Appendix 2

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# Engineering Recommendation G99

Issue 1 – Amendment ~~4~~X

~~16 May 2018~~TBA

## Requirements for the connection of generation equipment in parallel with public distribution networks on or after 27 April 2019

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**Amendments since publication**

| Issue | Date | Amendment |
|---|---|---|
| G99/1 -1 | 23 Jul 2018 | Housekeeping modification<br>1. To implement the Authority's decision on DC0079, ie to disallow the use of VS protection and to provide new RoCoF requirements for type tested generation. Changes to clauses 10.6.7.1; A.2-1; A.2-3; A.7.1.2.6; A7.2.2.6; D.2.1.<br>2. Correction of implementation date to 27 April 2019 throughout.<br>3. Minor typographical corrections – principally a number of corrected internal paragraph cross references, as well as a small number of spelling mistakes. |
| G99/1 -2 | 10 Dec 2018 | Implementation of GC0110 – modification to the compliance assessment for LFSM-O. Changes to the following paragraphs:<br>11.2.4.1; 12.2.4.1; A.7.2.4; B.5.6.3 – B.5.6.5; B.6.5.4 – B.6.5.6. |
| G99/1 -3 | 10 Dec 2018 | Modification to incorporate the **Integrated Micro Generation and Storage** procedure (otherwise known as the energy storage fast track procedure) into EREC G98 and G99.<br>A small number of minor typographical corrections throughout. |
| G99/1 -4 | Tbc. | 1. Various small modifications.<br>2. Modifications to foreword for the case that a G99 PGM is installed before 27 April 2019.<br>3. Paragraph 2.14 added in respect of applicable versions of G99 with respect to type testing, Equipment Certificate(s) and Manufactures' Information. |

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| | | 4. Minimum Generation replaced with Minimum Stable Operating Level.<br>5. Distribution Licence condition reference number updated from 4 to 12 in paragraph 6.4.5.1.<br>6. Paragraph 7.1.2 added in respect of regenerative equipment.<br>7. New paragraph 10.1.4 to clarify type tested interface protection and modification to paragraph 16.3.4.<br>8. Clarification of automatic reconnection for Generators with a CUSC contract in paragraph 10.3.3.<br>9. Figures 11.2 and 12.2 modified to show the range of droops that a Generator may choose to implement for LFSM-O.<br>10. Requirements of paragraph 13.2.6.1 simplified and definition of European Specification removed.<br>11. Clarification added to paragraph 6.2.4.4, 17.4.3, 18.4.3 and 19.5.7 in respect of Operational Notification. Similar clarification added as applicable to Type A PGMs in paragraph 16.4.3.<br>12. Paragraph 15.3,3 modified in respect of timing of submission of compliance forms. Paragraph 16.2.4 modification in respect of timing of submission of Type A compliance forms. Section 17.2 and 18.2 Connection process expanded to provide clarity.<br>13. Paragraphs 17.2.1 and 18.2.1 modification in respect of connection offer.<br>14. Paragraph 18.3.4 modification in respect of initial capacity limit on synchronisation for PPMs.<br>15. Paragraph 19.2.1 modification in respect of timing of Type D PGMD submission.<br>16. Clarification that a PGMD can be used in paragraph 19.2.4.<br>17. Paragraph 19.4 Witnessing and Commissioning included<br>18. Modifications to align the Type Testing for PPMs with the commissioning form.<br>19. RoCoF withstand test added to Form A2-2, A2-3, B2-1 and C2-1.<br>20. RoCoF stability test added to Form A2-4, Form B2-2, Form C2-2 Clarification in Form A3-1, B2-1, B3, C2-1 and C3 in respect of phased installations. Requirement for declaration that PGMD is complete removed from Form B3 and C3.<br>21. Note added to Form A2-2, Voltage fluctuations and flicker that measurements can be recorded as Form A2-1.<br>22. Logic interface port and wiring check anomalies corrected in Form A2-2 and A2-4. |

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| | | 23. Check for as installed data added to Type A Installation Document.<br>24. Clarification added to text in Section 21 in respect of Manufacturers Information.<br>25. Simplification of Type B simulation studies in respect of Reactive Power and Voltage Control studies, LFSM-O studies.<br>26. Sections B.5.2, B.5.3, B.5.4, B.5.5, B.6.2, B.6.3, B.6.4 and B.6.5 removed. References to these tests removed from the Type B PGMD. Ability for DNO to request these tests included in paragraph 17.2.3.<br>27. Paragraph 13.5.1 modified and paragraph13.5.3 added and Annex C.7.3 revised in respect of Type C reactive capability.<br>28. Paragraph C.5.3.4 modified to clarify reactive power required envelope of operation for PPMs.<br>29. Paragraph C.5.7.3 removed.<br>30. Duplicated words in Annex 6 removed.<br>31. Reference to Connection Agreement and Site Responsibility Schedule added to PGMD for Type B and Type C. Power Quality requirements added to the PGMD for Type C PGMs.<br>32. Annex C.7.3.1 and C.7.3.2 modified to clarify the simulation study voltage requirements for Synchronous PGMs and PPM.<br>33. Annex A.4.3 amended in respect of Infrequent Short-Term Parallel Operation |
| G99/1-5 | TBA | Modifications to 12.6 and 13.6 to clarify the fast fault current injection requirements for Types B, C and D. |

