Reliable Sustainable Connected

# Working Draft

***For the purpose of initiating an extensive consultation process at an early stage in an open and transparent manner***

# Requirements for Grid Connection Applicable to all Generators

**Within the context of the future Pilot Network Code**
**And the future Pilot Framework Guidelines by ERGEG**

***including dedicated Requirements for Specific Generating Unit Facilities***

**Disclaimer**

This draft is a *work in progress document* representing the status of ongoing work by TSO experts as of 19/08/2010 and is distributed with a sole purpose to provide an information on the state of the development of the future Pilot Code. It illustrates the set of requirements for generators for connection to the network that are currently under discussion within ENTSO-E within the context of the "Pilot Code for Grid Connection with special focus on Wind Generation". It does not in any case represent a firm, binding and definitive ENTSO-E position on the contents, the structure, or the prerogatives of the Pilot Code. Such position will be released for public consultation after the Framework Guidelines for Grid Connection by ERGEG have been officially released following the procedure as stated in the 3rd package.

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# 1 INTRODUCTION

The **Transmission System Operators** (**TSO**s) within **ENTSO-E** are responsible for providing and operating high and extra-high voltage grids for long-distance transmission of electricity as well as for exchanges with **Power Generating Facilities**, with lower-level regional distribution systems and with directly connected customers. A central part of the transmission task is the **TSOs**' responsibility to ensure system security with a high level of reliability and quality.

Secure system operation is only possible by close cooperation between owners of **Power Generating Facilities** and the **Network Operator**s. The system behaviour in disturbed operating conditions depends upon the response of **Power Generating Facilities** to deviations from nominal values of voltage and frequency. In context of system security the transmission **Network** and the **Power Generating Facilities** need to be considered as one entity from a systems engineering approach. It is therefore of crucial importance that **Power Generating Facilities** are obliged to meet the relevant technical requirements concerning system security as a prerequisite for grid connection and access. Appropriate dynamic behaviour of **Power Generating Facilities** and their protection and control facilities are necessary in normal operating conditions and in a range of disturbed operating conditions as illustrated in figure 1. in order to preserve or to re-establish system security.

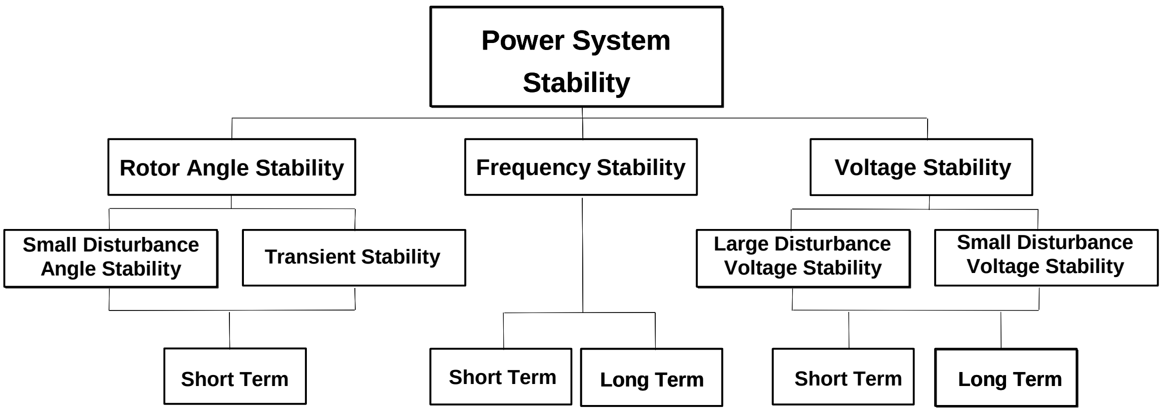


Figure 1: Classification of Power System Stability according to "Definition and classification of power system stability" IEEE/CIGRE Joint Task Force, June 2003

The requirements for **Power Generating Facilities** arise out of either the system needs as shown in the stability family tree (figure 1) or from general system management requirements. The latter covers information and control requirements to allow the **Network Operator** to manage the system taking into account system constraints.

To ensure system security within the interconnected transmission system and to provide a common security level it is essential that a common set of requirement for **Network** connection is defined as a basis for national legislation, national grid codes or bilateral agreements between each **Network Operator** and owners of **Power Generating Facilities** connected to its **Network**.

The purpose of this **Network Code** is to set out clear and objective requirements for generators for grid (**Network**) connection in order to contribute to non-discrimination, effective competition and the efficient functioning of the internal electricity market and to ensure system security.

## 2 COVERAGE AND GENERAL STATEMENTS

This **Network Code** defines a common set of requirements for **Power Generating Facilities** (including **Synchronous Generating Units, Power Park Modules and Offshore Generation Facilities)** to be connected to the **Network**. It sets up a common framework for **Network Connection Agreements** between **Network Operator**s and the Owner/Developer of the **Power Generating Facilities.**

This **Network Code** is based on the principle of equitable treatment and transparency of requirements for all **System Users**.

### 2.1 Application by Network Operators

**Network Operators** shall have the right to impose additional requirements covering aspects not specified in this **Network Code** on the **Power Generating Facilities** when needed for secure system operation due to local/regional specifics.

**Network Operators** are not entitled to change or modify requirements specified in this **Network Code** by own codes or bilateral contracts with **Power Generation Facility Operators** unless authorized by derogation.

Requirements in this **Network Code** define common principles and parameters or ranges of parameters. **Network Operators** can select coverage for their **Network** (by explicit choice of disabling requirements which is not required in their context and by selection of threshold or parameters). This enables the **Network Operators** to consider specific regional system conditions (e.g. large or small a.c. systems, areas of strong or weak connection to their main a.c. system and areas with high or low density of demand or concentration of generation). Obligation to comply with the requirements placed upon **Power Generating Facilities** defined in this **Network Code** shall be ensured through appropriate national legislation, national grid codes or bilateral agreements between the **Network Operator** and the **Power Generating Facility Operator**. These provisions should also contain the specification of individual parameters for requirements, where this **Network Code** allows this.

### 2.2 Application to the Power Generating Facilities

These requirements apply to **Generating Units** connected to transmission and distribution systems depending on voltage level of their PCC and their MW capacity size according to the categories defined in this **Network Code**.

It should be noted that Power **Generating Facilities** to which some requirements do not apply because of the category they belong to, are encouraged to meet as many of the requirements within this **Network Code** as practical and cost effective. **Power Generating Facilities** which are not compatible with this **Network Code** may in abnormal system situations be disconnected by the **Network Operator**, as defined locally.

In case of modernisation/replacement of equipment in existing **Power Generating Facilities** the new installations shall comply with the requirements relevant to the part of the plant which is being modernised/replaced. The **Network Operator** shall be notified of the planned change at an early stage of planning to ensure adequate specification.

Generation data, schedules and actual generation shall subject to defined local procedures or on request be provided by **Power Generating Facilities** connected to lower-level distribution systems to the **TSO** for system security analysis.

### 2.3 Compliance of the Power Generating Facilities with the requirements

To establish that **Power Generating Facilities** fully comply with the requirements, this **Network Code** establishes a non-discriminatory, effective and transparent compliance process. An investigation of the behaviour of Power **Generating facilities** during and after disturbances to the system can be considered as a supplemental performance check, verifying compliance with the technical requirements in operation.

If a **Power Generating Facility** can not fully comply with a requirement it can apply for a release from/change of this specific requirement to the **Network Operator** by the means of a **Derogation** according to the compliance procedures defined in this **Network Code**.

Existing **Power Generating Facilities** are required on request by the **Network operator** to provide information to the relevant **Network Operator** about their capability to comply or not with the requirements according to the compliance procedures defined in this **Network Code**.

## 3 CONTENTS OF REQUIREMENTS FOR GENERATING UNITS

The requirements for generating units called for by this **Network Code** are essential for **TSOs** to manage the following responsibilities for operating interconnected power transmission systems:

- system management
- system balancing / frequency stability
- voltage stability
- system robustness
- system restoration after a disturbance.

Regarding:

- the extensive growth of **Generating Units** connected to the distribution grid (especially combined heat and power generators, wind generators and other relevant renewables),
- their impact on the electric system in normal and disturbed situations
- the improvements of their technical capabilities and performances

it is of crucial importance that these requirements are shared as well by **Generating Units** connected to the transmission **Networks** as to the lower-level distribution **Networks**.

### 3.1 System management

In order to ensure proper system operation, **Network Operators** need to perform security analysis for present and forecasted situations (e.g. to define transmission capacities, to identify congestions, to prepare the remedial actions in case of contingencies). To perform such analysis **Network Operators** need to know for example:

- the availability of **Generating Units** to produce power and to provide ancillary services (actual and forecasted)
- their technical characteristics and capabilities and to be informed of temporary limitations (e.g. **Reactive Power** supply limitations, inability to change **Active Power**)
- generation schedules
- the actual active and **Reactive Power** output from the **Generating Units**

To prevent disturbances to the **Network**, to manage constraints or to restore the **Network** after a disturbance **Network Operators** need to have the right and the facilities to modify the actually scheduled generation.

### 3.2 System balance / frequency stability

Electric power generation and load demand (including grid losses) always need to be balanced. Any imbalance between power generation and load demand results in a system-wide deviation of the frequency from its nominal value (50 Hz). It decreases or increases when the load demand is higher or lower respectively than the power generation. To maintain/re-establish the equilibrium the mechanism of load-frequency control is applied by the **TSOs**. The necessary control and balancing power is provided mainly by **Power Generating Facilities** by means of primary, secondary and tertiary control reserves.

To adjust the dispatchable **Generating Units** to match the actual demand it is necessary that these **Generating Units** are able to increase/decrease their production quickly and that generation reserve margins are available in both directions.

Moreover, to be able to cope with big disturbances with major impact on frequency, it is required that **Generating Units** stay connected within a definite frequency range to avoid the aggravation of the situation that could lead to a collapse of the whole system.

### 3.3 Voltage stability

In order to maintain the voltage in acceptable ranges throughout the **Network** and to prevent the transmission systems from voltage collapses, the **Generation Units** have to be able to provide **Reactive Power** to the **Network** within a definite range.

Shortage of **Reactive Power** can lead to unacceptable low voltage levels and finally to a voltage collapse of the system. Thus the **Network Operator**s need to care for a balanced voltage profile in the grid by advising the **Generating Units** the supply of **Reactive Power** or a **Network** voltage level which is achieved by the provision of **Reactive Power** by **Generating Units**.

### 3.4 Robustness of Power Generating Facilities Generating Units

The transmission systems are inevitably exposed to perturbations like electrical faults, tripping of lines or **Generating Units** causing voltage dips and low/high quasi-steady state voltage and/or deviations of the frequency from its nominal value.

**Generating Units** have to be robust to such perturbations and stay connected to the grid under predefined conditions in order to limit the risk of cascading effects and finally of a system collapse. The additional loss of **Generating Units** in such situations has adverse effects on the voltage profile, the frequency and on load flows and could deteriorate the already weakened stability, overload lines and potentially result in a black-out.

In case the tripping of a **Generation Unit** cannot be avoided:

- the capability to reconnect as soon as possible shall be ensured to be able to use the unit to restore normal operating conditions in the **Network**,
- the reconnection shall be subject to prior agreement with the **Network Operator** to avoid potential aggravation of the system state.

If a perturbation leads to isolation of a part of the grid with some **Generating Units** and consumers from the interconnected system the performance features of the generating units in this island should enable a stable operation of such an island.

### 3.5 System restoration

After a severe black-out transmission systems are restored step by step by reconnecting parts of the disturbed **Network** to the sustained parts.

To enable system restoration by own means it is necessary for **Network Operators** to have **Generating Units** available to be started, to establish stable operation and to restore voltage to the **Network** without external voltage (black start capability, houseload operation capability and island operation capability).

To ensure a fast restoration after a black out generating units shall have the capability of a stable island and houseload - operating mode in case of disconnection from the **Network** if agreed technically feasible.

## 4 STRUCTURE OF CODE TO REFLECT TECHNOLOGICAL CAPABILTY

This Network Code is based upon equitable treatment and transparency of requirements for all **System Users**. Equality of treatment is however balanced with the aim of achieving the overall most economic total system. This is reflected in marginal differences in treatment of different generation technologies with different inherent characteristics. It is also reflected in avoidance of unnecessary investments in some Regions in certain capabilities which are only required in other Regions.

The structure of the requirements for generators is illustrated in figure 2 and summarised as follows:

- General requirements (chapter 5) that apply for all type of **Power Generating Facilities** connected to the **Network**

- Requirements for **Synchronous Generating Units** directly connected to the onshore **Network** (chapter 6) applicable to conventional **Synchronous Generating Units** independently from the technology or energy source such as: biomass, coal (including lignite), gas, hydro (including pump storage), nuclear, solar thermal etc

- Requirements for **Power Park Modules,** whose technology is not based on a **Synchronous Generating Unit** directly connected to the onshore **Network** (chapter 7). This section includes **Power Park Modules** such as solar installations, wind farms (including squirrel cage induction generators, Doubly Fed Induction Generators and **Synchronous Generating Units** with converters), etc

- Requirements for **Offshore Generators** (chapter 8), includes all technologies connected to an offshore or onshore **Network Connection Point**.

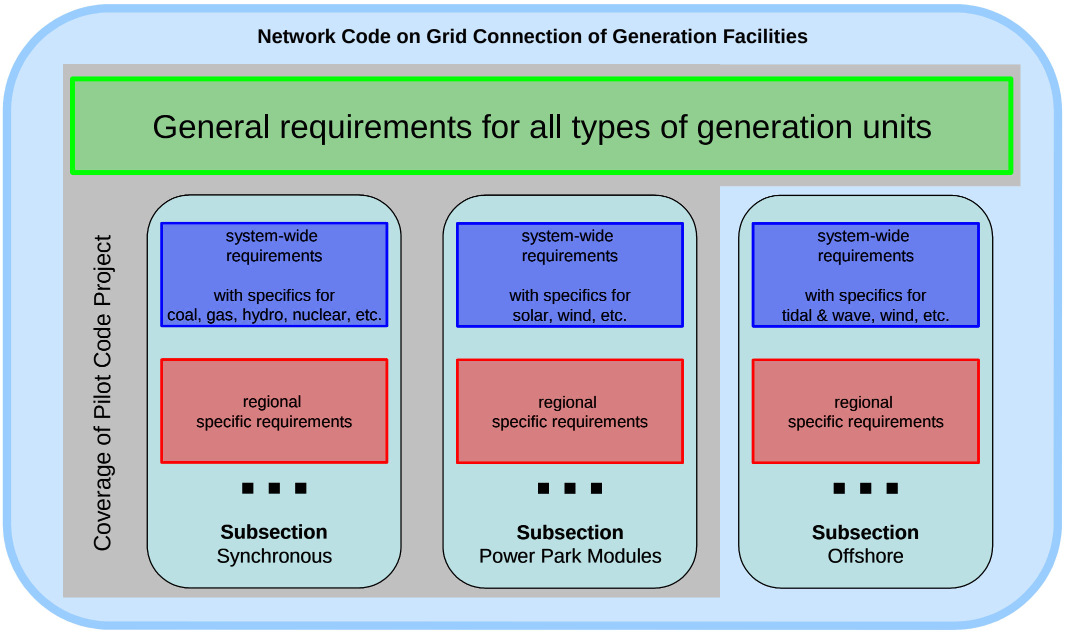


Figure 2: Structure of the Network Code “Requirements for Generators”.

**Generating Units** within the scope of this **Network Code** are categorised as follows:

- A **Synchronous Generating Unit** or **Power Park Module** is of **Type A** if its **PCC** is below 110 kV and its **Maximum Capacity** is 400 W or more.
- A **Synchronous Generating Unit** or **Power Park Module** is of **Type B** if its **PCC** is below 110 kV and its **Maximum Capacity** is at or above the threshold according to table 1.
- A **Synchronous Generating Unit** or **Power Park Module** is of **Type C** if its **PCC** is below 110 kV and its **Maximum Capacity** is at or above the threshold according to table 1.
- A **Synchronous Generating Unit** or **Power Park Module** is of **Type D** if its **PCC** is at 110 kV or above.

| Synchronous Area | capacity threshold Type B | capacity threshold Type C |
|---|---|---|
| Continental Europe | 0.1 MW | 50 MW |
| Nordic | 0.1 MW | 1.5 MW |
| Great Britain | 10 MW | 50 MW |
| Ireland | 0.1 MW | 5 MW |
| Baltic | 1 MW | 5 MW |

Table 1: Thresholds for **Type B and C Synchronous Generating Units** or **Power Park Modules**

## 5 GENERAL REQUIREMENTS

Table 2 provides an overview to which types of **Generating Units** the requirements of this chapter shall apply.

| Requirement | Title | Type A | Type B | Type C | Type D |
|---|---|---|---|---|---|
| R5.1 | FREQUENCY RANGES | X | X | X | X |
| R5.2 | VOLTAGE RANGES | | | | X |
| R5.3 | RATE OF CHANGE OF FREQUENCY WITHSTAND CAPABILITY | X | X | X | X |
| R5.4 | ACTIVE POWER CONTROLLABILITY AND CONTROL RANGE | | | X | X |
| R5.5 | LOSS OF STABILITY | | | X | X |
| R5.6 | STEADY-STATE STABILITY | | | X | X |
| R5.7 | INERTIA | | | X | X |
| R5.8 | FREQUENCY SENSITIVE MODE | | | X | X |
| R5.9 | LIMITED FREQUENCY SENSITIVE MODE (OVERFREQUENCY) | X | X | X | X |
| R5.10 | LIMITED FREQUENCY SENSITIVE MODE (UNDERFREQUENCY) | | | X | X |
| R5.11 | FREQUENCY RESTORATION CONTROL | | | X | X |

| Requirement | Title | Type A | Type B | Type C | Type D |
|---|---|---|---|---|---|
| R5.12 | DISCONNECTION DUE TO UNDERFREQUENCY | | | X | X |
| R5.13 | MONITORING OF FREQUENCY RESPONSE | | | X | X |
| R5.14 | SHORT CIRCUIT CONTRIBUTION | | | X | X |
| R5.15 | BLACK START | | | X | X |
| R5.16 | CAPABILITY TO TAKE PART IN ISOLATED NETWORK OPERATION | | | X | X |
| R5.17 | TRIP TO HOUSELOAD | | | X | X |
| R5.18 | IDENTIFICATION OF HOUSELOAD OPERATION | | | X | X |
| R5.19 | ELECTRICAL PROTECTION SCHEMES AND SETTINGS | | X | X | X |
| R5.20 | CONTROL SCHEMES AND SETTINGS | | X | X | X |
| R5.21 | PRIORITY RANKING OF PROTECTION AND CONTROL | | X | X | X |
| R5.22 | AUTO RECLOSURES | | X | X | X |
| R5.23 | SYNCHRONISATION | | X | X | X |
| R5.24 | SYSTEM PARALLELING AND TORSIONAL OSCILLATIONS | | | X | X |
| R5.25 | RECONNECTION AFTER TRIPPING ONTO AUXILIARY SUPPLY | | | X | X |
| R5.26 | CAPABILITY OF RECONNECTION AFTER AN INCIDENTAL DISCONNECTION DUE TO A NETWORK DISTURBANCE | | X | X | X |
| R5.27 | INFORMATION EXCHANGE | | X | X | X |
| R5.28 | INSTRUMENTATION | | | X | X |
| R5.29 | POWER/VOLTAGE QUALITY RAPID VOLTAGE CHANGES | X | X | X | X |

| Requirement | Title | Type A | Type B | Type C | Type D |
|---|---|---|---|---|---|
| R5.30 | CHANGES TO/MODERNISATION OR REPLACEMENT OF EQUIPMENT OF GENERATING UNITS | | X | X | X |
| R5.31 | SIMULATION MODELS | | | X | X |
| R5.32 | INSTALLATION OF DEVICES FOR SYSTEM OPERATION AND/ OR SECURITY | | | X | X |
| R5.33 | COOPERATION FOR ANALYSIS OF FAULTS AND DISTURBANCES | | X | X | X |

