Fault Ride Through
ENTSO-E Requirements for Generators - Interpretation

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Background

- Interpretation of the ENTSO - E Requirements for Generators – Fault Ride Through
  - General Requirements for Types A - D Power Generating Modules
  - Requirements for Synchronous Power Generating Modules – Types A – D
  - Requirements for Power Park Modules – Types A – D
- ENTSO-E Frequently asked Questions document
- Implications of the Fault Ride Through requirements and differences to current GB Requirements
- Consideration of early adoption of the ENTSO-E Requirements for Generators for Synchronous Generators
- Conclusions / Discussion

General Requirements for Types B Power Generating Modules

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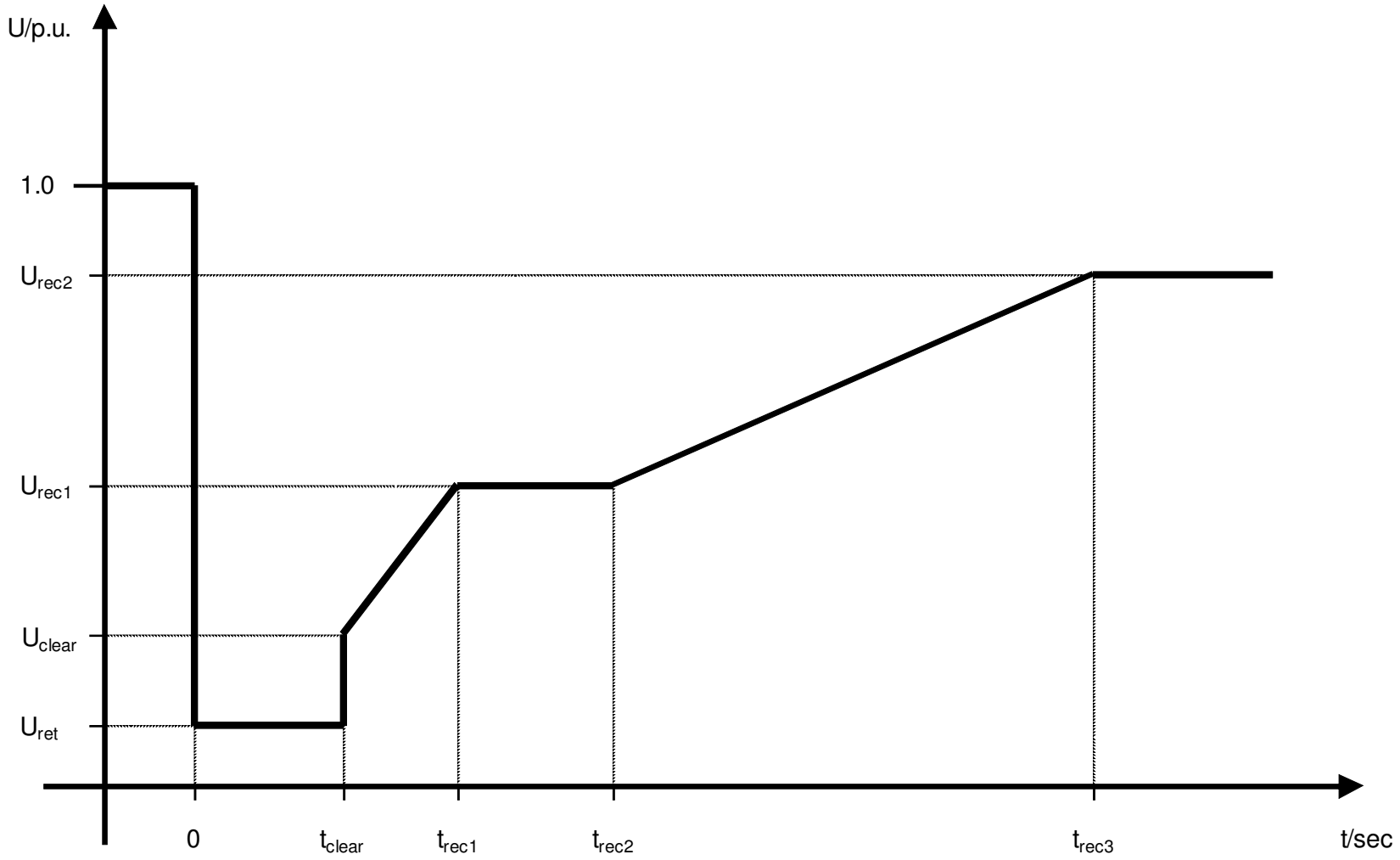
- Article 8 - Type A Power Generating Modules (800W – 1MW) – There are no Fault Ride Through requirements for Type A Power Generating Modules.
- Article 9 – Type B Power Generating Modules (1MW – 10MW)
  - Specified under Article 9(3)
  - Each TSO will define a voltage – against time profile at the Connection Point (Figure 3) in which each Power Generating Module shall be capable of staying connected to the network and continuing stable operation after the power system has been disturbed by secured faults on the Network
  - The voltage against time profile shall be expressed by a lower limit of the course of the phase to phase voltages on the Network Voltage level at the Connection Point during a symmetrical fault, as a function of time before, during and after the fault. This lower limit is defined by the TSO using the parameters in Figure 3 according to Tables 3.1 and 3.2
  - Requirements equally apply to Type C and D Power Generating Modules although some additional amendments apply to the voltage against time curve for Type D Power Generating Modules

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



Interpretation of Voltage against time profile

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- Figure 3 defines the Fault Ride Through profile of a Power Generating Module. The diagram represents the lower limit of a voltage-against time profile by the voltage at the Connection Point, expressed by the ratio of its actual value and its nominal value in per unit before, during and after a fault. Uret is the retained voltage at the connection point during a fault, tclear is the instant when the fault has been cleared. Urec1, Urec2, trec1, trec2 and trec3 specify certain points of lower limits of voltage recovery after fault clearance.

