



+ ESIG Grid-Forming  
workshop –

+ Case Study – 300MW  
GFM BESS –

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& Policy

**ZENOBE**





# Presentation contents

1. **UK case study – Zenobe 200MW Blackhillock GFM BESS:** Operational inertia data from one of the world's first and largest GFM BESS installations
2. **Policy/Regulatory recommendations:** How to enable the opportunity for GFM resources and overcome the incentive and coordination challenge



# Case Study – Zenobe 200MW Blackhillock GFM BESS

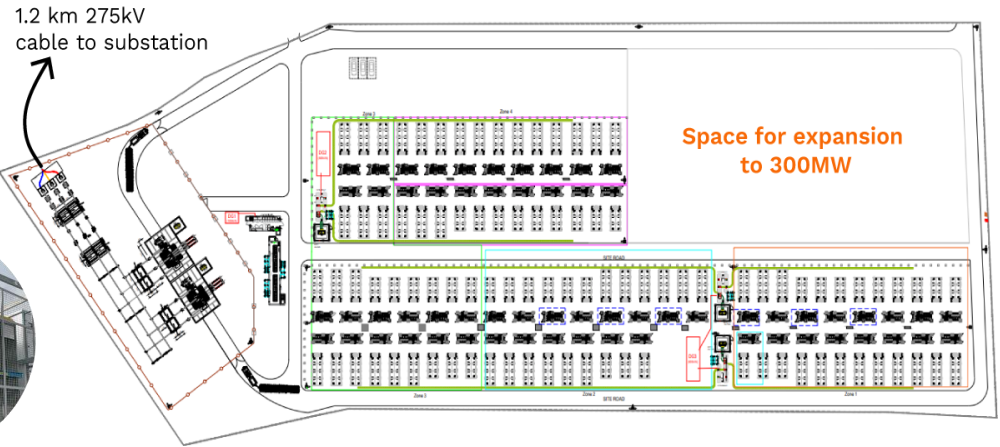
Blackhillock is the first, operational Transmission-connected Grid-Forming BESS in the UK. It provides critical stability services (inertia, SCL), previously provided by fossil fuel assets



Battery system (Wartsilla)



Inverter system (SMA)

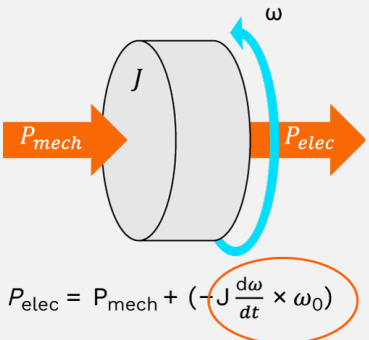


## Technical capabilities

<b>Connection</b>	275kV at BLHK275 substation
<b>Active power</b>	200MW export / 210MW import*
<b>Stored energy</b>	400MWh (200MW x 2hr)*
<b>Inertia</b>	380MW.s (24/7 contracted with NESO), ~5GVA.s (max, at 0MW steady state)
<b>Short-Circuit Level (SCL)</b>	120MVA (contracted), 300MVA (capability)

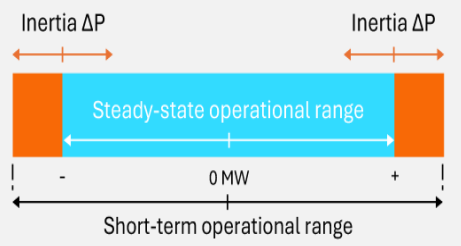
\*based on phase 1 development, to be expanded in 2026

### Grid-forming inverter



- ✓ Mimics traditional generators to provide real inertia
- ✓ Adjustable inertia for dynamic grid stabilisation

### Inertia for stability & flexibility



- ✓ Provides grid resilience
- ✓ Dynamically adjustable for different grid conditions
- ✓ Fast response to stabilise frequency

# Case Study – Zenobe 200MW Blackhillock GFM BESS

14<sup>th</sup> March 2025 event: 3x large units, providing 5% of system demand, tripped, exceeding the *Infrequent Infeed Loss Limit*. System frequency dropped below operational limits

