TECHNICAL PAPER – DEFINITION OF A SET OF REQUIREMENTS TO GENERATING UNITS

September 2008

COVER NOTE

It is the TSOs' responsibility to ensure the interconnected electric power system security with a high level of reliability and quality concerning system management, frequency stability and voltage stability to prevent any large disturbance or to facilitate system restoration after a disturbance.

Secure system operation is only possible by close cooperation of generating units with the TSOs, because the system behaviour especially in disturbed operating conditions largely depends on the response of generating units to deviations from nominal values of voltage and frequency. It is therefore of crucial importance that generating units are obliged by the TSOs to meet technical requirements relevant to system security. Moreover appropriate dynamic behaviour of generating units, protection levels and control facilities are necessary in normal operating conditions and in a range of disturbed operating conditions in case of perturbations to the system or during system restoration in order to preserve or to re-establish system security and equipment integrity.

To ensure system security within the interconnected UCTE system and to provide a common security level it is essential that the TSOs within UCTE have a common understanding on requirements to generating units. The document "TECHNICAL PAPER – DEFINITION OF A SET OF REQUIREMENTS TO GENERATING UNITS" sets up such a minimum set of requirements.

Regarding the recent growth of generating units connected to the distribution grid (especially combined heat and power generators and wind generators), their impact on the electric system in normal and disturbed situations and 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 system as to the lower-level distribution grids.

The minimum requirements in this paper set up a common framework for grid connection agreements between TSOs and power plants. TSOs are therefore asked to implement these requirements into national regulations. They are entitled to impose additional or more precise requirements on the generating units when needed for secure system operation. Observation of the requirements placed upon generating units and the pertinent contractual framework conditions shall be ensured by appropriate bilateral agreements between the TSO and the power plant.

The implementation of the requirements by generating units and the respective impact on secure system operation will be observed and analysed continuously by UCTE. The experiences derived therefrom will result in a further development of this set of requirements.

DISCLAIMER

The present Requirements to Generating Units are to be considered as a 'non final discussion paper' subject to further review and possible improvements and/or modifications namely by UCTE and its members and cannot therefore be considered as a final and binding document or a position paper. Moreover, the said Requirements do not bind or create any liability whatsoever on behalf of UCTE and/or on behalf of all or part of its members, collectively or individually. Any possible generating unit complies with the present Requirements under its sole and unique liability and responsibility, and by doing so waives expressly to invoke towards any person UCTE's and/or all or part of its members' possible liability in front of any courts/tribunals/arbitrators, national or international or similar body.

CONTENT

1 INTRODUCTION

The Transmission system operators (TSOs) within UCTE are responsible for providing and operating high and extra-high voltage grids for long-distance transmission of electricity as well as for supply of lower-level regional distribution systems and directly connected, usually industrial customers with energy-intense and sensitive production processes. Besides this transmission and supply task it is also the TSOs' responsibility to ensure the system security with a high level of reliability and quality. To perform a secure system operation and to meet the reliability and quality demands the provision of several so called system services is necessary.

System services refer to the services essential to the proper functioning of the electrical power transmission and distribution system as a whole provided by TSOs for connection users in addition to the transmission and distribution of electrical energy, which thereby determine the quality of power supply:

- Frequency stability
- Voltage stability
- System restoration after a disturbance
- System management

Due to the fact that TSOs cannot ensure the security of operation irrespective of the conditions of operation of power stations, TSOs call for a regular coordination at the level of generation and for a sufficient performance of equipment connected to their networks with robustness to face disturbances and to help to prevent any large disturbance or to facilitate restoration of the system after the collapse.

Secure system operation is only possible by close cooperation of generating units with the TSOs, because the system behaviour especially in disturbed operating conditions largely depends on the response of generating units to deviations from nominal values of voltage and frequency. Regarding system security the transmission system and the generating units need to be considered as one entity from a systems engineering approach. It is therefore of crucial importance that generating units are obliged by the TSOs to meet the relevant technical requirements concerning system security. Moreover appropriate dynamic behaviour of generating units, protection levels and control facilities are necessary in normal operating conditions and in a range of disturbed operating conditions in case of perturbations to the system or during system restoration in order to preserve or to re-establish system security and equipment integrity.

