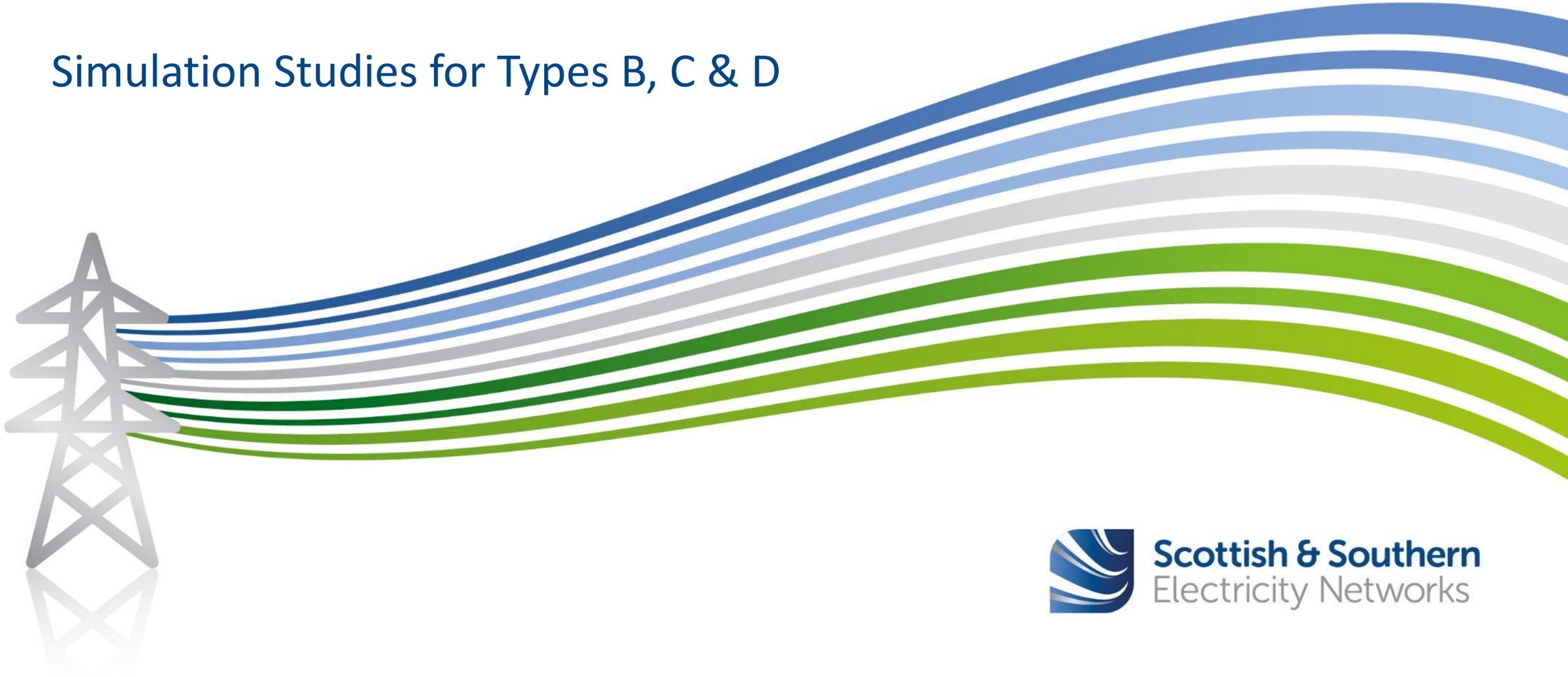
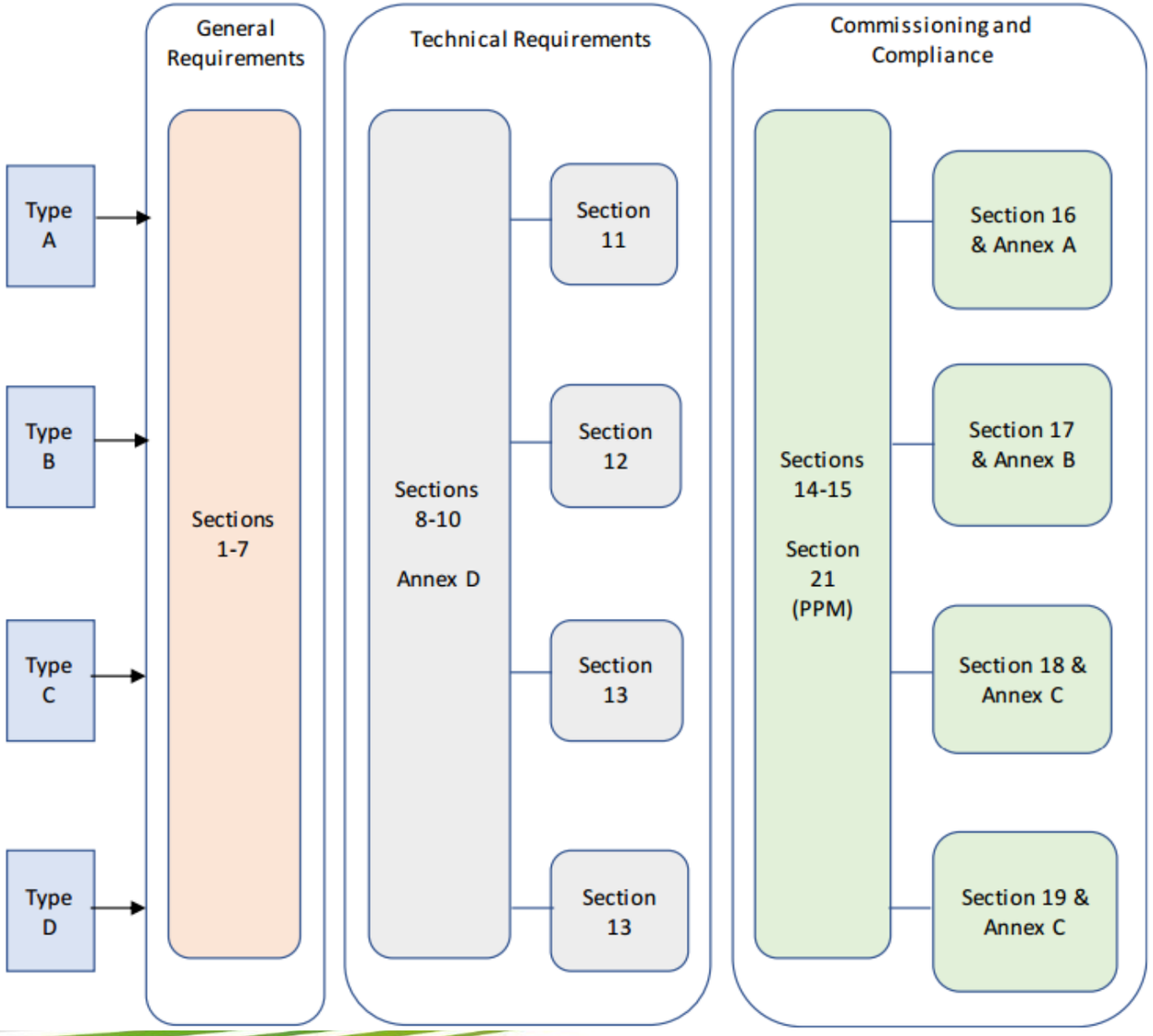
EREC G99

Simulation Studies for Types B, C & D



Scottish & Southern Electricity Networks

EREC G99 Structure



Scottish & Southern Electricity Networks

EREC G99 Compliance Demonstration

Submission Stages

- **Generators can choose how to demonstrate G99 compliance**
- Compliance documentation – Power Generating Module Document (PGMD) shall be submitted to SSEN at different stages (Initial Submission, ION, FONS)

Key to Submission Stage

A – Application: Submission of the Standard Application Form.

For **Types B & C: IS – Initial Submission:** The programme of initial compliance document submission to be agreed between the **Generator** and the **DNO** as soon as possible after acceptance of a Connection Offer. Initial Submission of this **Power Generating Module Document** to be completed at least 28 days before the **Generator** synchronising the **Power Generating Module** for the first time.

For **Type D: ION – Interim Operational Notification:** The programme of initial compliance document submission to be agreed between the **Generator** and the **DNO** as soon as possible after acceptance of a Connection Offer. Initial Submission of this **Power Generating Module Document** to be completed at least 28 days before the **Generator** synchronising the **Power Generating Module** for the first time.

FONS – Final Operational Notification Submission: The **Generator** shall submit post energisation verification test documents to obtain **Final Operational Notification** from the **DNO**.

Scottish & Southern Electricity Networks

EREC G99 Compliance Demonstration

Possible sources of confirmation of compliance

- **Generators can choose how to demonstrate G99 compliance**
- The PGMD forms set the DNO's expectation as to what are the possible sources of confirmation of compliance

Key to evidence requested

S-Indicates that **DNO** would expect to see the results of a Simulation study

P-**Generating Unit** design data

MI-**Manufacturer** Information, generic data or test results as appropriate

D-Copies of correspondence or other documents confirming that a requirement has been met

T-Indicates that **DNO** would expect to see results of, and/or witness, tests or monitoring which demonstrates compliance

TV -Indicates Type Test reports (if **Generator** pursues this compliance option)

Submission Stages

Requirements

Possible Sources of Evidence

G99 Reference	Compliance Requirement of the Power Generating Module	Submission Stage	Evidence Requested (and / or)	Compliance Y, O, UR, N	Generator's Statement *(Provide document references with any additional comments)*
17.2.1, 17.2.3, 17.4.1	Confirmation that a completed Standard Application Form has been submitted to the **DNO**	A, IS, FONS	P, MI, D		
9.4.3	**Power Quality – Voltage fluctuations and Flicker**: The installation must be designed in accordance with EREC P28	IS	MI, D, TV		