## Event timeline:

- 08:51:37 – DRAX unit 1 (655MW Biomass) tripped
- 08:51:42 – DRAX units 2&3 (1.2GW Biomass) tripped
- 08:52:00 – 3x pump storage units (370MW) instructed on
- 08:52:09 – System frequency nadir of 49.67Hz
- 08:53:00 – 900MW of small plant & BESS instructed on
- 08:53:06 – 600MW of Fast Reserve dispatched
- 08:53:32 – System frequency returned to operational limit (49.8Hz) within 3 mins and 50.0Hz in 12 mins

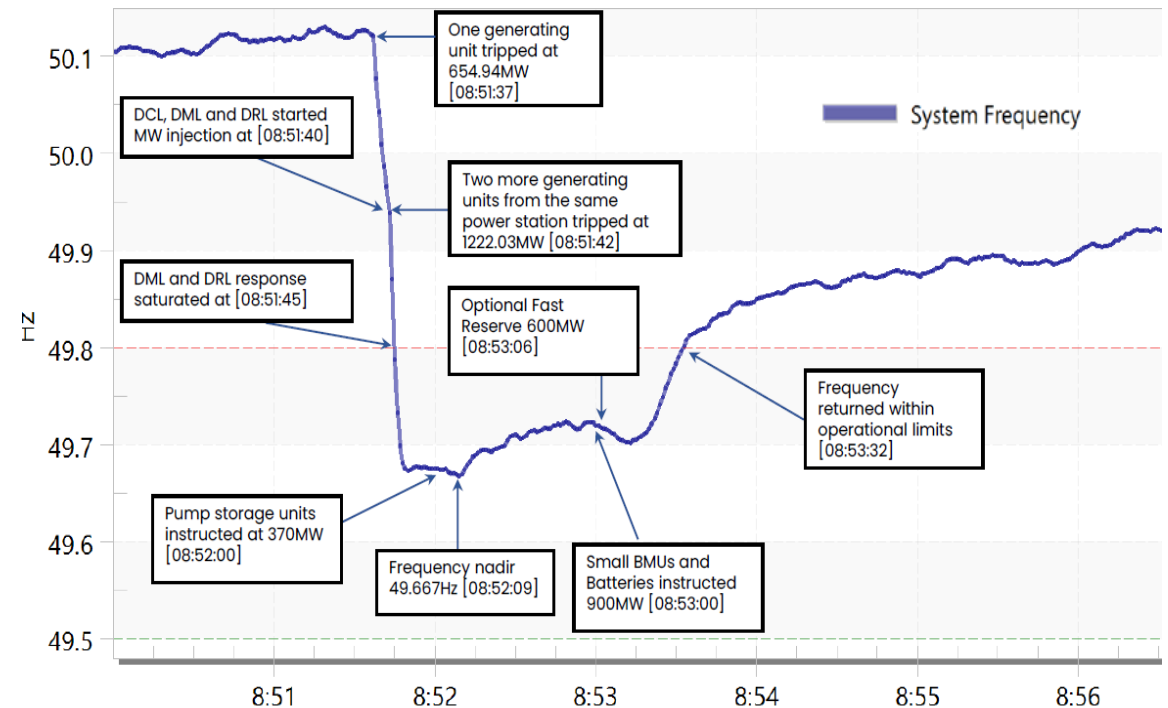
## Blackhillock inertia response:

- Pre-event, Blackhillock was exporting 196MW, and in *Voltage Control mode* (4% droop) with a target voltage of 1.02 p.u.
- Blackhillock provided the contracted inertia response of 380MWs, contributing to the system inertia

## Conclusions:

- Despite a large infeed loss (~1.8GW, or 5% of 36GW load), there was **no embedded generation/customer impacts**
- **Instantaneous/automatic (Blackhillock) arrested the RoCoF to improve the system stability.** Together with ancillary frequency response, System Frequency was returned to within operation limits in minutes

