SCOTTISHPOWER RENEWABLES

ESIG - 2022 SPECIAL TOPIC WORKSHOP: GRID-FORMING IBRS
June 6-9, 2022
The Curtis Denver – Denver, Colorad

Experience of using Grid Forming converters for Islanding and Black Start at Dersaloch Wind Farm.

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This presentation is a summary of papers presented at the 2020 Wind Integration Workshop

Overview

- Background & Site Used
- The Project
- The Test Setup
- Implementation by Operator
- Example results
- Comments and Conclusions

SPR would like to acknowledge the funding support provided by the Scottish Government via the Low Carbon Infrastructure Transition Programme (LCITP) and the support and access provided by SP Energy Networks the local transmission owner/ operator

The Background and Site

General increase in renewables penetration means more convertor connected generation dominated – need services from wind not previously sought by system operator

- Dersalloch Windfarm
  - 69MW windfarm in Ayrshire, Scotland
  - 23 of 3MW direct drive SGRE D3 wind turbines
  - 3.4MVA 33/0.69kV WTG transformers
  - 90MVA Grid Transformer

The How

VSM Dersalloch

Pilot at Dersalloch to test and validate the software

- Phase 1 – World's first windfarm to provide inertial response
- Phase 2 – Operate entire windfarm in island mode
- Phase 3 – Black start the windfarm without grid
- Phase 4 – Black start parts of the transmission system from the windfarm

Simulations of the wind turbine and wind farm by SGRE in RTDS. (2018 onwards)

Test and validation in grid connected mode (2019)

More simulations by SGRE

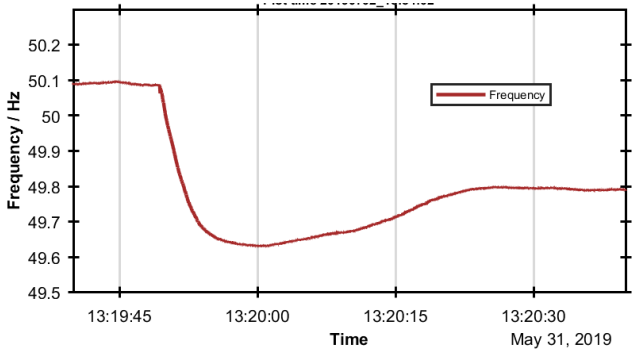
Design review performed by SPR's consultants

System and Protection by SPEN

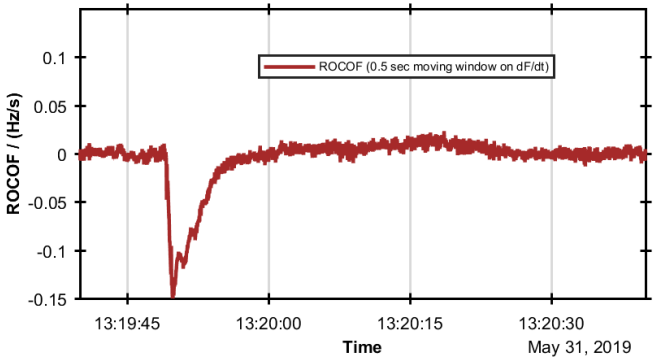
Test and demonstration in island and black start modes (2020)

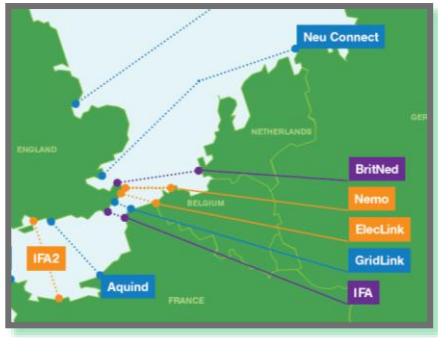
IFA trip 31 May 2019 13:19. Park H = 4 s. ~-0.1 Hz/s, 0.5 Hz frequency drop. Windfarm response ~0.6-1.2 MW