Scottish & Southern Electricity Networks

Simulation Studies

General

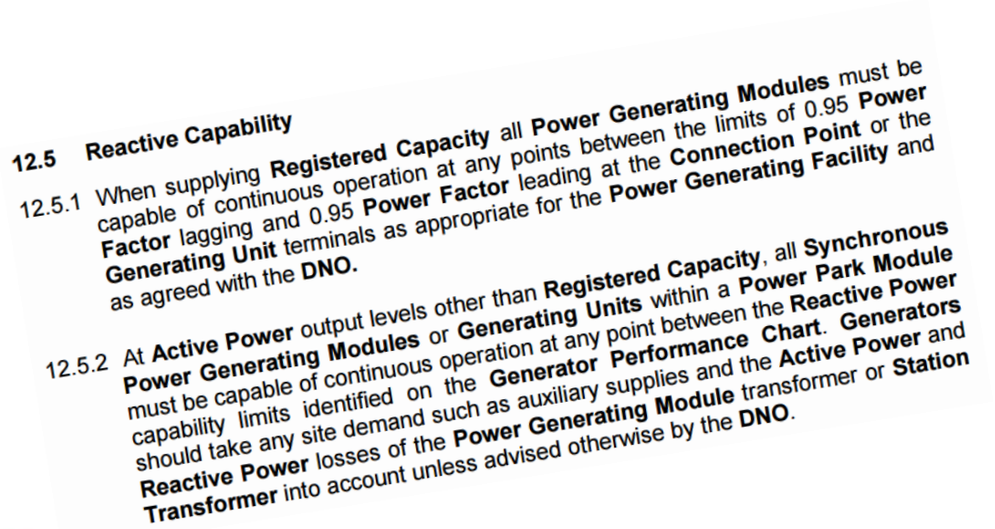
- Simulations studies are required for Types B, C and D Power Generating Modules (PGMs) as explained in Annex B.4 and Annex C.7 as applicable
- Generators with Types B, C and D PGMs will need to submit simulation studies in the form of a report:
  - Reports should be in English with all diagrams and graphs plotted clearly with legible axes and scaling provided to ensure any variations in plotted values is clear
- Generators with Type C and Type D PGMs will need to submit appropriate simulation models:
  - The model will be in a compiled form compatible with the current version* of PSS/E used by SSEN.
  - PSS/E Version 33.4 is currently used by SSEN.

Type B

Scottish & Southern Electricity Networks

Reactive Power Capability

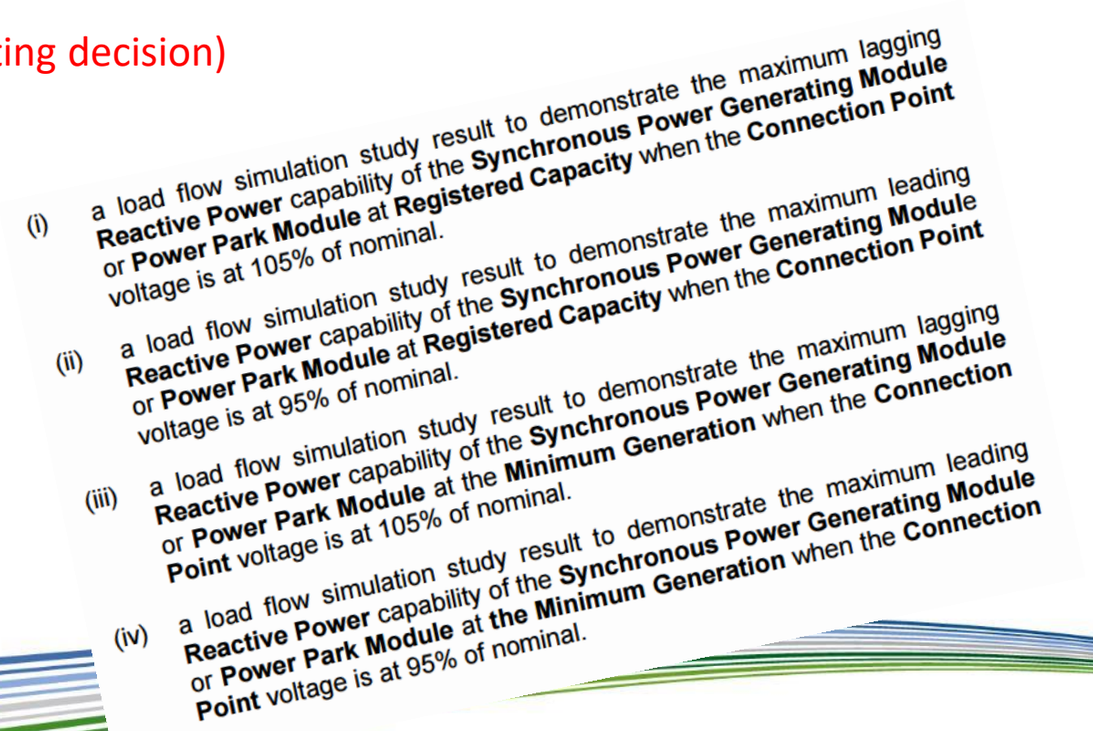
- Requirements as set out in Section 12.5
- Simulation study in accordance with Annex B.4.2 and by submission of a report
  - **Note:** Simplification is proposed in G99 amendment 4 (awaiting decision)



12.5 Reactive Capability

12.5.1 When supplying **Registered Capacity** all **Power Generating Modules** must be capable of continuous operation at any points between the limits of 0.95 **Power Factor** lagging and 0.95 **Power Factor** leading at the **Connection Point** or the **Generating Unit** terminals as appropriate for the **Power Generating Facility** and as agreed with the **DNO**.

12.5.2 At **Active Power** output levels other than **Registered Capacity**, all **Synchronous Power Generating Modules** or **Generating Units** within a **Power Park Module** must be capable of continuous operation at any point between the **Reactive Power** capability limits identified on the **Generator Performance Chart**. **Generators** should take any site demand such as auxiliary supplies and the **Active Power** and **Reactive Power** losses of the **Power Generating Module** transformer or **Station Transformer** into account unless advised otherwise by the **DNO**.



(i) a load flow simulation study result to demonstrate the maximum lagging **Reactive Power** capability of the **Synchronous Power Generating Module** or **Power Park Module** at **Registered Capacity** when the **Connection Point** voltage is at 105% of nominal.

(ii) a load flow simulation study result to demonstrate the maximum leading **Reactive Power** capability of the **Synchronous Power Generating Module** or **Power Park Module** at **Registered Capacity** when the **Connection Point** voltage is at 95% of nominal.

(iii) a load flow simulation study result to demonstrate the maximum lagging **Reactive Power** capability of the **Synchronous Power Generating Module** or **Power Park Module** at the **Minimum Generation** when the **Connection Point** voltage is at 105% of nominal.

(iv) a load flow simulation study result to demonstrate the maximum leading **Reactive Power** capability of the **Synchronous Power Generating Module** or **Power Park Module** at **the Minimum Generation** when the **Connection Point** voltage is at 95% of nominal.

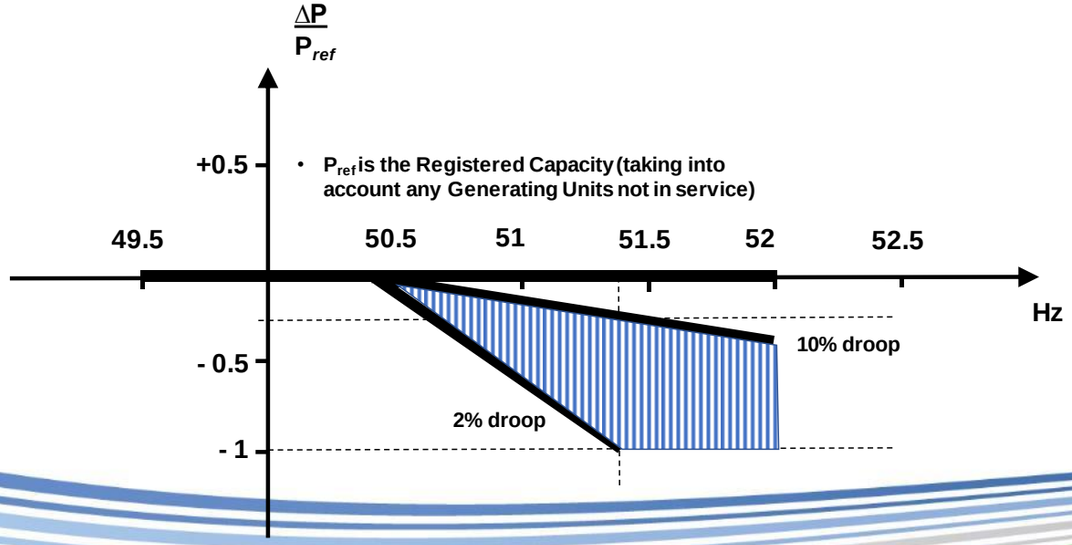
Scottish & Southern Electricity Networks

Voltage Control and Reactive Power Stability

- Requirements as set out in Section 12.4
- Simulation study in accordance with Annex B.4.3 and by submission of a report
  - **Note:** Annex B.4.3 is proposed to be **removed** from G99 (consultation now closed, awaiting decision)

Limited Frequency Sensitive Mode – Over Frequency (LFSM-O)

- Requirements as set out in Section 12.2.4
- Simulation study in accordance with Annex B.4.5 and by submission of a report
  - **Note:** Simplification is proposed in G99 amendment 4 (awaiting decision)



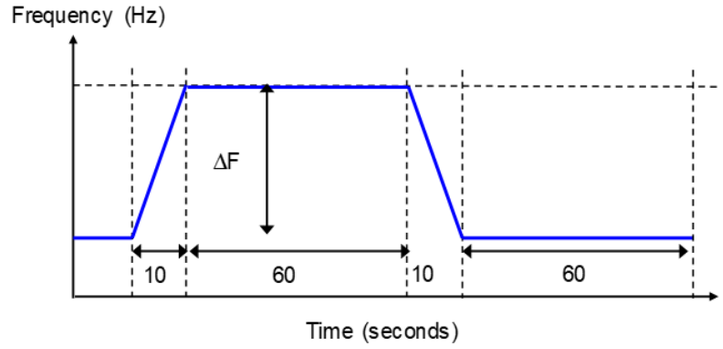


Figure B.4.1 – LFSM-O frequency step response simulation

Figure B.4.2 – Not used

B.4.5.3 Simulation studies shall be performed for **Limited Frequency Sensitive Mode** (**LFSM**). The simulation study results should indicate **Active Power** and frequency. The **Active Power** reduction should occur between 50.4 Hz and 52 Hz in accordance with the **Droop** setting.

