System Operability Framework 2015 (SOF)

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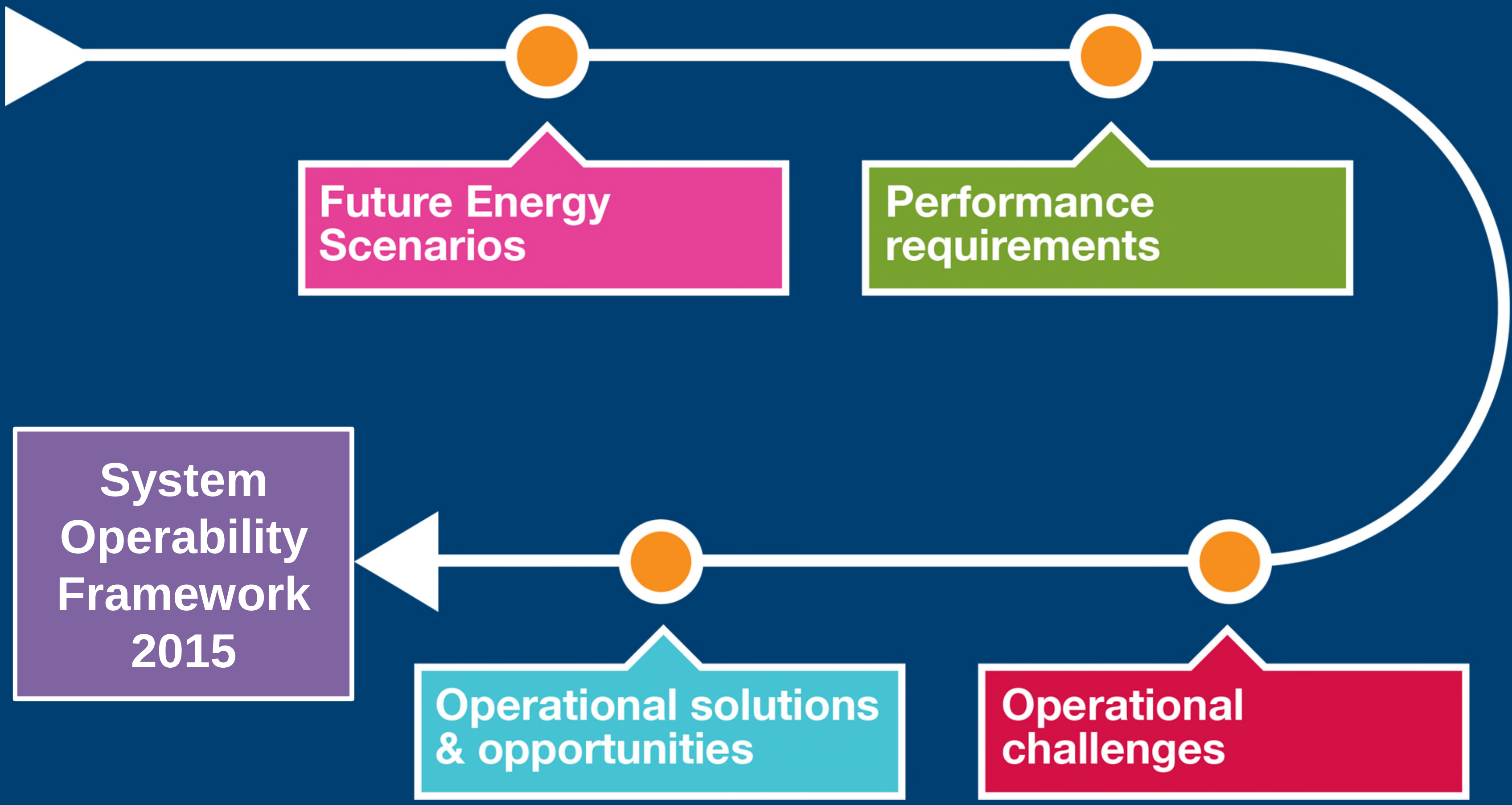
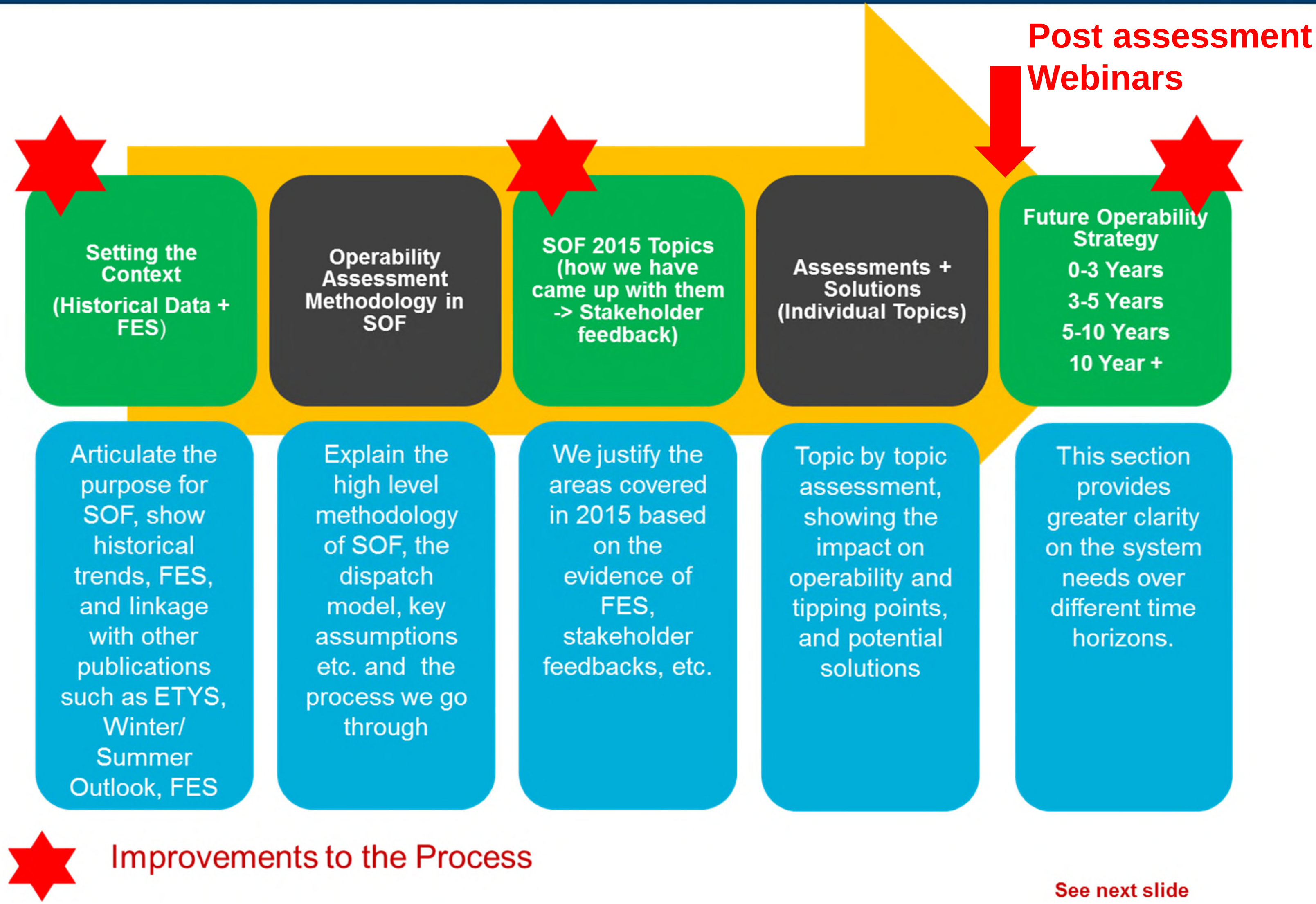
Contractibility and Finance-ability of New Services

Vandad Hamidi & Patrick Cassels

SOF 2015 Development Process



SOF 2015 Development Process



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Short Term (0-2 Years):

Need for capabilities which are already available both technically and commercially or immediate requirement for code changes.

Medium Term (2-5 years):

Need for services from new connections, use of existing investment processes, work on new code changes, highlight immediate innovation needs and influence future design.

Long Term (5+ Years):

Need to secure long term capability, influence new connections, ensure more innovative solutions are developed (e.g. NIA/NIC projects), carry out R&D, significant specification & capability requirements, strategy development.

