EirGrid plc

HVDC Interconnectors

Proposed Modifications to the Grid Code

06 November 2009

It is proposed to amend the Grid Code by adding in the text in blue and by deleting the text in red strikethrough:

PC PLANNING CODE

PC.3 SCOPE

The **Planning Code** applies to the **TSO** and to the following **Users:**

(a) **Generators** and **Generator Aggregators** with **Registered Capacity** greater than 10 MW;

(b) all **Generators** connected to the **Transmission System**;

(c) **Distribution System Operator**;

(d) **Transmission Asset Owner**; ~~and~~

(e) **Demand Customers** including both **Dispatchable Demand Customers** and **Demand Side Units**; and

(f) **HVDC Interconnectors.**

The above categories of **User** will become bound by the **Planning Code** prior to generating, distributing or consuming electricity, as the case may be, and references to the various categories (or to the general category) of **User** should, therefore, be taken as referring to a prospective **User** in that role as well as to **Users** actually connected.

PC.A4.14 HVDC Interconnector Characteristics and Registered Data

Minimum technical, design and operational criteria to be met by **HVDC Interconnectors** are specified in the **Connection Conditions**.

For an **HVDC Interconnector** fill in the following:

HVDC Interconnector Registered Import Capacity for import to the **Transmission System** (MW) ____

HVDC Interconnector Registered Export Capacity for export from the **Transmission System** (MW) ____

CC CONNECTION CONDITIONS

CC.3 SCOPE

The **Connection Conditions** apply to the **TSO** and to the following **Users**:

(a) **Generators** with **Registered Capacity** greater than 2MW;
(b) The **Distribution System Operator**;
(c) **Demand Customers**; ~~and~~
(d) **Dispatchable Demand Customers**; and
(e) **HVDC Interconnectors.**

in relation to their connection to the **Transmission System**.

CC.5 PLANT DESIGNATIONS

CC.5.3 The **TSO's** standard practice currently requires that, unless otherwise agreed with the **TSO**, the following standard designations apply:

(a)	**Generation Units** and **HVDC Interconnectors**:	for hydro and wind: G1, G2 etc. for thermal: U1, U2 etc. for HVDC: I1, I2 etc.
(b)	**Generator transformers** (i.e. transformers for **Generation Unit** production) and **HVDC Interconnector Transformers**	at 400 kV; T4001, T4002 etc. at 220 kV; T2001, T2002 etc. at 110 kV; T101, T102 etc.

CC.7.2.5 Grid Connected Transformers

CC.7.2.5.5 An **HVDC Interconnector Transformer** shall be designed such that the **Reactive Power** capability is possible over the full range of **Transmission System Voltages** (specified in CC.7.5.1.1 (f)). The **TSO** and an **HVDC Interconnector** owner will liaise on matters related to the **HVDC Interconnector Transformer** at the design stage.

CC.7.2.5.6 **HVDC Interconnector Transformer** windings shall be connected in star (with the star point or neutral brought out) on the higher **Voltage** side and in delta on the lower **Voltage** side or as agreed with the TSO.

CC.7.5 HVDC Interconnector

CC.7.5.1 The conditions specified in this section of the code apply to all **HVDC Interconnectors** connected to or connecting to the **Transmission System**.

CC.7.5.1.1 Each **HVDC Interconnector,** shall have these minimum capabilities, for the avoidance of doubt, additional performance capabilities are required from **System Services**:

(a) operate continuously at **MW Output** at **Transmission System Frequencies** in the range 49.5Hz to 50.5Hz;

(b) operate and remain connected to the **Transmission System** at **Transmission System Frequencies** within the range 47.5Hz to 52.0Hz ;

(c) remain connected to the **Transmission System** at **Transmission System Frequencies** within the range 47.0Hz to 47.5Hz for a duration of 30 seconds required each time the Frequency is below 47.5Hz;

(d) remain synchronised to the **Transmission System** during rate of change of **Transmission System Frequency** of values up to and including 1 Hz per second;