(a) 33 kV PQ analyser frequency

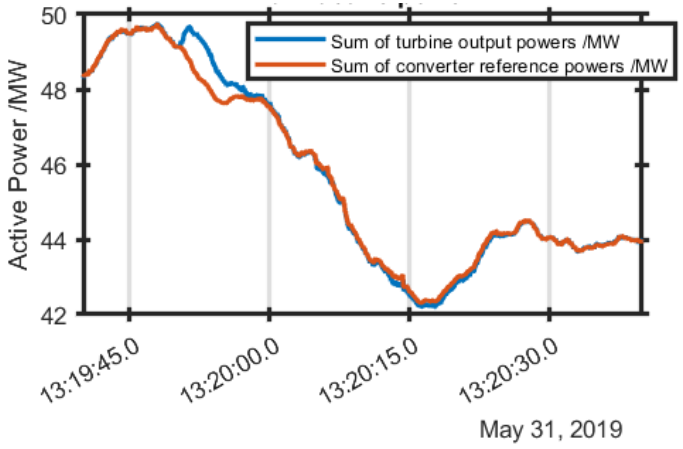


(b) SPR 33 kV PQ analyser ROCOF

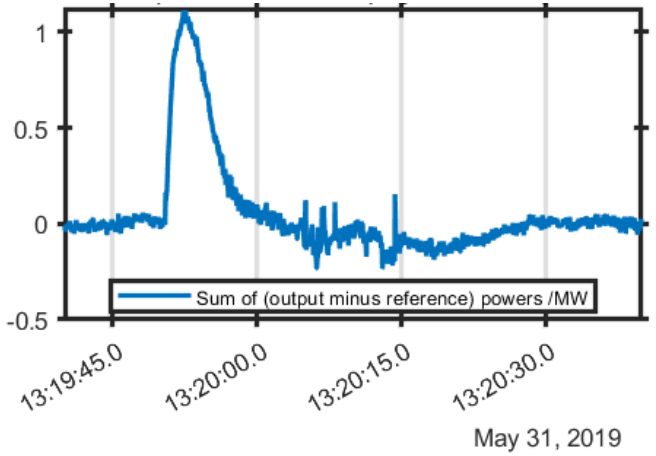




(c) WIndfarm power output and reference



(d) Windfarm power output minus reference



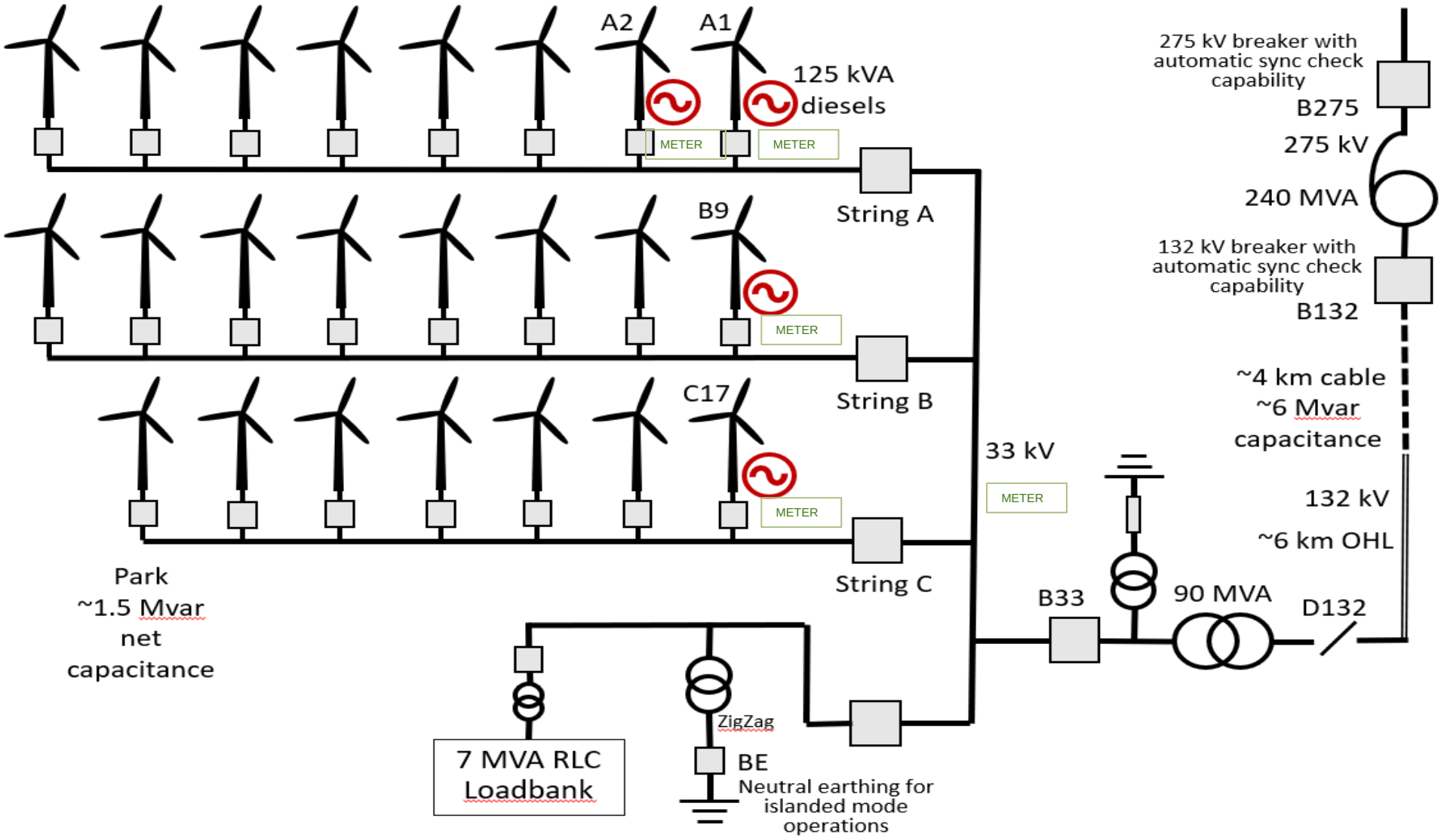
$$\Delta P \approx -\frac{2 \times H \times S_{Rating}}{f_0} \times \frac{df}{dt}$$

$$\Delta P \approx -\frac{2 \times 4 \times 69}{50} \times -0.11$$

$$\Delta P \approx 1.2 \text{ MW}$$

Test Setup

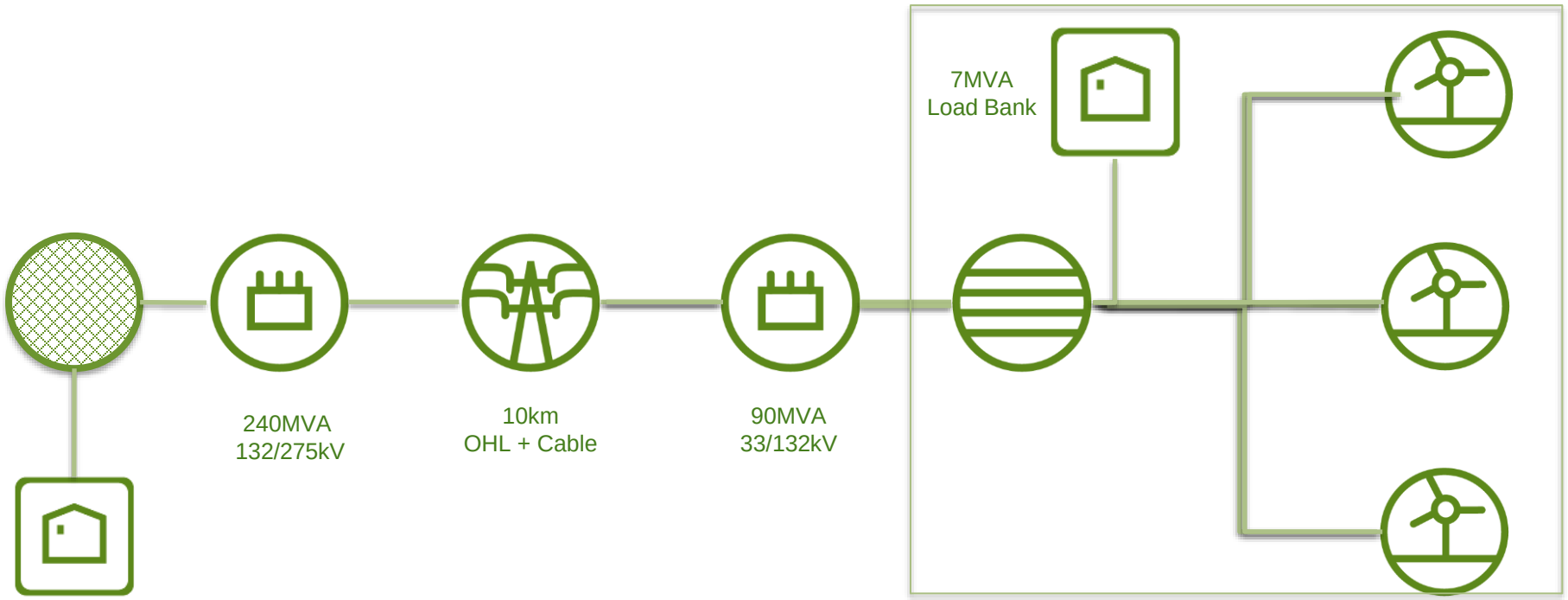
Single Line Diagram (Simplified)



