Fault Ride Through Study Work

Antony Johnson
National Grid – TNS Technical Policy

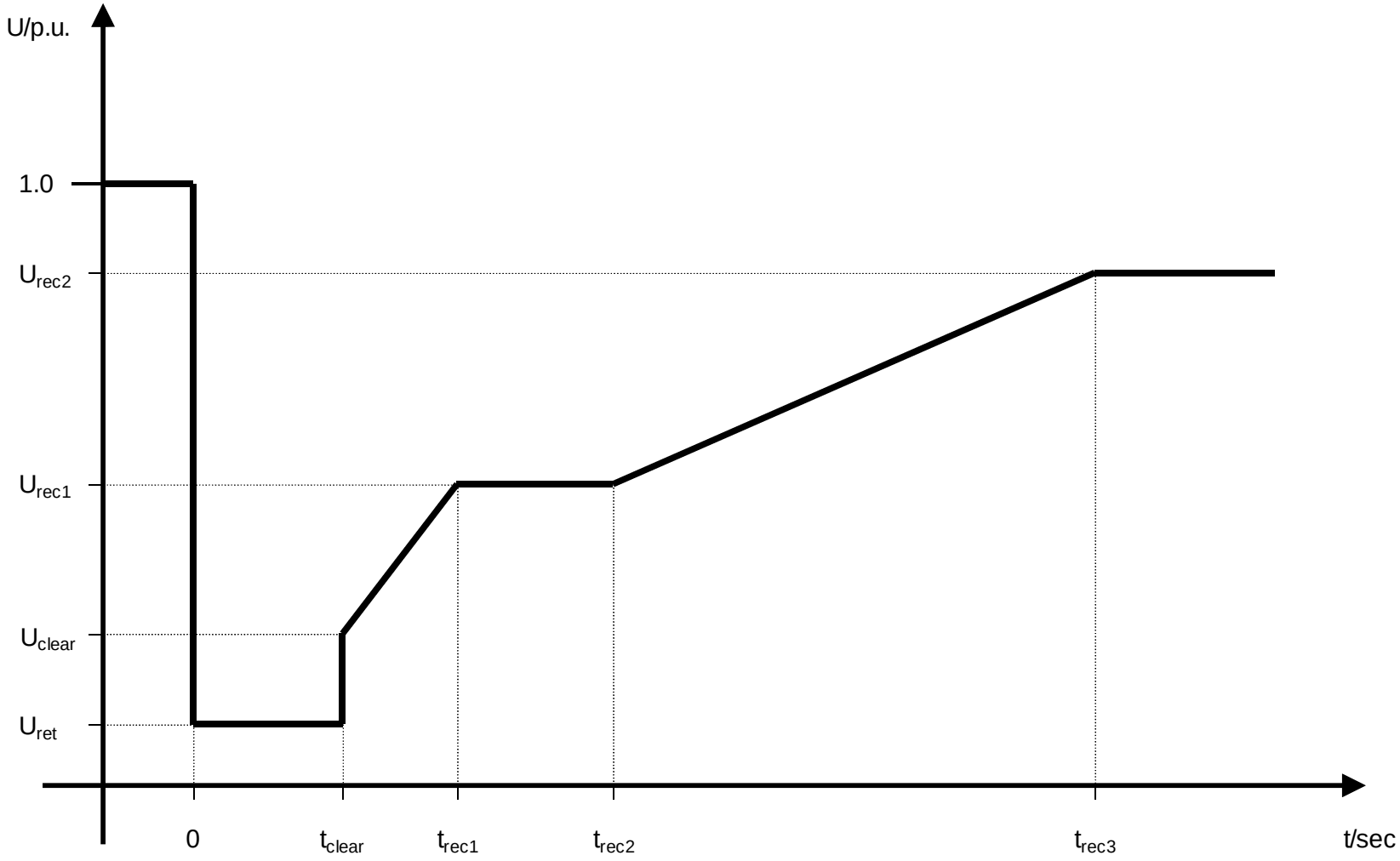
Overview

- High Level Fault Ride Through Requirements
- ENTSO-E Requirements and Implementation
- High Level determination of Voltage Against Time Curves
- Study Cases
- Summary
- Discussion

High Level Fault Ride Through Requirements

- Required to:-
  - Ensure Generation remains connected and stable during main protection operating times for Transmission System faults.
  - Prevent voltage collapse during Transmission System Faults
  - Ensure appropriate recovery of active power following fault clearance to prevent frequency collapse
  - Ensure sufficient generation robustness and network resilience to transmission faults cleared in backup protection operating times.
  - Ensure requirements are consistent with the credible operating and design criteria covered in the SQSS
  - Be achievable by manufacturers and Generators

ENTSO-E RfG - Fault Ride Through Requirements – Voltage Against Time Profile – Figure 3



ENTSO-E RfG - Voltage Against Time Parameters – Table 7.1 – Type D Synchronous Power Generating Modules

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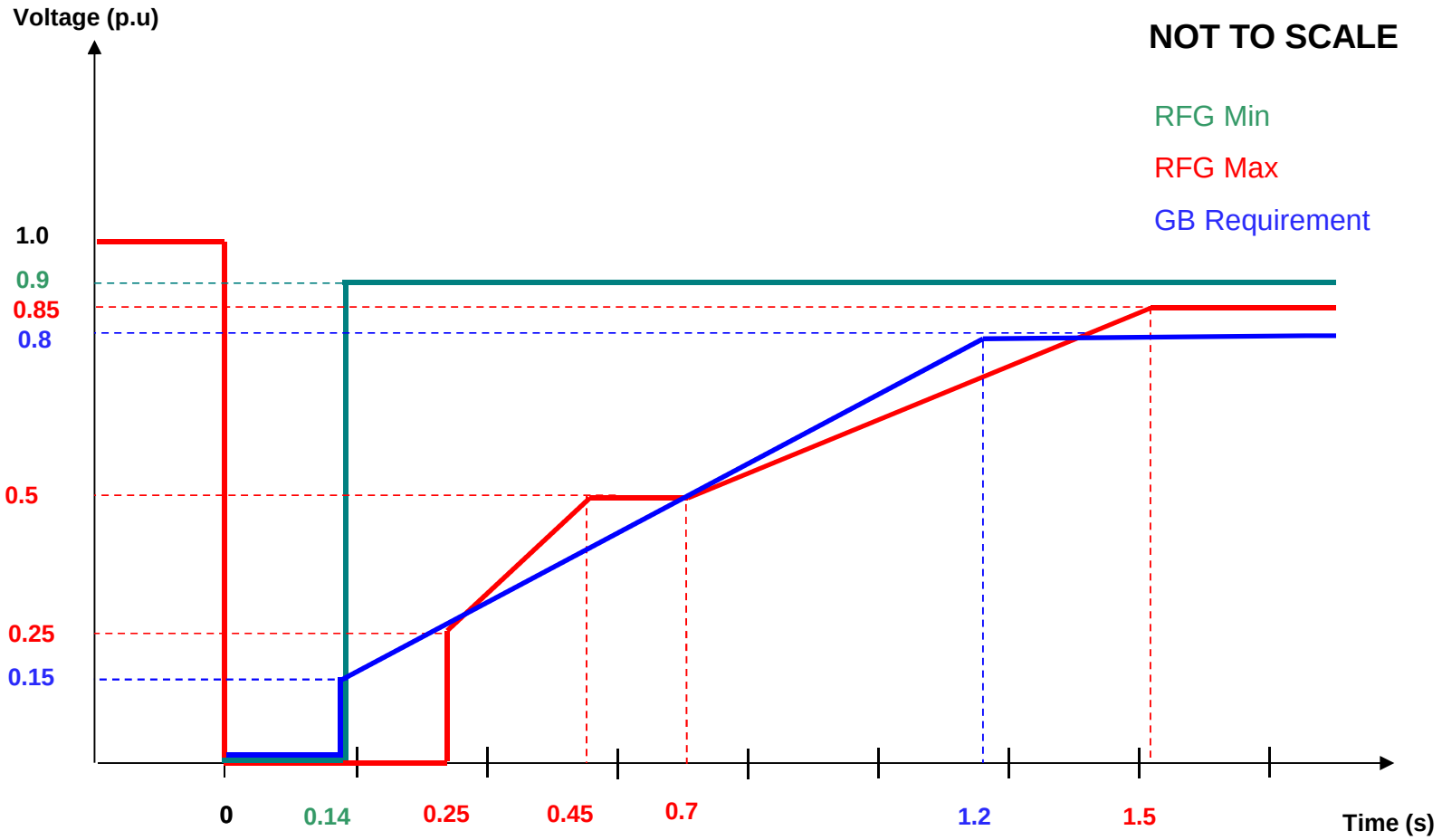
Voltage parameters [pu]		Time parameters [seconds]	
Uret:	0	tclear:	0.14 – 0.25
Uclear:	0.25	trec1:	tclear – 0.45
Urec1:	0.5 – 0.7	trec2:	trec1 – 0.7
Urec2:	0.85 – 0.9	trec3:	trec2 – 1.5

Table 7.1 – Fault Ride Through Capability of Synchronous Power Generating Modules

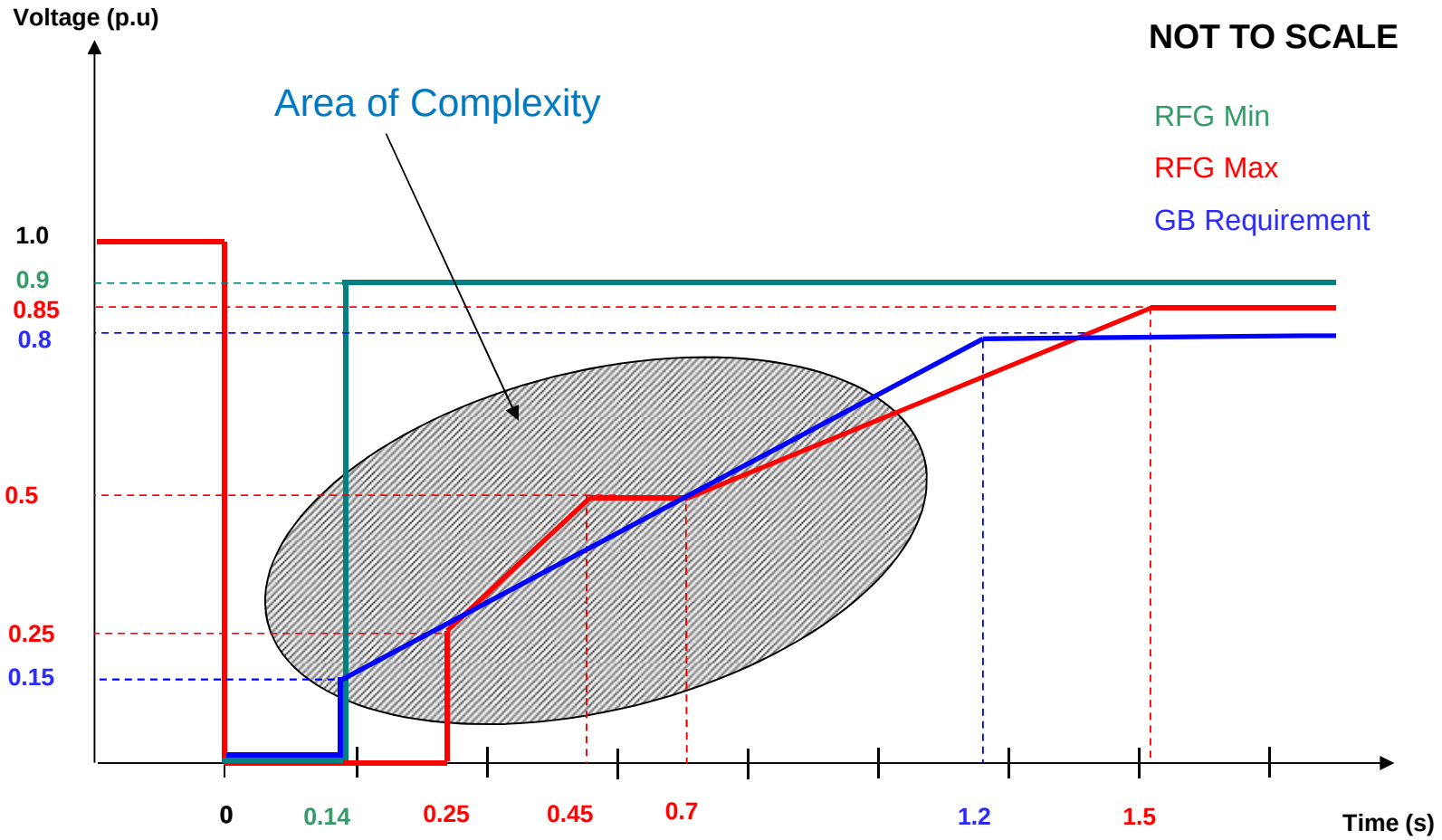
ENTSO-E RfG - Voltage Duration Profile – Range compared with GB Requirement



Implementation

- For the purposes of this section of work – consider the requirements only in respect of Large directly connection Synchronous Plant
- Determine Voltage against curve within range permitted by ENTSO-E Drafting – study work dependant
- Active Power Recovery as per current GB requirements There should be no reason to change this unless there is good reason not to do so.
- Asymmetrical faults – as per current GB requirement – applicable only for faults cleared in main protection operating times?
- Pre and post fault conditions – specified in the Bilateral Agreement
- Reactive Power injection for Synchronous Generators not specified in the ENTSO-E Requirements for Generators and would remain at National level.