settings, shall be agreed with the **DNO** and recorded in the **Connection Agreement**. The information to be provided is detailed in Schedule 5a and Schedule 5b of the Data Registration Code.

12.4.4 The final responsibility for control of **Distribution Network** voltage does however remain with the **DNO**.

12.4.5 Automatic Voltage Control (AVC) schemes employed by the **DNO** often assume that power flows from parts of the **Distribution Network** operating at a higher voltage to parts of the **Distribution Network** operating at lower voltages. Export from **Power Generating Module**s in excess of the local loads may result in power flows in the reverse direction. In this case AVC referenced to the low voltage side may not operate correctly without an import of **Reactive Power** and relay settings appropriate to this operating condition. When load current compounding is used with the AVC and the penetration level of **Power Generating Module**s becomes significant compared to normal loads, it may be necessary to switch any compounding out of service.

12.4.6 **Power Generating Module**s can cause problems if connected to networks employing AVC schemes which use negative reactance compounding and line drop compensation due to changes in **Active Power** and **Reactive Power** flows. ETR 126 provides guidance on connecting generation to such networks using techniques such as removing the generation circuit from the AVC scheme using cancellation CTs.

**12.5** Reactive Capability

12.5.1 When supplying **Registered Capacity** all **Power Generating Module**s shall 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 Module**s or **Generating Unit**s within a **Power Park Module** shall be capable of continuous operation at any point between the **Reactive Power** capability limits identified on the **Generator Performance Chart**. **Generator**s 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**.

**12.6** Fast Fault Current Injection

12.6.1 **Fast Fault Current** injection is necessary to support the **Total System** during a fault on the **Transmission System**. The design of **Fast Fault Current** injection is tailored to this, and does not relate directly to faults on the **Distribution Network**, not least as those will tend to have longer clearing times than those of the **Transmission System** for which **Fast Fault Current** injection is designed. In this Section 12.6 the faults referred to are **Transmission System** faults which clear within 140 ms and which will be seen in the **Distribution Network** as a voltage depression. For this section 12.6 voltage and current quantities are assumed to be positive phase sequence values.

12.6.2 Each **Power Park Module** shall be required to satisfy the following requirements:

(a) For any balanced ~~or unbalanced~~ fault on the **Transmission System** which results in the voltage at the **Connection Point** falling below 0.9 pu each **Power Park Module** shall, unless otherwise agreed with the **DNO**, be required to inject ~~a current~~ reactive current $I_R$ that lies above the heavy black line shown in Figure 12.5.

(b) Figure 12.5 defines the reactive current $I_R$ that is to be supplied during a fault on the **Transmission System** and which is dependent on the pre-fault operating conditions, and the voltage retained at the **Connection Point**. Each **Power Park Module** shall be required to inject a reactive current $I_R$ which shall not be less that its pre-fault reactive current and which shall as a minimum increase with the fall in retained voltage each time the retained voltage at the **Connection Point** falls below 0.9 pu, whilst ensuring that the overall rating of the **Power Park Module** is not exceeded.

