# Fault Ride Through

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# Summary

- Resume of Actions
- Assumptions
- Mode A Requirements
- Assessment of Compliance
- Mode B Requirements
- Assessment of Compliance
- Legal text
- Summary

# Resume of Actions (1)

- Industry are invited to engage with NGET to ensure National Grid are appropriately modelling the new large nuclear fleet in System studies (Extended at WG 6)
- Review Emergency Restoration Code for overlapping requirements with FRT and RFG – *Completed – None*
- Work group report to be prepared reflecting interim position pre-final RFG draft.- *In draft form*
- Consider extension of GC0062 terms of reference (ToR) and industry representation to consider work on Embedded Generation and Mode B faults – *Discuss*
- Generator representatives to check with NGET that machines and models used for modelling purposes are correct, and provide updates to assumptions if necessary - *Ongoing*

# Resume of Actions (2)

- NGET to circulate latest draft version of RfG - *Completed*
- NGET to provide clear guidance on pre/post fault network status for modelling – *Completed – See slide pack*
- Legal text to state that tripping is not permitted in compliance simulations – *Completed*
- RI/AJ would review whether post fault voltage returning to 0.9p.u voltage (pu) is unduly penalising for generators, or whether system issues dictate – *Completed – 0.9p.u requirement specified – Also see slide pack.*

# Terms of Reference

- The initial Fault Ride Through issues raised in EDF's Paper ref PP12/04 related to Mode B faults (faults cleared in excess of 140ms) and the process to demonstrate compliance
- Following a series of Workshops in 2012 and 2013 it was agreed that this issue would be best addressed by early adoption of the RfG requirements which were subsequently included within the Terms of Reference
- As part of the workgroup research it became clear that RfG only applies to Secured Faults (ie faults cleared within 140ms) and therefore early adoption of RfG would not address the issues raised in EDF's paper.
- A solution to the original Grid Code defect would therefore be an amendment to the Mode B requirements only. However, as the Workgroup has assessed the RfG requirements (and this will need to be included as part of the GC0048 provisions) a decision needs to be made in respect of whether an individual GB modification is made in respect of just the Mode B requirements or whether the GB Code should also include the full RfG requirements bearing in mind it would only apply to a limited number of Generators ahead of the introduction of RfG.

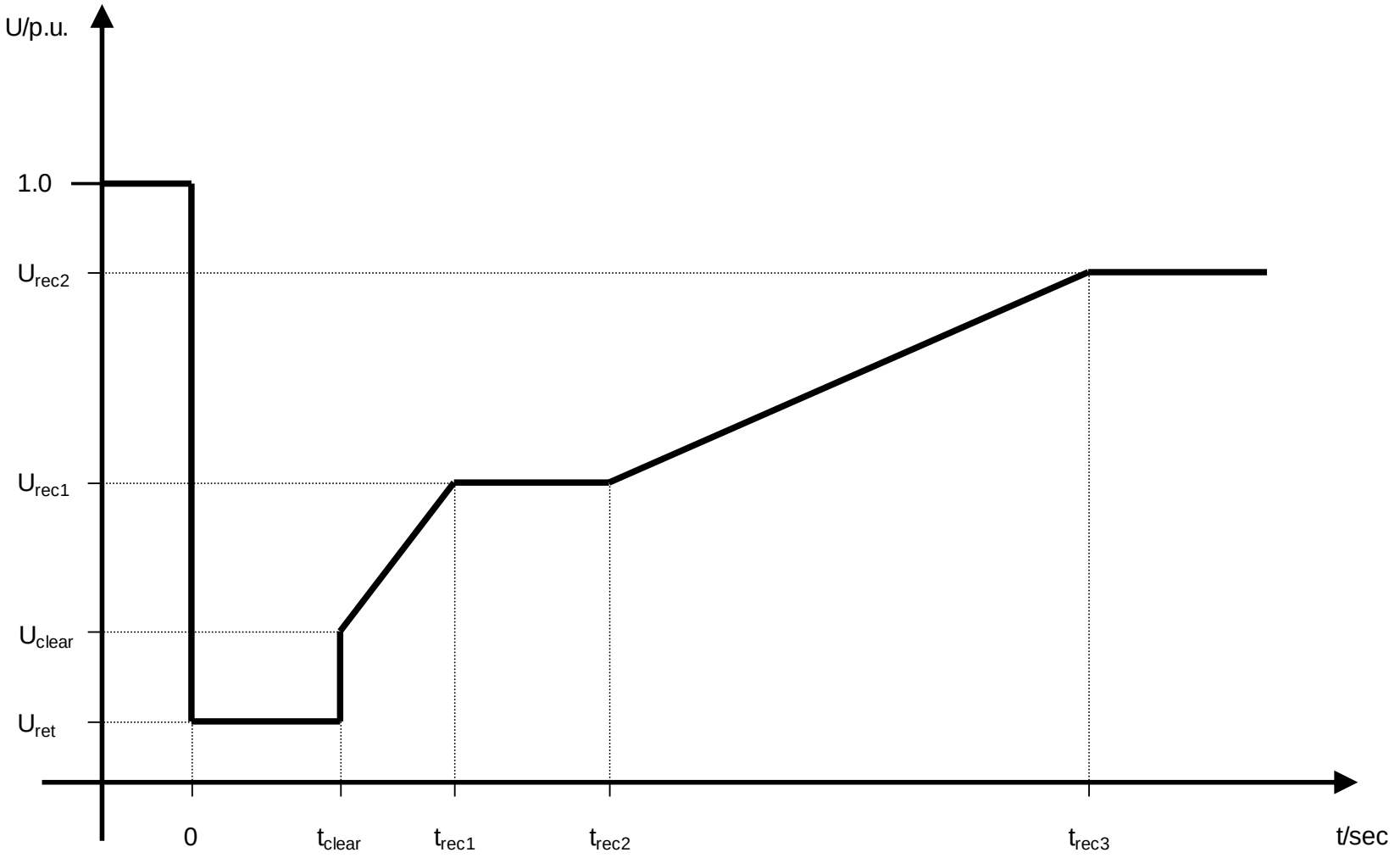
# High Level Summary of Fault Ride Through Proposals

- Mode A Faults – As per RfG with National Parameters selected
- Mode B Faults – Based on GB text with revised voltage duration curve.
- Scope – These proposals only apply to Large Power Stations directly connected at 200kV or above. For Large, Medium and Small Power Stations connected at 132kV and below, the requirements will be addressed through the second phase of this working group.
- The draft legal text and working group report only covers the requirements applicable to directly connected synchronous plant connected at or above 200kV
- A separate working group representation will be required for the fault ride through requirements applicable to Embedded Plant – This will also need to be completed as part of the GC0048 work so there could be opportunities for a joint working group/subgroup

# RfG Developments

- RfG was formally agreed and accepted by the European Commission on 26th June 2015.
- It will now go through the legal translation process before being finally implemented into European law which is expected in the first quarter of 2016.
- The RfG requirements will become binding on any Generator who has let contracts for major plant items two years after Entry into force (ie first quarter of 2018).
- A copy of the latest version of RfG has been forwarded to Workgroup members as requested at the last meeting
- There have been no significant material changes to the RfG Fault Ride Through requirements since the last meeting held on 24th April 2015 other than minor word changes.

