be utilised as efficient CCGT, DS3 service provider, outside of “RoCoF constrained” periods as requirements evolve

LUMCLOON energy Ltd.

Alternative Solutions Project

- Lumcloon designed as a DS3 plant
- Further refinement of the design / clever operational strategies allow for added inertia at low MW output
- Flexibility in configuration means it is not a plant to only solve an inertia problem for a small % of hours per year
- Lumcloon evaluating this programme, the response to the new Grid Code RoCoF standards, and ready to adapt to the market requirements
- Market and regulatory signals still required

SCC- Siemens Combined Cycle

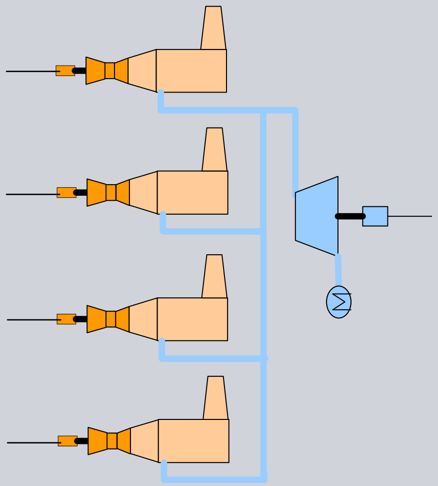
SIEMENS

Picture: SCC-800 3x1, parallel & Island mode operation, city of Gothenburg Sweden

Siemens Combined Cycle

SCC-800 concept

- Technology for DS3 services = Ultraflexible multi shaft CCGT plants
- Solutions;
  - Synchronized with 100-105% turndown
  - 100% SIR
  - Synchronous condenser at full turndown
  - RoCoF capability 4Hz/sec
  - Fast ramping < RM1



Operational flexibility

Modes of operation

Siemens Combined Cycle, SCC-800

SIEMENS

Modes of CCGT operation

Operation	Pros	Cons
Staged with 1-4 GT's	efficiency	DS3
All GT's	DS3	efficiency

SIEMENS

Modes of operation

Yearly operation profile: 4000h turndown – 4500h 100% generation, 360 start/stop or 100% regulations/year

SCC-800 4x1C, site cond. 15°C							
Operation mode	GT's on line	ST on line	Operating range, %	Net MW	SIR (Synchronous Inertial Response)	SRP (Steady state Reacitve Power)	RM
Staging	1-4	Yes	13 - 104	38 – 295	low-high/flexible*	flexible*/low-high	<1
Low load 1	4	Yes	13 - 104	38 - 295	high/flexible*	flexible*/high	<1
Low load 2	4	Yes	minus 5 - 104	minus 15 – 295**	high/flexible*	flexible/high	<1

*) increased generator rating/inertia / flywheel

**) >295 MW, supplementary firing

	Annual operation[%] time at different ambient conditions
T2 = -10°C	10
T2 = 5°C	20
T2 = 15°C	40
T2 = 25°C	20
T2 = 30°C	10

SIEMENS

SCC-800 DS3 contribution, summary

- SIR Synchronous Inertial Response
  - All turbines synchronized, high turn down, generators and optional flywheel to DS3 requirement
- SRP Steady-state Reactive Power
  - 1 / 0,5 PU lag/lead condenser operation at full turn down, 1 PU = DS3 requirement
- RoCoF Rate of Change of Frequency
  - Capability 4Hz/sec
- FFR Fast Frequency Response
  - dP/dT, 10 MW/s / GT
- DDR Dynamic Reactive Response
  - Optimized with static excitation
- RM Ramping Margin
  - <RM 1

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Industry Presentations

REDT Vanadium Redox Flow Battery (VRFB) For RoCoF

Eirgrid Workshop

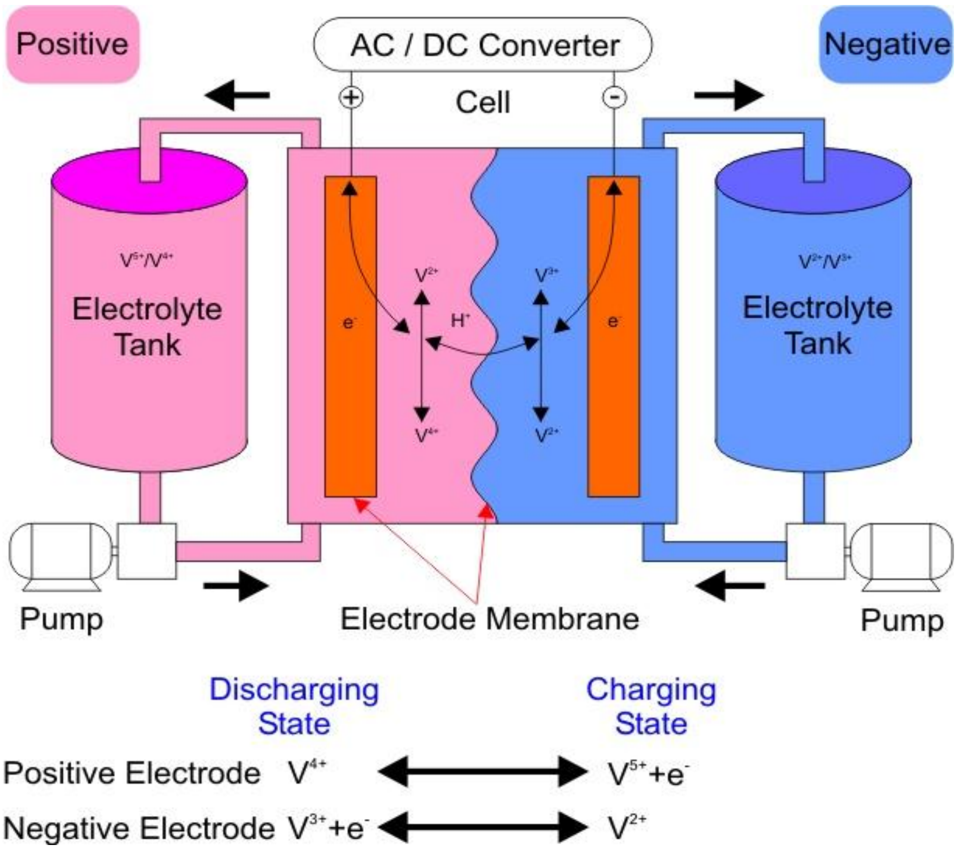
John Ward, REDT Energy Ltd.
Dublin.

Agenda

- Background to the Technology
- VRFB – What is it ?
- Review of VRFB technology - performance at stack level and scale up to grid systems
- RoCoF capability
- Conclusion

REDT
Renewable Energy Storage

VRFB – What is it ?



Key features for reliability:

- **Power and energy independent**
  Scalable from 5kW to 10MW, with 3 to18 hours discharge duration

- **Deep discharge capability**
  Capable of 10,000 cycle life with minimal degradation >20 year life

Partial cycles have no effect on system life

- **Safe operation**
  Ambient temperature, non-flammable, environmentally sound – zero emissions.

VRFB 5kW Stack – Building block

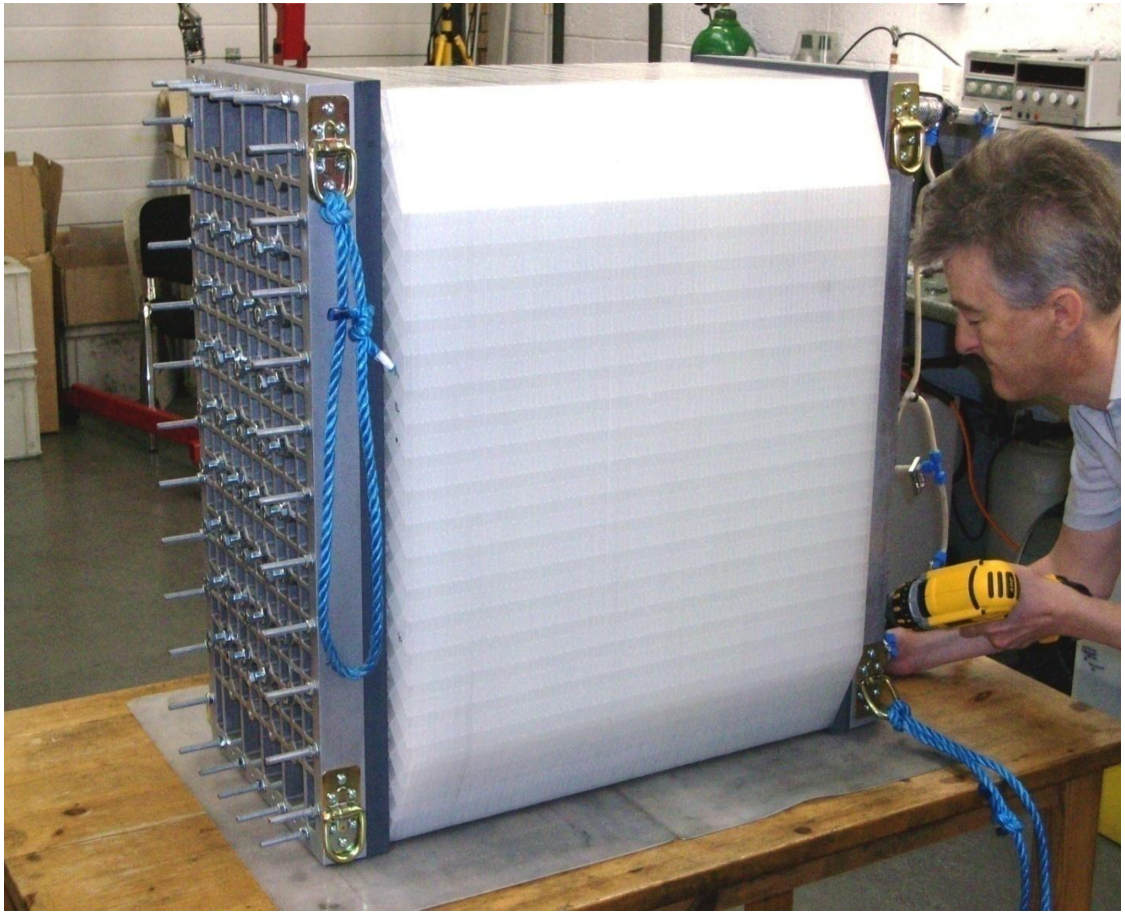
All polymer materials, high integrity sealed system