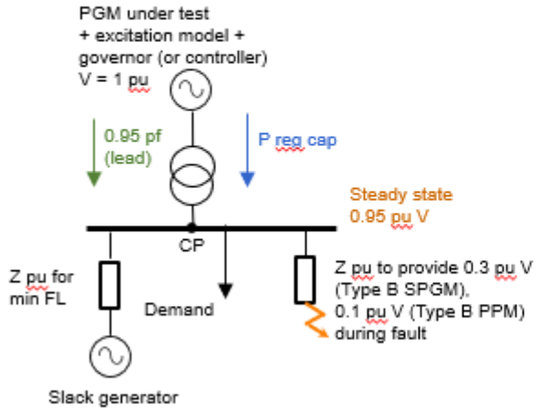
Scottish & Southern Electricity Networks

Fault Ride Through (FRT)

& Fast Fault Current Injection (FFCI) for **PPM only**

- Requirements as set out in Section 12.3 (FRT) and Section 12.6 (FFCI)
- Simulation study in accordance with Annex B.4.4 and by submission of a report

Time series study required to demonstrate fault ride through compliance



#	Set V @ CP	Set P	Set pf	Fault time
1	0.95	Reg Cap	0.95	140 ms

B.4.4.2 The **Generator** shall supply time series simulation study results to demonstrate the capability of **Synchronous Power Generating Modules** and **Power Park Modules** to meet paragraphs 12.3 and paragraph 12.6 as applicable by submission of a report containing:

(i) a time series simulation study of a 140 ms three phase short circuit fault with a retained voltage as detailed in Table B.4.1 applied at the **Connection Point** of the **Power Generating Module**.

(ii) a time series simulation study of 140 ms unbalanced short circuit faults with a retained voltage as detailed in Table B.4.1 on the faulted phase(s) applied at the **Connection Point** of the **Power Generating Module**. The unbalanced faults to be simulated are:

1. a phase to phase fault
2. a two phase to earth fault
3. a single phase to earth fault.

Table B.4.1

	Retained Voltage
Power Generating Module	
Synchronous Power Generating Module	30%
Power Park Module	10%

B.4.4.3 The simulation study should be completed with the **Power Generating Module** operating at full **Active Power** and maximum leading **Reactive Power** and the fault level at the **Connection Point** at minimum as notified by the **DNO**.

Scottish & Southern Electricity Networks

Fault Ride Through (FRT)

Type B Requirements (EREC G99 Section 12.3)

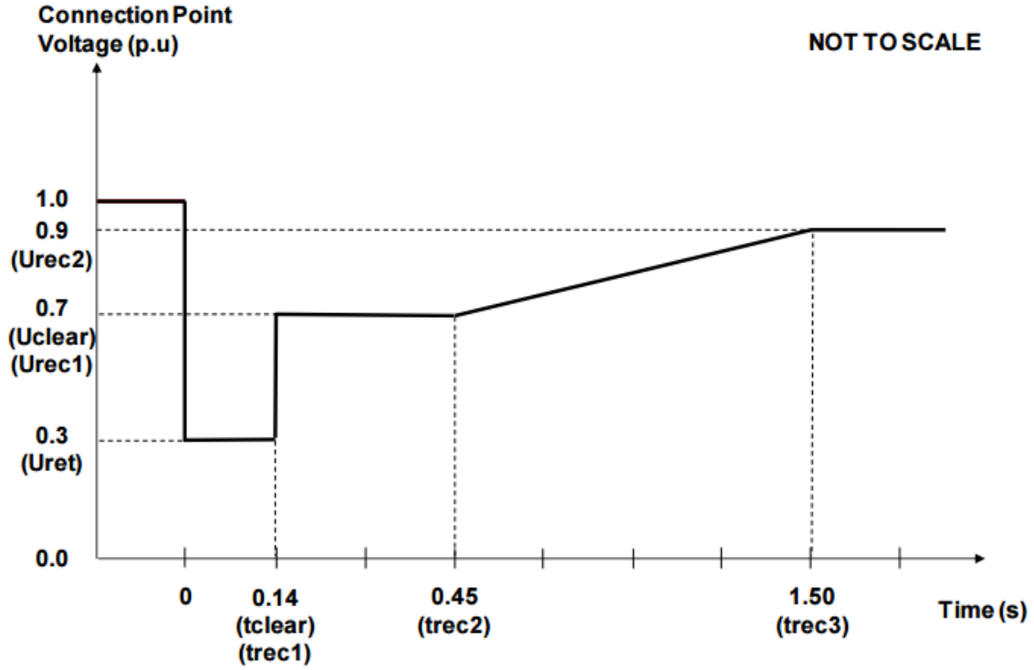


Figure 12.3 - Voltage against time curve applicable to Type B Synchronous Power Generating Modules

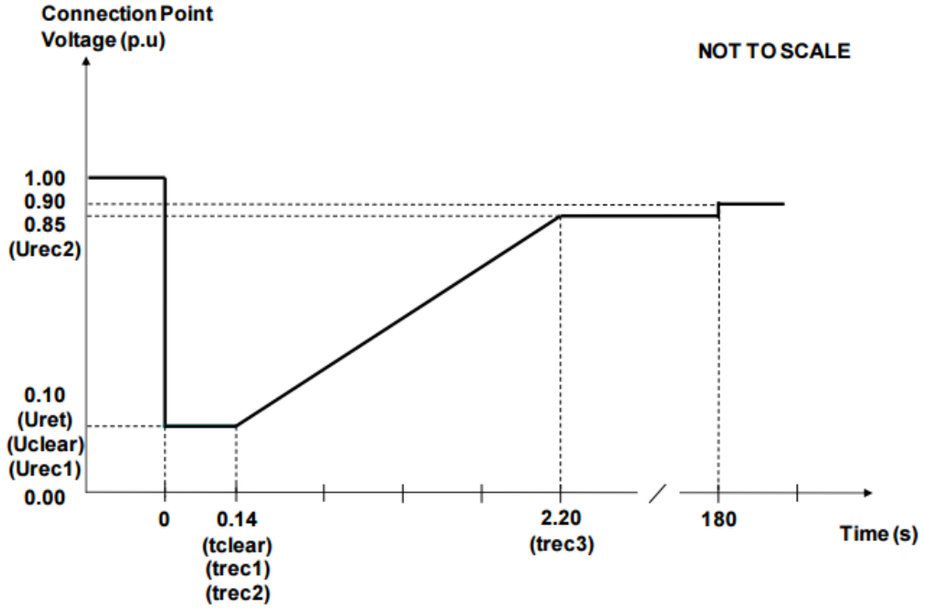


Figure 12.4 - Voltage against time curve applicable to Type B Power Park Modules

Scottish & Southern Electricity Networks

PPMs – Fast Fault Current Injection

Type B Requirements (EREC G99 Section 12.6)

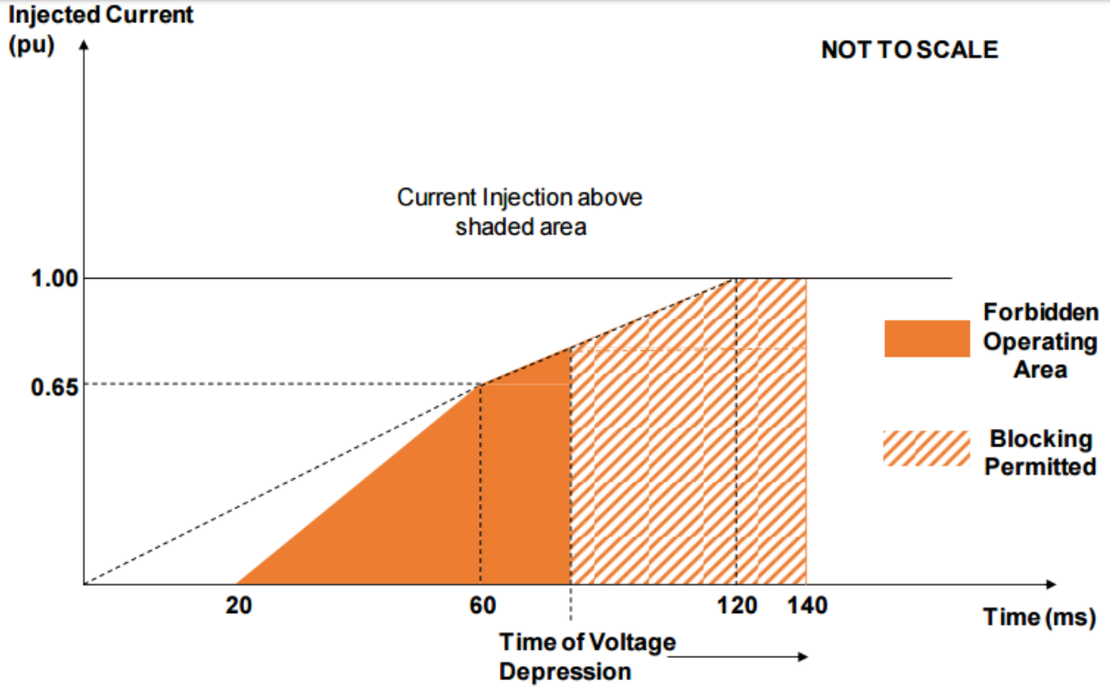


Figure 12.5 (a) Chart showing area of Reactive Current injections for voltage depressions of less than 140 ms duration