ENTSO-E RfG - Voltage Against Time Parameters – Table 3.1 – Type B & C Synchronous Power Generating Units

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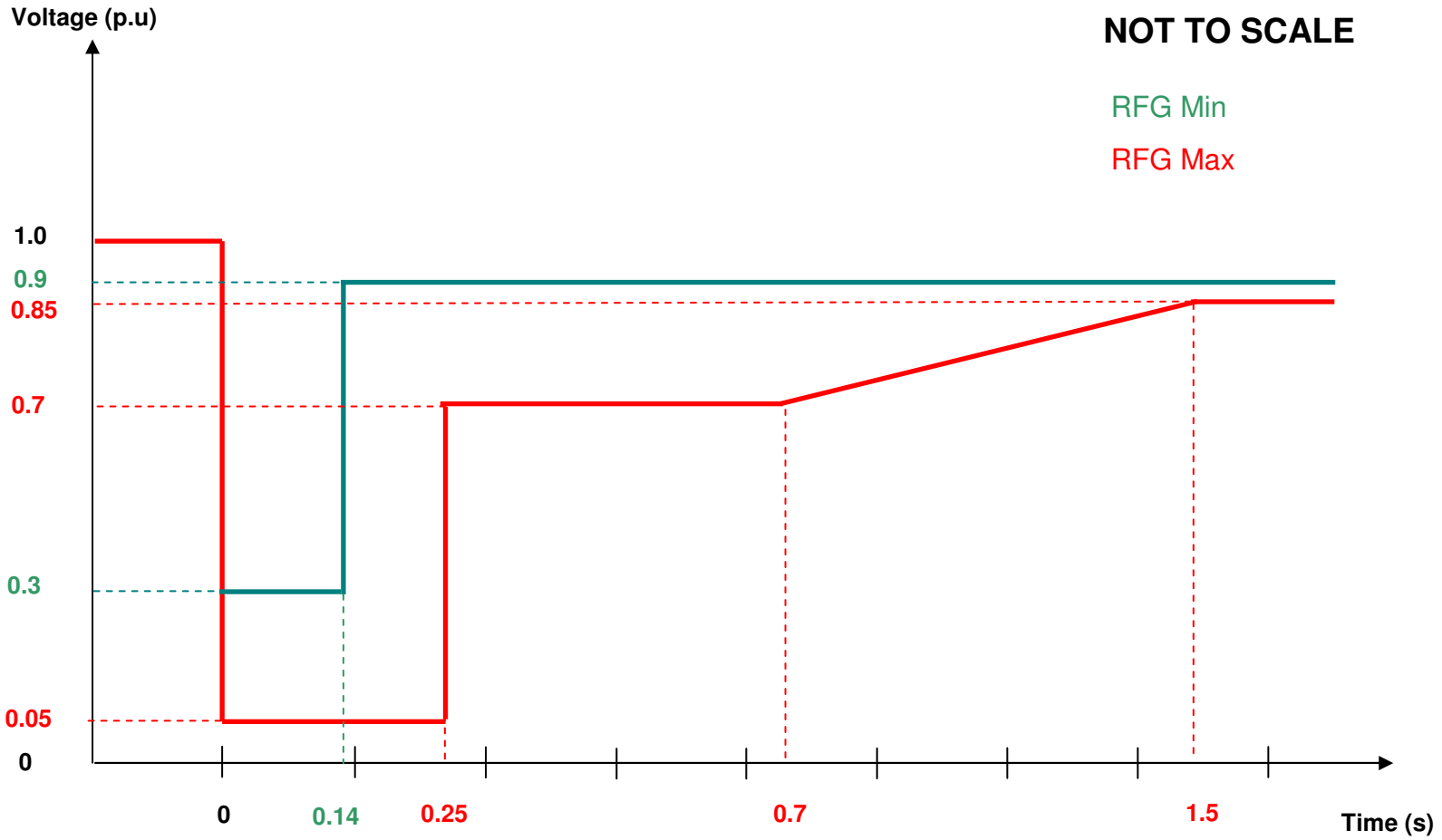
Voltage parameters [pu]		Time parameters [seconds]	
Uret:	0.05 – 0.3	tclear:	0.14 – 0.25
Uclear:	0.7 – 0.9	trec1:	tclear
Urec1:	Uclear	trec2:	trec1 – 0.7
Urec2:	0.85 – 0.9 and ≥ Uclear	trec3:	trec2 – 1.5

Table 3.1 – Fault Ride Through Capability of Synchronous Power Generating Modules

ENTSO-E RfG - Voltage Against Time Profile

Type B & C Synchronous Power Generating Modules - Table 3.1



ENTSO-E RfG - Voltage against Time Parameters – Table 3.2 – Type B & C Power Power Modules