Low impedance membrane electrode structure

Charge/discharge ratio 1:1

5kWe nominal,
8.5kWe peak (15 mins)

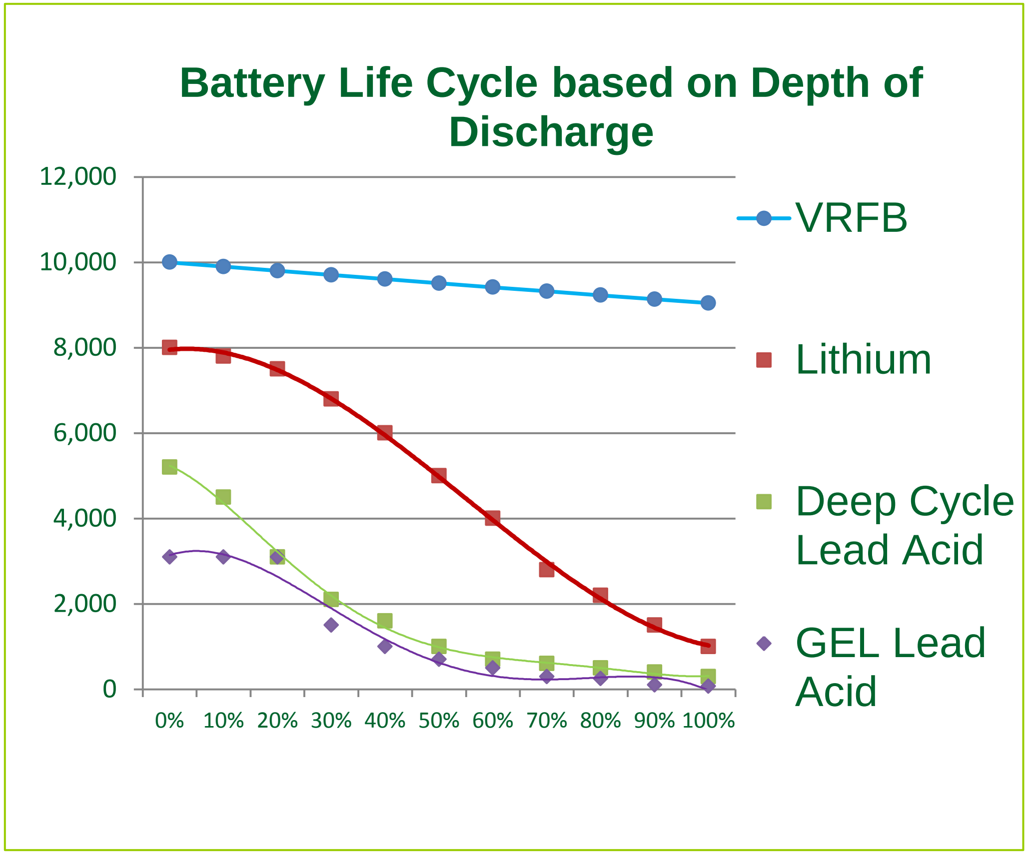
Future target of 15kW



REDT

Renewable Energy Storage

Vanadium Redox Flow Battery Benefits

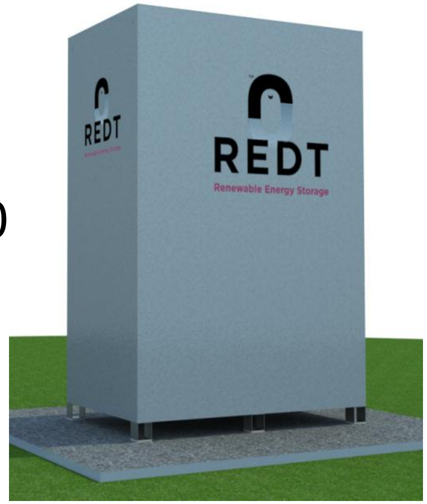


- **Low LCOE >20 year life**
  - Lowest cost over life in class
  - Modular from 5kW to 5MW to match loads, scale duration from hours to days
  - Stack life > 10,000 cycles, electrolyte indefinite life, re-usable & recyclable
- **Performance**
  - Deep discharge cycles, uses 100% of available capacity
  - Charge retention, almost indefinite in standby mode
  - 75-85% round trip efficiency

REDT
Renewable Energy Storage

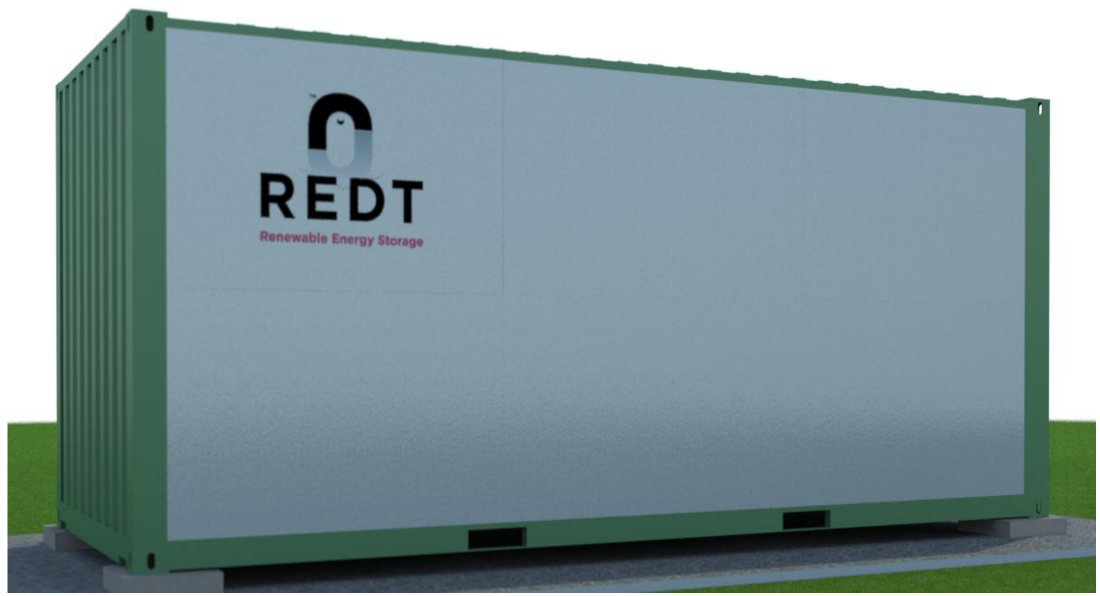
Containerised modular VRFB system designs -standardised for volume production

5-30
10-30



5-60
10-60

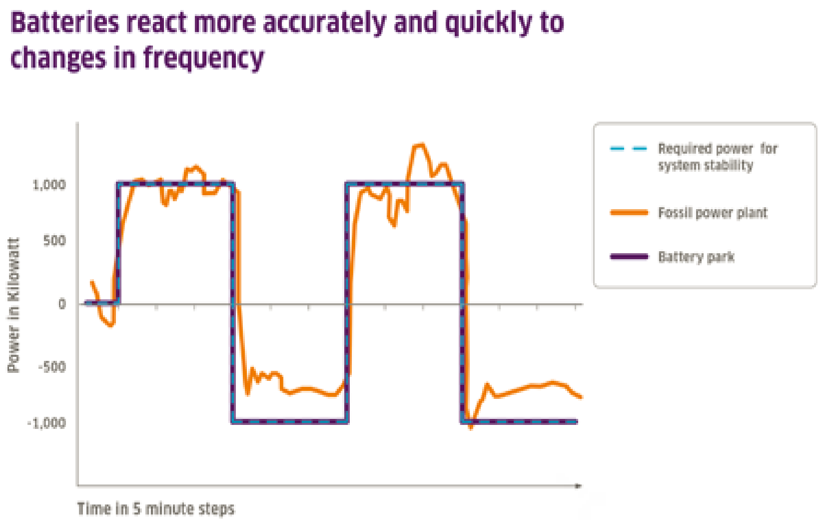
15-180
30-180
45-180
60-180



ISO Standard 20’ container section – 60kW x 180kWh

- 12 x 5kW rated stacks per battery
- Insulated air flow thermal control system
- Argon blanketed electrolyte
- Safety – leakage, fire, hydrogen detection
- 96,000 Litres of electrolyte per container
- Excess electrolyte enables deep discharge

Why Flow Batteries for Frequency Control ?