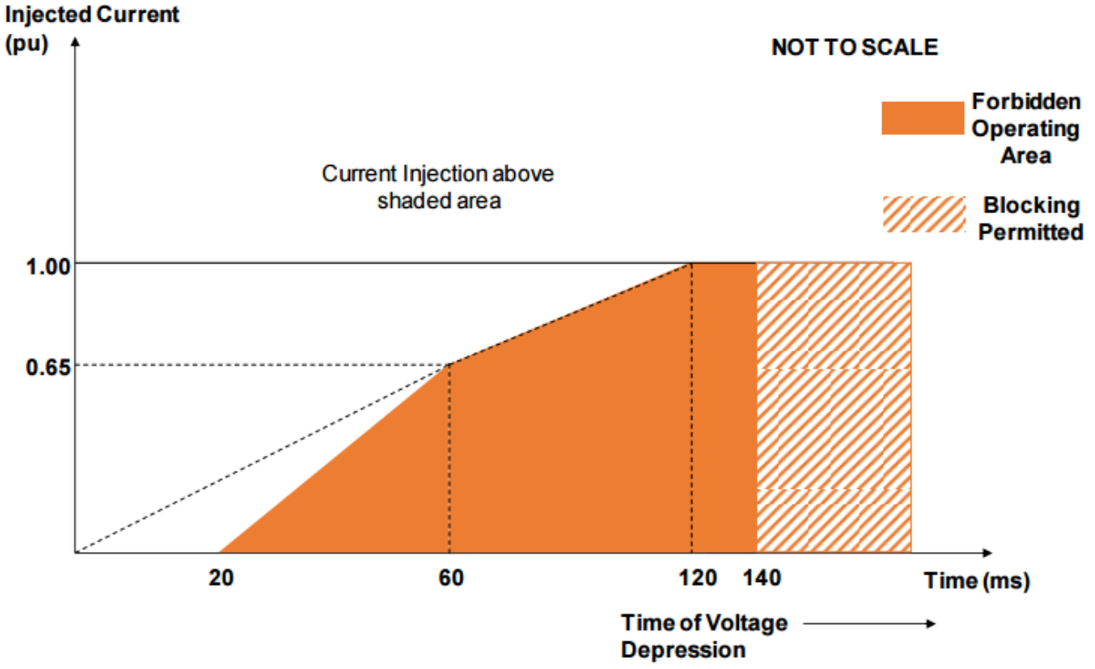


Figure 12.5 (b) Chart showing area of Reactive Current injections for voltage depressions of greater than 140 ms duration

Scottish & Southern Electricity Networks

Types C & D

Scottish & Southern Electricity Networks

Synchronous Power Generating Modules

Scottish & Southern Electricity Networks

Power System Stabiliser Tuning

Required by Grid Code

- In the case of a Synchronous Power Generating Module with a Power System Stabiliser the Power System Stabiliser tuning simulation study report required by the Grid Code C.1.2.5.6 shall be submitted in accordance with Grid Code EPC.A.3.2.1

Reactive Power Capability

- Requirements as set out in Section 13.5
- Simulation study in accordance with Annex C.7.3 and by submission of a report and model
  - **Note:** Slight modification is proposed in G99 amendment 4 (awaiting decision)

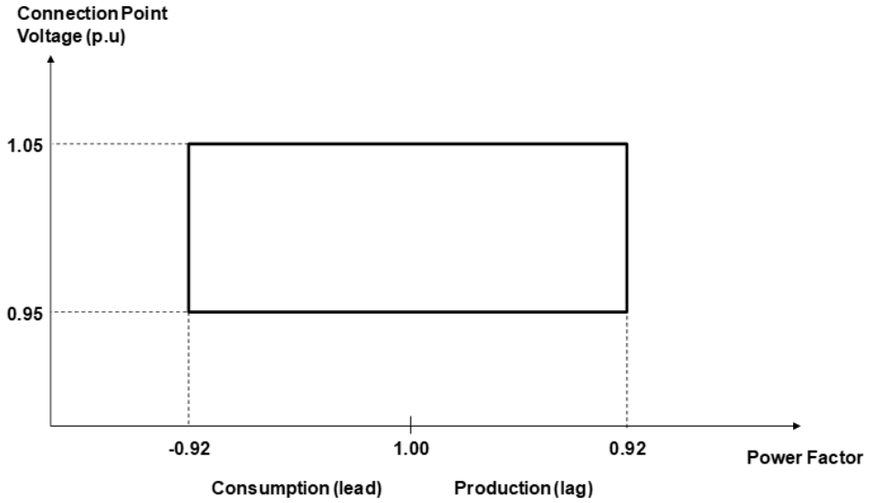
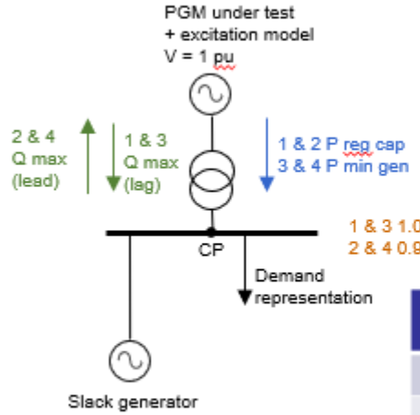
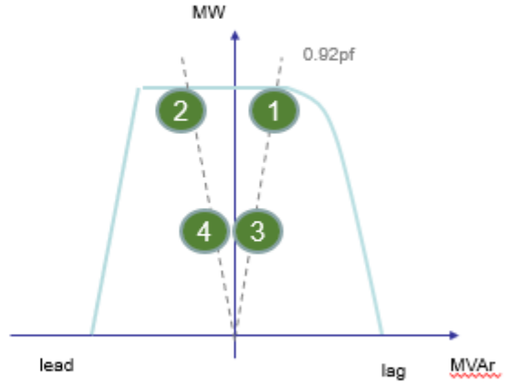


Figure 13.10 Reactive Power capability requirements (Synchronous Power Generating Modules)

Studies to demonstrate compliance with performance chart



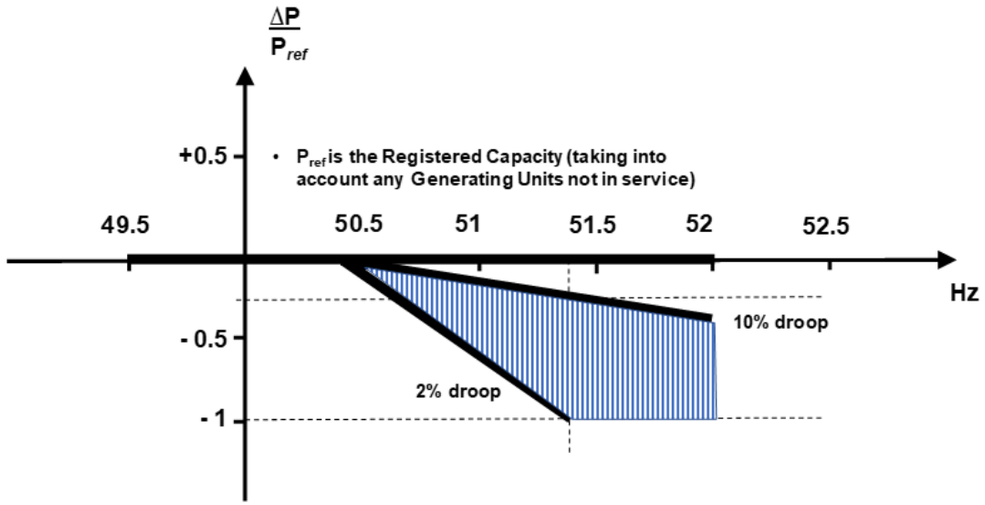
#	Set V @ CP	Set P	Calc Q
1	1.05	Reg Cap	Max lag
2	0.95	Reg Cap	Max lead
3	1.05	Min Gen	Max lag
4	0.95	Min Gen	Max lead



Scottish & Southern Electricity Networks

Limited Frequency Sensitive Mode – Over Frequency (LFSM-O) & Frequency Sensitive Mode (FSM)

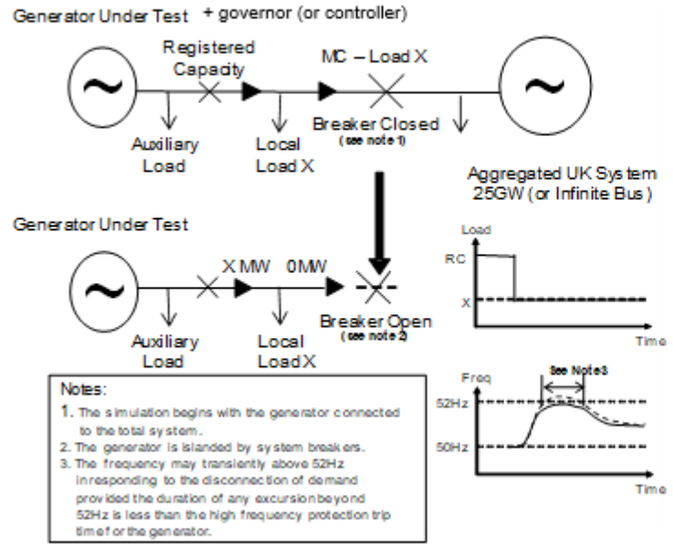
- Requirements as set out in Section 13.2.4
- Simulation study in accordance with Annex C.7.6 and by submission of a report and model



P_{ref} is the reference **Active Power** to which ΔP is related and. ΔP is the change in **Active Power** output from the **Power Generating Module**.

Figure 13.2 Active Power Frequency Response capability when operating in LFSM-O

Time series study required to demonstrate frequency response to increasing f

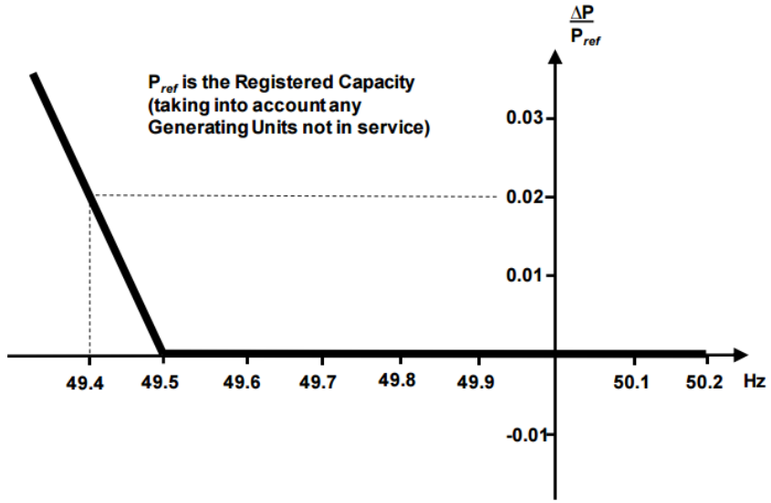


#	Scenario	Set P	Action	Output
1	Loss of infinite bus	Reg Cap	Open system breaker as Notes	Reduction in P (as per droop setting)
2	Freq step	Reg Cap	Inject freq step change into governor / controller model	Reduction in P (as per droop setting)
3	Freq ramp	Reg Cap	Inject freq ramp into governor / controller model	Reduction in P (as per droop setting)

Scottish & Southern Electricity Networks

Limited Frequency Sensitive Mode – Under Frequency (LFSM-U)

- Requirements as set out in Section 13.2.5
- Simulation study in accordance with Annex C.7.7 and by submission of a report and model

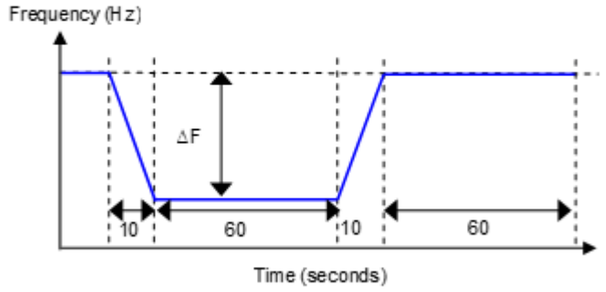


P_{ref} is the Registered Capacity, taking into account any Generating Units not in service to which ΔP is related and ΔP is the change in **Active Power** output from the **Power Generating Module**. The **Power Generating Module** has to provide a positive **Active Power** output change with a **Droop** of 10% or less based on P_{ref}.