SOF 2015 Topics

Topic	Assessment	Impact
System Inertia	Whole System Minimum Inertia	Decreasing whole system minimum inertia in future years
	RoCoF	Trip of embedded generators protected by RoCoF relays
	Frequency Containment	Increase in volume of response
System Strength and Resilience	Protection	Difficulty detecting and clearing faults on weaker networks
	Voltage Dips	Widespread voltage dips and disconnection of embedded generation
	Voltage Management	Voltage containment and need for additional reactive compensation
	Resonance and Harmonics	Power quality issues and need for additional filtering
	LCC HVDC Commutation Failure	Inability to operate LCC HVDC links in weak network conditions
	Demand Reduction by Voltage Control	Reduction in effectiveness of demand reduction by voltage control
	Black Start	Reduction in black start plant and system restoration challenges
Embedded Generation	System Stability	Stability issues associated with increase in embedded generation
	Low Frequency Demand Disconnect	Risk of cascade loss of generation should LFDD relays operate
	Active Network Management	Uncoordinated TSO/DSO actions in constraint management
	Demand Forecasting	Increased demand forecasting error and increase in balancing actions
New Technology	Interaction with Generator Shafts	Shaft fatigue if not mitigated
	Control Interaction	Potential oscillations and plant failure
	Compliance of New Nuclear Fleet	Increase in derogation cost
	Electric Vehicles and Heat Pumps	New demand pick up times/volume

SOF 2015 Headlines

Low Frequency Demand Disconnection (LFDD) Schemes require review

Potential instability in load blocks used in system emergency restoration. Broader network restoration needs

Need for new capabilities on the transmission system to manage system stability as a result of embedded generation connection

Embedded Generation and Fault Ride Through Challenge

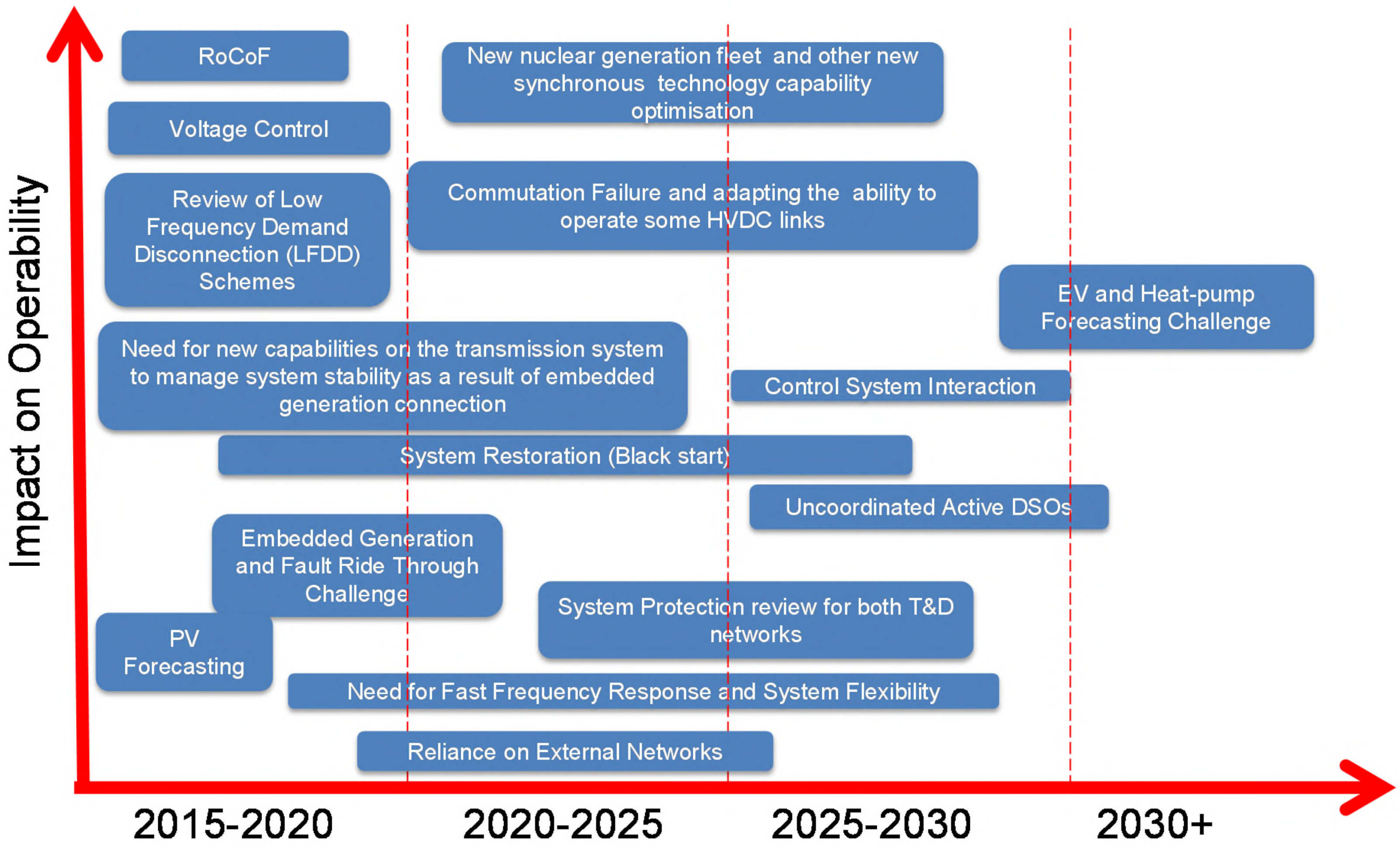
	Change	Affected Subjects	Impact
Changes in Generation and Demand Side	System Inertia	RoCoF relays	Trip of Embedded Generator protected by RoCoF relays
		Frequency Containment	Increase in volume of response
	Short Circuit strength and System Resilience	Protection	Difficulty in detecting and clearing faults on weaker parts of the networks
		Voltage Dips	Widespread voltage dip and disconnection of embedded generation
		Voltage Management	Voltage containment and need for additional reactive compensation
		Resonance and Harmonics	Power quality issues and need for additional filtering
		LCC HVDC Commutation Failure	Inability to operate HVDC links in weaker networks
		Demand Reduction by Voltage Control	Reduction in effectiveness of demand reduction by voltage control
		System Emergency Restoration	Reduction in Black Start plants and difficulty in system restoration
		Reliance on External Networks	Increased exposure to external grid disruption, increasing co-ordination
	Increase in Embedded Generation	System Stability	Range of stability issues associated with increase in EGs
		Low Frequency Demand Discussion	Cascaded loss of generation should LFDDs operate
		Active Network Management	Uncoordinated TSO/DSO actions in constraint management
		Demand Forecasting	Increase in demand forecasting errors and increase of balancing actions
Changes in Network and Technology	New Technology	Interaction with generator shafts (SSR, SSTI)	Shaft fatigue if not mitigated
		Control Interaction	Potential oscillations, and plant failure
		Compliance of new nuclear fleet	Increase in derogation cost
		Electric Vehicles and Heat Pumps	New demand pick up times/volume

New nuclear generation fleet and other Synchronous technology capabilities

Fault level decline is both more pronounced and more extensive than previously seen. Review of protection system is required

Need for Fast Frequency Response and System Flexibility

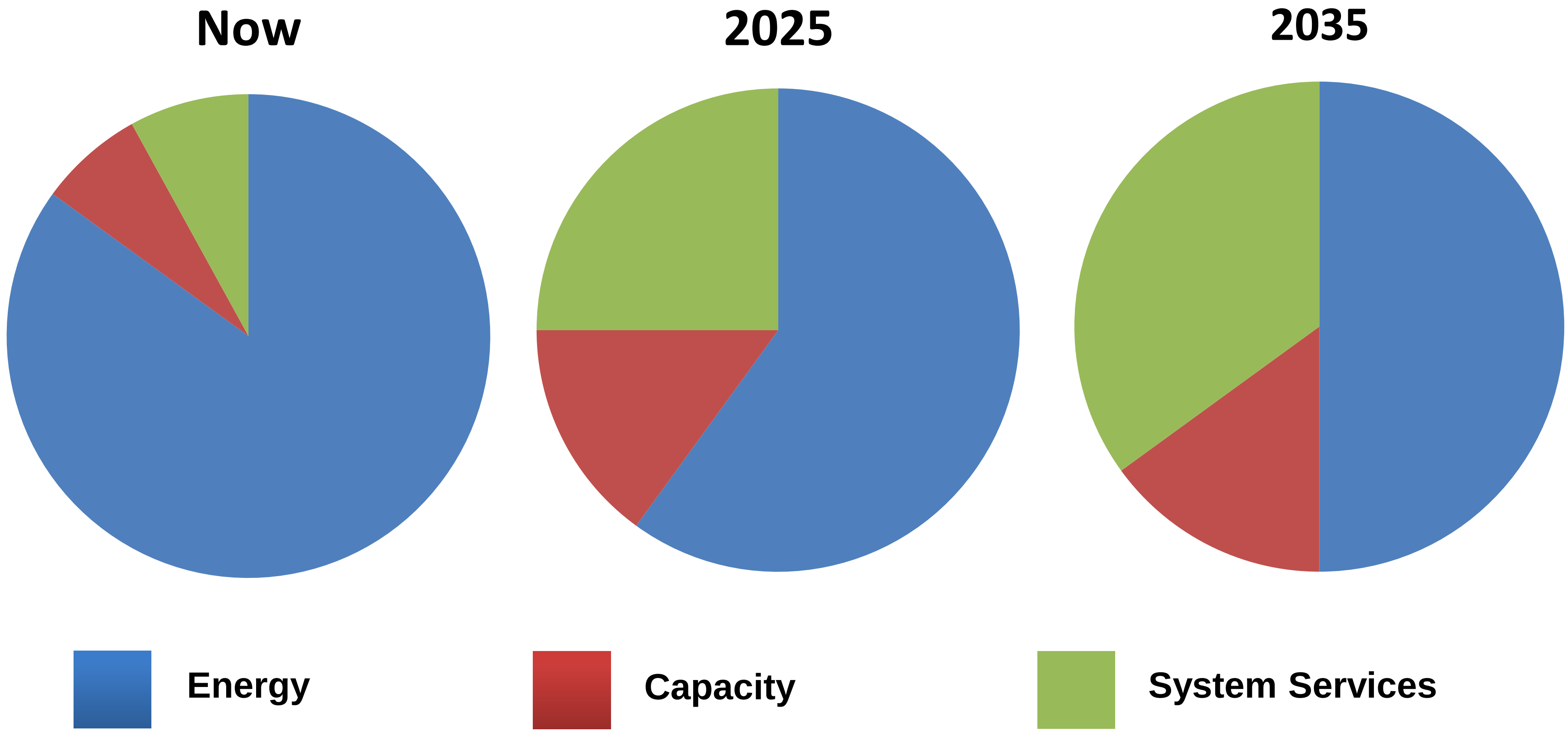
Timeline



Impact on Operability
RoCoF
Voltage Control
Review of Low Frequency Demand Disconnection (LFDD) Schemes
New nuclear generation fleet and other new synchronous technology capability optimisation
Commutation Failure and adapting the ability to operate some HVDC links
EV and Heat-pump Forecasting Challenge
Need for new capabilities on the transmission system to manage system stability as a result of embedded generation connection
Control System Interaction
System Restoration (Black start)
Uncoordinated Active DSOs
Embedded Generation and Fault Ride Through Challenge
System Protection review for both T&D networks
PV Forecasting
Need for Fast Frequency Response and System Flexibility
Reliance on External Networks
2015-2020
2020-2025
2025-2030
2030+

What does SOF Identify?

