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2025 CIGRE UK Study Committee C4 Technical Liaison Meeting

Grid Integration challenges for co-locating Battery Energy Storage Systems (BESS) with existing onshore windfarms in Scotland

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Content

Introduction

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To maximise the use of spare active power capability in existing onshore windfarms, many developers are co-locating BESS with existing onshore windfarms. This practice allows for a faster deployment of BESS that have become essential to provide fast frequency response services to maintain a stable 50Hz frequency in the transmission system. This presentation details challenges faced during the grid integration of BESS with existing onshore windfarms in Scotland including but not limited to: GB Grid Code compliance, system studies, control systems and grid forming BESS for system restoration.

Background

In GB, National Energy System Operator (NESO) current connection system is based on a queue systems where depending on the size of your generation or demand, certain reinforcements to the grid are required. These reinforcements to the grid could take years to occur leaving developers with connection dates very far in the future.

To achieve net zero goals, some developer have found a way to market with co-locating different renewable energy technologies on existing operational generating assets . This approach have facilitated co-location of BESS, that are used for providing fast frequency response service, with onshore windfarm as normally no change to the Transmission Entry capacity of the onshore windfarm is required.

Grid Code compliance

Challenging requirements depending on criteria of isolation and controllability set out in the GB Grid Code

Existing site issued with FON complying with CC of GB Grid Code

New BESS needs to comply with ECCs of GB Grid Code
Compliance process – EON, ION and FON

Combined windfarm + BESS simulations

GF requirements

BESS only	Load flow analysis
	Reactive compensation / Power factor capabilities
	Short circuit
	P28 studies / Transformer energisation
	Earthing measurements and earthing system study
	Provision of DIgSILENT model (RMS Model) - BESS and PPC
	Provision of PSCAD model (EMT Model) - BESS and PPC
	Protection setting & co-ordination
	Harmonic & voltage flicker assessment
	Transient stability and dynamic performance including fault ride through/FFCI and voltage assessment
	Fault infeed
	Load rejection
	Voltage control
	Frequency control
Windfarm and BESS combined	Load flow analysis
	Reactive compensation / Power factor capabilities
	Short circuit
	P28 studies / Transformer energisation
	Provision of DIgSILENT model (RMS Model) - Windfarm
	Provision of DIgSILENT model (RMS Model) - Hybrid controller
	Provision of PSCAD model (EMT Model) - Hybrid controller
	Protection setting & co-ordination
	Harmonic & voltage flicker assessment
	Transient stability and dynamic performance including fault ride through/FFCI and voltage assessment
	Fault infeed
	Load Rejection
	Voltage control
	Frequency control
	Sub-Synchronous Oscillations (Plant and apparatus interactions)

Co-location configurations with existing windfarm – Grid Following and Grid Forming BESS

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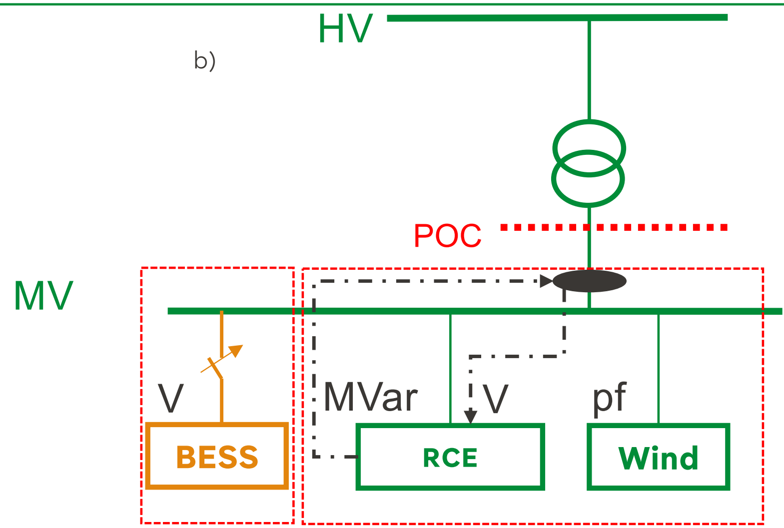
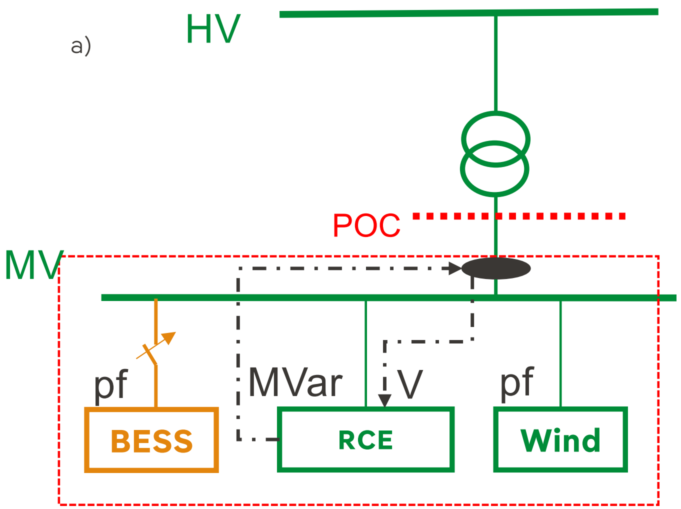
1. Voltage control - Wind farm + Reactive Power Compensation Equipment (RCE) (e.g. STATCOM, SVC etc) + BESS
   a. RCE provides voltage control – Trigger modelling requirement by GB Grid Code as PC.A.9 for existing plant
   b. RCE + BESS – parallel voltage control – should not trigger existing asset models as per PC.A.9 requirements although NESO is requesting SSO studies for the whole site in EMT so development of EMT models for existing assets is required
   c. Windfarm + RCE– provides voltage control (RCE compensating for lack of capacitive reactive power) if parallel with BESS voltage control should not trigger existing assets models as per PC.A.9 requirements although NESO is requesting SSO studies for the whole site in EMT so development of EMT models for existing assets is required