14th March 2025 event – System Frequency timeline

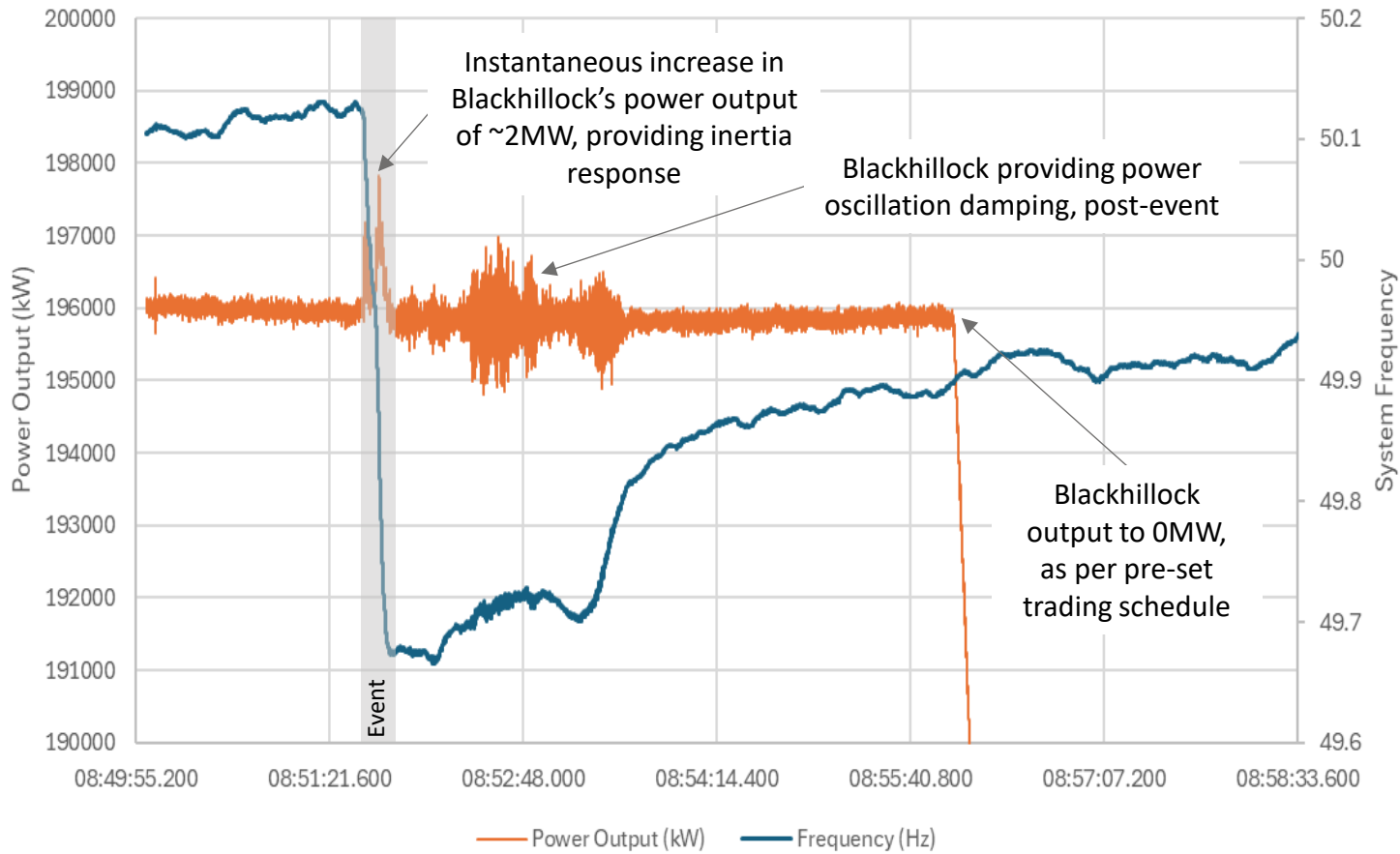




# Case Study – Zenobe 200MW Blackhillock GFM BESS

Contracted inertia response provided during event with minimal change to Blackhillock's Active Power MW and MWh energy

System Frequency (blue) and Blackhillock Active Power (orange)

