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CIGRE UK NGN 10 Year Anniversary

Deployment of Synchronous Compensators in the GB Transmission Network to Address Challenges from Increasing Renewable Generation

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1. Motivation

- Changing GB generation mix with reducing system inertia and increasing converter connected devices.
- Risk of undesirable operation of loss of mains (LoM) protection.
- Risk of loss of commutation on the current-sourced converter based HVDC Link.

2. Objectives of investigation

This work proposes to investigate the benefits of synchronous compensation in addressing concerns pertinent to:

- the quantitative study of the benefits of synchronous compensation to system rate of change of frequency (RoCoF);
- the quantitative study of the impact that synchronous compensation has on the risk of loss of commutation on the Western Link.

3. Methodology

Models used for RoCoF and Largest Loss Risk Study

- **Mathematical analysis:** to theoretically quantifying the impact that synchronous compensation on RoCoF and loss risk tolerance.

$$dP = \left(\frac{2 \times H_{sys}}{f_0}\right) \times \left(\frac{df}{dt}\right)$$

dP is the change in power, H_{sys} is the system inertia, f_o is the system frequency, and *df* is the change in frequency over time *dt*.

- **Single bus model:** to further verify RoCoF and loss risk tolerance with system dynamics, such as governor and load responses to frequency events.

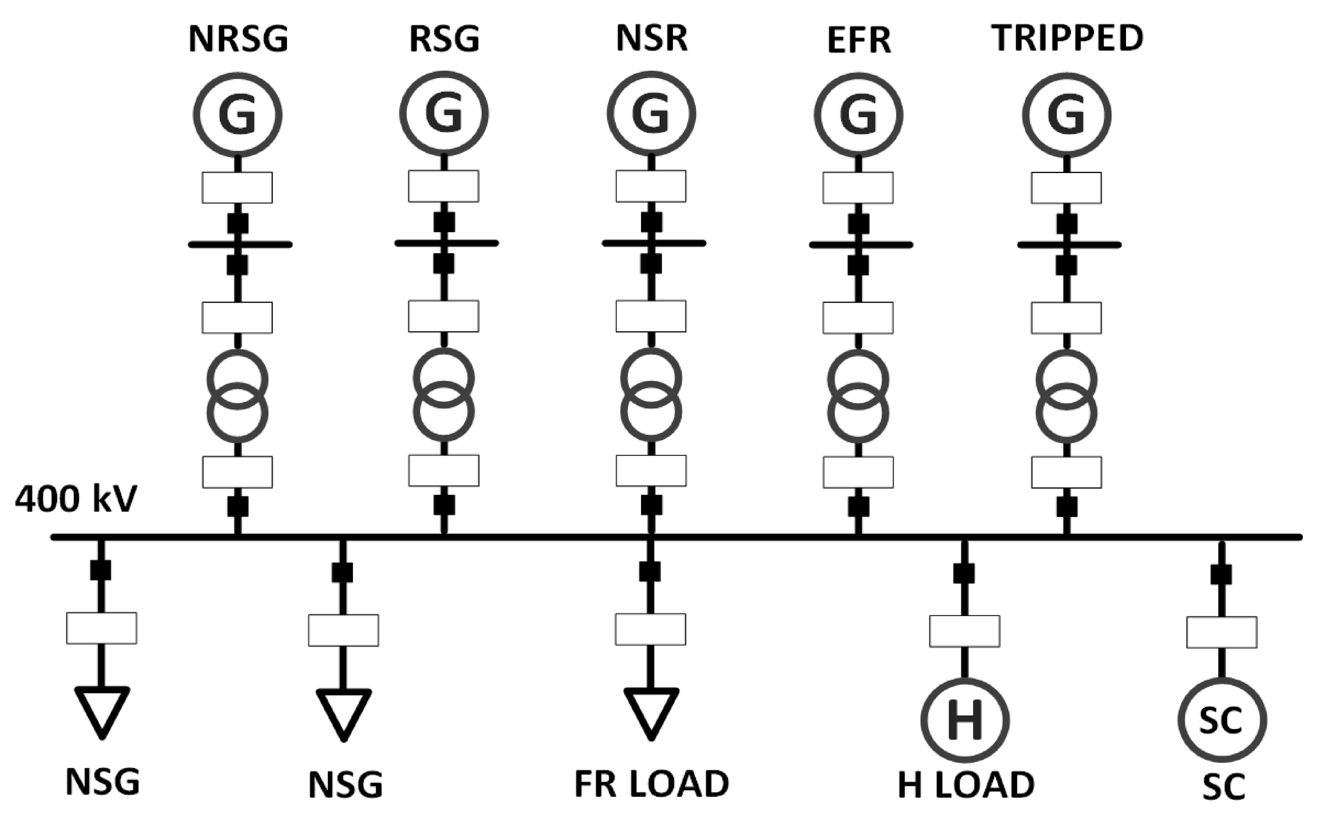

Fig. 1: Single bus GB transmission network model

Elements of in the single bus model include:

- **Non-responsive synchronous generator (NRSG):** only responding to frequency events via inertia;
- **Responsive synchronous generator (RSG):** providing both inertia and traditional primary frequency response (TFR);
- **Non-synchronous response (NSR):** non-synchronous sources providing active power responses with in 5s;
- **Enhanced frequency response (EFR):** sources providing frequency response in 1 s or less;
- **Tripped element**: representing loss of generation event;
- **Non-synchronous generation (NSG):** non-synchronous generation that do not provide response to frequency deviations;

Elements of in the single bus model include (cont'd):

- **Frequency responsive (FR) load**: transmission load components that provide active power response;
- **H Load:** transmission demand inertial response is represented by the inertial (H) load.
- **Synchronous compensator (SC):** additional synchronous compensation provided by the SC element.

Model used for fault level and Short Circuit Ratio (SCR)

A 37-node simplified representation of the GB system, developed at the University of Strathclyde, is used to investigate the impact that synchronous compensation has on fault level and Short Circuit Ratio (SCR).

Each node of the 37-node simplified representation of the GB system has terminals for the connection of generators, and has lumped demands within the model to approximate losses associated with parts of the transmission network not explicitly represented.

National Grid, the system operator, released a reduced model, depicted in Fig. 2B, for academic studies. Both reduced models were used to compare and improve confidence in results.