What matters most?



Impact on System Services

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Provision of Future System Services

Mandatory Requirements

Market Solutions

Contractibility

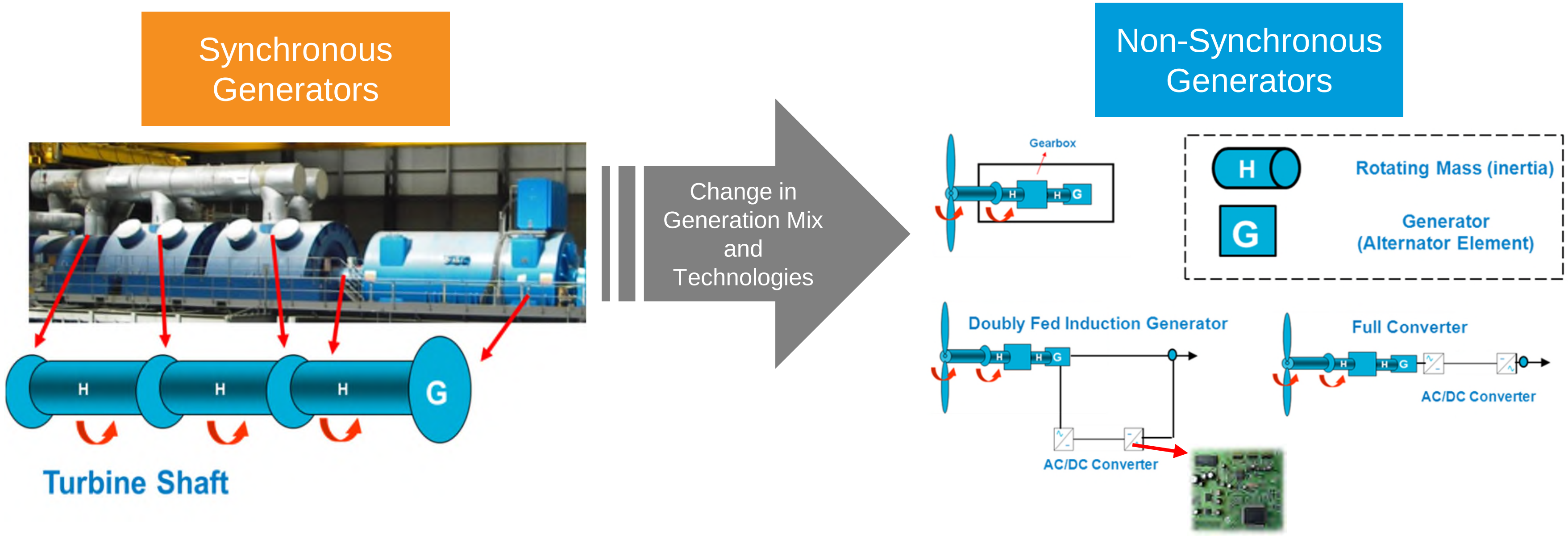
Finance-ability

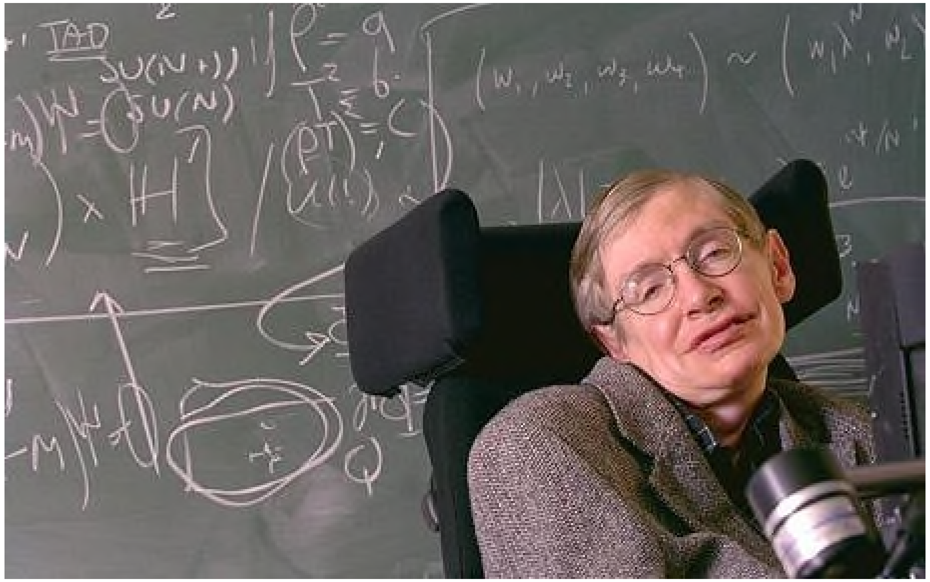
New Services and Potential Providers

Provider / Service	Demand Side Services	Energy Storage	Flexible Synchronous Generation	Flexible non-Synchronous Generation	Interconnector Services	Synchronous Compensator	Support from Embedded Generation	DSO Services	New Services from Non-synchronous Generation
RoCoF Alternative									
Frequency Management									
Voltage Management									
Protection System Support									
System Restoration									
LFDD Alternative									
Commutation of HVDC links									

System Inertia - Background

- System inertia – a measure of how strong the system is in response to transient changes
- System inertia has a direct effect on:
  - Rate of Change of Frequency (RoCoF)
  - **Frequency containment and response requirement**
  - System stability





You lose half your audience every time you use an equation!

Impact of Inertia on Frequency Control

The lower the system inertia -> the higher of rate of change of frequency and vice versa

The higher the size of loss-> the higher the rate of change of frequency and vice versa

$$H_{Total}=H_G+H_D+H_{EG}$$

$$\text{RoCoF}=\frac{df}{dt}=\frac{1}{2}\times f_0\times\frac{\Delta MWloss}{H_{Total}}$$

H_{Total} *:Total System Inertia*

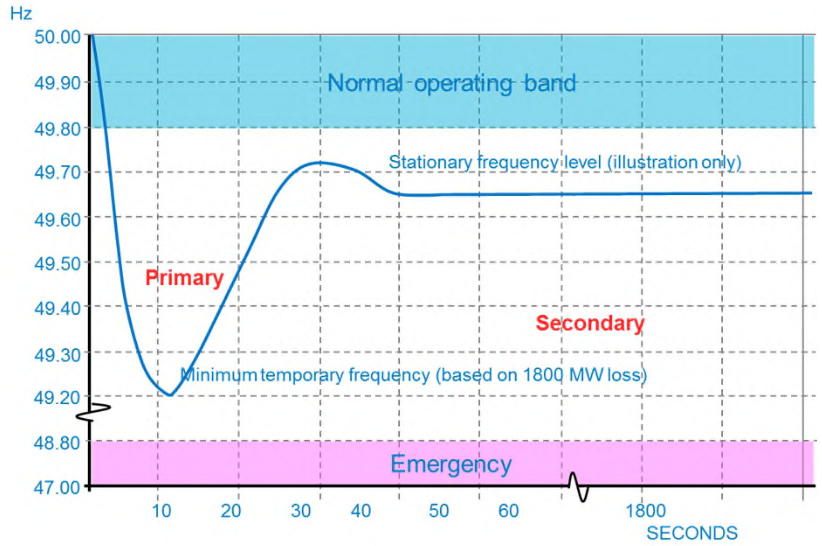
H_G *:Inertia from Transmission Generation*

H_D *:Inertia from Demand*

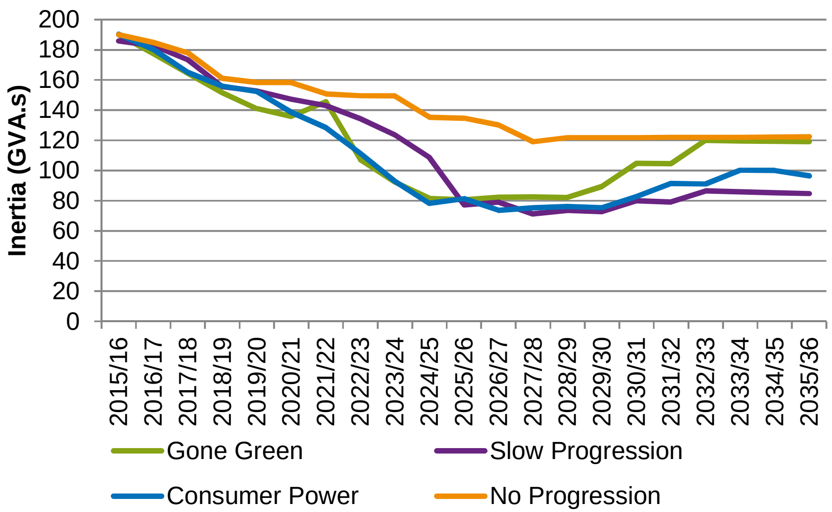
H_{EG} *:Inertia from Embedded Generation*