A VRFB can provide 10x approx. the system services of a conventional power plant due to its speed and overload capability

(Sasaki, Kadoya, IEEE Paper)

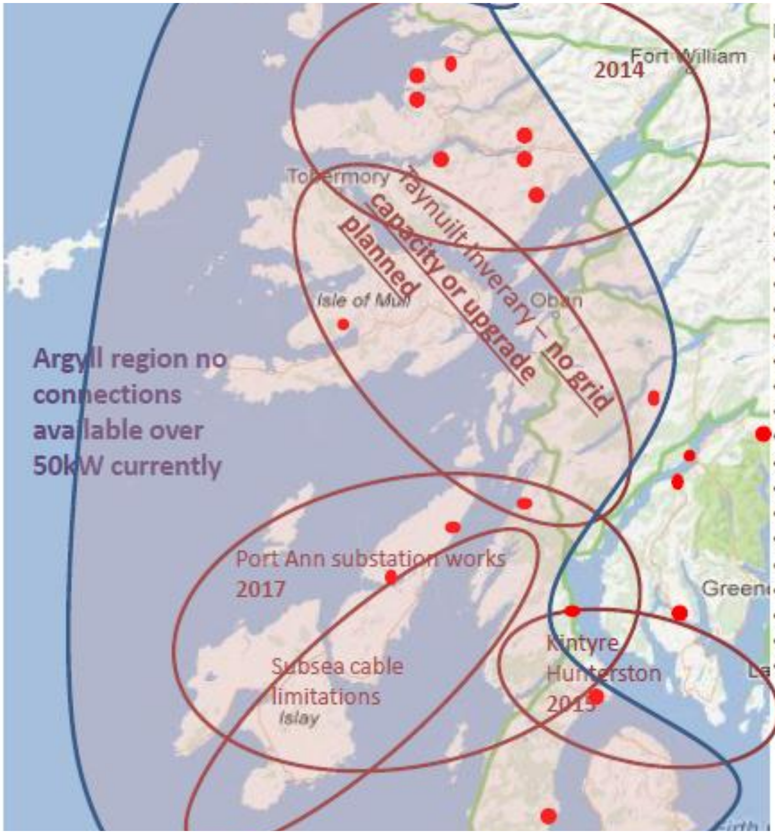
No Time Delay in responding to a signal

Existing power stations require to be at 80% capacity to provide services 'spinning reserve'

Conventional power not scalable as required – 400 MW Blocks ? = 40MW RoCoF ??

Cost and performance – Zero Fuel required

Regional Context – The Western Isles



Distribution constraints <1MW capacity

- Kingairloch
- Kinlochmoidart
- Glenuig
- Liddesdale
- Poorhouse
- Rahoy
- Shona Beag
- Claonaig
- Dippen
- Strachur
- Butterbridge
- Colintraive
- Newton
- Strontian
- Crinan
- Lussagiven
- Stonefield
- Tarbert, Jura
- Eredine
- Kenmore
- Tiroran bridge
- Bow more
- Port ellon
- Port askaig

- Argyll generation severely constrained
- SSE cable upgrades scheduled for 2015
- Test site for VRFB selected by CES

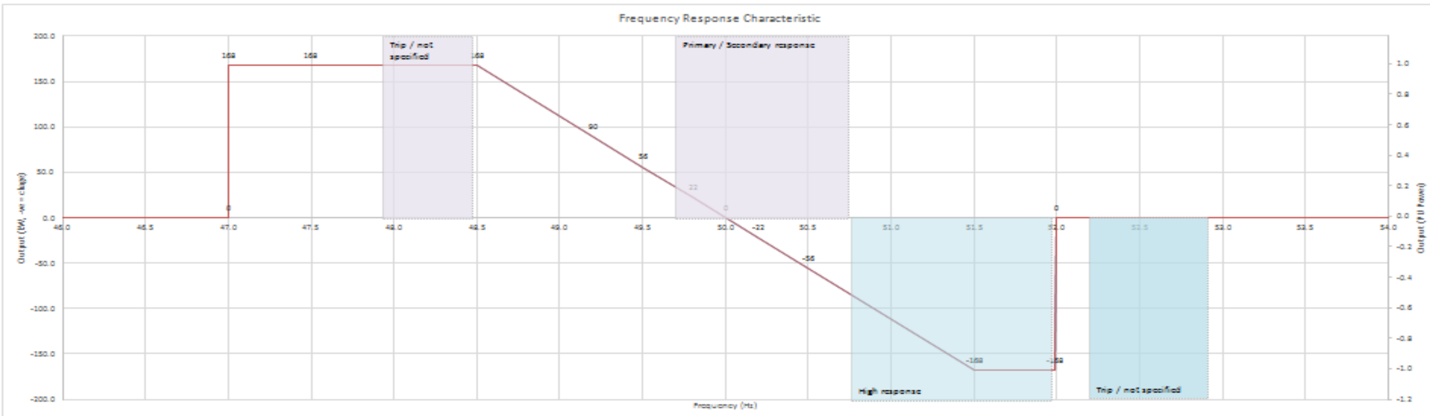
Parker SSD EGT Control System

Parker SSD PCS working with the REDT VRFB has a system response time of less than 5m/s and can therefore perform multiple intra-cycle control functions. Electronics and cable inductance are limiting factors not the energy storage system itself.

Figure 1 - 500kW Parker Grid Tie Inverter (representative)

Firm Frequency Response (FFR) Profile
Gigha 105kW rated system - RoCoF

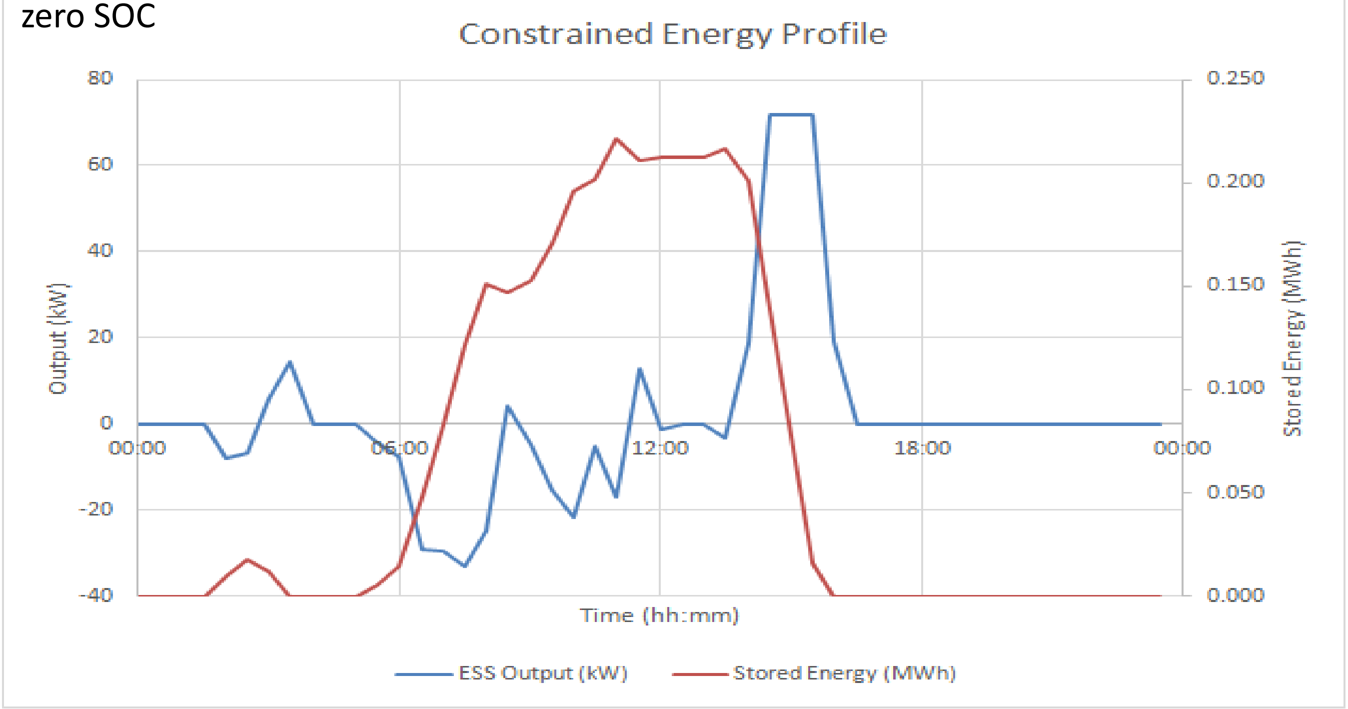
If we were doing FFR for real, this is what the battery would be doing.



	Deviation from 50 Hz	Frequency	Frequency Text	Output (PU)	Output (kW)	Notes
Trip	2.0	52.0	> 52 Hz	Trip	Trip	
"High" FFR Response	1.5	51.5	>= 51.5 Hz	-1.00	-168	Operation required for >= 90s
	0.5	50.5	>= 50 +0.5 Hz	-0.33	-56	
	0.2	50.2	>= 50 +0.2 Hz	-0.13	-22.4	
No response	0	50		0.00	0	
"Primary" and "Secondary" FFR Response	-0.2	49.8	<= 50 -0.2 Hz	0.13	22	
	-0.5	49.5	<= 50 -0.5 Hz	0.33	56	
	-0.8	49.2	<= 50 -0.8 Hz	0.53	90	
	-2.5	47.5	< 47.5 Hz	1.00	168	Operation required for >= 20s
Trip	-3.0	47.0	< 47 Hz	Trip	Trip	

Constrained Energy Profile – Typical day
Gigha system 105kW x 1.26MWh

Blue = ESS kW, Charging when negative Red = Stored energy MWh start/finish @ zero SOC



Wind	330 kW	Data from Assessent Tool v1_7
Solar	105 kW	Markers in orange in Data worksheet
ESS Rating	105 kW	

Process for determining the profile
Find a 'typical' day of constrained operation for the ESS, by simulation of the ESS operation in a Wind + PV constrained Gigha application.
Typical day has been chosen as a day for which the constrained energy output was the 50th percentile = 15/02/2012
Choose 48 half-hours residing mainly in the 15/02/12 day, for which the ESS could start and end at the same SOC (zero in the below).

