Zero-miss Phenomenon in Offshore Wind Farms

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Agenda

1)Overview of zero-miss phenomenon

2)General introduction to the project

3)Zero-miss at 220kV in Burbo Extension

4)Mitigation for 220kV

5)400kV zero-miss issue

6)Discussion

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What is Zero-miss?

- Zero-miss is a phenomenon that occurs during simultaneous energisation of inductive and capacitive equipment. The inductive equipment can be a shunt reactor and capacitive equipment can be cable or harmonic filter.

- If energized at voltage zero (current max), the high DC component of the inductive equipment makes the current flowing through the circuit breaker (CB used for energisation) not see a zero-crossing for several seconds.

When does this occur?

- Theoretically, this occurs during simultaneous energisation of cable and reactor when reactor compensates for >50% of the cable

- Also occurs during simultaneous energisation of harmonic filter (capacitive component) and reactor where reactor compensates for more than 50% of the harmonic filter

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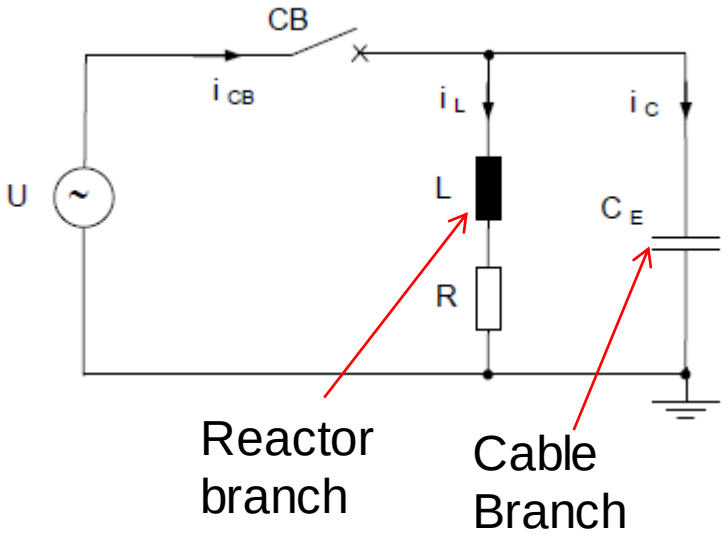
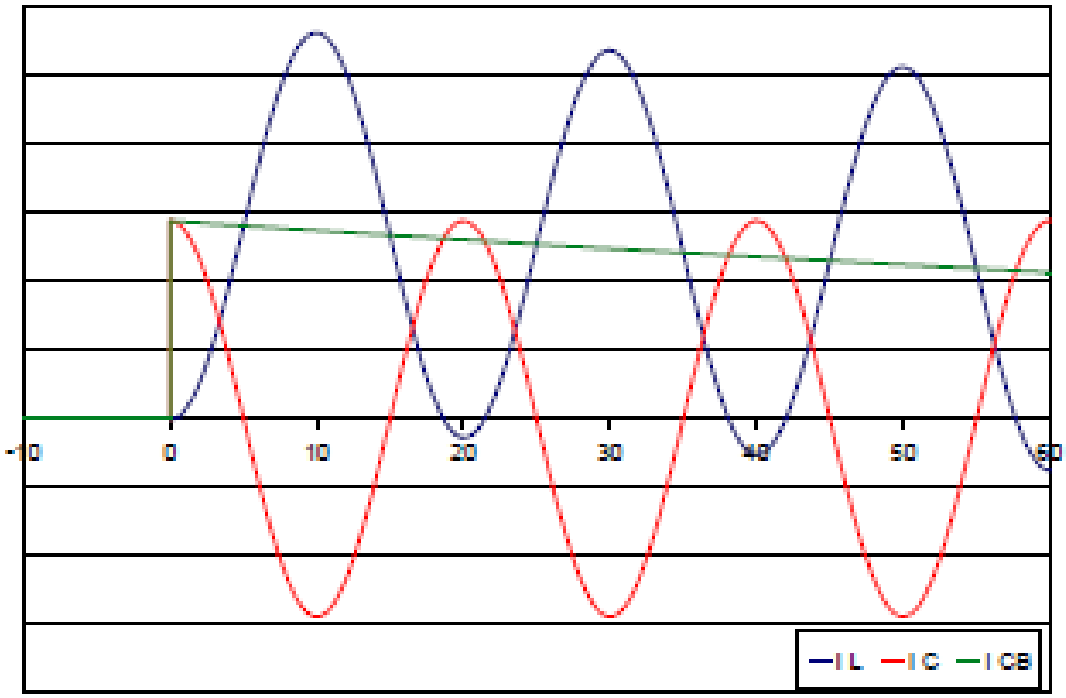
Theory behind zero-miss