The Project

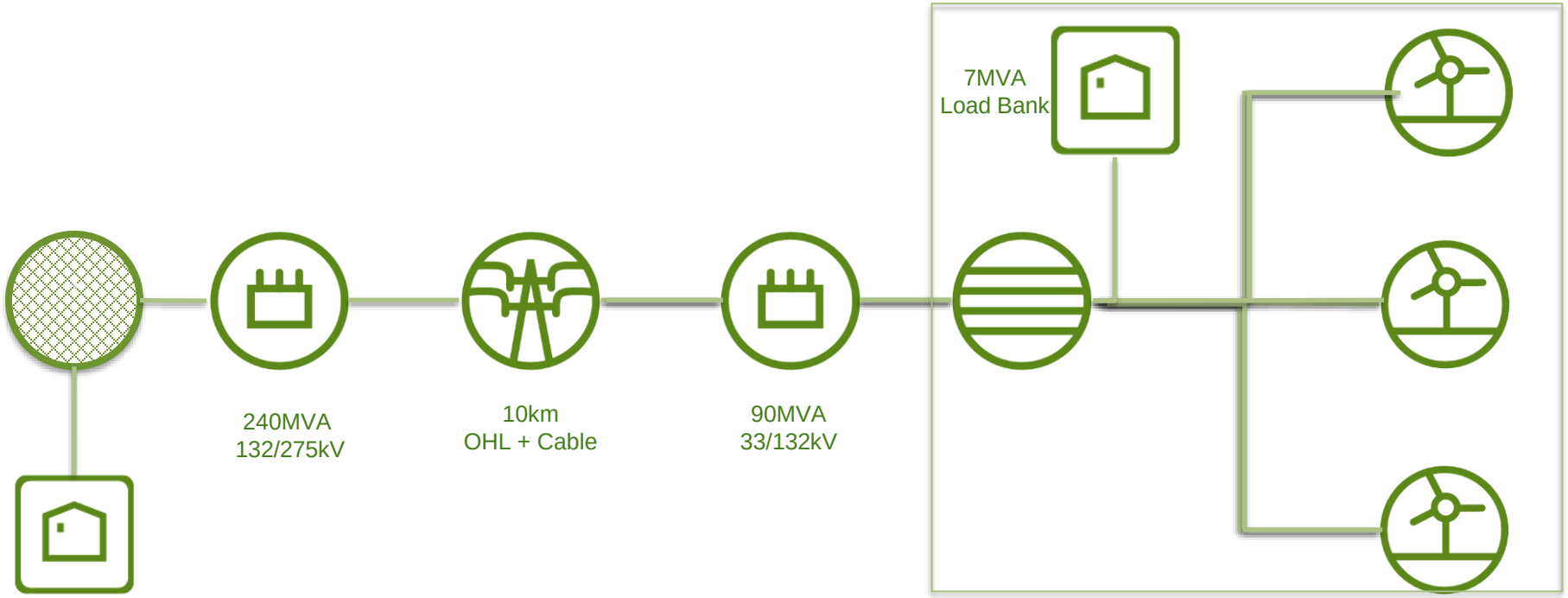
Island mode

- Move from grid connected to island operation
- Synchronise with the grid at 33 kV (SPR breaker)