(e) remain connected to the **Transmission System** at **MW Output** at **Transmission System Voltages** within the ranges specified in CC.8.3.2 for step changes in **Transmission System Voltage** of up to 10%;

(f) sustained operation in accordance with the **Reactive Power** capability referred to in OC4.8 at **Transmission System Voltages** within the ranges specified in CC.8.3.2, unless otherwise specified;

(g) remain connected during and following **Voltage** dips at the **HV** terminals of the **HVDC Interconnector Transformer** of 95% of nominal **Voltage** (5% retained) for duration 0.2 seconds and **Voltage** dips of 50% of nominal **Voltage** (i.e. 50% retained) for duration of 0.6 seconds. Following the fault clearance the **HVDC Interconnector** should return to prefault conditions subject to normal frequency control and **Automatic Voltage Regulator** responses;

(h) operate within all normal operating characteristics at a minimum short circuit level at the **Connection Point** of 1000 MVA;

(i) remain connected to the **Transmission System** during a negative phase sequence load unbalance in accordance with IEC 60034-1;

(j) have support triggers to allow the **HVDC Interconnector** to provide **System Services** as outlined in OC4.8;

(k) in **Emergency** capable of reversing the power flow on the **HVDC Interconnector** at a rate which shall be no less than the **HVDC Interconnector Registered Capacity** within five seconds, up to ten times during the life of the plant and no more than two times in any given twelve months;

(l)	**HVDC Interconnector Minimum Load**	not greater than the lesser of 3% of the **HVDC Interconnector Registered Capacity** or 50 MW;
(m)	**HVDC Interconnector Ramp-up Capability**	not less than the greater of 10% of the **HVDC Interconnector Registered Capacity** per minute or 50 MW per minute, when the **HVDC Interconnector** is in the **Normal Dispatch Condition**;
(n)	**HVDC Interconnector Ramp-down Capability**	not less than the greater of 10% of the **HVDC Interconnector Registered Capacity** per minute or 50 MW per minute, when the **HVDC Interconnector** is in the **Normal Dispatch Condition;**
(o)	**Forbidden Zones**	within the lesser range of between + and - 3% of the **HVDC Interconnector Registered Capacity** or 30 MW in either flow direction and not more than 2 specified zones.
(p)	**Block Load for an HVDC Interconnector**	not greater than the lesser of 3% of the **HVDC Interconnector Registered Capacity** or 30 MW in either flow direction.
(q)	Time from off-line to **HVDC Interconnector Minimum Load** in either flow direction	Not greater than 30 minutes.
(r)	Time from **HVDC Interconnector Minimum Load** in either flow direction to off-line	Not greater than 30 minutes.

CC.7.5.1.2 Where the **TSO** approaches an **HVDC Interconnector**, the **HVDC Interconnector** will co-operate with the **TSO** in the development of procedures and facilities to improve the response of each **HVDC Interconnector** during conditions of system stress. This shall be subject to the agreement of the **HVDC Interconnector** that the procedures are consistent with secure operation of the **HVDC Interconnector's Plant**, such agreement not to be unreasonably withheld.

CC.7.5.2 The **HVDC Interconnector** station owner must ensure that the reversal of flow capabilities are provided for such that the average **HVDC Interconnector Ramp Rate** from **HVDC Interconnector Registered Export Capacity** to **HVDC Interconnector Minimum Import Load** or **HVDC Interconnector Registered Import Capacity** to the **HVDC Interconnector Registered Export Capacity** of at least 50 MW per minute. For the avoidance of doubt this aggregate **HVDC Interconnector Ramp Rate** will include any time needed to pass through deadbands or **Forbidden Zones** of operation.

CC.7.5.3 The **HVDC Interconnector** will be able to connect to the transmission system under the following conditions:

(a) **Transmission System Frequency** within the limits 48.0 to 52.0 Hz;

(b) **Transmission System Voltage** within the limits as specified in CC.8.3.2, not withstanding CC.7.5.9;

(c) **Transmission System** Short Circuit Level at the point of connection no less than 1000 MVA.