A simple RLC circuit illustrating zero-miss



Currents when cable is 100% compensated and switched in at voltage zero (current maximum)

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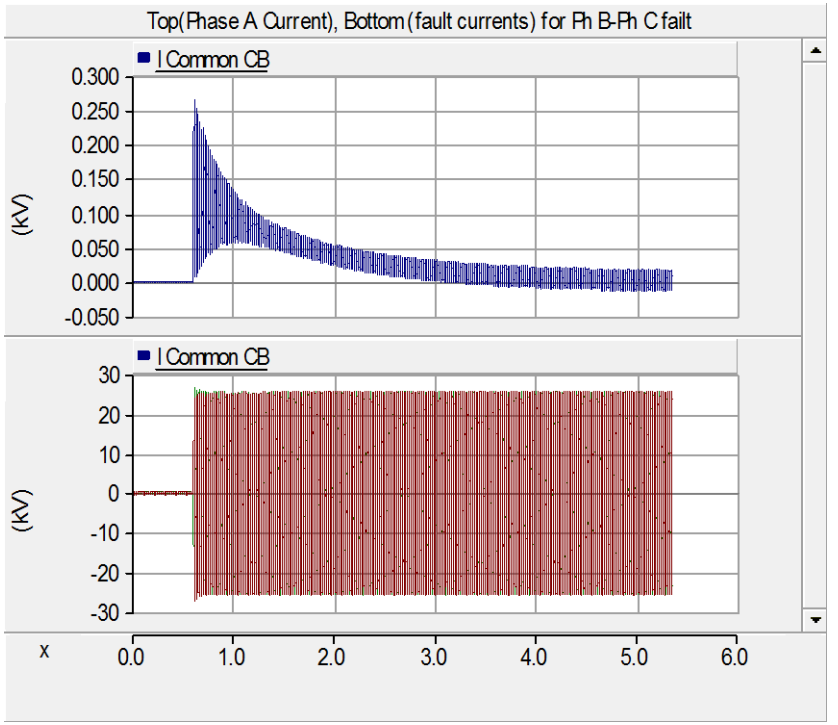
Is there a problem due to zero-miss?

- Zero-miss itself is NOT a problem if we don't need to operate the breaker after energisation until the system reaches steady-state
- Also, for a 3-ph fault on the equipment (cable, reactor or filter), this is again not a problem because the ac fault current will be more dominant than the DC component making the current to cross zero. Hence, the breakers can be opened
- If there is a unbalanced fault on equipment (e.g. L-G, L-L-G, L-L), we are able to open the breaker pole for the faulty phases but may not be possible to open healthy phase poles as they may not see a zero-crossing
- If we still try to open, there is a possibility of damage to the circuit breakers and also to any personnel if precautions are not taken.



Output currents through the circuit breaker for B-C fault

Why do we energize this way

Reactive power compliance requirement (UK Grid Code: CC.6.3.2)

- As per the Grid Code, we are supposed to be operating at Unity Power Factory (zero Q transfer) at the PCC with an allowed tolerance of ±5% of transfer capacity
- We should be compliant with this requirement also during energisation, otherwise we need to seek derogation from TSO

Voltage Fluctuation requirement (UK Grid Code: CC.6.1.7)

- In case of long export cables there is a high possibility that, we exceed the allowed 3% voltage fluctuation if we energize cable alone. Hence, cable and reactor are energized together to reduce the voltage fluctuation

Possibility of reducing number of circuit breakers

- If we can manage the risk of zero-miss (or have a mitigation measure in place), we can reduce the number of circuit breakers required