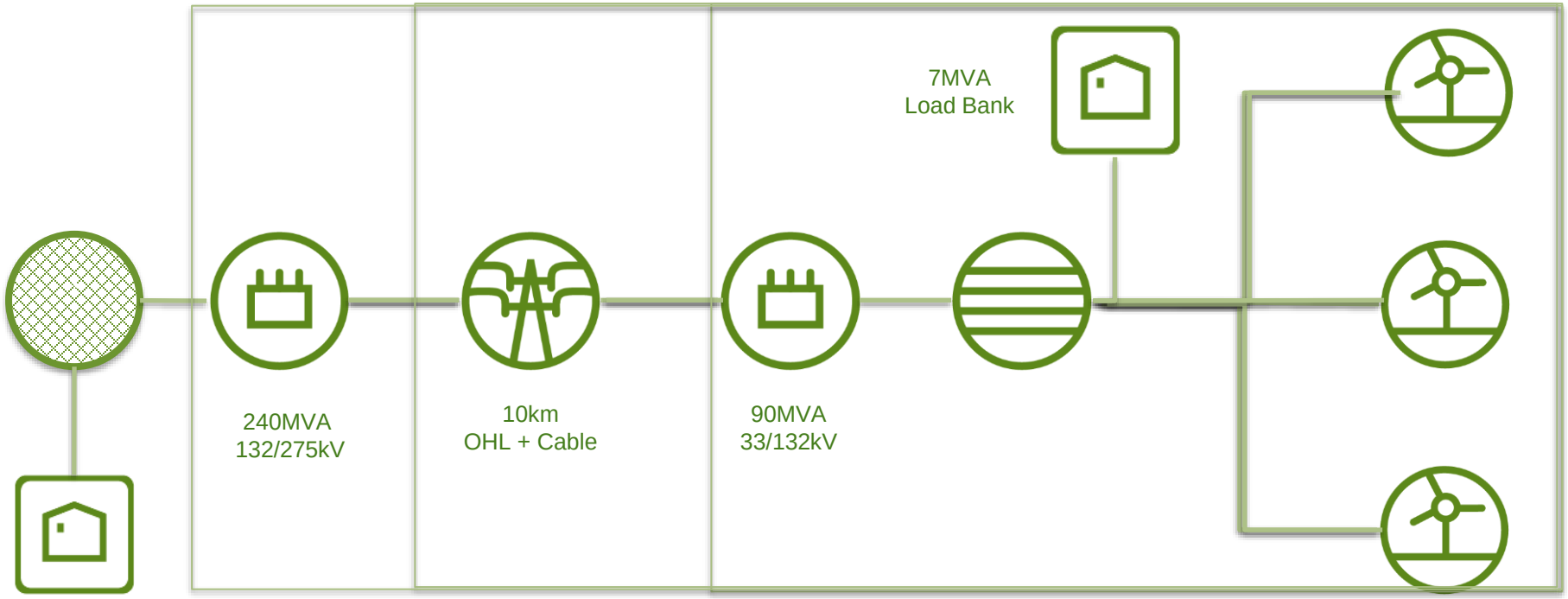
Black start – wind farm

- Start the wind park from de-energised state using wind turbines both ramps and direct-online, grid breaker open
- Synchronise with the grid at 33 kV (SPR breaker)



Black start – wind farm + grid transformers + OHL

- Start the wind park, grid transformers and OHL from de-energised state using wind turbines using both voltage ramps and direct-online energisation
- Synchronise with the grid at 132 kV (TO breaker)



Operator Considerations

Operator Main Concerns

- Electrical
  - Protection systems operation
  - Transient over-voltages
  - Harmonics
  - Power oscillations
  - Earthing
- Mechanical
  - Impact on WTGs of Grid Forming
- Operational Challenges
  - Potential for network to be unknowingly energised.
  - Connection of an earthing point in island

- SPR reviewed the protection and control strategy for the wind park and directed a number of changes to incorporate
  - More use of forms of voltage protection at the main switchboard (SWB),
  - Making the overcurrent more sensitive at main SWB,
  - Disabling WTG transformer voltage protection,
  - Introduced inter-tripping between all main SWB feeders and the WTG transformer breakers,
  - And disabling all auto-reclose schemes.

SPR performed load flows and indicative energisation studies to check that the wind park would be kept within ratings – cross-checked with SGRE studies.