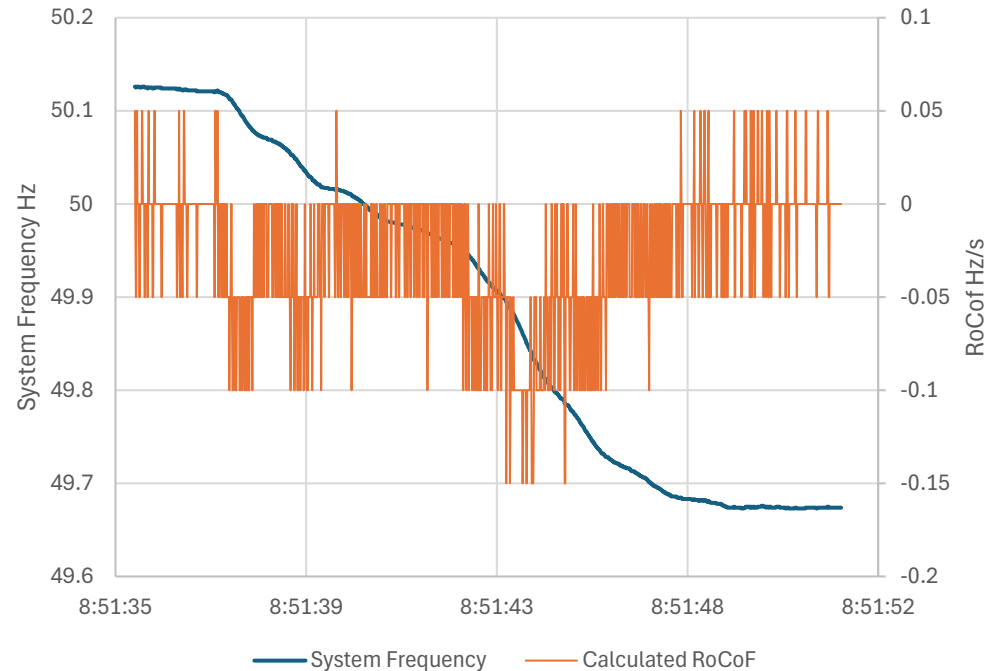




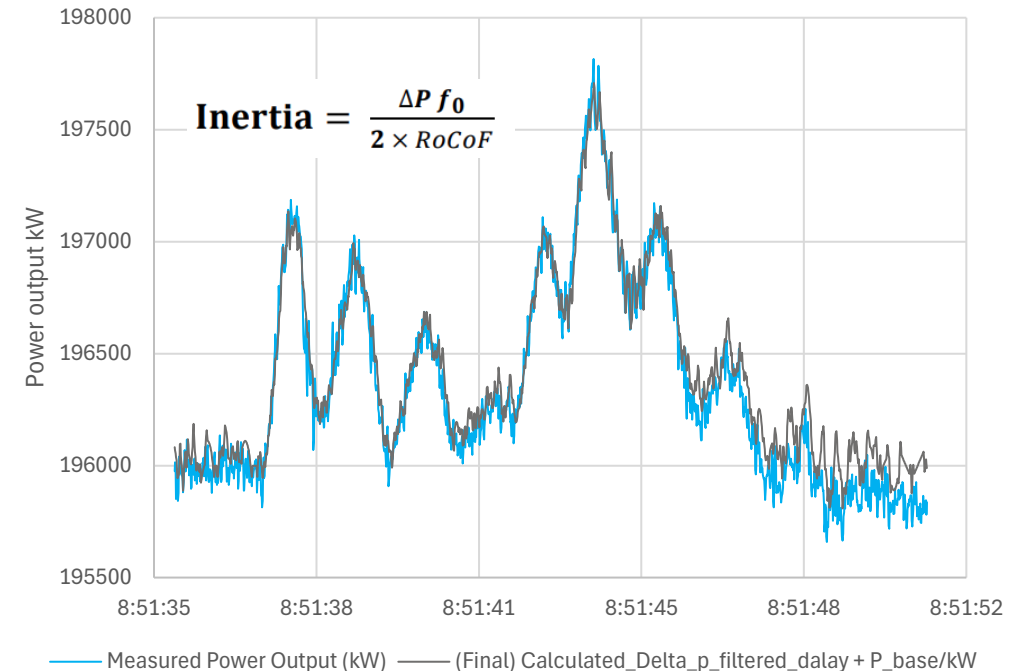
# Case Study – Zenobe 200MW Blackhillock GFM BESS