Where supply from the **Transmission System** is temporarily lost, **HVDC Interconnectors** must be able to reconnect to the **Transmission System** and reach **Minimum Load** within 30 minutes of the **Transmission System** supply being restored.

CC.7.5.4 Each **HVDC Interconnector**:

a) must ensure that they do not cause any sub synchronous resonance, undamped oscillations or harmful shaft torsional oscillations on existing generators on the **Transmission System**. Where it is determined that

the **HVDC Interconnector** does cause such oscillations or resonances a solution to remove these shall be agreed with the **TSO**.

b) where further studies are required to examine an oscillation or resonance issue there shall be an exchange of the necessary data between the **HVDC Interconnector** and the **TSO**, such exchange of data shall not be unreasonably withheld. The **HVDC Interconnector** shall provide a report to show the contribution that the **HVDC Interconnector** control system design will have on the torsional mode frequencies.

Input provisions for addition of a future sub synchronous damping controller shall be made by the **HVDC Interconnector**.

c) shall provide controls to damp power oscillations on the AC network.

CC.7.5.5 Each **HVDC Interconnector** must be capable of:

a) contributing to **Frequency Control** by continuous modulation of **Active Power** supplied to the **Transmission System**;

b) contributing to **Voltage Control** by continuous changes to the **Reactive Power** supplied to the **Transmission System**;

CC.7.5.6 **Users** shall install **HVDC Interconnector** controllers that comply with OC4.8. **Users** shall not change frequency or load related control settings of the **HVDC Interconnector** controllers without agreement with the **TSO**.

CC.7.5.7 **Standards for Frequency Control**

CC.7.5.7.1 Each **HVDC Interconnector** must be fitted with a fast acting control device to provide frequency response under normal operating conditions in accordance with OC4. The control device must be designed and operated to the appropriate

(a) European Standards; or

(b) In the absence of a relevant European Standards, such other standard which is in common use within the European Union.

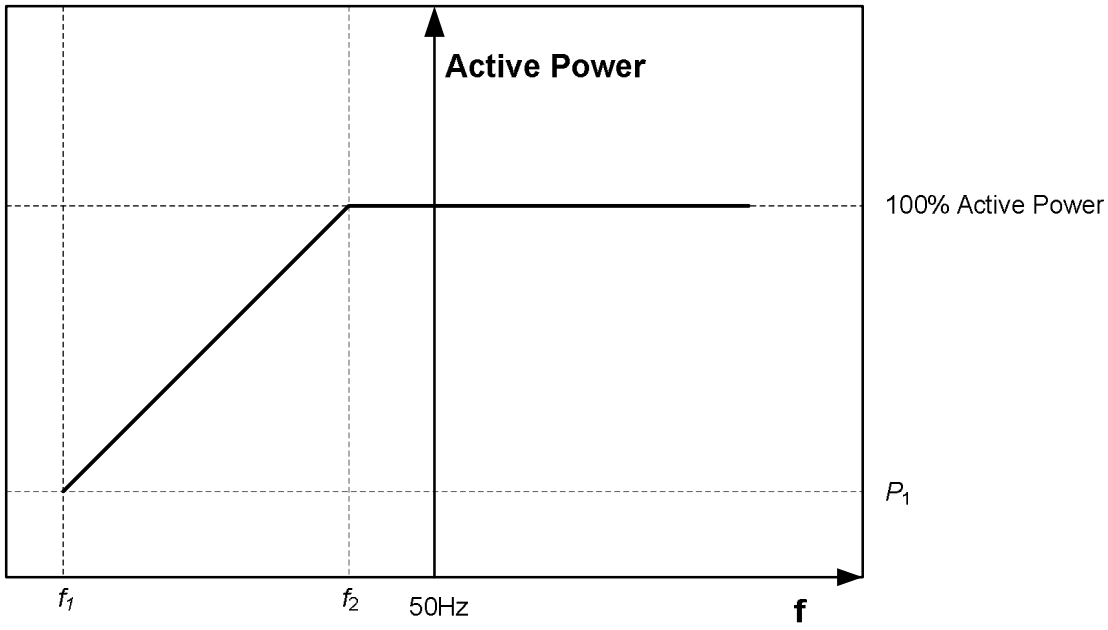
CC.7.5.7.2 An **HVDC Interconnector** must be capable of maintaining its **Active Power** output (i.e. when operating in a mode analogous to a **Generator**) to the **Transmission System** at a level not less than the amount determined by the linear relationship shown in the figure below for **System Frequency** changes within the range f_1 to f_2 Hz, such that if the **System Frequency** drops to f_1 Hz the **Active Power** output shall not decrease by more than 100 - P_1 where P_1 is the upper active power limit as a percentage of the **Active Power** output before the frequency change event, where;