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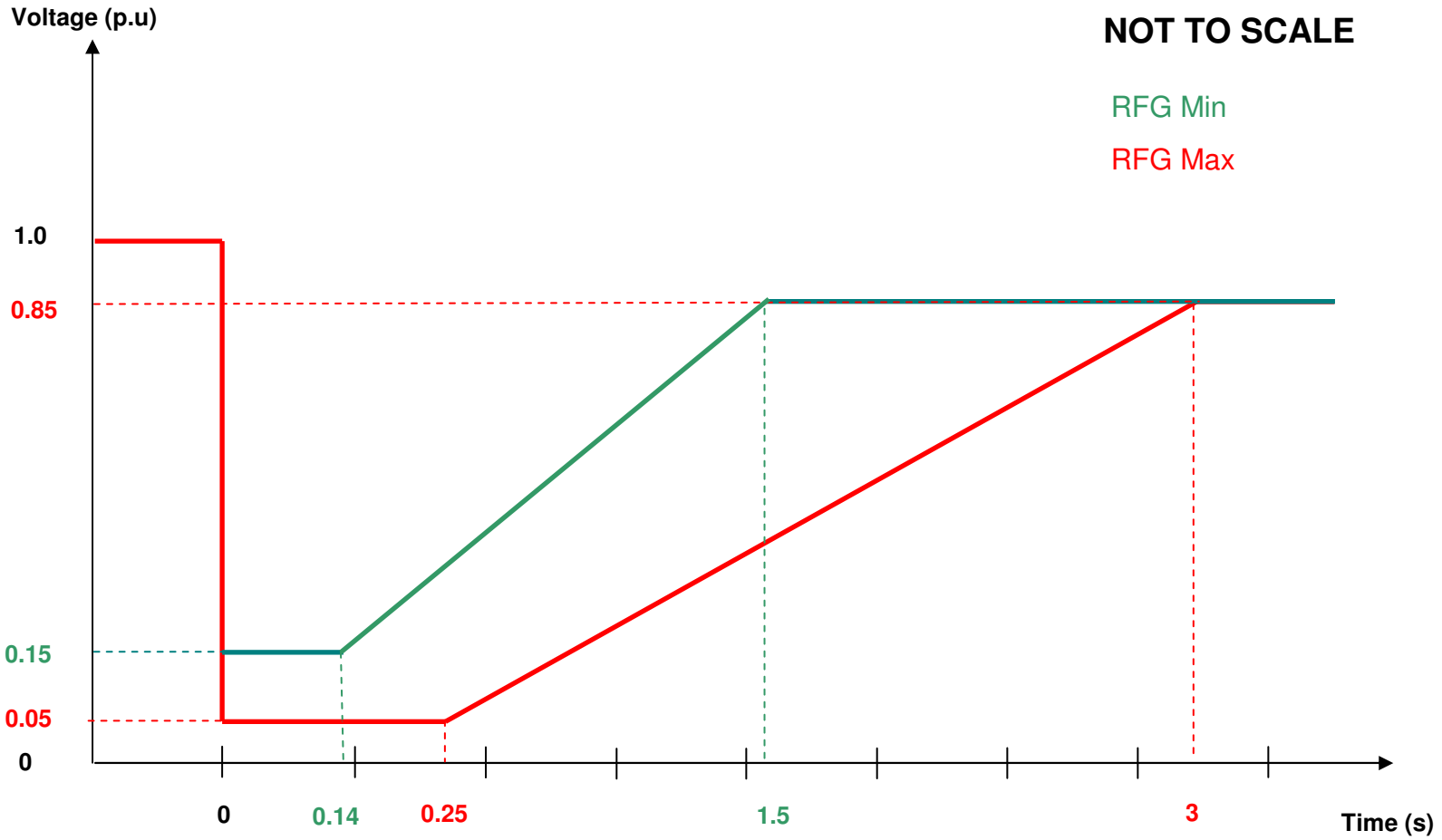
Voltage parameters [pu]		Time parameters [seconds]	
Uret:	0.05 – 0.15	tclear:	0.14 – 0.25
Uclear:	Uret – 0.15	trec1:	tclear
Urec1:	Uclear	trec2:	trec1
Urec2:	0.85	trec3:	1.5 – 3.0

Table 3.1 – Fault Ride Through Capability of Synchronous Power Generating Modules

ENTSO-E RfG - Voltage Against Time Profile

Type B & C Power Park Modules - Table 3.2



Additional Requirements for Type B & C Power Generating Modules

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- Each TSO shall define the pre and post fault conditions for fault ride through in terms of:-
  - Conditions for the calculation of the pre-fault minimum short circuit capacity at the Connection Point
  - Conditions for pre-fault Active and Reactive Power operating point of the Power Generating Module at the Connection Point and Voltage at the Connection Point
  - Conditions for the calculation of the post fault minimum short circuit capacity at the Connection Point

Additional Requirements for Type B & C Power Generating Modules

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- Each Network Operator shall provide on request by the Generator the pre and post fault conditions to be considered for fault ride through as an outcome of the calculations at the Connection Point as defined in Article 9(3)(a).
  - The pre fault minimum short circuit capacity at each Connection Point expressed in MVA;
  - The pre-fault operating point of the Power Generating Module expressed in Active Power output and Reactive Power output at the Connection Point and Voltage at the Connection Point and
  - The Post – Fault minimum short circuit capacity at each Connection Point expressed in MVA.
  - Alternatively generic values for the above conditions derived from typical cases may be provided by the Relevant Network Operator.

Additional Requirements for Type B & C Power Generating Modules

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- The Power Generating Module shall be capable of staying connected to the Network and continue stable operation when the actual course of the phase to phase voltages on the Network Voltage level at the Connection Point during a symmetrical fault, given the pre fault and post fault conditions according to Article 9(3) (a) point 2), unless the protection scheme for internal electrical faults requires the disconnection of the Power Generating Module from the Network. The protection schemes and settings for internal electrical faults shall be designed not to jeopardise fault ride through performance.
- While still respecting Article 9(3) point 5), undervoltage protection (either fault ride through capability or minimum voltage defined at the connection point voltage shall be set by the Power Generating Facility Owner to the widest possible technical capability of the Power Generating Module unless the Relevant Network Operator requires a less wide setting according to Article 9(5)(b). The settings shall be justified by the Power Generating Facility Owner in accordance with this principle.
- Fault Ride Through capabilities in case of asymmetrical faults shall be defined by each TSO whilst respecting the provisions of Article 4(3).