ENTSO-E RfG - Voltage Duration Profile – Range compared with GB Requirement



Determination of Voltage against time curve and other characteristics

- For Directly Connected Synchronous Generation the area of complexity is in the zone shown in slide 8.
- System studies required to determine voltage against time curve.
- As a minimum the voltage against time curve should cater for the list of events defined in the SQSS plus overall industry resilience
- No reason to change other factors such as active power recovery and reactive current injection.
- There are still some potential issues over the length of the voltage depression for longer duration faults eg 85% volts for 1.5 seconds where as GB is 85% for 3 minutes
- Need to understand the impact on station auxiliaries .

Determination of Voltage against time curve

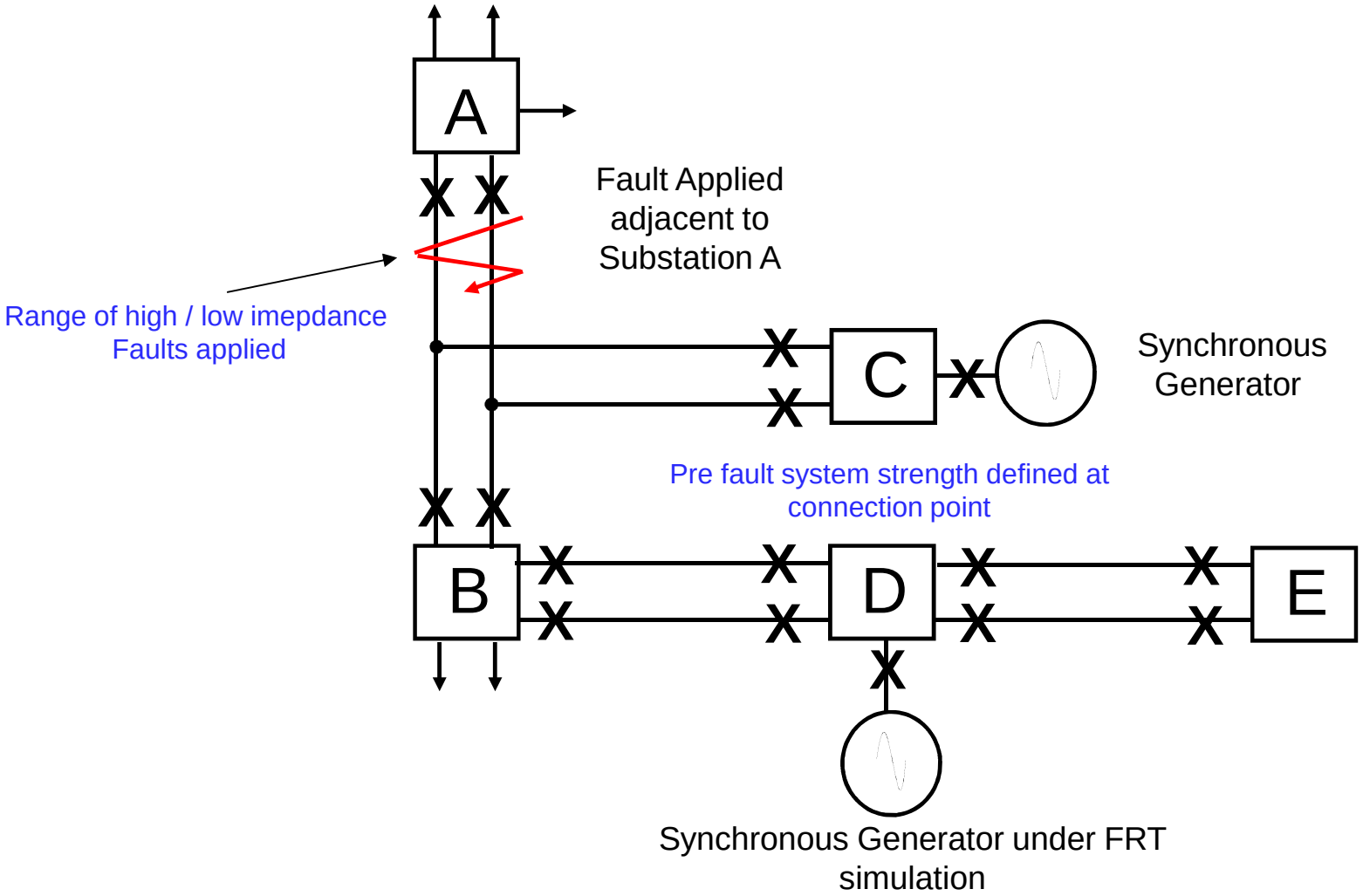
- Achievable requirements
- Robust to range of System Conditions – Generation to remain connected remote from fault cleared in back up operating times
- Requirements to be consistent with ENTSO-E RfG and not more onerous than current GB Specification

Study Cases

- Full GB Network under 2013 minimum demand conditions ~ 18GW
- Range of scenarios investigated
  - Low non-synchronous generation
  - Medium non-synchronous generation
  - High non-synchronous generation
- Range of faults applied to strategic parts of the network, including
  - Seabank
  - Drax / Eggborough
- Standard fault clearance times applied plus longer duration faults to cater for issues such as backup protection
- Analysis of high impedance faults
- Effect on voltage profile observed.
- Studies run in Digsilent Power Factor Factory