REDT
Renewable Energy Storage

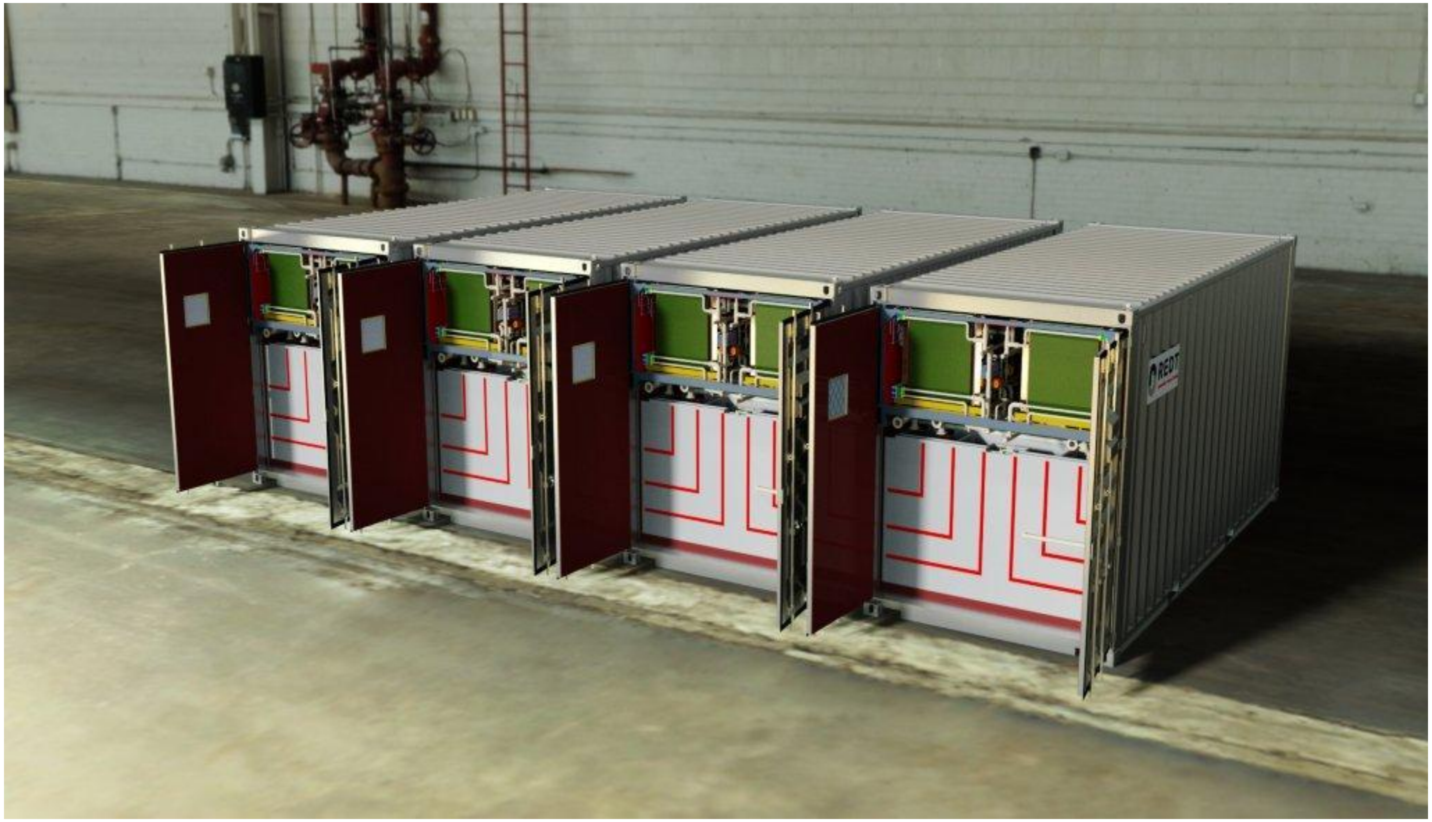
Conclusions

- VRFB can provide unique suite of system services
- Ability to perform RoCoF is significant
- Rapid changes in power levels have no effect on system performance/life
- Upward and downward regulation capability

REDT

Renewable Energy Storage

Thank you for your attention – Questions ?



www.redtenergy.com

Industry Presentations

Dundalk, Ireland, 21th of November 2014

SMART POWER GENERATION

Grange Backup Power Ltd
Alternative RoCoF Solutions Workshop

Peter Duffy / Niclas Back

Grange Backup Power Ltd

Potential Alternative RoCoF Solutions

1	Solve embedded windfarm 'islanding' problem – Ref. frequency	Inv
2	Reduce size of largest infeed	Ops
3	Reduce no. of non-compliant RoCoF gens	Ops
4	Issue 'blue alert' to DSUs and AGUs	Ops
5	"Park" on-load gens with this capability	Ops
6	"Park" off-load gens with this capability	Ops
7	Reduce min gen of some existing plant where econ. possible	Inv
8	New windfarms to include 'RoCoF capability' where econ. possible	Inv
9	Build new 'thermal' plant with Synch Comp & Fast Response	Inv
10	Buid/Install new devices/equip. e.g. batts, synch & asynch FWs	Inv
11	Build new 'non-thermal' plant e.g. Comp Air & Pumped Storage	Inv
12	Build new Interconnector(s) e.g. HVDC or AC	Inv