(i) $f_2 \geq f_1$

(ii) $48Hz \leq f_1 \leq 50Hz$

(iii) $48Hz \leq f_2 \leq 50Hz$

(iv) $95\% \leq P_1 \leq 100\%$ Active Power



Settings for each of f_1, f_2 and P_1 shall be specified by the **TSO** at least 120 **Business Days** prior to the **HVDC Interconnector's** scheduled **Operational Date**. The **HVDC Interconnector** shall be responsible for implementing the appropriate settings during **Commissioning**.

Alterations to these settings may be requested in real-time by the **TSO** and the implementation of the settings shall commence within 10 seconds of receipt of the signal from the **TSO**.

Note: This clause is in addition to any other obligations for **Frequency** Performance that the **HVDC Interconnector** may already have.

CC.7.5.8 **HVDC Interconnector Frequency Control**

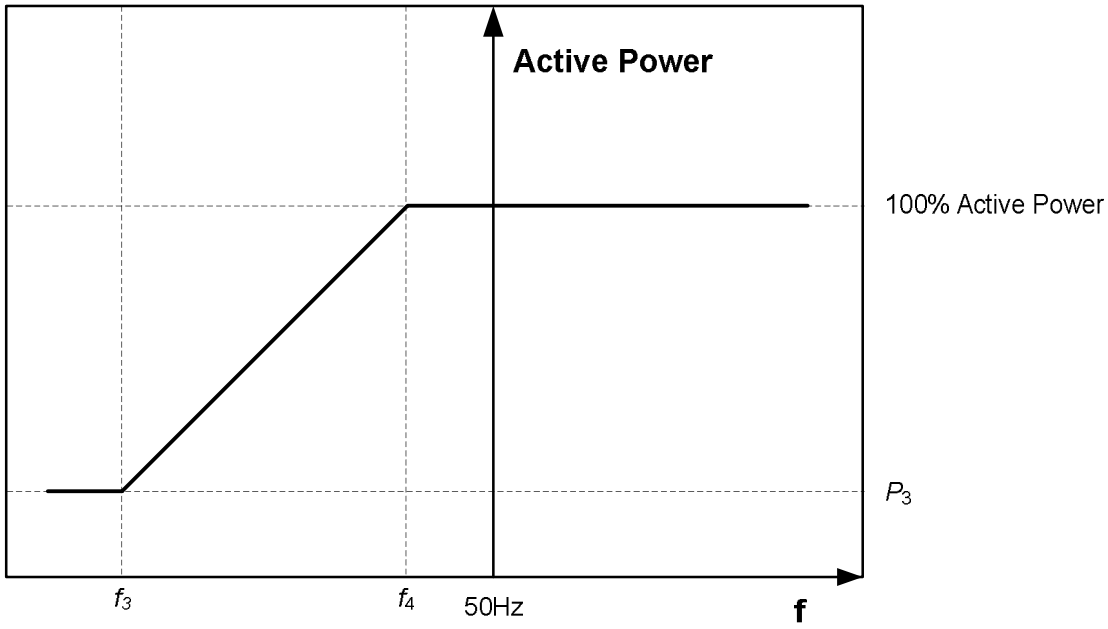
CC.7.5.8.1 An **HVDC Interconnector** must be capable of maintaining its **Active Power** input (i.e. when operating in a mode analogous to **Demand**) from the **Transmission System** at a level not greater than the amount determined by the linear relationship shown in the figure below for **System Frequency** changes within the range f_3 to f_4 Hz, such that if the **System Frequency** drops to f_3 Hz the **Active Power** input decreases by more than 100 - P_3 where P_3 is the lower **Active Power** limit as a percentage of the **Active Power** output before the frequency change event, where;