Table 2: Assignment of general requirements to types of **Generating Units**

R5.1 **FREQUENCY RANGES.**

*(Applies to **Type A, B, C and D**)*

Any automatic disconnection of a **Generating Unit** from the **Network** is prohibited within the frequency ranges and time periods specified by table 3 because of the deviation in **Network** frequency from its nominal value.

| Synchronous Area | Frequency Range | Time period per event |
|---|---|---|
| Continental Europe | 46.5 Hz – 47.5 Hz | 10 sec |
| | 47.5 Hz – 48.0 Hz | 10 min |
| | 48.0 Hz – 51.5 Hz | Unlimited |
| | 51.5 Hz – 53.0 Hz | 10 sec |
| Nordic | 47.5 Hz – 49.0 Hz | 30 min |
| | 49.0 Hz – 51.0 Hz | Unlimited |
| | 51.0 Hz – 52.0 Hz | 30 min |
| | 52.0 Hz – 52.5 Hz | 3 min |
| Great Britain | 47.0 Hz – 47.5 Hz | 20 sec |
| | 47.5 Hz – 48.5 Hz | 90 min |
| | 48.5 Hz – 51.0 Hz | Unlimited |
| | 51.0 Hz – 51.5 Hz | 90 min |
| | 51.5 Hz – 52.0 Hz | 15 min |
| Ireland | 47.0 Hz – 47.5 Hz | 5 min |
| | 47.5 Hz – 49.5 Hz | 60 min |
| | 49.5 Hz – 50.5 Hz | Unlimited |
| | 50.5 Hz – 52.0 Hz | 60 min |
| Baltic | not available yet | not available yet |

Table 3: Frequency ranges and minimum time periods for operation

In abnormal operating conditions, e. g. islanded operation during system restoration wider frequency ranges may apply temporarily.

A **Generating Unit**, if required by the **Network Operator**, will be equipped with frequency for disconnection of the **Generating Unit** at abnormal frequencies. The relays shall be set according to agreement with the **Network Operator** taking into account the frequency ranges and time periods for permanent and temporary operation in table 3.

The **Generating Unit** will not be tripped by control systems failure (relays, contactors, etc.) within the ranges of table 3.

## R5.2 VOLTAGE RANGES.

*(Applies to **Type D**)*

Any automatic disconnection of a **Generating Unit** from the **Network** is prohibited within the voltage ranges (rms value at busbar/grid **Connection Point**) and time periods specified by tables 4.1 and 4.2 because of the deviation in **Network** voltage from its nominal value.

| Synchronous Area | Voltage Range | Time period per event |
|---|---|---|
| Continental Europe | 0.80 pu – 0.85 pu | 30 min |
| | 0.85 pu – 0.90 pu | 180 min |
| | 0.90 pu – 1.0875 pu | Unlimited |
| | 1.0875 pu – 1.10 pu | 60 min |
| Nordic | 0.90 pu – 1.05 pu | Unlimited |
| | 1.05 pu – 1.10 pu | 60 min |
| Great Britain | 0.90 pu – 1.10 pu | Unlimited |
| Ireland | 0.90 pu – 1.118 pu | Unlimited |
| Baltic | not available yet | not available yet |

Different equipment ratings may apply for permanent operation above 1.05 pu (420 kV).

Table 4.1: Voltage ranges and minimum time periods for operation (300 kV ≤ 1 pu ≤ 400 kV)

| Synchronous Area | Voltage Range | Time period per event |
|---|---|---|
| Continental Europe | 0.80 pu – 0.85 pu | 30 min |
| | 0.85 pu – 0.90 pu | 180 min |
| | 0.90 pu – 1.115 pu | Unlimited |
| | 1.115 pu – 1.15 pu | 60 min |
| Nordic | 0.90 pu – 1.05 pu | Unlimited |
| | 1.05 pu – 1.10 pu | 60 min |
| Great Britain | 0.90 pu – 1.10 pu | Unlimited |
| Ireland | 0.90 pu – 1.118 pu | Unlimited |
| Baltic | not available yet | not available yet |

Table 4.2: Voltage ranges and minimum time periods for operation (110 kV ≤ 1 pu ≤ 300 kV)

A **Generating Unit**, if required by the **Network Operator**, will be equipped with voltage protection for disconnection of the **Generating Unit** at voltages. The relays shall be set according to agreement with the **Network Operator** taking into account the voltage ranges and time periods for permanent and temporary operation in tables 4.1 and 4.2.

The **Generating Unit** will not be tripped neither by voltage protections operation nor control systems failure (relays, contactors, etc) within the ranges of tables 4.1 and 4.2.

R5.3 **RATE OF CHANGE OF FREQUENCY WITHSTAND CAPABILITY.**

*(Applies to **Type A, B, C and D**)*

For each **Synchronous Area Generating Units** shall not disconnect from the network due to rates of change of frequency up to 6Hz/s.

R5.4 **ACTIVE POWER CONTROLLABILITY AND CONTROL RANGE.**

*(Applies to **Type C and D**)*

The **Active Power** output of any **Generating Unit** connected to the **Network** shall be controllable. It has to be capable of operating at the **PCC** within a range between **Maximum Capacity** and **Minimum Operating Level**. The **Power Generating Facility** control system shall be capable of receiving an **Instruction** sent by the **Network Operator** and shall implement the **Setpoint** within a **Network Operator** specified time. Manual measures shall be possible in the case of any automatic remote control devices out of order.

Unless advised by the **Network Operator,** the deviation between the scheduled value and the actual value of load at **Steady State Load** (period specified by the **Network Operator**) shall not exceed a percentage of the **Generating Unit** capacity (subjected to the prime mover resource), that will also be specified by the **Network Operator**.

**Maximum Rates of Change** or a **Minimum Rates of Change** of **Active Power** depend on the type of generation facility.

R5.5 **LOSS OF STABILITY.**

*(Applies to **Type C and D**)*

In the event of the loss of stability of a single **Generating Unit**, this **Generating Unit** should disconnect automatically from the **Network** in order to support preservation of system security and/or to prevent damage from the **Generating Unit**. The **Power Generating Facility Operator** will comply with the criteria established by the **Network Operator** to recognize loss of stability and the subsequent automatic disconnection.

R5.6 **STEADY-STATE STABILITY.**

*(Applies to **Type C and D**)*

**Steady-state Stability** of a **Generating Unit** is required for any operating point in the **P-Q-Capability Diagram** in case of power oscillations (currently frequencies of 0.15 to 2 Hz are observed). Tripping and power reduction is prohibited. All **Generating Units**

shall remain in stable operation after any normal occasion in the network such as short term voltage variations due to switching actions, lightning faults etc.

R5.7 **INERTIA.**

*(Applies to **Type C and D**)*

All **Power Generation Facilities** may be required to provide inertia. Some types of **Power Generating Facilities** provide this inherently, e.g. **Synchronous Generating Units**. The **Network operator** shall have the right to require for **Power Generating Facilities** which do not provide this inherently, a **Synthetic Inertia** facility to deliver an equivalent performance, e. g. a power change in proportion to the rate of change of frequency.

R5.8 **FREQUENCY SENSITIVE MODE.**

*(Applies to **Type C and D**)*

Each **Power Generating Unit** shall be capable of providing **Active Power Frequency Response** according to figure 3. The corresponding parameters are specified by each **TSO** within the ranges according to table 5. In case of overfrequency each **TSO** will determine whether the **Active Power** shall stop when reaching the **Minimum Operating Level** and stay at this level or whether it shall be further decreased in case of further increasing frequency.

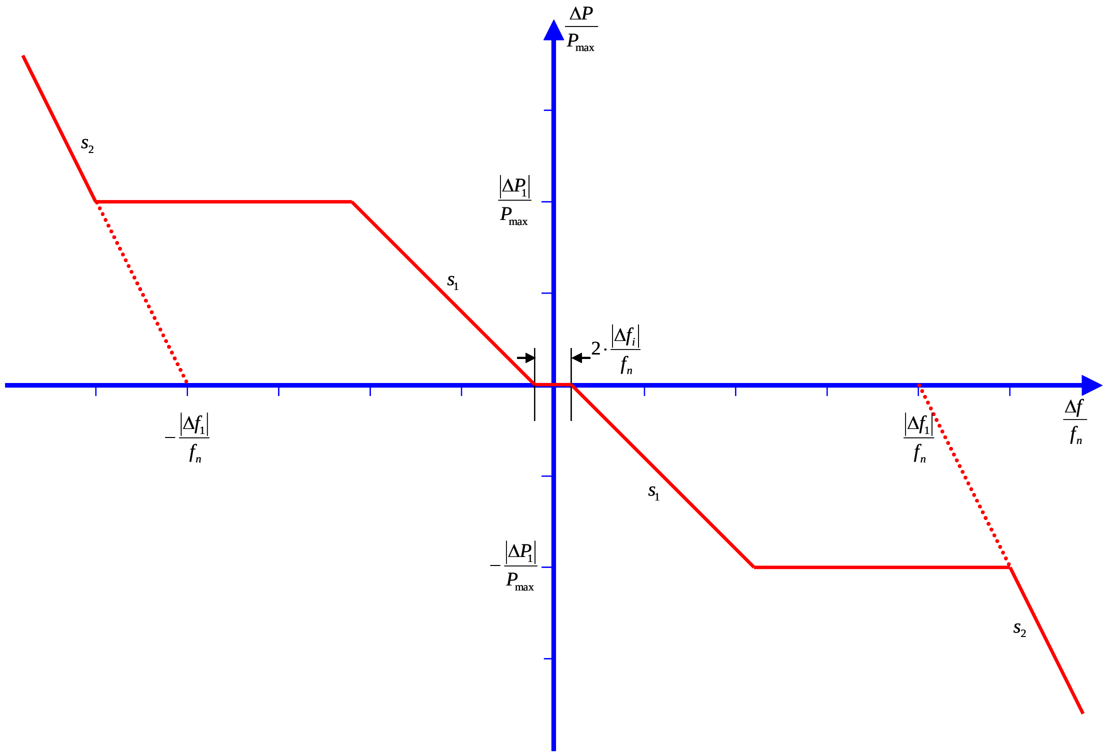


Figure 3: **Active Power Frequency Response** of **Power Generating Units** in frequency sensitive mode

| Parameters | Ranges | Ranges in % |
|---|---|---|
| Active power range related to **Maximum Capacity** $\frac{\lvert\Delta P_1\rvert}{P_{max}}$ | - | 2 – 10 % |
| Threshold of frequency deviation from nominal frequency $\frac{\lvert\Delta f_1\rvert}{f_n}$ | 200 – 500 mHz | 0.4 – 1.0 % |
| Static or dynamic Insensitivity range $\frac{\lvert\Delta f_i\rvert}{f_n}$ | ±10 – 15 mHZ | ±0.01 – 0.015 % |
| Slope $s_1$ | - | 2 – 20 % |
| Slope $s_2$ | - | 2 – 12 % |

Table 5: Parameters for **Active Power Frequency Response** in frequency sensitive mode

Each **Power Generating Units** shall be capable of activating full **Active Power Frequency Response** at least according to figure 4. The corresponding parameters are specified by each **TSO** within the ranges according to table 6. The initial delay shall be as short a possible and reasonably justified if greater than 2 sec.

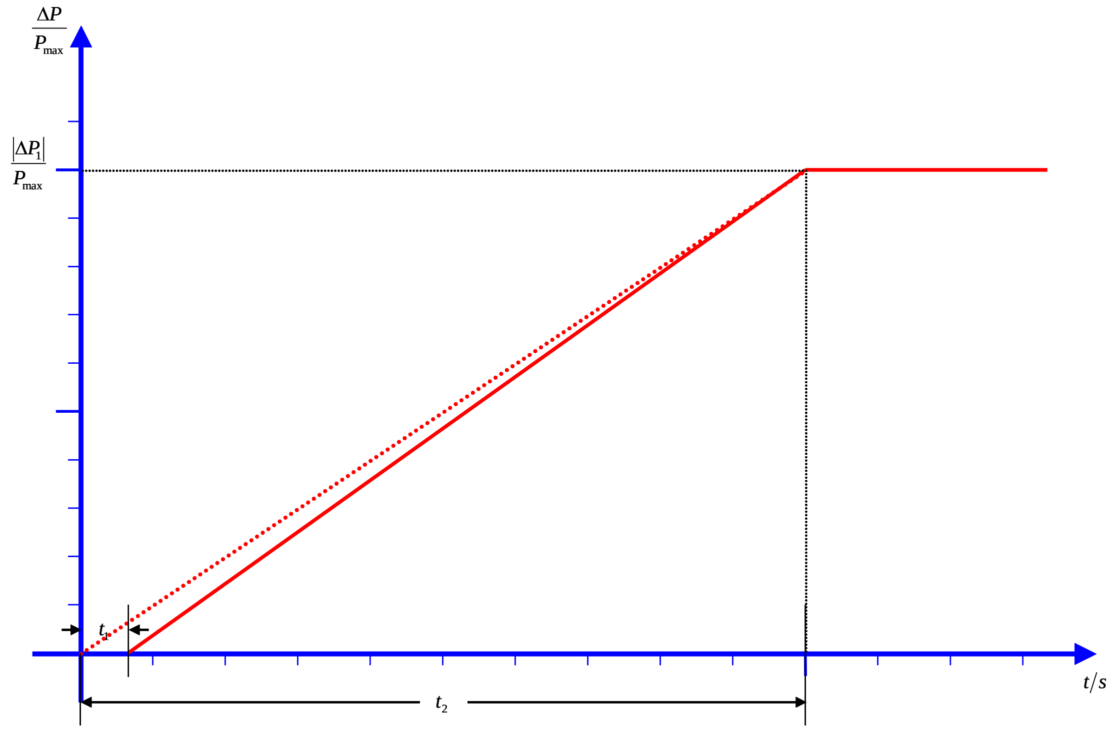


Figure 4: Timeframe for full activation of **Active Power Frequency Response**

| Parameters | Ranges |
|---|---|
| Active power threshold related to **Maximum Capacity** $\frac{\lvert\Delta P_1\rvert}{P_{max}}$ | 2 – 10 % |

| | |
|---|---|
| Initial delay $t_1$ | ≤ 2 sec |
| Full activation timeframe $t_2$ | 6 – 30 sec |

Table 6: Parameters for full activation of **Active Power Frequency Response**

Each **Power Generating Units** shall be capable of providing full **Active Power Frequency Response** for a period specified by the **TSOs** for each **Synchronous Area** between 15 min and 30 min.

For stabile operation of a **Power Generating Unit** during network operation and island operation it is necessary that both a proportional speed controller and the power controller are always in operation (e. g. speed controller output signal and the power output signal are added). The speed controller determines the dynamic behaviour, whereas a slower power controller adapts the steady state operating point.

R5.9 **LIMITED FREQUENCY SENSITIVE MODE (OVERFREQUENCY).**

*(Applies to* ***Type A, B, C and D****)*

Each **Power Generating Units** shall be capable of providing **Active Power Frequency Response** according to figure 5 when not operating in frequency sensitive mode. The initial delay of activating **Active Power Frequency Response** shall be as short a possible and reasonably justified if greater than 2 sec. The **Power Frequency Response** shall be activated in a range of 1 - 10% of **Maximum Capacity** per second.

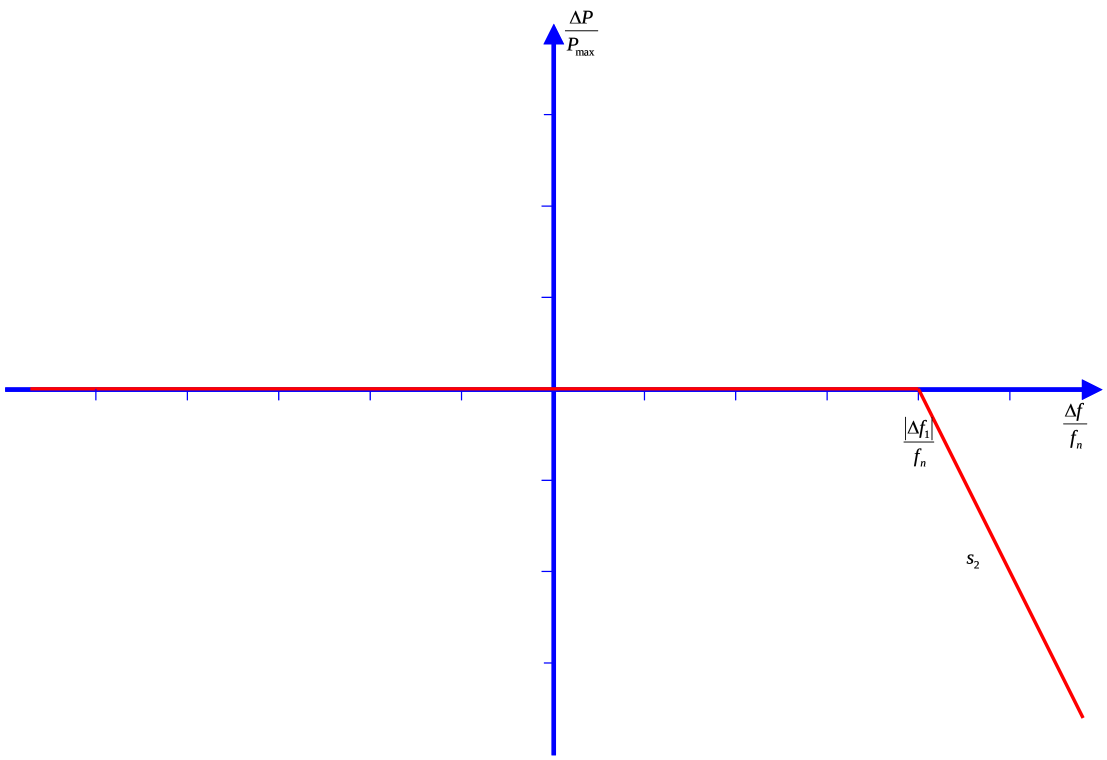


Figure 5: **Active Power Frequency Response** of **Power Generating Units** in limited frequency sensitive mode (overfrequency)

Stable operation of the generating unit during **LIMITED FREQUENCY SENSITIVE MODE (OVERFREQUENCY)** shall be ensured. Any contradiction between power and speed control during **LIMITED FREQUENCY SENSITIVE MODE (OVERFREQUENCY)** shall be prohibited.