Figure 13.3 - Limited Frequency Sensitive Mode – Under frequency capability of Power Generating Modules

Time series study to demonstrate low frequency control

Study parameters	Output
PGM at 80% Registered Capacity	
Large reduction in f - ramped over 10 s	Increase in P to Registered Capacity
60 s of steady state f	
Increase f - ramped over 10 s	Reduction in P back to 80% Registered Capacity
	60 s of steady output

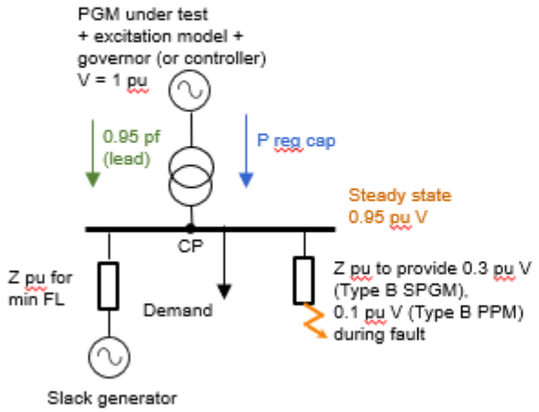


Scottish & Southern Electricity Networks

Fault Ride Through (FRT)

- Requirements as set out in Section 13.3 (FRT)
- Simulation study in accordance with Annex C.7.5 and by submission of a report and model

Time series study required to demonstrate fault ride through compliance



#	Set V @ CP	Set P	Set pf	Fault time
1	0.95	Reg Cap	0.95	140 ms

Scottish & Southern Electricity Networks

Fault Ride Through

Types C & D requirements (EREC G99 Section 13.3)

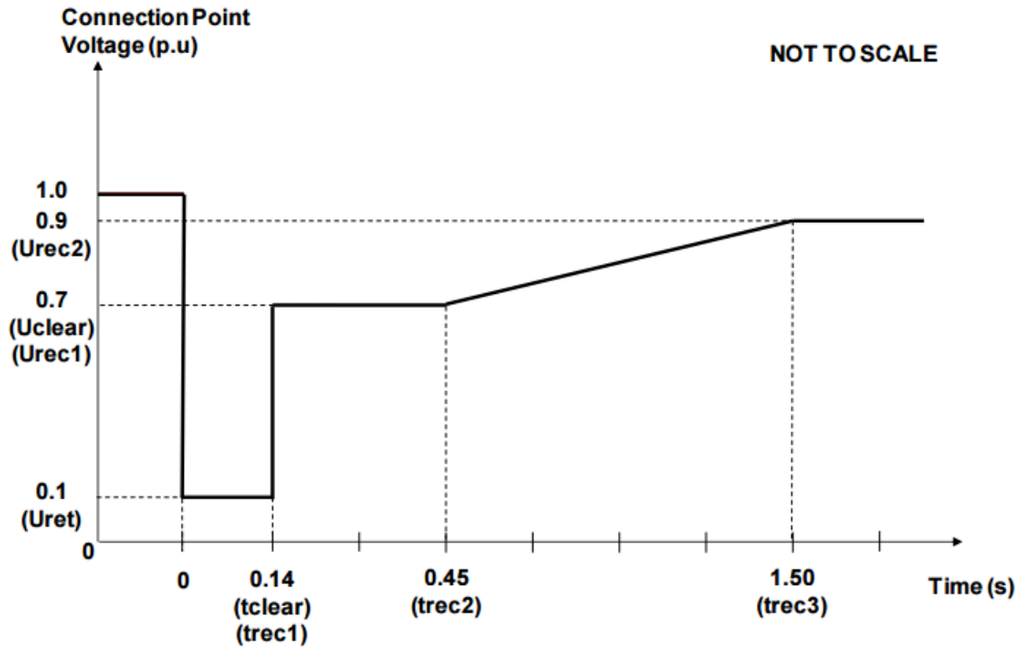


Figure 13.6 Voltage against time curve applicable to Type C and Type D Synchronous Power Generating Modules connected below 110 kV

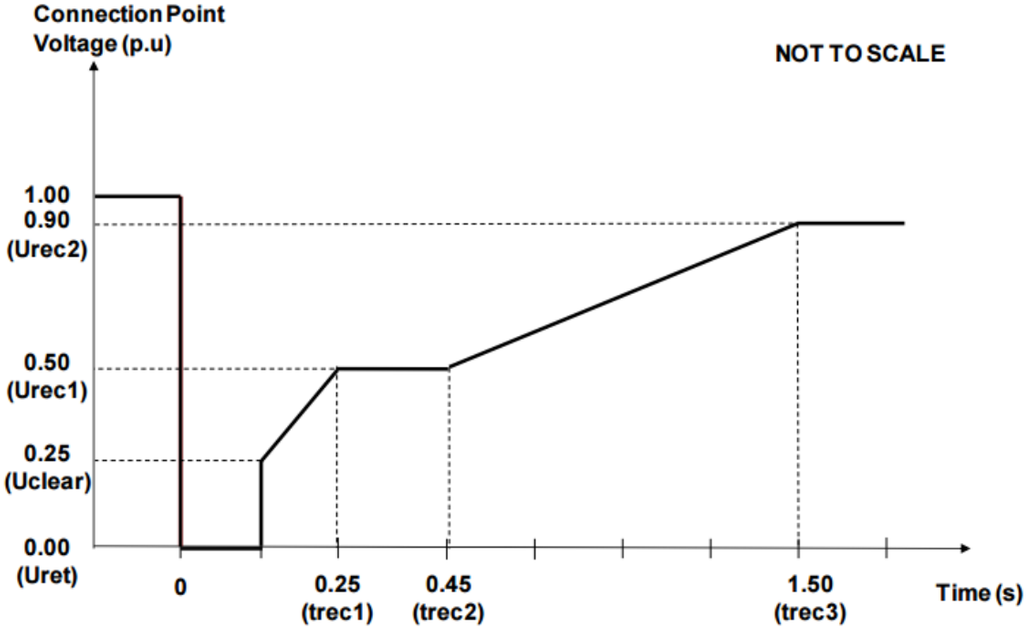


Figure 13.7 - Voltage against time curve applicable to Type D Synchronous Power Generating Modules connected at or above 110 kV

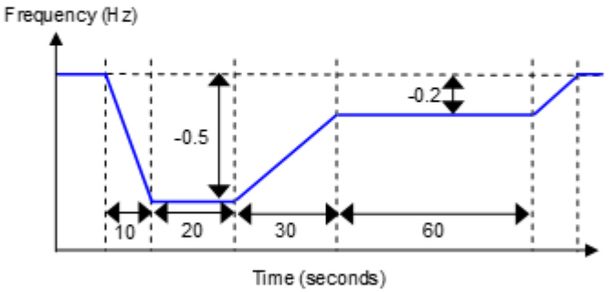
Scottish & Southern Electricity Networks

Model Validation

- Demonstration of the frequency control or governor/load controller/plant model, **Excitation System** and voltage controller by carrying out simulation studies in accordance with Annex C.7.8

Study to verify frequency controller models

Study parameters	Output
PGM at 80% Registered Capacity	
Ramped reduction in f (0.5 Hz over 10 s)	Increase in P
20 s of steady state f	
Ramped increase f (0.3 Hz over 30 s)	Reduction in P
	60 s of steady output
Also simulate actual tests for synchronous PGMs and overlay results	



Study to verify excitation/ controller models

Study parameters	Output
Synchronous PGM operating open circuit at rated V: 10% step increase in terminal V ref 90% to 100%	Terminal V Field V P Q Power system stabiliser output if applicable
All PGM operating at Registered Capacity, Terminal voltage 100%, pf = 1 2% step increase in Vref	
Also simulate actual tests for all PGMs and overlay results	

thern
vorks

Power Park Modules

Scottish & Southern Electricity Networks

Power System Stabiliser Tuning

Required by Grid Code

- In the case of Power Park Modules with a Power System Stabiliser at the Connection Point the Power System Stabiliser tuning simulation study report required by the Grid Code C.2.2.4.1 shall be submitted in accordance with Grid Code ECP.A.3.2.2

Reactive Power Capability

- Requirements as set out in Section 13.5
- Simulation study in accordance with Annex C.7.3 and by submission of a report and model
  - **Note:** Modification is proposed in G99 amendment 4 (awaiting decision)

C.7.3.2 For **Power Park Modules** the **Generator** shall supply simulation studies to demonstrate the capability to meet Section 13.5 by submission of a report containing:

(i) a load flow simulation study result to demonstrate the maximum lagging **Reactive Power** capability of the **Power Park Module** at **Registered Capacity** when the **Connection Point** voltage is at 103% of nominal.

(ii) a load flow simulation study result to demonstrate the maximum leading **Reactive Power** capability of the **Power Park Module** at **Registered Capacity** when the **Connection Point** voltage is at 97% of nominal.

(iii) a load flow simulation study result to demonstrate the maximum lagging **Reactive Power** capability of the **Power Park Module** at the **Minimum Stable Operating Level** when the **Connection Point** voltage is at 103% of nominal.

(vi) a load flow simulation study result to demonstrate the maximum leading **Reactive Power** capability of the **Power Park Module** at **the Minimum Stable Operating Level** when the **Connection Point** voltage is at 97% of nominal.

