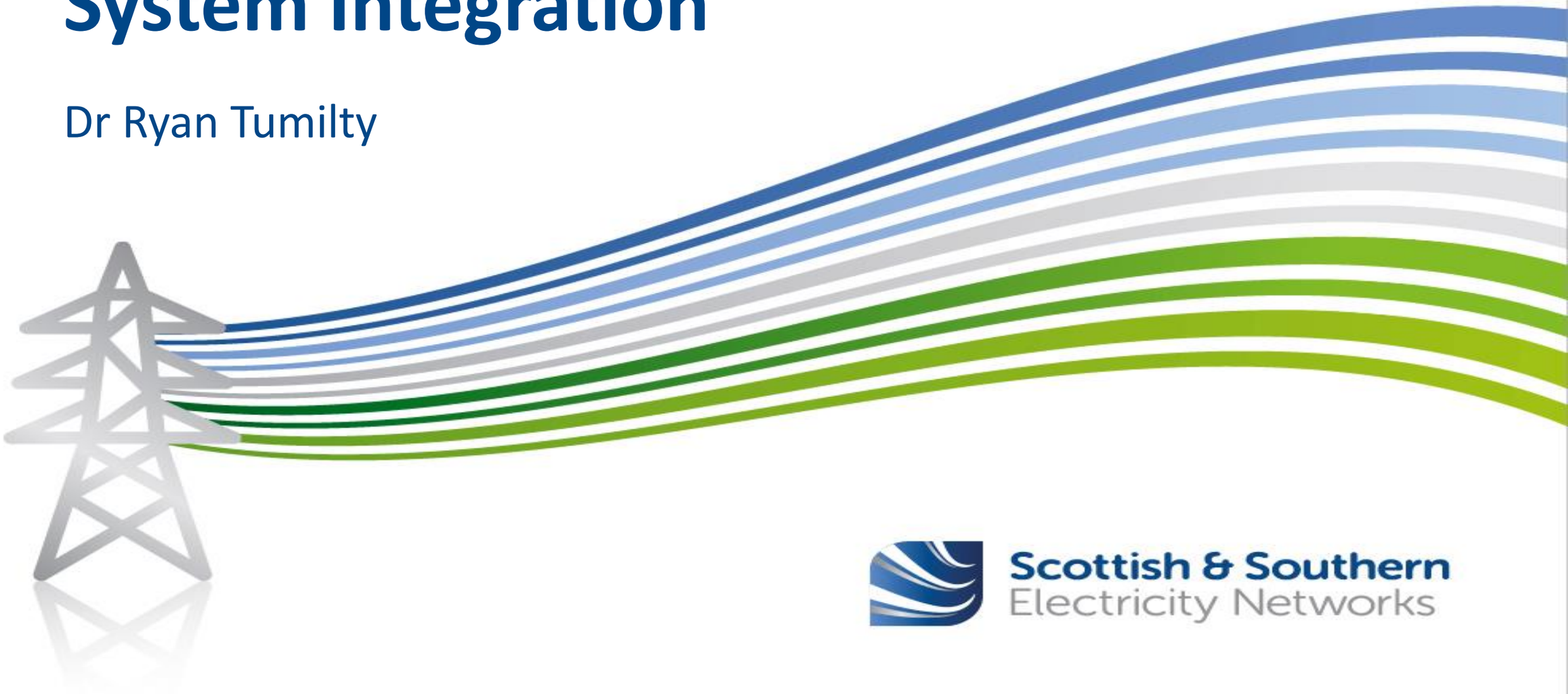
# Caithness – Moray HVDC System Integration