Validation of Blackhillock's inertia response performing as expected and contracted

### System Frequency and RoCoF during event



### Blackhillock expected vs actual inertia response



- Blackhillock's contracted inertia = 380MWs
- At 1Hz/s RoCoF, equates to change in output ( $\Delta P$ ) of 15.2MW
- During this event, the max RoCoF was  $\sim 0.15\text{Hz/s}$
- **Validating the  $\Delta P$  of  $\sim 2\text{MW}$** , shown on previous slide

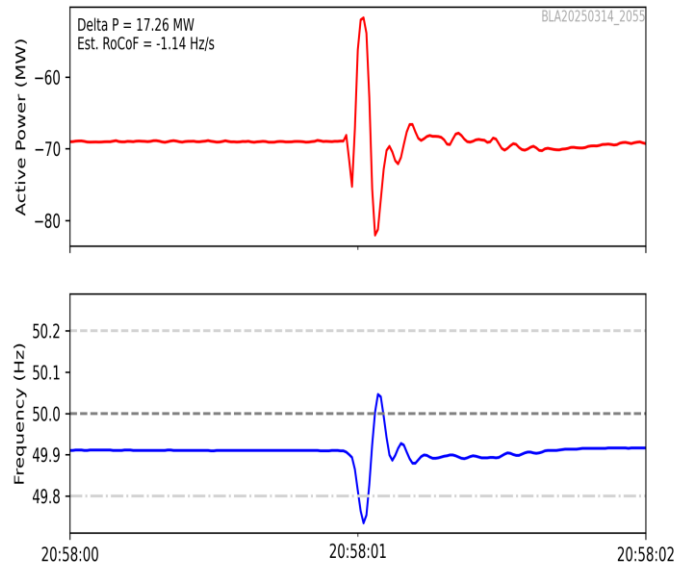
- Expected (grey) and actual (blue) power response are closely aligned, showing the **battery performing as contracted**
- Expected inertia response (grey) is calculated at a 100Hz sampling rate, causing minor measurement inaccuracy



# Case Study – Zenobe 200MW Blackhillock GFM BESS

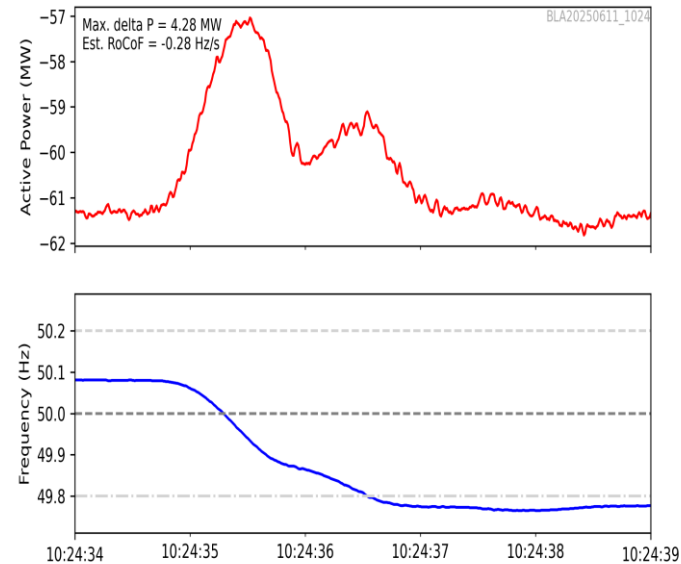
Blackhillock is responding as expected across a range of network events. Data sharing with NESO contributes to post-event network diagnoses and support from GFM technology