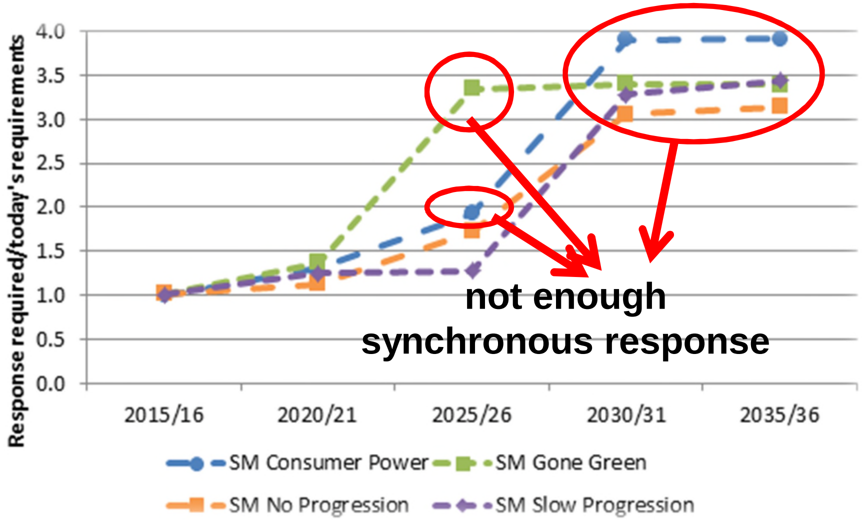
f_0: nominal frequency (50Hz)

$\Delta MWloss$: size of loss

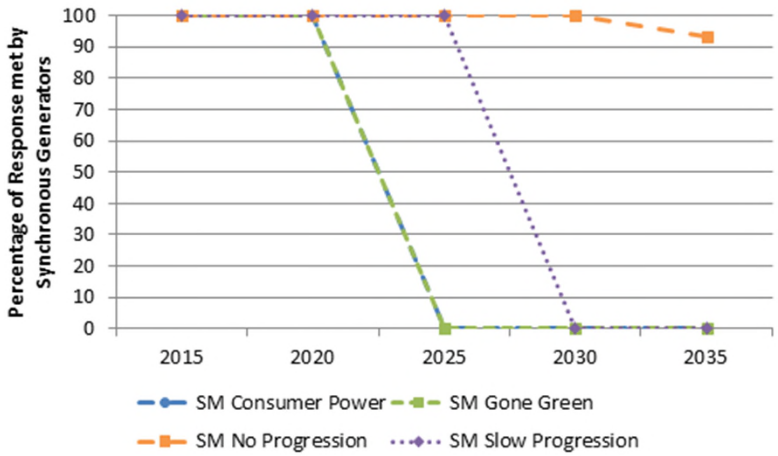


Topic 1 – Frequency Response





- The reduction of system inertia increases the response requirement -> 30-40% extra by 2020
- Having sufficient volume of response from “conventional” sources will become challenging
- In some scenarios none of the system response requirement can be provided by synchronous plants



Background – System Inertia Variations in 2020

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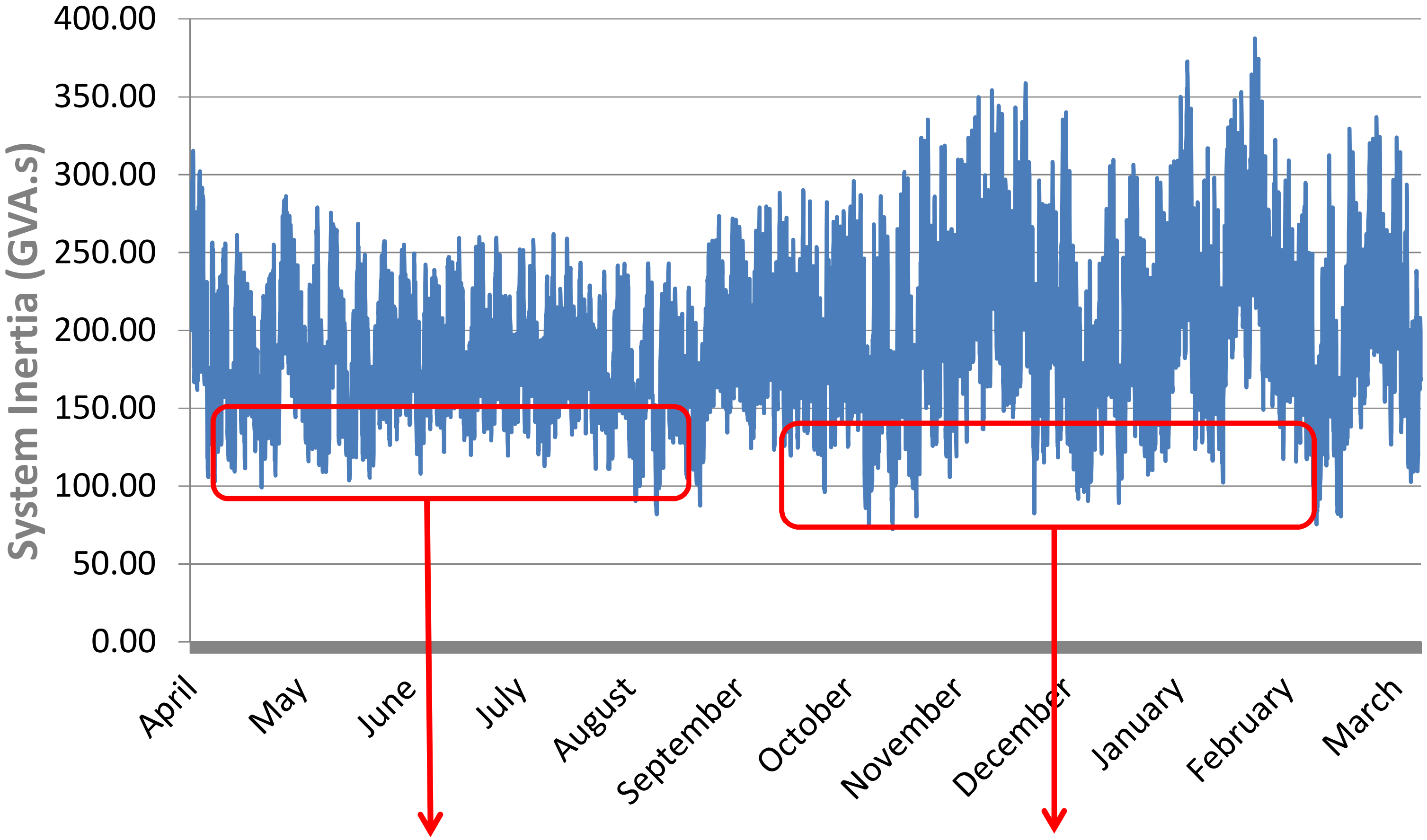
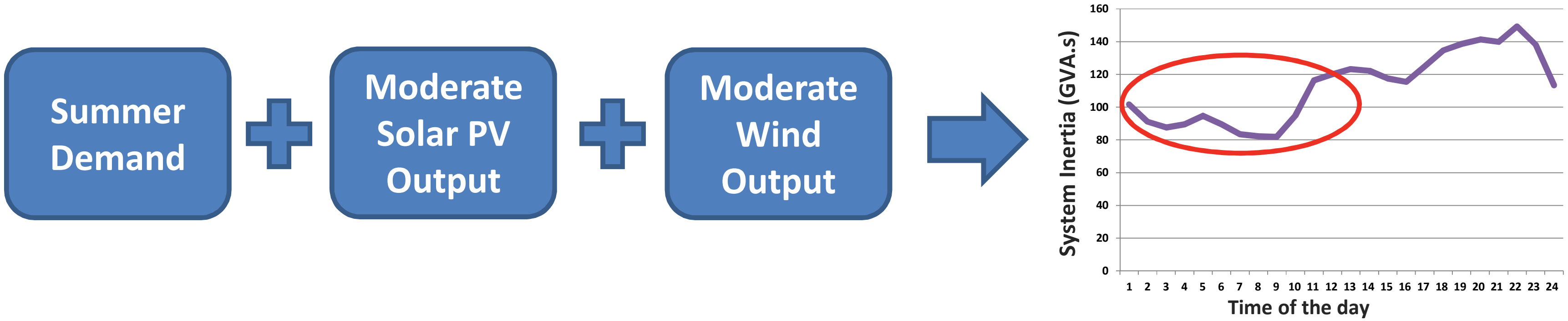