# 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 Units

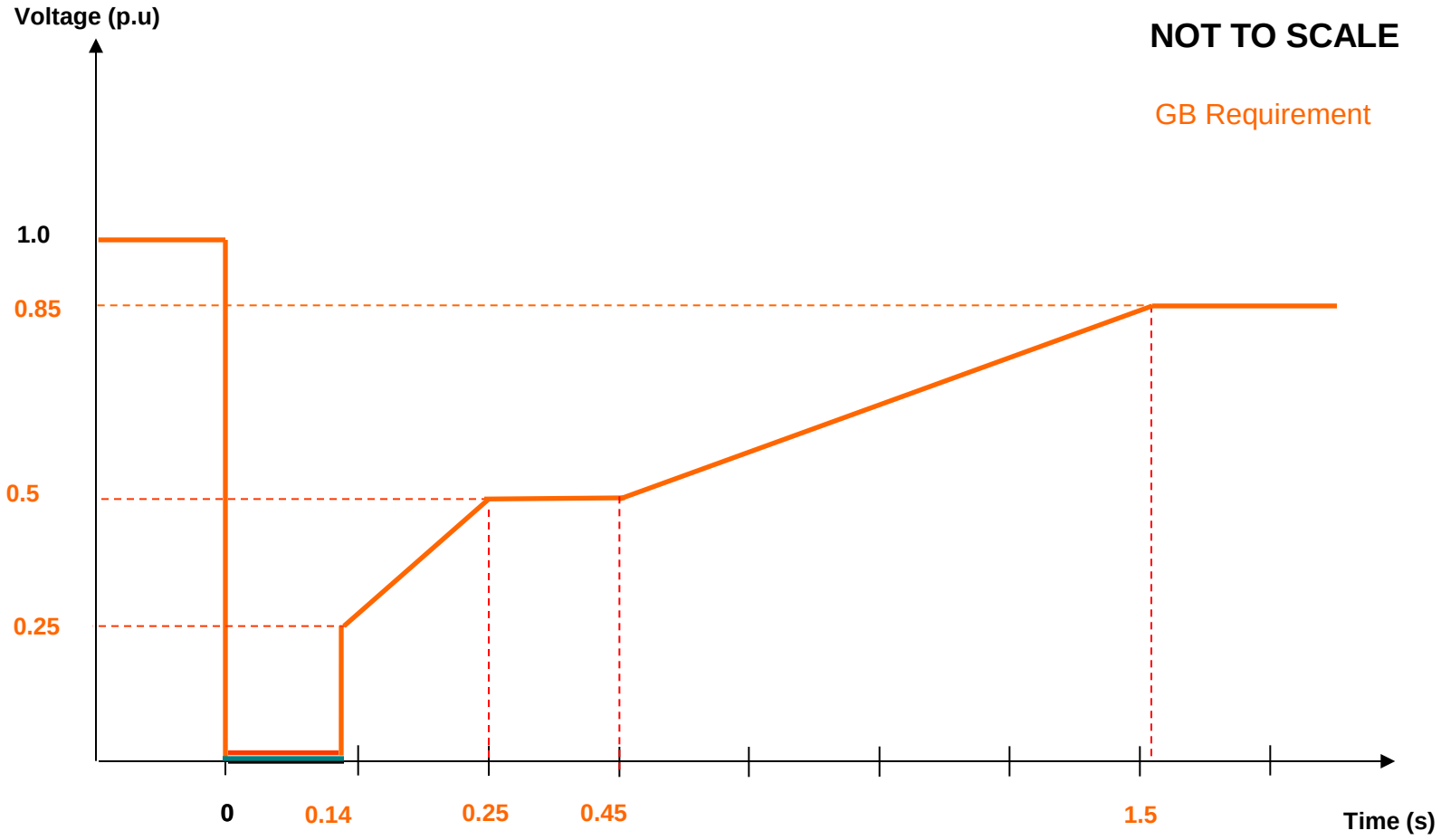
nationalgrid

| Voltage parameters [pu] | | Time parameters [seconds] | |
|---|---|---|---|
| Uret: | 0 | tclear: | 0.14 – 0.15 (or 0.14 – 0.25 if System protection and secure operation security require) |
| 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 – Parameters for Figure 3 for fault ride through capability of synchronous power generating modules.

# GB Mode A Requirements

## Voltage Against Time Curve



# GB Parameters – Consistent with Table 7.1

nationalgrid

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

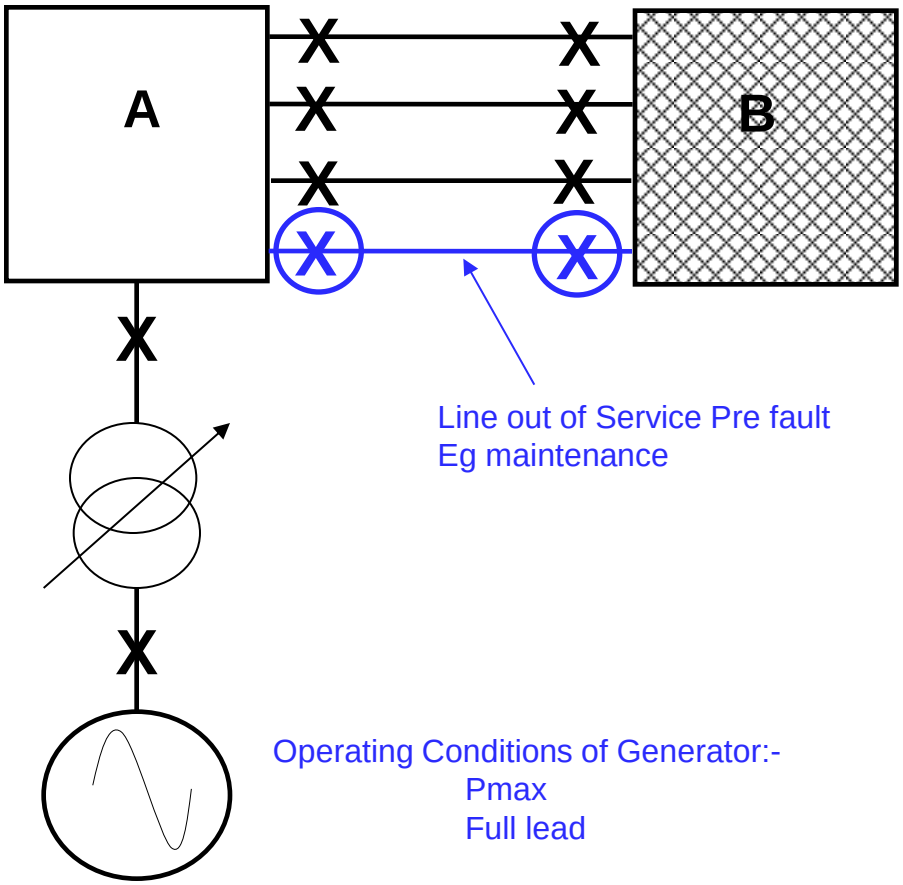
Table 7.1 – Parameters for Figure 3 for fault ride through capability of synchronous power generating modules.

# GB Proposed Mode A Requirements Including RfG Requirements

- National Grid will specify:
  - Pre and post Fault Short Circuit Levels
  - The pre fault operating conditions of the Generator
- Generator must remain connected and stable for a balanced and unbalanced three phase short circuit fault.
- Active Power must be restored within 0.5 seconds of restoration of the voltage to the minimum levels specified in CC.6.1.4
- RfG only requires assessment for balanced faults. It is envisaged that the same requirements would apply to unbalanced faults.