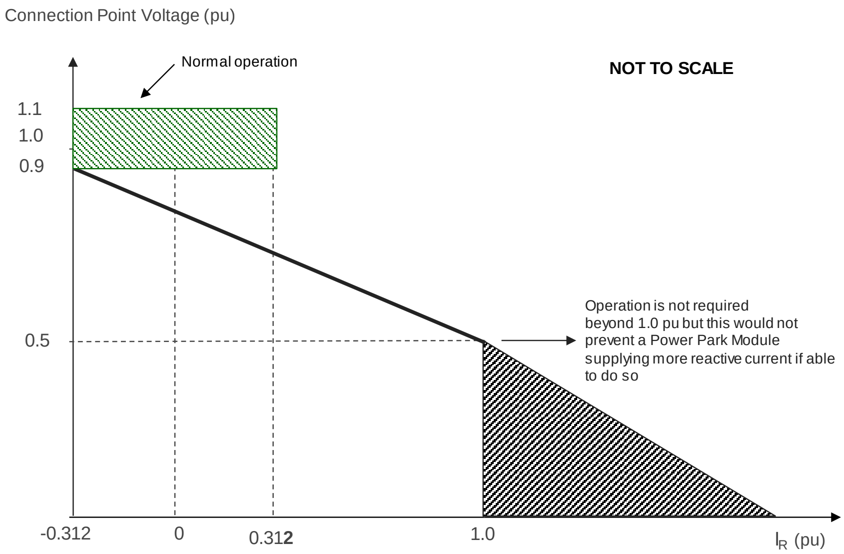



**Figure 12.5 – locus of magnitude of injected current**

(c) In addition each **Power Park Module** shall be required to satisfy the reactive current requirements shown in Figures 12.6 which shows how the reactive current should be injected over time from the fault inception. The injected current shall be above the shaded area shown in Figure 12.~~5~~ 6 (a) ~~and~~ or Figure 12.~~5~~ 6 (b)~~.~~ with priority being given to reactive current injection with any residual capability being supplied as active current. Under any fault condition, where the voltage falls below 0.9 pu, there would be no requirement for each **Power Park Module** or constituent **Generating Unit** to exceed its transient or steady state rating.

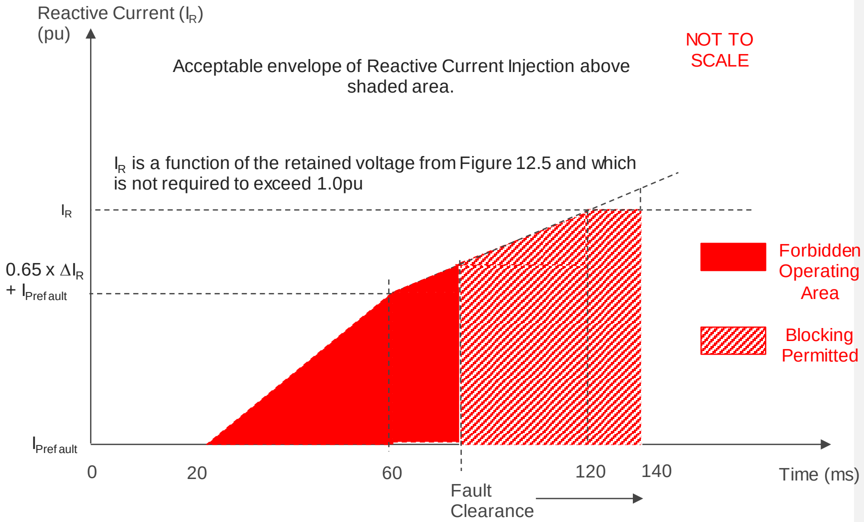



**Figure 12.6(a) Chart showing area of Reactive Current injections for voltage depressions of less than 140 ms duration**

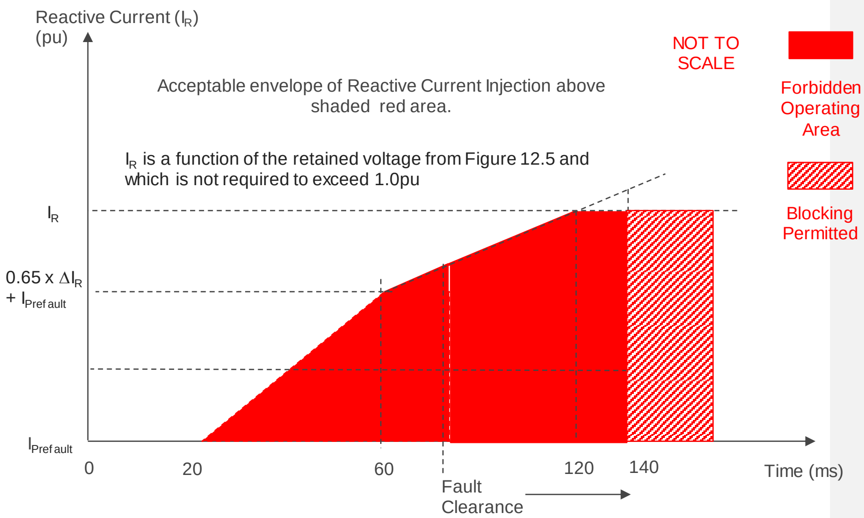
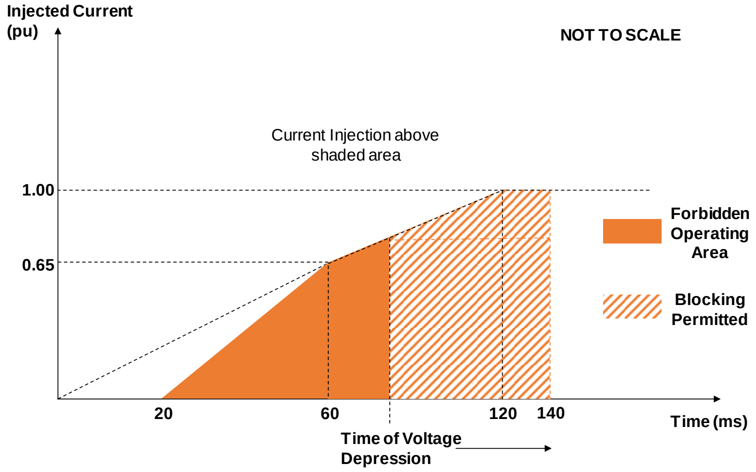