b)



a)



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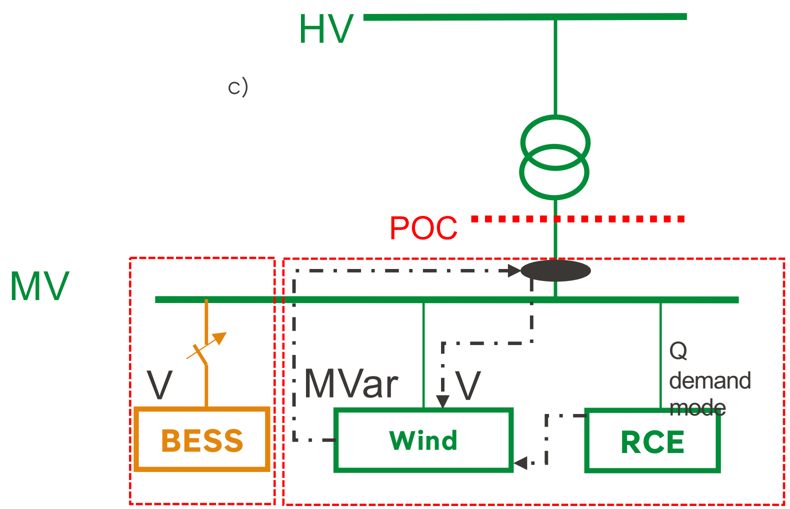

Co-location configurations with existing windfarm – Grid Following and Grid Forming BESS