# Mode A Fault Ride Through

*Determination of Short Circuit Levels*

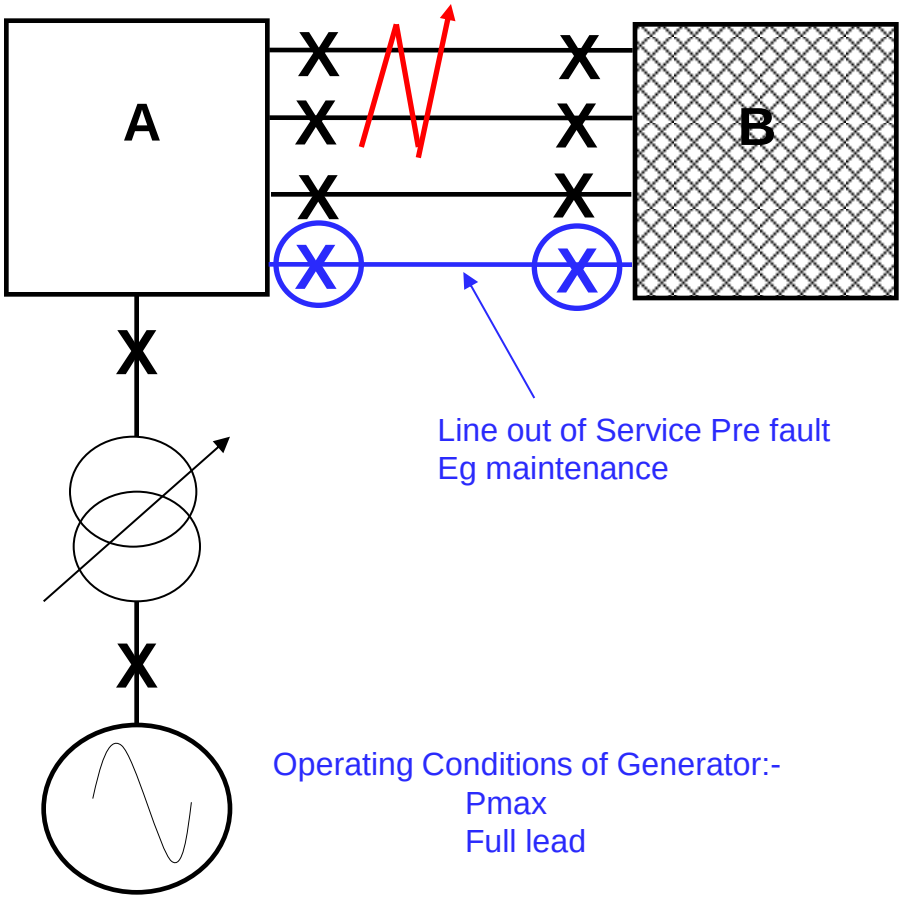



Substaiton B - Modelled as an Infinite Bar with appropriate Short Circuit Level

# Mode A Fault Ride Through

*Determination of Short Circuit Levels*

Three Phase soliid double circuit fault applied 1% from Substation A




Substaition B - Modelled as an Infinite Bar with appropriate Short Circuit Level

Line out of Service Pre fault
Eg maintenance

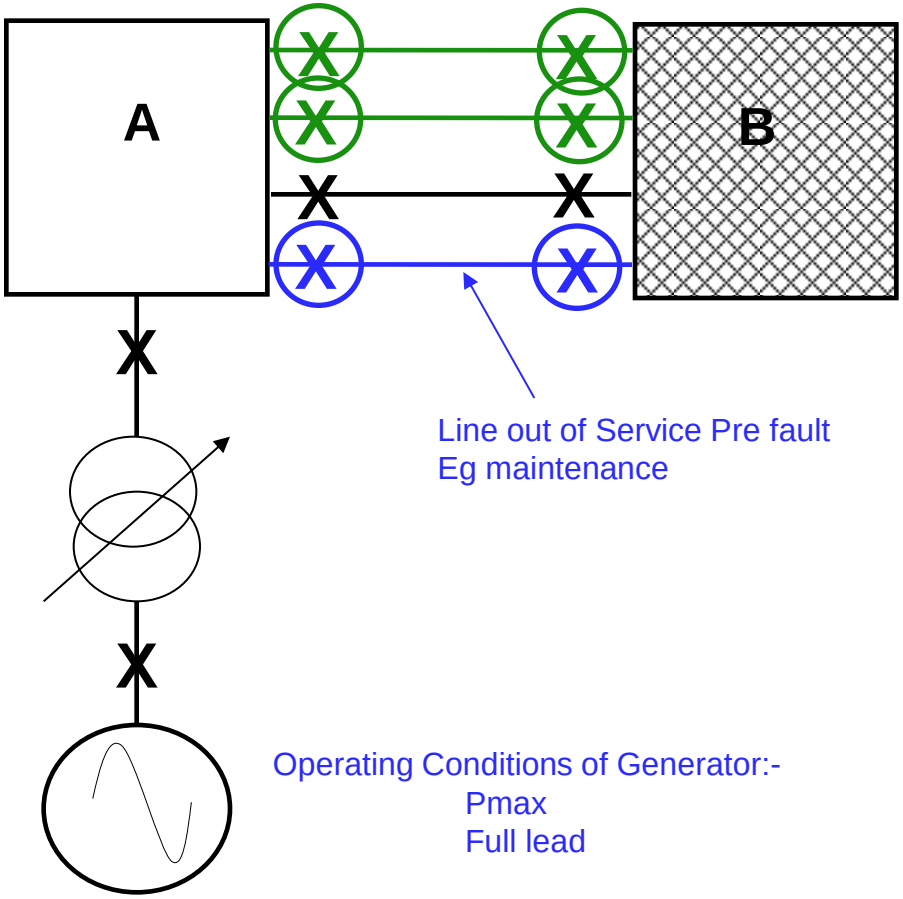
Operating Conditions of Generator:-
Pmax
Full lead

# Mode A Fault Ride Through

*Determination of Short Circuit Levels*

Fault Cleared by opening all circuit breakers 140ms later

Note:- this is the most onerous condition – See next slide

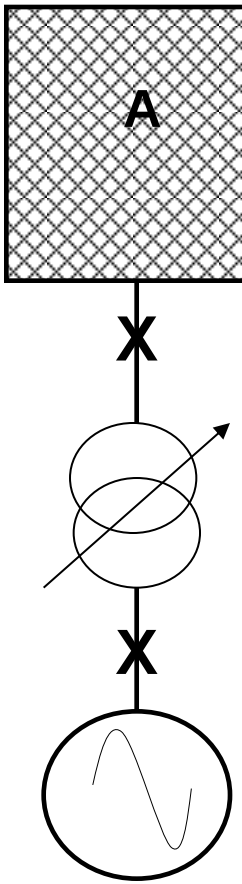



Substaton B - Modelled as an Infinite Bar with appropriate Short Circuit Level

Line out of Service Pre fault
Eg maintenance

Operating Conditions of Generator:-
Pmax
Full lead

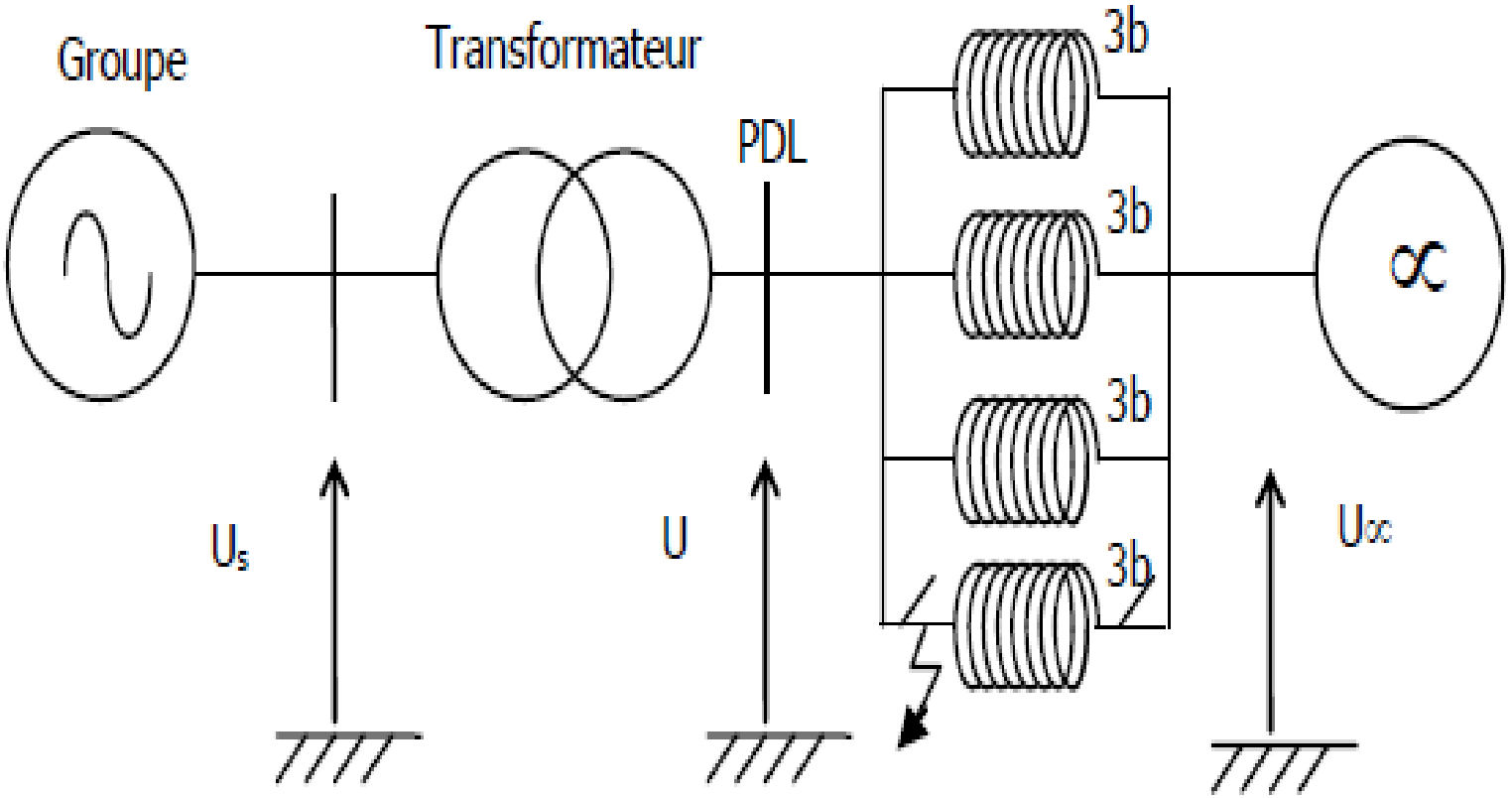
# Mode A Fault Ride Through Suggested Model