**Unknown Frequency disturbance**  
14<sup>th</sup> March 2025 (20:55)



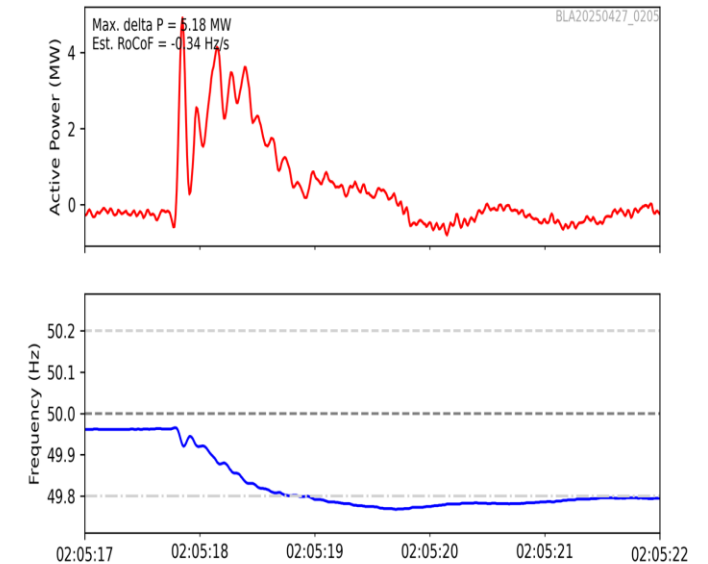
- Localised event. Possible phase angle jump caused by a local interruption as the RoCoF was very large
- Blackhillock max  $\Delta P$  = 17MW
- Blackhillock provided **instantaneous, phase angle jump power response**

**Loss of Sizewell nuclear (~0.9GW)**  
11<sup>th</sup> June 2025



- Correct response provided through the plants operational range
- Blackhillock max  $\Delta P$  = 4.3MW
- Blackhillock provided **Instantaneous Inertia power over the event duration**

**Viking Link HVDC trip (~1.4GW)**  
27<sup>th</sup> April 2025



- Nearby loss of large load, explaining the more erratic nature of the fault
- Blackhillock max  $\Delta P$  = 5.2MW
- Blackhillock provided **Instantaneous Inertia power over the event duration**

# Learnings and recommendations

GFM BESS have a proven potential to save \$bns in ratepayer cost. Overcoming the coordination and incentive problem is key to unlocking this potential.

- Utilities across the US continue to propose **expensive, single-use synchronous condensers** for Stability needs
- UK learnings show these Stability needs can be solved by BESS with GFM at a significantly lower cost
  - Case Study = Zenobe's Blackhillock 200MW GFM BESS is responding as expected across the full range of network stability events
  - Coordination problem can be unlocked with clear incentives

## Policy/Regulatory recommendations

- Grid Planners and Utilities need to **model the capabilities of GFM resources**
  - Identify where these GFM resources (e.g. BESS projects in late-stage development) can optimize network investments / cost
- **Option 1 (UK) = ISOs oversee Power Quality**, as opposed to local TOs and utilities
  - ISOs could build Stability Services into market design / procurements or interconnection process for new resources
- **Option 2 = Incentivize Utilities to contract GFM resources**
  - Where GFM resources present the best / lowest cost option to solve grid needs vs traditional network investment
  - GFM resources can stack this capability alongside full market participation, without distorting the market or causing a "double-payment" issue
  - Regulate Utilities with performance-based ratemaking vs traditional return on CAPEX model



