Document. **Final version of proposed Grid Code Changes – 002F.**

Issued to. **Antony Johnson at NGESO with no restriction on issuing to others.**

Signed by. **E A Lewis -** Eric Lewis Company director **Enstore** on 17 March 2023.

Contents

0. Commercial conditions:

1. This text has a reference " **Final version of proposed Grid Code Changes – 002F.** hence called **The Data.**
2. **The Data** has been independently produced by **Enstore** and presents **Enstore's** views on the design of inverters and the design of a future AC Grid.
3. **The Data** replaces all previous **Enstore** data on this topic.
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Signed by…**Eric A Lewis** … Eric A Lewis BSc (Eng) CEng MIET- Company Director. 17-03-2023.

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Notes :

- Blue text are the Enstore's notes.
- Red text are the proposed changes to the existing Grid Code.
- Black text is data from the existing Grid Code.

1. Proposed changes to the Grid code.

The changes listed in this document are to implement the following important benefits:

1. All **GBGF-I** inverters can produce **Active Phase Jump Power** to increase the stability of the GB AC Grid.
2. Each **GBGF-I** inverter can have one or more values for its defined **Phase Jump Angle Limit** to enable the optimum **Active Phase Jump** Power to be produced for different operating conditions.
3. To eliminate the need for a definition of a **Transmission Stability Service (TSS)** in the **GBGF Grid Code** that was initially proposed in other data**.**
4. To provide a revised **Active Phase Jump Power** definition for AC Grid phase angle changes up to the **Allowed Phase Jump Angle** that will be defined by **NGESO** in the **SQSS**. This will enable **GBGF-I** inverters to reliably replace **GBGF-S** be they either Synchronous generators and or Synchronous compensators.
5. To have an improved definition of the **Control 5 Hz Bandwidth Limit.**
6. To define how **GBGF-I** inverters can remain in the **Normal Mode** for AC Supply voltages below 0.9 pu.
7. To give data on the **Rise Time** of the **Allowed Phase Jump Angle** which is the time taken for the **Allowed Phase Jump Angle** to occur.

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There are eight new or changed proposed definitions with Enstore's notes in Blue text, original Grid Code in Black text and proposed changes in Red Text.

Control 5 Hz Bandwidth Limit	For a **GBGF-I** operating in the **Normal Mode**, any signal that directly affects the amplitude, and or frequency and or phase of the **GBGF-I's** output voltage are required to have their bandwidth limited to 5 Hz. For the avoidance of doubt, this does not apply to signals that do not directly affect the **GBGF-I's** output voltage that include: ➢ Signals to control the internal operation of any directly associated plant connected to the **GBGF-I**. ➢ The operation of the **GBGF-I** inverter's internal software including damping. For the avoidance of doubt, the **Control 5 Hz Bandwidth Limit** does not apply to signals that produce well controlled power variations in the AC Grid with a low amplitude in the **GBGF-I's** output power at frequencies below 50 Hz that comply with the flicker limitations defined in Engineering Recommendation P28. For the avoidance of doubt, the **Control 5 Hz Bandwidth Limit** also does not apply to the **Withstand Mode** as a **GBGF-I** can have any bandwidth in the **Withstand Mode** to avoid a trip of the inverter.

The Grid Code in ECC.6.3.19.3 (v) (d) then becomes:

include an **Active Control Based Power** part of the control system that can respond to changes in the **Grid Forming Plant** or external signals from the **Total System** available at the **Grid Entry Point** or **User System Entry Point** but with a bandwidth below 5 Hz to avoid AC **System** resonance problems for a **GBGF-I** operating in the **Normal Mode**. For a **GBGF-I** operating in the **Withstand Mode**, the 5 Hz bandwidth limit does not apply