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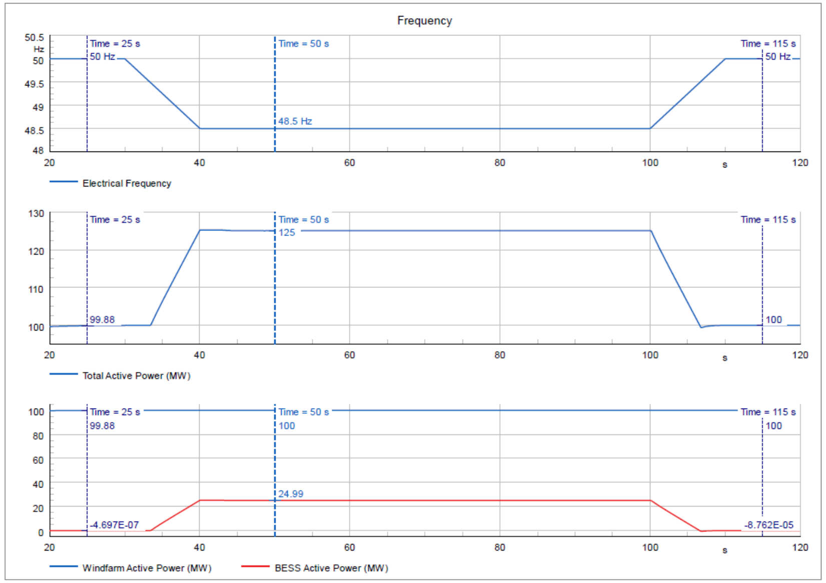
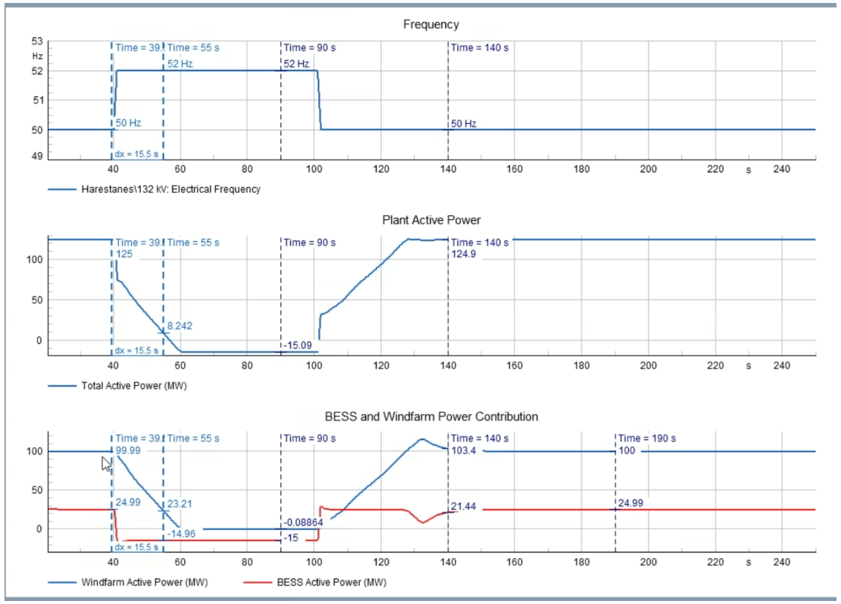
Combined site RMS simulation – Frequency control





Combined site LFSM-U

LFSM-O

Grid Forming BESS co-location and system restoration

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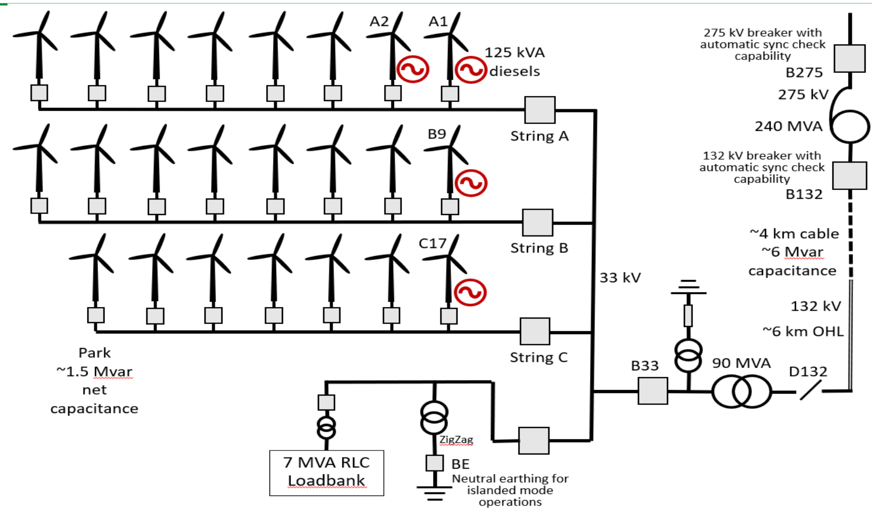
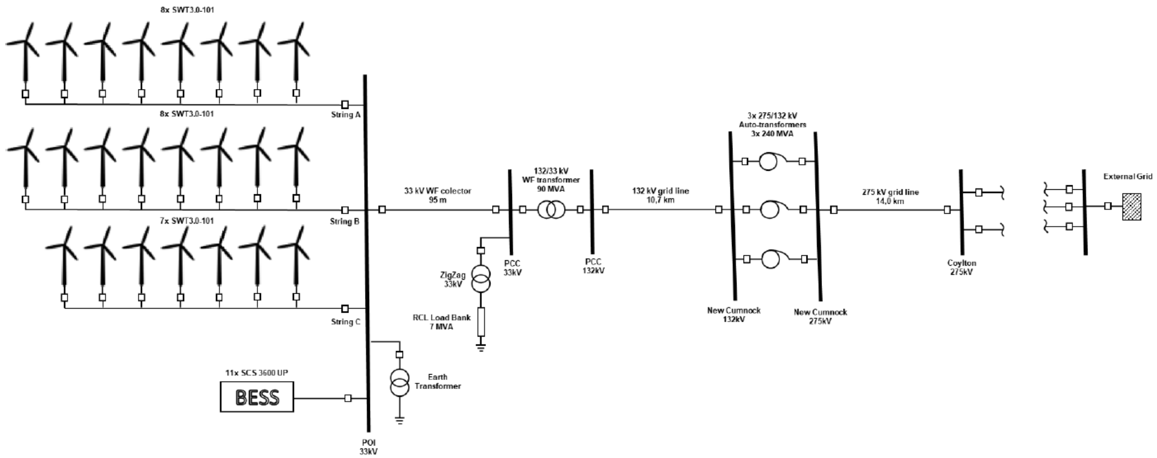
Dersalloch restoration trails 2020