R5.10 **LIMITED FREQUENCY SENSITIVE MODE (UNDERFREQUENCY).**

*(Applies to **Type C and D**)*

Each **Power Generating Units** shall be capable of providing **Active Power Frequency Response** according to figure 6 when not operating in frequency sensitive mode. The initial delay of activating **Active Power Frequency Response** shall be as short a possible and reasonably justified if greater than 2 sec. The **Power Frequency Response** shall be activated in a range of 1 - 10% of **Maximum Capacity** per second.

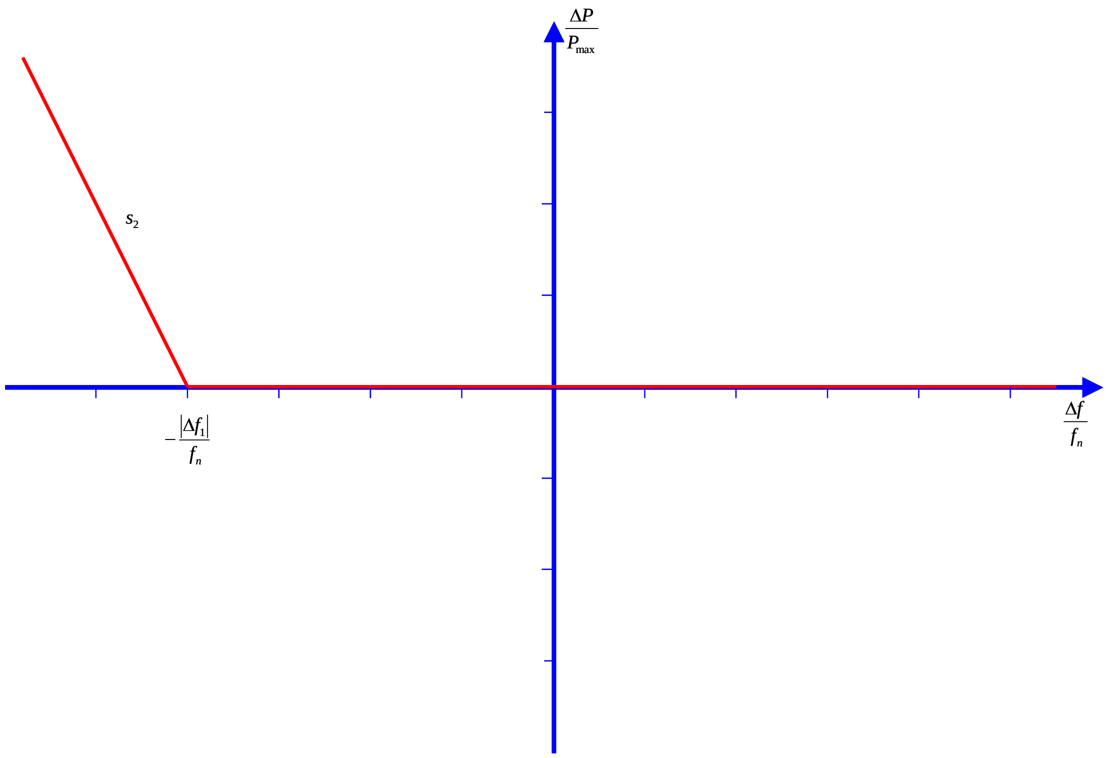


Figure 6: **Active Power Frequency Response** of **Power Generating Units** in limited frequency sensitive mode (underfrequency)

Stable operation of the generating unit during **LIMITED FREQUENCY SENSITIVE MODE (UNDERFREQUENCY)** shall be ensured. Any contradiction between power and speed control during **LIMITED FREQUENCY SENSITIVE MODE (UNDERFREQUENCY)** shall be prohibited.

R5.11 **FREQUENCY RESTORATION CONTROL.**

*(Applies to **Type C and D**)*

The **Power Generating Facility** shall provide facilities which work to restore frequency to its nominal value and/ or maintain power exchange flows between control areas at their scheduled values. These facilities will be specified by each **TSO** according to principles agreed for each **Synchronous Area**.

R5.12 **DISCONNECTION DUE TO UNDERFREQUENCY.**

*(Applies to **Type C and D**)*

Pump-storage **Power Generating Facilities** shall be capable of disconnecting pumps in case of under-frequency. This feature has to be activated according to the defence plan for each **Synchronous Area**.

R5.13 **MONITORING OF FREQUENCY RESPONSE.**

*(Applies to **Type C and D**)*

To monitor the operation of frequency response the communication interface shall be equipped to transfer the following signals between the **Power Generating Facility** and the Network control centre on request by the **Network Operator**:

- **Generating units** participating in the provision of frequency repsonse
  - status signal of frequency response (on/off)
  - scheduled **Active Power** output
  - actual value of the **Active Power** output
  - actual **Setpoint** value for frequency response
  - range of frequency response (upper/lower limit)
  - for **Power Park Modules** available power reflecting maximum unrestricted power, taking account variable source, e.g. wind or sun

The **Setpoint** value for automatic generation control power is transmitted by the **Network Operator** from the load-frequency controller in the system control centre to the communication interface of the **Power Generating Facility**.

Furthermore the **Network Operator** and the **Power Generating Facility Operator** can agree on additional monitoring and/or recording devices to be installed in power generation stations to check the performance of the frequency response provision of participating generating units (e.g. by observing the change of the **Active Power** output in case of deviations of the frequency from its nominal value).

R5.14 **SHORT CIRCUIT CONTRIBUTION.**

*(Applies to **Type C and D**)*

For all **Generating Units** short circuit contribution will be provided by continuous voltage control with or without deadband. The measurement point for the voltage is **PCC**.

R5.15 **BLACK START.**

*(Applies to **Type C and D**)*

**Black Start** capability shall be agreed between the **TSO** and the **Power Generating Facility**. The consent of the **Power Generating Facility Operator** shall not be withheld if the provision of this capability is inherently available in the technology of the facility.

A **Generating Unit** with black start capability shall be able to start from shut down within a timeframe specified by the **Network Operator** without any external energy supply. The **Generating Unit** shall be able to energise a part of the **Network** upon instruction from **Network Operator** and shall be able to synchronise with other

**Network** within the frequency limits defined by R5.1 and voltage limits defined by R5.2.

The generator voltage regulation shall be enabled, in order to assure that load connections which cause dips of voltage, are automatically regulated. The **Generating Unit** protection shall be stabilized against in-rush currents.

The **Generating Unit** shall

- be capable of regulating load connections in block load with a maximum size of 10% of **Maximum Capacity**, without frequency dropping dynamically by more than 1 Hz.
- control frequency in case of overfrequency and underfrequency within the whole **Active Power** output range as well as at houseload level;
- be capable of parallel operation of a few generating units within one isolated network;
- control voltage automatically during the system restoration phase;
- have sufficient fuel resources available on site to operate continuously with nominal **Active Power** for at least 6 hours without any external energy supply.

The **TSO** shall have the right to ask the **Power Generating Facility Operator** to demonstrate the capability to energise a previously isolated circuit and to subsequently contribute to successful synchronisation in accordance with its established system restoration procedures.

R5.16 **CAPABILITY TO TAKE PART IN ISOLATED NETWORK OPERATION.**

*(Applies to **Type C and D**)*

Each **Network Operator** in coordination with the responsible **TSO** selects whether the capability to take part in **Isolated Network Operation** is required.

The capability to take part in **Isolated Network Operation** shall be possible within the frequency limits defined by R5.1 and voltage limits defined by R5.2.

Each **Generating Unit** shall be capable of frequency control, as defined in R5.8. In the case of a power surplus, it shall be possible to reduce the loading of the **Generating Unit** to any operating point of the **P-Q-Capability Diagram**.

**Isolated Network Operation** of this kind shall be sustainable for several hours as defined by the **Network Operator** and will not exceed 24 hours. Details shall be agreed between the **Power Generating Facility Operator** and the **Network Operator**.

In the case of **Isolated Network Operation**, the **Generating Unit** shall be capable of regulating the load connections in block load, the size of which is determined by each TSO without frequency dropping dynamically by more than 1 Hz in the isolated network system. The **Network Operator** shall also establish the time interval between two successive load connections.

R5.17 **TRIP TO HOUSELOAD.**

*(Applies to **Type C and D**)*

The **Generating Unit** shall be designed for tripping to houseload from any working point permitted by the **P-Q-Capability Diagram**, if its minimum start-up time is longer than 30 minutes.

Tripping to houseload is required in case of disconnection of the **Generating Unit** from the **Network** in line with protection strategy agreed between the **Network Operator** and the **Power Generation Facility Operator** in the event of disturbances to the system.

**Generating Units** shall be capable of continuing operation following tripping to houseload irrespective of any auxiliary connection to the external grid. The minimum operation time in that mode depends on each **Network Operator's** standards.

All **Power Generating Facility** control systems shall remain in automatic mode. Manual intervention by the **Power Generating Facility Operator** is prohibited 3 within the first 3 minutes after tripping.

R5.18 **IDENTIFICATION OF HOUSELOAD OPERATION.**

*(Applies to **Type C and D**)*

The position signal of the circuit breaker at the **PCC** is not sufficient to identify houseload operation. Houseload operation conditions can occur even if this circuit breaker remains closed (e. g. in case the circuit breakers of all outgoing lines from the **PCC** are open). **Power Generating Units** shall unload to stable houseload operation in these cases as well.

R5.19 **ELECTRICAL PROTECTION SCHEMES AND SETTINGS.**

*(Applies to **Type B, C and D**)*

Protection schemes and settings relevant for the **Power Generating Facility** and the **Network** and any changes to them shall be coordinated and agreed between the **Network Operator** and the **Power Generating Facility Operator**. Settings to protect the **Network** are determined by the **Network Operator** taking into account the characteristics of the **Power Generating Facility**. Electrical protection of the **Generating Unit** shall take precedence over operational controls (e.g. voltage controllers, excitation equipment) and shall disconnect the **Generating Unit** from the **Network** in case of unacceptable operational states.

Protection schemes can include:

- external and internal short circuit
- asymmetric load (Negative Phase Sequence)
- stator and rotor overload
- over-/under-excitation
- over-/under-voltage at the grid Connection Point
- over-/under-voltage at the generator terminals
- inter-area oscillations
- Robustness against power swings (e.g. angle and voltage stability)
- over- and under-frequency

- asynchronous operation (pole slip)
- protection against subsynchronous resonance (shaft torsions)
- generator line protection
- unit transformer protection
- backup schemes against protection and switchgear malfunction
- overfluxing (U/f)
- inverse power
- rate of change of frequency
- neutral vector displacement

R5.20 **CONTROL SCHEMES AND SETTINGS**.

*(Applies to **Type B, C and D**)*

Schemes and settings of the turbine and generator control and any changes to them shall be agreed between the **TSO**, **Network Operator** and the **Power Generating Facility Operator** if relevant for system stability, especially for:

- isolated (Network) operation
- damping of oscillations
- behaviour in case of disturbances to the system

R5.21 **PRIORITY RANKING OF PROTECTION AND CONTROL.**

*(Applies to **Type B, C and D**)*

To ensure that the various, protection, control, market and other functions of the **Power Generating Facility**, do not interfere with each other in an unintended way, the following priority ranking shall be given:

- Network system and electrical generating unit protection
- **Synthetic Inertia** (if applicable)
- Frequency control (**Active Power** reduction)
- Power Restriction
- Balance Regulation including **Deload**
- Power gradient constraint

R5.22 **AUTO-RECLOSURES.**

*(Applies to **Type B, C and D**)*

**Network Operators** shall have the right to request successful single-phase auto-reclosures on generator supply lines (radial connection of one or more generators to the public grid) and single-phase or three-phase auto-reclosures on **Network** lines to be withstood by **Generating Units** without adverse impacts on their operation.

R5.23 **SYNCHRONISATION.**

*(Applies to **Type B, C and D**)*

When starting a **Synchronous Generating Unit**, synchronisation shall be performed by the **Power Generating Facility Operator** with the circuit breaker at the generator terminals after authorization by the **Network Operator**. The **Generating Unit** shall be equipped with the necessary synchronisation facilities. Synchronisation of **Generating Units** shall be possible for frequencies within the ranges set out by table 3. The **Network Operator** and the **Power Generating Facility Operator** agree on the settings of synchronisation devices (voltage, frequency, phase angle range, deviation of voltage and frequency).

R5.24 **SYSTEM PARALLELING AND TORSIONAL OSCILLATIONS.**

*(Applies to **Type C and D**)*

Normal line switching operation in the network can excite shaft torsional oscillations that result from transient steps of the **Active Power** output of a **Generating Unit.** Transient **Active Power** steps up to 50% of **Maximum Capacity** of a **Generating Unit** are considered a routine part of normal operation and shall be taken into account when specifying the shaft characteristics. More severe, but less frequent steps can occur including a three-phase fault at generator terminals.

R5.25 **RECONNECTION AFTER TRIPPING ONTO AUXILIARY SUPPLY.**

*(Applies to **Type C and D**)*

Reconnection of the **Generating Unit** after tripping onto auxiliary supply should be performed by the circuit breaker at the **PCC** or by the circuit breaker on the high-voltage side of the last step-up transformer before the **PCC** after a synchro-check.

R5.26 **CAPABILITY OF RECONNECTION AFTER AN INCIDENTAL DISCONNECTION DUE TO A NETWORK DISTURBANCE.**

*(Applies to **Type B, C and D**)*

The conditions to reconnect a **Generating Unit** to the network after an incidental disconnection due to a network disturbance are defined by the **TSO**. In addition, automatic reconnection of a **Generating Unit** shall be subject to prior agreement with the **TSO**.

R5.27 **INFORMATION EXCHANGE.**

*(Applies to **Type B, C and D**)*

**Power Generating Facilities** shall be equipped according to the standard of the **Network Operator** to transfer information between the **Network Operator** and the **Power Generating Facility** in real time or periodically with time stamping. The information exchange shall include, for example:

- **Power Generating Facility** to **Network Operator**:
  - generation schedules of the **Power Generating Facility** (in advance, e.g. day ahead and changes of the schedules immediately)
  - indications of switchgear of the generator connection to the extent necessary for system operation
  - tap-changer position of the step-up transformer if necessary for system operation
  - actual values of active and **Reactive Power** (net values), frequency and voltage
  - protection commands (if applicable)
  - water level (as applicable i.e. hydro units) if necessary for system operation
  - notification on tripping onto auxiliary supply
  - notification on activation of speed control
  - if applicable, available secondary control capacity
  - information on restrictions on active and **Reactive Power** supply capability

- Measured Voltage (at **PCC**)

- **Network Operator** to **Power Generation Facilities** or generation dispatch centers:
  - (de-)activation of primary/secondary control (if performed automatically)
  - target values for secondary control, if applicable
  - target values for tertiary control, if applicable
  - requested **Reactive Power** output or voltage (HV-side)
  - position signals of switchgear and measured values in the **Network Operator** substation to the extent it is individually agreed
  - alert signals indicating emergency states
  - requested **Active Power** in particular in abnormal or emergency situations (including shut down of power generation units)

Type and exchange of warning or alert signals indicating certain states of the system or the **Power Generating Facility** (e. g. emergency situations) are subject to individual agreements between the **Network Operator** and the **Power Generating Facility Operator**.

R5.28 **INSTRUMENTATION.**

*(Applies to **Type C and D**)*

A **Power Generating Facility** shall also have a facility to provide fault recording/dynamic system behaviour monitoring /quality of supply monitoring which records at least:

- voltage
- **Active Power**
- **Reactive Power**
- Frequency
- Harmonics and other **Network Operator** specified quality of supply parameters

The settings of the fault recording equipment, including triggering criteria, the sampling rates etc. will be agreed with the **Network Operator** in coordination with the responsible **TSO**. The dynamic system behaviour monitoring will normally include an oscillation trigger (specified by the **Network Operator** in coordination with the responsible **TSO**) detecting poorly damped power oscillations. The facilities for quality of supply and dynamic system behaviour monitoring shall include arrangements for the **Network Operator/ TSO** the access to information. The communications protocols for recorded data will be agreed with the **Network Operator/ TSO**.

R5.29 **POWER/VOLTAGE QUALITY RAPID VOLTAGE CHANGES.**

*(Applies to **Type A, B, C and D**)*

**Power Generating Facilities** shall ensure that their connection to the **Network** does not result in the level of distortion or fluctuation of the supply voltage on the **Network**, at the **PCC**, exceeding that allocated to them following consultation with the **Network Operator**. **Power Generating Facilities** shall also operate in a manner which will not breach the requirements of CENELEC Standard EN 50160.

**Power Generating Facilities** shall ensure they conform to International Electrotechnical Commission (IEC) standards "Electromagnetic Compatibility-Limits-Limitation of emission of harmonic currents for equipment connected to medium and high voltage power supply systems" (IEC/TR3 61000-3-6) and "Electromagnetic Compatibility-Limits-Limitation of voltage fluctuation and flicker for equipment connected to medium and high voltage power supply systems" (IEC/TR3 61000-3-7) and any other relevant standard in this context.

R5.30 **CHANGES TO/MODERNISATION OR REPLACEMENT OF EQUIPMENT OF GENERATING UNITS.**

*(Applies to **Type B, C and D**)*

Changes to the equipment of the **Power Generating Facility** with impact on the requirements of this network code shall be notified to and agreed with the **Network Operator** in coordination with the responsible **TSO** in advance. In case of modernisation/ replacement of equipment in existing **Power Generating Facilities** the new installations shall comply with the respective requirements. The use of existing spare components that do not comply with the requirements (e. g. a generator with insufficient capability to provide **Reactive Power**) has to be agreed with the **Network Operator** in coordination with the responsible **TSO** in each single case.