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

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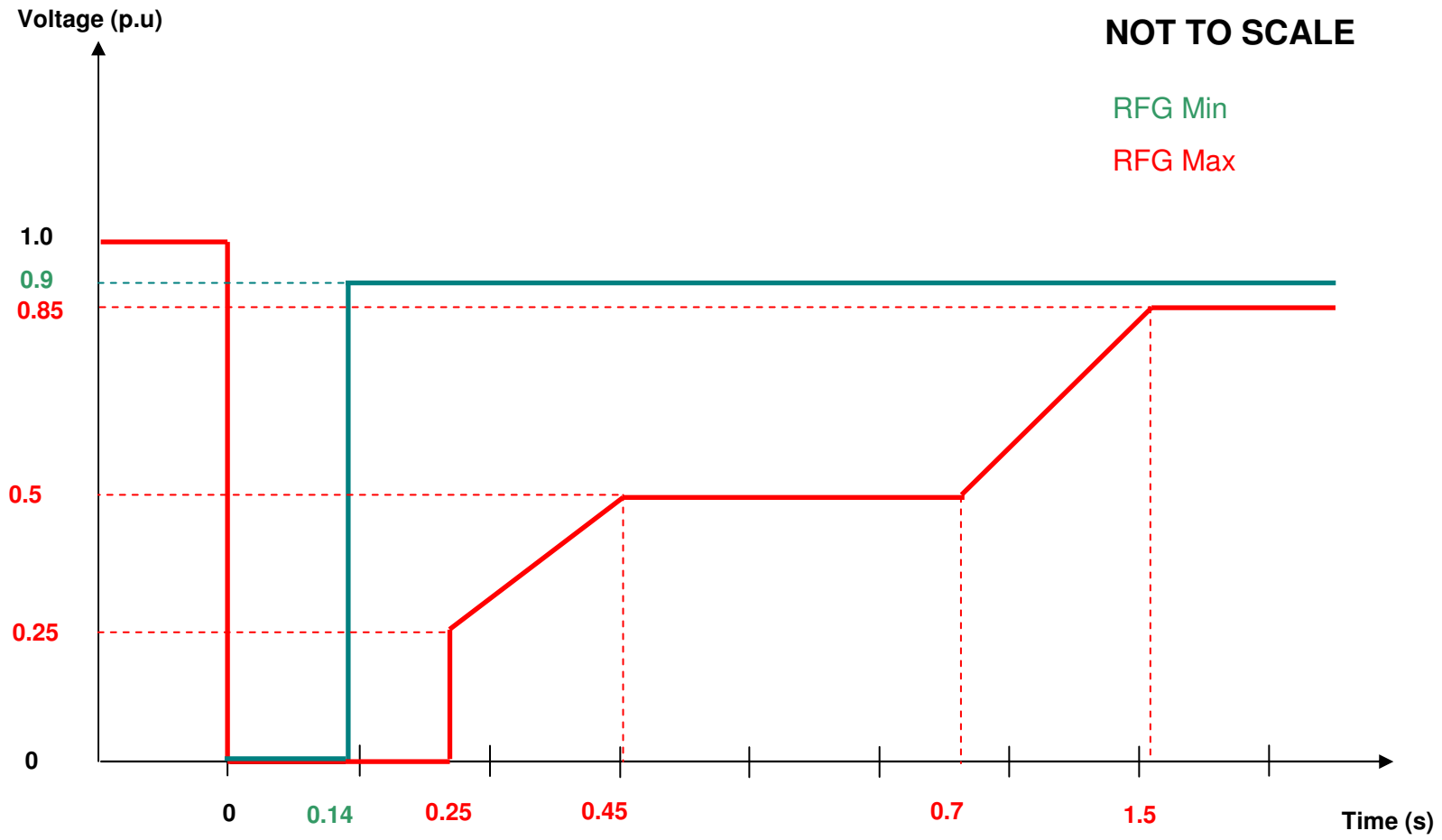
Voltage parameters [pu]		Time parameters [seconds]	
Uret:	0	tclear:	0.14 – 0.25
Uclear:	0.25	trec1:	tclear – 0.45
Urec1:	0.5 – 0.7	trec2:	trec1 – 0.7
Urec2:	0.85 – 0.9	trec3:	trec2 – 1.5

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

ENTSO-E RfG - Voltage Against Time Profile

Type D Synchronous Power Generating Modules Table 7.1



ENTSO-E RfG - Voltage Against Time Parameters – Table 7.2 – Type D Power Park Modules

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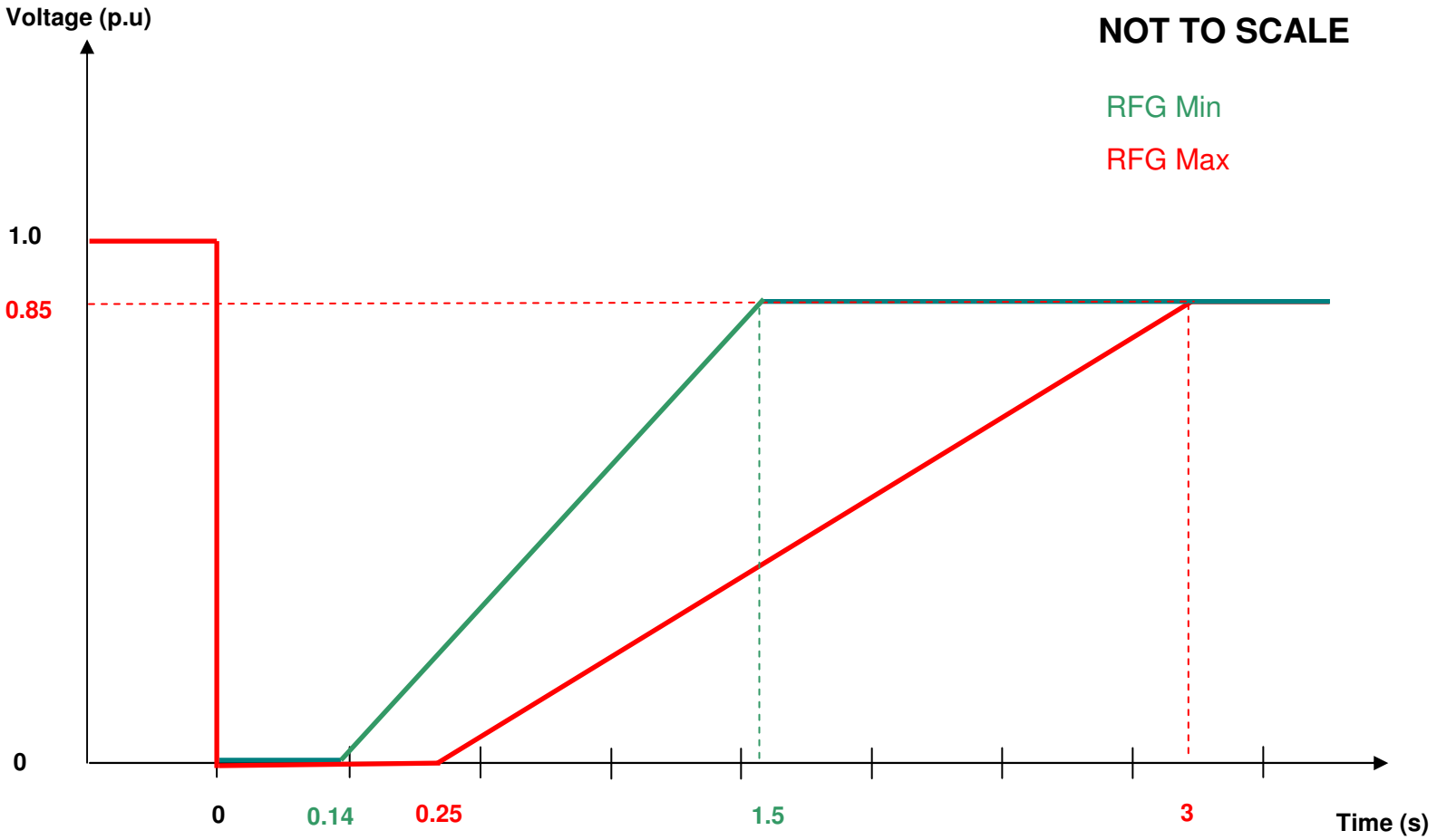
Voltage parameters [pu]		Time parameters [seconds]	
Uret:	0	tclear:	0.14 – 0.25
Uclear:	Uret	trec1:	tclear
Urec1:	Uclear	trec2:	trec1
Urec2:	0.85	trec3:	1.5 – 3.0

