GB Grid Forming Converters / Virtual Synchronous Machines

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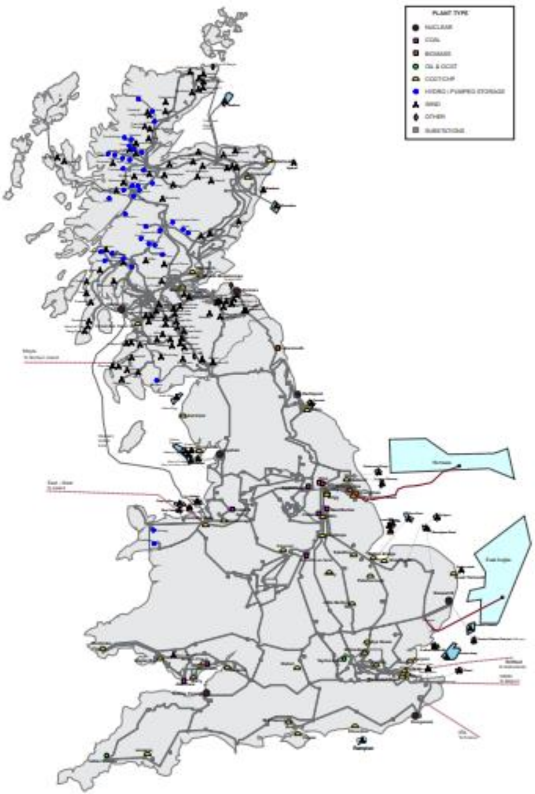
Summary

- Background the GB Transmission System
- The Operability Need
- Characteristics of Synchronous Plant compared with Power Electronic Converters
- History of Grid Forming / Virtual Synchronous Machines in GB
- Stability Pathfinder
- VSM Expert Group
- Updated Specification and Features
- Useful Information

Background to the GB Transmission System

Figure A1: GB Existing Power Stations



Key Statistics

- GB Transmission System operated by NGESO
- Network Transmission Assets owned and maintained by Transmission Licensees (NGET, SPT,SHE Transmission and Offshore Transmission Licensee's)
- Useful Documents
  - Electricity Ten Year Statement*
  - Future Energy Scenarios*
  - System Operability Framework*
  - (*See links at end of presentation)

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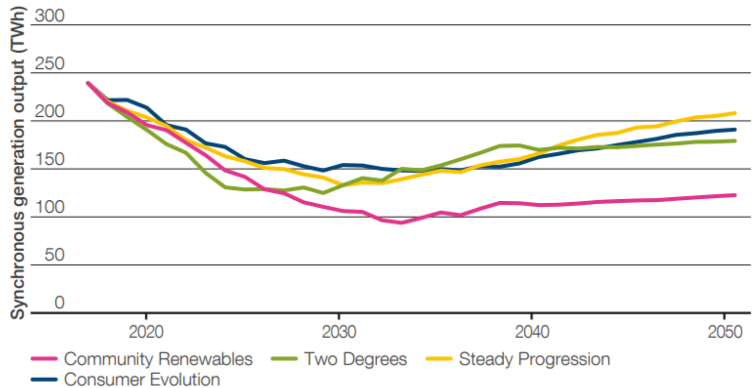
What is the operability need in GB?

The generation background is changing

- Synchronous generation capacity and output is decreasing
- More convertor based technologies are connecting to the system
- When seen in shorter terms (instantaneous power during the most exposed days/hours) rather than the annual average the fall is more extreme



We need to find alternative approaches to ensure stable operation

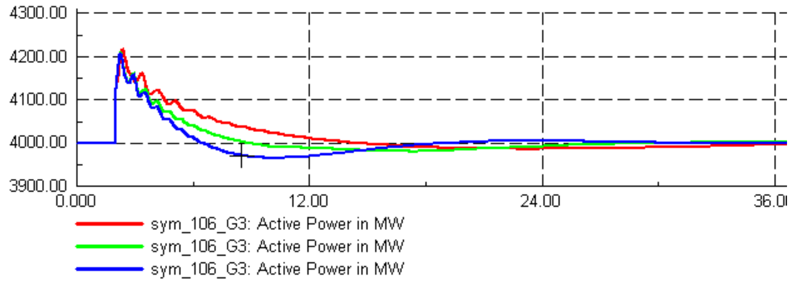
- Synchronous generators inherently deliver stabilising capabilities which are not inherently delivered from existing converter based generators:
  - Inertia – instantaneous frequency management
  - Fault current – instantaneous current injection
  - Dynamic voltage support – instantaneous reactive power
  - Limiting effects of vector shift