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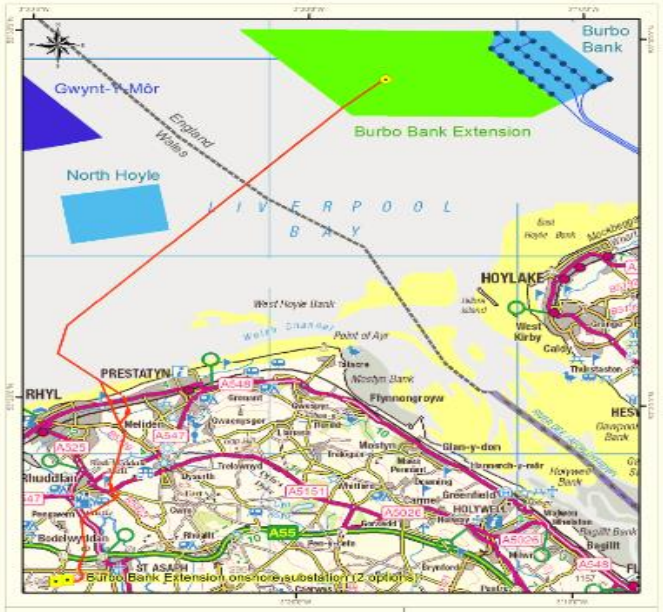
Burbo Extension - Transmission assets



General	▪ 256MW (32x8MW) rated generation ▪ NGET connection – Bodelwyddan 400kV substation, Wales
Offshore Substation (Platform)	▪ One 220kV Offshore platform structure ▪ Two 220/34kV 200MVA transformers ▪ Two 220kV circuit breaker bays
Export Cable	▪ One 220kV AC subsea cable ~23km long from offshore platform to beach near Rhyl ▪ One 220kV AC underground cable ~12km from Rhyl beach 400kV onshore substation
Onshore Substation 400 kV	▪ Two 200/200/80 MVA 400/220/7-13.9kV transformers ▪ One 220kV double busbar ▪ One 50MVAr STATCOM ▪ One 60MVAr reactor at 400kV and 125-55MVAr variable reactor at 220kV ▪ One 400kV double busbar and one 400kV generator bay ▪ One 60MVAr harmonic filter at 400kV and one 25MVAr harmonic filter at 220kV

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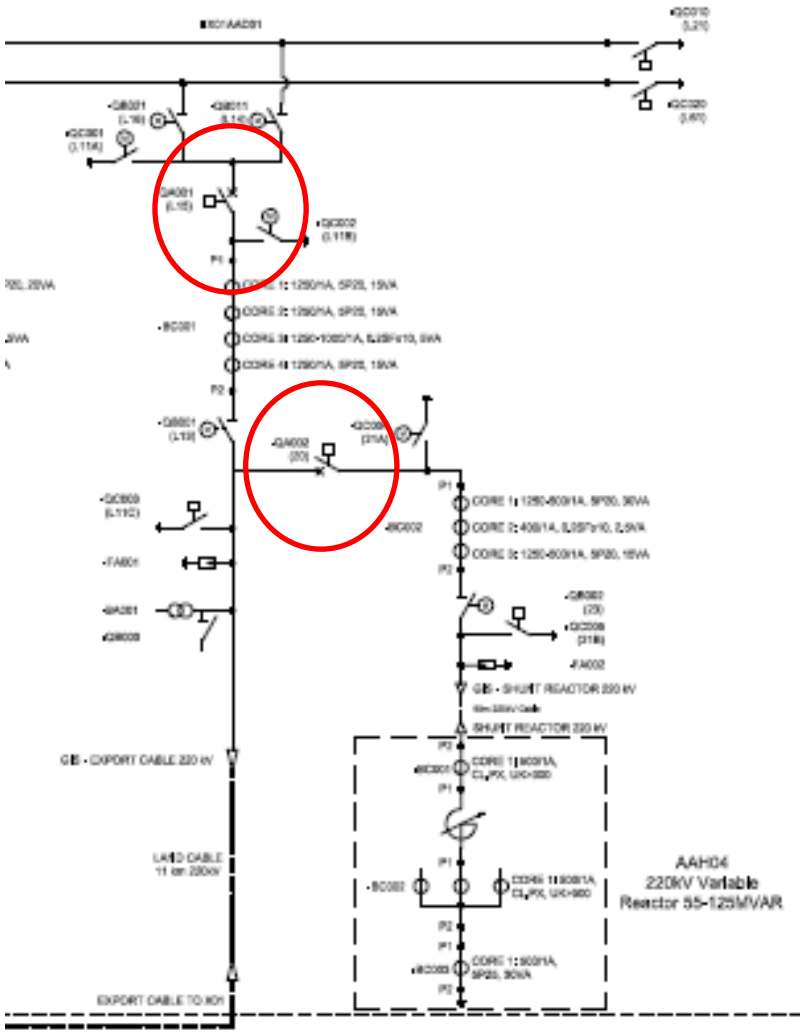
BBW02 220kV zero-miss issue