Fault Ride Through

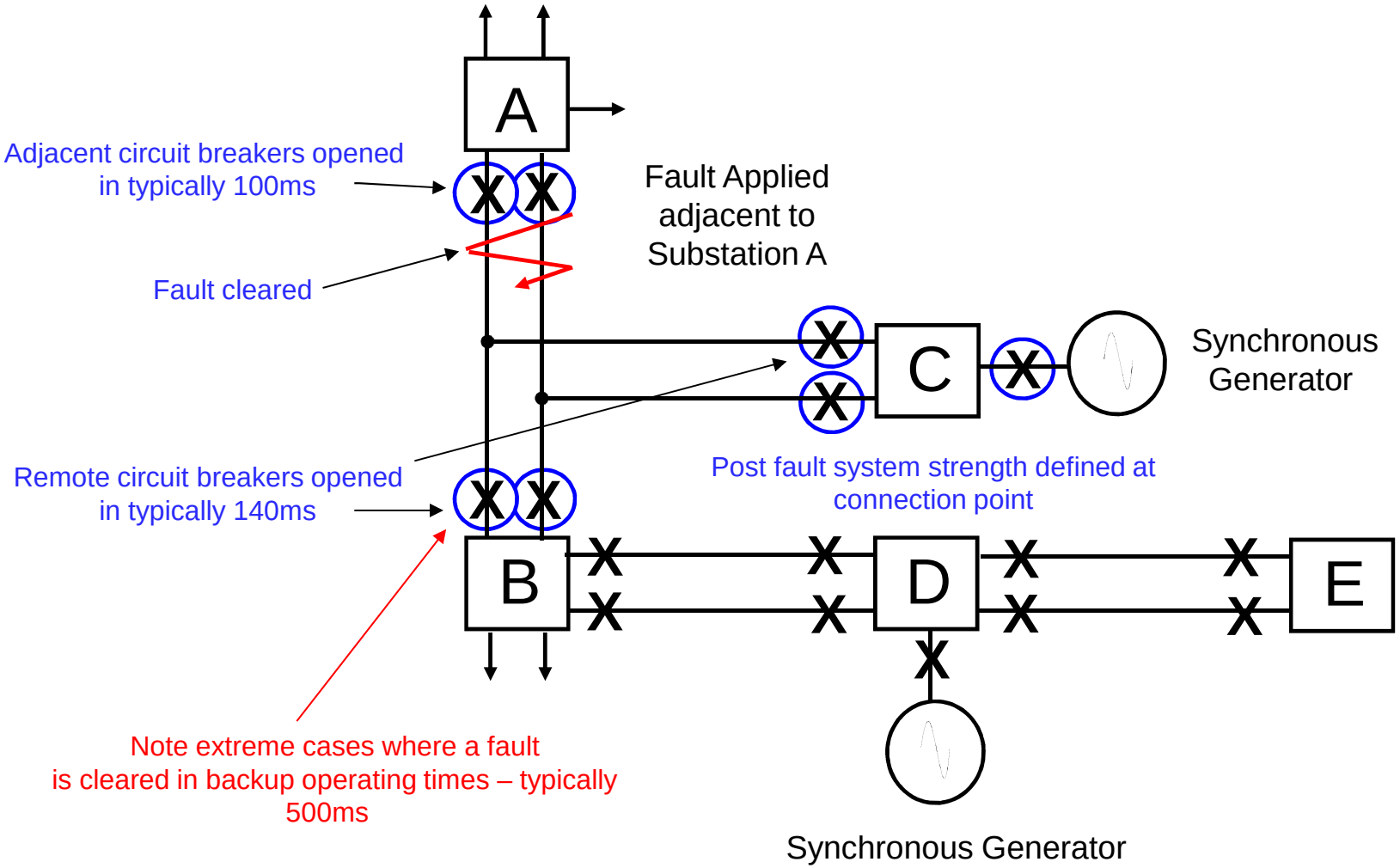
Example



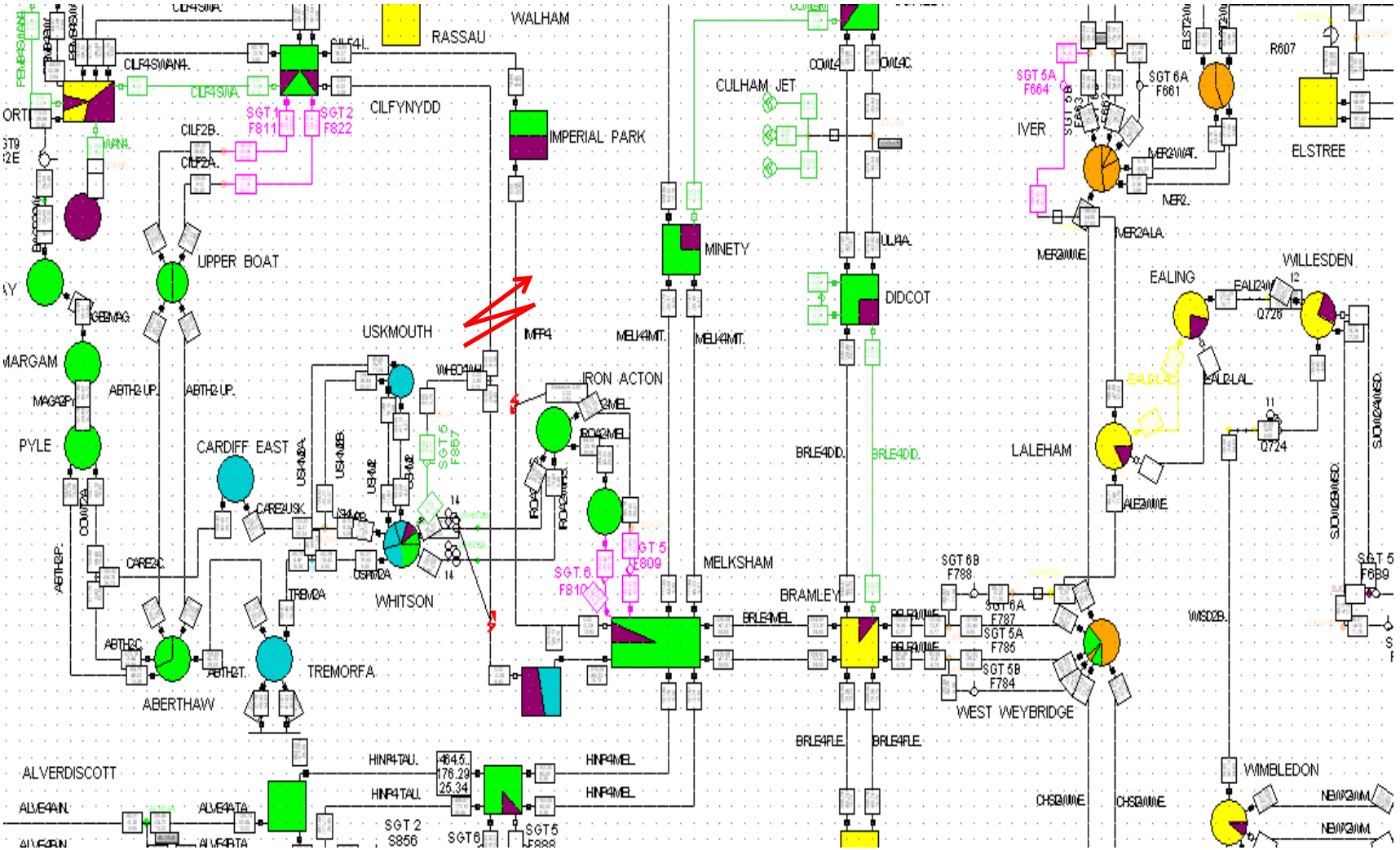
Operating conditions of generator specified pre fault eg Pmax, Qmax (imp / exp)

Fault Ride Through

Example

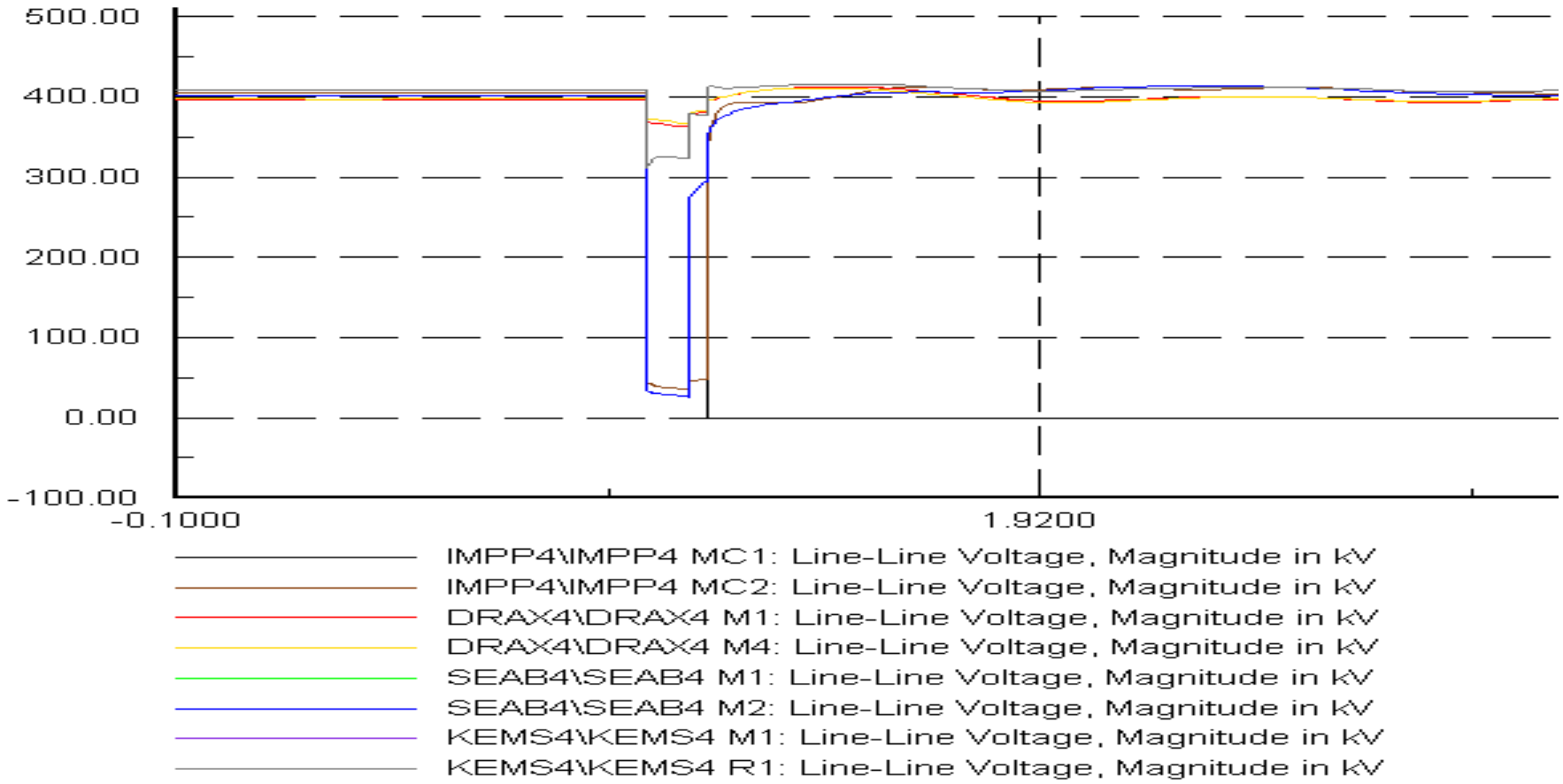


Seabank – Whitson – Clfynydd, Melksham - Imperial Park DC – 140ms Fault



Seabank – Whitson – Clfynydd, Melksham - Imperial Park DC – 140ms fault (Z=0)

Transmission Voltage



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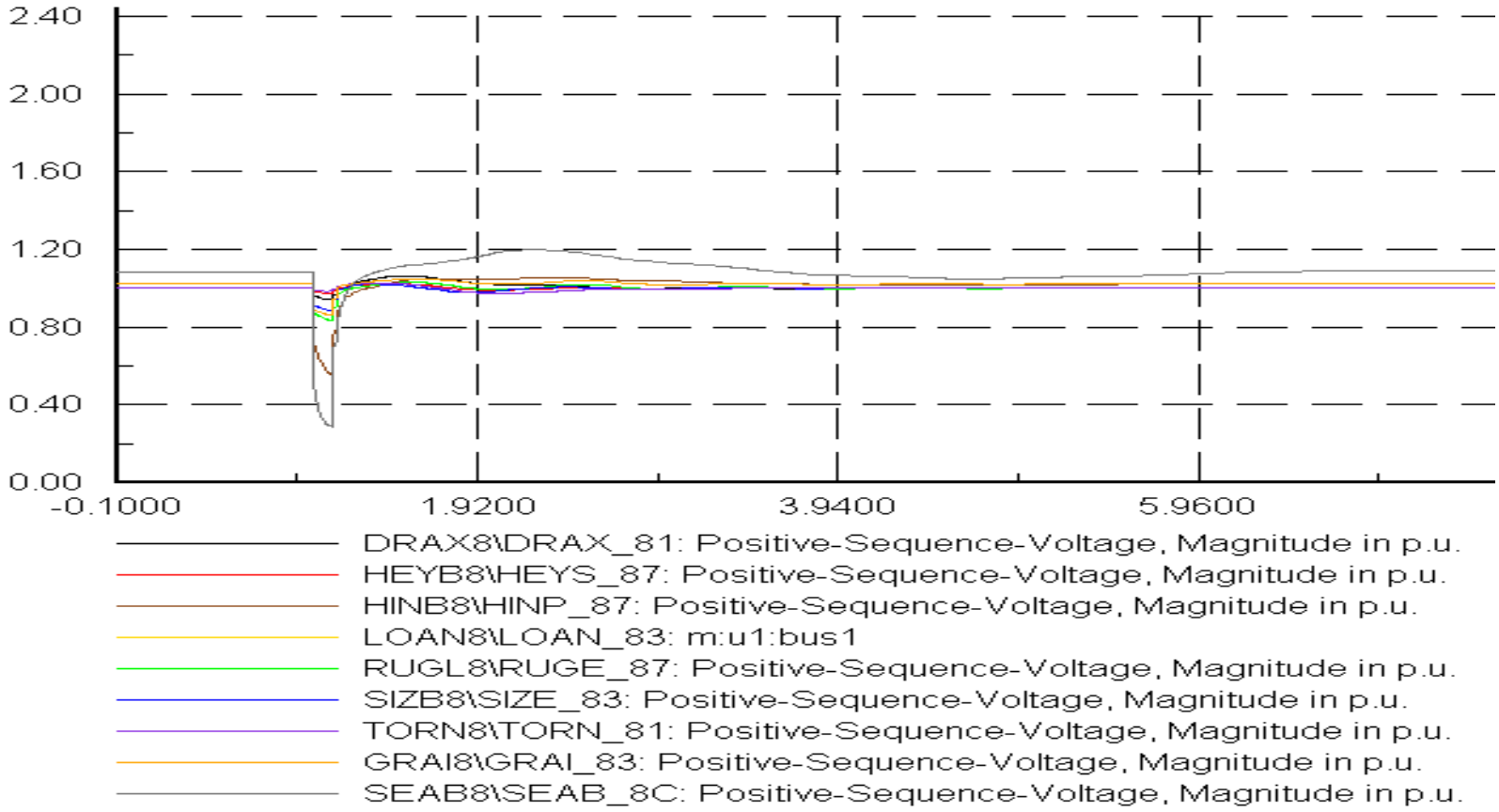
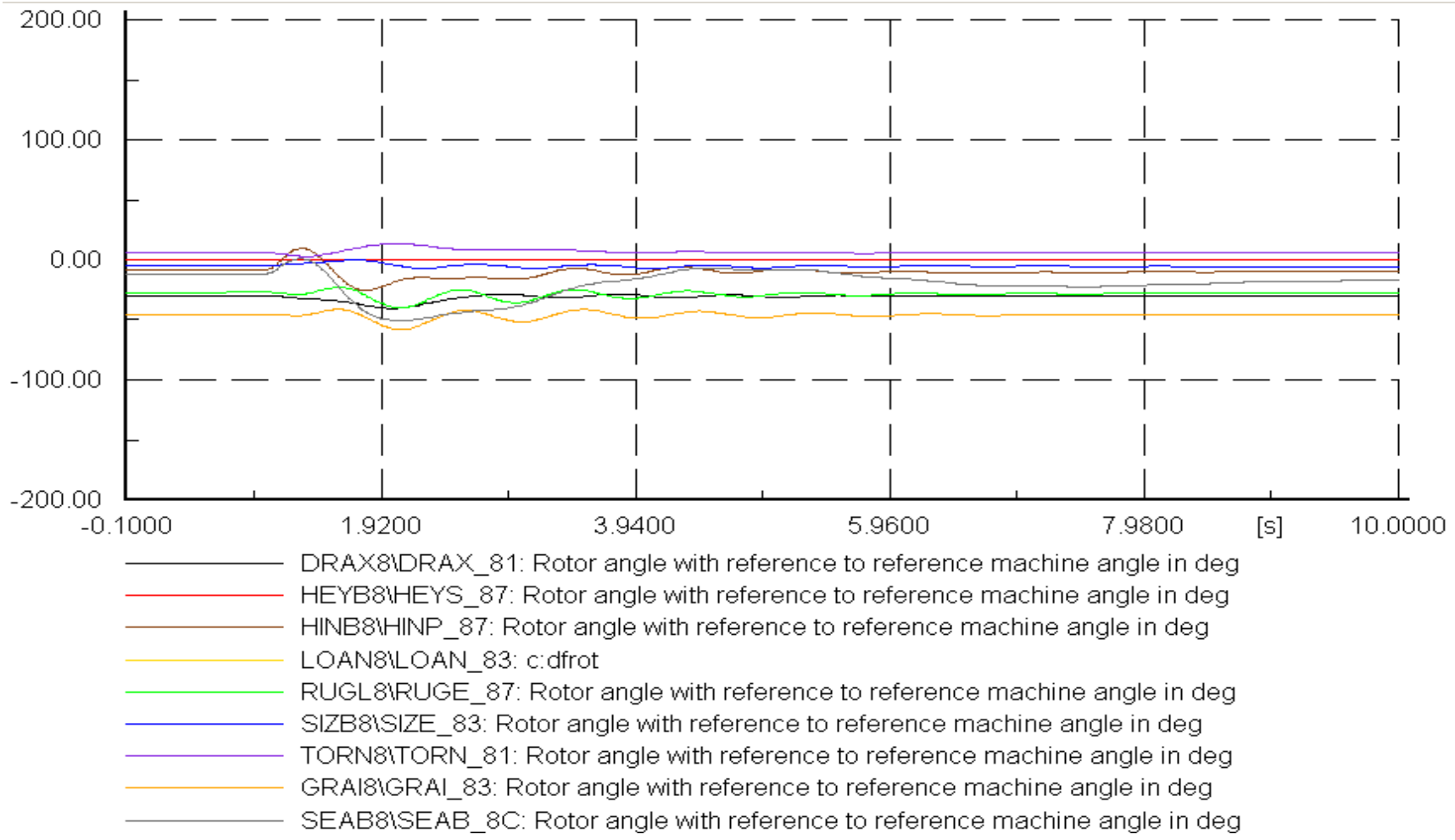
Generator Terminal Voltage