(i) $f_4 \geq f_3$

(ii) $48Hz \leq f_3 \leq 50Hz$

(iii) $48Hz \leq f_4 \leq 50Hz$

(iv) $0\% \leq P_3 \leq 100\%$ Active Power



Settings for each of f_3, f_4 and P_3 shall be specified by the **TSO** at least 120 **Business Days** prior to the **HVDC Interconnector's** scheduled **Operational Date**. The **HVDC Interconnector** shall be responsible for implementing the appropriate settings during **Commissioning**.

Alterations to these settings may be requested in real-time by the **TSO** and the implementation of the settings shall commence within 10 seconds of receipt of the signal from the **TSO**.

Note: This clause is in addition to any other obligations for **Frequency** Performance that the **HVDC Interconnector** may already have.

CC.7.5.8.2 At the **Grid Connection Point** the **Active Power** output under steady state conditions of any **HVDC Interconnector** directly connected to the **Transmission System** should not be affected by **Voltage** changes in the normal operating range specified by more than the change in **Active Power** losses at reduced or increased **Voltage**. The **Reactive Power** output under steady state conditions should be fully available at normal operating range.

CC.7.5.8.3 The **Frequency Deadband** for all **HVDC Interconnectors** should be no greater than 0.03Hz (for the avoidance of doubt, ±0.015Hz);

CC.7.5.9 **Standards for Reactive Control**

CC.7.5.9.1 All **HVDC Interconnectors** (excluding **Current Source Technology**) shall be capable of contributing to control of **Transmission System Voltage** by continuous modulation of **HVDC Interconnector Voltage** by means of a suitable continuously acting **Automatic Voltage Regulation (AVR)** which shall be in accordance with **Voltage Regulation Grade VR2.33 of BS4999 part 140**, or equivalent European Standards and the characteristics of which have been accepted by the **TSO** prior to the **Connection Date**, such acceptance not to be unreasonably withheld.

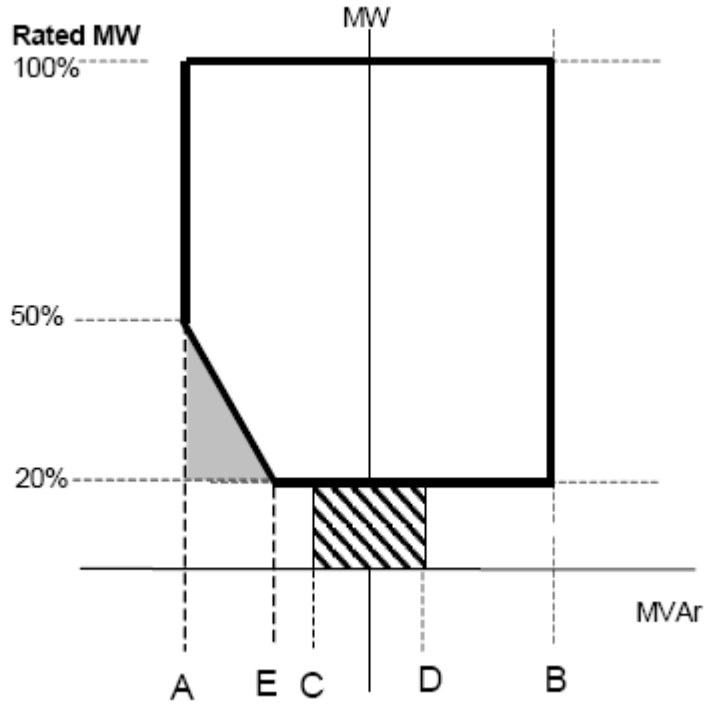
CC.7.5.10 **HVDC Interconnector Reactive Power**