R5.31 **SIMULATION MODELS.**

*(Applies to **Type C and D**)*

Each **Network Operator** in coordination with the responsible **TSO** shall have the right to require simulation models for the purpose of validation of the requirements of this **Network Code**. The models shall as a minimum be provided in the format required by the **Network Operator** in coordination with the responsible **TSO**, and the model shall show the behaviour of the generating unit in both steady-state simulations (load flow) and dynamic simulations at the **PCC**. For dynamic simulations the model shall contain at least the following sub-models (as applicable):

- Prime mover unit,
- Speed and power control,
- Voltage control (incl. **PSS**) and excitation system and limiters.
- Generator protection models
- Converter models for **Power Park Modules**

The structure/block diagrams of the model have to be fully documented, according the requirements of the **Network Operator** in coordination with the responsible **TSO**. The **Network Operator/ TSO** shall have the right to require generator recordings in order to compare the response of the model with these recordings.

R5.32 **INSTALLATION OF DEVICES FOR SYSTEM OPERATION AND/ OR SECURITY.**

*(Applies to **Type C and D**)*

If a **Network Operator** considers additional devices necessary to be installed in a **Power Generating Facility** site to preserve or restore system operation or security, the **Network Operator** and the **Power Generating Facility Operator** will investigate this request and agree on an appropriate solution.

R5.33 **COOPERATION FOR ANALYSIS OF FAULTS AND DISTURBANCES.**

*(Applies to **Type B, C and D**)*

**Power Generating Facility Operators** and **Network Operators** shall provide all necessary data and cooperate bilaterally for disturbance and stability analysis. **Power Generating Facility Operators** and **Network Operators** shall cooperate for analysis of disturbances to the system and the behaviour of the system during such an event. Especially deviations of the actual behaviour from the expected one (frequency, voltage, tripping onto auxiliary supply) shall be subject to a common analysis.

## 6 REQUIREMENTS FOR SYNCHRONOUS GENERATING UNITS

Table 7 provides an overview to which types of **Generating Units** the requirements of this chapter shall apply.

| **Requirement** | **Title** | **Type A** | **Type B** | **Type C** | **Type D** |
|---|---|---|---|---|---|
| R6.1 | REACTIVE POWER CAPABILITY AT MAXIMUM ACTIVE POWER | | X | X | X |
| R6.2 | REACTIVE POWER CAPABILITY BELOW MAXIMUM ACTIVE POWER | | X | X | X |
| R6.3 | FAULT RIDE THROUGH CAPABILITY OF SYNCHRONOUS GENERATING UNITS CONNECTED AT 110 kV OR ABOVE | | | | X |
| R6.4 | FAULT RIDE THROUGH CAPABILITY OF SYNCHRONOUS GENERATING UNITS CONNECTED BELOW 110 kV | | X | X | |
| R6.5 | POST FAULT ACTIVE POWER RECOVERY | | X | X | X |
| R6.6 | COORDINATION OF SPEED AND POWER CONTROL OF SYNCHRONOUS GENERATING UNITS | | | X | X |
| R6.7 | VOLTAGE CONTROL SYSTEM | | X | X | X |
| R6.8 | STEADY STATE VOLTAGE CONTROL | | X | X | X |
| R6.9 | TRANSIENT VOLTAGE CONTROL | | X | X | X |
| R6.10 | POWER OSCILLATIONS DAMPING CONTROL | | | X | X |

| Requirement | Title | Type A | Type B | Type C | Type D |
|---|---|---|---|---|---|
| R6.11 | EXCITER SPECIFICATION | | X | X | X |
| R6.12 | STATOR CURRENT LIMITER | | | | X |

Table 7: Assignment of requirements for **Synchronous Generating Units** to types of **Generating Units**

R6.1 **REACTIVE POWER CAPABILITY AT MAXIMUM ACTIVE POWER.**

*(Applies to **Type B, C and D**)*

Each **Network Operator** will define a U-Q-profile of any shape in whose boundaries a **Synchronous Generating Unit** will be required to provide **Reactive Power** at its nominal **Active Power**.

This U-Q-Profile has to be within an envelope, the red box in figure 7, the dimensions of which (**Power Factor** range and voltage range) are defined for each **Synchronous Area** in table 8, but the position of which is defined by each **Network Operator**. Nevertheless, the red box cannot be outside the green box of the figure 7.

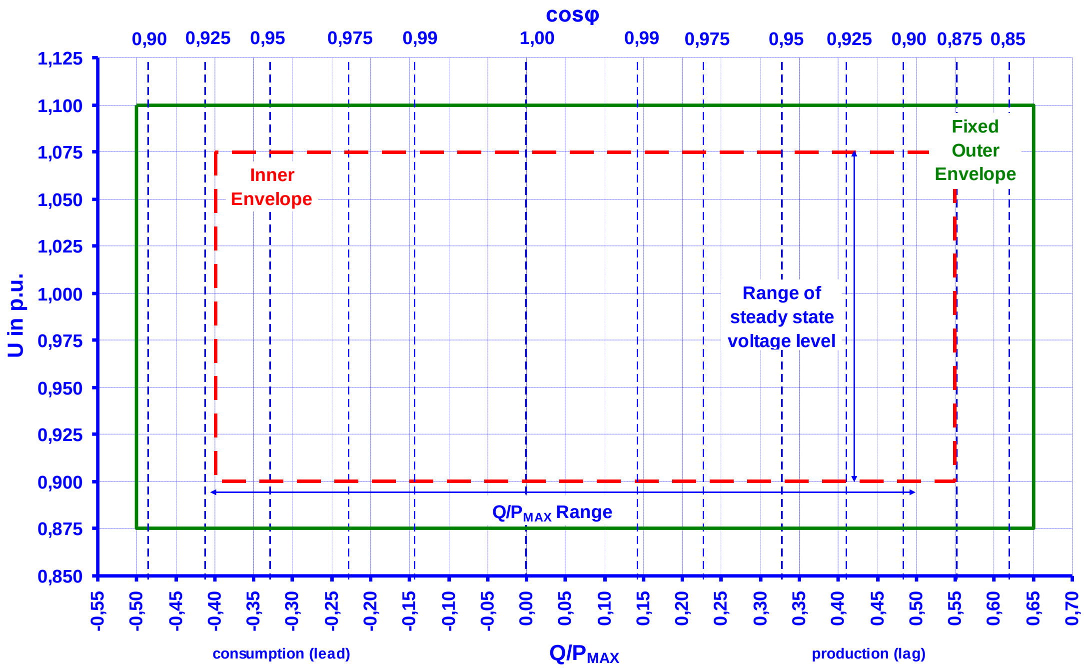


Figure 7 – **Reactive Power** capacity diagram

| Synchronous Area | Range of $Q/P_{max}$ | Range of steady state voltage level in PU |
|---|---|---|
| Continental Europe | 0.95 | 0.225 |
| Nordic | 0.95 | 0.150 |
| Great Britain | 0.95 | 0.100 |
| Ireland | 1.08 | 0.218 |
| Baltic States | Not defined yet | Not defined yet |

Table 8: Parameters for figure 7

The **Reactive Power** provision capability requirement applies to the HV-side of the last step-up transformer before the **PCC**. Beyond the voltage range specified by figure 7 the **Reactive Power** capability shall not be deliberately limited.

The **Synchronous Generating Unit** shall be able to pass repeatedly within 3 - 5 minutes through the agreed **Reactive Power** range. It shall be possible at any time to change the **Reactive Power** requirements within the agreed **Reactive Power** range.

For **Synchronous Generating Units** where the **PCC** is remote from the HV-side of the last step-up transformer before the **PCC**, supplementary **Reactive Power** may be required by the **Network Operator** from the **Synchronous Generating Unit** to compensate for the **Reactive Power** demand of the HV line, or cable, between these two points.

If required, additional facilities shall be provided on the **Synchronous Power Generating Facility** in order to be able to carry out voltage and **Reactive Power** control within the area of the **Network Operator**. The mode of operation is determined by the **Network Operator**.

R6.2 **REACTIVE POWER CAPABILITY BELOW MAXIMUM ACTIVE POWER.**

*(Applies to **Type B, C and D**)*

When operating at an **Active Power** output below the maximum **Active Power** ($P<P_{max}$), it shall be possible to operate the **Synchronous Generating Units** of the **Synchronous Power Generating Facility** in every possible operating point in accordance with the typical **P-Q-Capability Diagram** of a synchronous generator (figure 8). Even at reduced **Active Power** output, **Reactive Power** supply at the HV-side of the last step-up transformer before the **PCC** shall fully correspond to the typical **P-Q-Capability Diagram** of a synchronous generator taking the auxiliary service power and the losses at the generator transformer and the generator line into account.

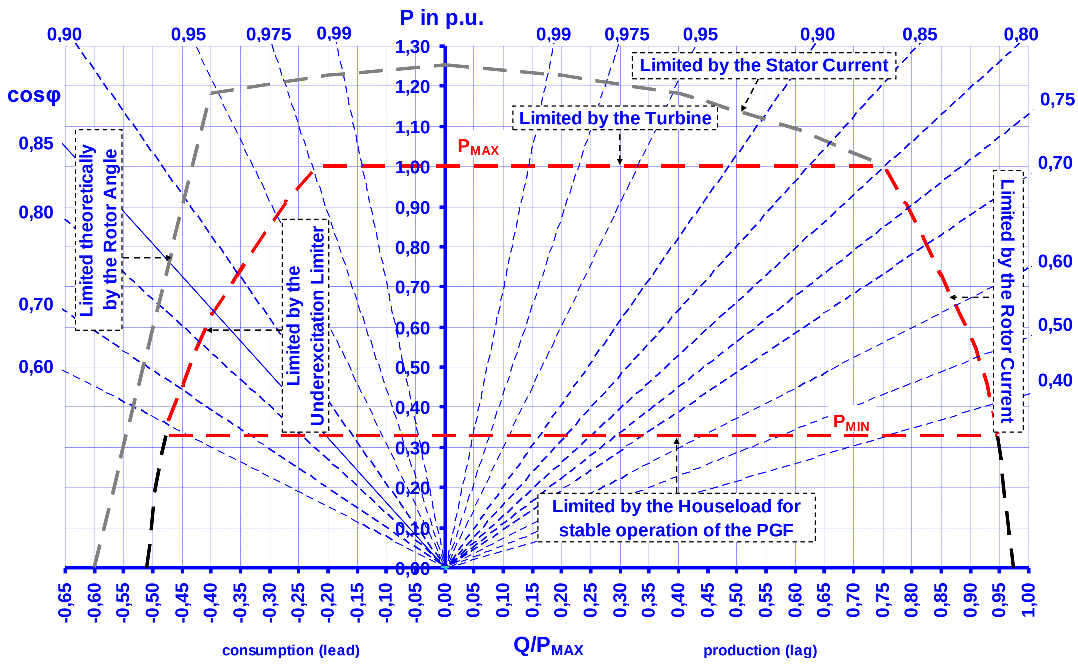


Figure 8 – Typical P-Q-Capability Diagram of a synchronous generator

## R6.3 FAULT RIDE THROUGH CAPABILITY OF SYNCHRONOUS GENERATING UNITS CONNECTED AT 110 kV OR ABOVE.

*(Applies to **Type D**)*

Each TSO shall have the right to define a voltage-against-time-profile for fault conditions which describes the conditions in which **Synchronous Generating Units** connected at 110 kV or above shall stay connected to the grid and to continue stable operation after the power system has been disturbed by **Secured Faults** on the TSO Network, unless the protection scheme requires the disconnection of a **Generating Unit** from the grid. This voltage-against-time-profile shall be expressed by the course of the phase of the grid voltage at the **PCC** which sustains the largest voltage drop during a fault (irrespective of the voltage drop of the other phases) as a function of time before, during and after the fault which remains on the red lines or inside the shaded area delimited by the red lines in figure 9. **Synchronous Generating Units** connected at 110 kV or above shall irrespective of the pre-fault working point of the generator stay connected to the grid and continue stable operation when the actual voltage in such conditions remains above this course.

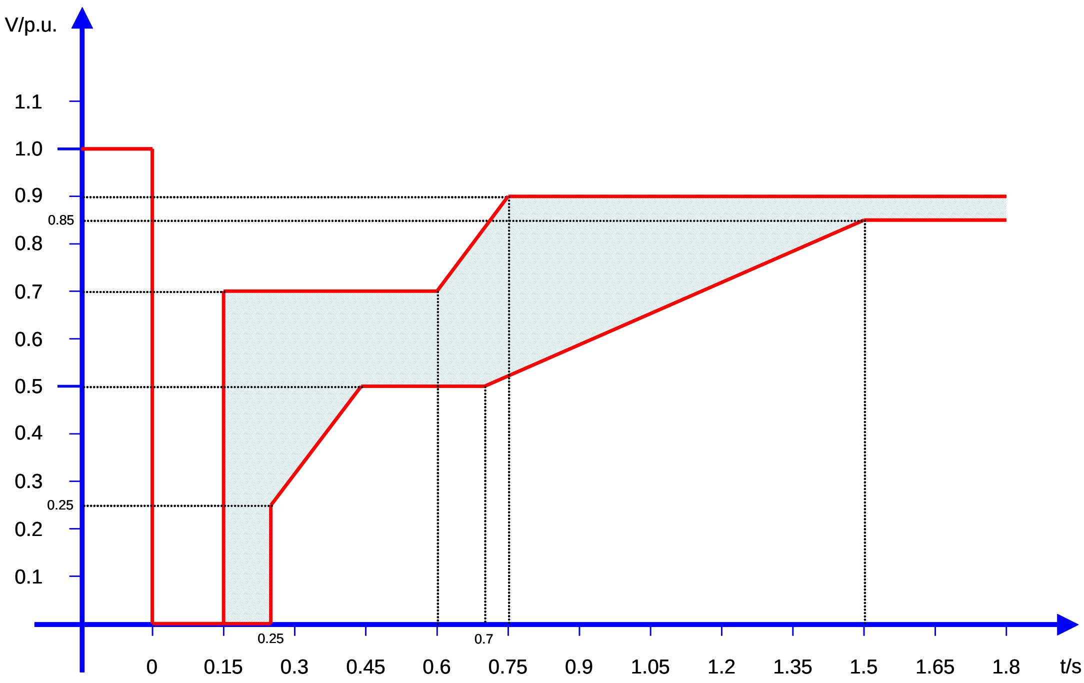


Figure 9 – Boundaries of a voltage-against-time-profile (red lines) at the **PCC** for **Synchronous Generating Units** connected at voltage levels at 110 kV or above

**Fast Valving** under fault conditions in order to aid angular stability shall be implemented if allowed or requested by the responsible **TSO.** Specifications shall be agreed between the **TSO** and the **Power Generating Facility Operator**.

R6.4 **FAULT RIDE TRHOUH CAPABILITY OF SYNCHRONOUS GENERATING UNITS CONNECTED BELOW 110 kV.**

*(Applies to **Type B and C**)*

Each TSO shall have the right to define a voltage-against-time-profile for fault conditions which describes the conditions in which **Synchronous Generating Units** connected below 110kV shall stay connected to the grid and to continue stable operation after the power system has been disturbed by **Secured Faults** on the TSO Network, unless the protection scheme requires the disconnection of a **Generating Unit** from the grid. This voltage-against-time-profile shall be expressed by the course of the phase of the grid voltage at the **PCC** which sustains the largest voltage drop during a fault (irrespective of the voltage drop of the other phases) as a function of time before, during and after the fault which remains on the red lines or inside the shaded area delimited by the red lines in figure 10. **Synchronous Generating Units** connected below 110 kV shall irrespective of the pre-fault working point of the generator stay connected to the grid and continue stable operation when the actual voltage in such conditions remains above this course. **Fast Valving** is prohibited.

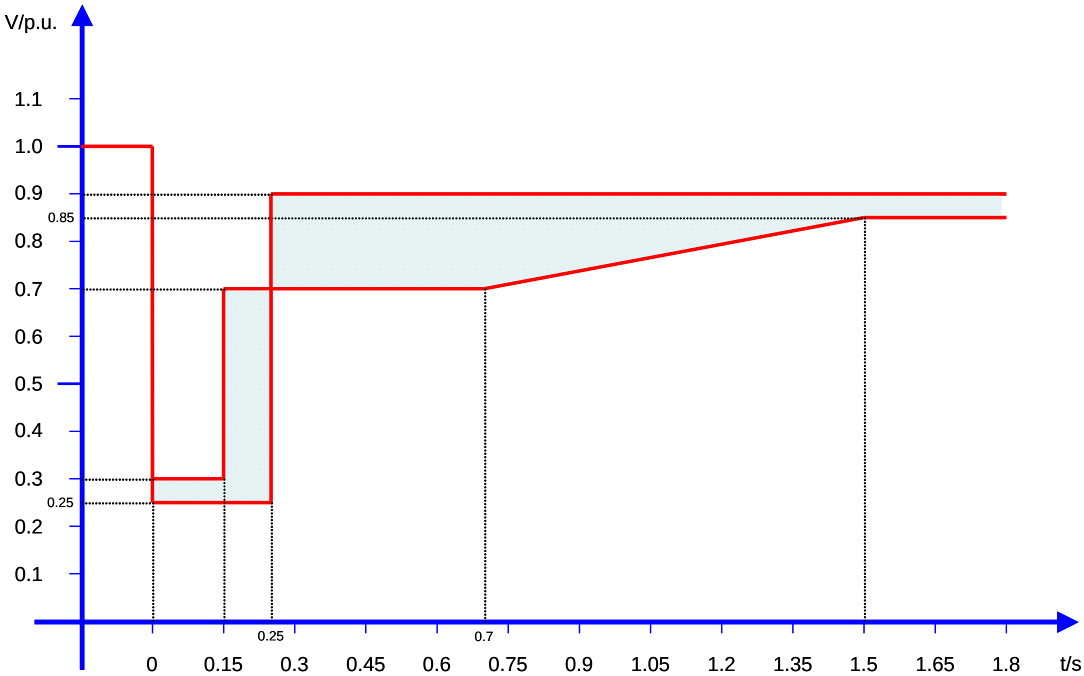


Figure 10 – Boundaries of a voltage-against-time-profile (red lines) at the **PCC** for **Synchronous Generating Units** connected at voltage levels below 110 kV

R6.5 **POST FAULT ACTIVE POWER RECOVERY.**

*(Applies to **Type B, C and D**)*

The responsible **TSO** will specify a time for **Active Power** recovery to 85% of the pre-fault value (between 0.5 and 10 seconds) starting from voltage recovery above 85%.

R6.6 **COORDINATION OF SPEED AND POWER CONTROL OF SYNCHRONOUS GENERATING UNITS.**

*(Applies to **Type C and D**)*

For stabile operation of a **Power Generating Unit** during network operation and island operation it is necessary that both a proportional speed controller and the power controller are always in operation (e. g. speed controller output signal and the power output signal are added). The speed controller determines the dynamic behaviour, whereas a slower power controller adapts the steady state operating point.