The technical requirements to generating units shall be accountable and measurable to allow the TSOs to check and verify their fulfilment according to established good practise during commissioning of new generating units as well as repeatedly during operation or after maintenance.

To ensure system security within the interconnected UCTE system and to provide a common security level it is essential that the TSOs within UCTE have a common understanding on these requirements to generating units and a common set is defined as a basis for bilateral agreements between each TSO and generating units connected to its grid.

2 RESPONSIBILITIES OF TSOS INVOLVING GENERATING UNITS

The requirements to generating units defined in this document are essential for TSOs to manage the following responsibilities for operating the interconnected UCTE electric power transmission system:

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

Regarding:

- the recent growth of generating units connected to the distribution grid (especially combined heat and power generators and wind generators),
- 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 system as to the lower-level distribution grids.

To ensure that these requirements are properly taken into account by power station operators, incentives such as performance checks with potential consequences in case of incompatibility are to be put into effect.

2.1 System supervision

In order to ensure proper system operation, TSOs need to perform security analysis for actual 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 TSOs need:

- to know the availability of generating units to produce power and to provide ancillary services (actually and forecasted)
- to know their technical characteristics and capabilities and to be informed of temporary limitations (e.g. reactive power supply limitations, inability to change active power)
- to be informed of generation schedules (hours/days ahead) especially for those units connected to the transmission grid
- to get the actual active and reactive power output from the generating units connected to the transmission and distribution grids

To prevent disturbances to the system or to restore the system after a disturbance TSOs need to be entitled and to have the facilities to modify the actually scheduled generation.

2.2 System balance / frequency stability

Electric power generation and load demand (including grid losses) always need to be balanced. The TSOs have to ensure at any time that this balance is maintained. To manage this responsibility TSOs need to have the ability to face:

- the variation of load demand, that leads to gaps between forecasted and actual consumption,
- the contingencies that occur on the grid by outages of generating units or loads.

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 / increases when the load demand is higher / lower than the power generation. To maintain / re-establish the equilibrium

the mechanism of load-frequency control is applied by the TSOs. The necessary control power by means of primary control, secondary control and minute reserves is provided by power stations. Market mechanisms are implemented for contracting this control power by the TSOs.

To adjust the overall power generation instantaneously to the actual load demand it is necessary that:

- the generating units are able to increase / decrease their production quickly, so generation reserve margins are needed in both directions
- due to the stochastic nature of load variation and contingencies, the control power provision mechanism has to work automatically.

Moreover, to be able to cope with big disturbances that deeply impact the 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.

2.3 Voltage stability

The voltage of a point in the grid is not constant. In a first approximation, it depends on:

- its 'electrical distance' from the generating units that support the voltage,
- the reactive power flow in the grid that implies the voltage profile,

In order to maintain the voltage in acceptable ranges everywhere in the grid, to prevent the network from voltage collapses, and to globally optimise the grid, the generation units have to be able to provide reactive power to the grid within a definite range. This range has to be wide enough, as reactive power cannot be transmitted throughout the grid over long distances.

Insufficient reactive power supply can lead to unacceptable low voltage levels and finally to a voltage collapse of the system. Thus the TSOs need to care for a balanced voltage profile in the grid by advising the generating units the supply of reactive power or a grid voltage level which is achieved by the provision of reactive power by generating units.

2.4 System robustness

The transmission grid is inevitably exposed to perturbations like tripping of lines or generating units. The often consequences of such perturbations are voltage dips 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 in a more or less spread area of the grid 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 system
- the reconnection shall be subject to prior agreement with the responsible TSO 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, this sub-network shall be viable, which can be ensured by the performance features of the generating units in this island.