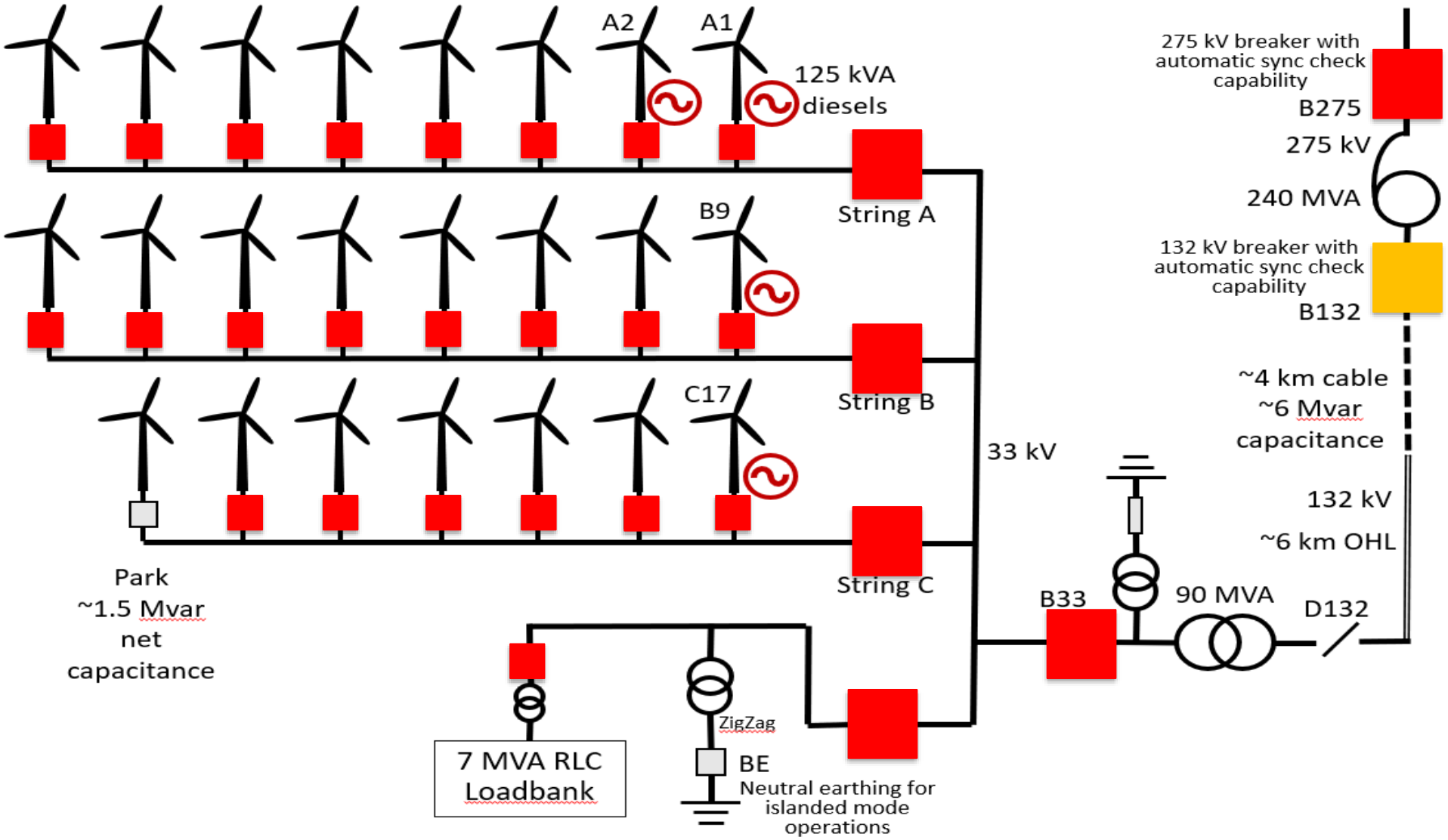
Protection

Review and update of protection systems identified the following main unresolvable issues:

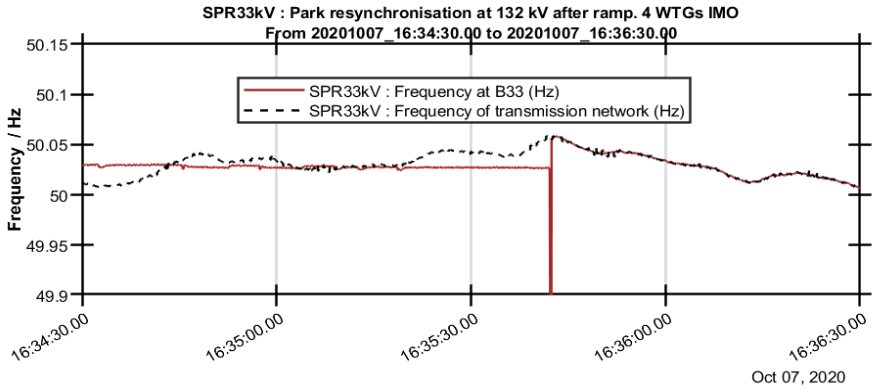
- During island mode
    - MV Line-Line-Line (LLL) faults with 23 WTGs and fault resistance (Rf) > 37 Ohms.
- The following faults cannot be detected during a blackstart mode of operation
    - MV LLL faults with 23 WTGs and Rf > 37 Ohms (windfarm network),
    - LV LLL faults with 1 or 23 WTGs and Rf = 0 Ohms (WTG LV voltage),
    - LV LLL faults with 1 WTG and Rf = 0 Ohms (auxiliary systems LV voltage).
- The identified MV faults are also an issue for the TO
- A risk assessment approach was used to allow the testing to continue