R6.7 **VOLTAGE CONTROL SYSTEM.**

*(Applies to **Type B, C and D**)*

A continuously-acting automatic excitation control system is required to provide constant terminal voltage of the **Synchronous Generating Unit** without instability over its entire operating range.

The **Excitation System** of a **Synchronous Generating Unit** shall include an **Excitation System** (**Exciter**), a continuously acting **Automatic Voltage Regulator** (**AVR**) and, if the **Synchronous Generating Unit** size is above a minimum **Active Power** capacity specified by the responsible **TSO**, a **Power System Stabiliser (PSS)** to prevent or attenuate power oscillations.

Control scheme characteristics, parameters and settings of the voltage control system components shall be agreed between the **Power Generating Facility Operator** and the responsible **Network Operator** based on the specifications by the responsible **TSO** and the responsible **Network Operator** before commissioning of the **Generating Unit.**

**Power Generating Facility Operators** shall provide to the responsible **Network Operator** all data, models and studies required by this **Network Code**, national legislation and/ or codes and requirements of the responsible **Network Operator** in order to evaluate and agree on the voltage control system.

R6.8 **STEADY-STATE VOLTAGE CONTROL.**

*(Applies to **Type B, C and D**)*

The **AVR** shall limit the change in terminal voltage to a drop not exceeding a percentage of rated terminal voltage specified by the responsible **Network Operator**, when the output is gradually changed from zero to rated **Apparent Power** at rated voltage, **Active Power** and frequency.

R6.9 **TRANSIENT VOLTAGE CONTROL.**

*(Applies to **Type B, C and D**)*

For a step change from 90 to 100% of the nominal terminal voltage, with the **Generating Unit** on open circuit, the **Exciter** response shall have a damped oscillatory characteristic. For this characteristic, the time for the terminal voltage of the **Generating Unit** to reach 100% shall be less than a value specified by the responsible **Network Operator**. The time to settle within 5% of the voltage change shall be specified by the responsible **Network Operator**.

To ensure that adequate synchronising power is maintained, when the **Generating Unit** is subject to a large voltage disturbance, the **Exciter** whose output is varied by the **AVR** shall be capable of providing its achievable upper and lower limit ceiling voltages to the generating unit field in a time not exceeding that specified by the **NETWORK OPERATOR**. The achievable upper and lower limit ceiling voltages may be dependent on the voltage disturbance. The **Exciter** shall be capable of attaining an **Excitation System on Load Positive Ceiling Voltage** specified by the **Network Operator** for at least 10 sec when responding to a sudden drop in voltage of 10% or more**.**

The field voltage should be capable of attaining a negative ceiling level specified by the **Network Operator** after the removal of the step when responding to a sudden drop in voltage of 10% or more at the Generating Unit terminals.

The **Network Operator** shall have the right to require that the **Exciter**

- shall be capable of maintaining free firing when the Generating Unit terminal voltage is depressed to a level which may be 25% of rated terminal voltage
- shall be capable of attaining a positive ceiling voltage not less than 80% of the **Excitation System On Load Positive Ceiling Voltage** upon recovery of the Generating Unit terminal voltage to 80% of rated terminal voltage following fault clearance.

R6.10 **POWER OSCILLATIONS DAMPING CONTROL.**

*(Applies to **Type C and D**)*

The arrangements for the supplementary control signal shall ensure that the **PSS** output signal relates only to changes in the supplementary control signal and not the steady state level of the signal. Additionally the **PSS** shall not react to non-oscillatory power changes.

The output signal from the **PSS** shall be limited to not more than ±10% of the **Generating Unit** terminal voltage signal at the **AVR** input. The gain of the **PSS** shall be such that an increase in the gain by a factor of 3 shall not cause instability.

The **PSS** shall include elements that limit the bandwidth of the output signal. The bandwidth limiting shall ensure that the highest frequency of response cannot excite torsional oscillations on other **Power Generating Units** connected to the network. The bandwidth limit shall be specified by the responsible **TSO**.

The **PSS** shall be active within the **Exciter** at all times when synchronised including when the **Under Excitation Limiter** or **Over Excitation Limiter** are active. When synchronising or de-synchronising a **Generating Unit**, the **PSS** may be out of service.

Where a **PSS** is fitted to a pumped storage unit it shall function when the pumped storage unit is in both generating and pumping modes.

A facility to inject a band limited random noise signal into the **AVR** voltage reference shall be provided for demonstrating the frequency domain response of the Power **PSS**. The tuning of the **PSS** shall result in improved damping of corresponding **Active Power** response of the **AVR** in combination with the **PSS** compared to the **Active Power** response of the **AVR** alone over a frequency range specified by the responsible **TSO**.

R6.11 **EXCITER SPECIFICATION.**

*(Applies to **Type B, C and D**)*

The **Exciter** shall include elements that limit the bandwidth of the output signal. The bandwidth limiting shall be consistent with the speed of response requirements and ensure that the highest frequency of response cannot excite torsional oscillations on other **Power Generating Units** connected to the network. The bandwidth limit shall be specified by the responsible **TSO**.

The **Exciter** shall be equipped with an **Under Excitation Limiter**. The **Under Excitation Limiter** shall prevent the **Automatic Voltage Regulator** reducing the generator excitation to a level which would endanger synchronous stability. The **Under Excitation Limiter** shall operate when the **Exciter** is providing automatic control. The **Under Excitation Limiter** shall respond to changes in the **Active Power** and the **Reactive Power**, and to the square of the generator voltage in such a direction that an increase in voltage will permit an increase in leading **Reactive Power**. The characteristic of the **Under Excitation Limiter** shall be substantially linear from no-load to the maximum **Active Power** output of the **Generating Unit** at any setting and shall be readily adjustable.

The resulting maximum overshoot in response to a step injection which operates the **Under Excitation Limiter** shall not exceed 4% of the **Generating Unit** rated **Apparent Power**. The operating point of the **Generating Unit** shall return to a steady-state value at the limit line and the final settling time shall not be greater than 5 seconds. When the step change **AVR** reference voltage is reversed, the field voltage should begin to respond without any delay and should not be held down by the **Under Excitation Limiter**. Operation into or out of the preset limit levels shall ensure that any resultant oscillations are damped so that the disturbance is within 0.5% of the **Generating Unit** rated **Apparent Power** within a period of 5 seconds.

The **Generator** shall also make provision to prevent the reduction of the **Generating Unit** excitation to a level which would endanger synchronous stability when the **Excitation System** is under manual control.

The generator **Excitation System** shall be equipped with an **Over Excitation Limiter**, if requested by the responsible **Network Operator**. The settings of the **Over Excitation Limiter** shall ensure that the generator excitation is not limited to less than the maximum value that can be achieved whilst ensuring the **Generating Unit** is operating within its design limits. Any operation beyond the over excitation limit shall be controlled by the **Over Excitation Limiter** without tripping the **Generating Unit**.

The **Generator** shall also make provision to prevent any over-excitation restriction of the generator when the **Excitation System** is under manual control, other than that necessary to ensure the **Generating Unit** is operating within its design limits.

R6.12 **STATOR CURRENT LIMITER.**

*(Applies to **Type D**)*

The operation of the **Stator Current Limiter** and the **Over Excitation Limiter** shall be coordinated. The **Stator Current Limiter** shall act delayed to the **Over Excitation Limiter** to fully utilise the transient over excitation capability of the **Generating Unit**. The operation of the **Stator Current Limiter** shall not result in a reduction of the generator terminal voltage below 85% - 90 % of the rated voltage.

If the stator current does not reach the admissible range when the generator voltage is at 85% - 90% of the rated value the **Stator Current Limiter** shall either reduce the **Active Power** output automatically until the stator is in the admissible range or alternatively the **Active Power** output shall be reduced manually after an alarm signal from the **Stator Current Limiter**.

## 7 REQUIREMENTS FOR POWER PARK MODULES

Table 9 provides an overview to which types of **Generating Units** the requirements of this chapter shall apply.

| Requirement | Title | Type A | Type B | Type C | Type D |
|---|---|---|---|---|---|
| R7.1 | REACTIVE POWER CAPABILITY AT MAXIMUM ACTIVE POWER | | X | X | X |
| R7.2 | REACTIVE POWER CAPABILITY BELOW MAXIMUM ACTIVE POWER | | X | X | X |
| R7.3 | FAULT RIDE THROUGH CAPABILITY OF POWER PARK MODULES CONNECTED AT 110 kV OR ABOVE | | | | X |
| R7.4 | FAULT RIDE THROUGH CAPABILITY OF POWER PARK MODULES CONNECTED BELOW 110 kV | | X | X | |
| R7.5 | REACTIVE POWER CONTROL MODES | X | X | X | X |
| R7.6 | FAST ACTING VOLTAGE CONTROL | | X | X | X |
| R7.7 | PRIORITY TO ACTIVE OR REACTIVE POWER CONTRIBUTION | | | X | X |
| R7.8 | POST FAULT ACTIVE POWER RECOVERY | | X | X | X |
| R7.9 | VOLTAGE SUPPORT MONITORING | | X | X | X |
| R7.10 | SYNTHETIC INERTIAL CAPABILITY TO A LOW FREQUENCY EVENT | | | X | X |

Table 9: Assignment of requirements for **Power Park Modules** to types of **Generating Units**

R7.1 **REACTIVE POWER CAPABILITY AT MAXIMUM ACTIVE POWER.**

*(Applies to **Type B, C and D**)*

Each **Network Operator** will define a U-Q-profile of any shape in whose boundaries a **Power Park Module** will be required to provide **Reactive Power** at its nominal **Active Power**.

This U-Q-Profile has to be within an envelope, the red box in figure 11, the dimensions of which (**Power Factor** range and voltage range) are defined for each **Synchronous Area** in table 10, but the position of which is defined by each **Network Operator**. Nevertheless, the red box cannot be outside the green box of the figure 11.

Working Draft

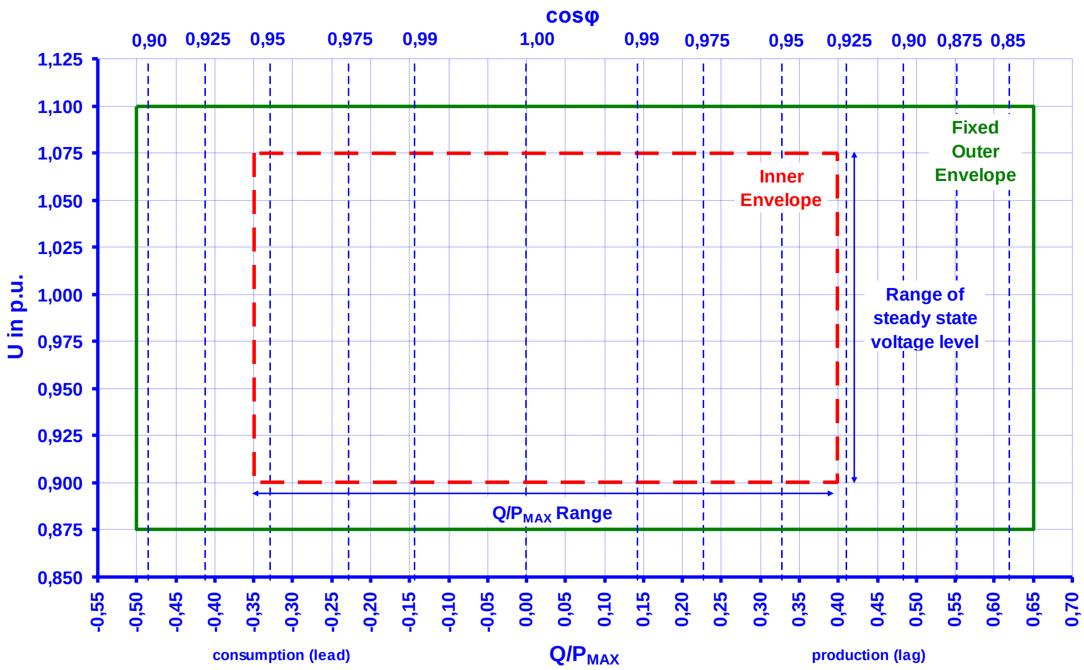


Figure 11 – **Reactive Power** capacity diagram

| Synchronous Area | Range of $Q/P_{max}$ | Range of steady state voltage level in PU |
|---|---|---|
| Continental Europe | 0.75 | 0.225 |
| Nordic | 0.95 | 0.150 |
| Great Britain | 0.60 | 0.100 |
| Ireland | 0.66 | 0.218 |
| Baltic States | Not defined yet | Not defined yet |

Table 10: Parameters for figure 11

The **Reactive Power** provision capability requirement applies to the HV-side of the last step-up transformer before the **PCC**. Beyond the voltage range specified by figure 11 the **Reactive Power** capability shall not be deliberately limited.

The **Power Park Module** shall be able to pass repeatedly within 3 - 5 minutes through the agreed **Reactive Power** range. It shall be possible at any time to change the **Reactive Power** requirements within the agreed **Reactive Power** range.

For **Power Generating Facilities** where the **PCC** is remote from the HV-side of the last step-up transformer before the **PCC**, supplementary **Reactive Power** may be required by the **Network Operator** from the **Power Park Module** to compensate for the **Reactive Power** demand of the HV line, or cable, between these two points.

If required, additional facilities shall be provided on the **Power Park Module** in order to be able to carry out voltage and **Reactive Power** control within the area of the **Network Operator**. The mode of operation is determined by the **Network Operator**.

R7.2 **REACTIVE POWER CAPABILITY BELOW MAXIMUM ACTIVE POWER.**

*(Applies to **Type B, C and D**)*

When operating at an **Active Power** output below the maximum **Active Power** ($P<P_{max}$), it shall be possible to operate the **Power Park Module** in every possible operating point in accordance with P-Q-diagram in figure 12.

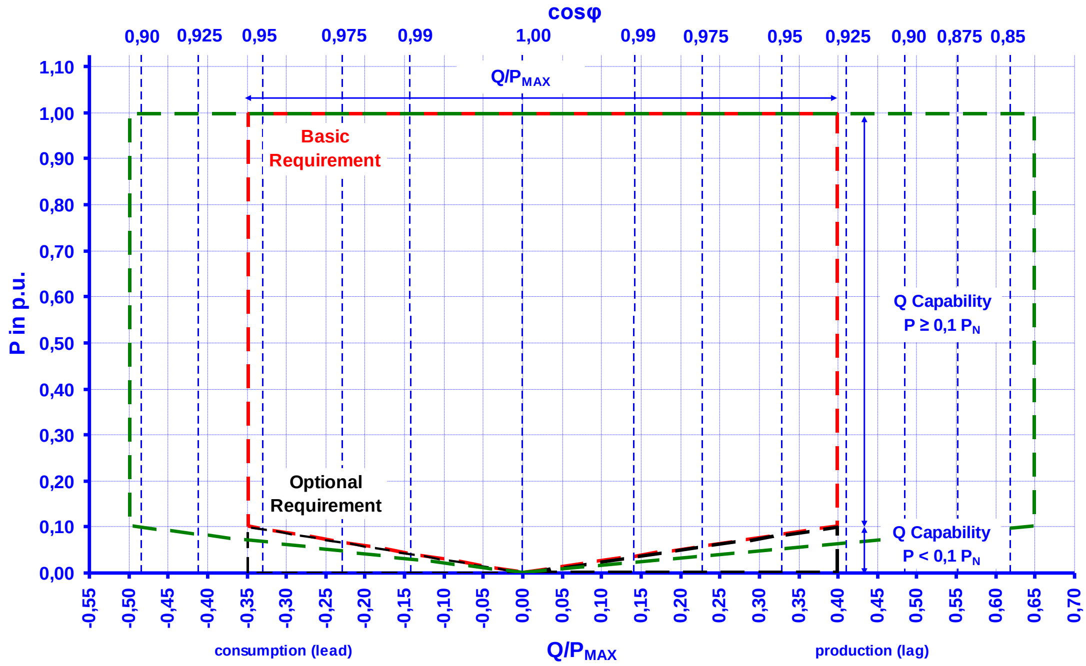


Figure 12 – Typical P-Q-Capability Diagram of a **Power Park Module**

The **Power Park Module** shall be capable of providing **Reactive Power** at any working point inside the red envelope in figure 12. In this controlled mode it is allowed to operate the **Power Park Module** outside the specified range of **Reactive Power**.

If required by the **Network Operator**, additional facilities shall be installed at the **Power Park Module** in order to be capable of providing **Reactive Power** at any working point inside the blue envelope in figure 12.

The **Power Park Module** shall be able to pass repeatedly within a few minutes through the agreed **Reactive Power** range. It shall be possible at any time to change the **Reactive Power** requirements within the agreed **Reactive Power** range.

R7.3 **FAULT RIDE THROUGH CAPABILITY OF POWER PARK MODULES CONNECTED AT 110 kV OR ABOVE.**

*(Applies to **Type D**)*

Each TSO shall have the right to define a voltage-against-time-profile for fault conditions which describes the conditions in which all parts of **Power Park Modules** connected at 110kV or above shall stay connected to the grid and to continue stable operation after the power system has been disturbed by **Secured Faults** on the TSO Network, unless the protection scheme requires the disconnection of a **Power Park**

**Module** from the grid. This voltage-against-time-profile shall be expressed by the course of the phase of the grid voltage at the **PCC** which sustains the largest voltage drop during a fault (irrespective of the voltage drop of the other phases) as a function of time before, during and after the fault which remains on the red lines or inside the shaded area delimited by the red lines in figure 13. All parts of **Power Park Modules** connected at 110 kV or above shall stay connected to the grid and continue stable operation when the actual voltage in such conditions remains above this course.