2.5 System restoration

After a severe black-out:

- it could be impossible or it can be very time consuming to reconnect step by step parts of the disturbed network to the sustained grid
- the security requirements of particular generating units (especially nuclear power stations) imply that external voltage shall be available within limited time

To enable system restoration by own means it is necessary for each TSO to have generating units available to be started and operated stable restore voltage to the grid without external voltage (black start capability, houseload operation capability).

3 COVERAGE AND GENERAL STATEMENTS

This technical paper defines a common set of requirements to generating units to be connected to the UCTE transmission system. It sets up a common framework for grid connection agreements between TSOs and power stations. TSOs are entitled to impose additional requirements on the generating units when needed for secure system operation. Requirements in this paper with the purpose to define UCTE-wide common methods and principles have to be detailed in the coverage of single TSOs (e. g. by explicit threshold or parameter values) especially to be able to consider specific regional system conditions (e. g. areas with high or low density of demand or concentration of generating units). Observation of the requirements placed upon generating units and the pertinent contractual framework conditions shall be ensured by appropriate bilateral agreements between the TSO and the power station.

The requirements defined in this paper shall apply to all new generating units above a minimum size of capacity. This capacity threshold can be defined by each TSO individually according to its specific system characteristics. A generating unit is considered as “new” if it does not exist or has not been contracted bindingly with the manufacturer as of the release date of this paper.

In principle these requirements shall fully apply to all generating units covered by this paper ensuring that they will not endanger human safety or suffer any physical damage. If in single cases a generating unit can not (fully) comply with a certain requirement for material/serious technical reasons a release from / change of this specific requirement shall be agreed with the responsible TSO on a bilateral basis.

Each TSO shall endeavour to ensure that these requirements are met by generating units connected to its lower-level distribution systems as well, e. g. by agreeing with the distribution systems operators on these requirements. Especially information on generation schedules and actual generation shall be provided by power stations connected to lower-level distribution systems to the TSO on request for system security analysis.

If in single cases a contradiction between the following requirements and a national legal basis might occur then the national legal basis prevails. In such cases TSOs shall work towards a future adaptation of the legal basis to gain compliance with these requirements.

4 CLASSIFICATION OF REQUIREMENTS

A reasonable approach to identify the importance of requirements to generating units is to classify them according to their impact and consequences for system operation under normal and emergency conditions (insecure operation and system restoration after a collapse). Ranking criteria are the impacts of these requirements on system security and reliability. The following categories are applicable:

- Relevance to UCTE system security

  The relevance to UCTE system security is characterised by criteria that have system-wide impacts and are intended to prevent system-wide emergency situations or even black-outs. Especially criteria with respect to the grid frequency such as operation of generating units in over- or underfrequency conditions or disconnection of generating units in case of deviations of the frequency from its nominal value, or frequency limits for indefinite nominal active power supply can be identified in this category. Another issue to be mentioned are wide-scale inter-area oscillations that can be antagonised appropriately by Power System Stabilizers or comparable installations. Furthermore the mutual provision of control power needs some system-wide common standards as it is strongly related to the frequency criteria.

- Relevance to TSO security level

  This category is characterised by requirements, that are needed to ensure system security on a regional basis and that have significant impact on the regional grid the generating unit is connected to. The requirements support to achieve a comparable security level within the UCTE interconnected transmission system. Typical requirements for this category are reactive power supply conditions, operation in emergency situations such as the capability to withstand grid faults without tripping and also the behaviour of generating units after disconnection from the grid to enable a fast reconnection in the restoration phase (black start units, capability of house load operation).

- Relevance to impacts on the local/regional grid

  Requirements mainly covering normal operation conditions of the regional grid the generating units are connected to belong to this category. Examples are settings of voltage control and protection equipment to co-ordinate grid and unit protection and other equipment design parameters. Some of these aspects can need coordination between neighbouring TSOs.

5 COMMON LEVEL OF REQUIREMENTS

Based on the structuring the common level of the requirements is to be defined. The necessary degree can be determined by the extent of the system-wide impact of each requirement. For the most important mandatory requirements with relevance to UCTE system security a common level of methods and principles is necessary and a common agreement on specific parameters and settings is endeavoured.