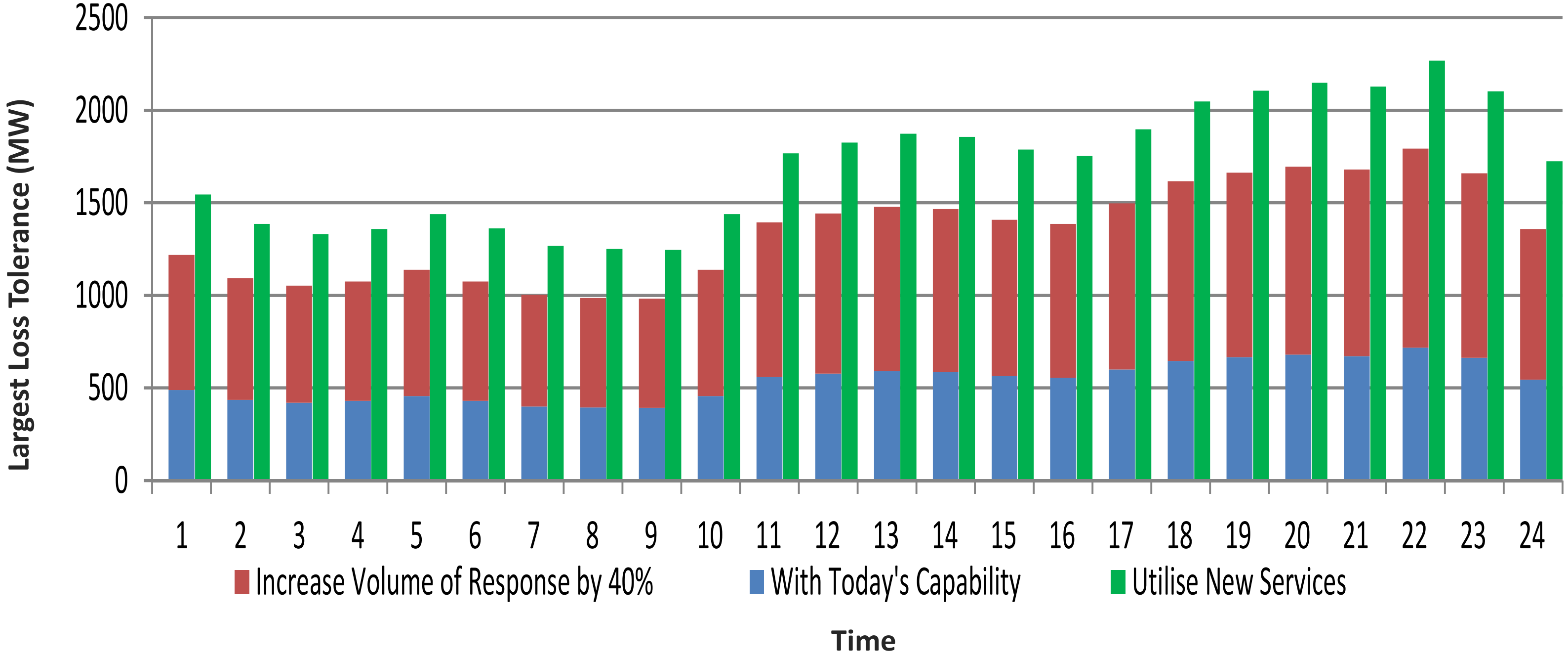
Low demand period- Sunny Season

Windy Season

Low Inertia Periods

Background – A day in 2020





Background – A day in 2020

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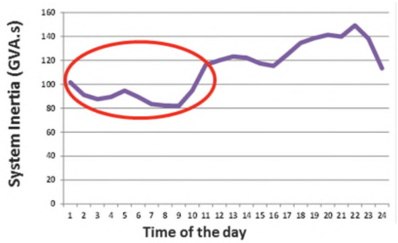
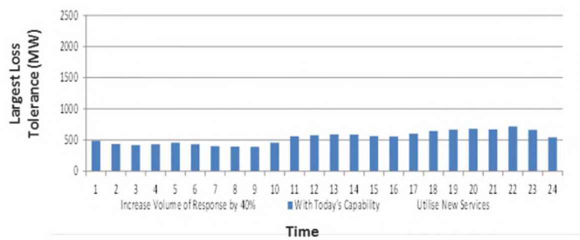
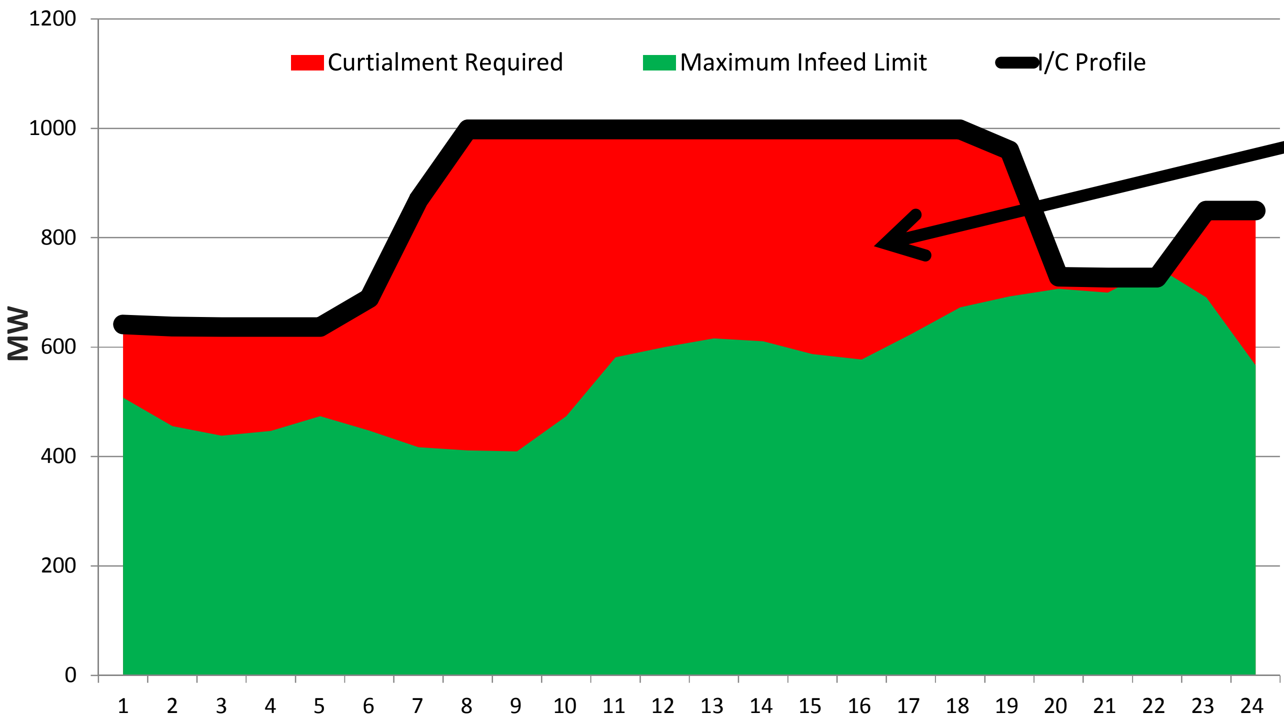
Do nothing!







Curtailment volume just on one I/C pole

French I/C: 14269MWh

\+

Britned: 1x: 6549MWh

New I/C:?

Total: 20.8 GWh +

Background – A day in 2020

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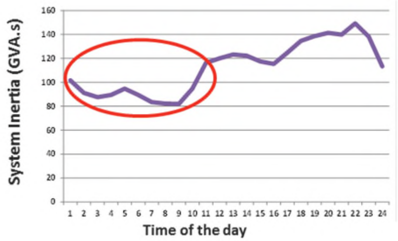
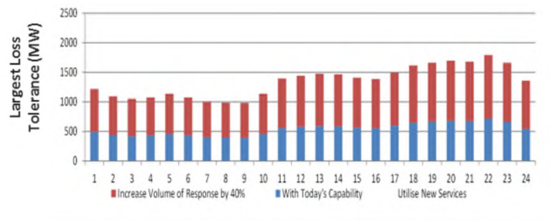
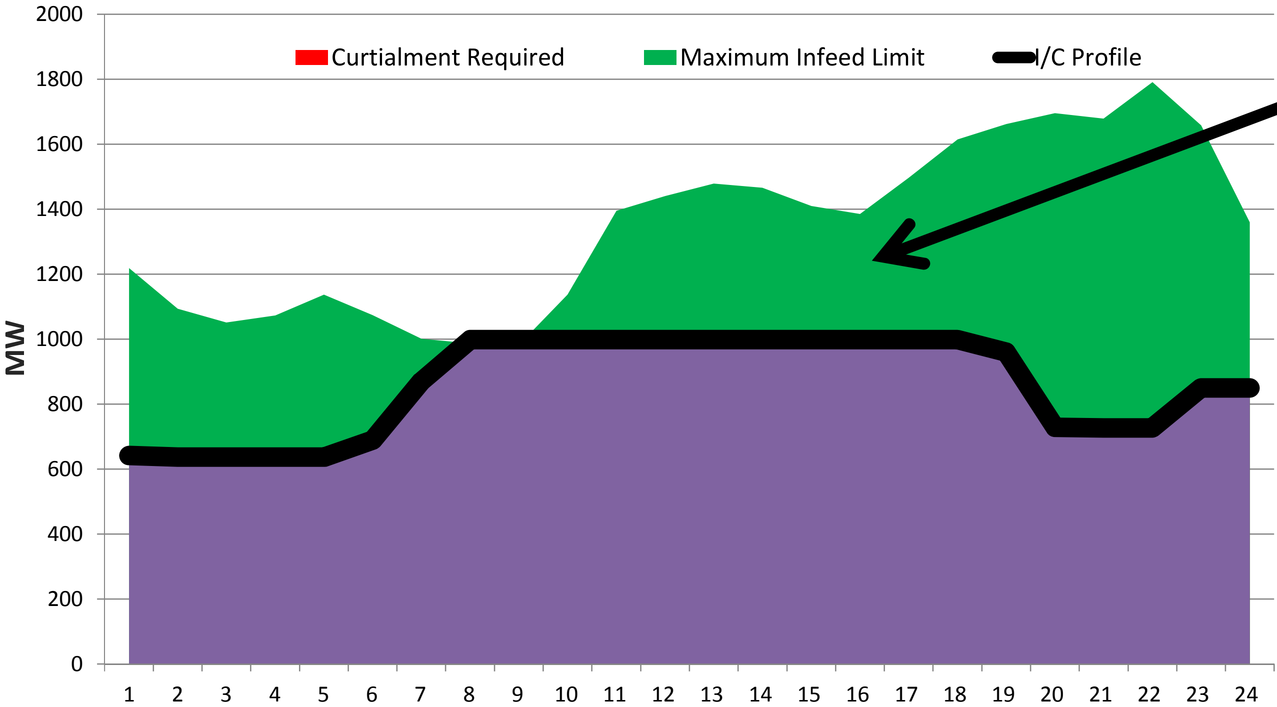
Increase Response