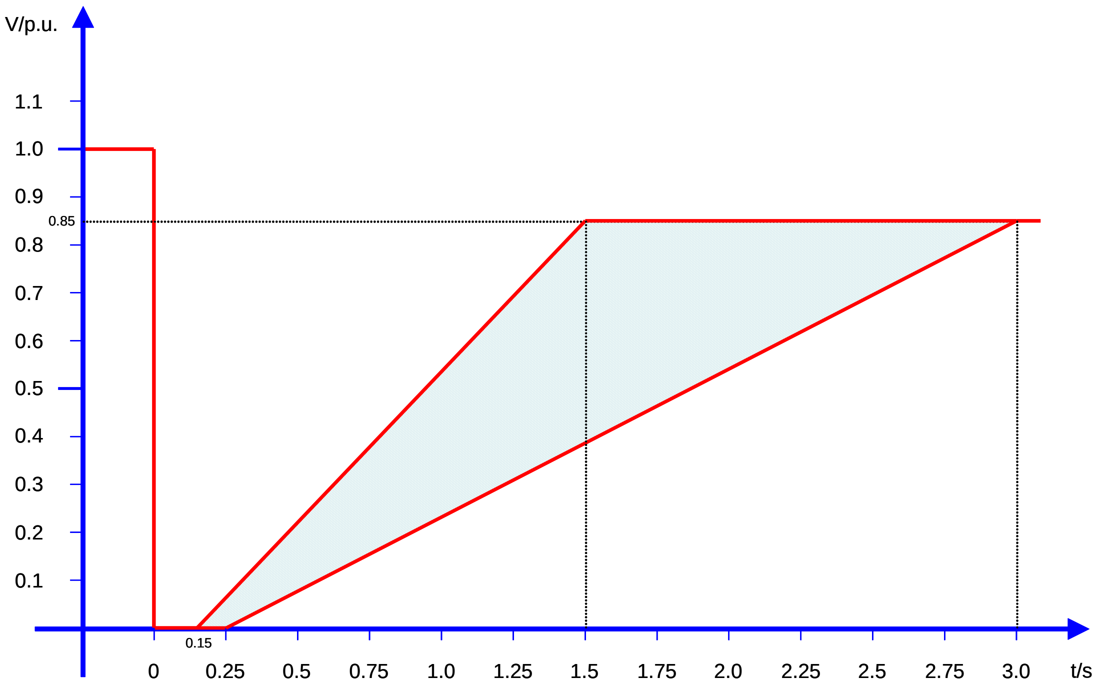


Figure 13 – Boundaries of a voltage-against-time-profile (red lines) at the **PCC** for **Power Park Modules** connected at voltage levels at 110 kV or above

## R7.4 FAULT RIDE THROUGH CAPABILITY OF POWER PARK MODULES CONNECTED BELOW 110 kV.

*(Applies to **Type B and C**)*

Each TSO shall have the right to define a voltage-against-time-profile for fault conditions which describes the conditions in which all parts of **Power Park Modules** connected below 110kV shall stay connected to the grid and to continue stable operation after the power system has been disturbed by **Secured Faults** on the TSO Network, unless the protection scheme requires the disconnection of a **Power Park Module** from the grid. This voltage-against-time-profile shall be expressed by the course of the phase of the grid voltage at the **PCC** which sustains the largest voltage drop during a fault (irrespective of the voltage drop of the other phases) as a function of time before, during and after the fault which remains on the red lines or inside the shaded area delimited by the red lines in figure 14. All parts of **Power Park Modules** connected below 110 kV shall stay connected to the grid and continue stable operation when the actual voltage in such conditions remains above this course.

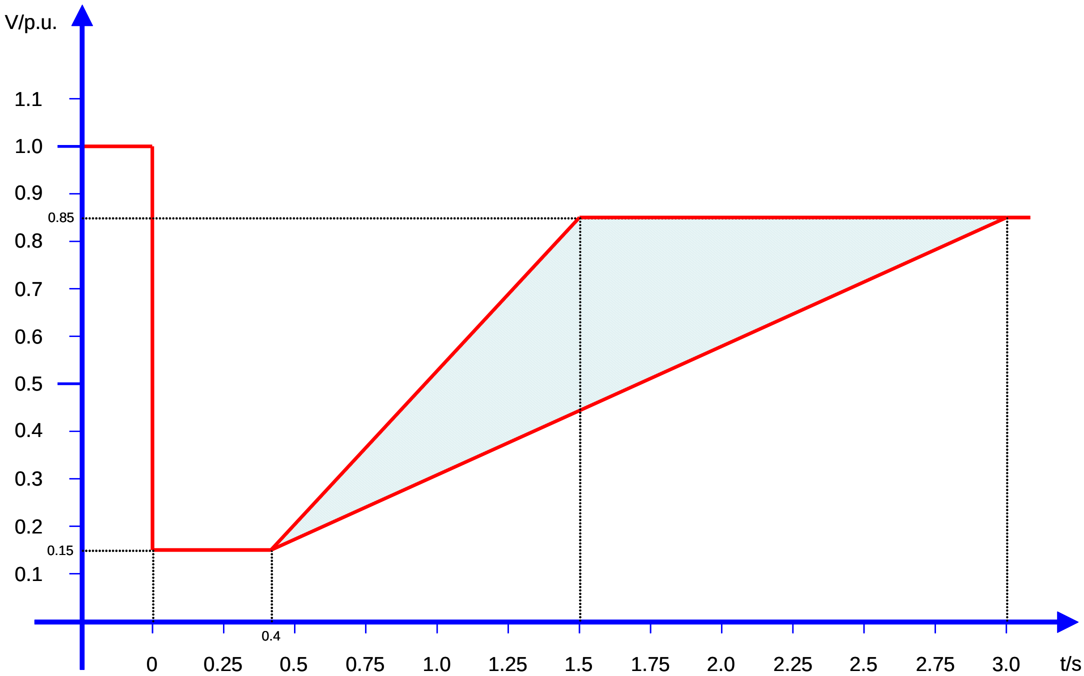


Figure 14 – Voltage-against-time-profile at the **PCC** for **Power Park Modules** connected at voltage levels below 110 kV

R7.5 **REACTIVE POWER CONTROL MODES.**

*(Applies to **Type A, B, C and D**)*

A **Power Park Module** shall be capable of providing **Reactive Power** automatically by any of the following three control modes:

a) Voltage control

The **Power Park Module** shall be capable of controlling the voltage at the PCC by provision of **Reactive Power** exchange with the System with a **Setpoint** voltage covering at least 0.95 to 1.05pu in steps no greater than 0.01pu with a **Slope** with a range of at least 2 to 7% in steps no greater than 1%. The **Setpoint** may be operated with or without a deadband selectable in a range from 0 to +-10% of nominal grid voltage in steps no greater than 1% (figure 15). Following a step change in voltage 90% of the change in **Reactive Power** output shall be achieved within 1 second and settle at the value defined by the operating slope within 5 seconds with a steady state reactive tolerance no greater than 5%.

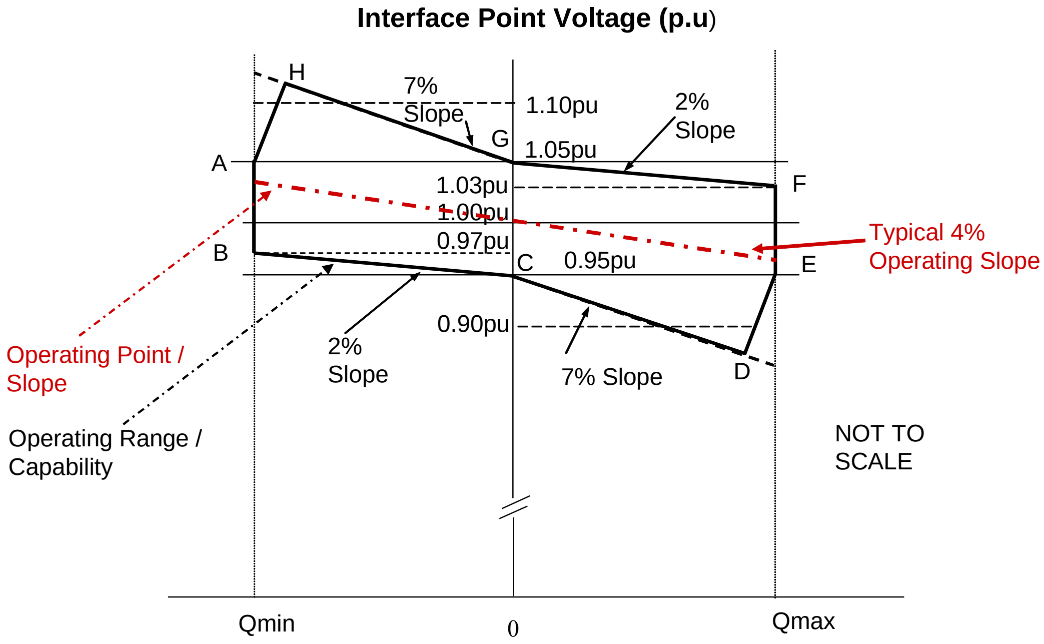


Figure 15 – Steady-state voltage control of **Power Park Modules**

b) Reactive Power Control

The **Power Park Module** shall be capable of setting the **Reactive Power** target anywhere in the full **Reactive Power** range (applicable at full **Active Power**) with setting steps no greater than 5Mvar or 5% (whichever is smaller) of full **Reactive Power**, controlling the **Reactive Power** at the **PCC** to an accuracy within +-5Mvar or +-5% (whichever is smaller) of the full **Reactive Power**. It is accepted that the **Reactive Power** output may be limited during operation at lower **Active Power**, although the limitation should not be less than that identified by the **Reactive Power** capability chart.

c) **Power Factor** Control

The **Power Park Module** shall be capable of controlling the **Power Factor** at the PCC within the Q range defined by R7.1 and R7.2 with a target **Power Factor** in steps no greater than 0.01. The **Network Operator** will determine the target **Power Factor** value and the tolerance of Mvar (or %) within a period of time, following a sudden change of **Active Power** output or step change in system voltage.

The control mode, parameter settings and the working point for steady-state **Reactive Power** exchange shall be determined by the **Network Operator** in coordination with the responsible **TSO**. The determination shall relate to one of the following three possibilities:

- Voltage **Setpoint**
- Reactive Power **Setpoint**
- **Power Factor** (cosφ) **Setpoint**

R7.6 **FAST ACTING VOLTAGE CONTROL.**

*(Applies to **Type B, C and D**)*

Voltage control according to figure 16 shall be activated in the event of a voltage deviation of more than X % of the effective value of the generator voltage (0% ≤X ≤ ±10%). This voltage control shall ensure the supply of a reactive current at the LV side of the first step-up transformer with a contribution of at least 2 % of the rated current per percent of the voltage deviation (figure 16). The **Power Park Module** shall be capable of feeding the required reactive current no later than 40ms after the fault inception into the network (control response time).

Reactive current supply during the fault duration shall not be less than 1pu of the short term dynamic rating of the equipment (>=1.0pu), required to be delivered down to 40% retained voltage at PCC.

The parameter settings and the working point for the fast acting voltage control shall be determined by the **Network Operator** in coordination with the responsible **TSO**.

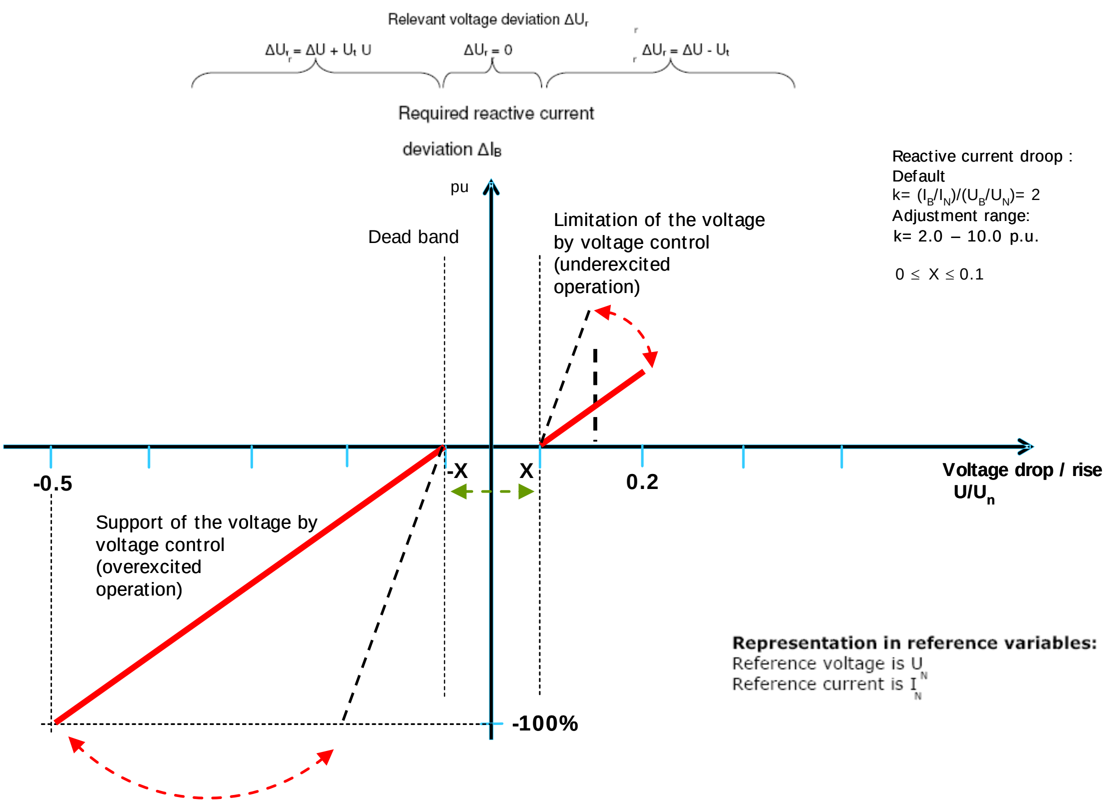


Figure 16 – Principle of voltage support during faults

Uncontrolled production of **Reactive Power** after fault clearances shall be limited to a time period specified by the **Network Operator** in coordination with the responsible **TSO**.

R7.7 **PRIORITY TO ACTIVE OR REACTIVE POWER CONTRIBUTION.**

*(Applies to **Type C and D**)*

The responsible **TSO** determines whether **Active Power** contribution or **Reactive Power** contribution has priority during faults. If priority is given to **Active Power** contribution, its provision shall be established no later than 150ms from the fault inception.

R7.8 **POST FAULT ACTIVE POWER RECOVERY.**

*(Applies to **Type B, C and D**)*

The responsible **TSO** will specify a time for **Active Power** recovery to 85% of the pre-fault value (between 0.5 and 10 seconds) starting from voltage recovery at PCC above 85%.

R7.9 **VOLTAGE SUPPORT MONITORING.**

*(Applies to **Type B, C and D**)*

If required by the TSO, if the voltage at the grid connection point falls and remains (positive sequence system) at a value of and below 85 % of the reference voltage and with a simultaneous **Reactive Power** direction to the **Power Park Module** (under-excited operation), the generating plant shall be disconnected from the grid after a time delay of 0.5 seconds. The voltage value refers to the highest value of the three line-to-line grid voltages.

If required by the TSO, if the voltage on the low voltage side of each individual generator transformer falls and remains at and below 80 % of the lower value of the voltage band based on a resetting ratio of 0.98, the generators shall disconnect themselves from the grid in volumes and after time periods determined by the **TSO**. The voltage value refers to the highest value of the three line-to-line grid voltages.

R7.10 **SYNTHETIC INERTIAL CAPABILITY TO A LOW FREQUENCY EVENT.**

*(Applies to **Type C and D**)*

**TSO**s shall have the right to require each **Power Park Module** which is greater than a MW size to be specified by the responsible **TSO** and determined in co-operation with other **TSO**s in the relevant each **Synchronous Area** to supply additional **Active Power** to the **Network** in the form shown below in figure 17, in order to limit the rate of change of **frequency** following a sudden generation loss.

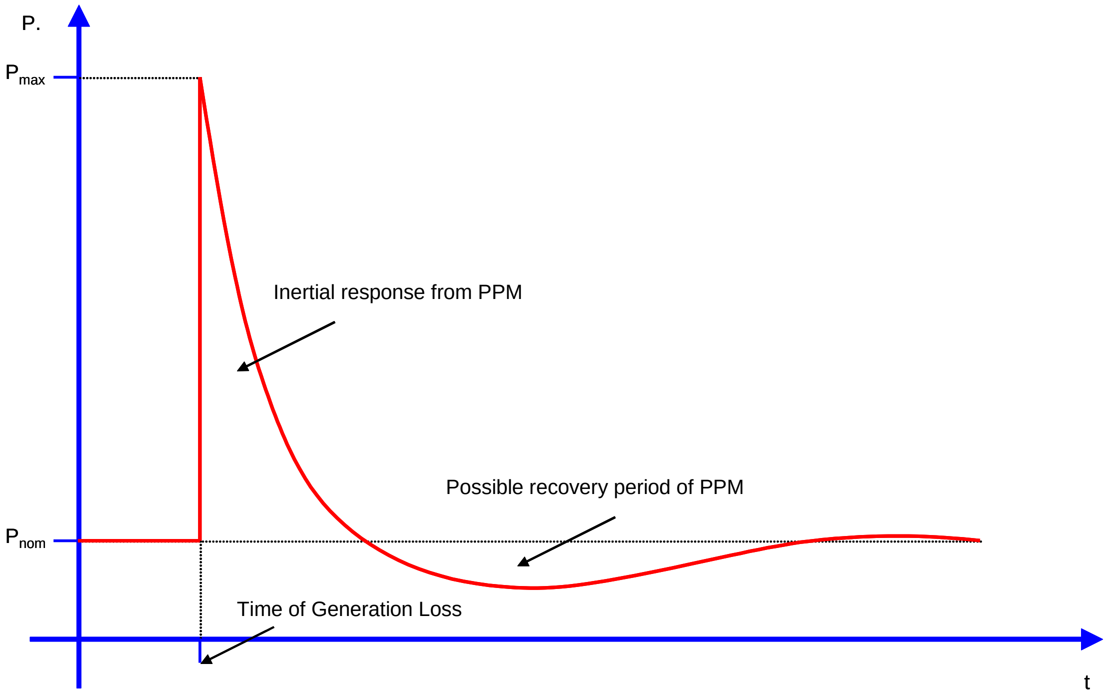


Figure 17: Example of **Active Power** provision by inertia

**Power Park Modules** which are insensitive to changes in **frequency** and do not inherently have a capability to supply additional **Active Power** to the **Network** in the form shown in figure 17 shall be required to install a control system which operates the **Power Park Module** so as to inject **Active Power** into the **Network** in the form shown in figure 17.

For a given rate of change of **frequency** defined by the responsible **TSO** or greater the maximum injected **Active Power** supplied to the **Network** shall be required to be at least a percentage defined by the responsible **TSO** of the **Maximum Capacity** of the **Power Park Module**.

The **Active Power** delivered to the **Network** should be fully available within a time no longer than 200ms. Following the initial increase in **Active Power** supplied to the **Network**, **Active Power** should not reduce back to 0MW quicker than a time period defined by the responsible **TSO**, the **TSO** having taken account of reasonable inertial energy release in context of the impact on the power recovery.