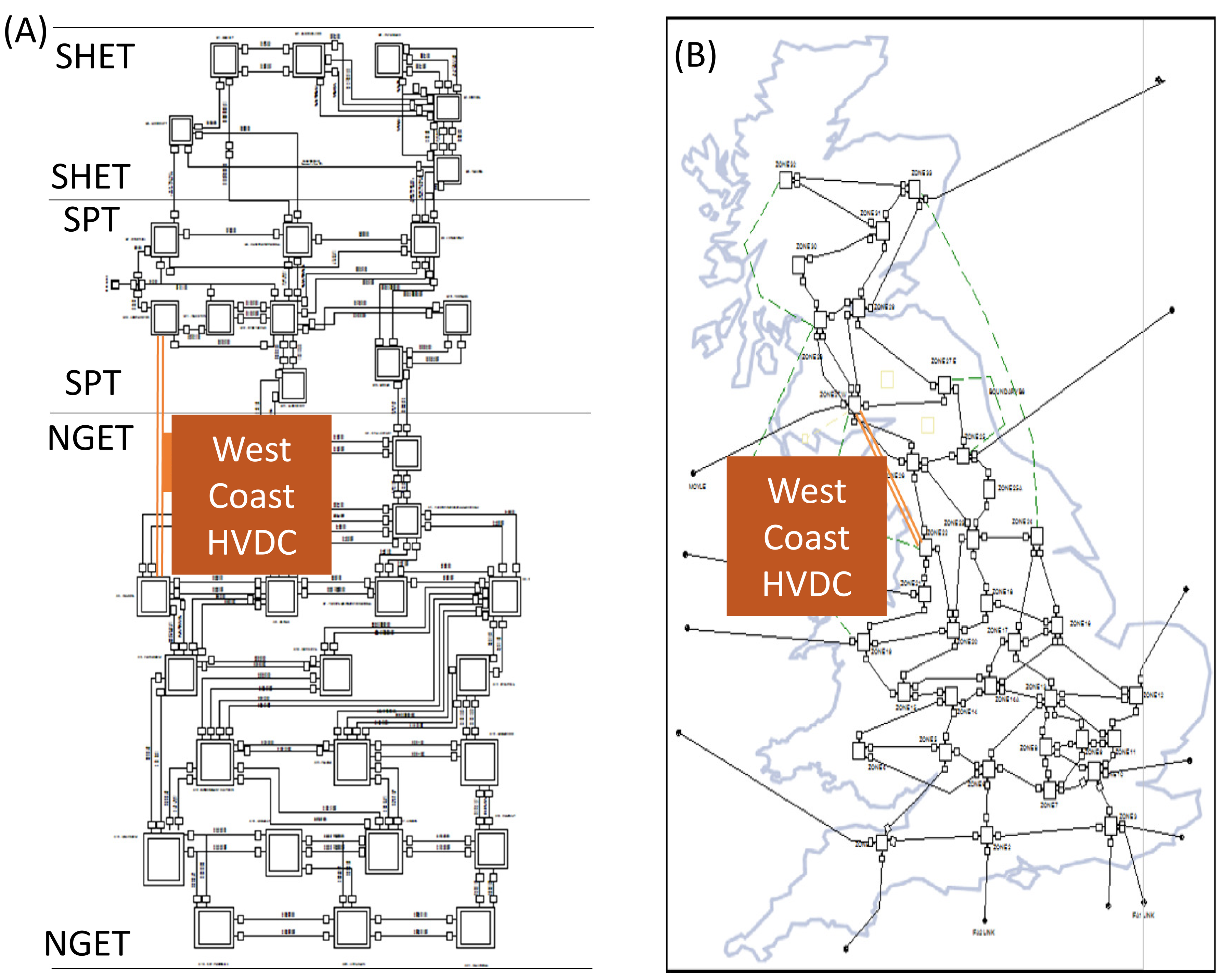

Fig. 2: Reduced network models: A – University of Strathclyde Reduced GB Model; B – National Grid Reduced GB Model.

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4. RoCoF and Largest Loss Risk Study

Scenario being studied:

- with and without the deployment of 5 GVA of synchronous compensation (SC) with an inertia constant of 2 s;
- system inertia of 75 GVAs (a low inertia scenario)
- a largest loss risk of 375 MW is calculated for a RoCoF limit of 0.125 Hz/s.

Mathematical assessment (Fig 3)

Mathematical calculation suggests that 5 GVA of SC, can reduce RoCoF from 0.125 Hz/s to 0.11 Hz/s or increase the LOIF tolerance from 375 MW to 425 MW with RoCoF at 0.125 Hz/s.

Study using single bus equivalent model (Fig. 4)

This study indicates that 5 GVA of SC, while considering dynamic system elements, can reduce the RoCoF from 0.116 Hz/s to 0.103 Hz/s for a 375 MW LOIF. Similarly, it was also observed that the deployment of 5 GVA of SC for a RoCoF of 0.125 Hz/s raised the LOIF tolerance to 460 MW from 410 MW without SC.