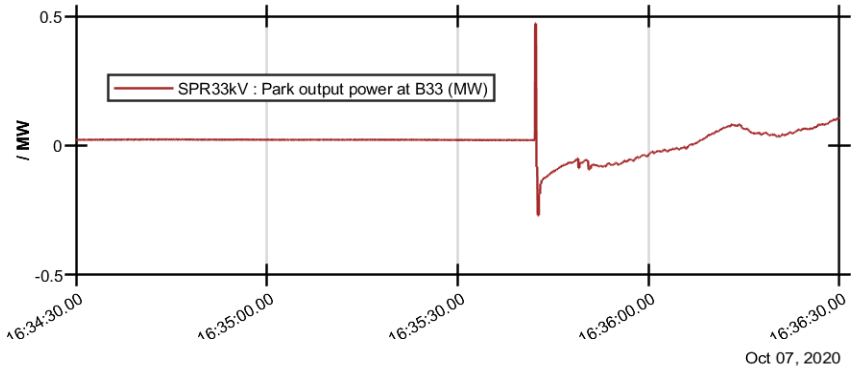
Results

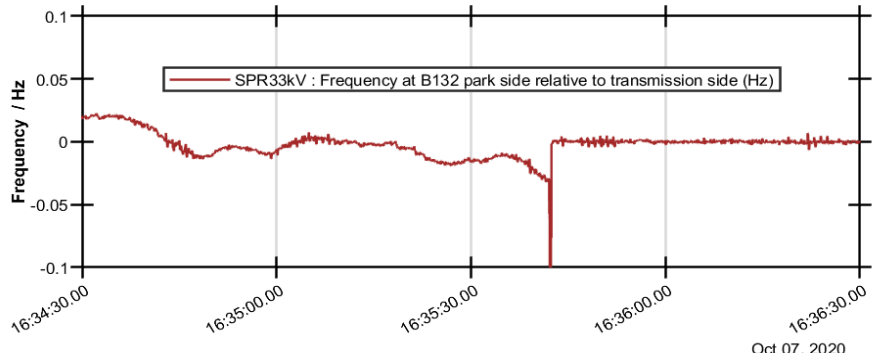
Re-synchronisation at 132kV at B132

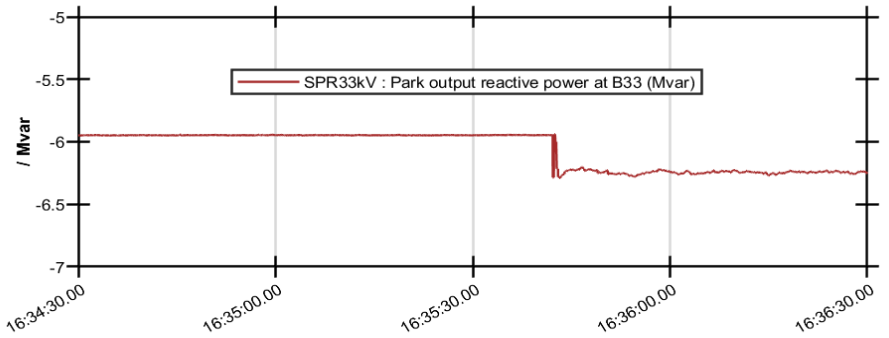


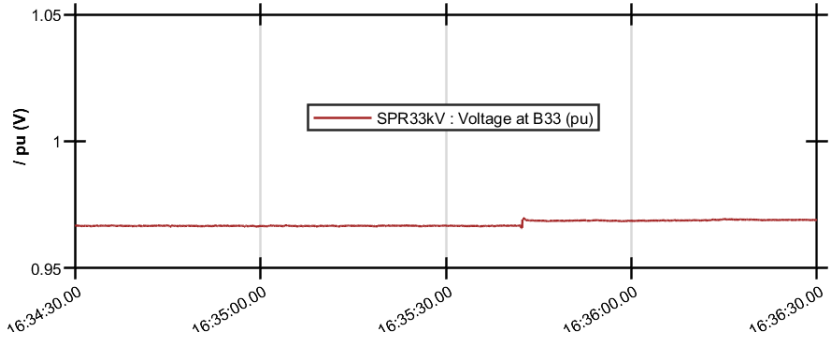
Re-synchronisation at 132kV at B132