Ancillary plant used for islanding and restoration to be replaced by Grid Forming BESS

Studies carried out to demonstrate BESS+ windfarm restoration capabilities as per requirements of NESO restoration tender for wind in 2022.

Ref	Requirement	Expected Capability following
1.01	Time to Connect	≤ 2hours.
1.02	Service Availability	≥ 80%.
1.03a	Voltage Control (Leading)	50MVAr
1.03b	Voltage Control (Lagging)	40MVAr
1.04a	Frequency Control (Lower)	47.5Hz
1.04b	Frequency Control (Upper)	52Hz
1.05	Resilience of supply, Black Start Service	≥ 10h
1.06	Resilience of Supply, BS Auxiliary Unit(s)	≥ 72h.
1.07	Block loading size	10 MW
1.08	Reactive Capability	50MVAr leading
1.09	Sequential Black Starts	≥ 3
1.10	Short Circuit Level	For t ≤ 80ms: I=2.93kA @ 33kV For t > 80ms: I= 2.93kA @ 33kV
1.11	Inertia Value	400 MVA.s. depending on power output





Grid Forming BESS co-location and system restoration

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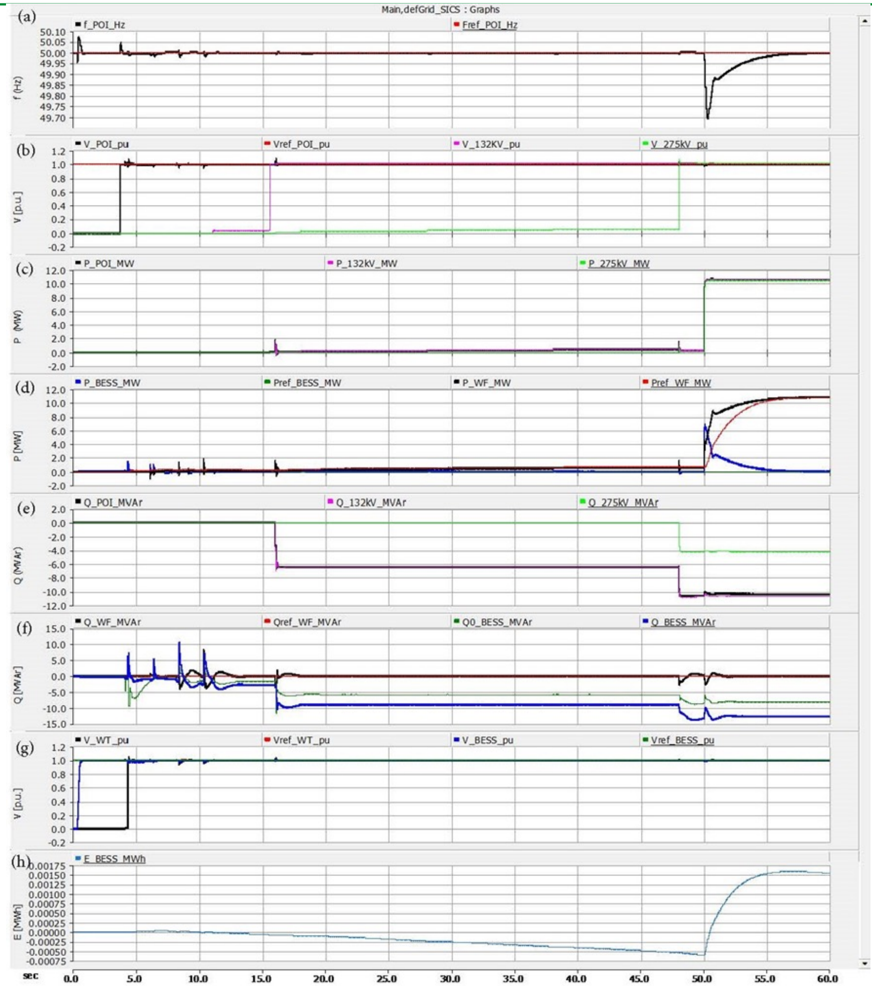
1. Blackout
2. Windfarm Grid incomer breaker (WG-1) opened
3. Auxiliary supplies to both BESS and main windfarm substation enabled
4. Check windfarm comms are healthy
5. Switch to group B in both BESS and main substation protection relays
6. Remove low voltage protection at WTGs
7. Start the BESS in grid forming mode.
8. Start four anchor WTGs, WTG A1, A2, B19 and C17 using BESS. (the turbines got external transformer and switchgear so breakers will be closed first then the WTG transformer will be energised and then the turbine)
9. Start rest of WTGs in windfarm array A (6 WTGs)
10. start rest of WTGs in windfarm array B (7 WTGs)
11. Start rest of WTG in windfarm array C (6 WTGs)
12. Complete island created with control of frequency close to 50Hz and voltage close to 1pu
13. Grid incomer closed under instruction of NGESO to energise upstream infrastructure in the transmission network and provide blockloading up to 20MW