Dr Ryan Tumilty



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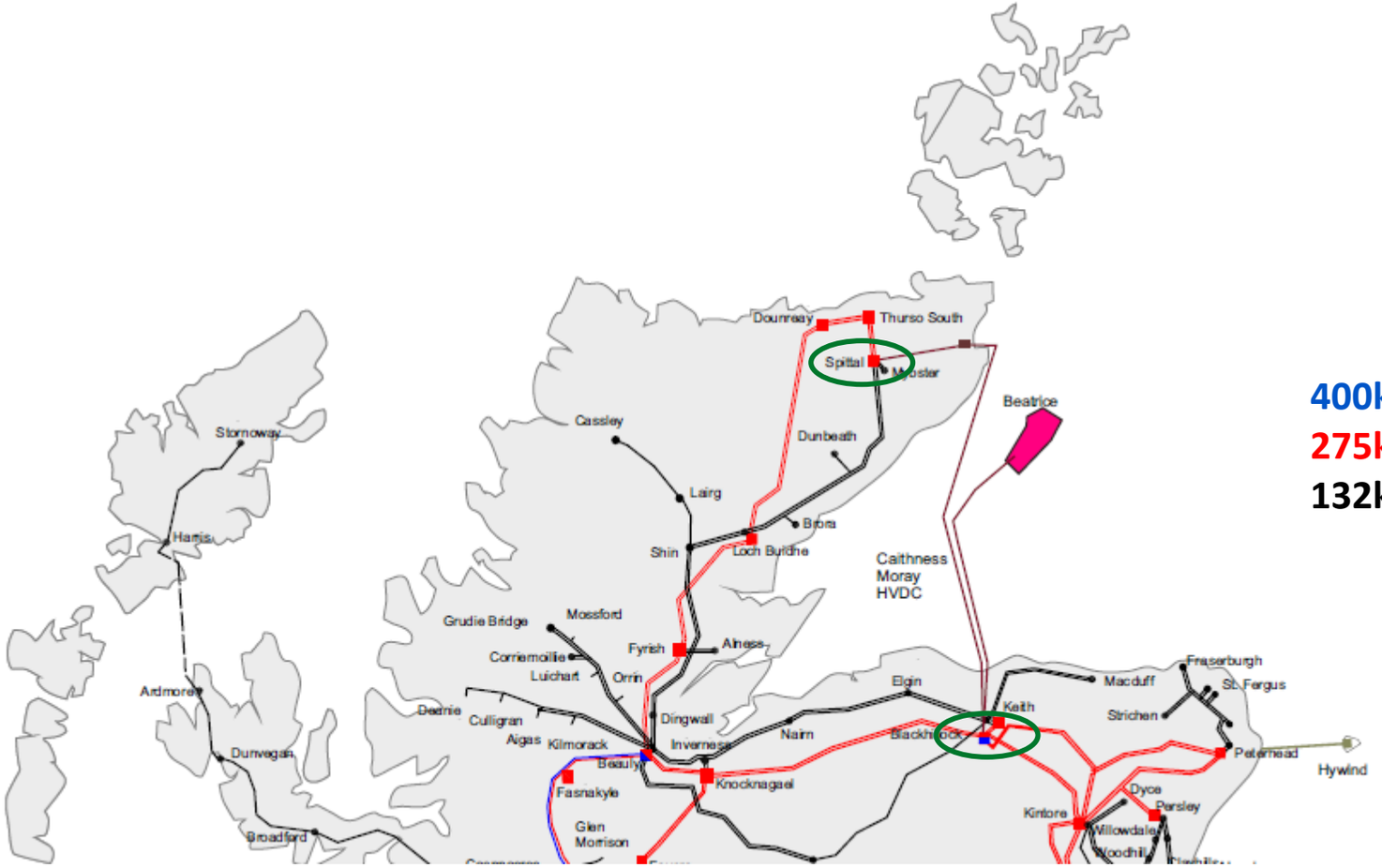
# Overview

- System integration challenges
- Key Challenge: Potential Overload Condition
- System Studies
- Control Requirements