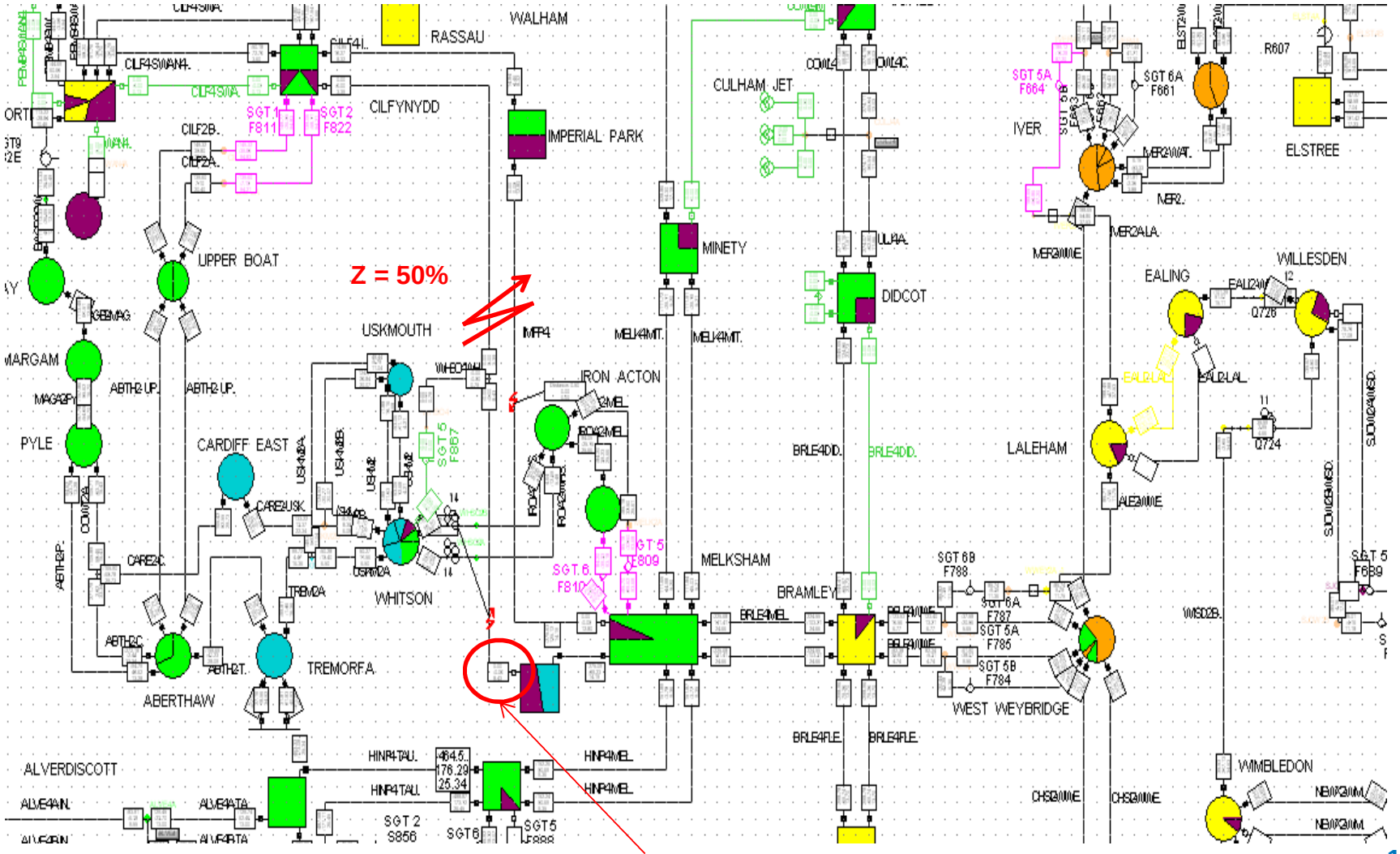


Seabank – Whitson – Clfynydd, Melksham - Imperial Park DC – 140ms fault (Z=0)

Rotor Angle

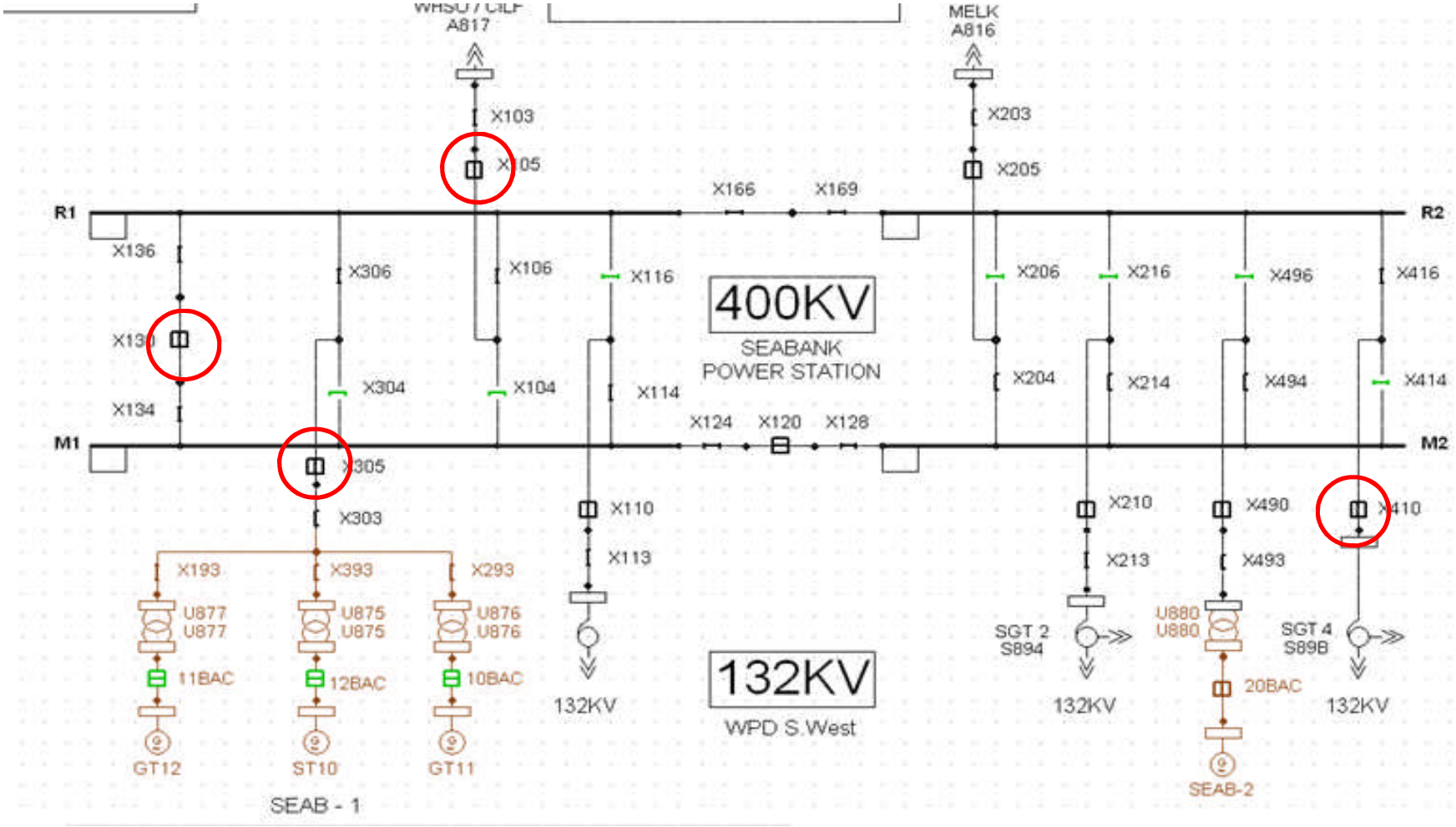


Seabank – Whitson – Clfynydd, Melksham - Imperial Park DC – 500ms fault (Z=0)



Stuck breaker – bar cleared 500ms later

Seabank – Whitson – Clfynydd, Melksham - Imperial Park DC – 500ms fault (Z=0)



Seabank – Whitson – Clfynydd, Melksham - Imperial Park DC – 500ms fault (Z=0)