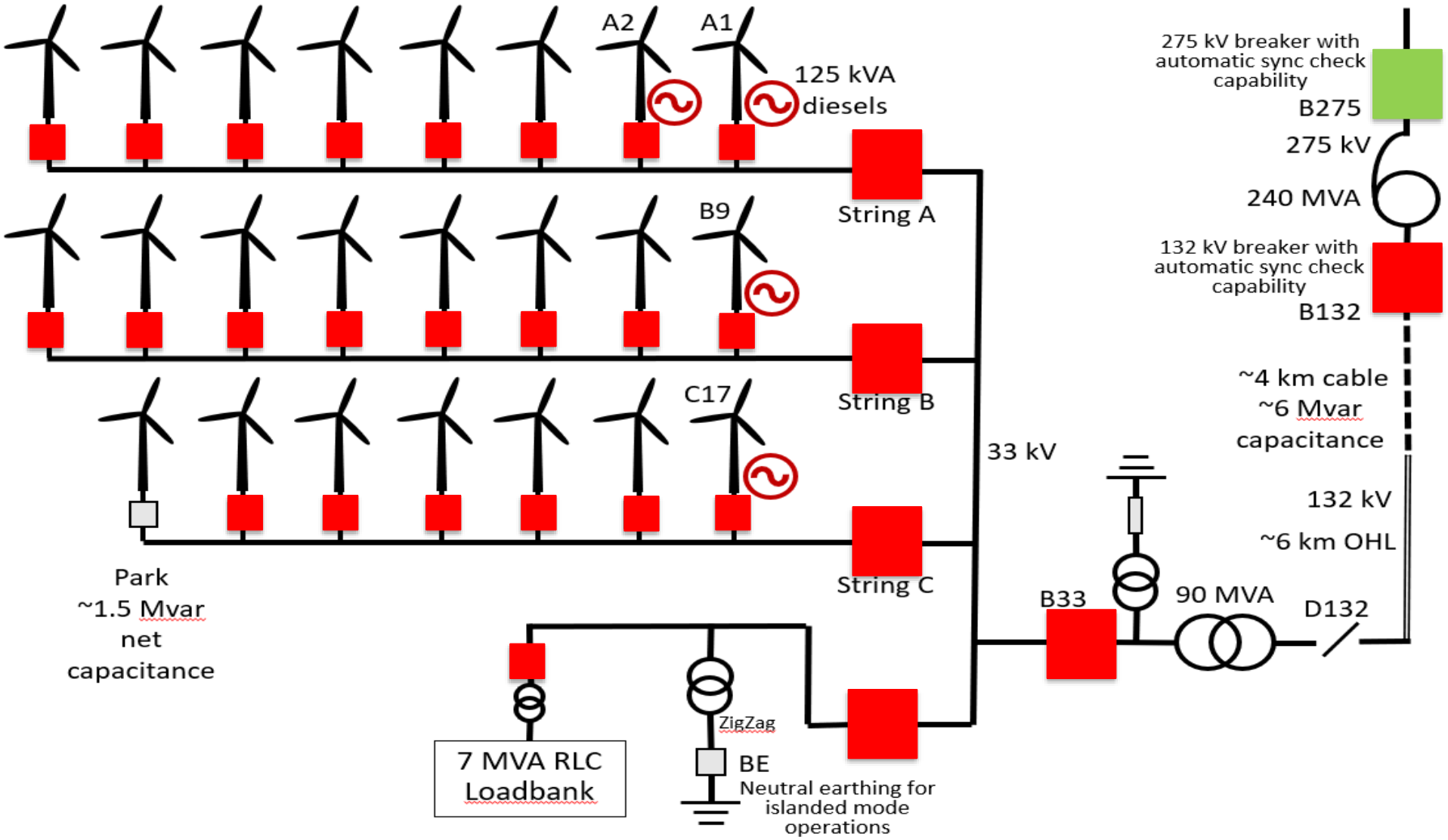






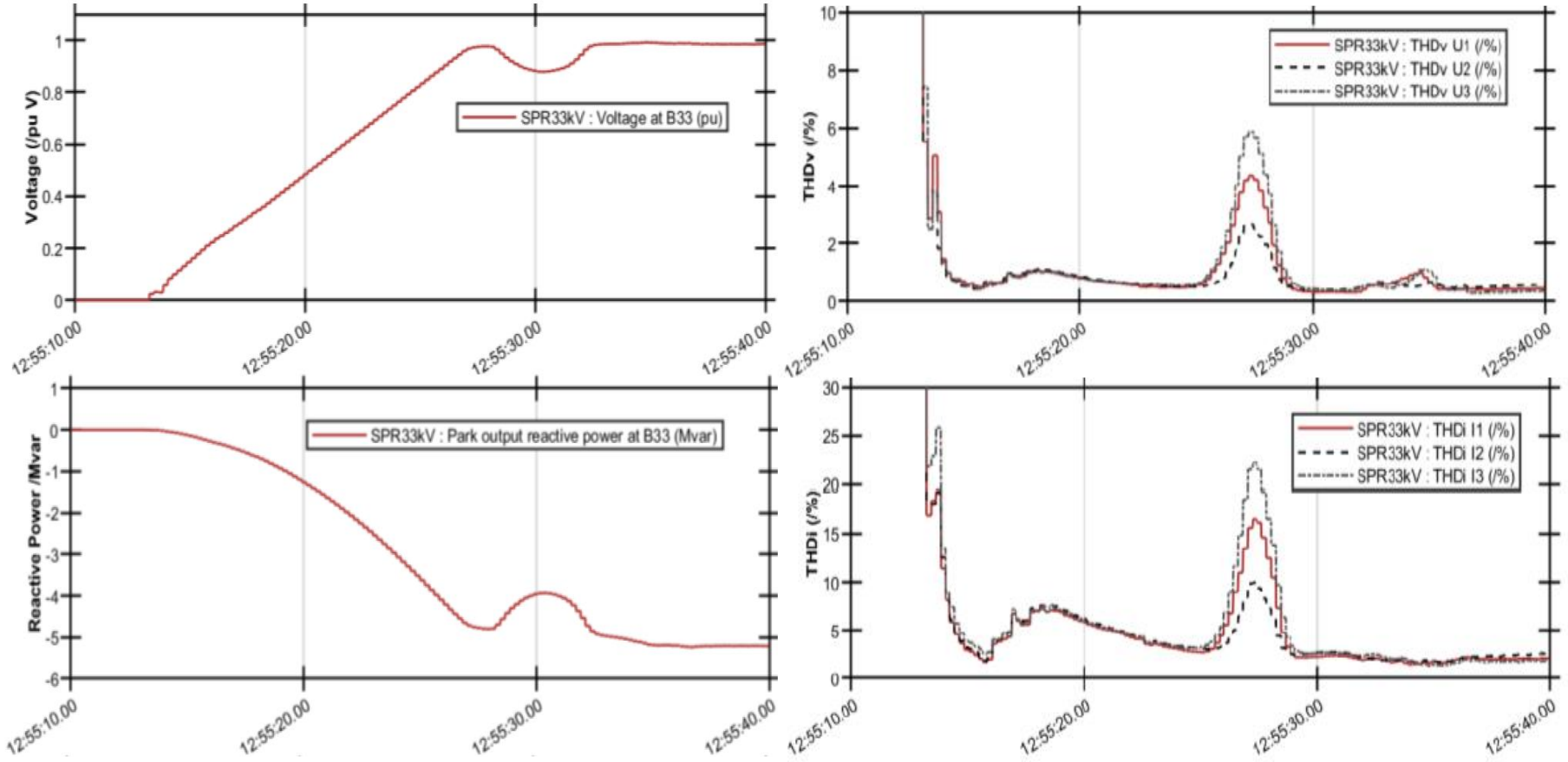


Ramp Energisation of Super Grid Transformer

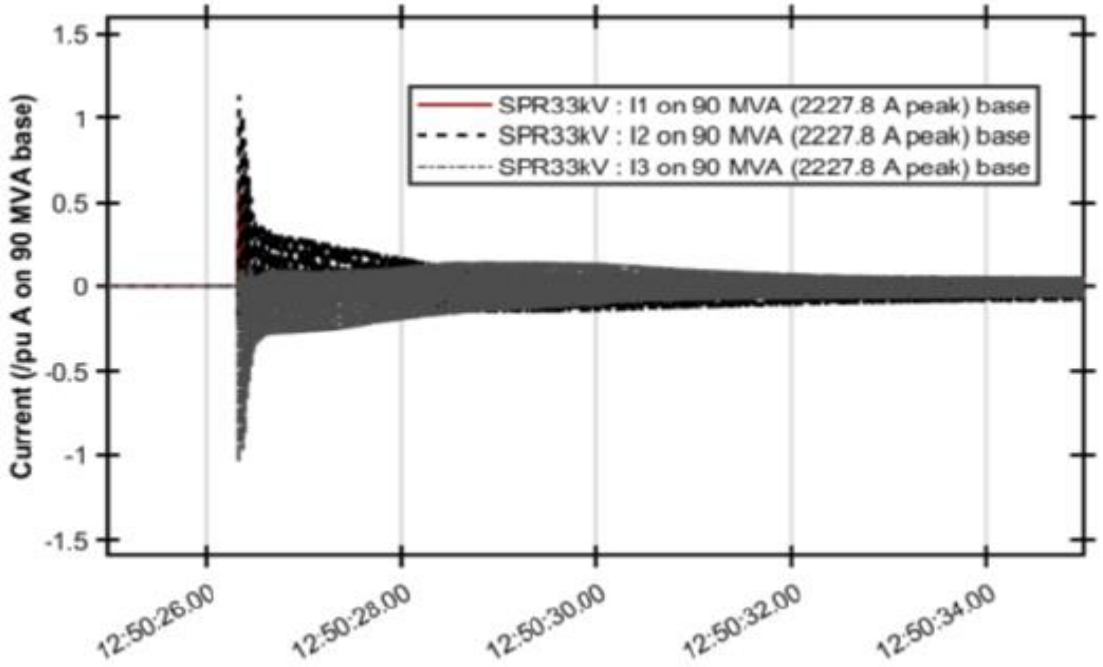


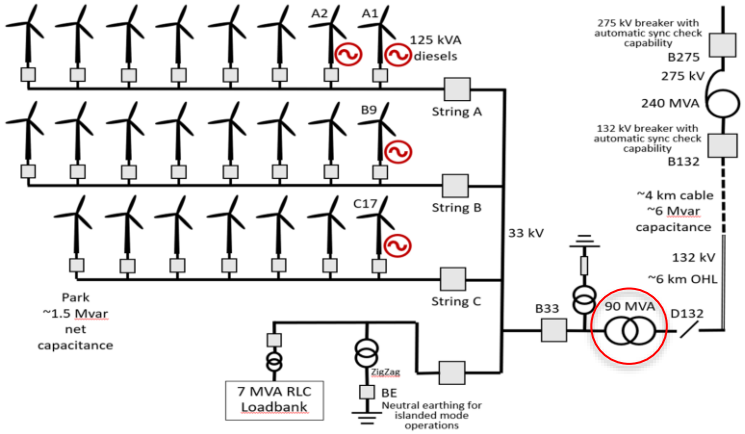
Ramp Energisation of Super Grid Transformer