# North of Scotland – System Integration Challenges

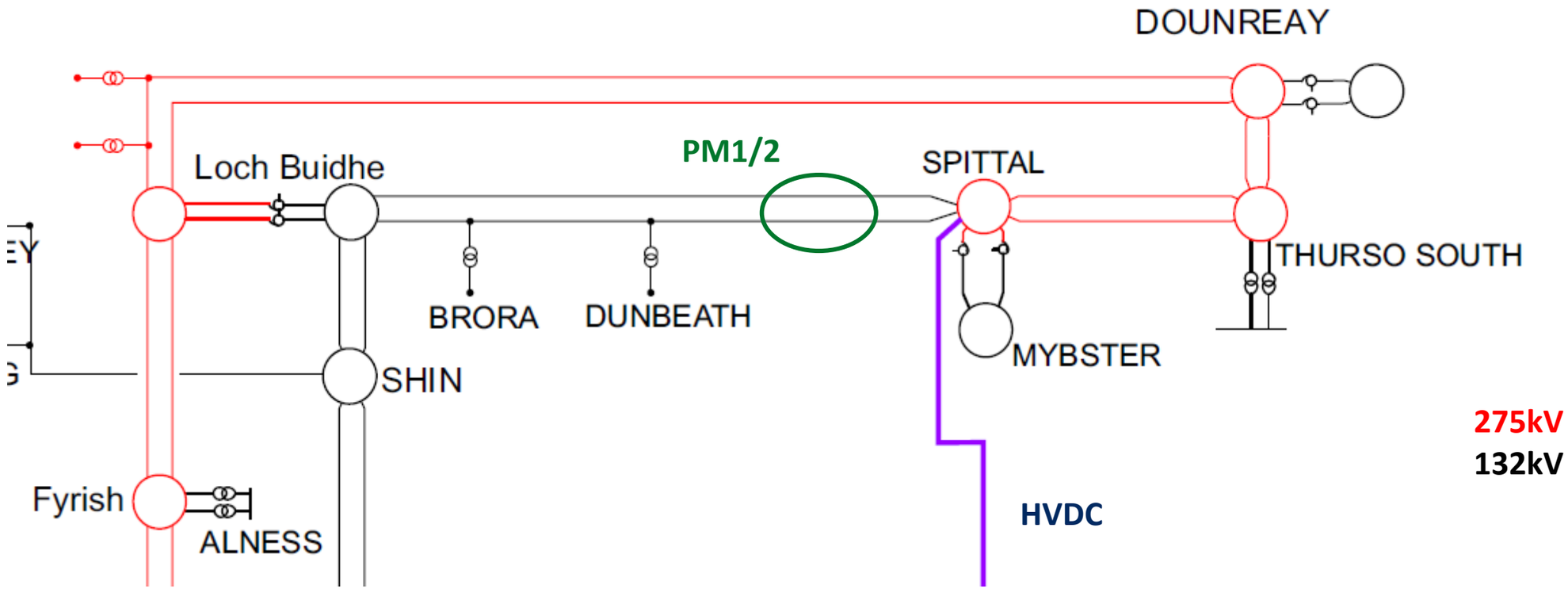
- Embedded HVDC link
- Relatively weak system with wide range of potential system strengths
- 275kV double circuit OHL in parallel with 132kV double circuit OHL
- Generation dominated by onshore wind



# Key Challenge: Potential Overload Condition

- Relatively low rating 132kV circuits terminating at Spittal (PM1/2)

- Potential for 132kV overloads on PM1/2 on 275kV N-D outages depending on generation and HVDC converter dispatch