WÄRTSILÄ

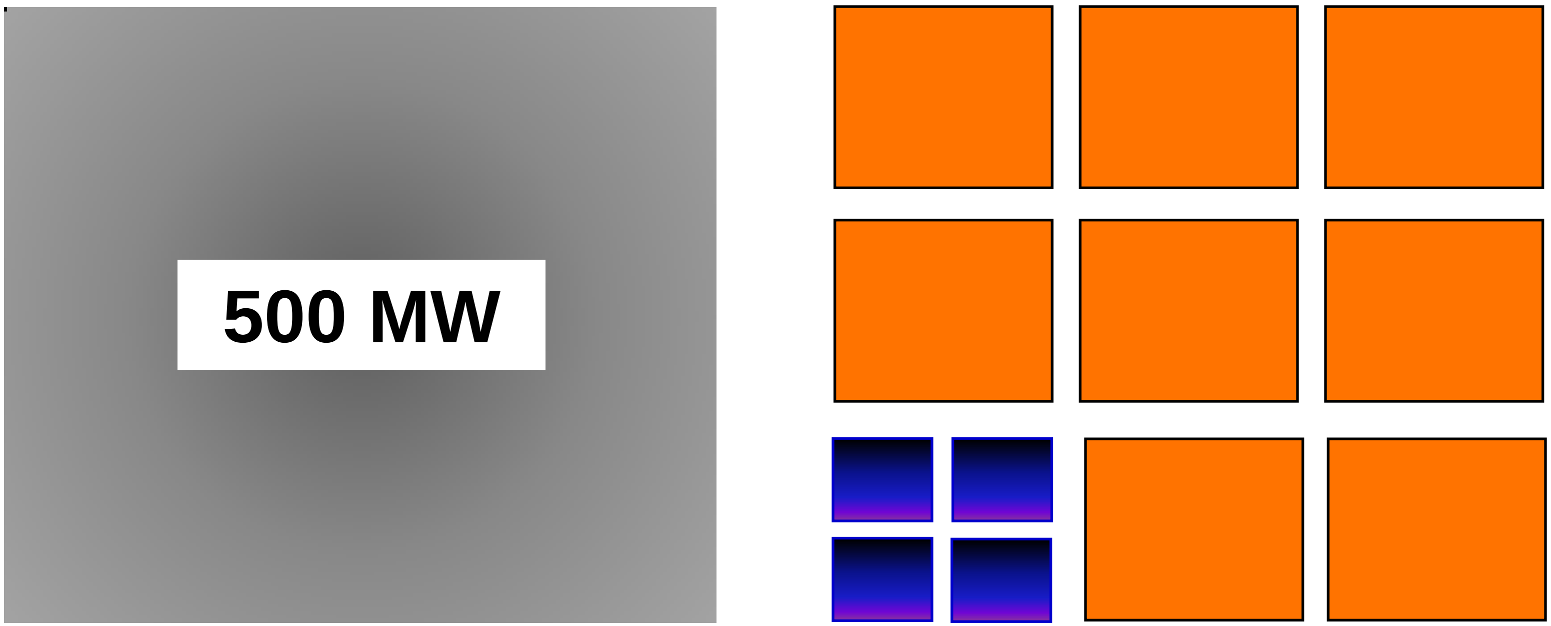
Technology

Reduce the size of the largest single infeed

- Centralized Power Generation
- **Distributed Power Generation**

SINGLE POWER PLANT

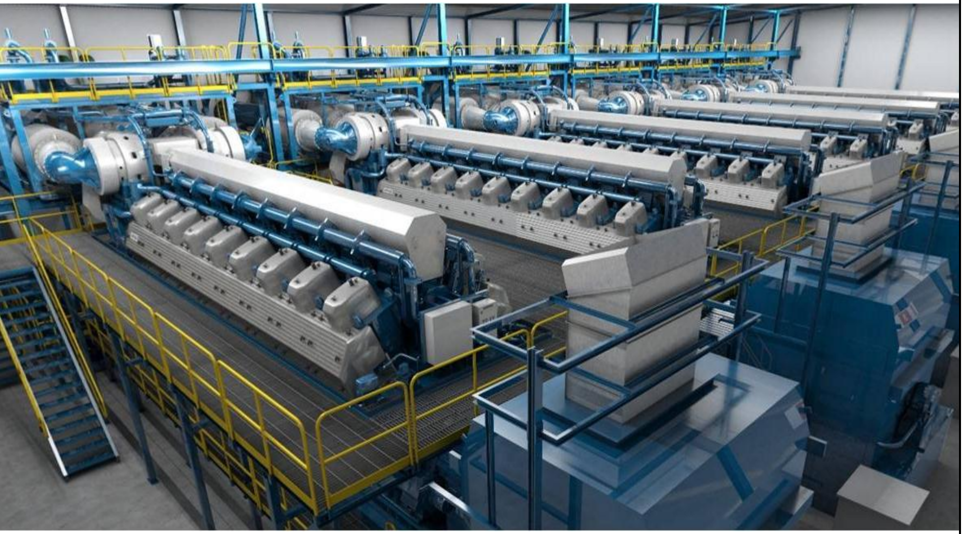
n INDEPENDENT PLANTS



n INDEPENDENT GENSETS

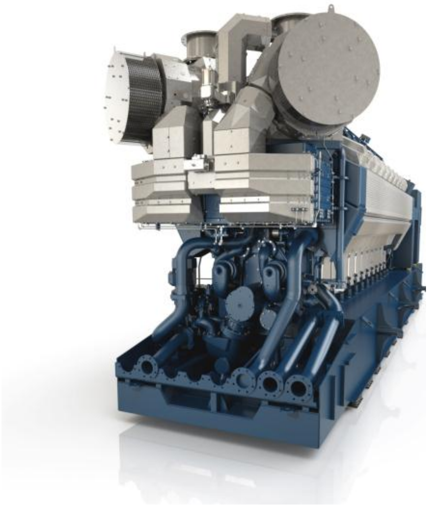
Gas vs Dual Fuel Engine

- **Gas engine**
  - W20V34SG 10 MW unit
  - W18V50SG 18 MW unit



- **Loading 30-90s from start**
- **2-5 minutes full load from start**
- **High ramping capability of 520 kWe/s (170%/min) for 50SG engine that has reached operating conditions *)**
- **Less site space**
- **Less CAPEX**

- **Dual Fuel Engine**
  - W20V34DF 10 MW unit
  - W18V50DF 17 MW unit



- **Loading 120-180s from start**
- **6-10 minutes full load from start**
- **High ramping capability of 480 kWe/s (170%/min) for 50DF engine that has reached operating conditions *)**
- **Dual Fuel**

*) Temperatures reached and stabilized

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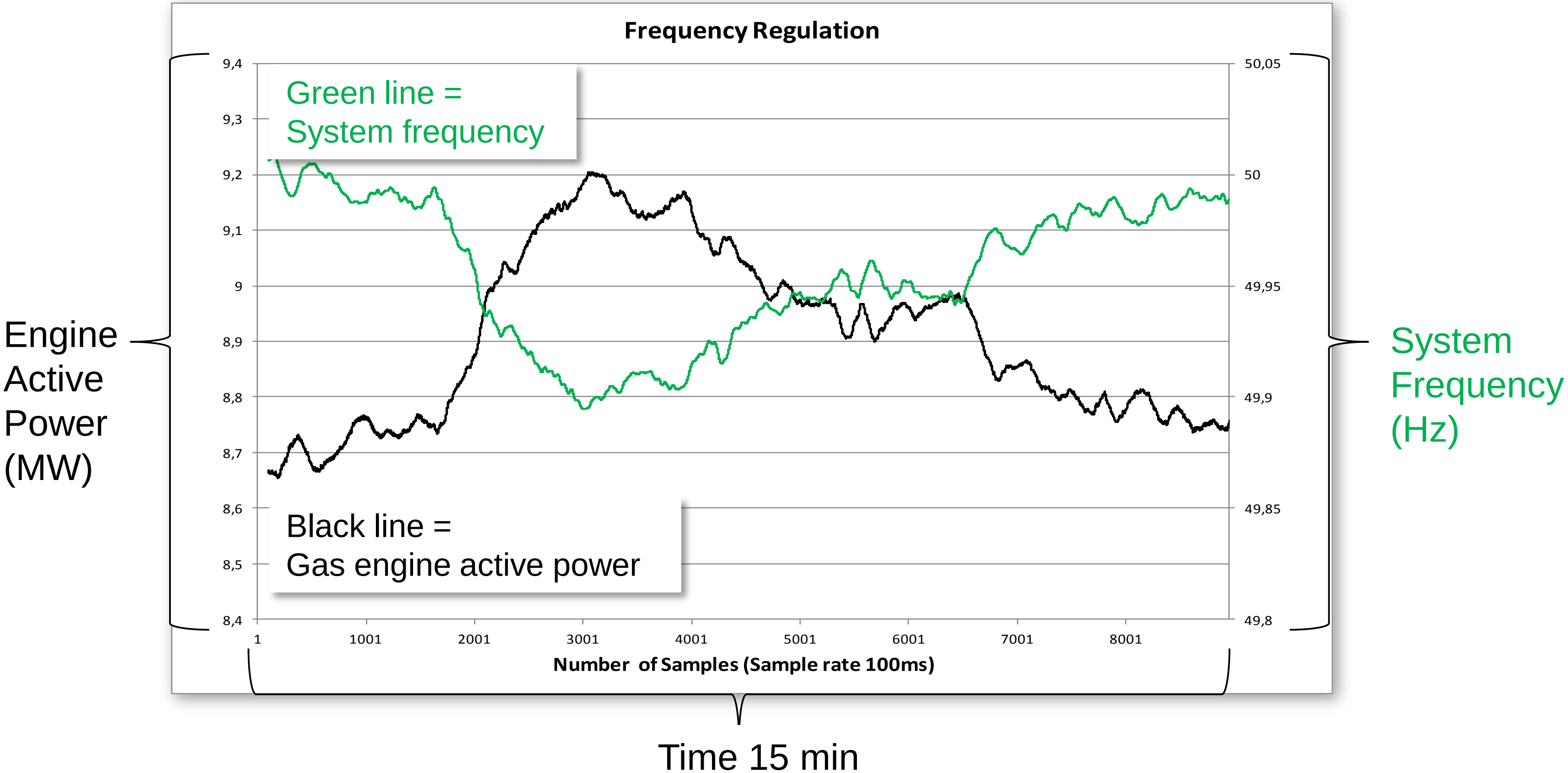
Accurate control for frequency regulation

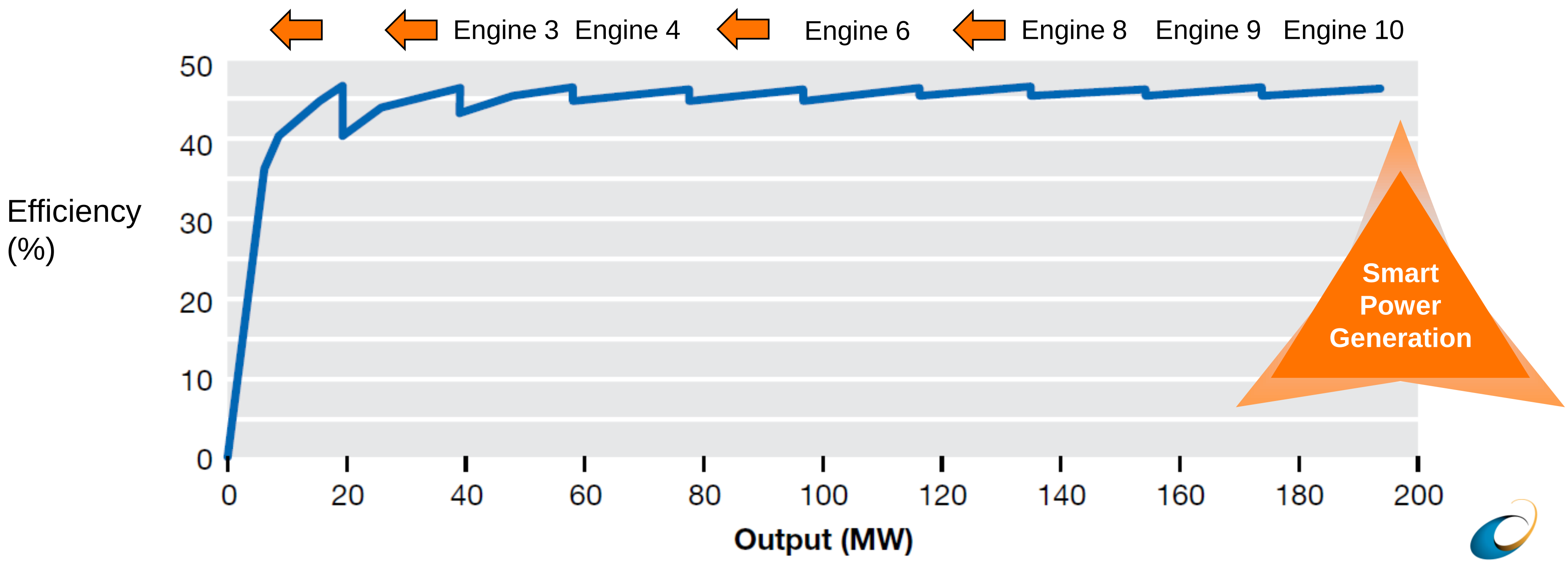
- Key items for frequency control:
  - **High ramping capability, fast response and accurate power control**



- Measurement from a engine operating with 10% of its nominal power output as Primary Reserve

Cascading of Machines

- Part of engines running while others standstill
  - **Enables stand-by (spinning) reserve capacity**
- Add units fast according to the need
- **Multi-engine solutions**, huge possibilities for operational flexibility with **high plant efficiency**:
  - Operation strategies easy to switch from hour to hour



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Integrated Synchronous Condenser Advantages