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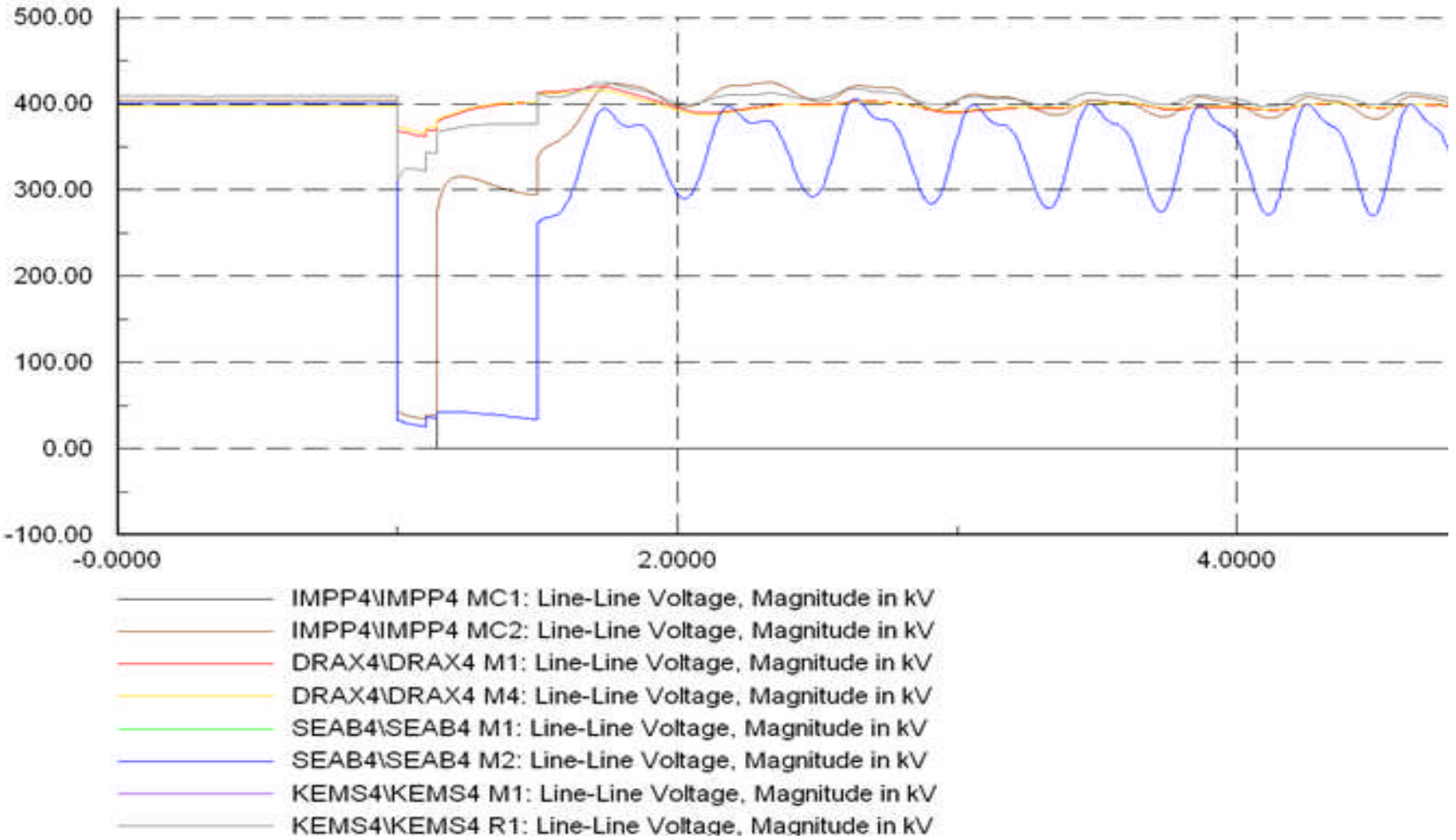
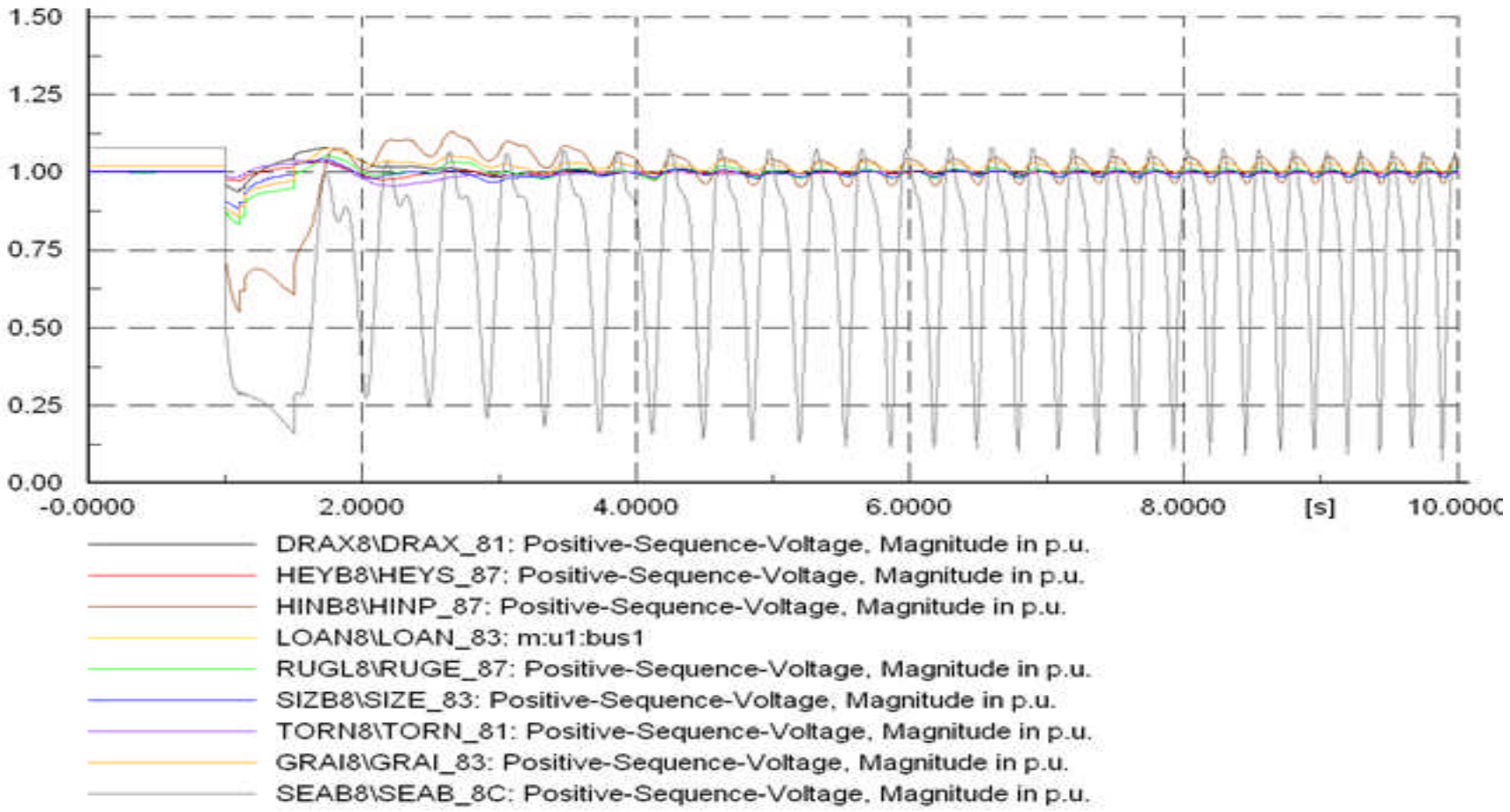


Seabank – Whitson – Clfynydd, Melksham - Imperial Park DC – 500ms fault (Z=0)

Generator Terminal Voltage



Seabank – Whitson – Clfynydd, Melksham - Imperial Park DC – 500ms fault (Z=0)

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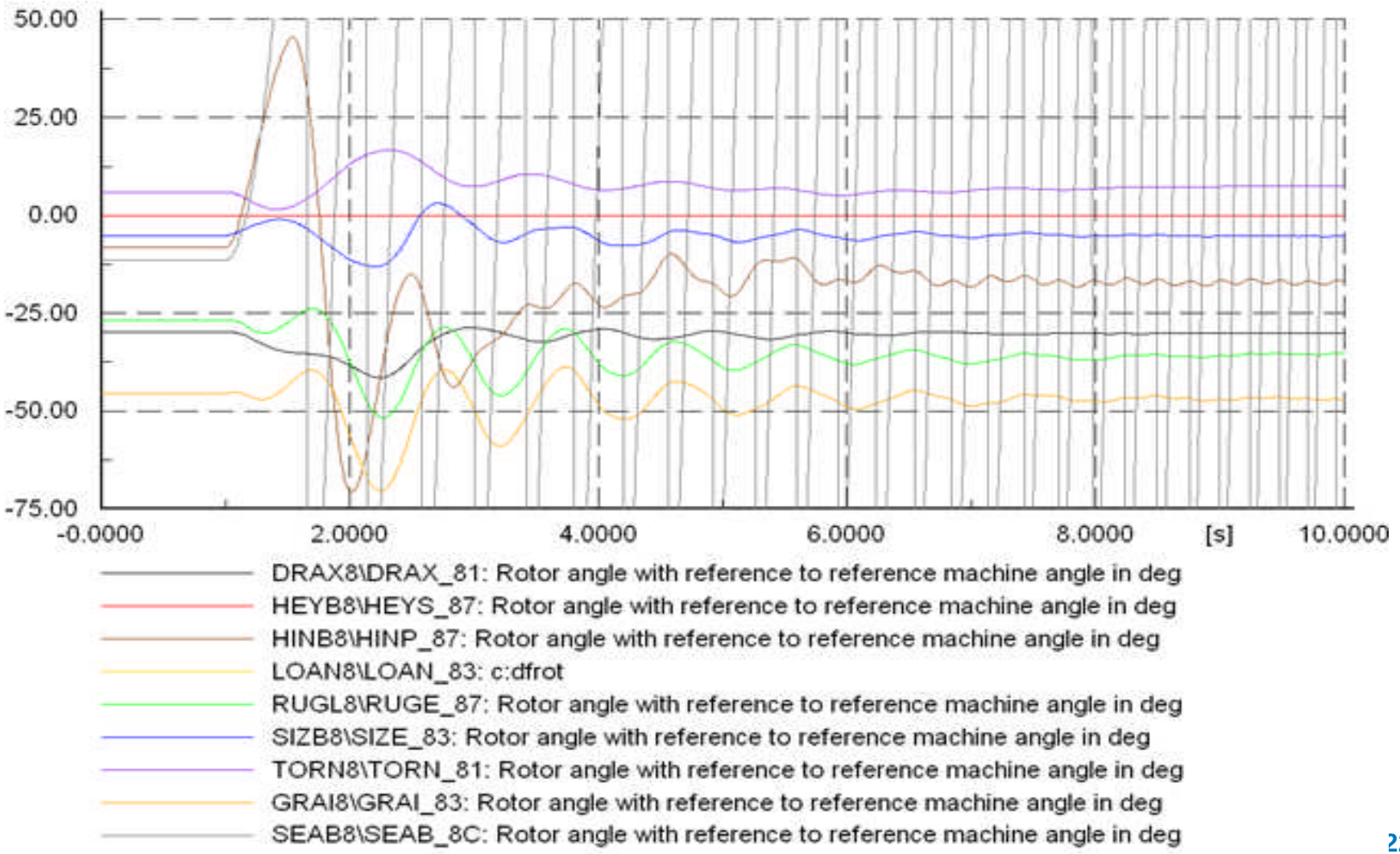
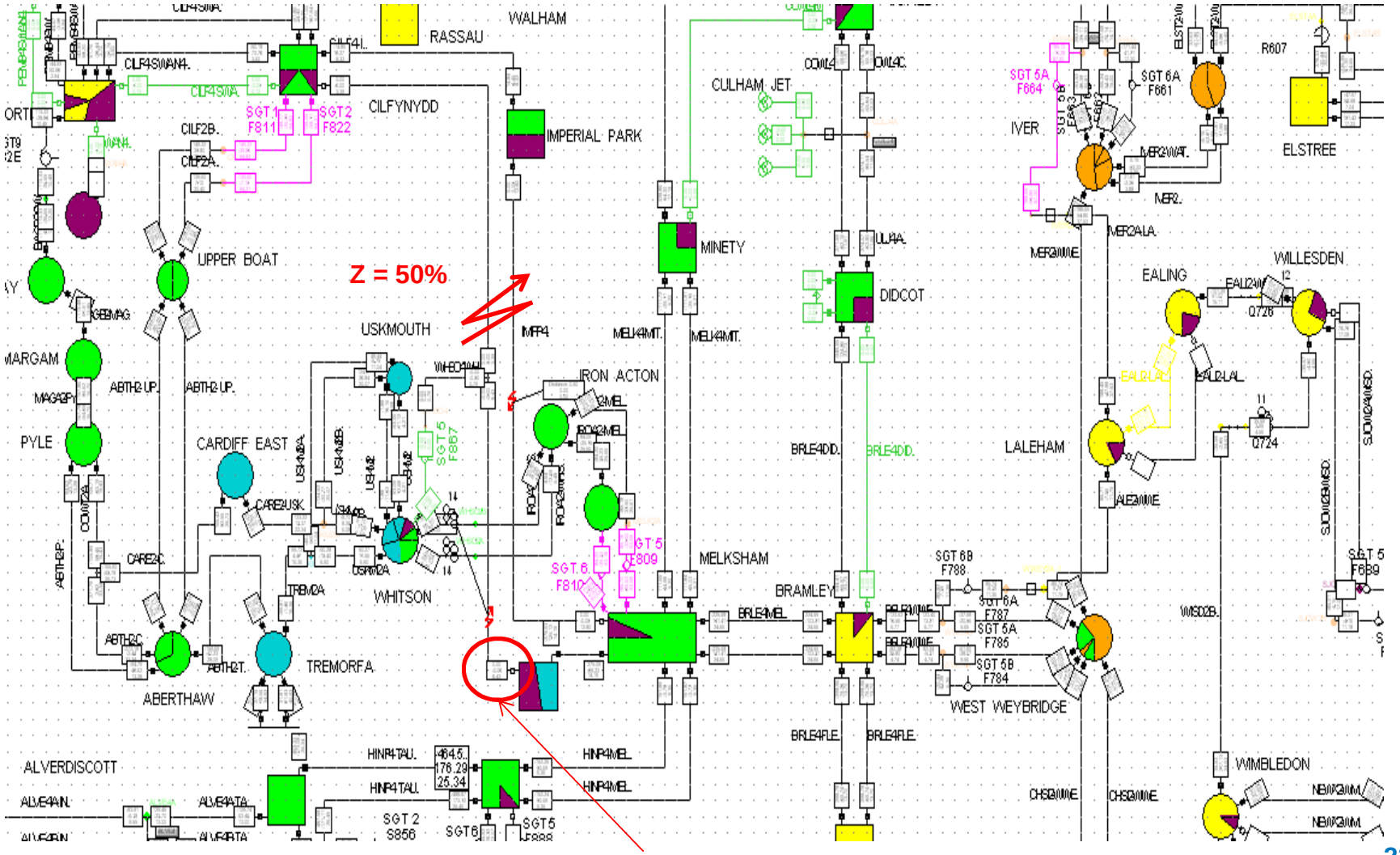
Rotor Angle