NGET will specify the pre fault and post fault Short circuit level as this is an easier representation

Operating Conditions of Generator:-
Pmax
Full lead

# RTE Model Fault Ride Through Model

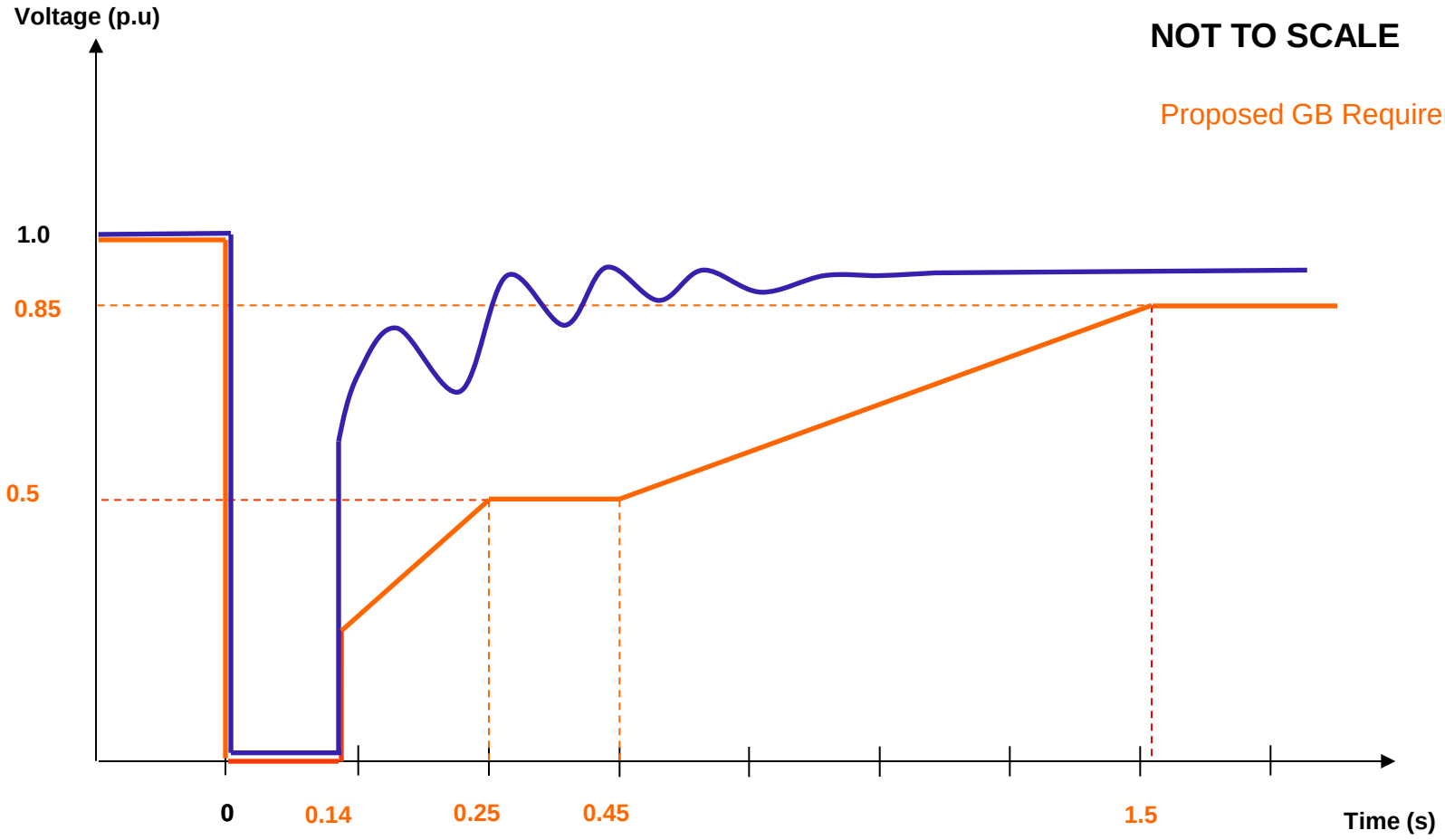


# Responsibilites

- NGET to provide equivalent model to include (See earlier slide)
  - Pre Fault Short Circuit Levels
  - Post Fault Short Circuit levels
  - Transmission System Circuit parameters
  - All Circuit Breaker operating times - assumed to open at 140ms. Note this is the most onerous case. In practice the local circuit breakers at Substation A would open within 80ms and the remote breakers would open typically within 100ms but exact protection operating times would need to be used. By using default values of 140ms at either end, considers the worst case.
  - Generator assumed to run at full output, max lead (ie underexcited)
  - Questions relate to derogations where faster fault clearance times are required
- Generator to:-
  - Insert Generator model (complete with control systems and auxiliaries) (into equivalent – see previous slide) and apply 140ms fault fat the connection point.
  - Note: Post Fault voltage profile is largely determined by system topology