For requirements with lower impacts it is assumed that a mutual agreement on methods and principles provides sufficient standardisation. At least it is ensured that the same issues are covered by each TSO within UCTE. Individual methods/principles and parameters/settings to achieve the same target are acceptable.

The fulfilment of the technical requirements shall be measurable to allow the TSOs to check and verify them according to established good practise during commissioning of new generating units as well as repeatedly during operation or after maintenance. Moreover an investigation of the behaviour of power stations during and after disturbances to the system can be considered as a performance check to verify the compliance with the technical requirements defined in this paper.

Methods and procedures for performance checks are not within the scope of this paper.

6 REQUIREMENTS WITH RELEVANCE TO UCTE SYSTEM SECURITY

6.1 Objectives

The requirements in this chapter are deemed to be relevant for the UCTE system security. The intention of these requirements is to prevent system-wide emergency situations or even black-outs. They define the ability to cope with situations that occur under normal system operation conditions as well as in case of disturbances to the system. In the latter case these requirements improve the capability of the system to return to a normal operation condition and avoid the aggravation of a disturbance to an emergency situation.

6.2 Steady-state stability requirements

Tripping and power reduction is prohibited due to phase swinging and power oscillations in the UCTE synchronous area (currently frequencies of 0.2 to 1.5 Hz are observed).

TSOs are entitled to require appropriate equipment/functions to be installed (e.g. Power System Stabilizer (PSS), Power Swing Blocking, etc.) to prevent or attenuate phase swinging and power oscillations. The settings of these equipment/functions are agreed between the responsible TSO and the power station operator.

Steady-state stability is normally required for any working point in the generator output diagram.

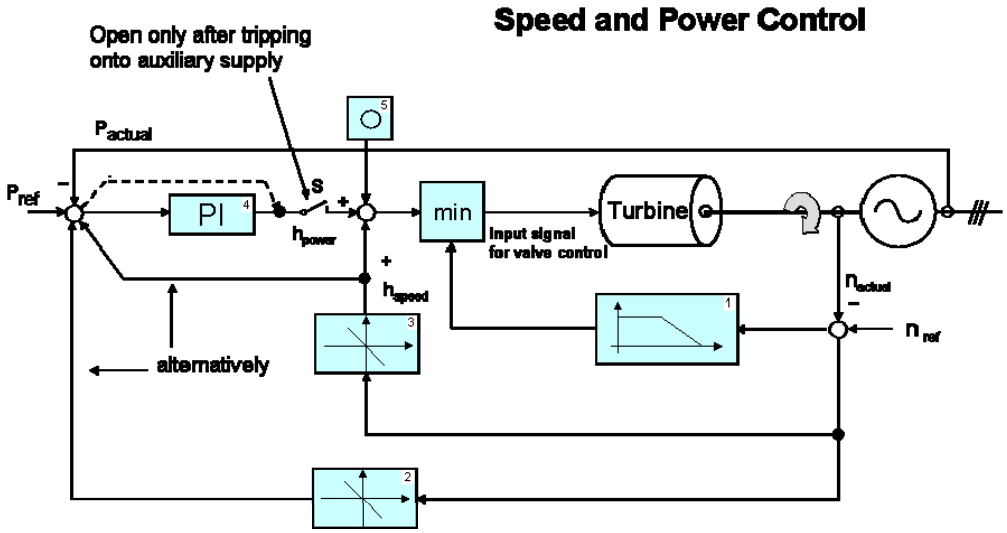
6.3 Speed and power control

The following control structure is an example for speed and power control[1], which ensures an appropriate operational performance especially under conditions according to chapter 6.4 and 6.5. It has to be ensured that the output signal of the speed controller is continuously active in the control loop to form the input signal for the turbine valves po-

[1] Different control structures are established in existing power stations within UCTE. These structures may require the selection of control modes or the change of parameters. The procedures for selecting/changing the control mode / parameters (e. g. frequency values to initiate such a change) shall be well agreed between the responsible TSO and the power station operator according to UCTE rules/recommendations.

sition.