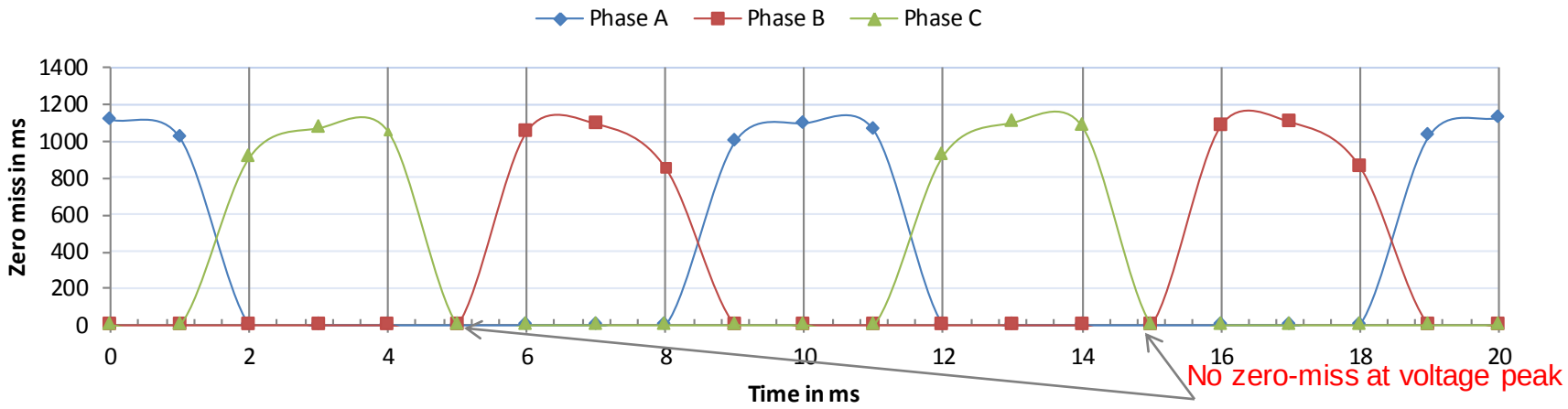
<u>Reactive Power Balance at 220kV</u>

Shunt Reactor: 55-125 MVAr

220kV Export Cable: ~35km, ~100MVAr



Results of Simultaneous energisation



Results of Single-pole energisation (no fault)

Switching Instant	Fault infeed from Grid	Zero miss period (ms)	V_CB (kV) peak	I_CB (kA) peak
Voltage Zero	Maximum	1150	214 (1.19pu)	0.742
Voltage Peak	Maximum	0	411 (2.3pu)	2.89

Results of energisation onto fault

Switching Instant	Fault infeed from Grid	Zero miss period (ms) L-G fault	Zero miss period (ms) L-L-G fault	Zero miss period (ms) L-L fault
Voltage Zero	Maximum	1010 – 1348	729 – 1648	1110
Voltage Peak	Maximum	756 – 976	455 - 1237	653 - 755