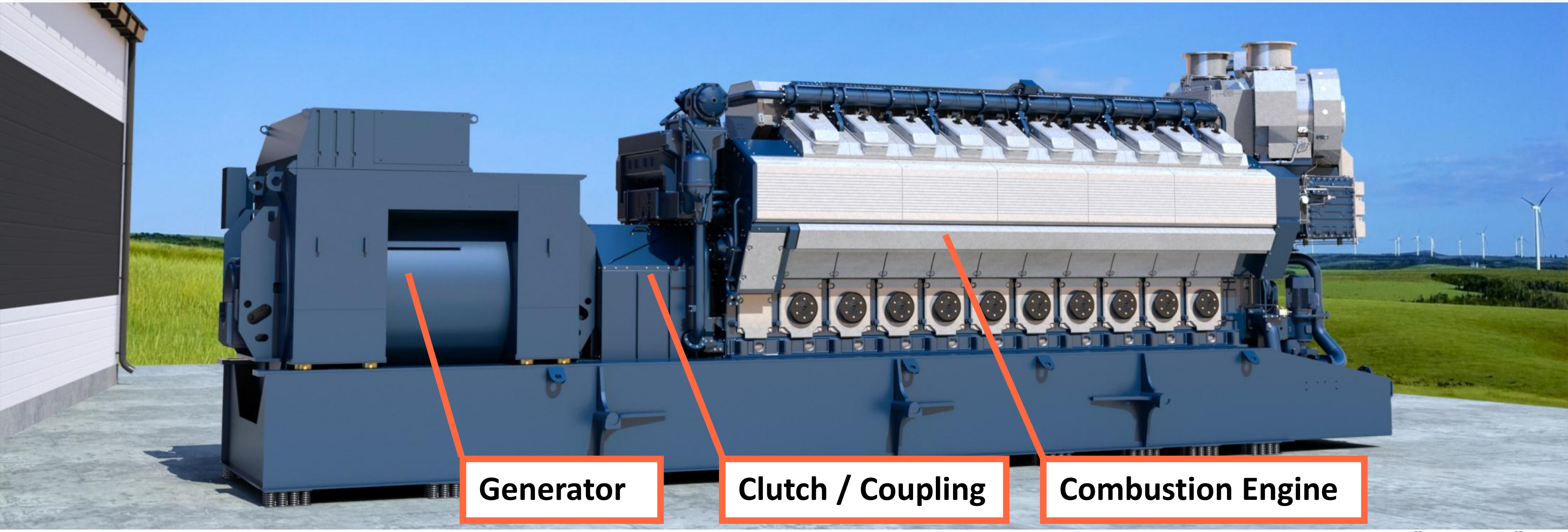
Normal operation

- Inertia support from engine and generator
- Voltage control and reactive power support

Synchronous condenser mode

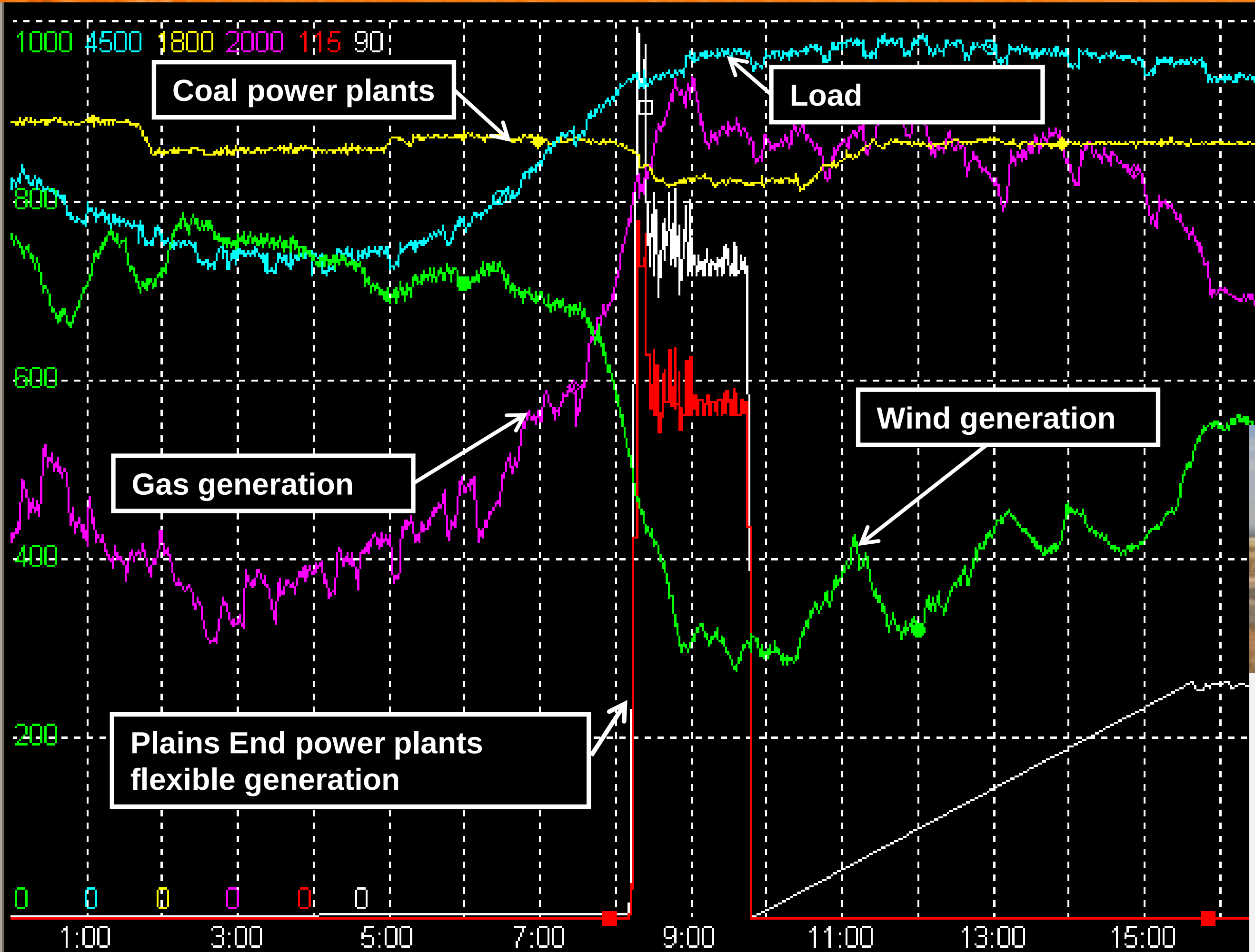
- Inertia support from generators
- System voltage control
- Reactive power support
- High reactive power response to a system fault

No additional infrastructure



Real life example – Wind integration with flexible plant

Case study: Smart wind chasing in Colorado, US



Screen shot from Colorado Dispatch Center, Xcel Energy, USA
3 May 2008

PLAINS END POWER PLANT, COLORADO, USA

Type:	Grid stability
Engines:	20 x Wärtsilä 18V34SG
	14 x Wärtsilä 20V34SG
Total output:	**227 MW**
Fuel:	Natural gas
Installed:	2002 and 2008

Remote controlled from Colorado Dispatch Center

EirGrid Grid Code and System Services (DS3)

- Analyse of services that can be provided:

New Services			Existing Services		
SIR	Synchronous Inertial Response		SRP	Steady-state reactive power	
FFR	Fast Frequency Response		POR	Primary Operating Reserve	
DDR	Dynamic Reactive Response		SOR	Secondary Operating Reserve	
RM1	Ramping Margin 1 Hour		TOR1	Tertiary Operating Reserve 1	
RM3	Ramping Margin 3 Hour		TOR2	Tertiary Operating Reserve 2	
RM8	Ramping Margin 8 Hour		RRD	Replacement Reserve (De-Synchronised)	
FPFAPR	Fast Post-Fault Active Power Recovery		RRS	Replacement Reserve (Synchronised)	
				Blackstart service	

	Possible		Require further investigation

Wärtsilä / Grange Backup Power Ltd can provide:

- Inertia on load
- Inertia when operating in synchronous compensation mode
- Increase inertia with heavy duty flywheel

Fast frequency response

- Load response after 0,5 sec
- Ramping next 4,5 sec 15 MW (13%) of Plant output

Wärtsilä / Grange meet EirGrid Criteria in table 2

- ✓ Technical Maturity
- ✓ Effectiveness in achieving policy objectives
- ✓ Operability
- ✓ Ability to deliver to required timelines
- ✓ Total cost to consumer
- ✓ Benefits

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Industry Presentations

RoCoF Alternative Solutions: Narrowing the Search Space

Peter Harte

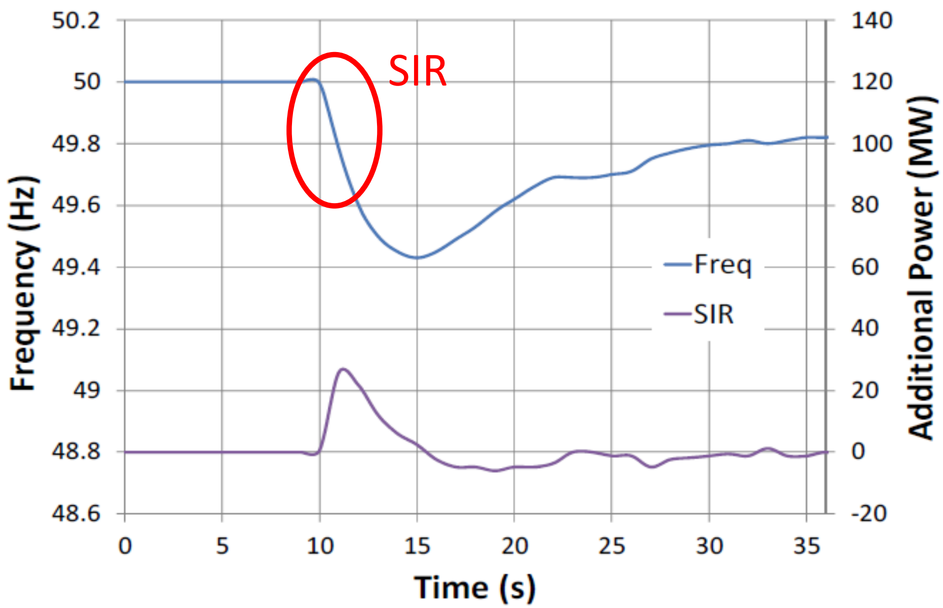
November 2014

The potential impact

Potential curtailment levels and value by year						
Year	MW	With DS3/ RoCoF	Without DS3/RoCoF	Increased curtailment	Value €m/yr (€40/MWh)	Value REFIT
2017	4000	3%	5%	2%	9	17
2018	4400	4%	7%	3%	14	29
2019	4800	5%	9%	4%	21	42
2020	5200	5%	11%	6%	34	68
2021	5200	5%	11%	6%	34	68
					112	223
Assumptions						
Price during curtailment (€/MWh)				40		
REFIT price (€/MWh)				80		
Wind capacity factor				31%		

Key Message: The cost of 1 year delay from 2017 to 2018 is not €17m, it's the fear of 5-10 years delay created by the uncertainty. Wind developers have the sites and grid connections. We need a "solution in a container".