In case of conditions described in chapter 6.4 or 6.5 the adaptation of the generation according to the required power frequency characteristic of the unit might lead to significant deviation from the scheduled generation. In these cases a manual or automatic adaptation of the value of P_{ref} by the power station operator aiming to meet commercial schedules is prohibited. Any rescheduling of the generation has to be performed only after directive of the system operator.



1: Automatic reduction of generation in proportion to the overfrequency with a droop of 4 – 8%. This overfrequency impact on generation shall be activated at a common frequency value in UCTE.

2: Primary control

3: Proportional speed control

4: Power control (Proportional Integral)

5: Speed load changer (manual adjustment of working point)

6.4 Capability of isolated grid operation

Stable operation of the generating unit during isolated grid operation (separation of a grid with one or more generating units from the UCTE interconnected system) shall be ensured (e. g. for thermal units by coordinated operation of turbine governor esp. speed governor control with boiler/steam production power control to enable fast adjustments of steam flow). During isolated grid operation an interception of the generation units in the isolated grid on the actual remaining demand should be possible. Details on the characteristics (e.g. minimum load, level of load change, load change rate) shall be agreed between the TSO and the power station operator.

To avoid contradiction between power and speed control during isolated grid operation the P_{ref} value should be blocked or the power control output signal should be switched to a speed load changer output signal.

6.5 Operation under overfrequency/underfrequency

Control power shall be provided according to chapter 6.7.

In line with national standards TSOs are entitled to define requirements which describe:

- Capability to unload to any working point down to minimum power in case of overfrequency due to surplus of generation. The generation of each unit has to be reduced automatically in proportion to the overfrequency with a droop of 4 – 8%. This overfrequency impact on generation shall be activated at a common frequency value in UCTE.
- Capability to increase automatically generation due to frequency decrease. The generation of each unit under primary control has to be increased automatically in proportion to the underfrequency.
- Each TSO is can agree with the power station operator on additional generation to be made available / to be reduced automatically (e. g. extraordinary primary control in case of larger frequency deviations of more than 200 mHz) taking into consideration system needs and technical capabilities of a generating unit.
- Changes of control parameters shall be agreed with the responsible TSO.

6.6 Disconnection of the generation unit from the grid

To enable the system to return to normal operating conditions after disturbances and to avoid the aggravation of such a disturbance to an emergency situation or a system collapse it is of crucial importance that generating units stay connected to the system if system parameters deviate from their nominal values to a certain extent ensuring that they will not endanger human safety or suffer any physical damage.

Any automatic disconnection of the generating unit from the grid is prohibited for frequencies between 47.5 and 51.5 Hz because of the deviation of the frequency from its nominal value. TSOs and power station operators can agree on wider frequency ranges and further conditions for disconnection to make best use of the technical capabilities of a generating unit if needed to prevent a major disturbance to its system. It can include that generating units do not disconnect from the grid unless a disconnection is triggered by unit protections (e. g. overspeed protection) to prevent damage to the unit or the turbine valves are completely closed by the overfrequency power reduction control scheme. This applies for generating units directly connected to the TSO grid as well as for generating units connected to TSO customer grids (e. g. industrial sites). If specific disconnection concepts are considered necessary e. g. to secure industrial processes, these concepts shall be agreed with the TSO in advance. In such cases both the generating units and associated loads shall be regarded.

Generating units shall be able to operate in under- and overvoltage situations. Each TSO is entitled to define a range of quasi-steady voltage at the grid connection point in which automatic disconnection from the grid is prohibited.

In the event of the loss of stability of a single generating unit, this generating unit shall disconnect automatically from the network in order to support preservation of system security and to prevent damage from the generating unit. The TSO and the power station operator will agree on the criteria to recognize loss of stability and the subsequent automatic disconnection.