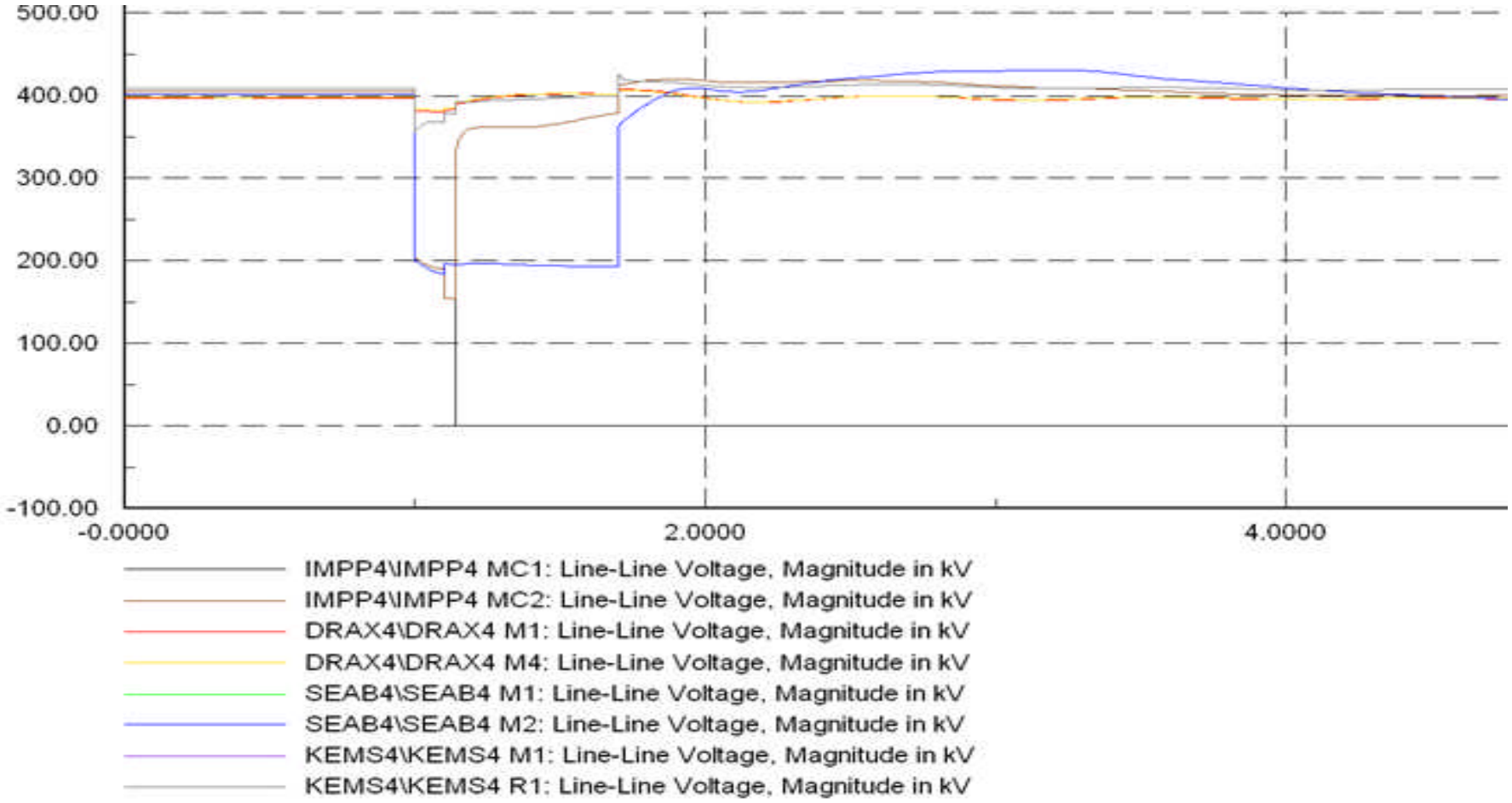
Seabank – Whitson – Clfynydd, Melksham - Imperial Park DC – 500ms fault (Z=50%)



Stuck breaker – bar cleared 500ms later

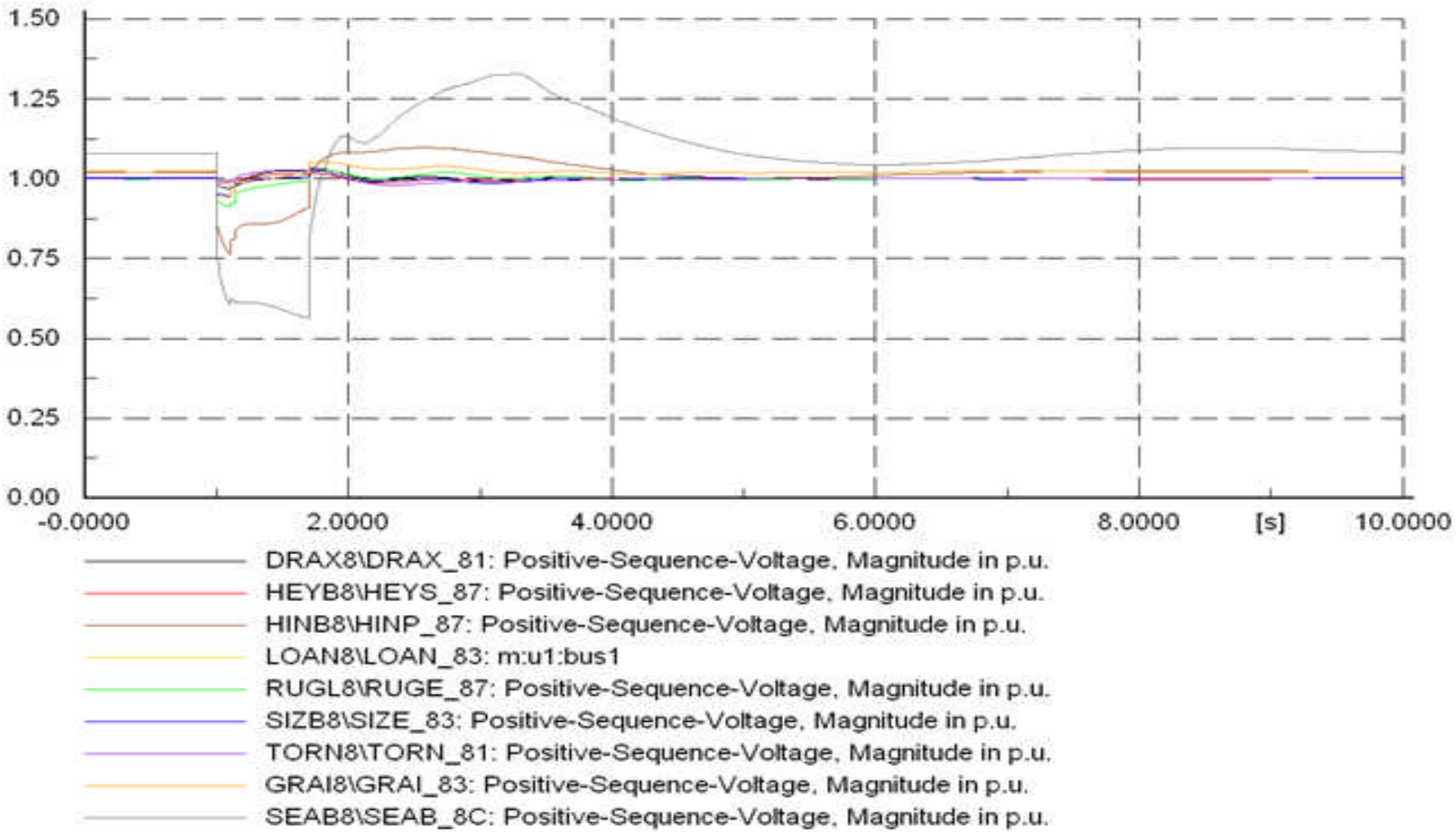
Seabank – Whitson – Clfynydd, Melksham - Imperial Park DC – 500ms fault (Z=50%)

Transmission Voltage



Seabank – Whitson – Clfynydd, Melksham - Imperial Park DC – 500ms fault (Z=50%)