Black start energisation with Vref_POI_pu = 1.0 p.u. a) frequency at the POI, b) voltage at POI, 132kV and 275kV, c) active power at the POI, 132kV and 275kV d) individual active power contribution from both WF and BESS, e) reactive power at the POI, 132kV and 275kV, f) individual reactive contribution from both WF and BESS, g) voltage at both WTG and BESS low voltage terminals, h) energy usage of the BESS

Grid Forming stability services

Same configuration as per restoration studies.

Studies carried out to demonstrate BESS capability to provide required services of inertia and short circuit levels as stability pathfinder requirement and also N-2 events simulations

In addition, BESS planned to be used for fast frequency response services such as:

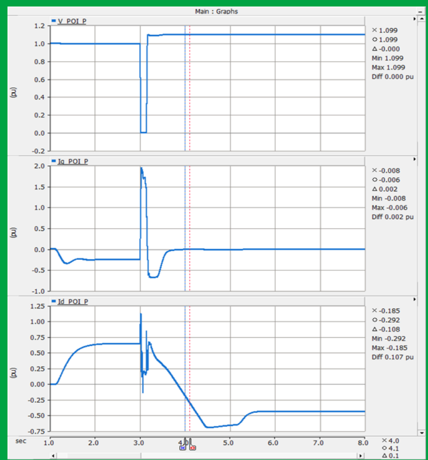
- **Dynamic Moderation**
- **Dynamic Containment**
- **Dynamic Regulation**

1.

Figure above show the post fault active power decreases in response to the over frequency event..

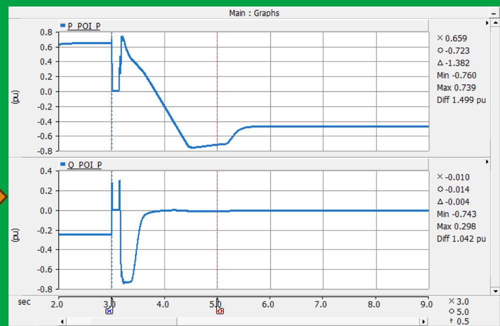
Test case - Three-phase to earth fault with duration of 140ms followed by a step rise to 1.1pu & Frequency rise from 50Hz to 52Hz at 1Hz/s

2.



During the fault reactive current is injected and active power reduces proportionally to the fault. After the fault was cleared there is decrease in active power. This is in response to the frequency event.

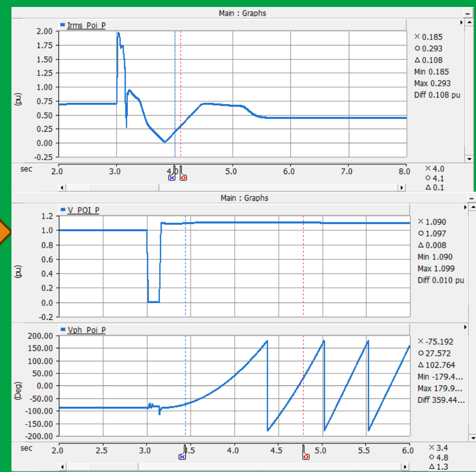
3.



After the fault reactive power changed to zero due to current limitations.

Active power after the fault is lower than it was before the fault due to the frequency event.

4.



Pre-fault voltage value is set to 1 p.u. Post fault voltage behind an impedance is set to 1.1p.u.

Conclusions

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Co-location could be a faster way to deploy BESS

Important to meet GB Grid Code

Control strategy for voltage control key in requirements of models for existing sites

Co-location allows for multiple markets grid services to be provided by BESS e.g. SCL, Inertia, restoration, Fast Frequency Services, Capacity Markets, Balance mechanism

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