a) There is a requirement for a continuously-acting automatic control system to provide control of the **Voltage** (or zero transfer of **Reactive Power** as applicable) at the **Grid Connection Point** without instability over the entire operating range of the **HVDC Interconnector**.

b) **HVDC Interconnector** must be capable of maintaining zero transfer of **Reactive Power** at the **Grid Connection Point** at all **Active Power** output levels under steady state **Voltage** conditions. The steady state tolerance on **Reactive Power** transfer to and from the **Transmission System** expressed in MVAr shall be no greater than 5% of the rated MW.

c) An **HVDC Interconnector** (excluding **Current Source Technology**) must be capable of supplying rated MW input/output at any point

between the limits 0.95 Power Factor lagging and 0.95 Power Factor leading at the **Connection Point.**



Point A is equivalent (in MVAr) to:	0.95 leading **Power Factor** at rated MW output
Point B is equivalent (in MVAr) to:	0.95 lagging **Power Factor** at rated MW output
Point C is equivalent (in MVAr) to:	-5% of rated MW output
Point D is equivalent (in MVAr) to:	+5% of rated MW output
Point E is equivalent (in MVAr) to:	-12% of rated MW output

CC.10.12 Power Quality

CC.10.12 .3 **HVDC Interconnectors** shall ensure that their connection to the **Transmission System** does not result in the level of distortion or fluctuation of the supply **Voltage** on the **Transmission System**, at the **Connection Point**, exceeding that allocated to them. These limits will be determined by the **TSO** during discussions with the **HVDC Interconnector**, where the necessary data will be exchanged between both parties, the exchange of data shall not be unreasonably withheld. This data may consist of impedance loci at the **Connection Point** and the **HVDC Interconnector** harmonic current emissions. Distortion and fluctuation limits are outlined in IEC/TR3 61000-3-6 (Harmonics) and IEC/TR3 61000-3-7 (Voltage fluctuation). **HVDC Interconnectors** shall also operate their **Plant** in a manner which will not cause the requirements in CENELEC Standard EN 50160 to be breached.

The **HVDC Interconnector** cannot be connected to the **Transmission System** until:

(a) the required harmonic studies have been completed by the **HVDC Interconnector** to show compliance with the standards outlined above and reviewed by the **TSO**;

(b) any appropriate remedies to enable the **HVDC Interconnector** to operate with harmonic distortion levels within agreed limits have been identified and implemented with the **TSO**.

CC.10.12.4 The harmonic voltage distortion emission limits and any special conditions pertaining to the quality of supply must be included in the **Connection Agreement**, and are subject to verification of compliance by the **TSO** through an ongoing approved monitoring programme to be implemented by the **HVDC Interconnector**, or as agreed with the TSO.

CC.10.13 HVDC Interconnector Transformer

CC.10.13.1 **HVDC Interconnector** shall provide:

(a) differential protection on the **HVDC Interconnector Transformer**. The connections between the **Grid Connection Point** circuit breaker and the **HV** terminals of the **HVDC Interconnector Transformer** shall be included in the protected zone of this differential protection.

(b) backup protection (to the **Transmission System**) on **HVDC Interconnectors.** The **TSO** acting reasonably shall require one or more of the following to be installed: **HVDC Interconnector** overcurrent protection, **Voltage** controlled **HVDC Interconnector** overcurrent protection or **HVDC Interconnector** distance protection;

(c) under **Frequency** protection; and

CC.10.13.2 The **TSO** may require an individual **HVDC Interconnector,** to install additional protection and/or control schemes, where the **TSO** can reasonably show that it is prudent or necessary to do so. These schemes may include but are not limited to the following:

(a) **HVDC Interconnector** over/under-voltage protection.