Generator Terminal Voltage



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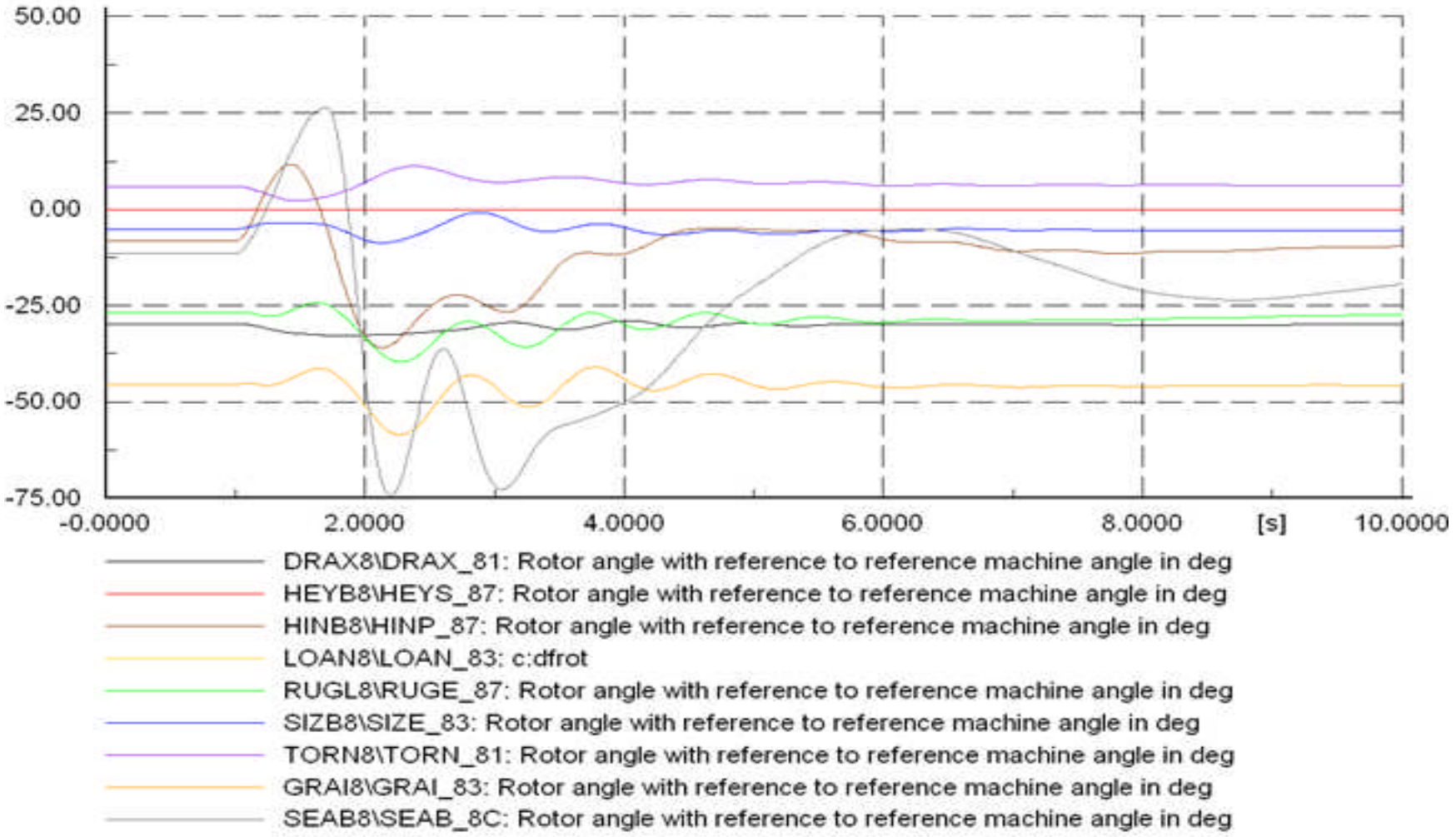
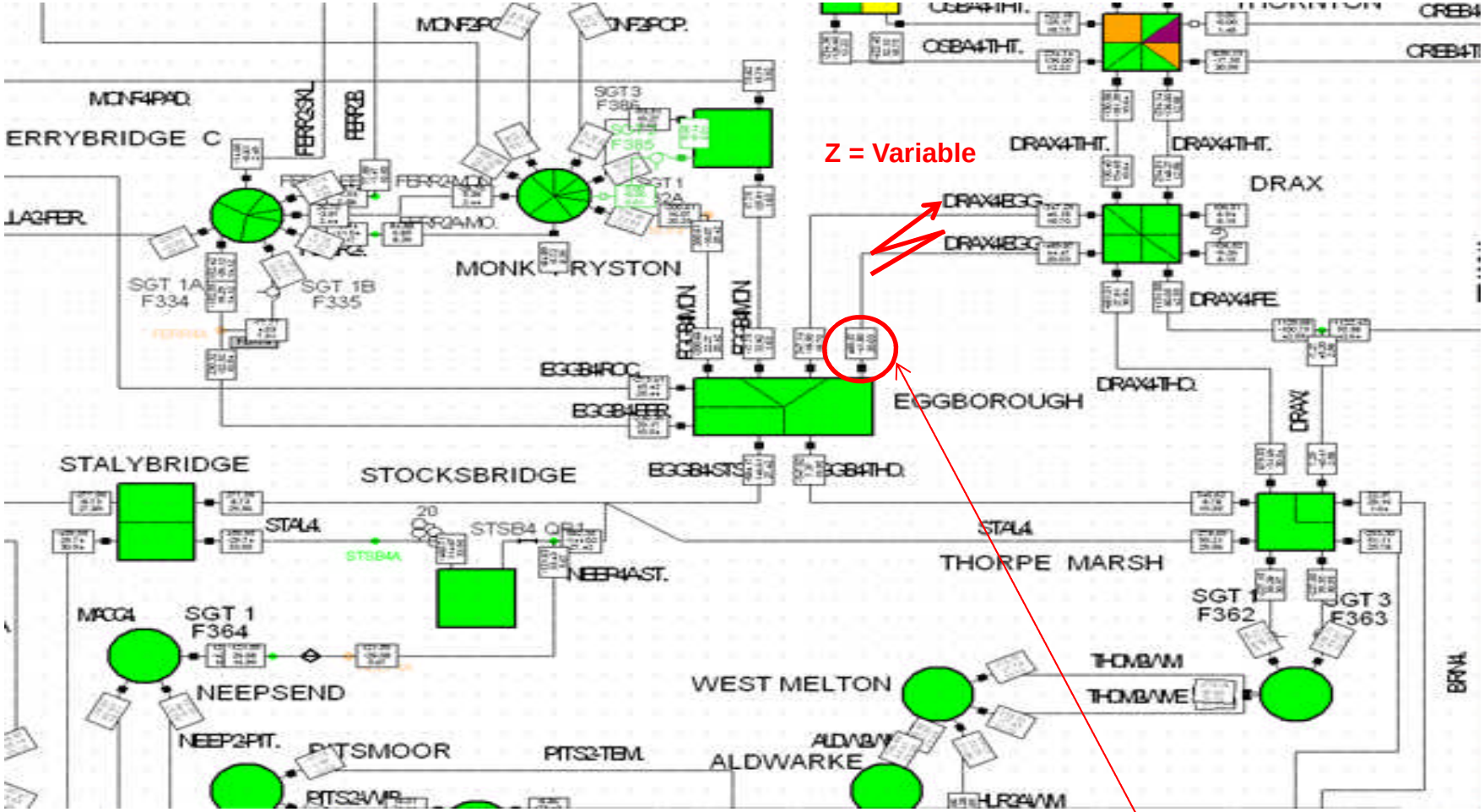
Rotor Angle



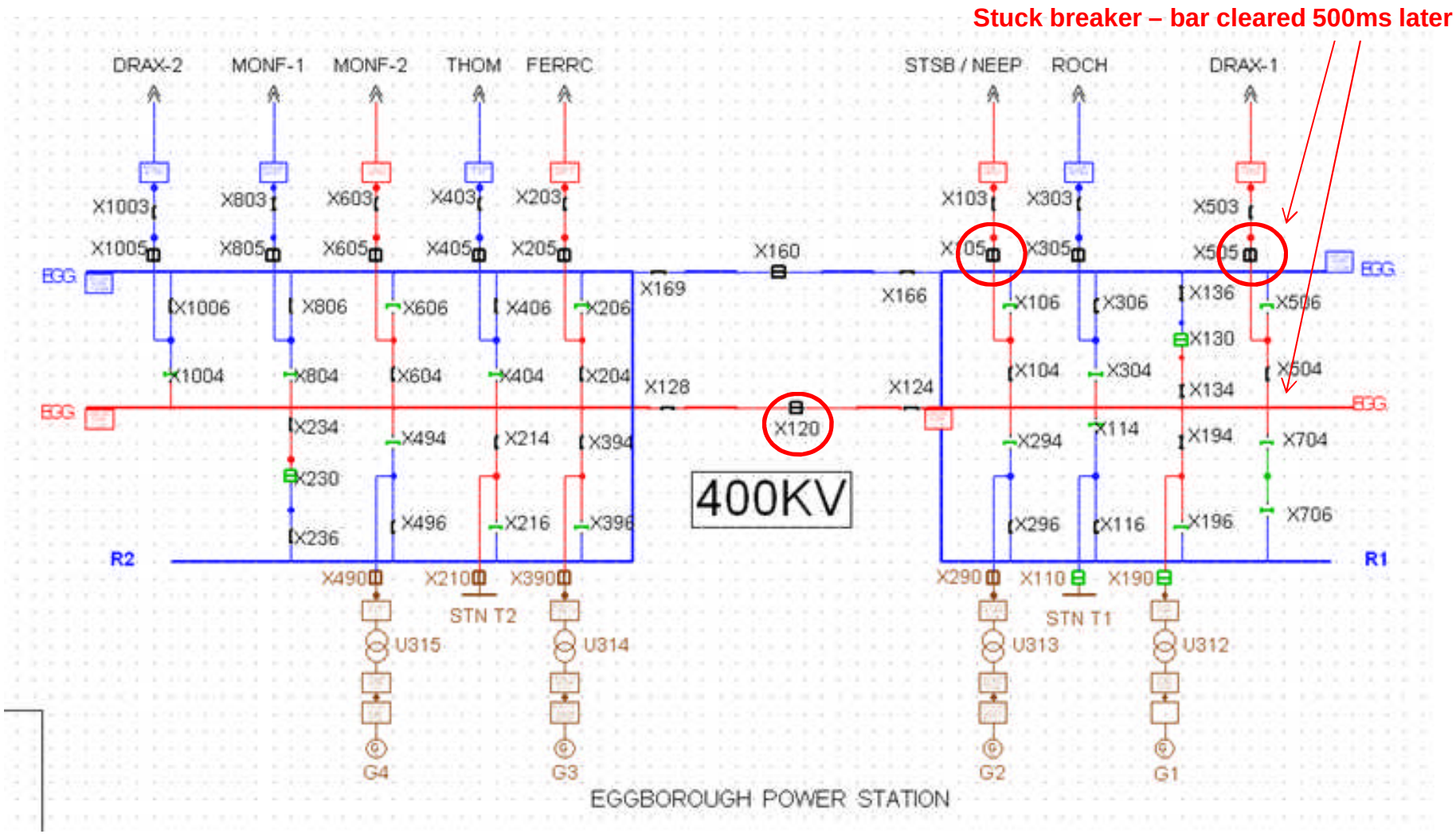
Drax – Eggborough Double Circuit

(Studies / scenarios as per Seabank – Plots not illustrated)