Headroom Created at cost of carrying 40% more response

Still not sufficient to accommodate larger Units & not a long term solution

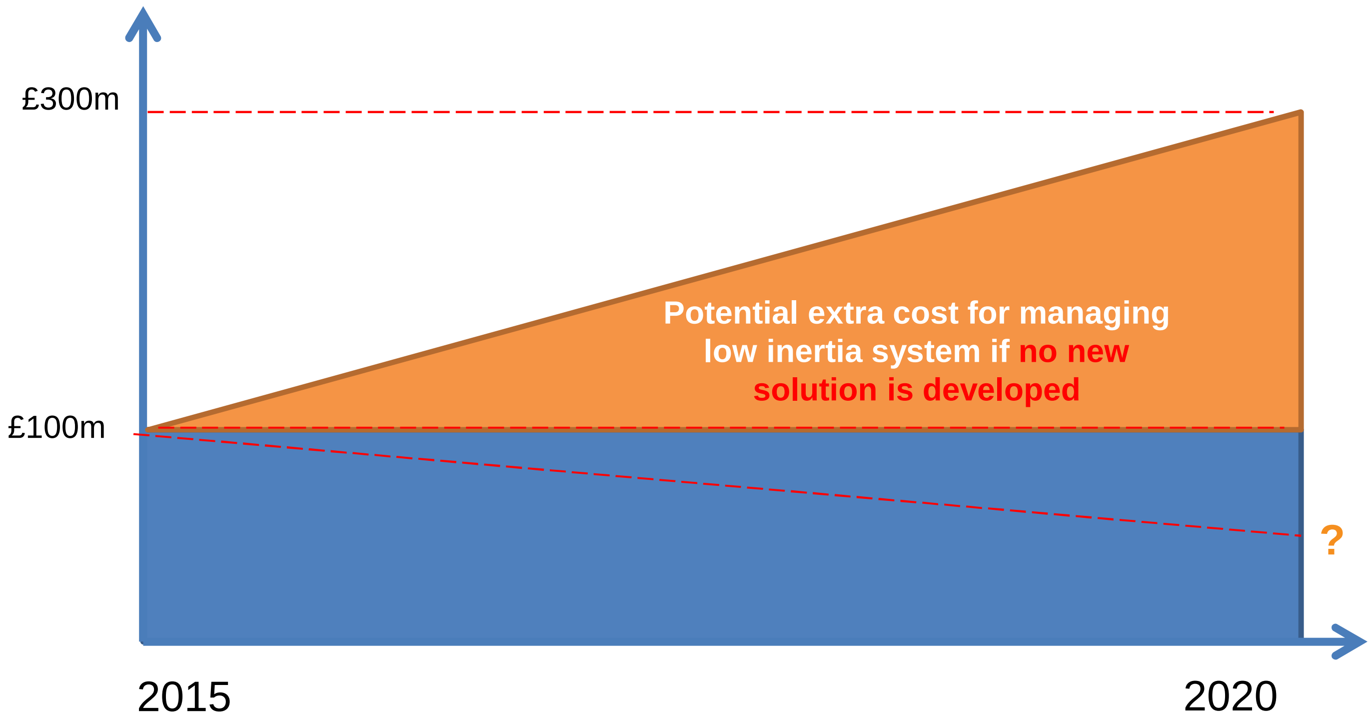
Operability Strategy – Frequency Response

System Needs

Better Response Services

Natural Inertia

New Services



For illustration purpose only

Background – A day in 2020

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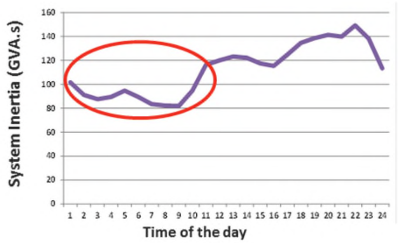
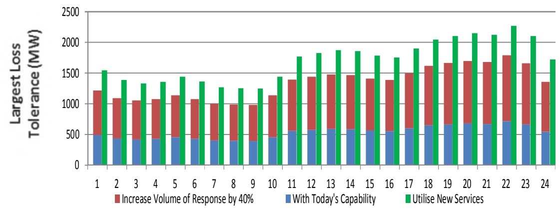
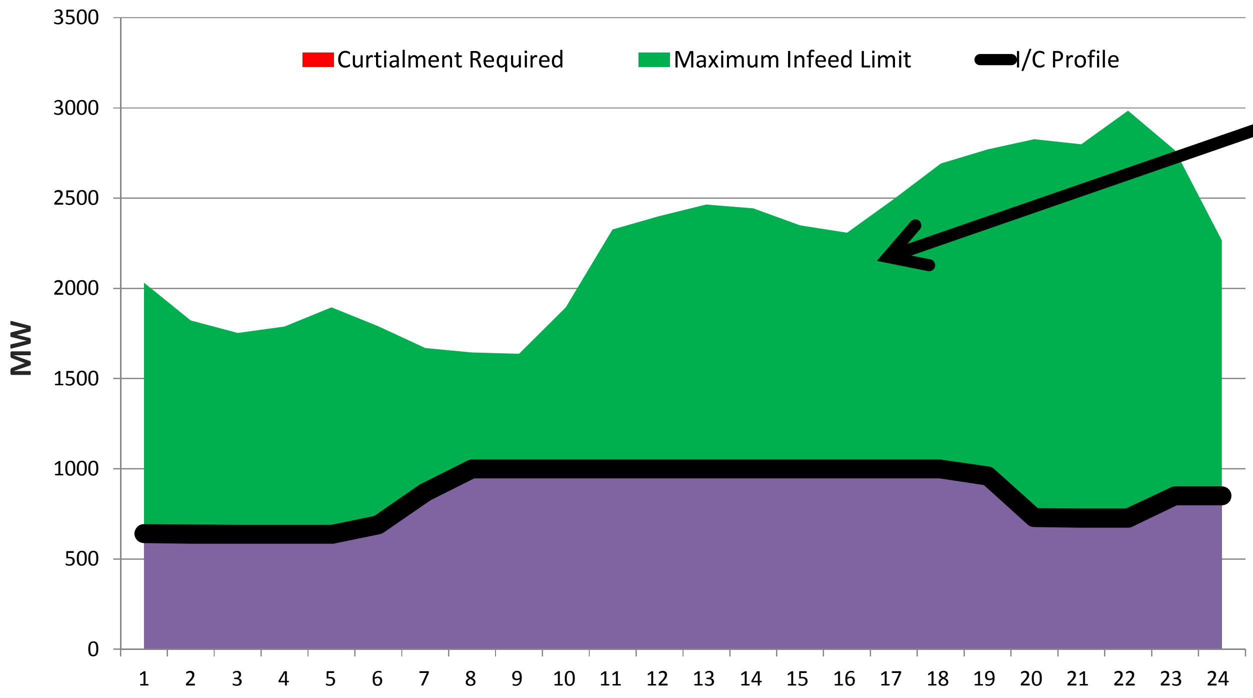
New Services







Much greater headroom by utilising enhanced services

Potential for reducing the cost of services by diversifying the market

Operability Strategy – Frequency Response

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System Needs	New Services			
Better Response Services	New Services on Solar PV and Wind	Energy Storage	Interconnector Services	Demand Side Services
Natural Inertia	Flexible Synchronous Generation	Flexible non-Synchronous Generation	Synchronous Compensator	

Topic 2 – Reactive Power

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Voltage Management

- High volts has evolved from a regional challenge to a national issue.
- Large volume of embedded solar generation offsets transmission MW and substantially increases transmission Mvar requirements.

Reactive Requirements

- 2.86Gvar of new reactors installed between now and 2017.
- Across all scenarios additional 4.8Gvar by 2025, 14Gvar by 2035.

Whole System Solutions

- Transmission options alone are not sustainable, efficient or effective against these projections.