Tripping of the generating unit onto auxiliary supply (houseload operation) due to under-/overfrequency, under-/overvoltage at the grid connection point or short-circuit in the transmission system shall be endeavoured generally after automatic disconnection from the grid taking into consideration the definitions in chapter 7.3.

6.7 Load-frequency control

6.7.1 Primary control

The capability to provide primary control is mandatory for generating units above a minimum capacity to be defined by each TSO.

Each TSO is entitled to define a minimum primary control range for generating units in terms of P_r. The primary control range must be adjusted as instructed by the TSO when participating in primary control.

The droop of the turbine controller shall be adjustable and has to be agreed between the TSO and the power station operator taking into consideration the TSO's needs for primary control reserve.

The total contractually agreed primary control power shall be fully activated at a quasi-steady frequency deviation of ± 200 mHz within 30 sec. The minimum duration for the capability to supply primary control is 15 minutes in case of a persisting frequency deviation. The same rate of power change shall apply in case of minor frequency deviations.

For primary control the accuracy of frequency measurement for new units shall be below 10 mHz and the measurement cycle must be in the range of 0.1 sec to 1 sec.

For primary control, the insensitivity range shall be as low as possible and should not exceed ± 10 mHz. A flexible dead band and its settings can be agreed between the TSO and the power station operator.

6.7.2 Secondary control

Each TSO defines requirements for provision of secondary control to be met on a mandatory basis or as a prerequisite to enter the control power market, specifically:

- secondary control range
- load change rates
- activation and supply duration
- control concepts

6.7.3 Monitoring of primary and secondary control

To monitor the operation of primary and secondary control the following signals shall be transmitted by the power station operator to a communication interface connected to the system control centre on request by the TSO:

- Generating units participating in the provision of primary control
    - status signal of primary control (on/off)
    - control mode of turbine governor (power control, speed control, temperature control for combined-cycle power stations)
    - actual value of the active power output
    - actual setpoint value for primary control

- Generating units participating in the provision of secondary control
    - status signal of secondary control (on/off)
    - control mode of turbine governor (power control, speed control)
    - scheduled active power output
    - actual value of the active power output
    - range of secondary control (upper/lower limit)
    - actual setpoint value for secondary control in the generating unit

The setpoint value for secondary control power is transmitted by the TSO from the load-frequency controller in the system control centre to the communication interface.

Furthermore the TSO and the power station operator can agree on additional monitoring and/or recording devices to be installed in power stations to check the performance of the primary and/or secondary control 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).

If the primary and/or control power is provided by a virtual generating unit via a "pool operator", the "pool operator" is obliged to provide the signals requested by the TSO at the communication interface. The TSO and the power station operator can agree on additional monitoring and/or recording devices to be installed in the power stations forming the pool to check the performance of the primary and/or secondary control provision.

7 REQUIREMENTS WITH RELEVANCE TO TSO SECURITY LEVEL

7.1 Objectives

The requirements in this chapter are necessary to ensure system security on a regional basis and have significant impact on the regional grid the generating unit is connected to. They aim to enable a stable voltage profile and to return to a local/regional voltage in the normal operation range quickly after disturbances. For example, with respect to this target generating units shall either stay connected to the grid in case of a voltage dip or, if a disconnection is inevitable, the tripping onto auxiliary supply is a prerequisite for a fast reconnection.

7.2 Transient stability requirements

- Short circuits in the grid near the generation unit (generator voltage dip exceeds certain value of nominal generator voltage determined by each TSO)

  Disconnection of generating units from the grid is prohibited, if faults are cleared as fast as possible taking into consideration the short-circuit power level at the grid connection point after fault clearance. The required fault clearance time to prevent disconnection is agreed between the TSO and the power station operator.

  In these cases automatic switching of auxiliary supply to reserve supply connections shall be avoided if normally the auxiliary supply is supplied from the feeding connection (e. g. generator leads or tertiary connection to the step-up transformer) unless it is ensured that by switching the auxiliary supply to reserve connections the

operation of the generating unit is not jeopardized.