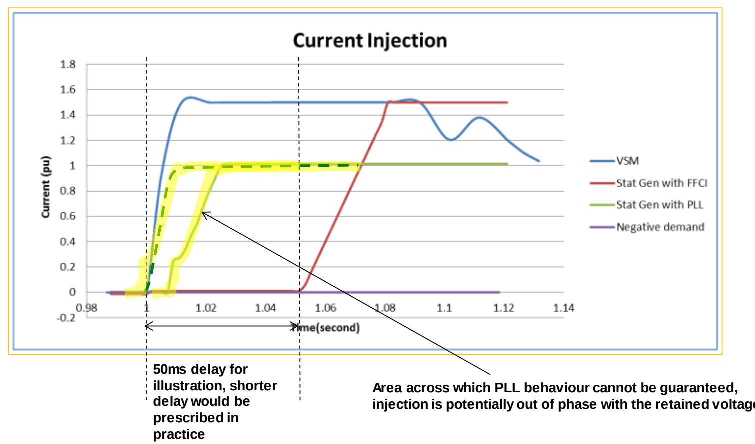
Characteristics of Synchronous Plant compared with Power Electronic Converters

Key Features

- Synchronous Generators are frequency sensitive and respond instantaneously to the loss of other generators in the System. Converter based PLL plant does not
- Synchronous Plant will supply 5 - 7pu fault current upon fault inception – Converter based plant will supply little more fault current than its plant rating
- Synchronous plant contributes to inertia, short circuit level and synchronising torque whereas converter based plant does not.
- Whilst PLL Converter control strategies can provide a system contribution they are based upon measurement and calculation resulting in a delayed response.

Active Power injection of Synchronous Plant during a frequency fall





History of Grid Forming / Virtual Synchronous Machines(VSM) in GB

- Papers published in 2013 indicating a major problem with large volumes of Converter based plant displacing Synchronous Generation
- Further research undertaken by National Grid in collaboration with the University of Strathclyde demonstrating the benefits of VSM even under System Split Conditions – Papers Published in Vienna 2016
- Grid Code Modification GC0100 (RfG Implementation) considered VSM as a possible solution for Fast Fault Current Injection
- VSM Expert Group Established April 2018 to consider feasibility of VSM as a concept and develop specification for possible inclusion in the GB Grid Code
- Stability Pathfinder Work released 2019 to explore long term stability products over the next 10 years which could include VSM
- Further research undertaken with University of Nottingham to develop a 100kW prototype VSM for proof of concept. Additional research undertaken with University of Strathclyde. Research papers on all aspects published in Dublin in 2019
- In GB, one full scale wind farm has been developing and testing the concepts of VSM/Grid Forming
- This information is being used in the GC0137 Grid Code Working Group

Stability Pathfinder

- Published in Summer 2019 seeking long term expressions of interest from developers to provide stability products over the next 10 years.
- The specification for this is available as part of the information pack which is available from the following link.
- https://www.nationalgrideso.com/publications/network-options-assessment-noa/network-development-roadmap

VSM Expert Group

- Established in April 2018 to consider if VSM is a feasible concept and develop a specification
- Comprises interested parties including Developers, Manufacturers, Consultants, Universities, Trade Associations etc
- Base specification developed as part of the Expert Group of which numerous comments were received.
- The output of this work has been heavily influenced by the research work undertaken, the feedback received from the Expert Group, and the Stability Pathfinder work
- This will now feed into the Grid Code Work Group where it has fed into the next iteration of the specification
- All the material and information developed during the Expert Group is available from the attached links at the end of this presentation.

Comments received following the first specification released during the VSM Expert Group

- As part of the VSM Expert Group, a draft specification was prepared in which numerous comments were received including
  - Plant Rating Requirements
  - Overload Capability
  - Inertia Requirements
  - Phase Angle requirements
  - Limited Frequency Sensitive Mode – Overfrequency (LFSM-O) performance
  - Active / Reactive Power performance during System faults
  - What type of plant is affected
  - Impedance and frequency ranges
  - Quality of Supply requirements
  - Are the requirements mandatory
  - Interaction with Stability Pathfinder and other markets
  - Data and models
  - Compliance testing and validation

Revised Specification – Dated 27 March 2020

- Thorough overhaul of specification – now based on a market approach with all plant types able to participate
- This is a market based approach – The requirements are not mandatory
- Capability based on plant performance not on minimum requirements – This addresses issues related to minimum performance such as rating and inertia requirements which was a problem identified with the previous specification
- The requirement for the plant owner to declare their plant capability (eg rating, inertia power, rating etc) are all key features of this revised specification
- The Grid Forming Plant will need to satisfy the applicable requirements of the Grid Code.
- The performance needs to be reversible – ie the same features should be achievable under high and low system frequencies
- The market approach is designed to be stackable so VSM/Grid Forming can easily be integrated with other Balancing Services such as Dynamic Containment and Firm Frequency Response.
-