**Figure 12.6(b) Chart showing area of Reactive Current injections for voltage depressions of greater than 140 ms duration**

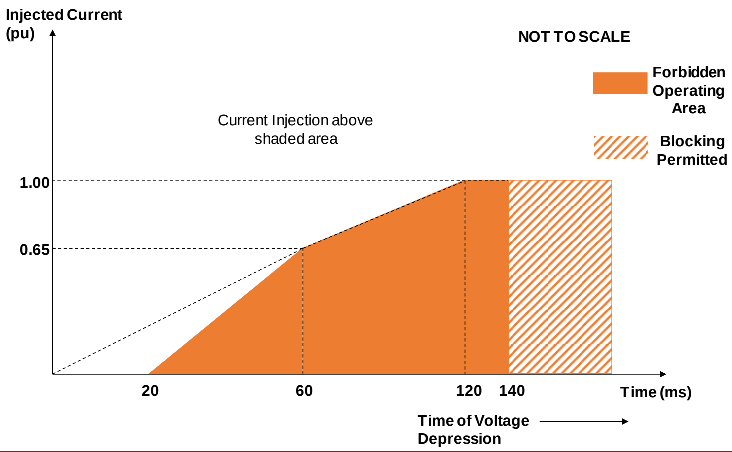
~~(a)~~(d) For the purposes of this requirement, the maximum rated current is taken to be the maximum current each **Generating Unit** can supply when operating at **Registered Capacity** and 0.95 **Power Factor** at a nominal voltage of 1.0 pu. For example, in the case of a 1 MW **Power Park Module** the **Registered Capacity** would be taken as 1 MW and the rated **Reactive Power** would be taken as 0.33 MVAr (ie **Rated MW** output operating at 0.95 **Power Factor** lead or 0.95 **Power Factor** lag) giving a MVA rating of 1.05 MVA. ~~For the avoidance of doubt, where the phase voltage at the **Connection Point** is not zero, the injected current shall be in proportion to the retained voltage at the **Connection Point** but shall still be required to remain above the shaded area in Figure 12.5(a) and Figure 12.5(b)~~. If, in this example, the **Power Park Module** consisted of 5 x 200kW **Generating Units** and 1 x 100kVAr reactive compensation equipment, each **Generating Unit** would need to be rated to produce 200 kW and + (330 kVAr – 100 kVAr) ÷ 5, ie 205.2 kVA.




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

Appendix 2






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

~~(b)~~(e) ~~In addition, the injected current from each **Power Park Module** shall be in proportion and remain in phase with the change in system voltage at the **Connection Point** during the period of the voltage depression. For the avoidance of doubt, the injected current will be purely reactive for a retained voltage of zero and the reactive component of the injected current will fall in inverse proportion to the retained voltage at the **Connection Point**. The voltage generated from the injected current of the **Power Park Module** shall be in phase with the retained voltage at the **Connection Point**, whilst the total injected current remains above the shaded area in diagrams 12.5(a) and 12.5(b). Also, as can been seen on the diagrams a small delay time of no greater than 20 ms once the voltage falls to below 0.9 pu is permitted before injection of the in phase reactive current.~~All **Power Park Module** equipment shall be designed to ensure a smooth transition between any of its voltage, power factor or reactive control modes and fault ride through mode in order to prevent the risk of instability which could arise in the transition between the steady state voltage operating range and abnormal conditions where the retained voltage falls below 0.90 pu of nominal voltage. Such a requirement is necessary to ensure adequate performance between the pre-fault operating condition of the **Power Park Module** and its subsequent behaviour under fault conditions.