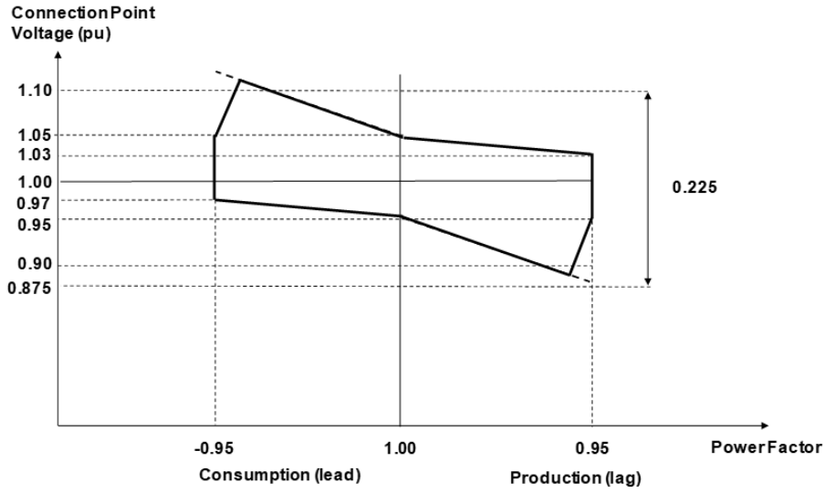


Figure 13.11 Reactive Power capability requirements (Power Park Modules operating at Registered Capacity, voltage above 33 kV)

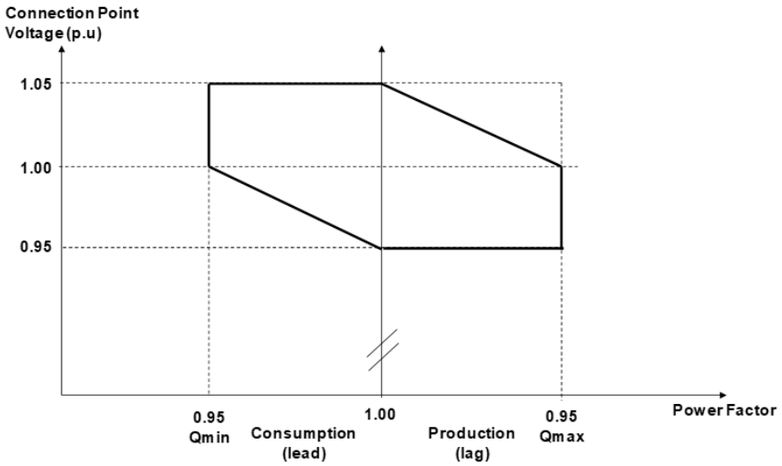
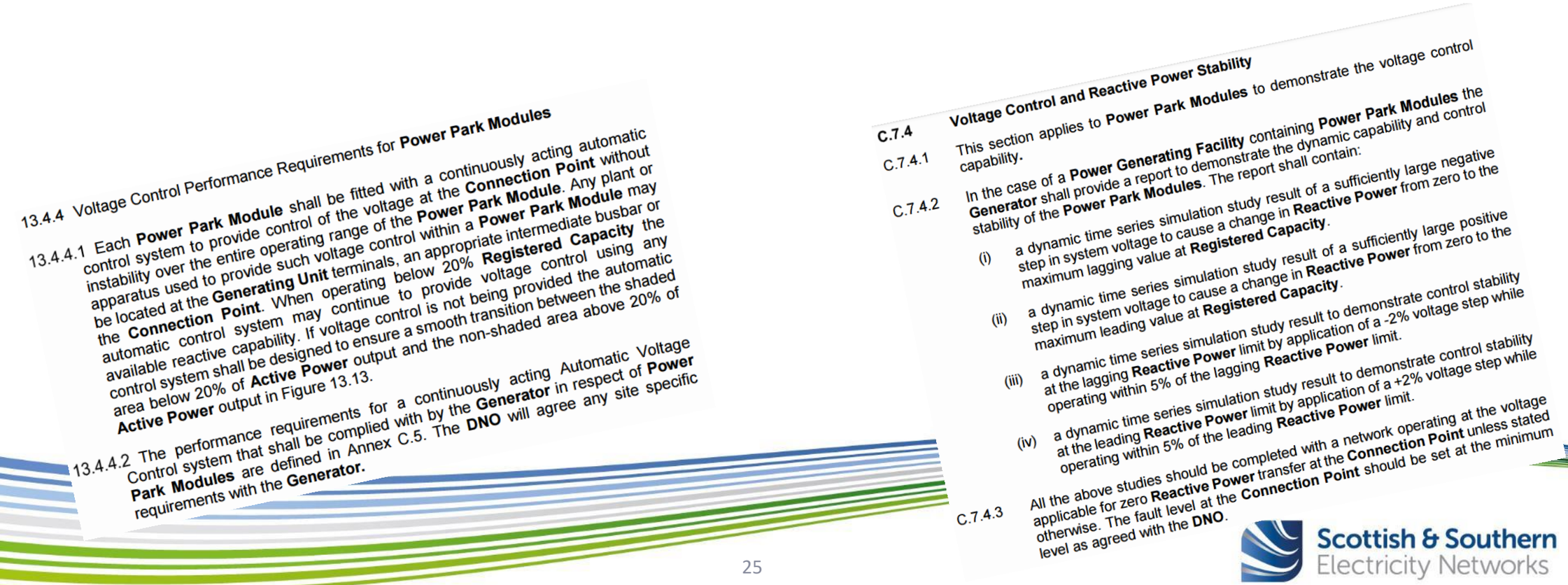


Figure 13.12 Reactive Power capability requirements (Power Park Modules operating at Registered Capacity, voltage at or below 33 kV)

Voltage Control and Reactive Power Stability

- Requirements as set out in Section 13.4
- Simulation study in accordance with Annex C.7.4 and by submission of a report and model



13.4.4 Voltage Control Performance Requirements for **Power Park Modules**

13.4.4.1 Each **Power Park Module** shall be fitted with a continuously acting automatic control system to provide control of the voltage at the **Connection Point** without instability over the entire operating range of the **Power Park Module**. Any plant or apparatus used to provide such voltage control within a **Power Park Module** may be located at the **Generating Unit** terminals, an appropriate intermediate busbar or the **Connection Point**. When operating below 20% **Registered Capacity** the automatic control system may continue to provide voltage control using any available reactive capability. If voltage control is not being provided the automatic control system shall be designed to ensure a smooth transition between the shaded area below 20% of **Active Power** output and the non-shaded area above 20% of **Active Power** output in Figure 13.13.

13.4.4.2 The performance requirements for a continuously acting Automatic Voltage Control system that shall be complied with by the **Generator** in respect of **Power Park Modules** are defined in Annex C.5. The **DNO** will agree any site specific requirements with the **Generator.**

C.7.4 Voltage Control and Reactive Power Stability

C.7.4.1 This section applies to **Power Park Modules** to demonstrate the voltage control capability.

C.7.4.2 In the case of a **Power Generating Facility** containing **Power Park Modules** the **Generator** shall provide a report to demonstrate the dynamic capability and control stability of the **Power Park Modules**. The report shall contain:

(i) a dynamic time series simulation study result of a sufficiently large negative step in system voltage to cause a change in **Reactive Power** from zero to the maximum lagging value at **Registered Capacity**.

(ii) a dynamic time series simulation study result of a sufficiently large positive step in system voltage to cause a change in **Reactive Power** from zero to the maximum leading value at **Registered Capacity**.

(iii) a dynamic time series simulation study result to demonstrate control stability at the lagging **Reactive Power** limit by application of a -2% voltage step while operating within 5% of the lagging **Reactive Power** limit.

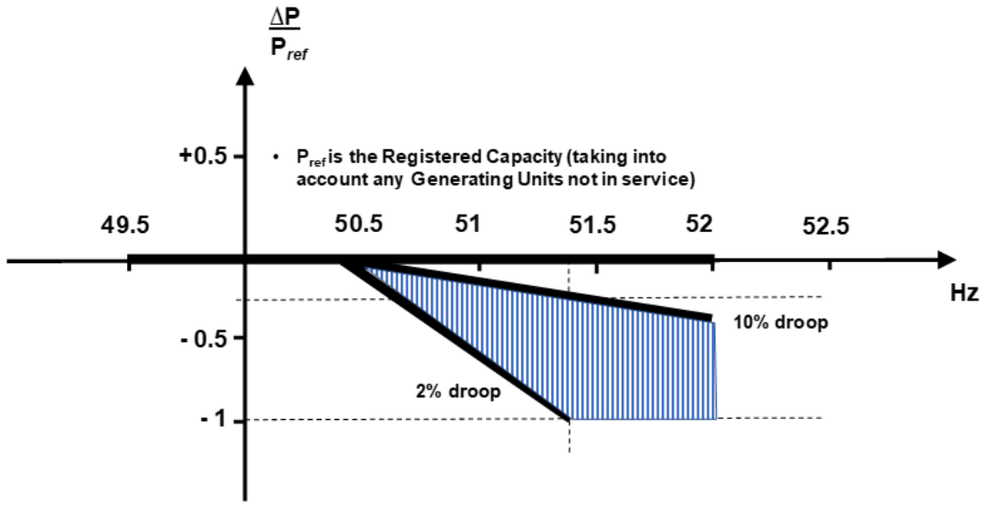
(iv) a dynamic time series simulation study result to demonstrate control stability at the leading **Reactive Power** limit by application of a +2% voltage step while operating within 5% of the leading **Reactive Power** limit.

C.7.4.3 All the above studies should be completed with a network operating at the voltage applicable for zero **Reactive Power** transfer at the **Connection Point** unless stated otherwise. The fault level at the **Connection Point** should be set at the minimum level as agreed with the **DNO**.