Specification - Parameter Submission

Quantity	Units	User Defined Parameter
Type of **Plant** (eg **Generating Unit**, **Electricity Storage Module**, **Dynamic Reactive Compensation Equipment**	N/A	
Reactance between the Internal Voltage Source and **Grid Entry Point** or **User System Entry Point**	pu on MVA	
Maximum Capacity	MW	
Inertia Power (MW supplied or absorbed per 1Hz/s frequency change or MJ supplied or absorbed per 1Hz/s frequency change)	MW or MJ	
Overload Capability	% on MVA	
Duration of Overload Capability	s	
Nominal **Grid Entry Point** or **User System Entry Point** voltage	kV	
Grid Entry Point or **User System Entry Point**	N/A - Location	
Continuous MVA Rating	MVA	
Continuous MW Rating	MW	
Method of delivery – Overating, Deloading or Continuous Operation	N/A	
Level of De-load required to deliver Inertia Power (as applicable)	MW	
Maximum Three Phase Short Circuit Infeed at **Grid Entry Point** or **User System Entry Point**	kA	
Maximum Single Phase Short Circuit Infeed at **Grid Entry Point** or **User System Entry Point**	kA	
Diagram of single phase and three phase fault infeed during the first 0.5 seconds following fault inception	Diagram	
Additional transient or continuous steady state power available either before or after the supplied **Inertia Power**.	MW and MVAr Time duration	
Will the **Grid Forming Plant** contribute to any other form of commercial service – for example Dynamic Containment, Firm Frequency Response,	Details to be provided	

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Notes

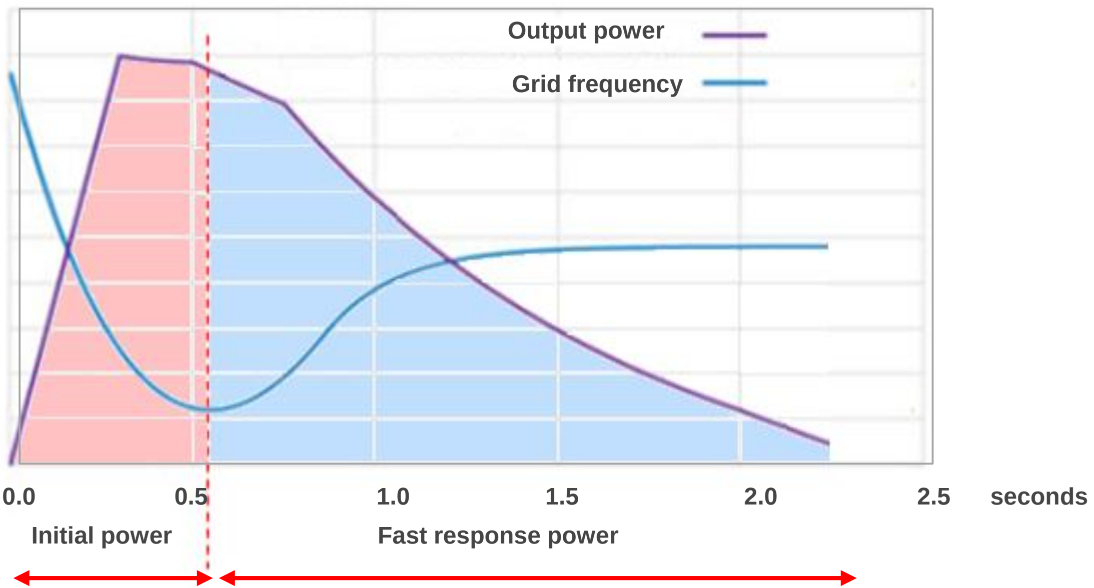
- Inertia Power

  The rise of the Active Power can take more than 5 ms what is important is that it starts within 5ms. One option is to describe this as " An instantaneous start of a fast rising transfer of Active Power", however there is some thought that it may be more appropriate to refer to the swing equation of a Synchronous Machine to give a more precise requirement.

  The performance of the Grid Forming Plant needs to be reversible – ie export under low system frequencies and import under high frequencies in the same way as a Synchronous Generator with inertia.