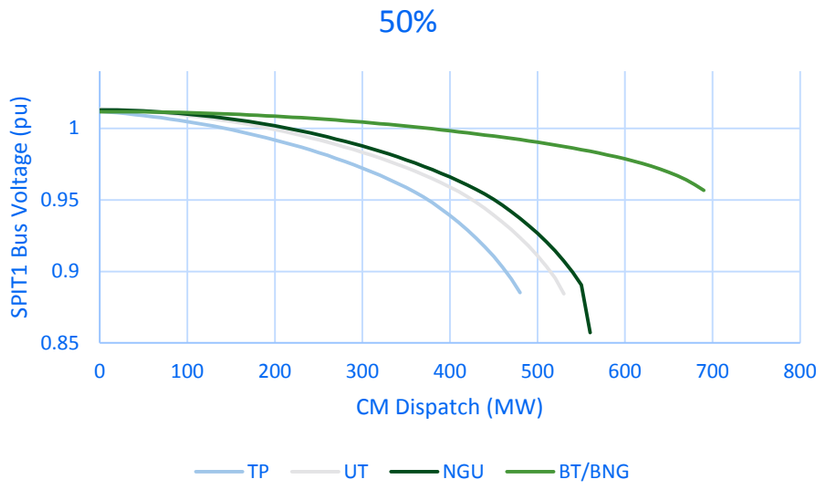


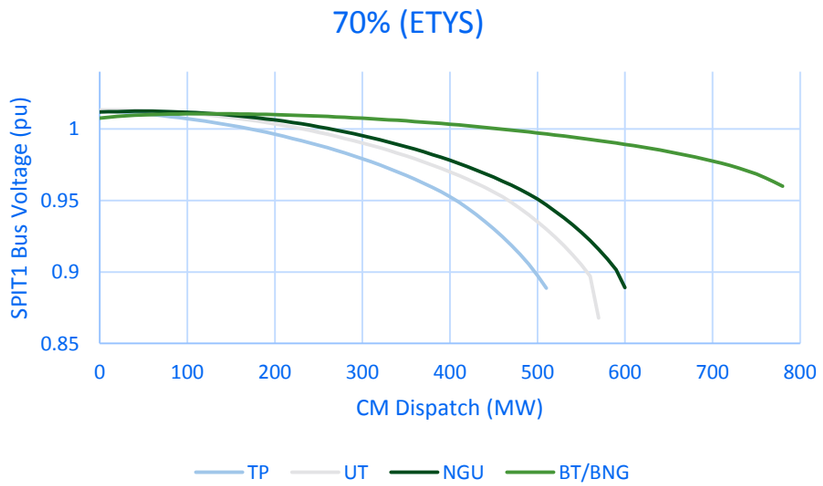
# System Studies

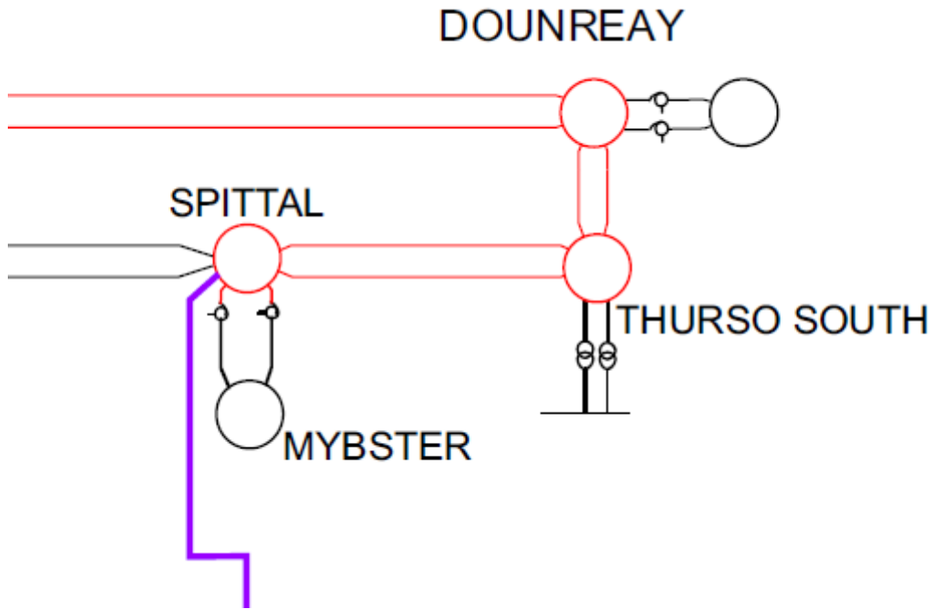
- System has a significant number of 275kV N-D outages which can be in parallel with the 132kV
- Load flow and dynamic system studies to understand the system conditions
- Potential overloads range from marginal to severe depending on system conditions
- *With the converter dispatched to reflect generation levels in Caithness risk of overloads should be low… but system design must look beyond ideal conditions…*

# System Studies – Voltage Collapse

- PV analysis exploring the range of outages, converter dispatches and generation levels