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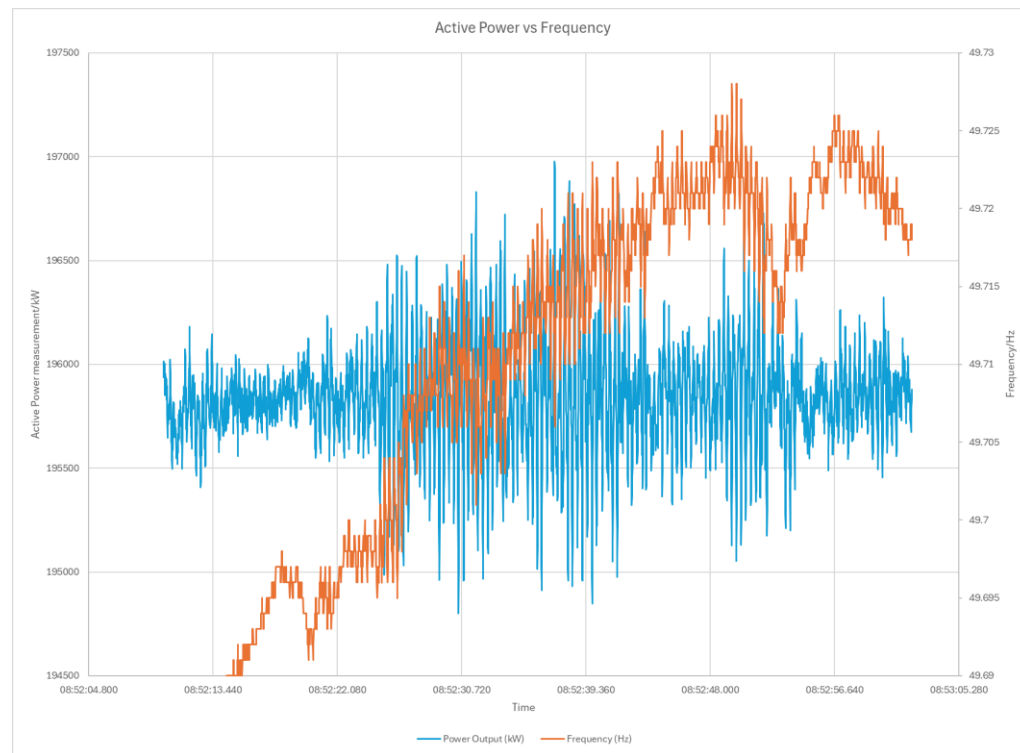
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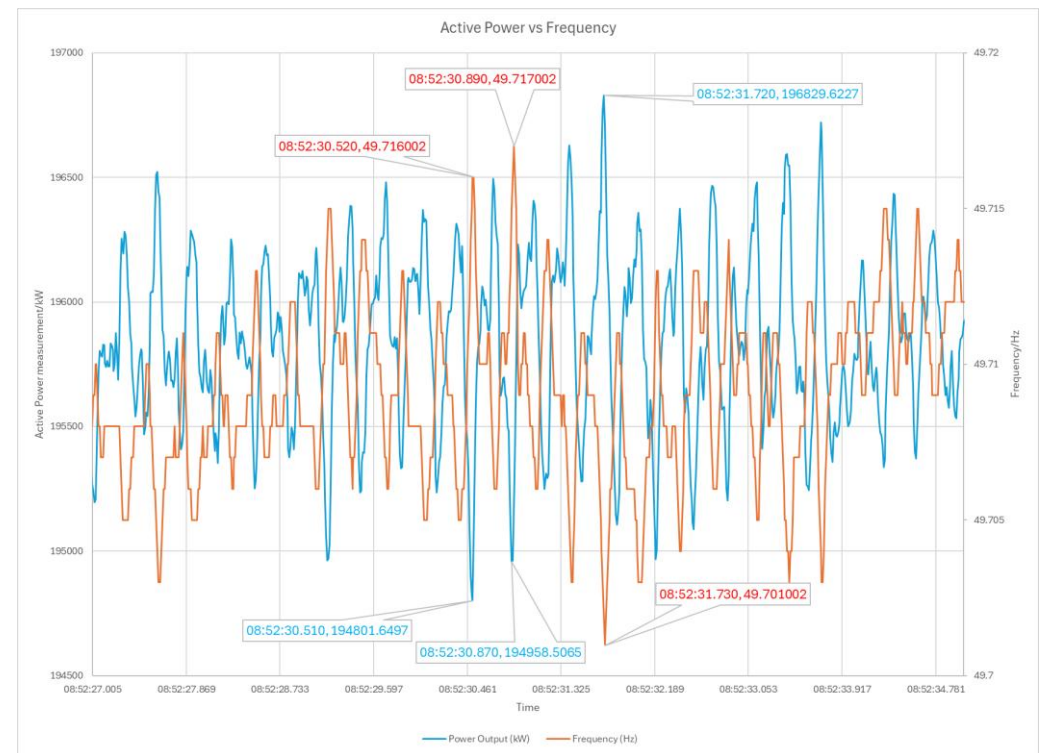
# Case Study – Zenobe 200MW Blackhillock GFM BESS

Blackhillock BESS provided positive damping contribution following the RoCoF event helping to maintain system stability