(f) Each **Power Park Module** shall be designed to reduce the risk of transient over voltage levels arising following clearance of the fault and in order to mitigate the risk of any form of instability which could result. **Generators** shall be permitted to block or employ other means where the anticipated transient overvoltage would otherwise exceed the 1.05 pu of nominal. Figures 12.6 (a) or Figure 12.6 (b) show the impact of variations in fault clearance time which shall be no greater than 140ms. The **DNO** may agree requirements for the maximum transient overvoltage withstand capability and associated time duration. Such capability and parameters will be recorded in the **Connexion Agreement**. Where the **Generator** is able to demonstrate to the **DNO** that blocking or other control strategies are required in order to prevent the risk of transient over voltage excursions **Generators** are required to both advise and agree with the **DNO** the control strategy, which must also include the approach taken to de-blocking. ~~The **Inverter** is permitted to block (ie reduce the current injection) when the voltage at the **Connection Point** has returned to >0.85 pu in order to mitigate against the risk of transient overvoltage instability that would otherwise occur due to transient overvoltage excursions. Figure 12.5 (a) and Figure 12.5 (b) show the required current injection during the duration of the voltage depression. Where the **Generator** is able to demonstrate to the **DNO** that blocking is required in order to prevent the risk of transient over voltage excursions arising following clearance of the fault, **Generators** are required to both advise of, and agree on, the control strategy with the **DNO**, which shall also include the approach taken to de-blocking. Notwithstanding this requirement, **Generators** should be aware of their requirement to fully satisfy the **Fault Ride Through** requirements of Section 12.3.~~

(g) To permit additional flexibility for example from **Power Park Modules** made up of full converter machines, DFIG machines or induction generators, the **DNO** will permit transient deviations below the shaded area shown in Figures 12.6 (a) or Figure 12.6 (b) provided that the overall reactive current supplied over time is greater than the minimum requirement shown in Figures 12.6 (a) or Figure 12.6 (b). This agreement will be formalised in the **Connexion Agreement.**

~~(c)~~(h) In the case of an unbalanced fault, each **Park Module** or each **Generating Unit** within a **Power Park Module** shall be required to inject maximum reactive current without exceeding the transient rating of the **Power Park Module** (or constituent element thereof).

~~(d) Each **Power Park Module** shall be designed to reduce the risk of transient overvoltage levels arising following voltage restoration. **Generators** shall be permitted to block where the anticipated transient overvoltage would not otherwise exceed the maximum permitted values specified in paragraph 12.4.1. Any additional requirements relating to transient overvoltage performance will be specified by the **DNO**.~~

### 12.7 Operational monitoring

12.7.1 At each **Power Generating Facility** the **DNO** will install its own Telecontrol/SCADA outstation which will generally meet all the **DNO**'s necessary and legal operational data requirements. The **DNO** will inform the **Generator** if additional specific data are required.

**Figure 13.13 Reactive Power capability requirements (Power Park Modules operating below Registered Capacity)**

**13.6** Fast Fault Current Injection

13.6.1 **Fast Fault Current** injection is necessary to support the **Total System** during a fault on the **Transmission System**. The design of **Fast Fault Current** injection is tailored to this, and does not relate directly to faults on the **Distribution Network**, not least as these will tend to have longer clearing times than those of the **Transmission System** for which **Fast Fault Current** injection is designed. In this Section 13.6 the faults referred to are **Transmission System** faults which clear within 140 ms and which will seen in the **Distribution Network** as a voltage depression. For this section 13.6 voltage and current quantities are assumed to be positive phase sequence values.

13.6.2 Each **Power Park Module** shall be required to satisfy the following requirements.

(a) For any balanced ~~or unbalanced~~ fault on the **Transmission System** which results in the voltage at the **Connection Point** falling below 0.9 pu each **Power Park Module** shall unless otherwise agreed with the **DNO**, be required to inject reactive current $I_R$ that lies above the heavy black line shown in Figure 13.14.