- Short circuits in the grid far from the generation unit (generator voltage dip is below certain value of nominal generator voltage determined by each TSO taking into account the ceiling voltage of excitation)

  Disconnection of generating units is prohibited until faults are cleared by reserve protection with maximum time delay according to each TSO's standard. Generator voltage shall remain within its admissible range by activating the ceiling function of excitation systems.

7.3 Tripping onto auxiliary supply

The generating unit must be designed for reliable tripping onto auxiliary supply from any working point permitted by the generator output diagram and particularly in situations according to chapter 6.6.

The position signal of the circuit breaker in the feeding bay at the grid connection point 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 grid connection point are open). Unloading the generating unit to stable houseload operation has to be ensured in such cases as well.

Exceptionally, if tripping onto auxiliary supply is not possible the generating unit shall be capable to reconnect to the system on request by the TSO within a determined timeframe.

Tripping onto auxiliary supply is required in case of disconnection of the generating unit from the grid in line with protection strategy agreed between the TSO and the power station operator in the event of disturbances to the system.

Generating units must be capable of continuing operation following tripping onto auxiliary supply without any connection to the external grid. The minimum operation time in that mode depends on each TSOs standards.

7.4 Voltage control

Each generation unit is obliged to contribute to control voltage either on the generator voltage level or the voltage level at the grid connection point within design parameters of the generators. This contribution shall be realised automatically and/or manually according to TSO standards. If voltage is controlled at the grid voltage level, the voltage control range is determined by the TSO.

7.5 Reactive Power Supply Capability

Each TSO is entitled to determine the reactive power supply capabilities of generating units on a national/regional basis or bilaterally taking into consideration the specific system characteristics including specifications and control schemes for step-up transformers and generators. During disturbances to the system sufficient capabilities to supply reactive power are required to prevent a system collapse and have to be mobilised on request even if this enforces a reduction of active power supply.

8 REQUIREMENTS WITH RELEVANCE TO IMPACTS ON THE LOCAL/REGIONAL GRID

8.1 Objectives

The requirements in this chapter mainly cover standards and facilities for normal operation conditions of the local/regional grid the generating units are connected to. They are based on operational standards and guidelines by the TSOs for system operation.

8.2 Electrical protection schemes and settings

Protection schemes and settings relevant for the power station and the grid shall be coordinated and agreed between the TSO and the power station.

Settings to protect the grid are determined by the TSO taking into account the characteristics of the power station.

Protection schemes can include:

- external and internal short circuit
- unsymmetrical load
- 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
- generator swinging
- over- and under-frequency
- asynchronous operation (pole slip)
- shaft torsions
- generator line protection
- unit transformer protection
- backup schemes against protection and switchgear malfunction

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 grid in case of unacceptable operational states.

8.3 Control schemes and settings

Schemes and settings of the turbine and generator control shall be agreed between the TSO and the power station if relevant for system stability, especially for:

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

8.4 Behaviour in case of auto-reclosures

TSOs are entitled to request successful single-phase auto-reclosures on generator feeding lines to be withstood by generating units without adverse impacts on their

operation.

TSOs are entitled to request successful single-phase auto-reclosures on transmission lines near to a connection point to be withstood by generating units without adverse impacts on their operation.

The requirements in case of three-phase auto-reclosures on transmission lines near to a connection point have to be agreed to in common by the TSO and the power station operator.

8.5 Black-start capability

This feature needs to be agreed individually between the TSO and the power station taking into consideration the TSOs needs for black-start capability and the local system conditions.

In particular, every black start generating unit shall have the capability to control voltage and speed/frequency during supply isolated operation.

8.6 Synchronisation

When starting a generating unit synchronisation shall be performed by the power station with the circuit breaker at the generator leads after authorization by the TSO. The generating unit shall be equipped with the necessary synchronisation facilities.