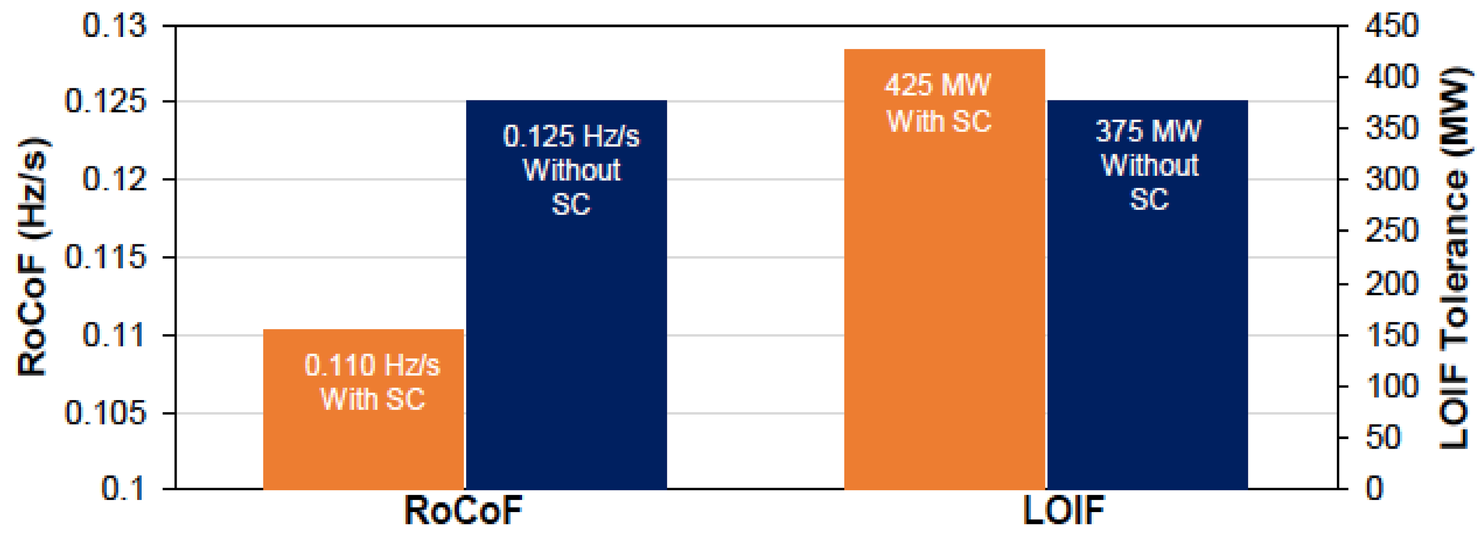


Fig. 3: Loss of in-feed (LOIF) tolerance and RoCoF comparison

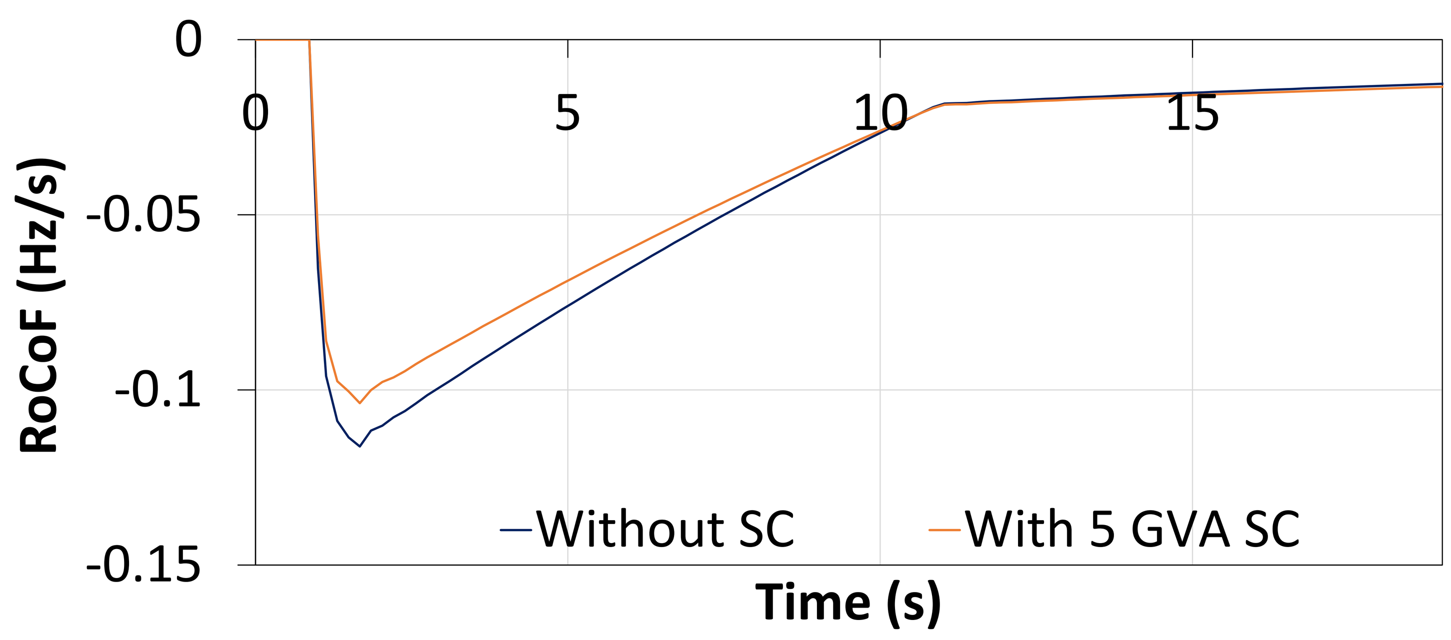


Fig. 4: RoCoF comparison with system dynamics

5. Fault Level and SCR Study

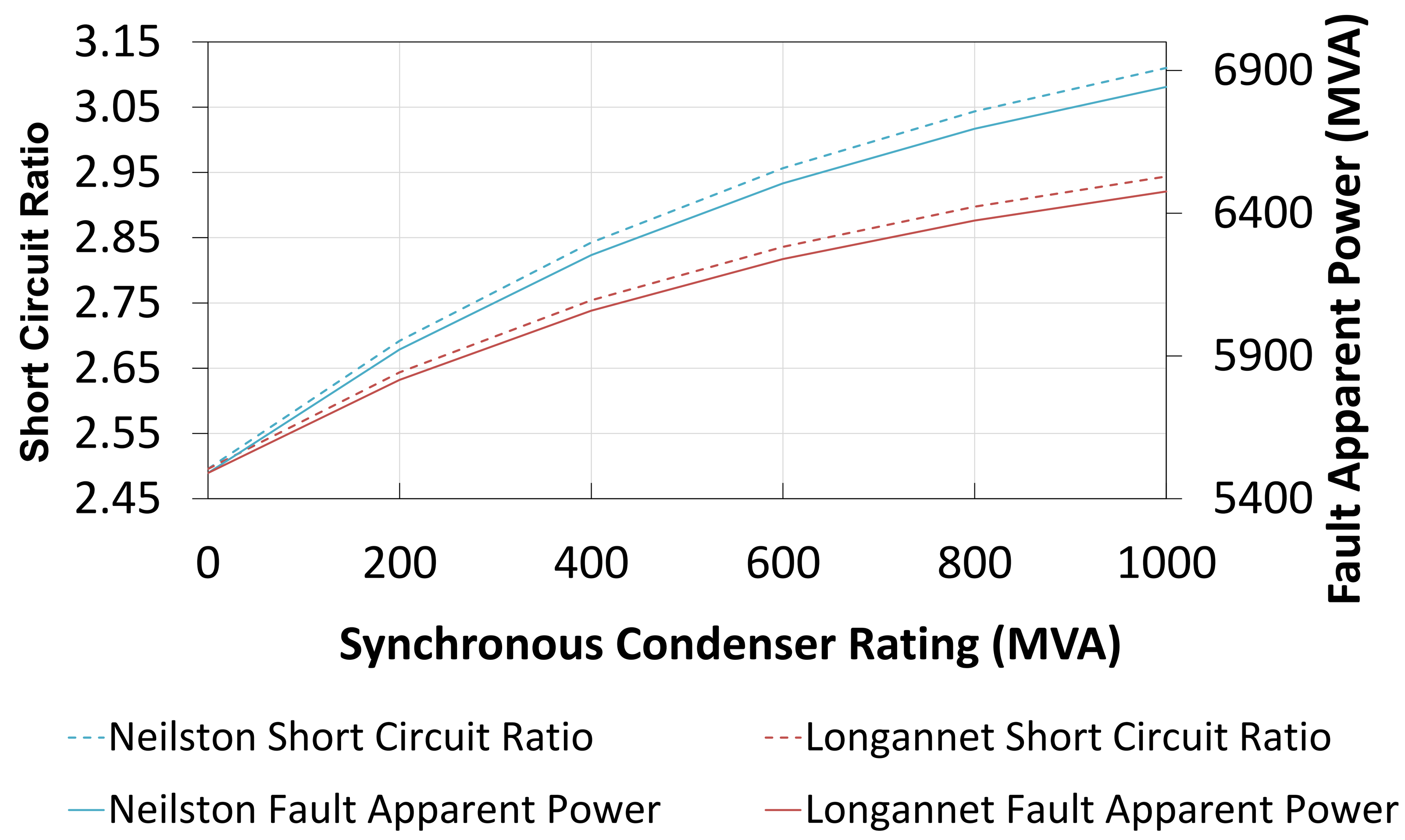
Scenario being studied:

- Minimum demand conditions
- Fault location: Hunterston power station
- Fault applied: three-phase busbar fault using IEC 60909 minimum short circuit tool in PowerFactory,
- with SC placed at Longannet and Neilston at varying capacities, 0 – 1 GVA in 200 MVA steps

Results:

•the fault level (at 80 ms after the fault inception) and SCR at Hunterston rises with increasing capacity of SC;

•the increase in fault level and SCR is pronounced if the SC is placed electrically closer to Hunterston.



6. Conclusions and Future Work

This work presents studies that investigate the potential benefits of synchronous compensation on various aspects of system performance, with a focus on the contribution to fault level and system inertia.

•**The RoCoF and largest loss risk study** indicates that conditions that would have originally been at the cusp of breaching the RoCoF limit can be brought further within acceptable limits when 5 GVA of SC is introduced to the network, raising the LOIF tolerance and potentially reducing constraint costs. This reduction in RoCoF, allows more time for other services to respond and could contribute to a reduction in the overall active power requirement for frequency containment. Furthermore, a reduction in the RoCoF can mitigate the risk of a cascading event because of the tripping of RoCoF protection applied to distributed generation, which would exacerbate the initial system disturbance.

•**The fault level and SCR study** indicates that the short circuit ratio at Hunterston rises with increasing capacities of synchronous compensation, effectively strengthening the AC system, and minimising the risk of commutation failure of the West Coast HVDC link during short circuits close to the northern terminal. Furthermore, the increase in fault levels and short circuit ratio is pronounced if the synchronous compensator is placed electrically closer to Hunterston.

Future work will focus on the development of a more detailed synchronous compensator model and its control algorithm for integration to the various network models for further study of its benefits and the investigation of the optimal location for the deployment of synchronous compensators in the GB transmission network.