- The term "*Internal Voltage Source*" may need its own definition
- The Grid Forming Plant shall be capable of operating as a voltage source behind an effective reactance or be capable of supplying Inertia Power into the Total System during and after a fault. The Grid Forming Plant can change its delivered steady state Active Power by varying the voltage of the Grid Forming Plant's Internal Voltage Source through changes in the Total System voltage but only at a low bandwidth below 5Hz. - *As an example, this can be used to supply the extra fast response power required to meet the requirements of the Stability Pathfinder RFI Technical Webinar Slides 14th Aug 2019 shown on slide 11.* – *See next slide of this presentation.*
- Additional power could be supplied over and above the Inertia Power for the plant to compete in other markets

The Stability Path Finder proposals – Slide Reproduced with kind permission from ENSTORE



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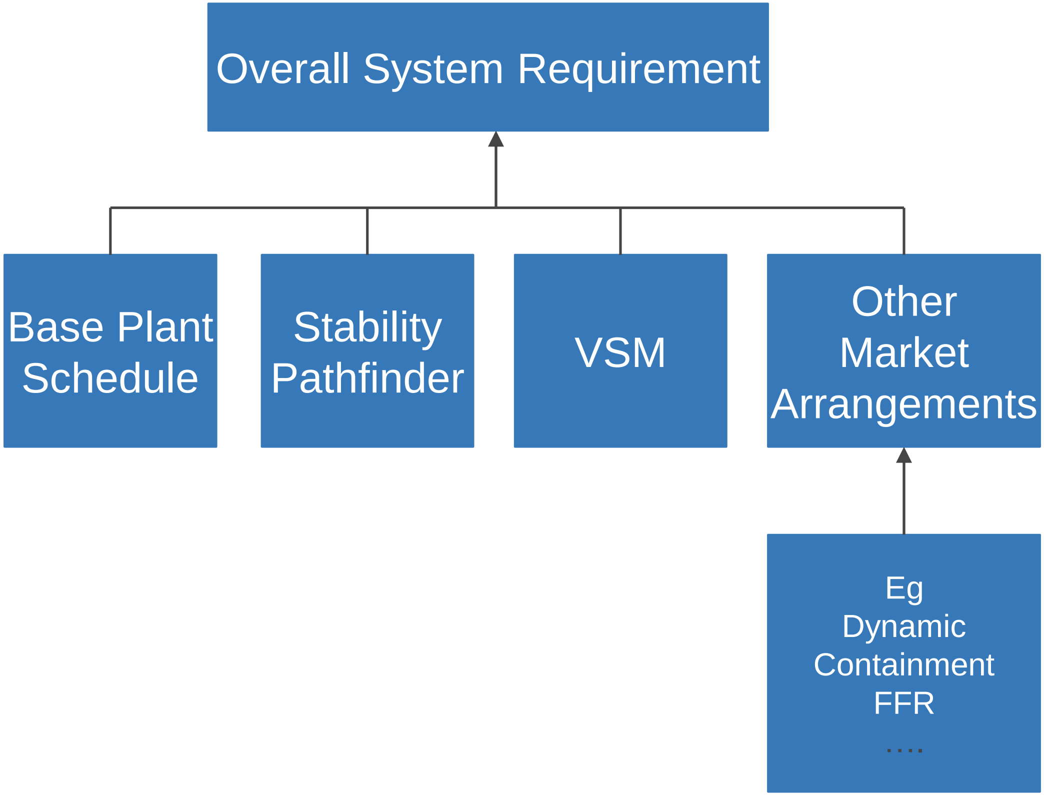
Integration with other Initiatives/Markets



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Next Steps

- Discuss current draft specification and seek comments
- Once the specification is prepared discuss and consider other issues such as:-
  - Data Submission and format
  - Models
  - Compliance assessment

- Questions

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Useful Information

Electricity Ten Year Statement

https://www.nationalgrideso.com/publications/electricity-ten-year-statement-etys

Future Energy Scenarios

http://fes.nationalgrid.com/

System Operability Framework

https://www.nationalgrideso.com/publications/system-operability-framework-sof

Grid Code Working Group GC0100 (RfG implementation including Fault Ride Through and Fast Fault Current Injection)

https://www.nationalgrideso.com/codes/grid-code/modifications/gc0100-eu-connection-codes-gb-implementation-mod-1

VSM Expert Group

https://www.nationalgrid.com/uk/electricity/codes/grid-code/meetings/vsm-expert-workshop

Stability Pathfinder

https://www.nationalgrideso.com/publications/network-options-assessment-noa/network-development-roadmap

VSM / GB Grid Forming Grid Code Working Group (GC0137)

https://www.nationalgrideso.com/codes/grid-code/modifications/gc0100-eu-connection-codes-gb-implementation-mod-1

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