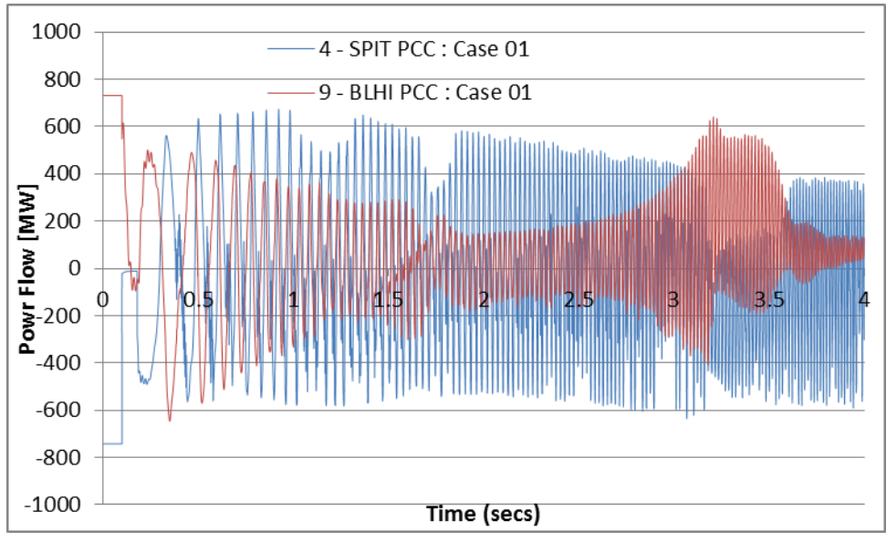



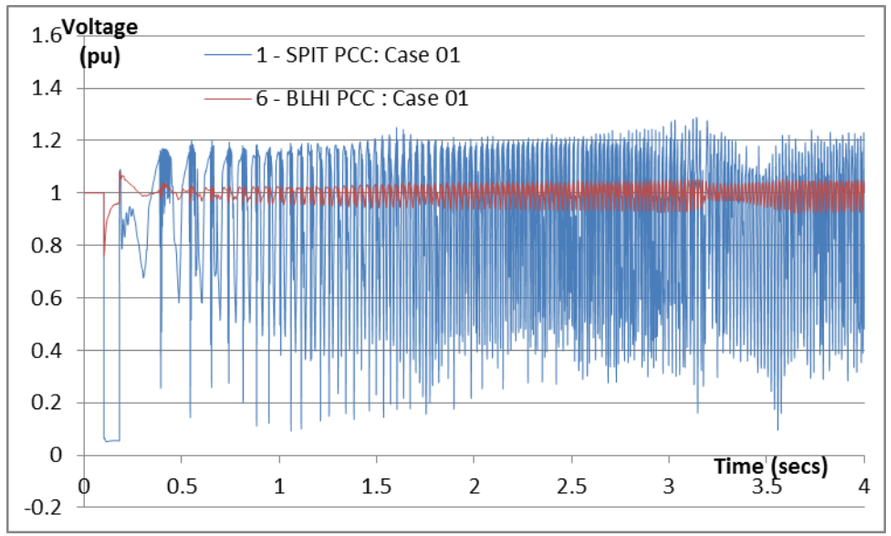



# System Studies – Voltage Collapse

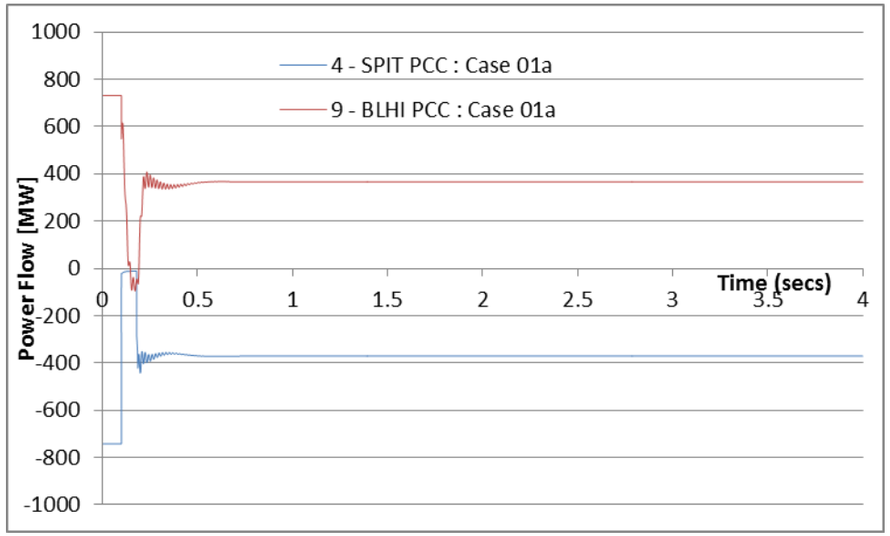
- Dynamic analysis to explore the timing of emergency control

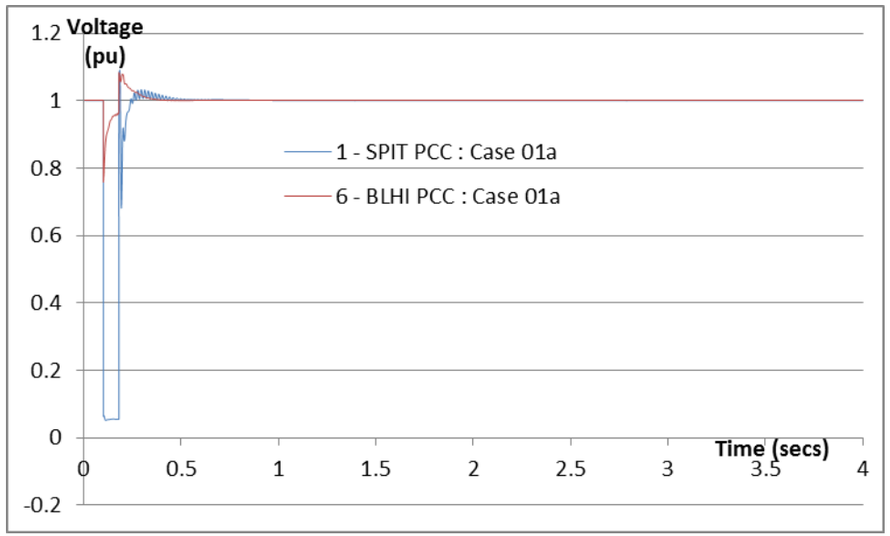
Without emergency action...