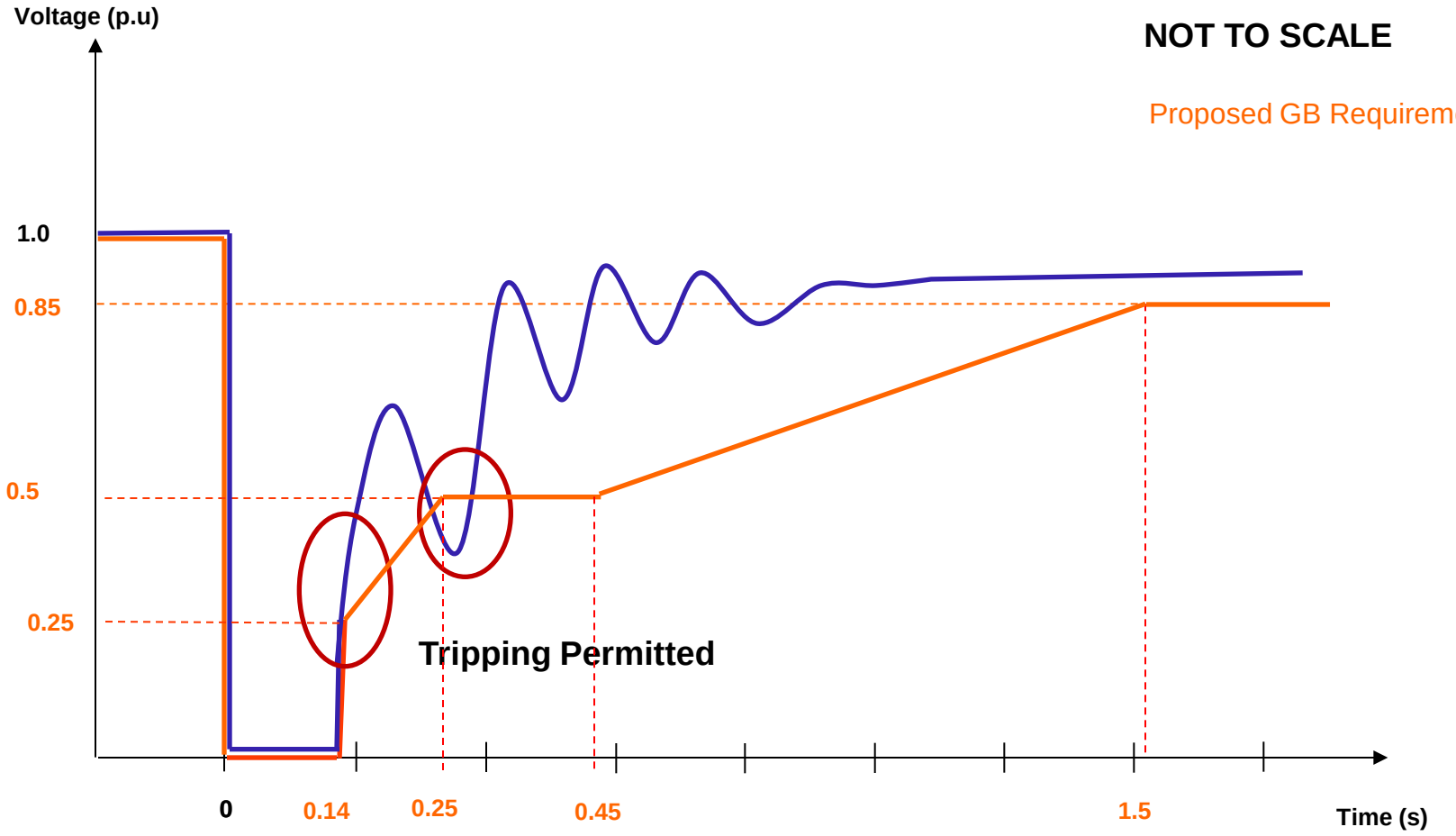
# GB Mode A Requirements

## Voltage Against Time Curve – Generator to remain Connected



# GB Mode A Requirements

## Voltage Against Time Curve – Generator Permitted to Trip



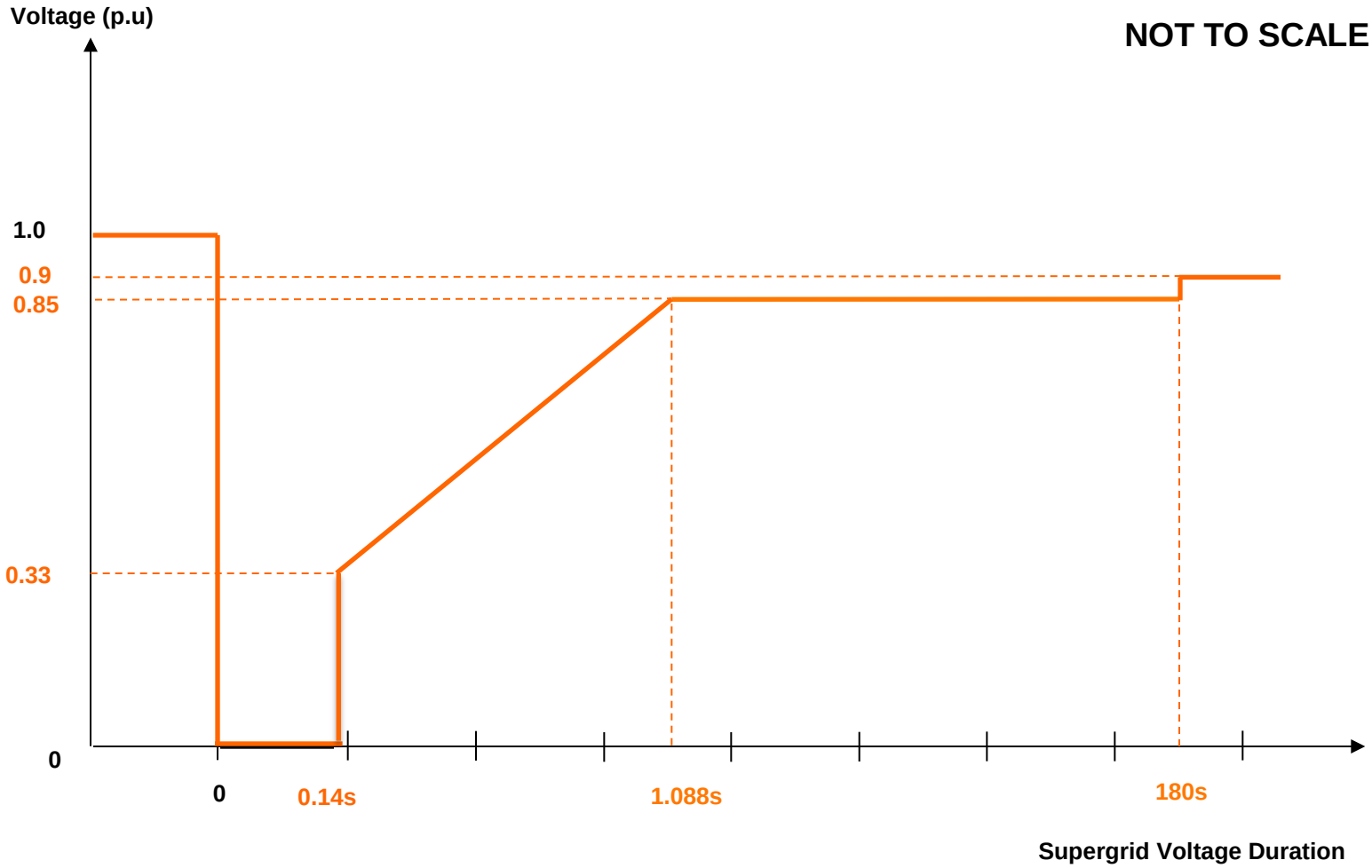
# Assessment of Compliance Design / Operational Requirements

- NGET will run initial stability studies at the application stage with the appropriate pre and post fault short circuit level.
- Results should demonstrate a stable system with the appropriate excitation system
- Generator to run detailed studies using the equivalent model supplied – see slide 16
- In cases of non compliance discussions will need to be held with NGET on appropriate actions
  - Enhanced Excitation
  - Faster fault clearing times
  - Others
  - Derogation issue against RfG?

# Mode B Faults

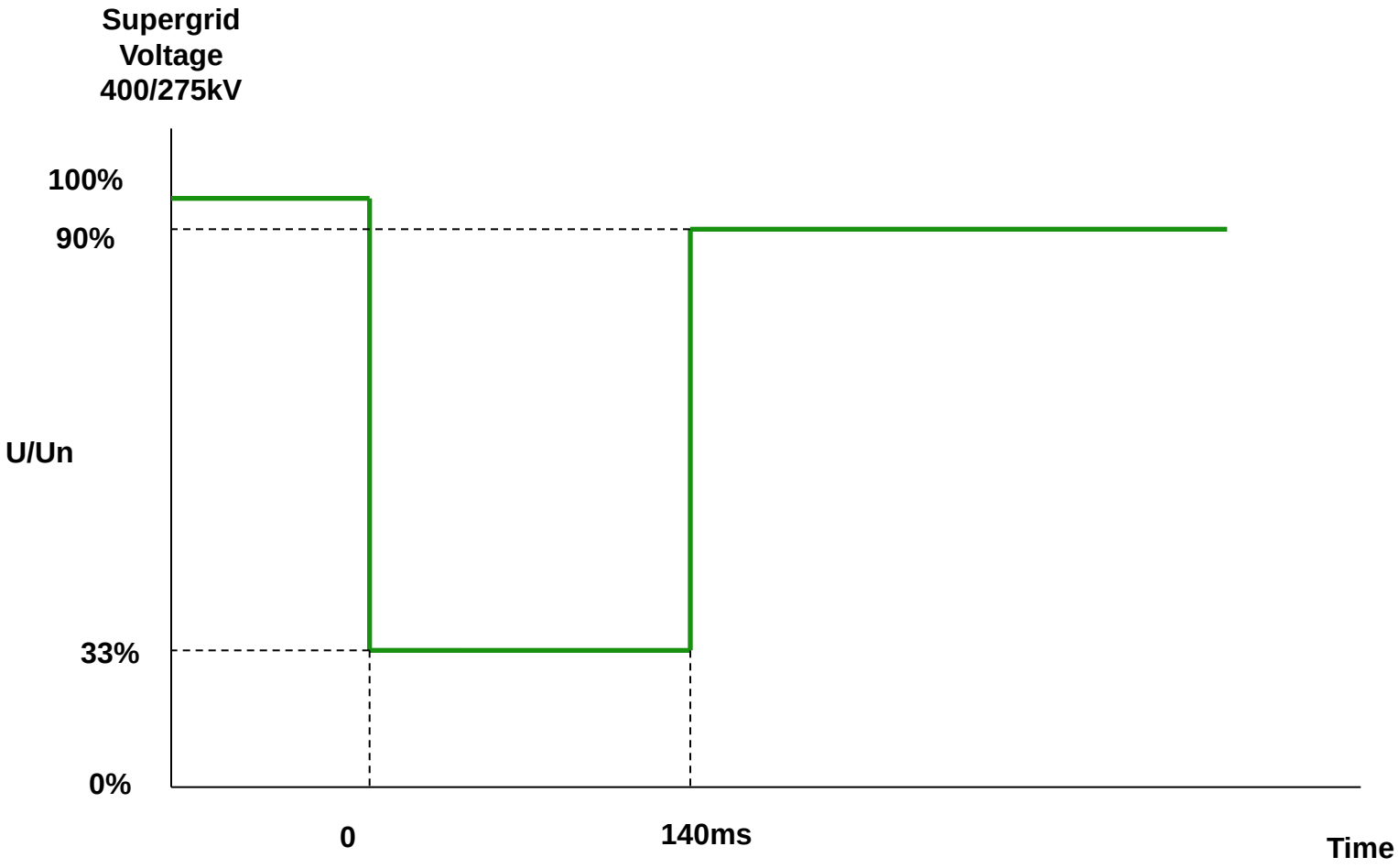
- As per current GB fault ride through requirements defined in CC.6.3.15.1(b) with a revised voltage duration curve – see next slide.
- Would apply specifically to Synchronous Generating Units only
- The existing Figure 5 would be changed to reflect the study work completed as part of this working group (Option 3)*.
- Note – this requirement would remain as a voltage duration curve – (ie each point on the profile represents a voltage level and an associated time duration).
  - * NOTE:- Voltage duration curve amended back to Option 3 based on further analysis work