Normal Mode	For this mode, a **GBGF-I** is operating in conditions that are below the **Peak Current Rating** where all the **GBGF** requirements apply as defined in ECC.6.3.19 including the 5 Hz bandwidth limit defined in ECC.6.3.19.3.(v) (d).
Withstand Mode	For this mode, a **GBGF-I** is operating in the conditions that require operation throughout the withstand conditions defined in ECC.6.3.13.2, ECC.6.3.19.5.1 and Table PC.A.5.8.2. These conditions can be at or below the **Peak Current Rating** value and all the specified **GBGF** requirements apply allowing for a changed bandwidth limit as permitted in ECC.6.3.19.3.(v) (d).
Phase Jump Angle Limit	The maximum **Phase Jump Angle** change at the **Grid Entry Point** or **User System Entry Point** that when applied to a **GBGF-I** will result in a controlled linear response in the **Normal Mode** at the rated **Active Phase Jump Power** without activating the **GBGF-I** current limiting functions.
Allowed Phase Jump Angle	The maximum **Phase Jump Angle** change with the corresponding minimum **Rise Time** at the **Grid Entry Point** or **User System Entry Point** that are allowed to occur in the AC Grid for the **Normal Mode**. These values are defined in the **SQSS**. When the **Allowed Phase Jump Angle** occurs, a **GBGF-I** will operate in a stable condition at the rated **Active Phase Jump Power** with the **Withstand Mode** activated.
Phase Jump Angle Withstand	The maximum **Phase Jump Angle** change at the **Grid Entry Point** or **User System Entry Point** that is allowed to occur in the AC Grid for closing a feeder. This can produce a **Phase Jump Angle** of up to 60 degrees that is defined by the settings of the closing AC breaker. When the **Phase Jump Angle Withstand** occurs, a **GBGF-I** will operate in a stable condition with the **Withstand Mode** activated.
Active Phase Jump Power	The transient injection or absorption of **Active Power** from a **Grid Forming Plant** to the **Total System** as a result of changes in the phase angle between the **Internal Voltage Source** of the **Grid Forming Plant** and the **Grid Entry Point** or **User System Entry Point**. In the event of either an instantaneous or a fast phase angle change, disturbance, or fault on the **Total System**, the flow of the **Active Phase Jump power** from a **Grid Forming Plant** to the **Total System** will instantly start to occur with a rate of change defined by the system's AC supply inductance. **Active Phase Jump Power** is an inherent capability of a **Grid Forming Plant** that starts to instantly respond and can have frequency components of over 1000 Hz. For the action to occur, a **GBGF-I** must have a defined real AC Grid impedance and a slow 5 Hz response of the **Internal Voltage Source** of the **Grid Forming Plant** in the **Normal Mode**. For a **GBGF-I** in the **Normal Mode**, it operates linearly up to the rated **Phase Jump Angle Limit**. For larger **Phase Jump Angle** changes, a **GBGF-I** operates in the **Withstand Mode** at a constant output power up to the **Allowed Phase Jump Angle** with a reduced power level permitted up to the **Phase Jump Angle Withstand** value.
Rise Time	The time taken for the **Allowed Phase Jump Angle** to go from zero to the new value.
Internal Voltage Source or IVS	All the text stays the same apart from the following deletion. ~~**For the avoidance of doubt, a virtual impedance, is not permitted in GBGF-I.**~~

For the avoidance of doubt the 5 ms delay, that was part of the previous **Active Phase Jump Power** definition, was only to allow for the response time of sensors and recording systems.

The recommended minimum **Phase Jump Angle Limit** is given in Table PC.A.5.8.2. that does not need to be changed.

There are also proposed text changes including keeping a GBGF inverter in the **Normal Mode** for larger AC supply voltage dips.

ECC.6.3.19.5.1 For any balanced fault which results in the positive phase sequence voltage falling below the voltage levels specified in CC.6.1.4 or ECC.6.1.4 (as applicable) at the **Grid Entry Point** or **User System Entry Point** (if **Embedded**), a **Grid Forming Plant** shall, as a minimum be required to inject a reactive current of at least their **Peak Current Rating** when the voltage at the **Grid Entry Point** or **User System Entry Point** drops to zero. For intermediate retained voltages at the **Grid Entry Point** or **User System Entry Point,** a **GBGF-I** should continue to operate in the **Normal Mode** unless it is essential for the **GBGF-I** to operate in the **Withstand Mode** and then the injected reactive current shall be on or above a line drawn from the bottom left hand corner of the normal voltage control operating zone (shown in the rectangular green shaded area of Figure ECC.6.3.19.5(a)) and the specified **Peak Current Rating** at a voltage of zero at the **Grid Entry Point** or **User System Entry Point** as shown in Figure ECC.16.3.19.5(a).

ECC.6.3.19.5.2 Figure ECC.6.3.19.5(a) defines the reactive current to be supplied under a faulted condition which shall be dependent upon the pre-fault operating condition and the retained voltage at the **Grid Entry Point** or **User System Entry Point** voltage. For the avoidance of doubt, each **Grid Forming Plant** (and any constituent element thereof), shall be required to inject a reactive current which shall be not less than its pre-fault reactive current and which shall as a minimum, increase each time the voltage at the **Grid Entry Point** or **User System Entry Point** (if **Embedded**) falls below 0.9pu and requires the **GBGF-I** to operate in the **Withstand Mode** whilst ensuring the overall rating of the **Grid Forming Plant** (or constituent element thereof) shall not be exceeded.

ECC.6.3.19.5.3 In addition to the requirements of ECC.6.3.19.5.1 and ECC.6.3.19.5.2, each **Grid Forming Plant** shall be required to inject reactive current above the shaded area shown in Figure ECC.6.3.19.5(b) when the retained voltage at the **Grid Entry Point** or **User System Entry Point** falls to 0pu. Where the retained voltage at the **Grid Entry Point** or **User System Entry Point** is below 0.9pu but above 0pu and requires the **GBGF-I** to operate in the **Withstand Mode** (for example when significant active current is drawn by loads and/or resistive components arising from both local and remote faults or disturbances from other **Plant** and **Apparatus** connected to the **Total System**) the injected reactive current component shall be in accordance with Figure ECC.6.3.19.5(a).

Once the **GBGF** Best Practice Work Group has finalised these proposed changes they all need to be progressed as a formal Grid Code and SQSS modifications.

Notes.

The proposed values for the **Allowed Phase Jump Angle** is 20 degrees with a minimum **Rise Time** of 1 millisecond. These values will need to be either confirmed by **NGESO** in the **SQSS** or alternative values selected.

2. Modification record.

Issue	Date	By	Details
001F	06/03/2023	Enstore	• Final issue
002F	17/03/2023	Enstore	• Internal Voltage Source deletion of some text listed.