With emergency action...



# Automatic Power Control (APOL)

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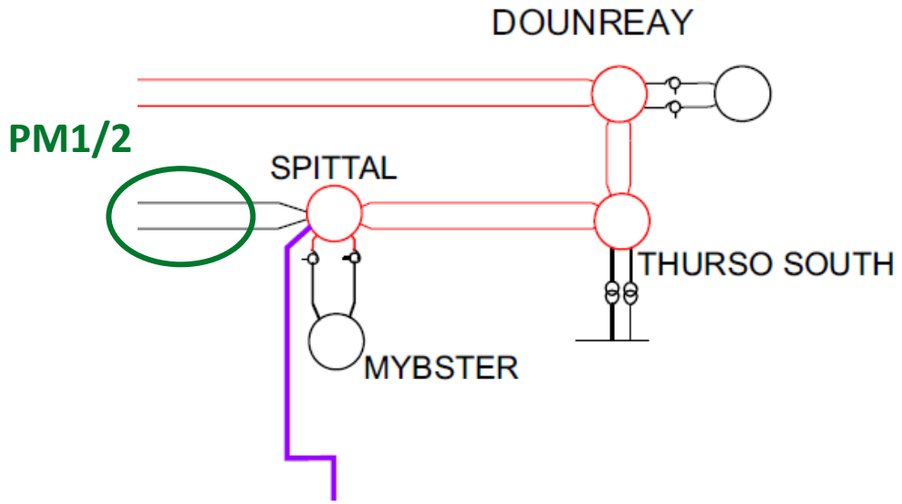
# Emergency Power Control (EPC)

# Automatic Power Control (APOL)

- Intended to correct small overloads on circuits PM1/2 within the short-term ratings of the conductors

- Monitor local flows on PM1/2 and ramp HVDC Converter power order

- Approx. 300MW/s ramp rate



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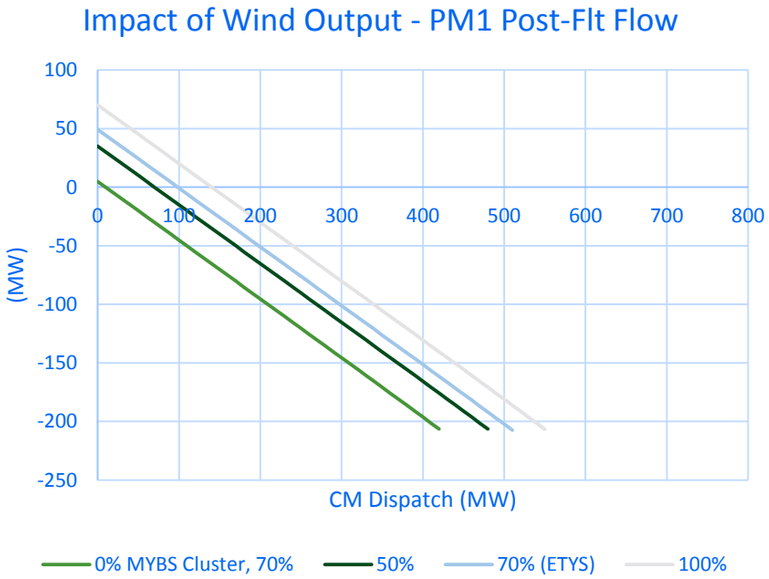
# Emergency Power Control (EPC)

- Fast acting control intended to avoid the onset of voltage instability
- Monitor flows on PM1/2 and take pre-set ramp-up/down action
- Approx. 2000MW/s ramp rate
- 30ms specification for scheme processing time
- Tested at the National HVDC Centre



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# System Strength

- System strength at the PCC can vary from <1GVA to >5GVA over the lifetime of the project
- Although VSC technology can operate within low system strength environments it proved challenging to engineer a single set of control parameters across the range which provided satisfactory performance
- Solution – transition to an extremely weak control mode based on system status as the lowest system strength can be mapped to 275kV N-D outages
- Sounds simple?

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