# Mode B  Voltage Duration Curve



# Voltage dips in excess of 140ms

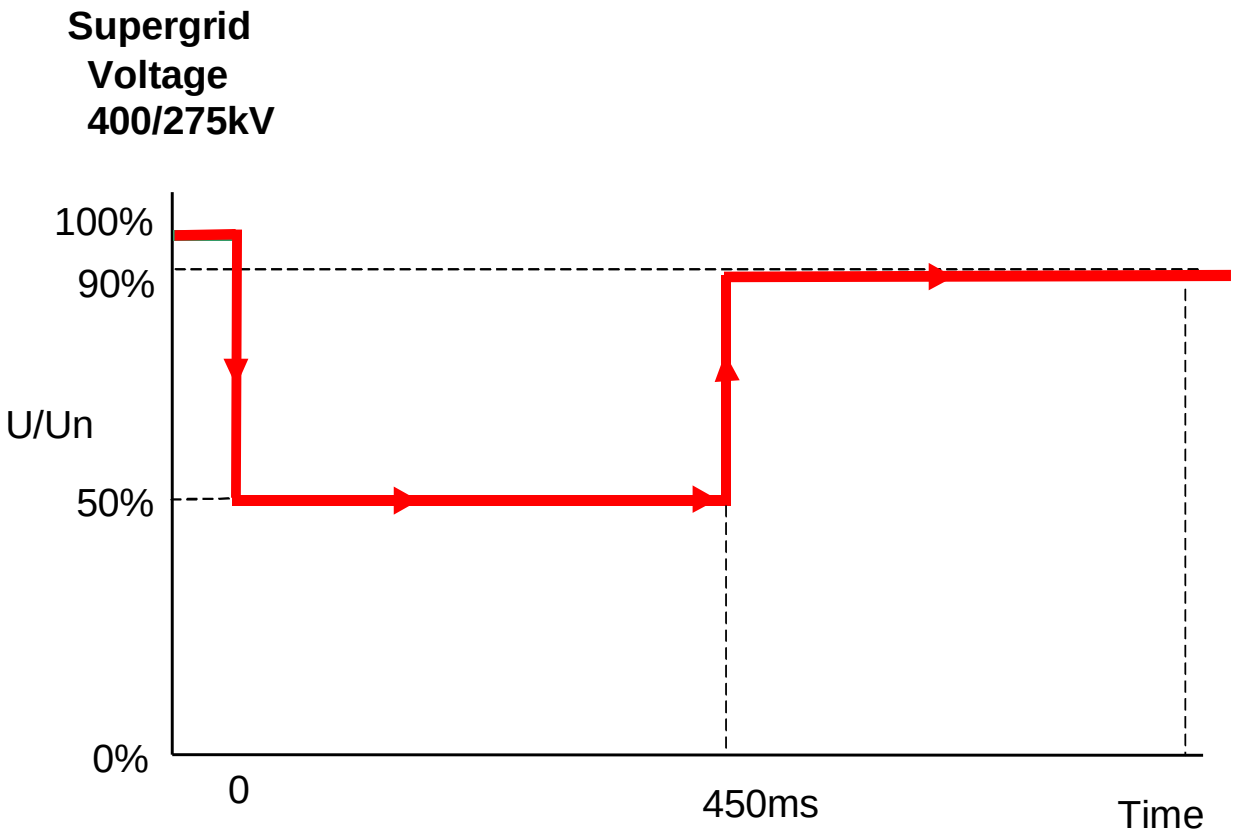
## *33% Retained Voltage*




**33% retained voltage, 140ms duration**

# Voltage dips in excess of 140ms

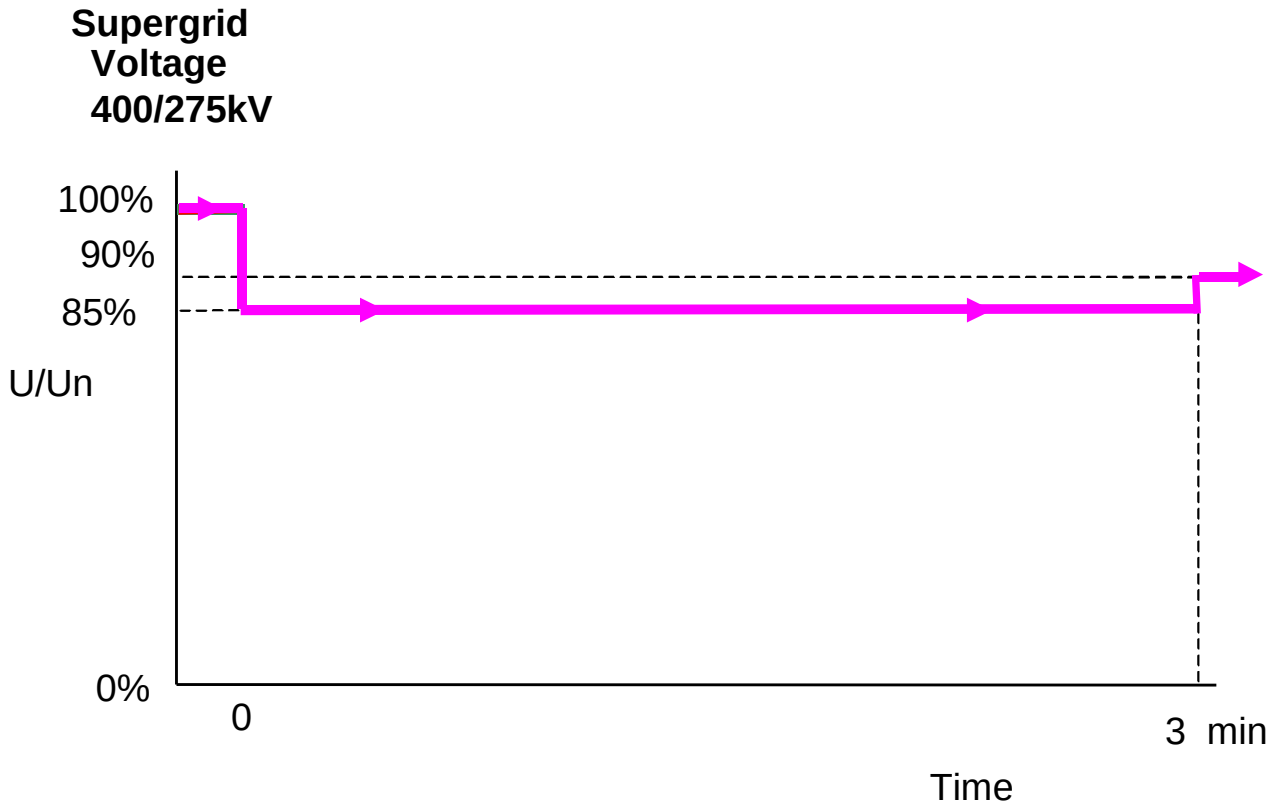
## *50% Retained Voltage*




50% retained voltage, 450ms duration

# Voltage dips in excess of 140ms

## *85% Retained Voltage*



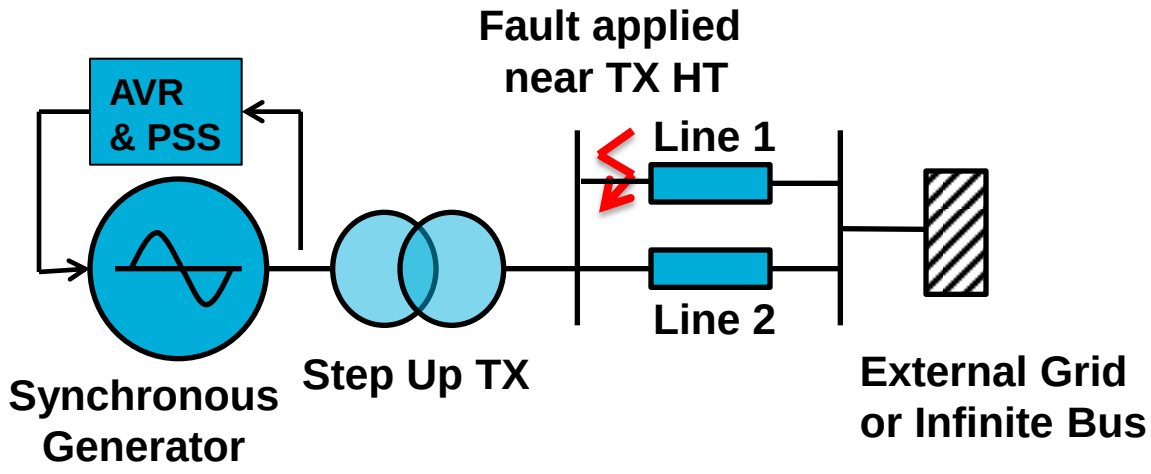

85% retained voltage, 3 minutes duration

# Fault Ride Through Studies Mode A – Method 1

**Model built as shown below:**
**Pre Fault conditions:**
- 0.95PF Leading at rated MW Load
- 1pu at Gen Terminals and TX HT Terminals
- Line Z1 and Z2 specified by National Grid (or alternatively Pre and Post Fault Levels)
- External Grid Voltage determined by balance

**During Fault:**
- Fault applied to Line 1 and 0 retained volts for 140ms observed at TX HT

**Post Fault Conditions:**
- Line 1 removed from service
- Generator must remain stable, connected and not pole slip



# Fault Ride Through Studies Mode A – Method 1

**Model built as shown below:**

**Pre Fault conditions:**

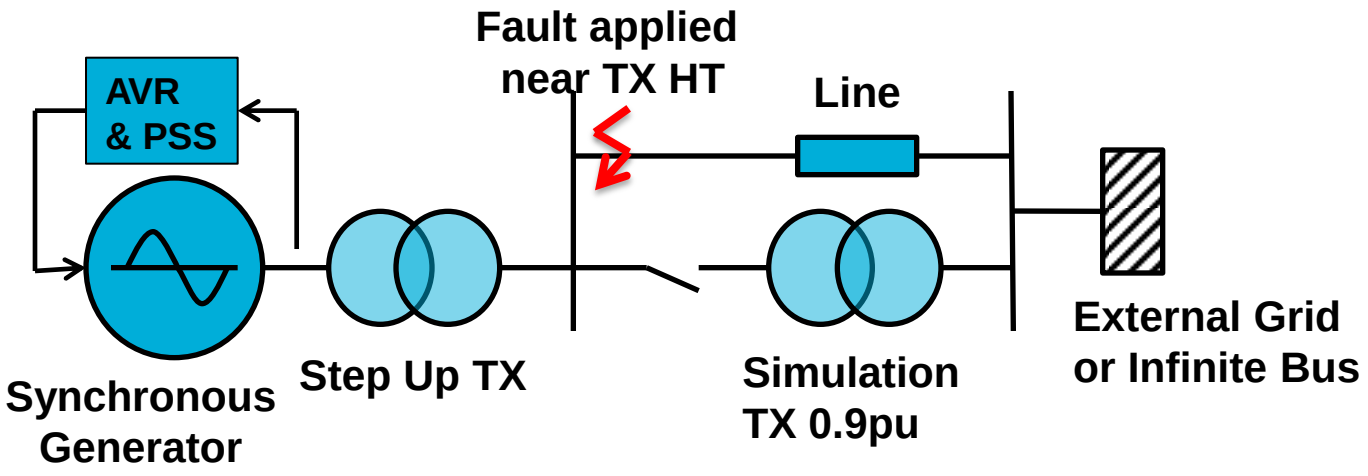