Table 7.1 – Fault Ride Through Capability of Power Park Modules

ENTSO-E RfG - Voltage Against Time Profile

Type D Power Park Modules - Table 7.2



Additional Requirements for Type B,C & D Power Park Modules (1)

- Each TSO shall have the right to require whilst respecting the provisions of Article 4(3) fast acting additional reactive current injection at the Connection Point to the pre-fault reactive Current injection in case of symmetrical (3-phase) faults:
- 1) The Power Park Module shall be capable of activating this additional reactive current injection during the period of faults either by
  - Ensuring the supply of the additional reactive Current at the Connection Point according to further specifications by the Relevant Network Operator in coordination with the Relevant TSO of the magnitude of this Current, depending on the deviation of the voltage at the Connection Point from its nominal value or
  - Alternatively, measuring Voltage deviations at the terminals of the individual units of the Power Park Module and providing an additional reactive current at the terminals of these units according to further specifications by Relevant Network Operator in coordination with the Relevant TSO of the magnitude of this current, depending on the deviation of the voltage at units terminals from its nominal voltage.

Additional Requirements for Type B,C & D Power Park Modules (2)

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- The Power Park Module (Article 15(2) (b) point 1) option a) or the individual units of the Power Park Module (Article 15(2) (b) point 1) option b.) shall be capable of providing at least 2/3 of the additional reactive Current within this time period specified by the Relevant TSO, which shall not be less than 10 ms. The target value of this additional reactive current defined by Article 15(2)(b) point (1) shall be reached with an accuracy of 10% within 60 milliseconds from the moment the voltage deviation has occurred as further specified according to Artcicle 15(2) point (1).
- The total reactive Current contribution shall be not more than 1 p.u of the short term dynamic Current rating (covering up to 0.4 seconds) of the Power Park Module (Article 15(2) (b) Point (1) option (a) or of the individual units of the Power Park Module (Article 15(2)(b) point (1) option (b) taking into account the pre-fault reactive current. If additional real current Current injection is given priority over additional reactive current injection, the total Current contribution can be further limited by the real Current based on limiting the apparent (vector addition of real and reactive current) to 1 p.u of the short term dynamic Current rating of the Power Park Module (Article 15(2) (b) point (1) option (a) of the individual units of the Power Park Modle (Article 15(2) (b) point (1) option (b).

Additional Requirements for Type B,C & D Power Park Modules (3)

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- With regard to fast acting additional reactive Current injection in case of asymmetrical (1-phase or 2-phase) faults the Relevant Network Operator in coordination with the Relevant TSO shall have the right to introduce while respecting the provisions of Article 4(3) a requirement for asymmetrical Current injection.
- With regard to post fault Active Power recovery after fault ride through, the Relevant TSO shall specify while respecting the provisions of Article 4(3) magnitude and time for Active Power Recovery the Power Park Module shall be capable of providing.

Additional Requirements for Type C & D Power Park Modules Only

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- With regard to priority to Active or Reactive Power contribution, the Relevant TSO shall define whilst respecting the provisions of Article 4(3), whether Active Power Contribution or Reactive Power Contribution has priority during faults for which fault ride through capability is required. If priority is given to Active Power contribution, its provision shall be established no later than 150ms from fault inception.

Explanation of ENTSO-E Fault Ride Through Requirements

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- Summarised in Question 24 of Frequently Asked Questions Document
- The FRT requirement is based on a voltage against time profile at the connection point which reflects the worst voltage variation during a fault and after its clearance. Power Generating Modules are required to stay connected to the Grid for voltages above these worst case conditions and shall continue stable operation after a secured fault on the network
- The requirements for Synchronous Generators are different to Power Park Modules.
- The reasons for Fault Ride Through are the same as in GB but the requirements are specified in a different way.