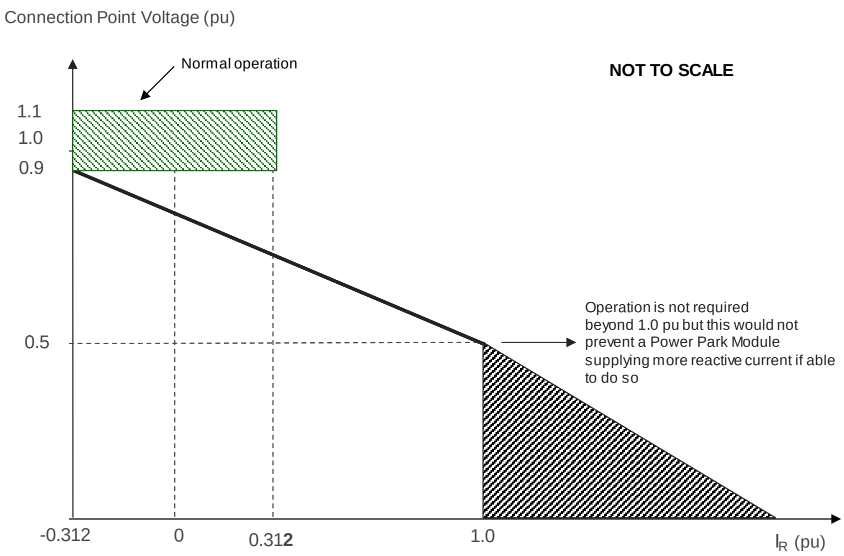



**Figure 13.14 – locus of magnitude of injected current**

(b) Figure 13.14 defines the reactive current $I_R$ that is to be supplied during a fault on the **Transmission System** and which is dependent on the pre-fault operating conditions, and the voltage retained at the **Connection Point**. Each **Power Park Module** shall be required to inject a reactive current $I_R$ which shall not be less that its pre-fault reactive current and which shall as a minimum increase with the fall in retained voltage each time the retained voltage at the **Connection Point** falls below 0.9 pu, whilst ensuring that the overall rating of the **Power Park Module** is not exceeded

(c) In addition each **Power Park Module** shall be required to satisfy the reactive current requirements shown in Figures 13.15 which shows how the reactive current should be injected over time from the fault inception. The injected current shall be above the shaded area shown in Figure 13.15 (a) or Figure 13.6 (b) with priority being given to reactive current injection with any residual capability being supplied as active current. Under any fault condition, where the voltage falls below 0.9 pu, there would be no requirement for each **Power Park Module** or constituent **Generating Unit** to exceed its transient or steady state rating. ~~be required to inject a current above the shaded area shown in Figure 13.14(a) and Figure 13.14(b).~~

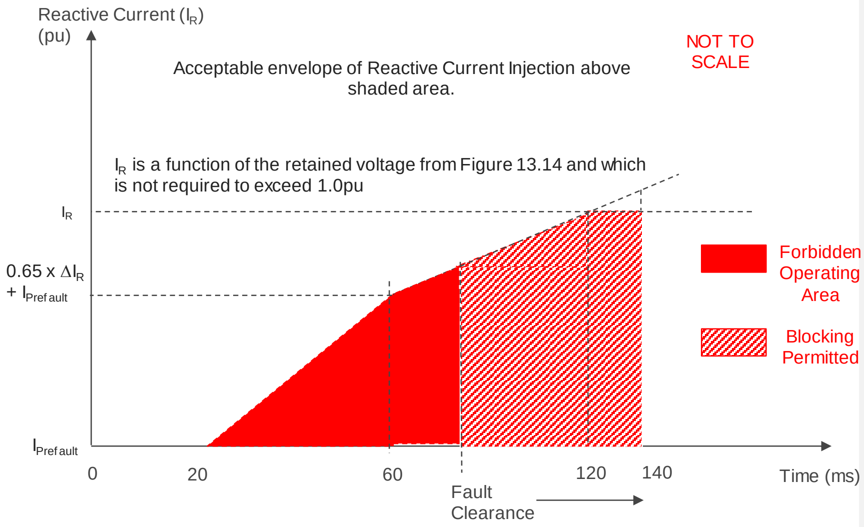
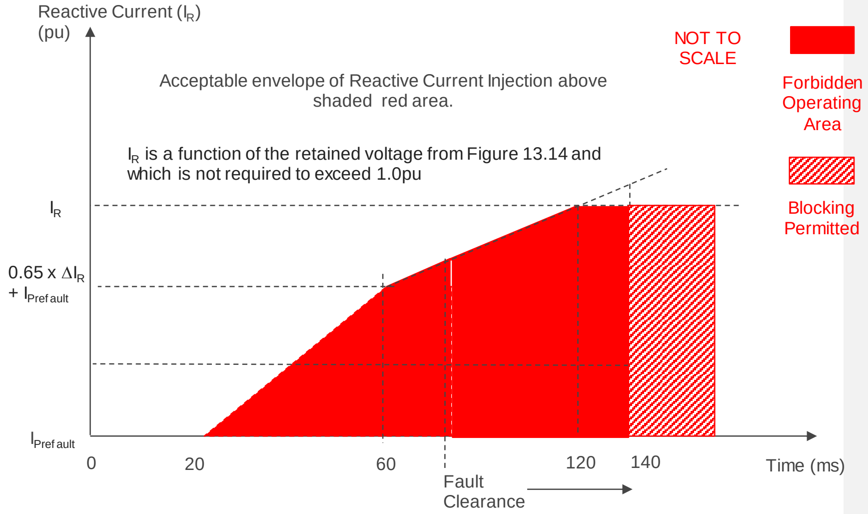



**Figure 13.15(a) Chart showing area of Reactive Current injections for voltage depressions of less than 140 ms duration**