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Mitigation Options

Option	Description	Advantage	Disadvantage
1	POW or controlled switching.	• Minimises the current by allowing to switch at maximum voltage.	• Higher tolerance and not a fully reliable solution • Need to be used along with sequential switching for best benefit
2	Pre Insertion Resistors.	• The resistance in series with CB damps out the DC component and eliminates the zero miss.	• PIRs are not available as standard design at 220kV GIS and thus make it an expensive option.
3	Delayed switched of reactor and cable • Energise cable first and few seconds of delay (to trip the cable if required) and energise the reactor	• Faults on the cable (or filter) will be taken care by cable CB as primary protection. • No issue with zero-miss	• Exceeds the reactive power spillage at TIP (onshore) for few seconds • Needs an agreement with NGET on energisation sequence
4	Reactor tee'd into cable with additional CB	• Enables sequential switching without risk of loss of wind farm. • Minimises the voltage fluctuations during energisation • No problem of excess MVAr spillage to Grid	• Requires a rather complex protection scheme.

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What is sequential switching

For an A-G fault of the cable

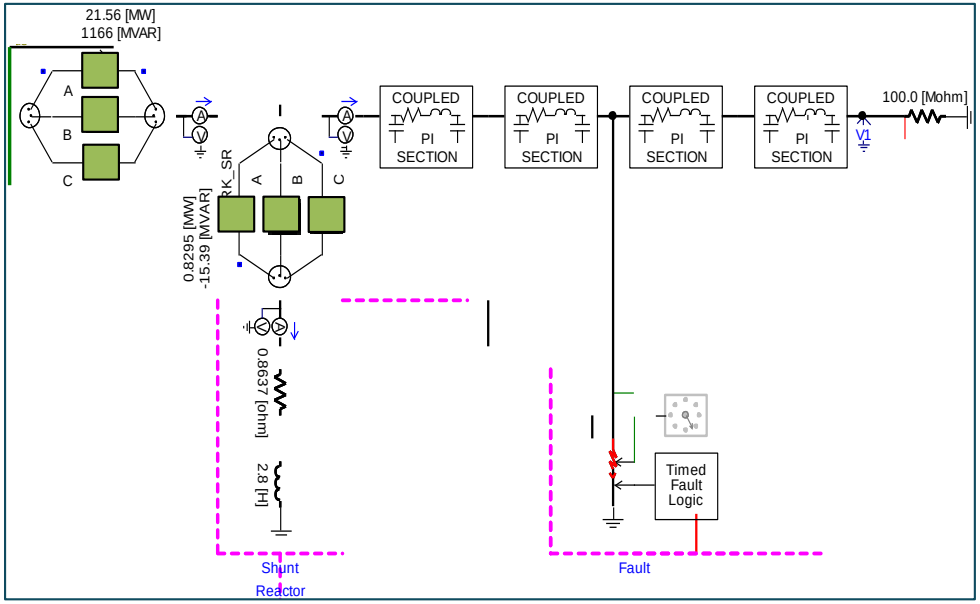
Step 1: Trip command to open the faulty phases of the common breaker used for energisation and hence clearing the fault in shortest possible time.

Step 2: Trip command to open the healthy phase poles of the reactor

Step 3: Trip command to open the healthy phase poles of the common breaker

Step 4: Trip command to open the faulty phase pole of the shunt reactor breaker

Step 5: Complete the switching sequence by opening the faulty phase pole of reactor breaker



This solution is proposed and to be implemented for BBW02 project.

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Zero miss – Lessons learnt from simulations and implementation

- Reactor Currents
  - In some cases, it was observed that the reactor currents of the healthy phases does not have a zero crossing by step 2
  - Due to this, an additional delay is implemented for opening of healthy phase of Reactor.

- Identification of fault
  - Sometimes it is not straightforward to identify the type of fault to initiate sequential tripping
  - It was also highlighted that certain mechanical protections of the reactor might pick-up and cause an unwanted three pole operation potentially causing damage to circuit breaker and could also be a HSE hazard.