The initial injected **Active Power** supplied to the **Network** shall be in proportion to the rate of Change of **Network Frequency.**

Following injection of the **Active Power** to the **Network** and the subsequent exponential decay, a recovery period shall be permitted. This recovery period shall be limited so as to prevent excessive subsequent loss of power after the initial injection in **Active Power.**

In addition, the control system of each **Power Park Module** shall:

- Operate whenever the **Power Park Module** is selected to **Limited Frequency Sensitive Mode** of operation.
- Have an adjustable rate of change of frequency dead band of between 0.001 Hz/s – 0.010Hz/s in step sizes of 0.001Hz/s, with the setting specified by the responsible **TSO** taking account of co-ordination wth other **TSOs** within the **Synchronous Area**.
- Include elements to limit the bandwidth of the output signal. The bandwidth limiting shall be consistent with the speed of response requirements and ensure that the highest frequency of response cannot excite torsional oscillations on other **Power Generating Units** connected to the **Network**. The bandwidth limit shall be specified by the **TSO**.

For the avoidance of doubt there is no requirement for the inertial control system to be active when the **Power Park Module** is operating in **Frequency Sensitive Mode**, although if this can be achieved without control system conflicts, availability of inertial response in this additional mode is desirable.

# 8 REQUIREMENTS FOR OFFSHORE POWER GENERATION FACILITIES

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# 9 COMPLIANCE REQUIREMENTS FOR POWER GENERATING FACILITIES

## 9.1 Compliance Process

R9.1 **DATA PROVISION. Power Generating Facility Operators** shall provide to the responsible **Network Operator** all data, studies and results of both practical and simulation test procedures required by this **Network Code,** national legislation and/ or codes and requirements of the responsible **Network Operator** in order to prove evidence of compliance and to enable the responsible **Network Operator** to issue and notify to the **Power Generating Facility Operator** an **Operational Notification.**

R9.2 **ENERGISATION OPERATIONAL NOTIFICATION (EON).** The Energisation Operational Notification by the responsible **Network Operator** facilitates the **Power Generating Facility Operator** to energise its internal networks. It shall be issued when the grid connection facilities including the protection and control interfaces between the responsible **Network Operator** and the **Power Generating Facility Operator** are established and operational procedures and responsibilities are agreed between the responsible **Network Operator** and the **Power Generating Facility Operator**. The **Power Generating Facility Operator** is not allowed to "synchronise" (the term includes connection of asynchronous generators) the **Generating Unit(s)** at this stage.

R9.3 **INTERIM OPERATIONAL NOTIFICATION (ION).** Before the achievement of full compliance an Interim Operational Notification by the responsible **Network Operator** facilitates the **Power Generating Facility Operator** to synchronise. It shall be issued after the data and study review process is completed successfully by the responsible **Network Operator**, covering:

- Interim Compliance statement by the **Power Generating Facility Operator** – confirming compliance item by item to the extent possible at this stage prior to practical testing
- Detailed technical data of the **Power Generating Facility** with relevance to the grid connection as specified by the responsible **Network Operator**
- If applicable, manufacturer capability type certificates of **Power Generating Units**
- Models as specified by the responsible **Network Operator** for its own steady-state and dynamic system studies
- Studies demonstrating expected steady-state and dynamic performance as specified by the responsible **Network Operator**
- Details of intended practical test procedures for demonstrating compliance

The above shall have been reviewed by the responsible **Network Operator** and the outcome (summarised as unresolved issues) made available to the **Power Generating Facility Operator** before the issue of the **ION** to allow an attachment of responsibilities and conditions associated with unresolved issues.

R9.4 **DURATION OF ION.** No **Power Generating Facility** is allowed to remain in the ION status for more than 24 months. If this is the case, the **Power Generating Facility Operator** shall apply to the responsible **Network Operator** for time limited derogation to complete the compliance process.

R9.5 **FINAL OPERATIONAL NOTIFICATION (FON).** A **FON** shall be issued by the responsible **Network Operator after**

- unresolved issues identified in the ION have been resolved,
- the compliance testing of the **Power Generating Facility** has been completed **successfully**,
- data, models and studies by the **Power Generating Facility Operator** have been updated and
- the final compliance statement has been provided by the **Power Generating Facility Operator** confirming compliance item by item.

If one or more unresolved issues have not been resolved and have no prospect of resolution, then the **Power Generating Facility Operator** can apply for derogation to the responsible **Network Operator**. If derogation has been granted and the **Power Generating Facility** is compliant with the revised requirements according to the derogation, then the **FON** shall be issued. If the derogation is rejected, the **Power Generating Facility** has no right of connection, and the responsible **Network Operator** shall have the right to decide the most appropriate action, including disconnection.

R9.6 **LIMITED OPERATIONAL NOTIFICATION (LON).** This status covers **Power Generating Facilities** which have previously reached **FON** status, but are temporarily subject to either a significant modification or loss of capability, due to implementation of one or more modifications/changes of significance to the performance of the **Power Generating Facility**. Examples of such changes include, but are not limited to:

- Voltage regulator / **PSS** replacements
- Governor & or load controller replacements
- Wind farm central controller reprogramming (affecting P or Q performance of the **Power Park Module**)
- Prime mover, e.g. gas turbine, replacement
- Change of main transformer with different electrical data.

The LON status applies as well, if the performance of the plant is no longer compliant with the relevant requirements due to equipment failures, like amongst others:

- Reduced reactive range (e.g. exciter problems)
- Frequency response capability has become limited or is not available.

If the period from discovery to resolution of the issue is longer than 3 months a **LON** shall be issued by the responsible **Network Operator** to the **Power Generating Facility Operator**.

The **LON** shall be issued by the responsible **Network Operator** to the **Power Generating Facility Operator** with a clear statement on unresolved issues and with responsibilities and timescales for expected resolution.

The duration of the **LON** shall be limited to 12 months, by which time the **Power Generating Facility Operator** needs to apply for time limited derogation to the responsible **Network Operator**, if the unresolved issue has not been resolved in spite of the best efforts of the **Power Generating Facility Operator** to resolve it.

R9.7 **RESPONSIBILITIES OF THE POWER GENERATING FACILITY OPERATOR.** The **Power Generating Facility Operator** shall ensure that the **Power Generating Facility** is compliant with the requirements of this **Network Code,** national legislation and/ or codes and requirements of the responsible **Network Operator** and that compliance is maintained throughout the lifetime of the **Power Generating Facility**.

The **Power Generating Facility Operator** may irrespective of its continued responsibility and liability delegate partially or completely the provision of evidence of compliance to third parties.

The **Power Generating Facility Operator** shall notify to the responsible **Network Operator** any intent to modify the technical capabilities of the **Power Generating Facility** that may have impact on its compliance to the requirements of this **Network Code,** national legislation and/ or codes and requirements of the responsible **Network Operator** in due time prior to such modifications.

The **Power Generating Facility Operator** shall notify to the responsible **Network Operator** any operational incidents or failures of the **Power Generating Facility** that have impact on its compliance to the requirements of this **Network Code,** national legislation and/ or codes and requirements of the responsible **Network Operator** as soon as possible without any intentional delay after the occurrence of such a incident.

The **Power Generating Facility Operator** shall notify to the responsible **Network Operator** any foreseen test schedules and procedures to verify compliance in due time prior to such test and shall facilitate the responsible **Network Operator** to witness such test and, if applicable, to record the performance of the **Power Generating Facility**. The test schedules and procedures shall be subject to approval by the responsible **Network Operator.**

R9.8 **LIFETIME COMPLIANCE MONITORING.** The responsible **Network Operator** shall have the right to monitor compliance of the **Power Generating Facility** to the requirements of this **Network Code,** national legislation and/ or codes and requirements of the responsible **Network Operator** throughout the lifetime of the **Power Generating Facility**. They may request compliance tests to be carried out periodically, if reasonable, and particularly after any failure or modification to the **Power Generating Facility** that may have impact on its compliance to the requirements of this **Network Code,** national legislation and/ or codes and requirements of the responsible **Network Operator**.

R9.9 **RESPONSIBILITIES OF THE RESPONSIBLE NETWORK OPERATOR.** The responsible **Network Operator** shall make publicly available its requirements to prove evidence of compliance. In particular this includes:

- All relevant documentation and certificates
- Detailed technical data of the **Power Generating Facility** with relevance to the grid connection to be provided by the **Power Generating Facility Operator**
- Requirements for models for steady-state and dynamic system studies by the responsible **Network Operator**
- Studies by the **Power Generating Facility Operator** for demonstrating expected steady-state and dynamic performance, which shall include where relevant but not be restricted to:
  - **PSS** Tuning
  - Reactive Capability across the voltage range
  - Voltage Control and Reactive Power Stability
  - Fault Ride Through
  - Load Rejection
  - Voltage and Frequency Controller Model Verification and Validation
  - Sub-synchronous Resonance control and Power Oscillation Damping control for DC Connections
- Procedures and conditions for issuing manufacturer capability type certificates

The responsible **Network Operator** shall make publicly available the allocation of responsibilities for compliance testing, certification and monitoring.

The responsible **Network Operator** may irrespective of its continued responsibility and liability delegate partially or completely its activities in the compliance process to third parties.

R9.10 **COMPLIANCE OF EXISTING POWER GENERATING FACILITIES.** Operators of existing **Power Generating Facilities** shall provide within two years after this **Network Code** has become effective to the responsible **Network Operator** all data, studies, results of both practical and simulation test procedures and compliance statements required by this **Network Code,** national legislation and/ or codes and requirements of the responsible **Network Operator** to the extent these data, studies and test results are available or can reasonably be procured or performed in order to prove evidence of compliance and to enable the responsible **Network Operator** to issue and notify to the **Power Generating Facility Operator** an **Final** or **Limited Operational Notification** (**FON** or **LON**).

If compliance to a requirement of this **Network Code,** national legislation and/ or codes and requirements of the responsible **Network Operator** is failed, but can be reasonably achieved a **LON** shall be issued by the responsible **Network Operator** to the **Power Generating Facility Operator** with a clear statement on unresolved issues and with responsibilities and timescales for expected resolution.

The duration of the **LON** shall be limited to 12 months, by which time the **Power Generating Facility Operator** needs to apply for time limited derogation to the responsible **Network Operator**, if the unresolved issue has not been resolved in spite of the best efforts of the **Power Generating Facility Operator** to resolve it.

If compliance to a requirement of this **Network Code,** national legislation and/ or codes and requirements of the responsible **Network Operator** can not be reasonably achieved, the **Power Generating Facility Operator** shall apply to the responsible **Network Operator** for lifetime derogation with respect to this requirement.

## 9.2 Model Provision and Verification for Synchronous Generating Units

*"Under Development"*

## 9.3 Compliance Tests for Synchronous Generating Units

R9.11 **COVERAGE OF COMPLIANCE TESTS.** The tests specified in this **Network Code** will normally be sufficient to demonstrate compliance of **Power Generating Facilities** with the requirements of this **Network Code** however the **Network Operator** may:

- agree on an alternative set of tests provided the **Network Operator** deems the alternative set of tests efficient and sufficient to demonstrate compliance of the **Power Generating Facility** to the requirements of this **Network Code**, national legislation and/ or codes and requirements of the responsible **Network Operator**; and/or
- require additional or alternative tests if information supplied to the **Network Operator** by the **Power Generating Facility Operator** during the compliance process indicate that the tests defined in this **Network Code** will not fully demonstrate compliance with the relevant section of the **Network Code**.

R9.12 **RESPONSIBILITIES FOR COMPLIANCE TESTS.** The **Power Generating Facility Operator** is responsible for carrying out the tests set out in and in accordance with this **Network Code** and the **Power Generating Facility Operator** retains the responsibility for the safety of personnel and plant during the test. The **Network Operator** shall have the right to witness all of the tests specified by this **Network Code** on site or remotely from the **Network Operator**'s control centre. The **Network Operator** decides whether he witnesses a test on site, remotely or not at all. For all on site **Network Operator** witnessed tests the **Power Generating Facility Operator** shall ensure that suitable representatives from the **Power Generating Facility** and manufacturer (if appropriate) are available on site for the entire testing period. In all cases the **Power Generating Facility Operator** shall provide suitable monitoring equipment to record all relevant test signals and measurements.

R9.13 **COST COVERAGE.** The cost of the tests shall be covered by the **Power Generating Facility Operator.**

R9.14 **ALTERNATIVE FUELS.** If t**he Power Generating Facility** is capable of operating on alternative fuels or fuel mixes, the **Network Operator** shall have the right to require appropriate tests to demonstrate performance when operating on each fuel or fuel mix.

R9.15 **EXCITATION SYSTEM OPEN CIRCUIT STEP RESPONSE TEST**

- Description & purpose of test:
  The **Generating Unit** shall demonstrate its small signal performance of the excitation system. The open circuit step response of the **Excitation System** will be tested by applying a voltage step change from 90% to 100% of the nominal **Generating Unit** terminal voltage, with the **Generating Unit** on open circuit and at rated speed.

- Test assessment:
  The test has been passed, if:
  - for a step change from 90% to 100% of the nominal **Generating Unit** terminal voltage, with the **Generating Unit** on open circuit, the Excitation System response has a damped oscillatory characteristic; and
  - the time of getting the voltage to the rated value by the voltage regulator is shorter than:
    a) 0.3 s – for thyristor static excitation circuits,
    b) 1 s – for electromechanical excitation circuits.

R9.16 **OPEN & SHORT CIRCUIT SATURATION CHARACTERISTICS TEST**

- Description & purpose of test:
  The **Generating Unit** shall demonstrate its idle running and short circuit characteristics to verify its short circuit ratio (SCR).

- Test assessment:
  The test has been passed, if the SCR of the **Generating Unit** is not less than 0.5, where:

$$SCR = \frac{\text{Open Circuit Field Current to obtain 1 pu generator terminal voltage}}{\text{Short Circuit Field Current to obtain 1 pu generator terminal voltage}}$$

## R9.17 REACTIVE POWER REJECTION TEST

- Description & purpose of test:
  The **Generating Unit** shall demonstrate its **Reactive Power** response of the **Excitation System** by applying a **Reactive Power** drop from nominal **Reactive Power** output to open circuit operation (idle operation).

- Test assessment:
  The test has been passed, if after the **Reactive Power** drop:
  - the Excitation System response shall have a damped oscillatory characteristic; and
  - the time of getting the voltage to the rated value by the voltage regulator shall be shorter than:
    a) 0.5 s – for thyristor static excitation circuits,
    b) 1.5 s – for electromechanical excitation circuits.

## R9.18 EXCITATION SYSTEM ON-LOAD RESPONSE TEST

- Description & purpose of test:
  The **Generating Unit** shall demonstrate its:
  - steady-state and dynamic stability of the **Excitation System**;
  - capability of the control system to damp power oscillations damping, if a **PSS** is installed.

- Test assessment:
  The test has been passed, if:
  - the **Excitation System** shall demonstrate performance in accordance with R 6.7 R 6.10 and R6.11; and
  - the continuously-acting automatic excitation control system provides constant terminal voltage control of the **Generating Unit** without instability over the entire operating range.

## R9.19 UNDER EXCITATION LIMITER PERFORMANCE TEST

- Description & purpose of test:
  The **Generating Unit** shall demonstrate its performance of the **Under Excitation Limiter** at low load points and subsequently at, or near, full load by testing its response to a step change corresponding to a 2% decrease in **AVR** reference voltage. The **Under Excitation Limiter** shall be active when the **AVR** is in both auto and manual modes and its settings shall be readily adjustable.

- <u>Test assessment:</u>
  The test has been passed, if:
  – the resulting maximum overshoot does not exceed 4% of the **Generating Unit's Maximum Capacity**;
  – the operating point of the **Generating Unit** shall return to a steady state value within 5 seconds;
  – the control of generator terminal voltage shall have a damped characteristic;
  – the automatic excitation control acts continuously without instability; and
  – the **Under Excitation Limiter** demonstrates performance in accordance with R6.11.

### R9.20 OVER EXCITATION LIMITER PERFORMANCE TEST

- <u>Description & purpose of test:</u>
  The **Generating Unit** shall demonstrate its performance of the **Over Excitation Limiter** and shall provide evidence that the **Over Excitation Limiter** has been set as high as the design limit of the generator allows by testing its response to a step increase in the **AVR** reference voltage that results in operation of the **Over Excitation Limiter** when operating at **Maximum Capacity** and within its continuous **Reactive Power** capability range. The size of the step will be determined by the minimum value necessary to operate the **Over Excitation Limiter** and shall be agreed by **Network Operator** and the **Generator**.

- <u>Test assessment:</u>
  The test has been passed, if:
  – the resulting operation beyond the over excitation limit is controlled by the **Over Excitation Limiter** without tripping the **Generating Unit**;
  – the **Over Excitation Limiter** operation demonstrates an appropriate time delay to avoid over excitation protection tripping;
  – the **Over Excitation Limiter** setting is as close as possible to the machine design limit;
  – the **Over Excitation Limiter** action shall not produce any MVAr or MW oscillations; and
  – the **Over Excitation Limiter** demonstrates performance in accordance with R6.11.

### R9.21 REACTIVE POWER CAPABILITY TEST

- <u>Description & purpose of test:</u>
  The **Generating Unit** shall demonstrate its technical capability to provide leading and lagging **Reactive Power** capability according to R6.1 and R6.2.

- <u>Test assessment:</u>
  The test has been passed, if:
  – the **Generating Unit** has been operated no shorter than 1 hour at maximum **Reactive Power** (leading and lagging) and each of
  a) maximum **Active Power**
  b) minimum **Active Power**

c) an **Active Power** working point between a) and b); and

- the **Generating Unit** has demonstrated its capability to pass the **Reactive Power** range (from maximum leading to maximum lagging) within 3 - 5 minutes when supplying minimum **Active Power**.

## R9.22 FREQUENCY SENSITIVE MODE RESPONSE TEST

- Description & purpose of test:
  The **Generating Unit** shall demonstrate its technical capability to continuously modulate **Active Power** over the full operating range to contribute to frequency control and shall verify the steady state parameters of regulations (insensitivity, droop, dead band, range of regulation) and dynamic parameters, including frequency step change response. The test shall be carried out by simulating frequency steps and ramps big enough to activate the whole **Active Power** frequency response range, taking into account the droop settings and the dead band. Simulated frequency deviation signals shall be injected simultaneously at both speed governor and load controller references if required, taking into account the speed governor and load controller scheme.

- Test assessment:
  The test has been passed, if:
  - activation time of whole full **Active Power** frequency response range as result of a step frequency change has been no longer than required by R5.8, table 6;
  - non-damped oscillations after the step change response have not occurred;
  - initial delay time has been as small as possible and no higher than 2 sec according to R5.8, table 6;
  - minimum time to maintain **Active Power** frequency response has been no shorter than defined according to R5.8;
  - droop settings and dead band are adjustable according to the respective requirements; and
  - insensitivity of **Active Power** frequency response has been not higher than defined according to R5.8, table 5.