Scottish & Southern Electricity Networks

Limited Frequency Sensitive Mode – Over Frequency (LFSM-O) & Frequency Sensitive Mode (FSM)

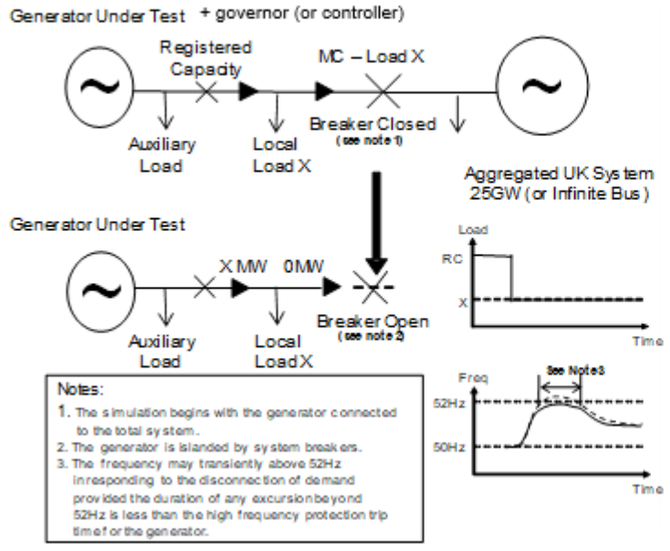
- Requirements as set out in Section 13.2.4
- Simulation study in accordance with Annex C.7.6 and by submission of a report and model



P_{ref} is the reference **Active Power** to which ΔP is related and. ΔP is the change in **Active Power** output from the **Power Generating Module**.

Figure 13.2 Active Power Frequency Response capability when operating in LFSM-O

Time series study required to demonstrate frequency response to increasing f

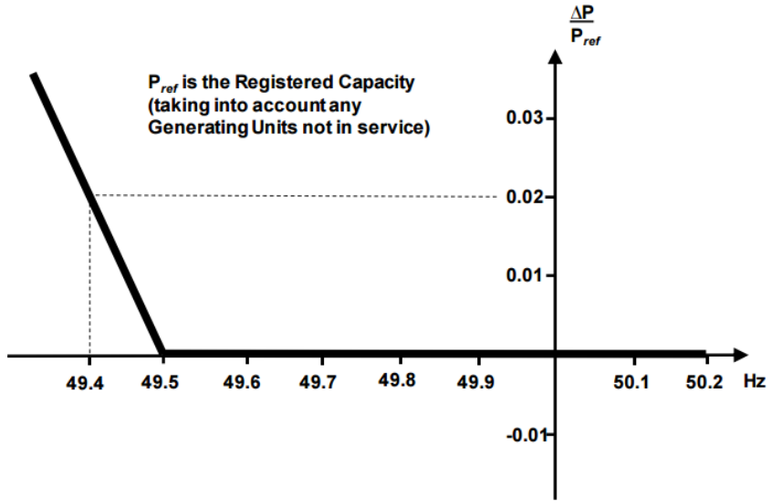


#	Scenario	Set P	Action	Output
1	Loss of infinite bus	Reg Cap	Open system breaker as Notes	Reduction in P (as per droop setting)
2	Freq step	Reg Cap	Inject freq step change into governor / controller model	Reduction in P (as per droop setting)
3	Freq ramp	Reg Cap	Inject freq ramp into governor / controller model	Reduction in P (as per droop setting)

Scottish & Southern Electricity Networks

Limited Frequency Sensitive Mode – Under Frequency (LFSM-U)

- Requirements as set out in Section 13.2.5
- Simulation study in accordance with Annex C.7.7 and by submission of a report and model

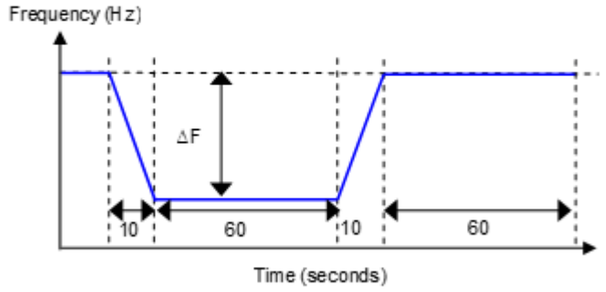


P_{ref} is the Registered Capacity, taking into account any Generating Units not in service to which ΔP is related and ΔP is the change in **Active Power** output from the **Power Generating Module**. The **Power Generating Module** has to provide a positive **Active Power** output change with a **Droop** of 10% or less based on P_{ref}.

Figure 13.3 - Limited Frequency Sensitive Mode – Under frequency capability of Power Generating Modules

Time series study to demonstrate low frequency control

Study parameters	Output
PGM at 80% Registered Capacity	
Large reduction in f - ramped over 10 s	Increase in P to Registered Capacity
60 s of steady state f	
Increase f - ramped over 10 s	Reduction in P back to 80% Registered Capacity
	60 s of steady output



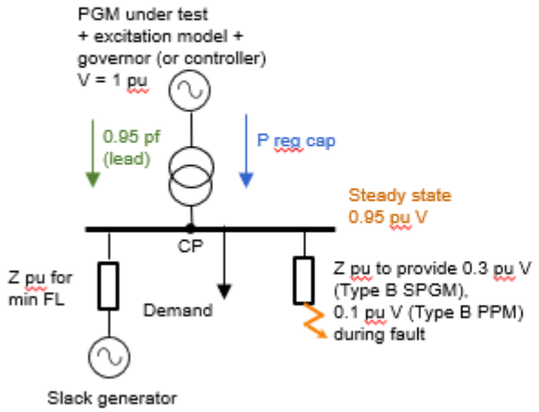
Scottish & Southern Electricity Networks

Fault Ride Through (FRT)

& Fast Fault Current Injection (FFCI) for **PPM only**

- Requirements as set out in Section 13.3 (FRT) and Section 13.6 (FFCI)
- Simulation study in accordance with Annex C.7.5 and by submission of a report and model

Time series study required to demonstrate fault ride through compliance



#	Set V @ CP	Set P	Set pf	Fault time
1	0.95	Reg Cap	0.95	140 ms

Scottish & Southern Electricity Networks

Fault Ride Through

Types C & D Requirements (EREC G99 Section 13.3)

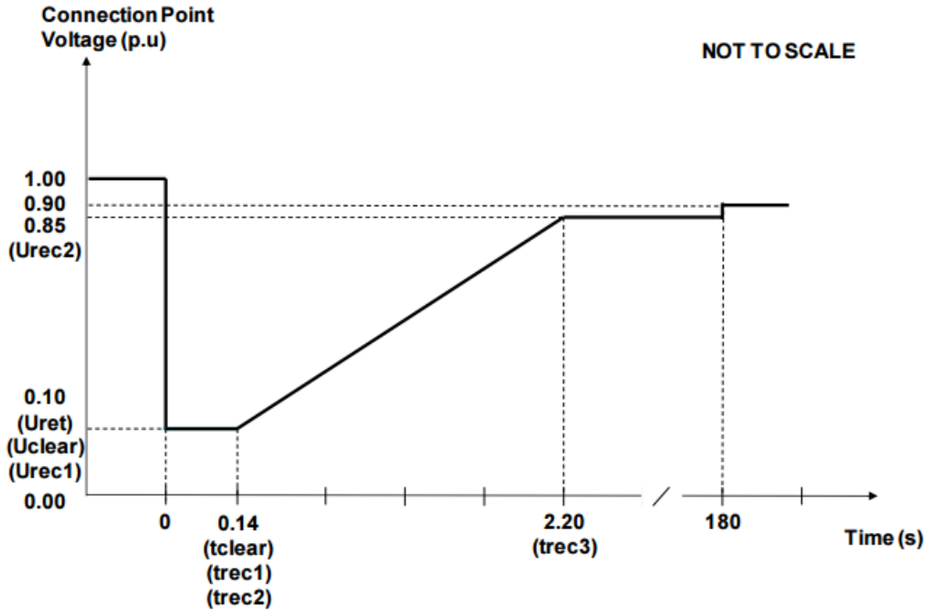


Figure 13.8 - Voltage against time curve applicable to Type C and Type D Power Park Modules connected below 110 kV

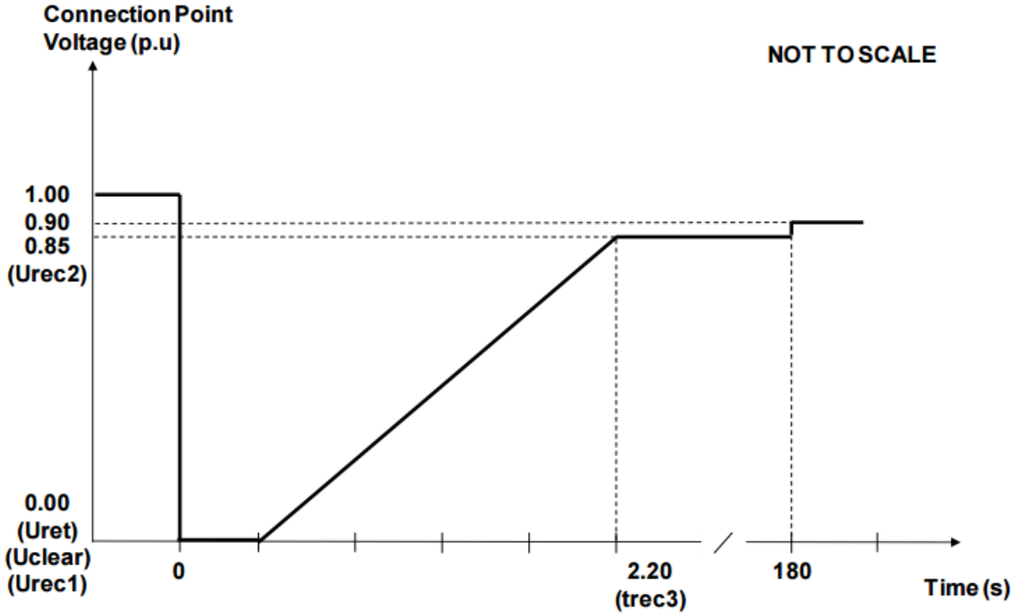


Figure 13.9 - Voltage against time curve applicable to Type D Power Park Modules connected at or above 110 kV

Scottish & Southern Electricity Networks

PPMs – Fast Fault Current Injection

Types C and D Requirements (EREC G99 Section 13.6)