Voltage, Reactive Power output, THDv, THDi at 33kV Wind Farm Breaker



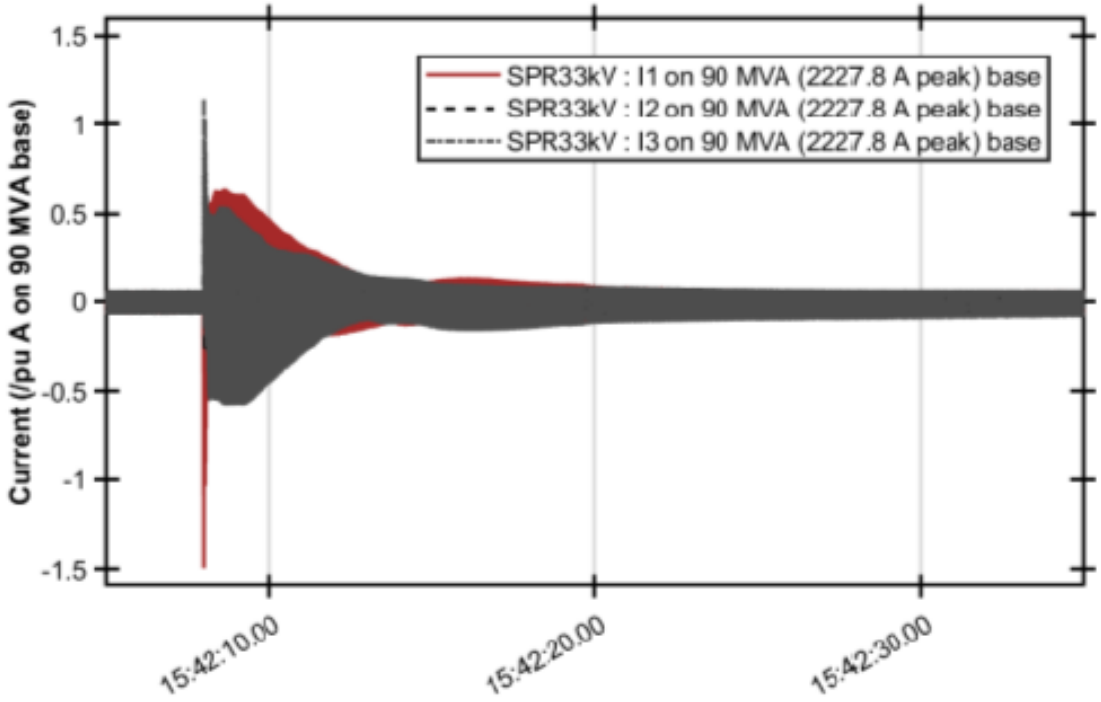
Current Envelope for DOL of 90MVA grid transformer (132/33kV)

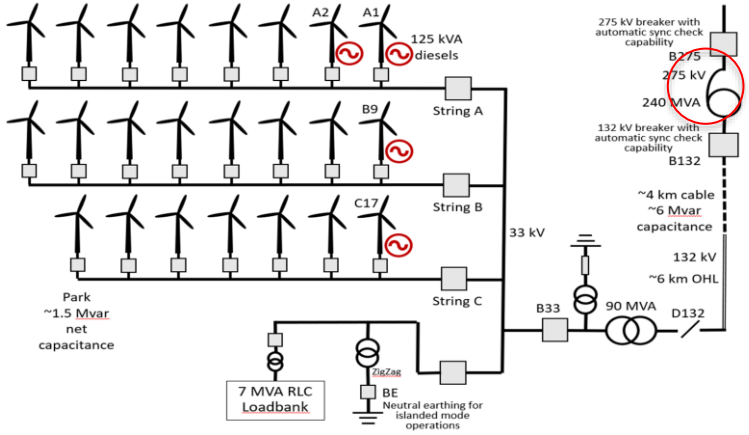




Direct Online Energisations

Current Envelope for DOL of 240 MVA grid transformer (275/132 kV)





Conclusions

Conclusions

- The protection and control systems on operational windfarms need adaption to be suitable to perform island and blackstart operations
- It is possible for a windfarms to energise itself with a small power source, energise part of the transmission system and then synchronise with the external grid
- The concept of wind-only power islands and wind led black-start is not unreasonable and is worthy of further investigation and development effort.
- However, there is still some work to be done to create an autonomous and resilient wind park islanding and blackstart system and
- Also for transmission networks to be able to operate safely with only small amounts of connected generation.

References

1. Roscoe, A., Brogan, P., Elliot, D., Knueppel, T., Gutierrez, I., Perez-Campion, J., Da Silva, R.: 'Response of a Grid Forming Wind Farm to System Events, and the Impact of External and Internal damping', in IET Renewable Power Generation Journal
2. Roscoe, A., Brogan, P., Elliott, D., Knueppel, T., Gutierrez, I., Perez-Campion, J., Da Silva, R.: 'Practical Experience of Operating a Grid Forming Wind Park and its Response to System Events', in 18th Wind Integration Workshop' (2019),
3. Roscoe, A., Brogan, P., Elliott, D., Knueppel, T., Gutierrez, I., Crolla, P., Perez-Campion, J., Da Silva, R.: 'Practical Experience of Providing Enhanced Grid Forming Services from an Onshore Wind Park', in 'Virtual 19th Wind Integration Workshop' (2020),
4. Roscoe, A., Brogan, P., Elliott, D., Knueppel, T., Gutierrez, I., Crolla, P., Perez-Campion, J., Da Silva, R.: 'Operator Considerations for the Implementation of' Testing Enhanced Grid Forming Services on an Onshore Wind Park', in 'Virtual 19th Wind Integration Workshop' (2020),

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Thank You For Listening

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