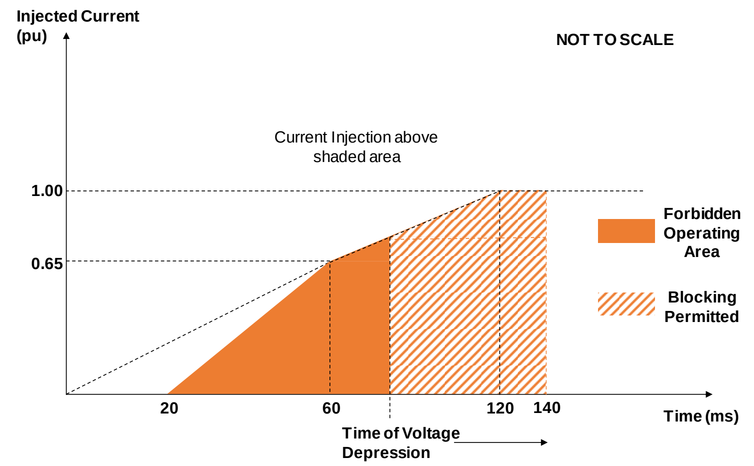



<u>**Figure 13.15(b) Chart showing area of Reactive Current injections for voltage depressions of greater than 140 ms duration**</u>

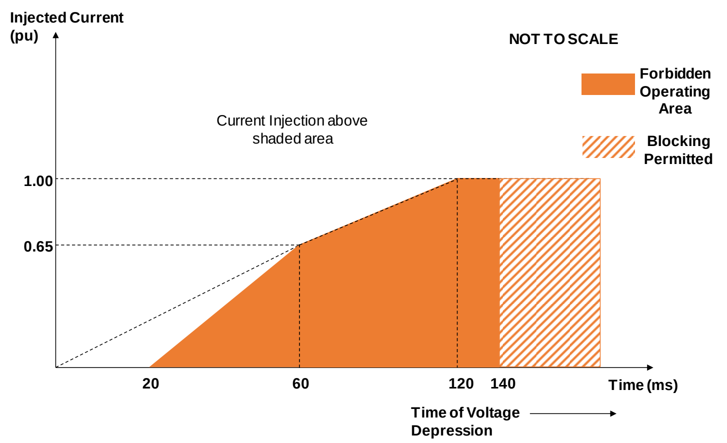
<u>(i)</u> For the purposes of this requirement, the maximum rated current is taken to be the maximum current each **Generating Unit** can supply when operating at **Registered Capacity** and 0.95 **Power Factor** at a nominal voltage of 1.0 pu. For example, in the case of a 10 MW **Power Park Module** the **Registered Capacity** would be taken as 10 MW and the rated **Reactive Power** would be taken as 3.28 MVAr (ie **Rated MW** output operating at 0.95 **Power Factor** lead or 0.95 **Power Factor** lag) giving an MVA rating of 10.53 MVA. <u>If, in this example, the **Power Park Module** consisted of 5 x 2 MW **Generating Units** and 1 x 1 MVAr reactive compensation equipment, each **Generating Unit** would need to be rated to produce 2 MW and + (3.3 MVAr - 1.0 MVAr) ÷ 5, ie 2.05 MVA.</u>

<u>(d)</u> ~~For the avoidance of doubt, where the phase voltage at the **Connection Point** is not zero, the injected current shall be in proportion to the retained voltage at the **Connection Point** but shall still be required to remain above the shaded area in Figure 13.14~~<u>5</u>~~(a) and Figure 13.15~~<u>4</u>~~(b).~~

~~(a)~~




~~**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~~

(e) All **Power Park Module** equipment shall be designed to ensure a smooth transition between any of its voltage, power factor, or reactive power control modes and fault ride through mode in order to prevent the risk of instability which could arise in the transition between the steady state voltage operating range and abnormal conditions where the retained voltage falls below 0.90 pu of nominal voltage. Such a requirement is necessary to ensure adequate performance between the pre-fault operating condition of the **Power Park Module** and its subsequent behaviour under fault conditions~~In addition, the~~

~~injected current from each **Power Park Module** shall be in proportion and remain in phase with the change in system voltage at the **Connection Point** during the period of the voltage depression. For the avoidance of doubt, the injected current will be purely reactive for a retained voltage of zero and the reactive component of the injected current will fall in inverse proportion to the retained voltage at the **Connection Point**. The voltage generated from the injected current of the **Power Park Module** shall be in phase with the retained voltage at the **Connection Point**, whilst the total injected current remains above the shaded area in diagrams 13.14(a) and 13.14(b). Also, as can been seen on the diagrams a small delay time of no greater than 20 ms once the voltage falls to 0.9 pu is permitted before injection of the in phase reactive current.~~.