Changing Daily Demand Profile

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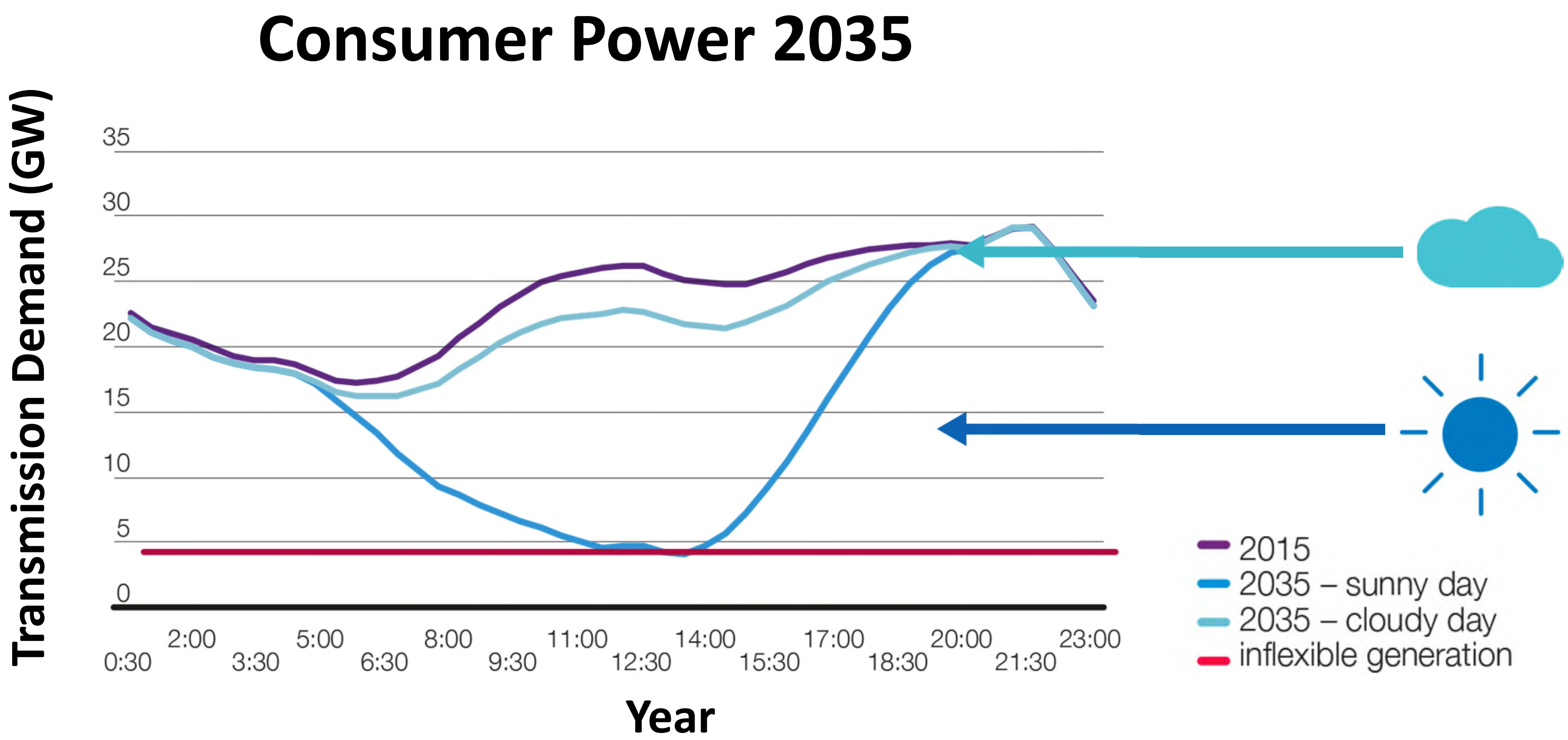

Falling Transmission Minimum Demand

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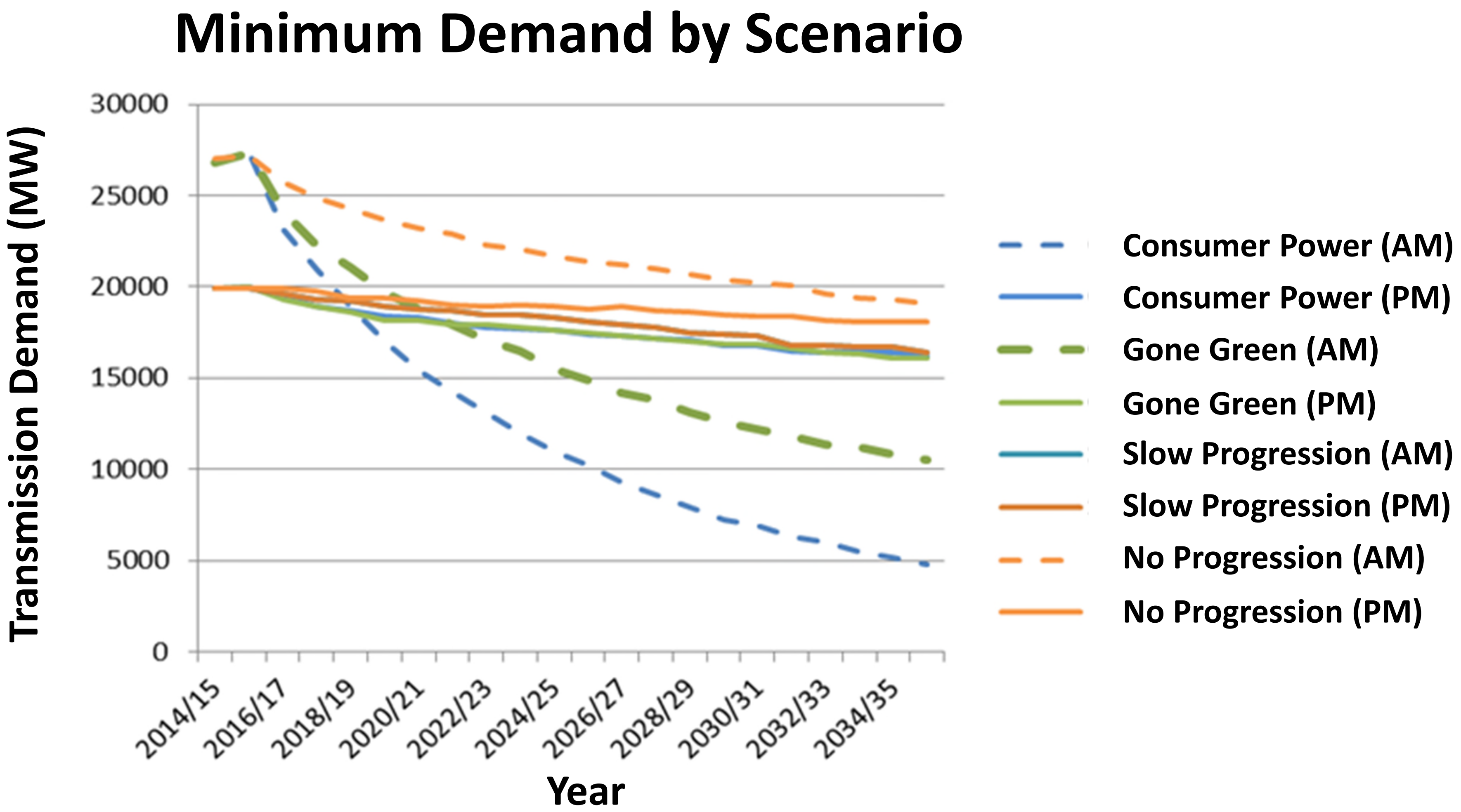
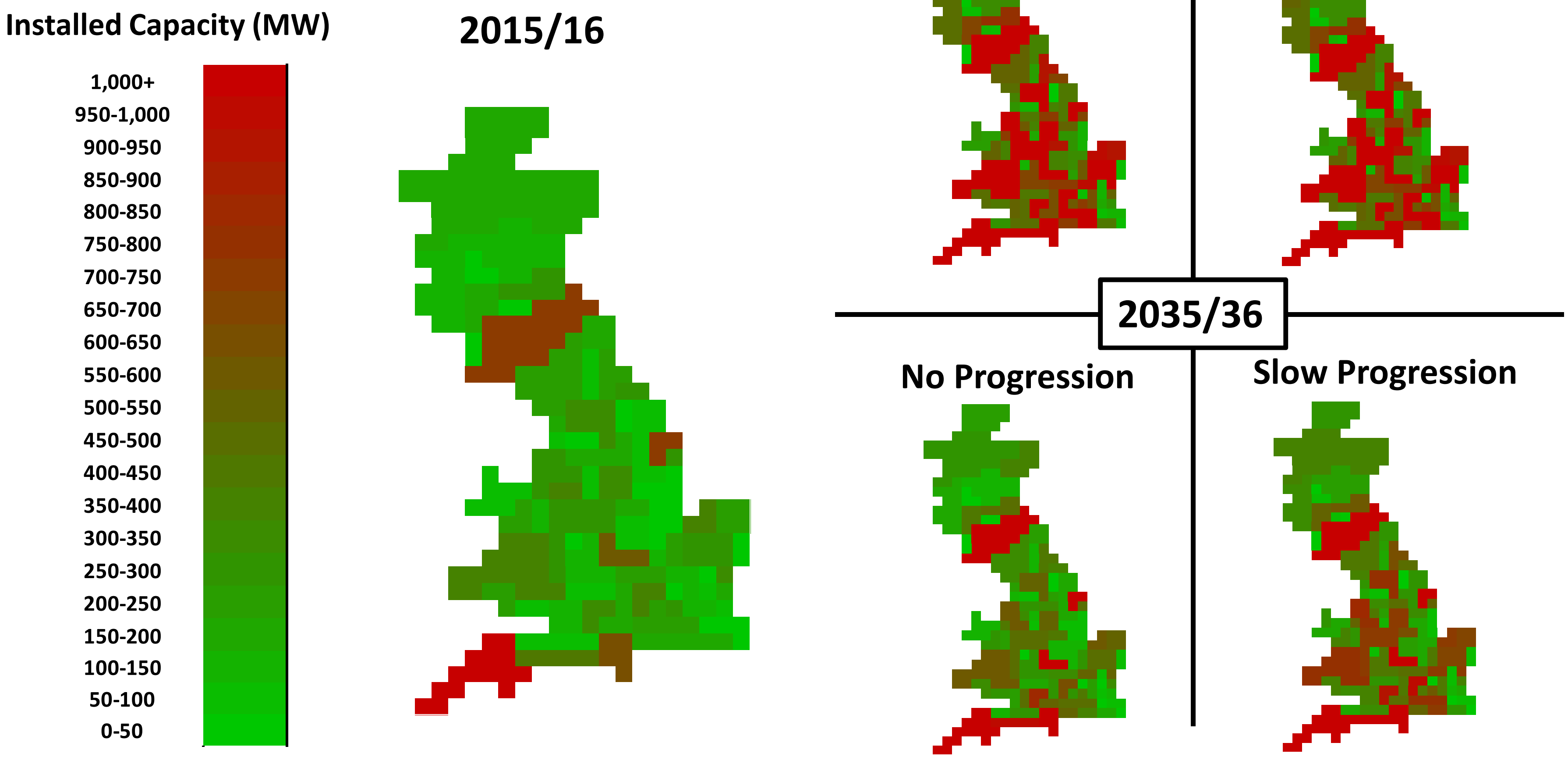