Synchronous Inertial Response



$$\boxed{ROCOF = \frac{\Delta P \cdot f}{2 \cdot S_n \cdot H}}$$

Where

- *Delta P* is the gap between supply and demand, typically largest infeed of 500MW
- f is the system frequency in Hz (50 for Ireland)
- S_n is the rating in MVA of the system or generator (ranges approx. 3,000 to 6,000)
- H is the inertial constant, ranging from 3-6 MWs/MVA for different gen types

Result 1: You need 25,000MWs to limit RoCoF to 0.5Hz/s in a 500MW loss of infeed.
Result 2: A 450MW generator experiencing a 0.5Hz/s RoCoF increases its power by 50MW

Sizing the deficit

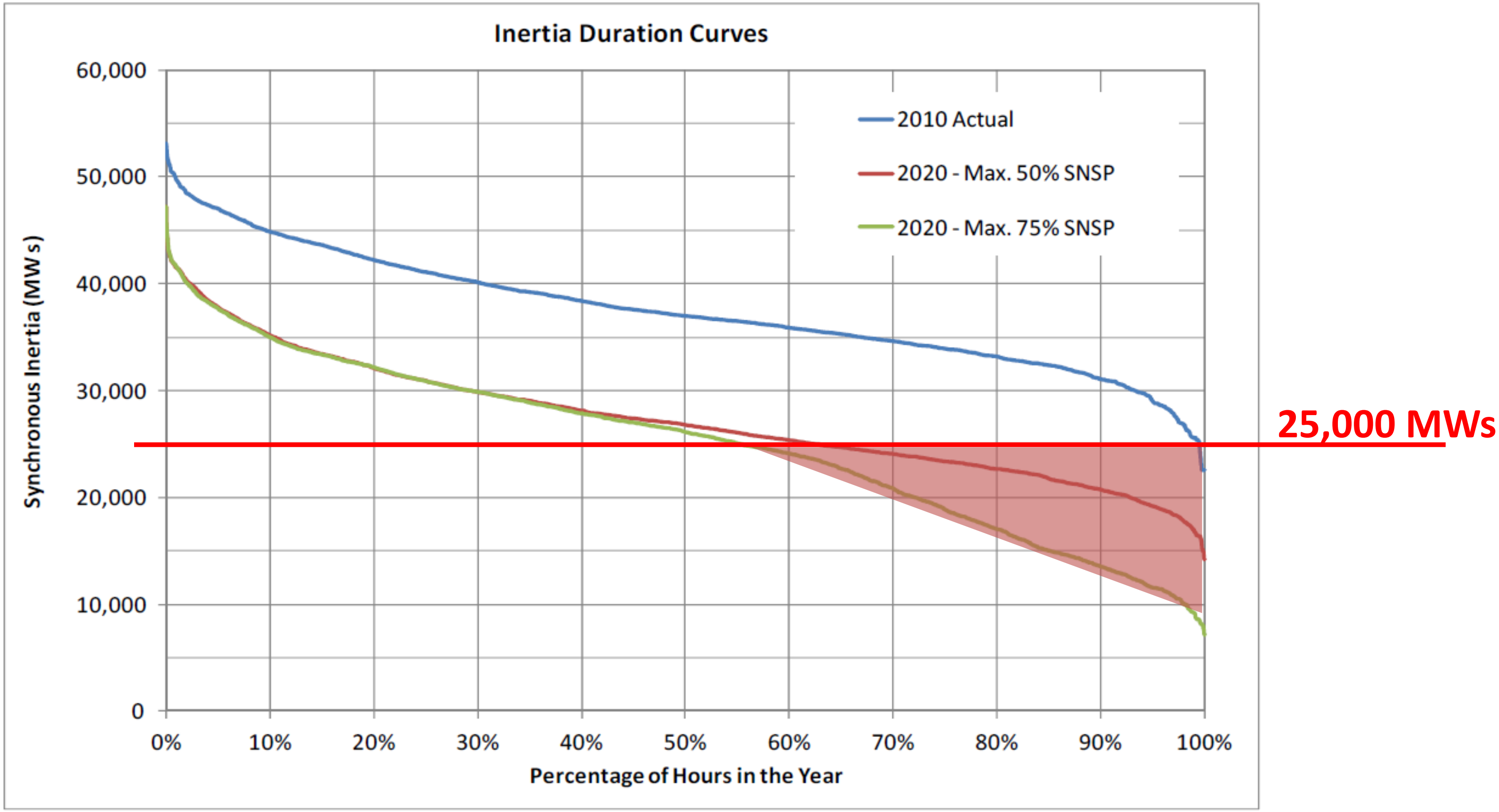


Figure 1: Synchronous Inertia Duration Curves calculated from actual 2010 and modelled 2020 data

Key Message: The right solution is likely to be a mix of high capex/low opex and vice versa (opex includes dispatch and balancing costs).

Narrowing the search space.

- Inertial response from converters requires a "hair trigger" response that gives a 100% injection of power whenever the grid begins to "wobble". But prime movers like batteries, wind turbines, interconnectors etc. really don't like rapid flicking from full import to full export.
  - Inertial response is proportional to rate (**df/dt**)
  - Reserve response is proportional to delta (**Δ f**).
  - If you detect the RoCoF, its already happened, no matter how fast the response thereafter.

- Proposition: Non-synchronous solutions show great promise for 13 of the 14 services, FFR, POR, SOR, FPFAPR, RR, DRP etc. They cannot provide inertial response, or SIR, and hence are <u>not an Alternative Solution for RoCoF</u>, unless someone can prove otherwise.

<u>Non Synchronous Solutions</u>

Wind Inertia
Batteries
High Speed flywheels
HVDC interconnectors
Pumped Hydro (VS)
Demand Side Management

Key message: Search space is limited to synchronous inertia sources, i.e. spinning copper coils, i.e. synchronous motors, synchronous generators and synchronous condensers

Some unviable choices.

Option	Can it deliver 15,0000 MWs of inertia?
Interposing motor-gens on non-sync device	Only the inertia of the motor generator is added. A world record sized 100MW battery with a motor generator (H=1MWs/MVA) would only yield 200MWs, and add losses and cost to a perfectly good source of FFR/POR/SOR/TOR/DRP/RM1/FPFAPR/arbitrage etc.
Adding weight to conventional plant drive trains	Fundamental redesign and rebuild of the heart of a conventional power plant. Very difficult to get OEM backing, and only possible on a 5-7 year scheduled upgrade timeline. Around 10 plants would need to double their H constants.
Building lots of peakers/flexible generation/pumpe d storage etc.	These must stack up on their own merits, i.e. they have to be running to supply inertia. Pumped hydro runs a lot, which yields many hours of inertia, but there's at least an 8 year lead time to permit and build one, and you'd need around 8 units. In the last 40 years we've built 1 unit. Financing will need to wait until concurrent auction of I-SEM, capacity and DS3. Inertia revenue alone won't build such plant.
Convert decommissioned plant to sync-comp	This shows more promise. There are significant losses in spinning both drive train and generator. If drive train decoupled, then lower inertia H-value. We should do all we can, but unlikely to be more than 600MW, yielding 1,000 to 3,000MWs.

The default solution – min_gen

Option 1: Cost of substituting part-load CCGT Units to fill inertia deficit							
Extra units required.	2	3	4	5	6	7	8
Part loading	100%	67%	50%	40%	33%	29%	25%
Efficiency at part load	58%	55%	50%	48%	46%	41%	38%
Cost of power (€/MWh)	43	45	50	53	55	62	66
Service required for (% of yr)	55%	6%	6%	6%	6%	6%	6%
Gain in inertia (MW-sec)	0	2400	4800	7200	9600	12000	14400
Units at 25% required	0	0	0	0	4	6	8
Upgrade capex (€m)	-	-	-	-	164	246	328
Annualised capex					19.2	28.7	38.3
Additional Annual cost fuel only (€	0	1.0	2.9	4.3	5.2	8.3	10.5
Cost per MWs per hour		0.8	1.1	1.1	4.5	5.5	6.0
Total annual cost							49

- Even though replacing up to 5 units at 40% min_gen is quite cheap, there is also a lot of wind curtailment (not costed above) in that dispatch.
- Converting units is very expensive and time consuming, and has very high fuel cost.