- 0.95PF Leading at rated MW Load
- 1pu at Gen Terminals and TX HT Terminals
- Line Z specified by National Grid
- External Grid Voltage determined by balance

**During Fault:**

- Fault applied to Line 1 and 0 retained volts for 140ms observed at TX HT

**Post Fault Conditions:**

- Fault and line removed and generator connected via Simulation TX setup to produce 0.9pu
- Generator must remain stable, connected and not pole slip



# Fault Ride Through Studies Mode B – Method 1

**Model built as shown below:**

**Pre Fault conditions:**

- 0.95PF Leading at rated MW Load
- 1pu at Gen Terminals and TX HT Terminals
- Line Z to achieve Fault Level in Table 2
- External Grid Voltage determined by balance

**During Fault:**

- Fault of appropriate impedance applied to TX HT to achieve voltage & time duration in Table 1

**Post Fault Conditions**

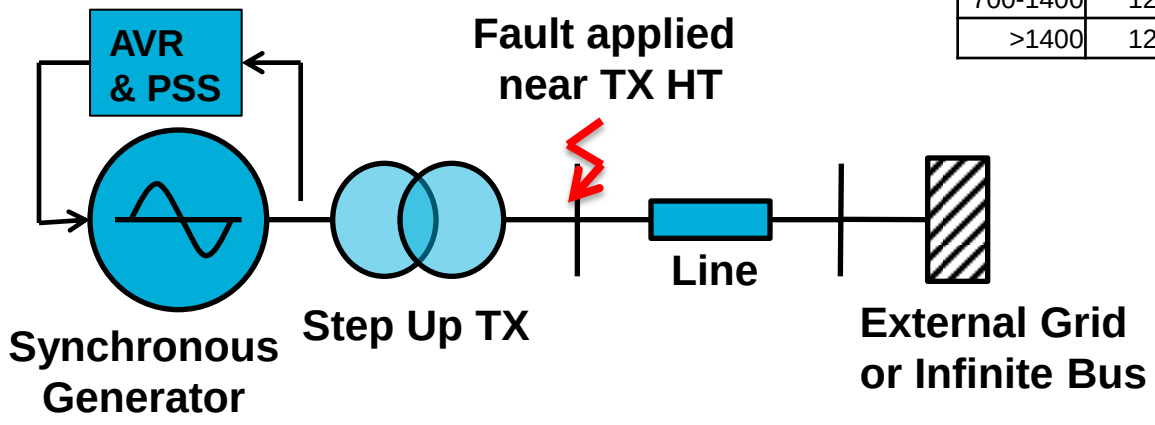
- Fault removed
- Generator must remain stable, connected and not pole slip

| Retained Volts (pu) | Duration (s) |
|---|---|
| 0.14 | 0 |
| 0.25 | 0.39 |
| 0.45 | 0.5 |
| 0.514 | 0.535 |
| 0.7 | 0.637 |
| 1.088 | 0.85 |
| 180 | 0.85 |