Explanation of ENTSO-E Fault Ride Through Requirements

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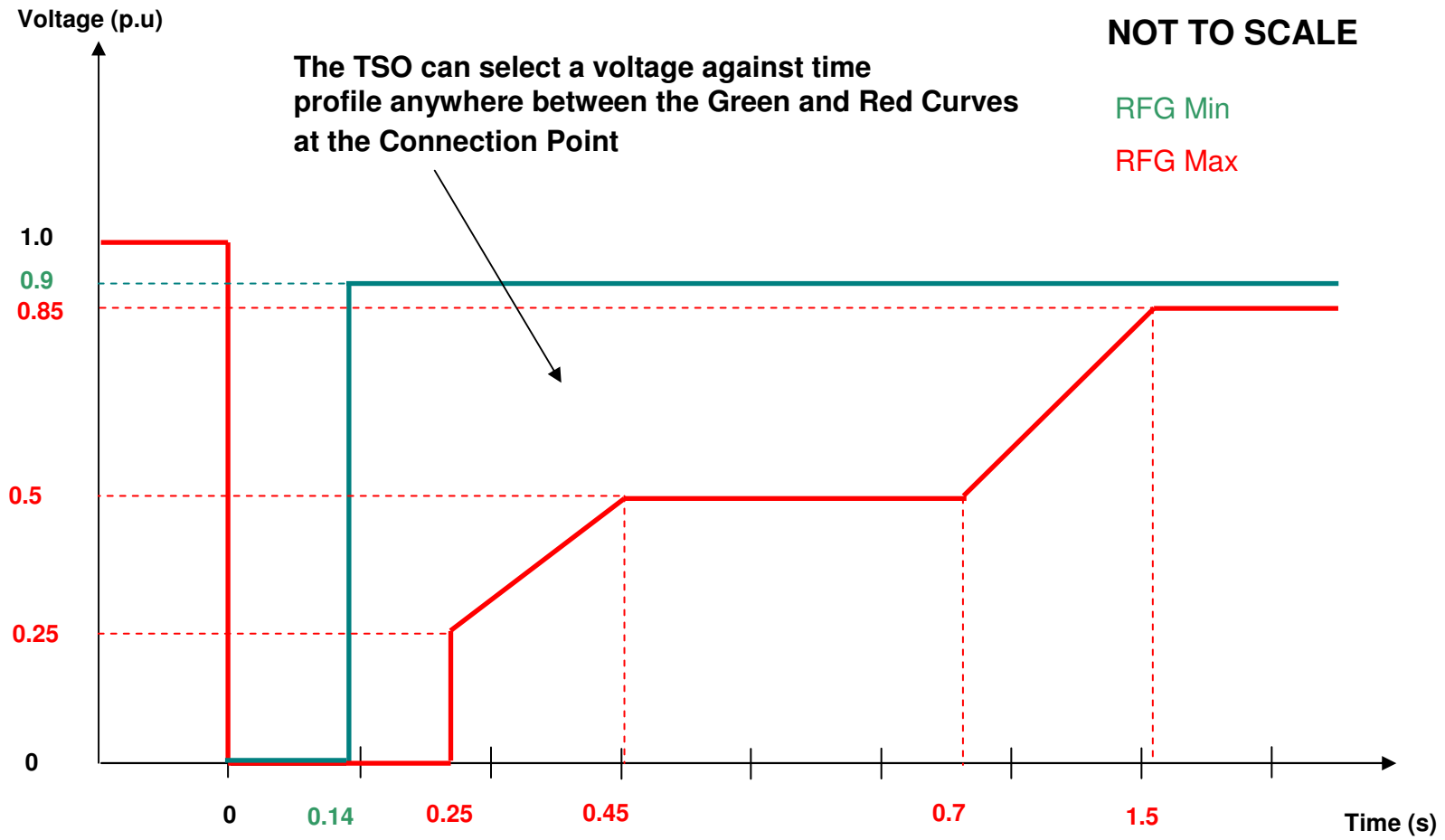
- Each TSO shall define the pre and post fault conditions at the Connection Point.
- The requirements are defined at the Connection Point
  - It is not clear if this would be on an individual basis for each Connection Point or globally across the System where each Connection Point is treated in the same way.
  - The implication is that the TSO should select the worst case which will require study work. Separate voltage profiles will be required for Synchronous Generators and Power Park Modules.

ENTSO-E RfG - Voltage Against Time Profile

Type D Synchronous Power Generating Modules - Example



Example – Figure 9 – Taken from FAQ 24 – Power Park Module

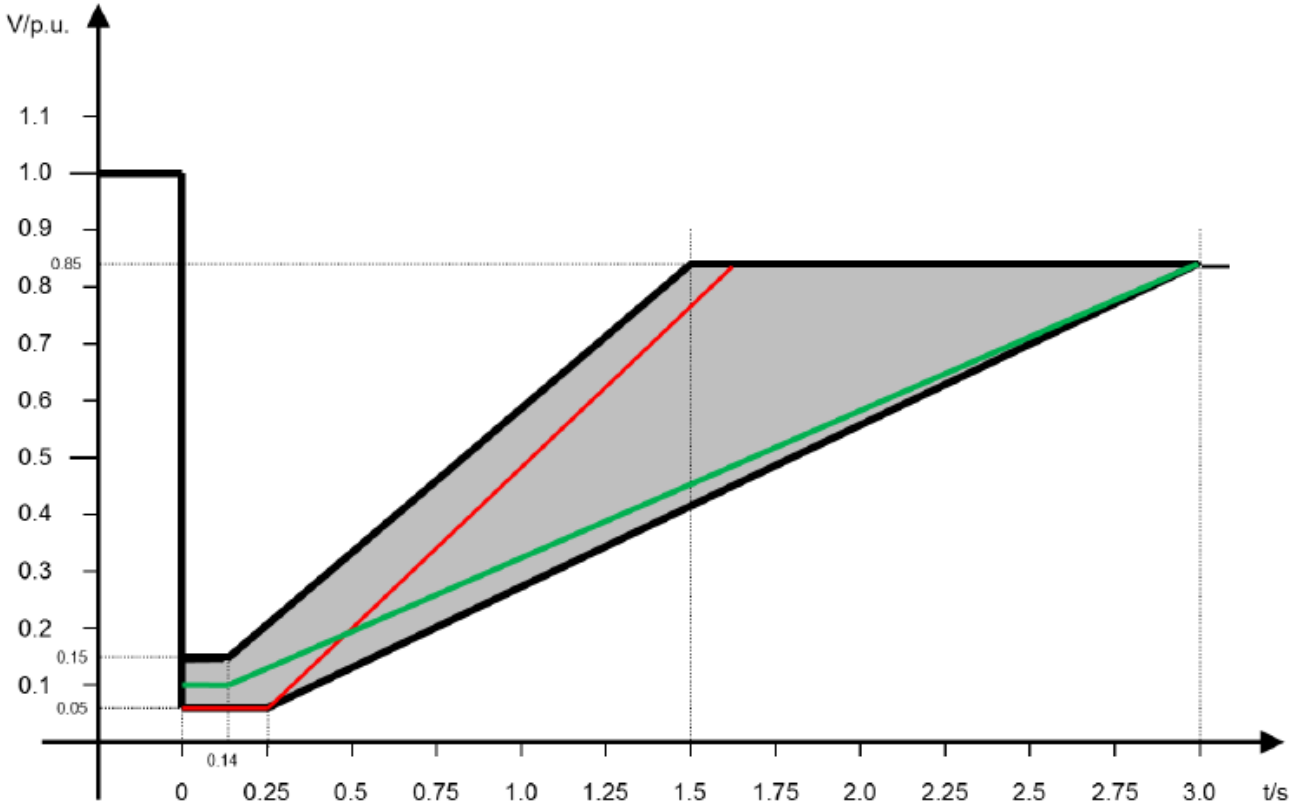


Figure 9: Area (grey) within which a voltage-against-time curve can be defined by the TSO for a Type B PPM, e.g. the given green or red curve