(f) Each **Power Park Module** shall be designed to reduce the risk of transient over voltage levels arising following clearance of the fault and in order to mitigate the risk of any form of instability which could result. **Generators** shall be permitted to block or employ other means where the anticipated transient overvoltage would otherwise exceed the 1.05 pu of nominal. Figures 13.15 (a) or Figure 13.15 (b) show the impact of variations in fault clearance time which shall be no greater than 140ms. The **DNO** may agree requirements for the maximum transient overvoltage withstand capability and associated time duration. Such capability and parameters will be recorded in the **Connexion Agreement**. Where the **Generator** is able to demonstrate to the **DNO** that blocking or other control strategies are required in order to prevent the risk of transient over voltage excursions **Generators** are required to both advise and agree with the **DNO** the control strategy, which must also include the approach taken to de-blocking.~~The **Inverter** is permitted to block (ie reduce the current injection) when the voltage at the **Connection Point** has returned to >0.85 pu in order to mitigate against the risk of transient overvoltage instability that would otherwise occur due to transient overvoltage excursions. Figure 13.14 (a) and Figure 13.14 (b) show the required current injection during the duration of the voltage depression. Where the **Generator** is able to demonstrate to the **DNO** that blocking is required in order to prevent the risk of transient over voltage excursions as specified in paragraph 13.6.2(d) **Generators** are required to both advise and agree with the **DNO** of the control strategy, which shall also include the approach taken to de-blocking. Notwithstanding this requirement, **Generators** should be aware of their requirement to fully satisfy the **Fault Ride Through** requirements of paragraph 13.3.~~

(g) To permit additional flexibility for example from **Power Park Modules** made up of full converter machines, DFIG machines or induction generators, the **DNO** will permit transient deviations below the shaded area shown in Figure 13.15 (a) or Figure 13.15 (b) provided that the reactive current supplied is greater than the minimum requirement shown in Figures 13.15 (a) or Figure 13.15(b). This agreement will be formalised in the **Connexion Agreement.**

(h) In the case of an unbalanced fault, each **Power Park Module** or each **Generating Unit** within a **Power Park Module** shall be required to inject maximum reactive current without exceeding the transient rating of the **Power Park Module**.

~~Each **Power Park Module** shall be designed to reduce the risk of transient over voltage levels arising following voltage restoration. **Generator**s shall be permitted to block where the anticipated transient overvoltage would not otherwise exceed the maximum permitted values specified in paragraph 13.4.1. Any additional requirements relating to transient overvoltage performance will be specified by the **DNO**.~~

**13.7** Black Start Capability

~~13.6.3~~13.7.1 The National Electricity Transmission System will be equipped with **Black Start Station**s. It will be necessary for each **Generator** to notify the **DNO** if its **Power Generating Module** has a restart capability without connection to an external power supply, unless the **Generator** shall have previously notified the **NETSO** accordingly under the **Grid Code**. Such generation may be registered by the **NETSO** as a **Black Start Station**.

**~~13.7~~13.8** Technical Requirements for Embedded Medium Power Stations

~~13.7.1~~13.8.1 Where a **Generator** in respect of an **Embedded Medium Power Station** is a party to the **CUSC** this Section 13.8 will not apply.

~~13.7.2~~13.8.2 In addition to the requirements of this EREC G99, the **DNO** has an obligation under ECC 3.3 of the **Grid Code** to ensure that all relevant **Grid Code** Connection Condition requirements are met by **Embedded Medium Power Station**s. These requirements are summarised in ECC 3.4 of the **Grid Code**. It is incumbent on the **Generator** who owns any **Embedded Medium Power Station** to comply with the relevant **Grid Code** requirements listed in ECC3.4 of the **Grid Code** as part of compliance with this EREC G99.

~~13.7.3~~13.8.3 Where data is required by the **NETSO** from **Embedded Medium Power Station**s, nothing in the **Grid Code** or this EREC G99 precludes the **Generator** from providing the information directly to the **NETSO** in accordance with **Grid Code** requirements. However, a copy of the information should always be provided in parallel to the **DNO**.

~~13.7.4~~13.8.4 **Grid Code** Connection Conditions Compliance

~~13.7.4.1~~13.8.4.1 The technical designs and parameters of the **Embedded Medium Power Station** shall comply with the relevant Connection Conditions of the **Grid Code**. A statement to this effect, stating compliance with ECP4.3 of the **Grid Code** is required to be presented to the **DNO** for onward transmission to the **NETSO**, before commissioning of the **Embedded Medium Power Station**. Note that the statement might need to be resubmitted post commissioning when assumed values etc have been confirmed.

~~13.7.4.2~~13.8.4.2 Should the **Generator** make any material change to such designs or parameters as will have any effect on the statement of compliance referred to in