The other solution sync-comps

Option 4: Use Off the shelf synchronous condensers							
Units required	0	34	67	101	134	168	202
Gain in inertia	0	2500	5000	7600	10100	12600	15100
Service required for	55%	6%	6%	6%	6%	6%	6%
Capex	0	411	822	1232	1643	2054	2465
Opex including losses		4.8	7.0	9.3	11.6	13.9	16.1
Annualised capex	0	48	96	144	192	240	288
Cost per MWs per hour		37.5	36.6	35.8	35.8	35.8	35.8
Total annual cost							304

- Based on a 75MVA sync comp (H=1MWs/MVA), with losses of around 1MW per unit
- Cost of €12.2m (from DS3 KEMA/IPA report p.19)
- Both capex and operating costs are off the scale (values are €m/year)

Developer Perspective

<u>New Site Development Programme</u>

Q1 ‘15 – Q3 ‘15	**AT RISK:** Site procurement, initial surveys, preplanning meetings, grid study
Q3 ’15 – Q1 ’17	**AT RISK:** Prepare, submit and receive planning permission, design solution
Q2 ’16 – Q2 ’17	**AT RISK:** Accept grid offer and commence work on planning connection
Q2 ’17 – Q4 ’17	Complete financing of the project, procurement, order equipment
Q4 ’17 – Q2 ’19	Detailed design and manufacture in factory sync comp
Q3 ’18 – Q3 ’19	Civils, electricals, traffo etc. on site, including grid connection
Q3 ’19 – Q3’ 20	Onsite installation and commissioning of synchronous condenser.

<u>Interact with EirGrid RoCoF Programme</u>

Oct’14 – Mar ’15	**AT RISK:** Phase 1 Alternative Solutions search
Apr ‘14 – Mar ’16	**AT RISK:** Phase 2 Detailed assessment of preferred options (Plexos/PSSE)
Mar ‘16 – Dec ’16	**AT RISK:** Procurement process to select preferred option.

Implications:

1. EirGrid need to complete the Alternative Solutions project in much less than 18 months
2. Regulators need to put commercial arrangements in place to allow alternative solutions to start early
3. That solution needs to recognise the “optionality” problem to keep developers moving in advance of final contract award. (If lower quantity of SIR is needed for both DS3 and “Alternative to RoCoF”, no regrets to purchase that now).
4. Only options that avoid permitting and/or new grid connections are likely to deliver in time.

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Discussion on Potential Solutions

- *Any comments on the list of solutions presented?*
- *Are there other potential solutions that haven’t been discussed?*

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Agenda

Item	Time	Speaker
Tea/Coffee	09.00	
Introduction and Welcome • Overview of RoCoF issue • RoCoF Alternative Solutions Project overview	09.30	Robbie Aherne
Regulatory Authorities Update	10:00	RAs
Potential Alternative Solutions • TSOs' list of potential alternative solutions • Presentations from industry • Discussion	10:15	Eoin Kennedy TBC All
Phase 1 Assessment Methodology • Proposed Phase 1 assessment methodology • Discussion	11.45	Eoin Kennedy All
Next Steps and Timelines	12.30	Robbie Aherne
AOB	12.50	All
Close / Networking Lunch	13:00	

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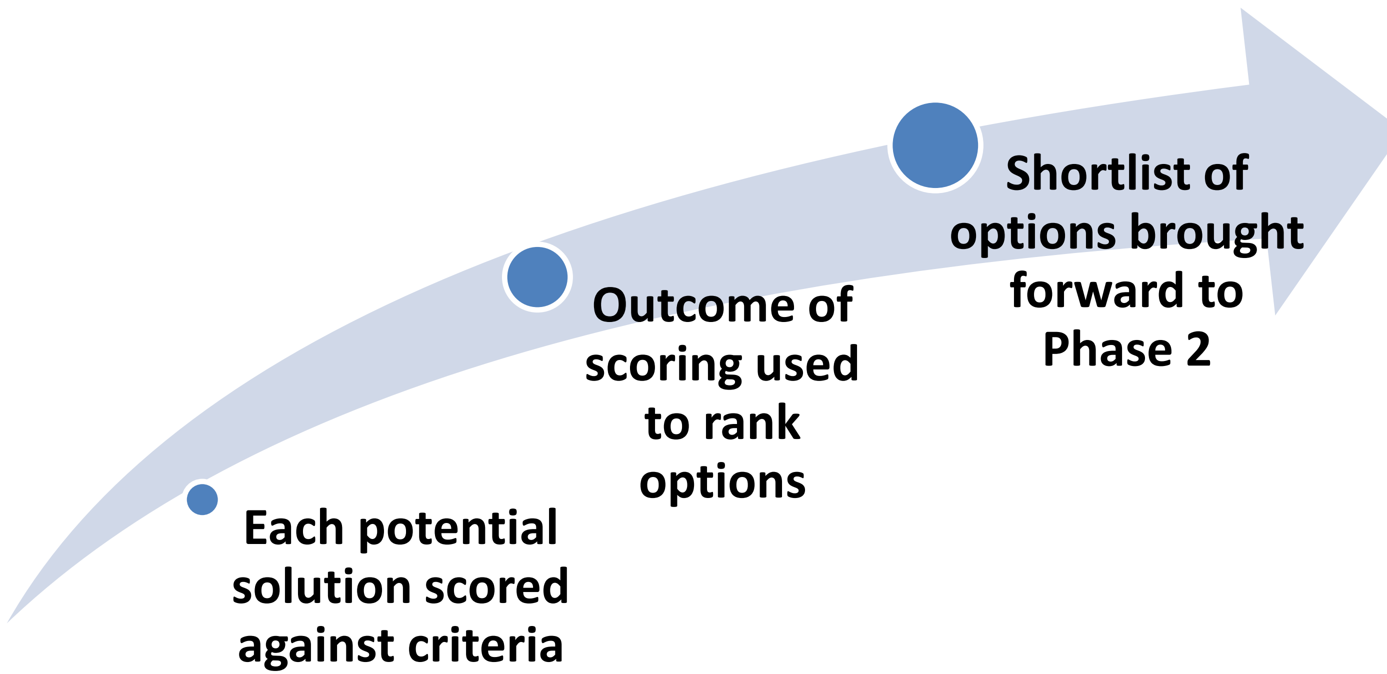
Phase 1 Assessment Methodology

Eoin Kennedy

Phase 1 Methodology

- Qualitative assessment against a set of criteria
- Technology assessment not a project assessment



Proposed Assessment Criteria

Technology maturity	Effectiveness in achieving policy objectives
Operability	Ability to deliver to required timelines
Total cost to the consumer	Benefits

Criteria 1 & 2

Technology maturity

- Maturity and robustness of technology
- Extent to which technology has been deployed elsewhere on a utility scale

Effectiveness in achieving policy objectives

- Ability to avoid high RoCoF
- Ability to enable the system to accommodate higher levels of non-synchronous generation

Criteria 3 & 4

Operability

- Interoperability with the power system
- Reliability of response provision

Ability to deliver to required timelines

- Timely delivery of the proposed solution

Criteria 5 & 6

Total cost to the consumer	• Sum of investment and operational costs i.e. total cost to the consumer
Benefits	• Other non RoCoF related benefits provided e.g. system services

Discussion on Methodology

- *Is the proposed set of criteria appropriate?*
- *Are there other criteria that should be included?*
- *Are certain criteria more/less important than others?*

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RoCoF – Next Steps

Robbie Aherne

Alternative Solutions Project

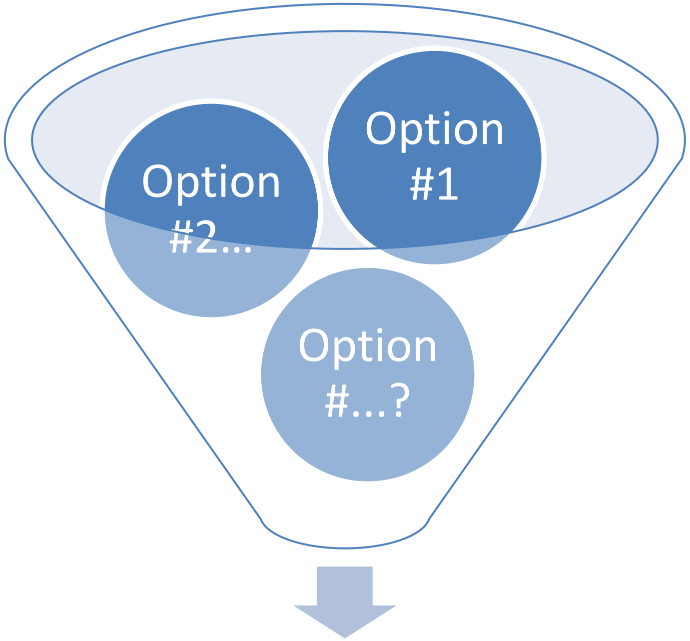
Phase 1 (5 months)

- Range of theoretical options assessed at a high level via weighted scoring matrix approach
- Subset of viable options (2 to 3) selected for Phase 2 analysis

Phase 2 (13 months)

- More detailed review of the viable options from Phase 1
- Analysis focused on technical and economic aspects of each option

Phase 2 - Alternative Solutions



Phase 2: Two to Three Options

- Technical and economic studies of shortlisted options
  - Dynamic simulations
  - Plexos studies to assess economic benefit

Next Steps and Communications

- Aim is for realistic/achievable programme of work
- Communication via DS3 Advisory Council and website/email
- Workshops/forums will also be used where TSOs or DS3 Advisory Council consider that wider participation would be beneficial

Next Steps for Industry

- Submit comments on topics discussed at workshop
- Provide information on potential alternative solutions and/or additional information (e.g. capabilities, costs, previous deployment etc.)
- Email to DS3@eirgrid.com by 12th December

Phase 1 Next Steps and Timeline

12th Dec

- Receive comments from industry on topics discussed at workshop
- Final date for submission of potential alternative solutions and/or additional information (capabilities, costs, previous deployment etc.)

20th March

- Publication of draft assessment results

10th April

- Receive comments from industry on draft assessment results

30th April

- Publish proposed final assessment results and provide to RAs
- Outline next steps and provide indicative plan for Phase 2

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