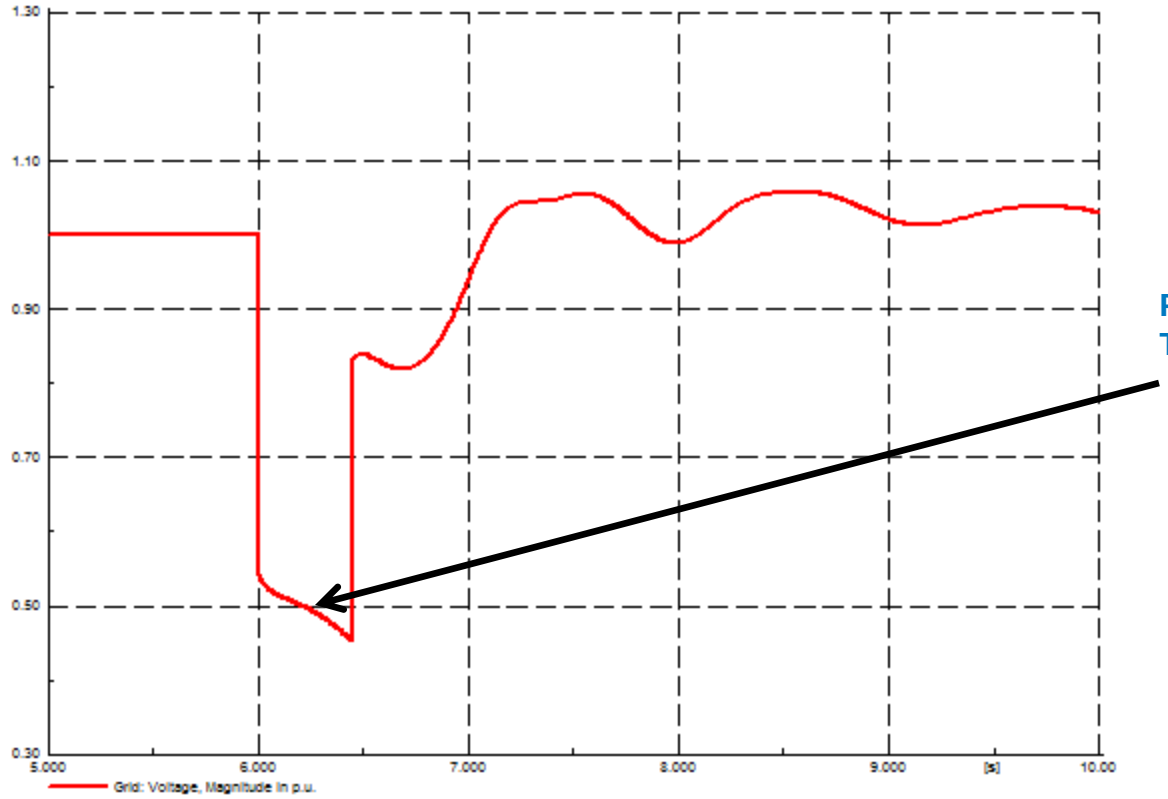
**Table 1**

**Table 2**

| MW | X/R | Fault MVA |
|---|---|---|
| 0-200 | 12 | 2300 |
| 200-450 | 12 | 4500 |
| 450-700 | 12 | 7000 |
| 700-1400 | 12 | 10000 |
| >1400 | 12 | 15000 |



# 1800MW M/C 450ms Fault at 0.5pu Retained Volts – Method 1




**Fault impedance selected**
**To give an average of 0.5pu**

# Fault Ride Through Studies Mode B – Method 2

**Model built as shown below:**

**Pre Fault conditions:**

- 0.95PF Leading at rated MW Load
- 1pu at Gen Terminals and TX HT Terminals
- Line Z to achieve Fault Level in Table 2 for 3ph S/C
- External Grid Voltage determined by balance

**During Fault:**

- Simulation TX connected with taps set to achieve appropriate voltage depression & time in Table 1

**Post Fault Conditions**

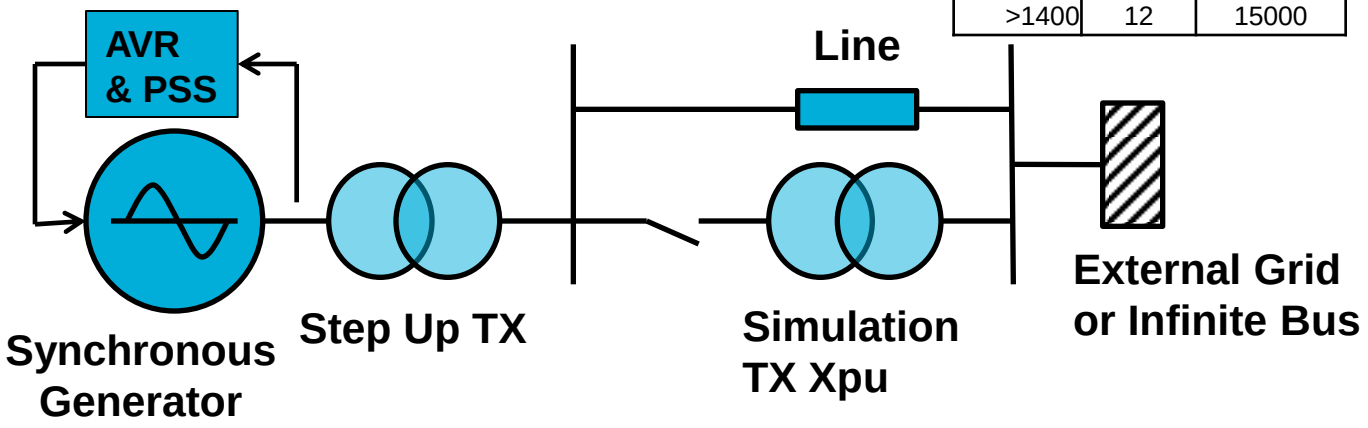
- Simulation TX removed from circuit
- Generator must remain stable, connected and not pole slip

**Table 1**

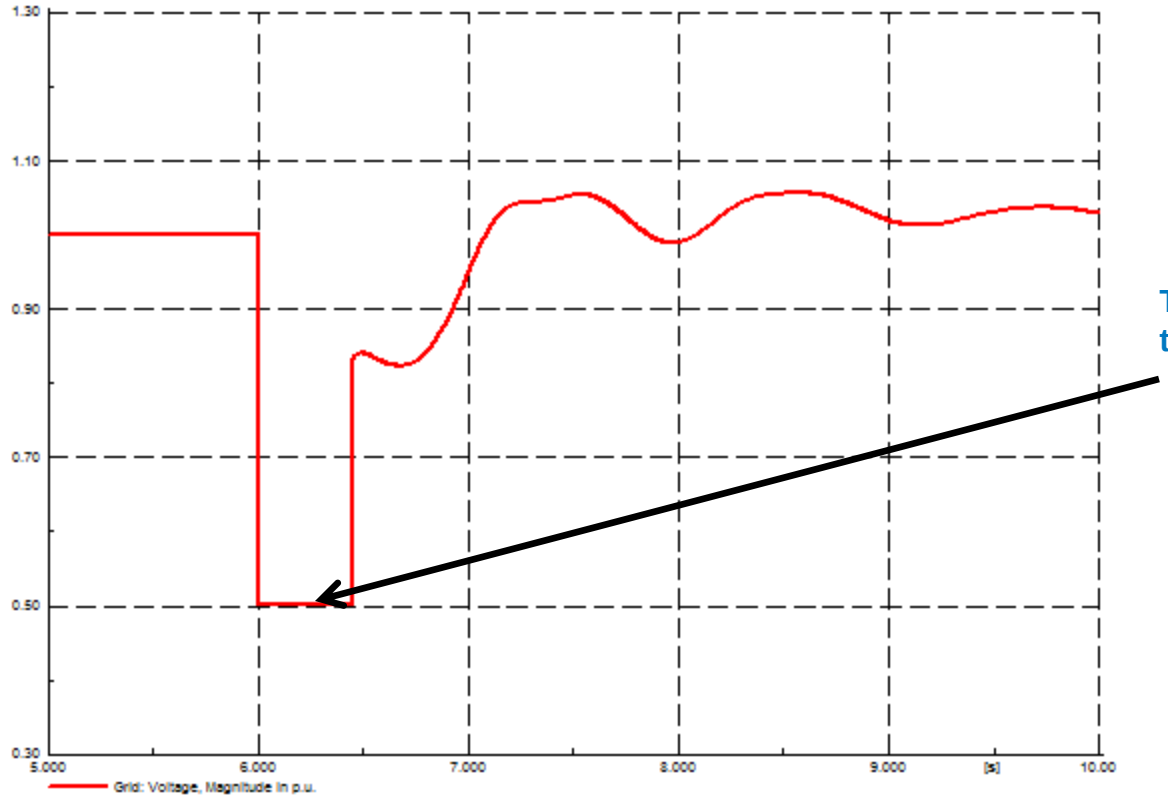
| Retained Volts (pu) | Duration (s) |
|---|---|
| 0.14 | 0 |
| 0.25 | 0.39 |
| 0.45 | 0.5 |
| 0.514 | 0.535 |
| 0.7 | 0.637 |
| 1.088 | 0.85 |
| 180 | 0.85 |

**Table 2**

| MW | X/R | Fault MVA |
|---|---|---|
| 0-200 | 12 | 2300 |
| 200-450 | 12 | 4500 |
| 450-700 | 12 | 7000 |
| 700-1400 | 12 | 10000 |
| >1400 | 12 | 15000 |



# 1800MW M/C 450ms Fault at 0.5pu Retained Volts – Method 2




**Transformer tap selected to give constant 0.5pu**

# Next Steps

- Work Group Members to consider the fault ride through proposals for directly connected Synchronous Generators.
- Consider Mode B requirements only or Mode A and RfG as well?
- Refine Grid Code Legal Text
- Develop Workgroup Report to reflect scope
- Consider changes on other documents – eg Guidance Notes for Synchronous Generators?
- Application to Embedded Synchronous Generators
- Further work