GB Grid Forming Converters / Virtual Synchronous Machines

ENTSO-E Offices

January 2020

A Johnson – National Grid ESO - GB

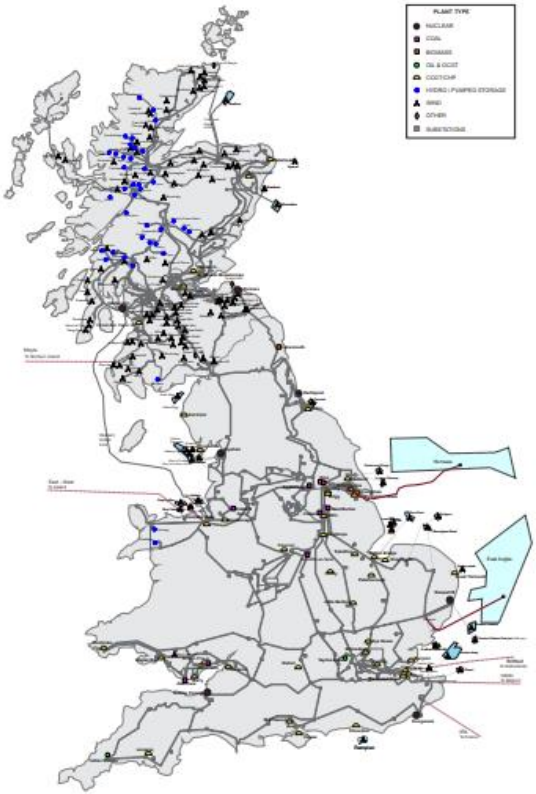
nationalgridESO

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 including features of the GB Grid Forming Specification
- Next Steps
- Useful Information

Background to the GB Transmission System

Figure A1: GB Existing Power Stations



Key Statistics

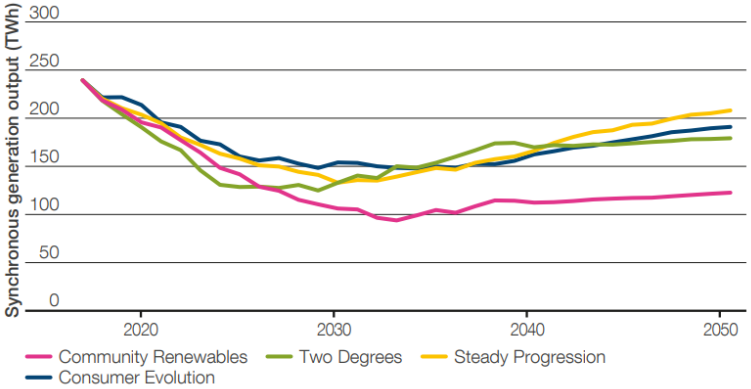
- GB Transmission System operated by NGESO
- Network Transmission Assets owned and maintained by Transmission Licensees (NGET, SPT,SHE Transmission and Offshore Transmission Licensee's)
- Useful Documents
  - Electricity Ten Year Statement*
  - Future Energy Scenarios*
  - System Operability Framework*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

nationalgridESO

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

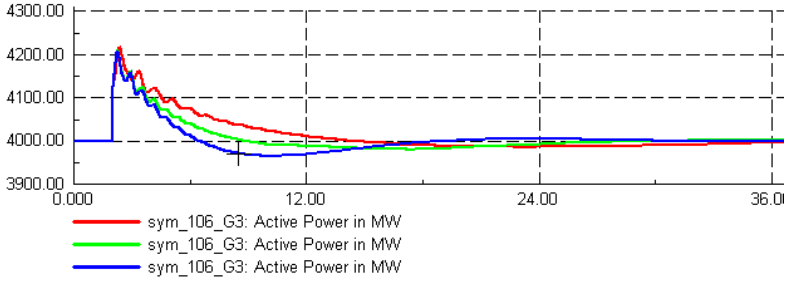
- Synchronous generators inherently deliver stabilising capabilities which are not inherently delivered from converter based generators:
  - Inertia – instantaneous frequency management
  - Fault current – instantaneous current injection
  - Dynamic voltage support – instantaneous reactive power
  -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