- Following the RoCoF event (08:51:36 to 08:51:48) sub-synchronous oscillations in system frequency were observed from 08:52:10 to 08:53:02
- Frequency was oscillated between 49.7Hz to 49.717Hz, with the oscillation frequency of around 3Hz
- Examining the active power and frequency more closely shows that the GFM-I provided the anti-phase damping and thus acted to return the frequency to a stable state
- The peak-to-peak value was 194.8MW to 196.8MW



Measured Active Power and Frequency



Zoom in Measured Active Power and Frequency to show the phase relationship

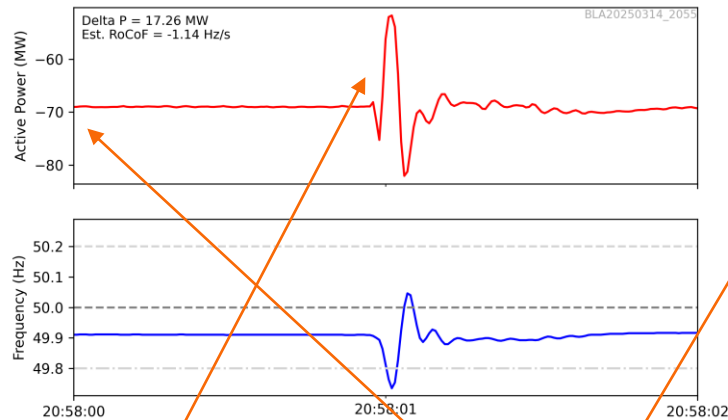


# Case Study – Zenobe 200MW Blackhillock GFM BESS

## Subsequent events

Date	Source	Frequency (Hz)		RoCoF		Blackhillock Power (MW)		
		Pre	f_min	NESO (500ms rolling measurement)	Back-calculated from Blackhillock inverter response	Initial	Delta	Infeed loss
14-Mar-25	Possible phase angle jump	49.91	49.73	n/a	-1.14	-69	17.3	n/a
11-Jun-25	Sizewell trip	50.08	49.77	-0.216	-0.28	-61	4.3	1192.75
27-Apr-25	Viking HVDC trip	49.961	49.77	-0.183	-0.34	0	5.2	986.9

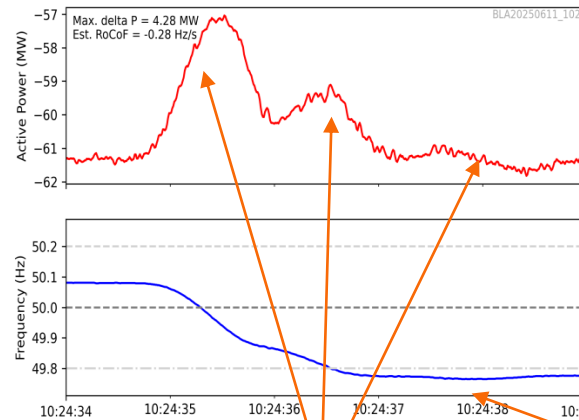
Frequency disturbance  
14<sup>th</sup> March 2025, 20:55



Maximum designed response supports the network

Correct response provided through the plants operational range

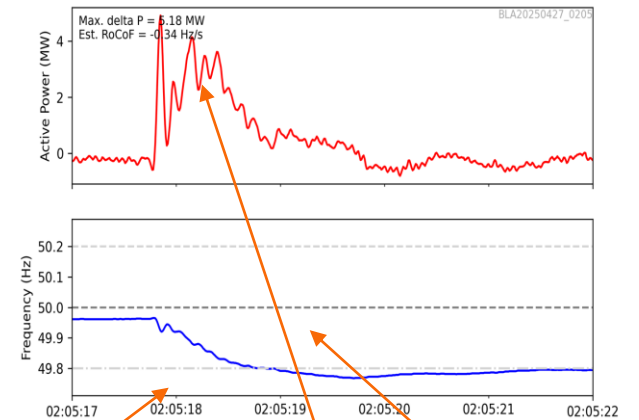
Loss of generator infeed (~0.9GW)  
11<sup>th</sup> June 2025 / Sizewell



Continues to support the network over the duration of the event

Similar overall response characteristic to similar loss of infeed events

HVDC trip (~1.4GW)  
27<sup>th</sup> April 2025 / Viking



Supporting stability within the overall event