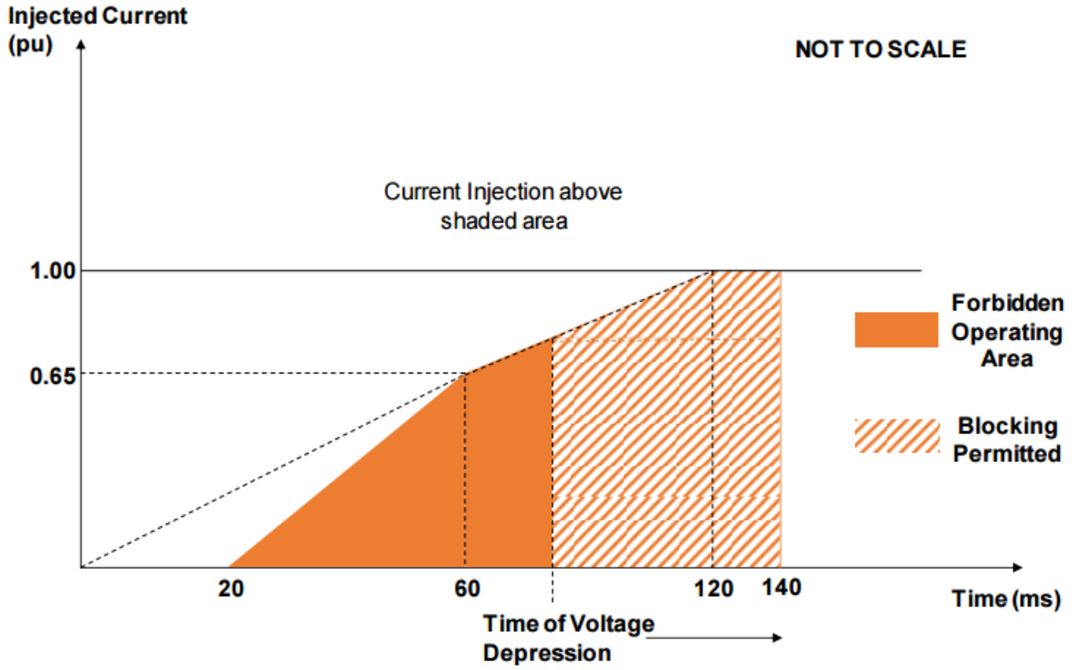


Figure 13.14 (a) Chart showing area of Reactive Current injections for voltage depressions of less than 140 ms duration

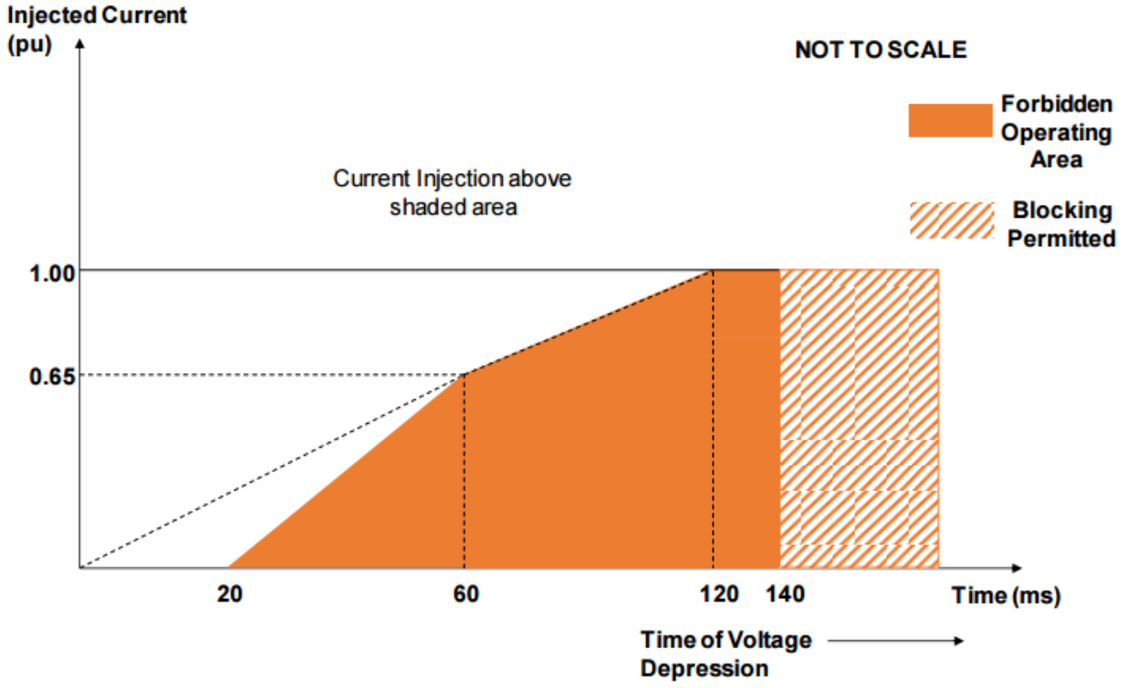


Figure 13.14 (b) Chart showing area of Reactive Current injections for voltage depressions of greater than 140 ms duration

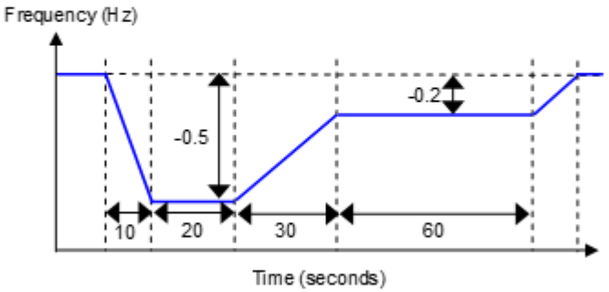
Scottish & Southern Electricity Networks

Model Validation

- Demonstration of the frequency control or governor/load controller/plant model, **Excitation System** and voltage controller by carrying out simulation studies in accordance with Annex C.7.8

Study to verify frequency controller models

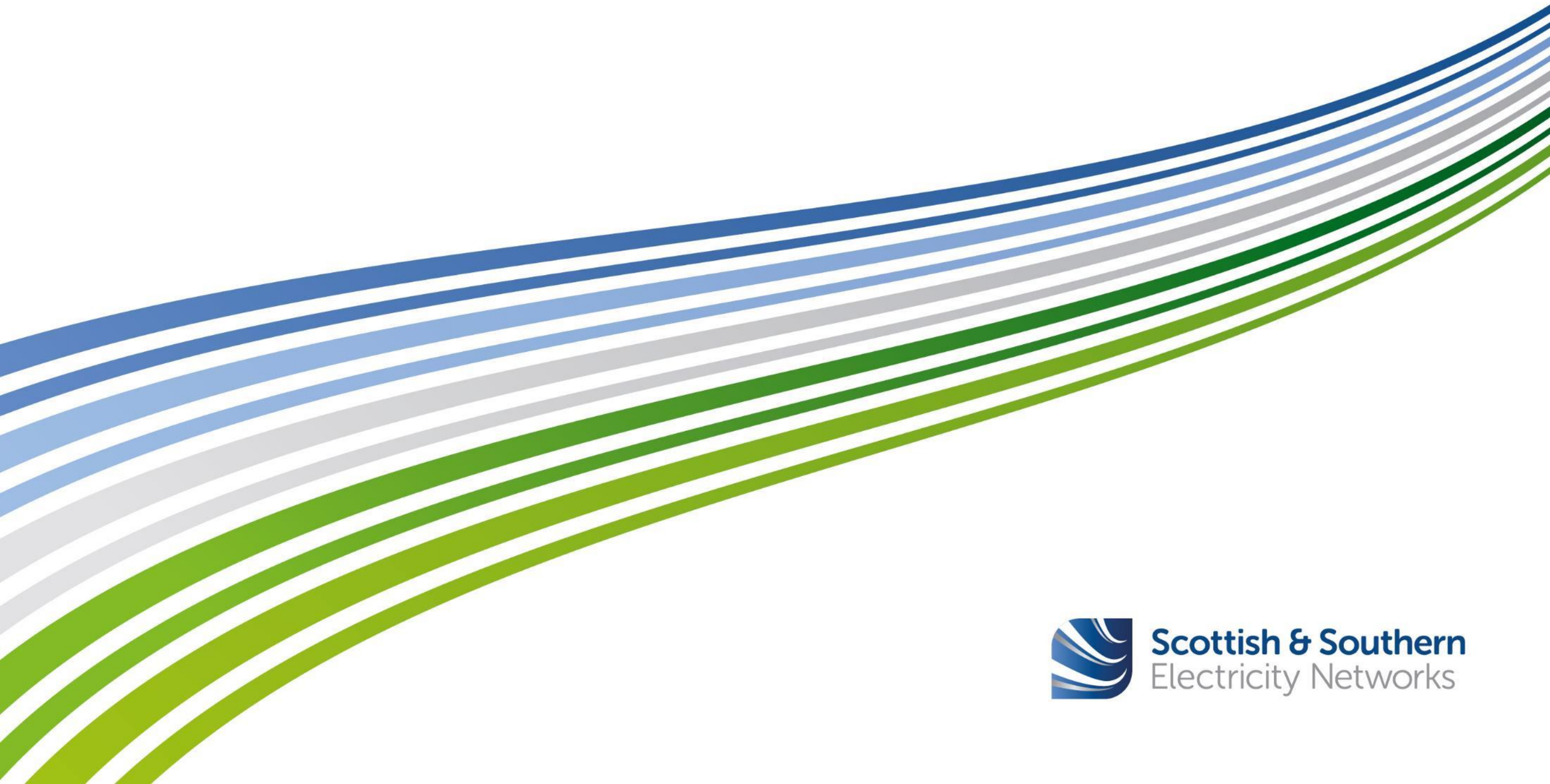
Study parameters	Output
PGM at 80% Registered Capacity	
Ramped reduction in f (0.5 Hz over 10 s)	Increase in P
20 s of steady state f	
Ramped increase f (0.3 Hz over 30 s)	Reduction in P
	60 s of steady output
Also simulate actual tests for synchronous PGMs and overlay results	



Study to verify excitation/ controller models

Study parameters	Output
Synchronous PGM operating open circuit at rated V: 10% step increase in terminal V ref 90% to 100%	Terminal V Field V P Q Power system stabiliser output if applicable
All PGM operating at Registered Capacity, Terminal voltage 100%, pf = 1 2% step increase in Vref	
Also simulate actual tests for all PGMs and overlay results	

thern
vorks



Scottish & Southern
Electricity Networks