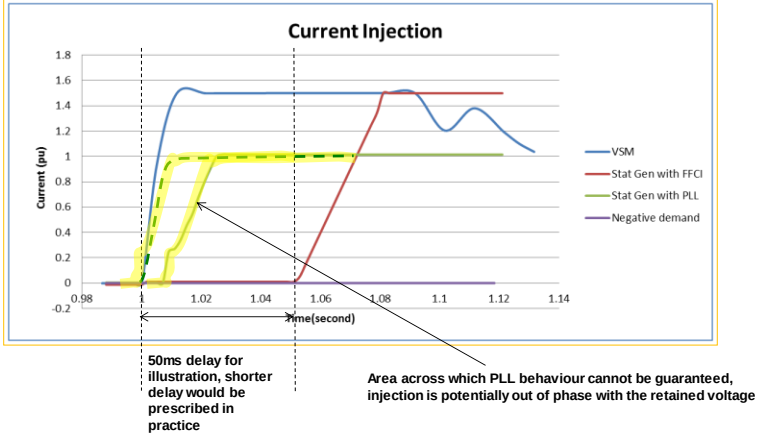
nationalgridESO

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.





nationalgridESO

High Convertor Penetration - Options

Key	
No	Doesn't Resolve Issue
P	Potential
I	Improves
Yes	Resolves Issue

Solution	Estimated Cost	RoCoF	Sync Torque/Power (Voltage Stability/Ref)	Prevent Voltage Collapse	Prevent Sub-Sync Osc. / SG Compitable	Hi Freq Stability	RMS Modelling	Fault Level	Post Fault Over Volts	Harmonic & Imbalance	System Level Maturity	Notes
Constrain Asyncronous 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
Syncronous Compensation	High	I	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Proven	
VSM	Medium	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	P	Modelled	
VSM0H	Low	No	Yes	Yes	No	P	P	P	Yes	P	Modelled	Has the potential to contribute but relies on the above Solutions
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		

nationalgridESO

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
- Proposal to establish a Grid Code Working Group presented to the Grid Code Review Panel in December 2019.
- In GB, one full scale wind farm has been developing and testing the concepts of VSM/Grid Forming

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 (see next slide) but requires further work
- 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 is aimed to develop a VSM/Grid Forming specification into the Grid Code.
- At this stage the intention is for Grid Forming to be initiated via market based mechanisms (ie not mandatory). Parties interested in offering their capability would submit their capability to the System Operator. The System Operator would then determine their requirement on a day ahead basis and select those providers required to satisfy the capability at the minimum cost (ie via competitive means). This would be different to the stability pathfinder work which is seeking long term solutions up to a 10 year period.
- All the material and information developed during the Expert Group is available from the attached links at the end of this presentation.

General Elements of the VSM / Grid Forming Specification Developed (1)

- Behave as a voltage source behind a reactance over a frequency band of 5Hz – 1KHz
- Have a short circuit current contribution of at least 1.5 pu on converter or Plant rating for a period of 0.5 seconds.
- Capable of a short time Active Power increase of 0.33pu to a maximum of 1.33 pu on converter or Plant rating – This could be achieved by over-rating or derating the plant say to 25-75% of Maximum Capacity
- During a fault or voltage depression which falls below 0.85 pu at the Connection Point, the phase, magnitude and frequency of the converter shall remain unchanged and contribute to the System for up to 0.5 seconds.
- During Frequency disturbances the plant shall be capable of providing an equivalent inertial response proportional to the rate of change of Frequency over the System Frequency range of 47 – 52 Hz
- During a vector shift/phase angle change at the Connection Point each Converter shall be capable of providing a response proportional to the angle change within the first cycle and up to the limit of ±1.33pu on converter MW rating.

General Elements of the VSM / Grid Forming Specification Developed (2)

- The Converter shall be capable of continuously supplying reactive current in proportion to the change in System voltage and contribute to Active and Reactive Power Damping
- There is a requirement for a fault ride through capability including Active Power recovery following fault clearance in addition to repeated fault ride through capability. As much fault current as possible is required to be provided within the rating of the converter.
- Each Converter should be able to withstand System voltage angle changes during and after the fault.
- During a fault or voltage deviation, reactive current is required to be injected into the fault as soon as possible but in any event within 5ms of inception of the disturbance.
- Each Converter is required to operate over System Short Circuit Levels of 3KA and above at the Connection Point.
- Each Converter should be able to satisfy the Grid Code Quality of Supply requirements.

Next Steps

Stability Pathfinder

- Continue to develop the stability pathfinder work

GB Grid Forming / VSM Work

- Establish GB Grid Code specification for Grid Forming /VSM in the Grid Code. The aim of this work will be to establish a specification for VSM / Grid Forming
- At the time of writing the high level approach is to be adopted:-
  - Non Mandatory
  - The arrangements will help facilitate a market around stability requirements in GB including consistency with the Stability Pathfinder work
  - The draft specification outlined on slides 10 and 11 will be undergoing substantial revision.

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

nationalgrideso.com

National Grid ESO, Faraday House, Warwick Technology Park,
Gallows Hill, Warwick, CV346DA

nationalgridESO