Example – Figure 10 – Taken from FAQ 24 – Power Park Module

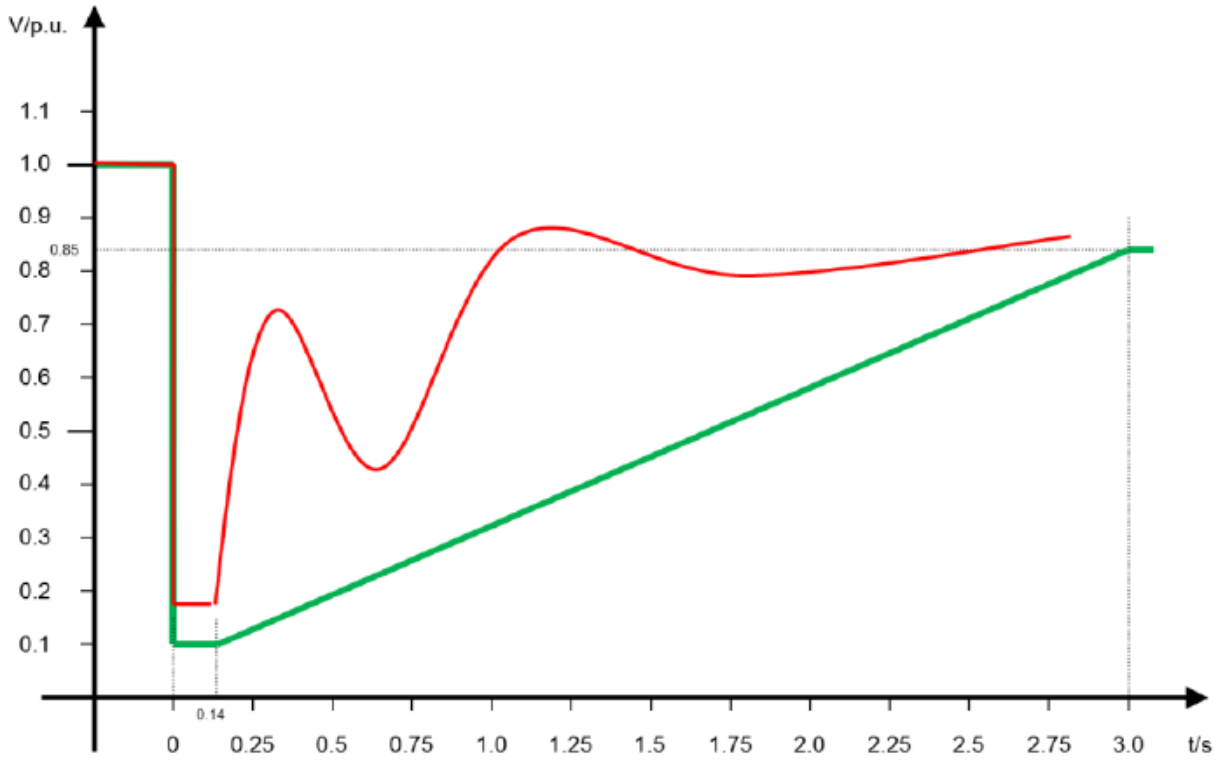


Figure 10: Case in which the recovery voltage (red curve) remains above the defined voltage-against-time curve (green curve) and because of which automatic disconnection of the Power Generating Module is not allowed.

Example – Figure 11 – Taken from FAQ 24 – Power Park Module

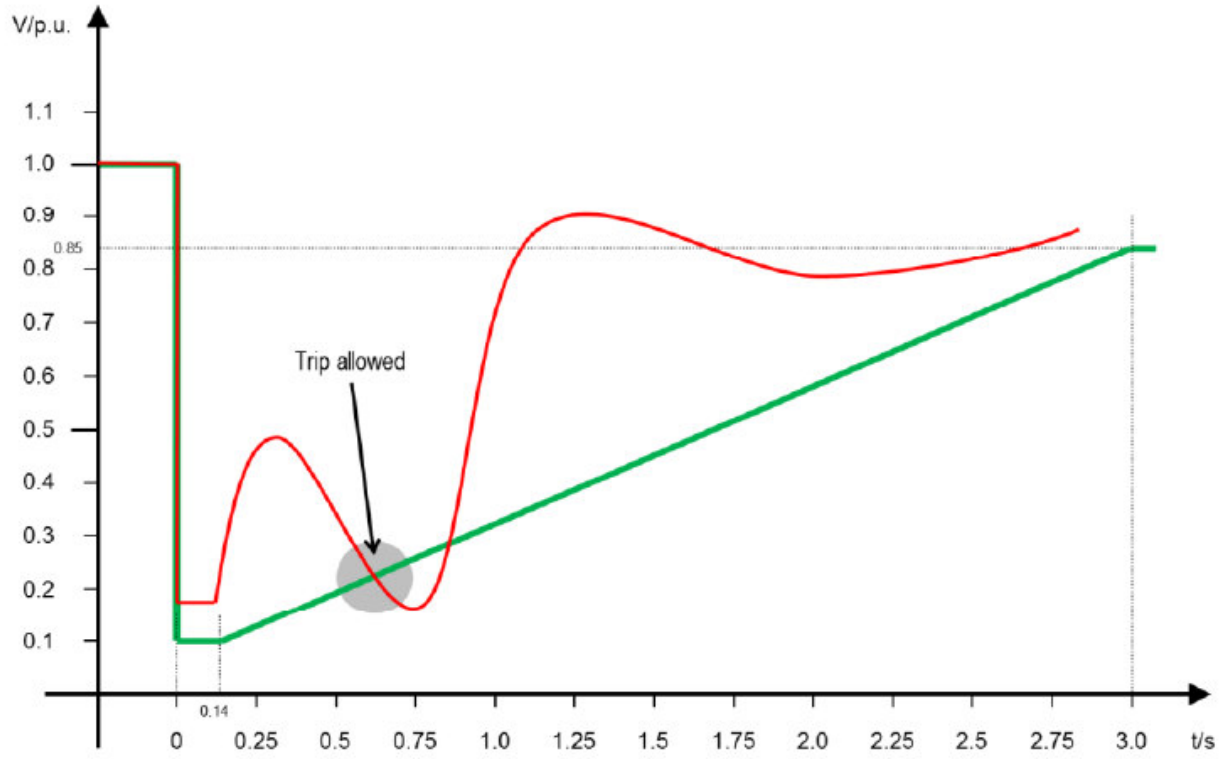


Figure 11: Case in which the recovery voltage (red curve) goes lower than the defined voltage-against-time curve (green curve) and because of which automatic disconnection of the Power Generating Module is allowed.