Increase in Embedded Generation

Installed Capacity of Embedded Generation



Increasing Constraint Cost of Mvar Provision

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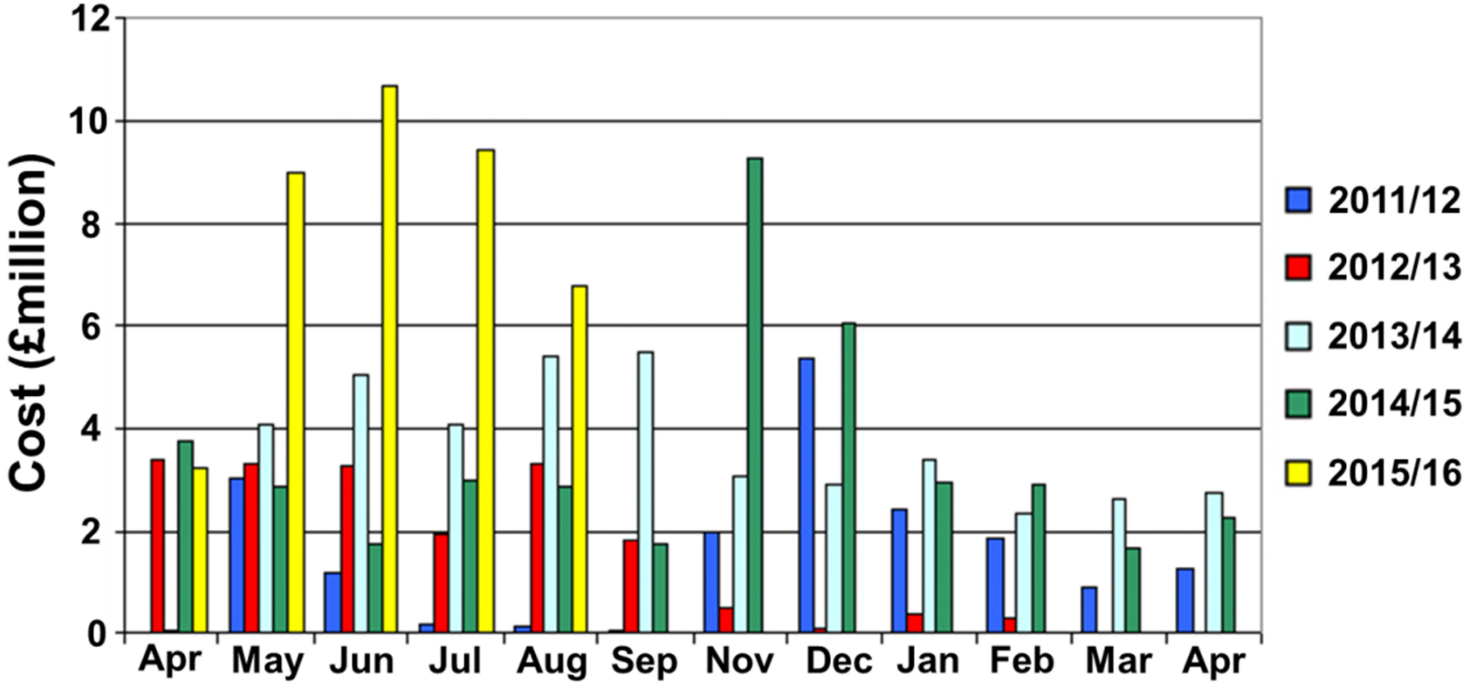
Cost to Constrain MW for Mvar Provision



Operability Strategy

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System Needs	New Services			
Enhanced Voltage Control from Generation	Support from Embedded Generation	Energy Storage	Flexible Synchronous Generation	DSO Services
	Synchronous Compensators	New Services from Solar PV and Wind	Interconnector Services	
Additional Reactive Compensation in Networks	Whole System Approach to Reactive Compensation			

Topic 3 – Black Start

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Black Start Strategy and Providers

- Reduction in thermal plant driving review of future strategy
- Potential role for interconnectors and aggregated distributed generation

Changing System Requirements

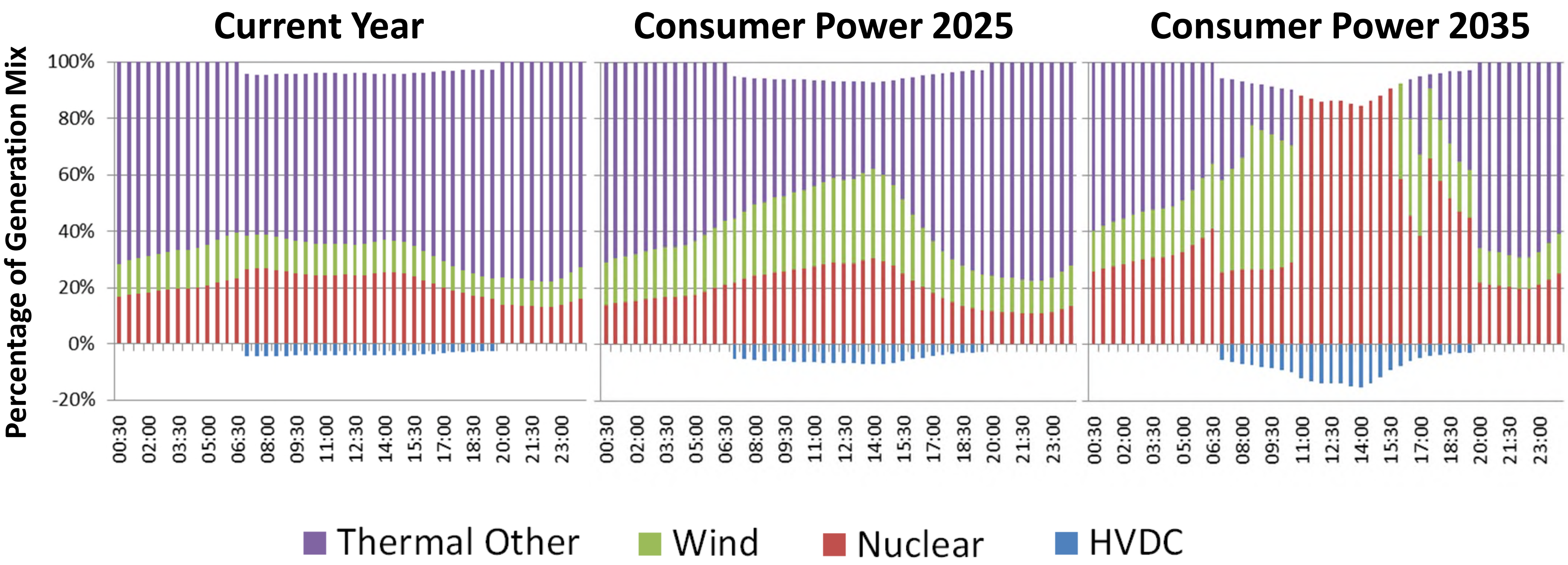
- Greater electrical distances between generation and load
- Increasing network energisation challenge

Increased Demand Side Significance

- Certainty of load blocks
- Protection of distributed generation

Plant Availability Prior to Black Start

- Decline in flexible thermal plant in merit at minimum demand periods will restrict black start plant availability in future years.



Operability Strategy

System Needs	New Services		
Active Power Delivery	Services from Aggregated Distributed Generation	Services from VSC Technologies	Options for New Synchronous Plant Black Start
Flexible Compensation	Aggregated Embedded Generation with Mvar Capability	Energy Storage for Network Energisation	Compensation from Non-synchronous Sources
Certainty of Block Loads	Revised Protection and Control Methods	Pre-emptive Islanding Approach	Coordinate DSR and Embedded Generation with Approach

Next Steps

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- Continue to develop commercial appraisal methodology:
  - Multiple-service approach
  - Dependencies
  - Consultation with the industry (early 2016)
- Extend technical assessments to economic assessment
- Workshop on New System Services Contracting (30th November)

SOF 2015 Launch Event

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- 30th November at National Grid HQ in Warwick

[9:30 - 10:00]	Arrival, Registration and Coffee
[10:00 - 10:10]	Welcome and Brief Overview of the Day
[10:10 - 10:25]	SOF in the Context of Electricity Network Capability
[10:25 - 10:35]	Future Energy Scenarios (FES) 2015 Updates
[10:35 - 11:30]	System Operability Framework 2015
[11:30 - 12:30]	Industry Perspectives on Key Themes of SOF 2015
[12:30 - 13:15]	Break (Business Lunch) and General Q&A
[13:15 - 15:15]	Contracting for New Services Workshop
[15:15 - 15:30]	Next Steps and Future Engagement

Thank you for your attention!

To provide further views on the themes discussed, please email:
box.transmission.sof@nationalgrid.com