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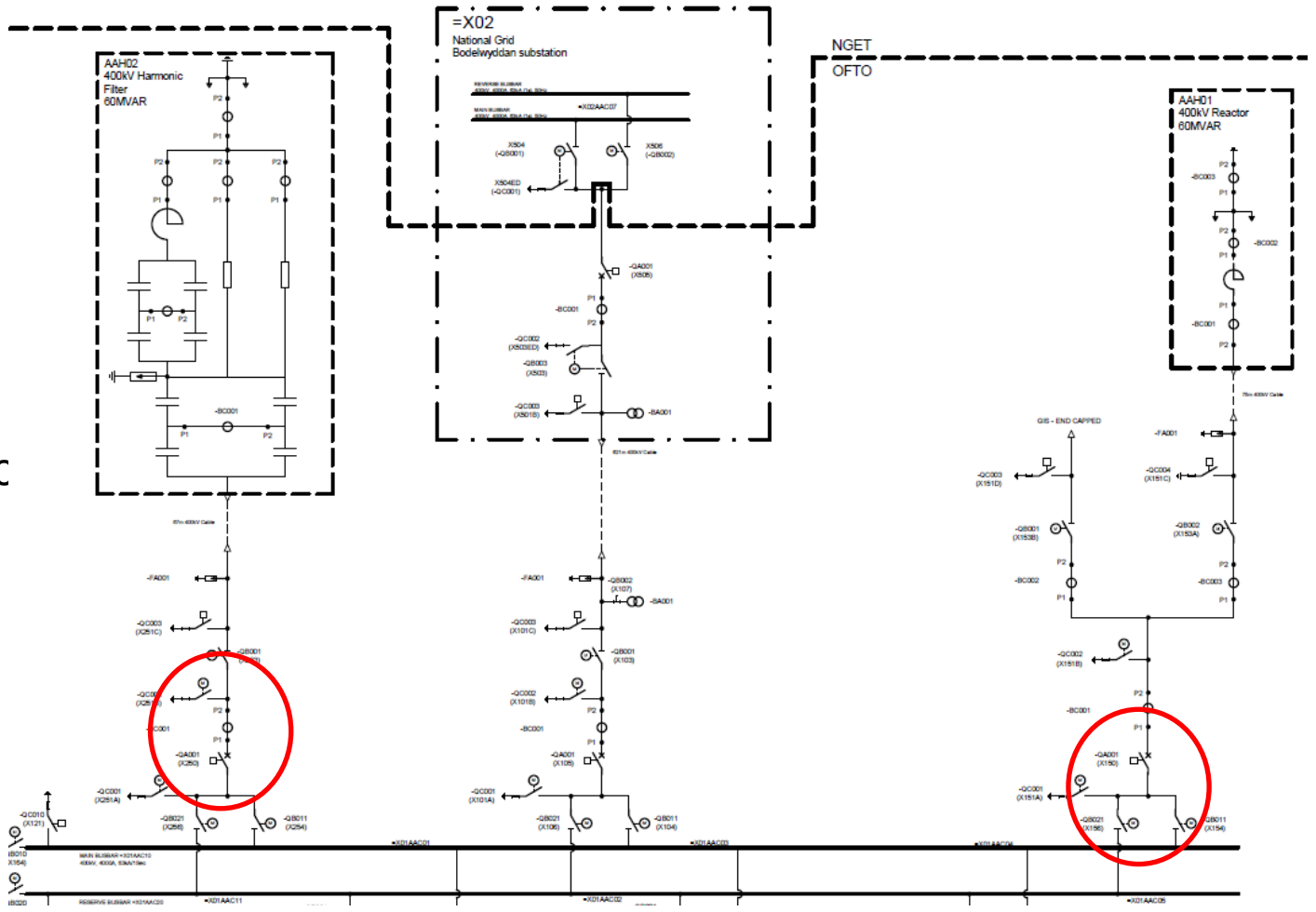
BBW02 400kV zero-miss issue

Reactive Power Balance at 400kV

Shunt Reactor: 60 MVAr

400kV Harmonic Filter: 60 MVAr



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Discussion

- What impacts does NGET see for reactive power non-compliance for few seconds to avoid this HSE hazard and technical issue?

- Can we raise GC modification to CC.6.3.2 to overcome this problem?

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Thank you for your attention.

Questions?

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