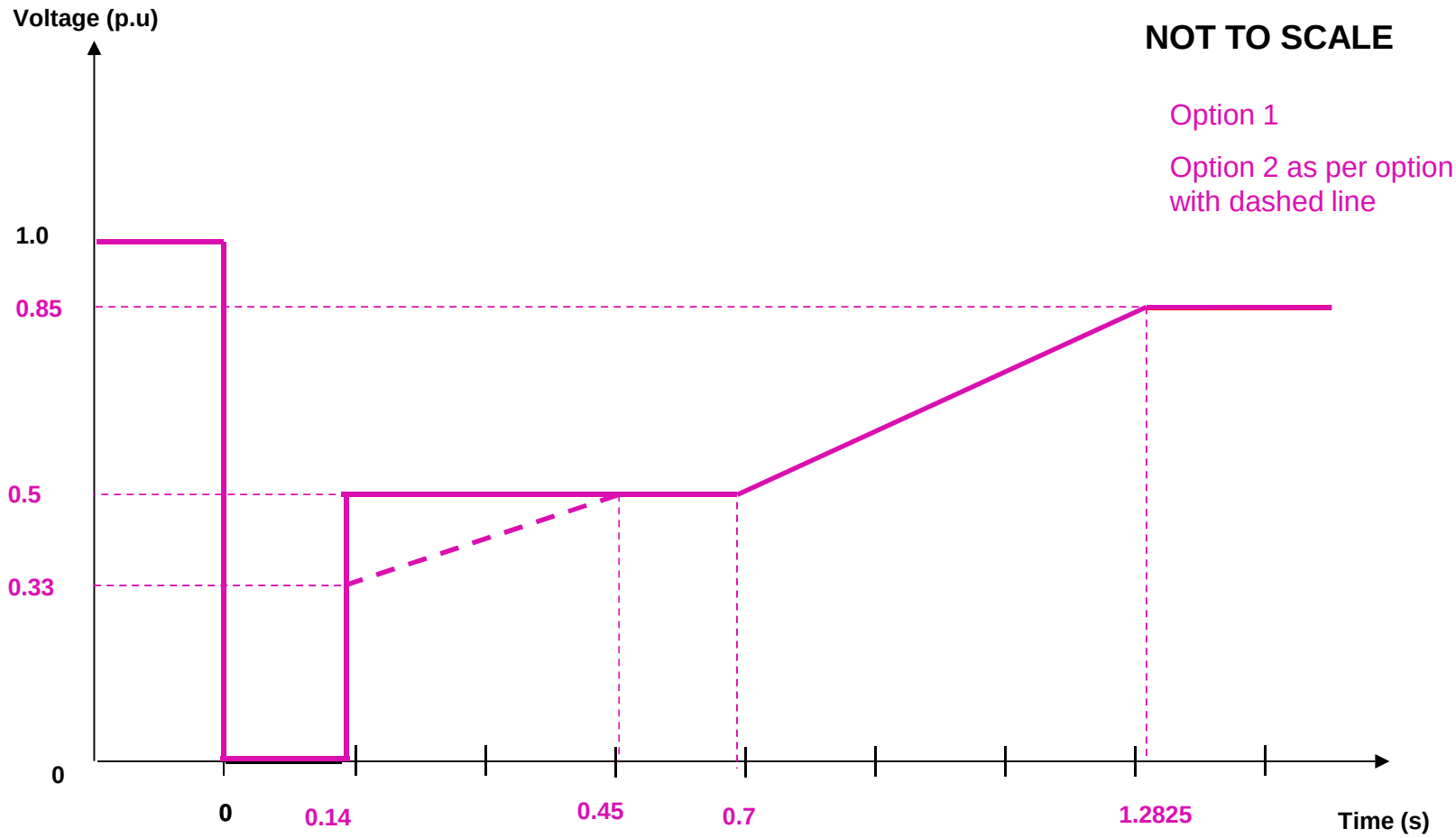


Stuck breaker – bar cleared 500ms later

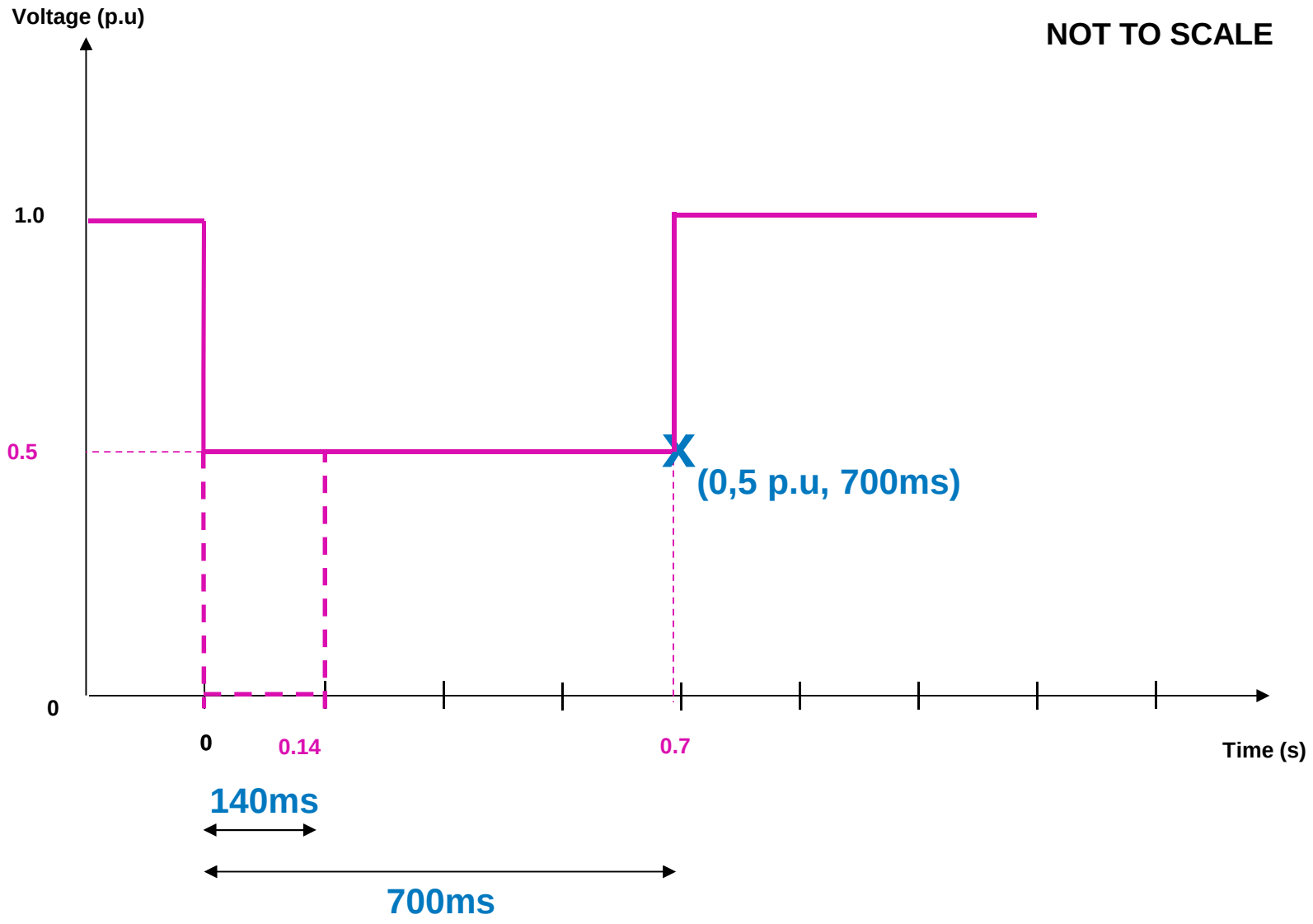
Eggborough 400kV Substation



ENTSO-E RfG - Voltage Duration Profile – Study Results



Study Case – eg 0.5 p.u for 70ms



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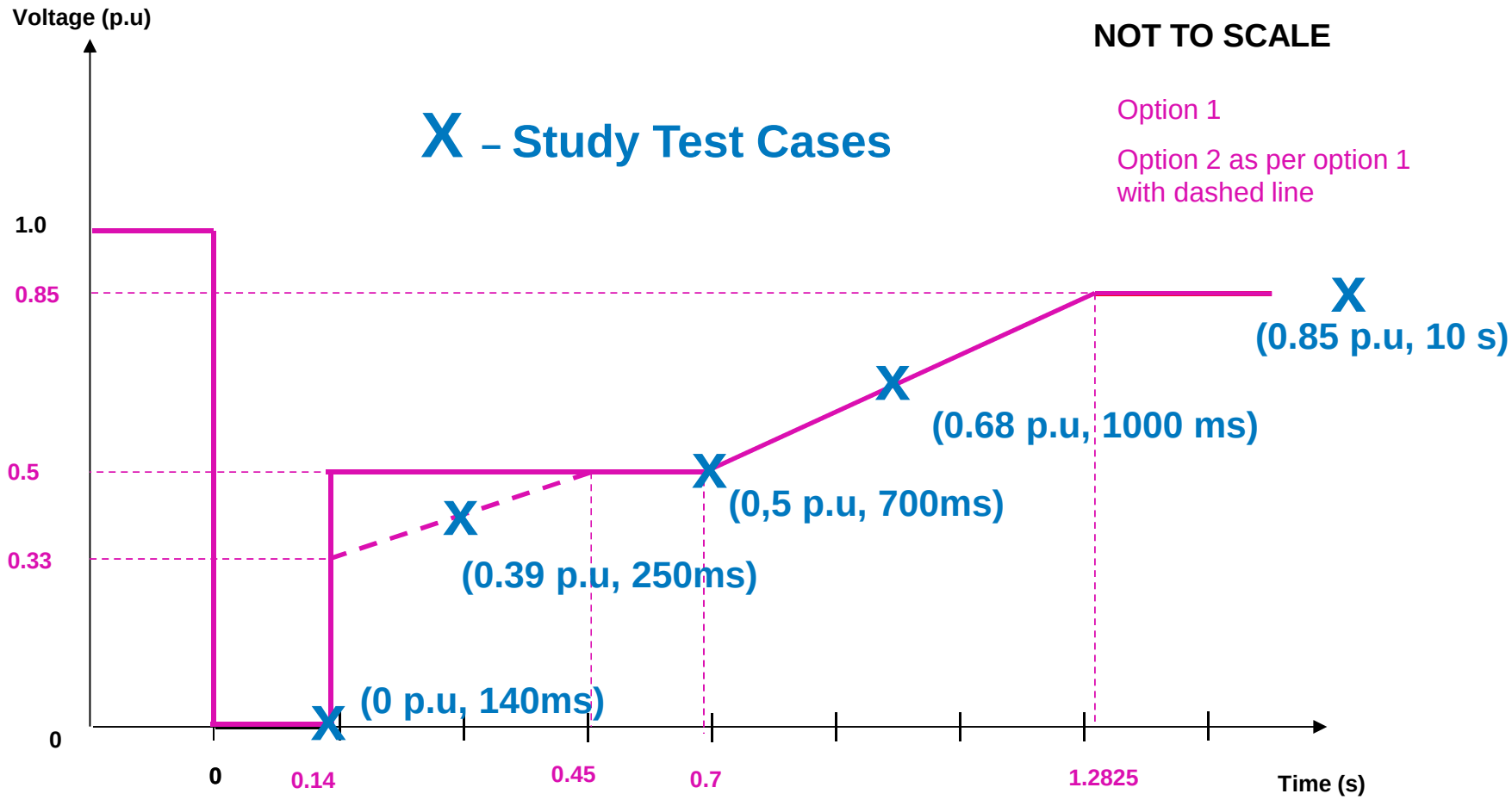
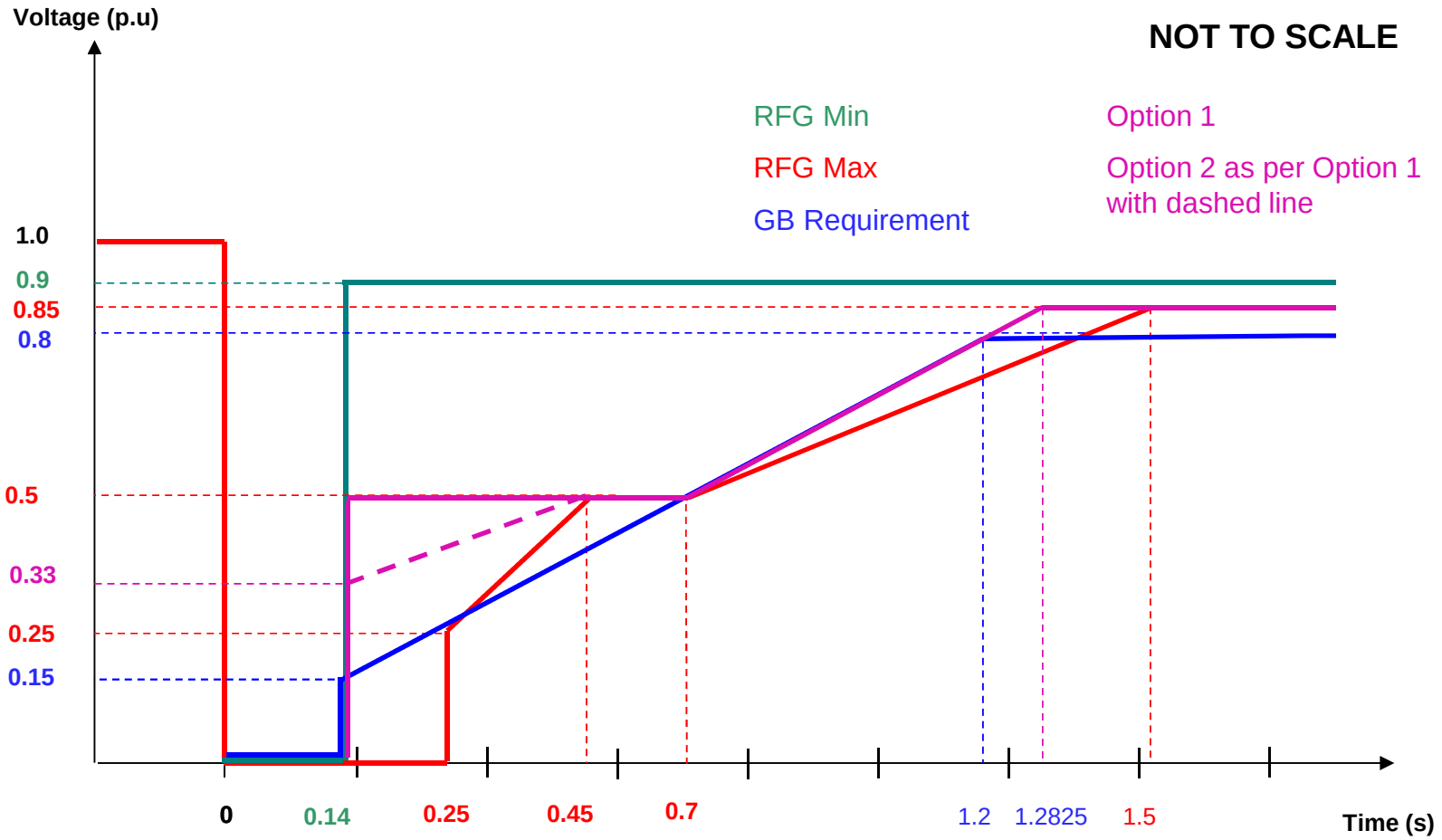


Voltage Duration Profile – Options compared with GB and ENTSO – E Requirement



Summary

- Two initial options proposed for voltage against time curve
- Suggested curves believed to provide a blend of the ENTSO-E Requirements and existing GB requirements. The proposals are fully consistent with the ENTSO-E requirements
- In the scenario's run, an event such as a stuck breaker has a significant impact on System Voltage recovery (ie voltage remains low)
- Adjacent Generators run at full load and full import of reactive Power (least stable)
- Additional study work required in respect of:-
  - Wider sensitivities
  - Other scenarios
  - Effect on Power Station Auxiliaries
  - System Frequency impacts
  - AVR Voltage – High post fault voltage observed

Discussion