(b) **HVDC Interconnector** over-frequency protection.

(c) **Power System** stabiliser.

CC.10.13.3 Distance protection shall be provided by the **TSO** on the **Grid Connection Point** circuit breaker of **HVDC Interconnector Transformers**.

CC.12 SIGNALS TO BE PROVIDED BY USERS

CC.12.2

(s), (t) and (u) are applicable to **HVDC Interconnector** owners:

(s) +/-MW and +/-MVAr at the terminals of the **HVDC Interconnector**;

(t) kV at **HVDC Interconnector Transformer LV** terminals;

(u) **HVDC Interconnector Transformer** tap position;

Changes to Glossary:

Block Load for an HVDC Interconnector	The level of output, in either flow direction, that an **HVDC Interconnector** immediately produces following **Synchronisation**. For avoidance of doubt, **Block Load** can equal 0 MW and can be different in either flow direction.
Current Source Technology	Current source inverters include all static devices generating an AC current from a rectified DC current source. The intermediate DC current is kept constant with a controlled rectifier and high inductance reactors, while the AC output is of variable **Frequency** and **Voltage**.
Forbidden Zones	A MW range within which a **Generator or HVDC Interconnector** cannot operate in a stable manner due to an inherent technical limitation of the apparatus or plant.
Grid Connection Point	The point at which a **Generating Unit** or a **CCGT Installation** or a **CCGT Unit** or an **HVDC Interconnector** or a **Customer** or an **External System**, is directly connected to the **Transmission System.**
HVDC Interconnector	**DC** electrical transmission system as a means for the bulk transmission of electrical power from one **User** system to another.
HVDC Interconnector Minimum Export Load	Minimum MW output an **HVDC interconnector** can export continuously to a remote network while maintaining stability
HVDC Interconnector Minimum Import Load	Minimum MW output an **HVDC interconnector** can import continuously from a remote network while maintaining stability
HVDC Interconnector Minimum Load	Absolute sum of the **HVDC Interconnector Minimum Export Load** and **HVDC Interconnector Minimum Import Load** representing the minimum range of bi-directional power transfer.
HVDC Interconnector's Plant	An **HVDC Interconnector** station subject to **Central Dispatch**
HVDC Interconnector Ramp-down Capability	The rate of decrease of an **HVDC Interconnector. Ramp-down Capabilities** apply over the bi-directional range from its **HVDC Interconnector Registered Import Capacity** to its **HVDC Interconnector Registered Export Capacity.**
HVDC Interconnector Ramp-up Capability	The rate of increase of an **HVDC Interconnector. Ramp-up Capabilities** apply over the bi-directional range from its **HVDC Interconnector Registered Export Capacity** to its **HVDC Interconnector Registered Import Capacity.**
HVDC Interconnector Ramp Rate	The maximum rate of increase or decrease of the power transferred, in either flow direction, by an **HVDC Interconnector**.
HVDC Interconnector Registered Capacity	The maximum **Capacity**, in either flow direction, expressed in whole MW, that an **HVDC Interconnector** can deliver on a sustained basis, without accelerated loss of equipment life, at the **Connection Point**.

HVDC Interconnector Registered Export Capacity	The maximum **Capacity**, expressed in whole MW that an **HVDC Interconnector** may export (transfer energy from the **Power System** to a remote network) on a sustained basis, without accelerated loss of equipment life, as registered with the **TSO**.
HVDC Interconnector Registered Import Capacity	The maximum **Capacity**, expressed in whole MW that an **HVDC Interconnector** may import (transfer energy from a remote network into the **Power System**) on a sustained basis, without accelerated loss of equipment life, as registered with the **TSO**.
HVDC Interconnector Transformer	A transformer whose principal function is to provide the interconnection between the **HVDC Interconnector** and the Network and to transform the **HVDC Interconnector** voltage to the Network voltage.