## R9.23 LIMITED FREQUENCY SENSITIVE MODE RESPONSE TEST

- Description & purpose of test:
  The **Generating Unit** shall demonstrate its technical capability to continuously modulate **Active Power** to contribute to frequency control in case of large frequency deviation in the system and shall verify the steady state parameters of regulations (insensitivity, droop, dead band , range of regulation) and dynamic parameters, including frequency step change response. The test shall be carried out by simulating high and low frequency steps and ramps big enough to activate at least 10% of **Maximum Capacity Active Power** change, taking into account the droop settings and the dead band. Simulated frequency deviation signals shall be injected simultaneously at both speed governor and load controller references if required, taking into account speed governor and load controller scheme.

- Test assessment:
  The test has been passed, if:
  – the test results (dynamic and static parameters) are in line with R5.9 and R5.10; and
  – non-damped oscillations after the step change response have not occurred.

R9.24 **FREQUENCY RESTORATION CONTROL TEST**

- Description & purpose of test:
  The **Generating Unit** shall demonstrate its technical capability to participate in frequency restoration control. The cooperation of **Frequency Sensitive Mode** and **Frequency Restoration Control** shall be checked.

- Test assessment:
  The test has been passed, if the test results (dynamic and static parameters) are in line with R5.8 and R5.11.

R9.25 **TRIPPING TO HOUSELOAD TEST**

- Description & purpose of test:
  The **Generating Unit** shall demonstrate its technical capability to trip to and stably operate on house load. The test will be done at full load of the **Generating Unit** before load shedding. Further test conditions will be determined by the network operator and will include:
  – operating point of the generating unit
  – frequency control mode
  – point of disconnection from the grid considering R5.17

- Test assessment:
  The test has been passed, if:
  – after tripping, the voltage/ frequency controller has kept generator voltage/ frequency in the permissible range;
  – all generating unit control systems have remained in automatic mode;
  – manual intervention by the **Power Generating Facility Operator** within the first 3 minutes after tripping has not occurred; and
  – the minimum houseload operation time according to R5.17 has been demonstrated.

R9.26 **BLACK START CAPABILITY TEST**

- Description & purpose of test:
  The **Generating Unit** shall demonstrate its technical capability to start from shut down without any external energy supply.

- Test assessment:
  The test has been passed, if:
  – the start-up time has been not longer than the timeframe specified by the **Network Operator**.

## 9.4 Compliance Simulations for Synchronous Generating Units

### R9.27 FREQUENCY SENSITIVE MODE RESPONSE SIMULATION

- Description & purpose of simulation:
  The model of the **Generating Unit** shall demonstrate its capability to simulate **Active Power** modulation over the full frequency range according to table 3 to study compliance in extreme network situations. The simulation shall be carried out by simulating frequency steps and ramps big enough to activate whole **Active Power** frequency response range, taking into account the droop settings and the dead band.

- Simulation assessment:
  The simulation has been passed, if:
  – the model has been validated against the compliance tests for frequency sensitive mode response; and
  – the model has demonstrated compliance with the requirements of operation across the full operating ranges including frequency.

### R9.28 LIMITED FREQUENCY SENSITIVE MODE RESPONSE SIMULATION

- Description & purpose of simulation:
  The model of the **Generating Unit** shall demonstrate its capability to simulate **Active Power** modulation over the full frequency range according to table 3 to study compliance in extreme network situations. The simulation shall be carried out by simulating high and low frequency steps and ramps big enough to reach **Minimum Operating Level** and trip to houseload as well as **Maximum Capacity**, taking into account the droop settings and the dead band.

- Simulation assessment:
  The simulation has been passed, if:
  – the model has been validated against the compliance tests for limited frequency sensitive mode response; and
  – the model has demonstrated compliance with the requirements of operation across the full operating ranges including frequency.

### R9.29 REACTIVE POWER CAPABILITY SIMULATION

- Description & purpose of simulation:
  The model of the **Generating Unit** shall demonstrate its capability to simulate leading and lagging **Reactive Power** capability within the according to R6.1 and R6.2.

- Simulation assessment:
  The simulation has been passed, if:
  - the model has been validated against the compliance tests for **Reactive Power** capability at the prevailing voltage at the time of the test;
  - the model has demonstrated compliance with the requirements across the voltage range according to R6.1, table 8; and
  - the model has demonstrated the level of **Reactive Power** capability available for the voltage range according to tables 4.1 or 4.2 respectively.

## R9.30 FAULT RIDE THROUGH CAPABILITY OF SYNCHRONOUS GENERATING UNITS SIMULATION

- Description & purpose of simulation:
  The model of the **Generating Unit** shall demonstrate its capability to simulate fault ride through capability according to R6.3 or R6.4.

- Simulation assessment:
  The simulation has been passed, if:
  - the model has demonstrated compliance with R6.3 or R6.4 respectively, and R6.5.

## R9.31 POWER OSCILLATIONS DAMPING CONTROL SIMULATION

- Description & purpose of simulation:

- Simulation assessment:
  The simulation has been passed, if:

## R9.32 VOLTAGE STEP SIMULATION

- Description & purpose of simulation:

- Simulation assessment:
  The simulation has been passed, if:

## R9.33 ISLAND OPERATION SIMULATION

- Description & purpose of simulation:

- Simulation assessment:
  The simulation has been passed, if:

R9.34 **BLOCK LOADING SIMULATION**

- Description & purpose of simulation:

- Simulation assessment:
  The simulation has been passed, if:

## 9.5 Model Provision and Verification for PPMs

*"Under Development"*

## 9.6 Compliance Tests for Power Park Modules

R9.35 **REACTIVE POWER CAPABILITY TEST**

- Description & Purpose of Test:
  The **Power Park Module** shall demonstrate its technical capability to provide leading (consumption) and lagging (production) **Reactive Power** capability as a whole **Power Park Module** according to R7.1 and R7.2. The test will be carried out at maximum **Reactive Power** (leading and lagging) and:
  – operation in excess of 60% of maximum capacity for 30 min;
  – operation within the range of 30 – 50 % of maximum capacity for 30 min; and
  – operation within the range of 10 – 20 % of maximum capacity for 60 min

- Test Assessment:
  The test has been passed, if:
  – the **Power Park Module** has been operated no shorter than requested duration at maximum **Reactive Power** (leading and lagging) and:
    a) operation in excess of 60% of maximum capacity ;
    b) operation within the range of 30 – 50 % of maximum capacity;
    c) operation within the range of 10 – 20 % of maximum capacity;
  – the **Power Park Module** has demonstrated its capability to pass the **Reactive Power** range (from maximum leading to maximum lagging) within 3 - 5 minutes when supplying **Active Power** within the range of 30 – 50% of maximum capacity, according to R7.2; and
  – no action of any protection within the operation limits defined by **Reactive Power** capacity diagram has occurred.

R9.36 **VOLTAGE CONTROL MODE TEST**

- Description & Purpose of Test:
  The **Power Park Module** shall demonstrate its capability to operate in voltage control mode according to R7.5.a. During the test it will be verified:
  – the implemented droop and dead band of the static characteristic;
  – the accuracy of the regulation;

- the insensitivity of the regulation; and
- time of **Reactive Power** activation.

- Test Assessment:
  The test has been passed, if:
  - the time of **Reactive Power** activation as result of step voltage change has been no longer than required, according to R7.5.a;
  - the range of regulation and adjustable the droop and dead band has been compliant with agreed characteristic parameters, according to R7.5.a;
  - the insensitivity of Voltage Control has been not higher as 0.01 pu according R7.5.a; and
  - following a step change in voltage 90% of the change in **Reactive Power** output has been achieved within 1 second and settled at the value defined by the operating slope within 5 seconds with a steady state reactive tolerance no greater than 5%.

R9.37 **REACTIVE POWER CONTROL MODE TEST**

- Description & Purpose of Test:
  The **Power Park Module** shall demonstrate its capability to operate in **Reactive Power** control mode according to R7.5.b. This test is complimentary to the Reactive Power Capability Test. During the test it will be verified:
  - the **Reactive Power Setpoint** range and step;
  - the accuracy of the regulation; and
  - the time of **Reactive Power** activation.

- Test Assessment:
  The test has been passed, if:
  - the **Reactive Power Setpoint** range and step has been ensured according to R.7.5b; and
  - the accuracy of the regulation has been compliant with R7.5.b.

R9.38 **POWER FACTOR CONTROL MODE TEST**

- Description & Purpose of Test:
  The **Power Park Module** shall demonstrate its capability to operate in **Power Factor** control mode according to R7.5.c. During the test it will be verified:
  - the **Power Factor Setpoint** range
  - the accuracy of the regulation; and
  - the response of **Reactive Power** due to step change of **Active Power**.

- Test Assessment:
  The test has been passed, if:
  - The **Power Factor Setpoint** range and step has been ensured according to R7.5c;
  - The time of **Reactive Power** activation as result of step **Active Power** change has been no longer than required according to R7.5.c; and

- the accuracy of the regulation has been compliant with the value, according to R7.5.c.

R9.39 **FREQUENCY SENSITIVE MODE RESPONSE TEST**

- Description & Purpose of Test:
  The **Power Park Module** shall demonstrate technical capability to continuously modulate **Active Power** over the full operating range to contribute to frequency control and shall verify the steady state parameters of regulations (insensitivity, droop, dead band, range of regulation) and dynamic parameters, including frequency step change response. The test shall be carried out by simulating frequency steps and ramps big enough to activate whole **Active Power** frequency response range, taking into account the droop settings and the dead band. Simulated frequency deviation signals shall be injected to perform this test.

- Test Assessment:
  The test has been passed, if:
  - the activation time of whole full **Active Power** frequency response range as result of a step frequency change has been no longer than required by R5.8, table 6;
  - non-damped oscillations after the step change response have not occurred;
  - the initial delay time has been as small as possible and no higher than 2 sec according to R5.8, table 6;
  - the minimum time to maintain **Active Power** frequency response has been no shorter than defined according to R5.8;
  - the droop settings and dead band are adjustable according to the respective requirements; and
  - the insensitivity of **Active Power** frequency response has been not higher than defined according to R5.8, table 5.

R9.40 **LIMITED FREQUENCY SENSITIVE MODE RESPONSE TEST**

- Description & Purpose of Test:
  The **Power Park Module** shall demonstrate its technical capability to continuously modulate **Active Power** to contribute to frequency control in case of large frequency deviation in the system and shall verify the steady state parameters of regulations (insensitivity, droop, dead band, range of regulation) and dynamic parameters, including frequency step change response. The test shall be carried out by simulating frequency steps and ramps big enough to activate at least 10% of **Maximum Capacity Active Power** change, taking into account the droop settings and the dead band. Simulated frequency deviation signals shall be injected to perform this test.

- Test Assessment:
  The test has been passed, if:
  - the test results (dynamic and static parameters) are in line with R5.9 and R5.10; and
  - non-damped oscillations after the step change response have not occurred.

R9.41 **FREQUENCY RESTORATION CONTROL TEST**

- Description & Purpose of Test:
  The **Power Park Module** shall demonstrate its technical capability to participate in frequency restoration control. The cooperation of Frequency Sensitive Mode and Frequency Restoration Control shall be checked.

- Test Assessment:
  The test has been passed, if the test results (dynamic and static parameters) are in line with R5.8 and R5.11.

R9.42 **LIMITED ACTIVE POWER CONTROL MODE (ACTIVE POWER CONTROLLABILTY)**

- Description & Purpose of Test:
  The **Power Park Module** shall demonstrate its technical capability to operate at a load level no higher than the **Setpoint** sent by Network Operator.

- Test Assessment:
  The test has been passed, if:
  - the load level of the **Power Park Module** has been kept below the sent **Setpoint**;
  - the **Setpoint** has been implemented within in the specified according to R5.4; and
  - the accuracy of the regulation has been compliant with specified value according to R5.4.

### 9.7 Compliance Studies for PPMs

*"Under Development"*

## 10 GLOSSARY

**Active Power Frequency Response** - Automatic response of **Active Power** output from a **Power Generating Facility**, in response to a change in **System Frequency** from the **Nominal System Frequency**

**Balance Regulation –** The process of ensuring an equate margin of generated power to support demand which is required in order to maintain the **Network** or any portion of it in an **Isolated Grid Operation** situation.

**Black Start -** The procedure necessary for recovery of a **Power Generating Facility** from a total Shutdown without any external energy supply.

**Connection Agreement -** A contract between the **Network Operator** and the **Power Generating Facility** which includes site specific requirements for the **Power Generating Facility** complimentary to requirements defined in the applicable **Network Code**.

**De-load -** The condition in which delivery of electrical power by a Generating Unit to the System to which it is synchronised has been reduced.

**Derogation -** A time limited or indefinite (as specified) acceptance in writing by the Responsible Body of a non-compliance of a **Power Generating Facility** with regard to identified NC requirements.

**Droop -** The ratio of the steady state change of speed or in Frequency to the steady state change in power output.

**DSO -** Distribution System Operator - is a company that is responsible for operating, maintaining and developing distribution systems.

**Emergency Instruction -** An instruction issued by the **Network Operator** to a **Power Generating Facility** which may require an action or response which is outside the limits provided by the **Power Generating Facility** regarding its plant and apparatus. This may include its availability, current capabilities, and operating characteristics.

**Energisation Operational Notification or EON -** A notification certificate by the **Network Operator** to a **Power Generating Facility** owner prior to energisation.

**Final Operational Notification or FON -** A notification certificate by the **Network Operator** to a **Power Generating Facility** owner confirming that the **Power Generating Facility** has demonstrated compliance with the **Network Code**.

**Generating unit -** A **Generating unit** is an indivisible set of installations which can generate electrical energy. The **Generating unit** may for example be a thermal power unit, a single-shaft combined-cycle plant, a single machine of a hydro-electric power plant, a wind turbine, a fuel cell stack, or a solar module. If there are more than one **Generating Units** within a **Power Generating Facility** that cannot be operated independently from each other then each of the combinations of these units shall be considered as one **Generating Unit**.

**Interim Operational Notification or ION -** A notification certificate by the **Network Operator** to a **Power Generating Facility** owner to undertake compliance tests to meet the **Network Code**.

**Instruction -** A command given orally, manually or by automatic remote control facilities from a **Network Operator** to a **Power Generating Facility** in order to perform an action requested by such a command

**Isolated Network Operation -** Independent operation of a part of the **Network** that is isolated after its disconnection from the interconnected system, having at least one **Generating Unit** in operation with ability to speed/frequency control.

**Maximum Capacity -** The maximum continuous power which can flow from a **Power Generating Facility** connected into the **Network**.

**Maximum Rate of Change –** The maximum rate of adjustment of a parameter (i.e. voltage or frequency) that is permissible in response to a triggering event (i.e. a new target **Setpoint**)

**Minimum Operating Level -** Maximum **Active Power** that generating units can generate continuously with minimum primary energy supply

**Minimum Rate of Change -** The minimum rate of adjustment of a parameter (i.e. voltage or frequency) that is permissible in response to a triggering event (i.e. a new target **Setpoint**)

**Network –** is a number of electrical power components connected together and working to transmit electrical power from one point to another within that **Network**.

**Network Code –** is a document setting out the code of practice, typically setting standards or operating procedures, agreed by Entsoe. The agreed document will subsequently be submitted to the CEER and ultimately will become European legislation.

**Network Operator –** The network operator is a **TSO** or a **DSO**.

**Operating Standards -** The standards utilised by the relevant **Responsible Body** and/or **Network Operator** to determine the requirements for operation of **Users** and/or the Network**.**

**Planning Data –** Data specified by each **Responsible Body** required to perform analysis of the **Power Generating Facility**

**Planning Standards –** The standards utilised by the relevant **Responsible Body** to ensure by analysis the requirements for connection of a **Power Generating Facility,** and associated **Network** reinforcement requirements.

**Point of Common Coupling or PCC –** Interface point between the **Power Generating Facilities** equipment and the **Network Operators** equipment

**Power Factor -** The ratio of Active Power to Apparent Power

**Power Generating Facility –** Any facility connected to a **Network** by a **PCC** which converts energy to electrical power for **Export** to that Network.
**Power Park Module or PPM -** Multiple interconnected **Generating Units** which are not synchronous and have a common **PCC** to the **Network**. Examples are wind farms, solar, wave and tidal **Generating Power Facilities**.

**P-Q-Capability Diagram –** The **Reactive Power** capability of a **Power Generating Facility** in context of varying **Active Power**.

**Power System Stabilizer or PSS** - additional feature of voltage control to damp electro-mechanical oscillations of the generating unit.

**Responsible Body -** The entity identified by National Legislation / Licence or Regulation to manage applications for **Derogation** within the geographical area of a **Network Operator.**

**Secured Fault** - A **Secured Fault** is defined as a fault, which the grid is required to withstand without loss of demand or generation according to the planning criteria, when this fault is cleared according to the primary protection scheme.

**Setpoint –** A target value for any parameter typically used in control schemes.

**Slope -** The ratio of the steady state change in Reactive Power output, in per unit of Reactive Power capacity, to the steady state change in voltage, as a percentage of the nominal voltage. For avoidance of doubt, the value indicates the percentage voltage reduction that results in a 1p.u. increase in Reactive Power generation.

**Speed/frequency control** - capability of a generating unit to control speed/frequency and to maintain stable operation within an isolated grid.

**Statement of Compliance -** A document provided by the **Power Generating Facility** to the Network Operator stating the current status with respect to compliance itemised for each element of NC and site specific requirements in a **Connection Agreement**.

**Steady-State Stability -** If the **Network** or a synchronous machine previously in the steady state reverts to this state again following a sufficiently “minor” fault, it has S**teady-State Stability**. If no control equipment is involved in this process, the characteristic is described as natural **Steady-State Stability**, otherwise as artificial **Steady-State Stability**. The instabilities may be a single swing or oscillatory.

**Synchronous Generating Unit –** A **Generating unit** that is synchronously connected to the network.

**Synthetic Inertia -** A facility provided to replicate the effect of inertia of a **Synchronous Generating Unit** to a prescribed level of performance.

**TSO** - Transmission System Operator - is a company that is responsible for operating, maintaining and developing the transmission system for a control area and its interconnections.

**Transient stability.** Should a Network which has suffered a “major” failure progress through decaying transient phenomena to its original steady state, it demonstrates transient stability with regard to the nature, location and duration of this fault. The steady state following a fault may be identical to that prior to the fault, or may differ from it. The non-linear formulae for synchronous machines shall be used for analysis of the transient stability. The term “overall stability” is commonly used in control technology.

**U-Q-Capability Diagram –** The **Reactive Power** capability of a **Power Generating Facility** in context of varying voltage.

**User Self Certificate of Compliance -** A statement by an Owner of a **Power Generating Facility** declaring its compliance with the applicable **Network Code** and site specific requirements in a **Connection Agreement** and defining specific requirements for which the plant is either non-compliant or has not yet had opportunity to demonstrate compliance.