Reconnection of the generating unit after tripping onto auxiliary supply is performed by the circuit breaker at the grid connection point in accordance to the TSOs standards, by the power station with the consent of the TSO.

Synchronisation of generating units shall be possible at least for frequencies between 49 and 51 Hz. Each TSO is entitled to require a wider frequency range.

The TSO and the power station operator agree on the settings of synchronisation devices (voltage, phase angle range, deviation of voltage and frequency).

8.7 Step-up transformer and generator design

The step-up transformer shall not have adverse impact on the operation of a generating unit, especially:

- Restricting the voltage range requested by the TSO at the grid connection point for quasi-steady operation.
- Restricting the reactive power supply capability by generators (as defined in chapter 7.5) as a consequence of a violation of the admissible range of the generator voltage.

For this purpose the TSO and the power station operator will agree on the P/Q-diagram of the generator and on the electrical design and parameters of new or refurbished step-up transformers. This may result in the necessity to require a step-up transformer with an on-load tap changer.

8.8 Active Power Supply

The minimum continuous load change rate between P_{min} and P_r is 1% P_r/min. If

necessary for secure system operation each TSO is entitled to require higher load change rates taking into consideration the type of generating unit. The consent of the power station operator will not be withheld except for substantial reasons.

Each TSO is entitled to define requirements needed for system operation governing steady-state and dynamic short-term active power supply as a function of system frequency and voltage. The consent of the power station operator will not be withheld except for substantial reasons.

8.9 Information exchange

Technical facilities must be provided to exchange information between the TSO and the power station in real time or periodically with time stamping. The information exchange shall include inter alia:

- Power station to TSO:
  - generation schedules of the power station (in advance, e.g. day ahead and changes of the schedules immediately)
  - position signals 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 (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
- TSO to power station:
  - (de-)activation of primary/secondary control (if performed automatically)
  - regulator signals for secondary control
  - if applicable, signals for tertiary regulation
  - requested reactive power output or voltage (hv-side)
  - position signals of switchgear and measured values in the TSO substation to the extent it is individually agreed
  - alert signals indicating emergency states

Type and exchange of warning or alert signals indicating certain states of the system or the power station (e. g. emergency situations) are subject to individual agreements between the TSO and the power station.

9 MISCELLANEOUS

Power stations and TSOs shall provide all necessary data and cooperate bilaterally for disturbance and stability analysis.

Power stations and TSOs 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.

Changes to the equipment of the power station with impact on the above requirements shall be notified to and agreed with the TSO in advance. In case of modernisation/ replacement of equipment in existing power stations 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 responsible TSO in each single case.

In case of disturbances or indications of disturbances to the systems, the TSO is entitled to advise the power station on their generation output including the right to start or stop certain units. In addition, automatic reconnection of a generating unit after tripping shall be subject to prior agreement with the TSO.

If a TSO considers devices necessary to be installed in a power station site to preserve or restore system operation or security, the TSO and the power station operator will investigate this request and agree on an appropriate solution.

The TSO and the power station operator staff shall be trained together for their relevant tasks and shall be prepared for emergency situations by repeated trainings.

10 GLOSSARY

Generating unit - A generating unit for electrical energy is a power station installation which can be delimited according to certain criteria. The generating unit may for example be a thermal power unit, a combined-cycle plant, the machine set of a hydro-electric power plant, a wind turbine, a fuel cell stack, or a solar module.

Isolated (grid) operation - independent operation of a part of the power system that is isolated after its disconnection from the interconnected system, having at least one generating unit in operation with ability to speed/frequency control.

P_r - nominal active power that generating units can supply continuously

P_{min} - maximum active power that generating units can generate continuously with minimum primary energy supply

Power station - A power station is a plant to convert any form of energy into electrical energy.

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

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

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.

UCTE Synchronous Area - is a part of a synchronous area covered by interconnected systems/TSOs which are members of the association. Different UCTE Synchronous areas may exist in parallel on a temporary or permanent basis.

Virtual generating unit - a group of generating units that is dispatched like a single unit