Explanation of ENTSO-E Fault Ride Through Requirements – FAQ 24

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- FAQ 24 clearly states that the TSO is not requiring the actual voltage recovery curve to be the shape of the voltage against time profile.
- The Voltage recovery curve will have a free controlled response during the post disturbance recovery period that will depend on the PPM technology (eg full converter, doubly fed etc) and the short circuit power of the Grid Connection Point.
- The voltage against time profile just expresses the lower limit for the actual voltage recovery curve for FRT capability

High Level differences with GB Grid Code FRT Requirements

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- The Fault Ride Through Requirements in GB apply only to faults at Supergrid Voltages (ie 200kV) or above
- Split into two sections – faults up to 140ms in duration and faults in excess of 140ms.
- For voltage dips in excess of 140ms a voltage – duration profile is defined which is not a voltage response curve that would be obtained by plotting the transient voltage response at a point on the Onshore Transmission System to a disturbance but rather each point on the profile (ie the heavy black line) represents a voltage level and an associated time duration which connected Generating Units and Power Park Modules must ride through (CC.A.4A.3).
- The same requirement applies to both Power Park Modules and Synchronous Generating Units.
- Requirements exist for Reactive Power Injection during the fault and Active Power recovery on fault clearance
- A more detailed comparison is covered in Table 2 (attached as a separate document) with this presentation

GB Grid Code Voltage Duration Curve - CC.6.3.15.1 (b) (i)

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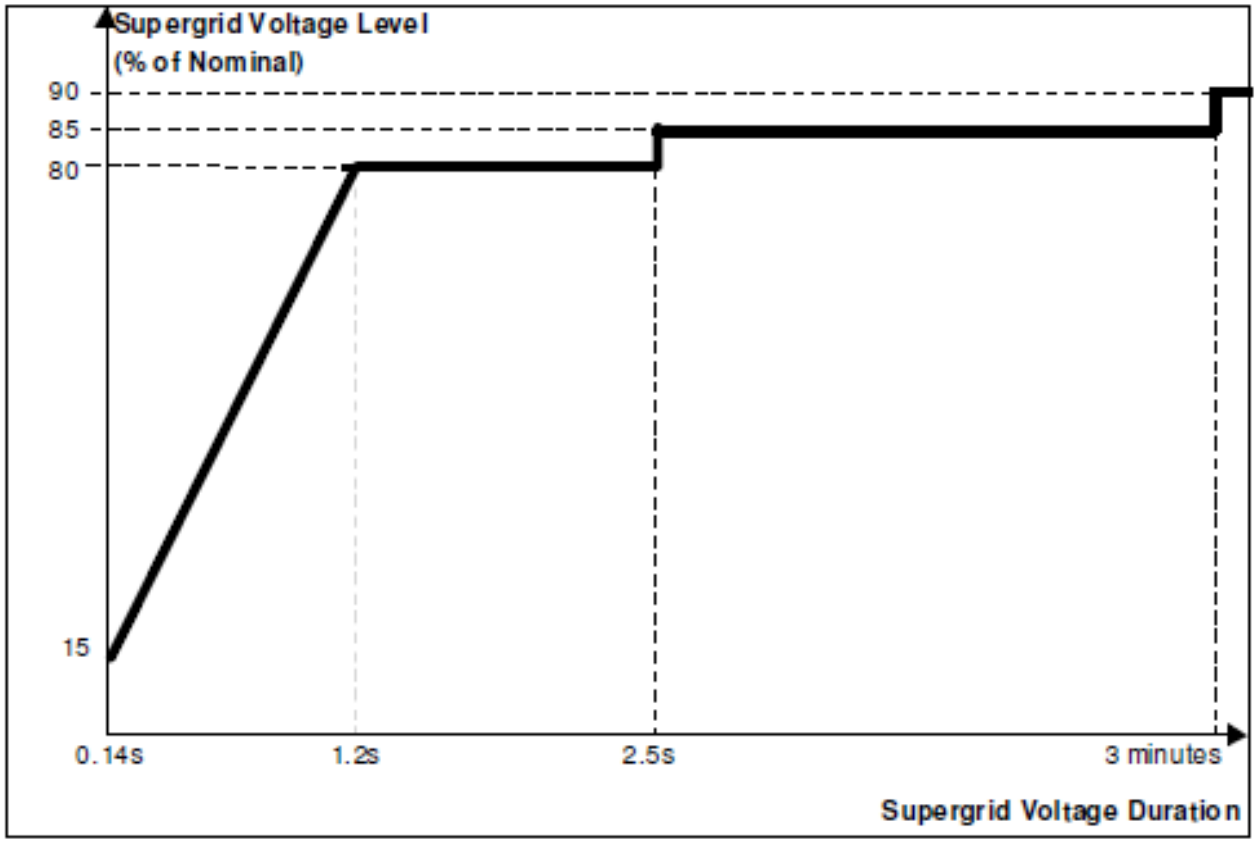

Figure 5

Proposed Way Forward

- Consider early adoption of the ENTSO-E Fault Ride Through Requirements (Type D) for Large and Medium Power Stations
- Leave the requirements for Power Park Modules unchanged (ie as per the Current Grid Code) until the ENTSO-E Requirements are formally adopted and implemented to all Codes (2016).
- Discuss the interpretation of the ENTSO-E RfG Fault Ride Through Requirements.
- Consider developing parameters and voltage against time curves for Synchronous Generating Units
- Develop Grid Code wording to reflect the ENTSO-E RfG for Synchronous Generating Units
- Any FRT wording would need to adopt the ENTSO-E RfG in total and not in part.