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Connection Rules for Generation and Management of Ancillary Services

Sub-group "Connection Rules for Generation and Management of Ancillary Services within WG "Network Issues"

UNION OF THE ELECTRICITY INDUSTRY
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CONTENTS

1 EXECUTIVE SUMMARY

The report deals with common issues on the connection of large generation plant into transmission networks, including independent owned generation and plants embedded in the distribution system. In particular this includes the need for Ancillary Services (AS) which has been investigated and an overview on how these services are managed in the different systems is presented.
Questions relevant to the connection rules have been debated with reference to the opportunity of defining appropriate obligations, the appropriate extension and the detail degree of any associated grid code, and how to treat the intermittent generation.
Questions relevant to AS definition and provision have been examined and in particular whether power plants connection rules, relevant to Ancillary Services provision, contribute to the quality aspects and to reliable operation.
A number of questions relevant to AS market, characteristics and provision responsibility have been addressed, pointing out the different solutions adopted in the various countries. In the Appendix all the experiences in the different systems are collected, while in the main text considerations of general validity are included.

2 INTRODUCTION AND SCOPE

The technical characteristics of generating units, as well as their ability to fulfil a set of operation requirements, greatly affect both system secure operation and the quality and continuity of the load supply.
Suitable plant dynamic behaviour, protection levels and control facilities are necessary to cope with a range of pre- and post-fault operating conditions in order to preserve system security and equipment integrity. Moreover generation plants shall provide both “mandatory and/or necessary” ancillary services, managed by the System Operator, such as reactive power supply, frequency control, fast start of stand-by generation, black-start capability, and “optional” services, such as back up supply and operating-spinning reserve.

The main scope of the report is collecting contributions developed according to the following conceptual framework:

- by distinguishing between hardware requirements (e.g. for control and protection devices) and operation requirements such as the supply of ancillary/system services or the acceptance of System Operator directives;
- by stressing what is mandatory to comply with in order to enable the System Operator to preserve the system security;
- by defining what is desirable or profitable to comply with in order to improve system adequacy (both technical and economical), that, in a certain sense, can be “contracted” between System Operator and System Users.

The perspective adopted in the report is to analyse the different solutions for the connection rules and the management of the ancillary services in the new liberalised environment taking into account the debate in progress within each country, seen from Transmission.

These different issues are illustrated with comments in the light of different practices adopted in the involved countries.

3 CONNECTION RULES FOR GENERATORS

Generators will supply the basic service of power and most of ancillary services in a deregulated environment. Producers may submit offers to provide the required capability in terms of power and AS using any technology, provided this meets the relevant minimum technical requirements specified by the System Operator. Suppliers must declare their plant capable of meeting the criteria both from a reliability and an operational point of view.

Most countries [FR] [DE] [UK] point out that large generators must have a form of Ancillary Services Agreement, to be able to provide basic services considered essential for the operation of the transmission network.

3.1 DELIVERY RELIABILITY STANDARDS

In providing both power and ancillary services, generators need to ensure that specific reliability standards can be met.
To assure the respect of reliability criteria, they must be properly classified and ranked in order to point out which of them are critical for reliability management. Specific sanctions should be imposed in the case of non-compliance of a producer with the reliability criteria.
The reliability criteria will deal with the following main areas:

- Voltage
- Frequency
- Operation in emergency control

The reliability criteria for which non compliance should incur sanctions may be classified on the basis of their relationship to the above listed main area.
To properly state the producer compliance with reliability criteria, they must be measurable, monitoring responsibilities must be clearly assigned and there should be clarity on accountability and implementation of corrective actions.

The control includes three types:
- initial control of performance, as a prerequisite for the first connection agreement,
- continuous control in operation,
- non continuous control.

The criteria above explained are suggestions to include the requirements of monopolistic structures in the connection agreements of independent generators.

Reliability Standards specification is often omitted because it is not part of system codes [NL] or identified with Ancillary Service provision [FR].
All technical facilities (such as synchronisation device) useful to the connection of the generating unit must correspond to established good practice as defined by the TSO [DE].

3.2 OPERATION REQUIREMENTS FOR GENERATION

To assure the quality of the primary service of power and the security of the whole system, the generating units must be capable of producing power under normal operating conditions, assuring that a number of relevant parameters are within a predefined range. Moreover, the unit must be capable of operating with specified performances under a number of emergency conditions, such as those following system perturbations or during restoration. All these requirements may be included as part of the System Standards, which are properly described in the following points and successively investigated in sub-paragraphs 3.2.1-3.2.8.
Sanction should be applied where non compliance to the operational requirements is verified.

3.2.1 Performance standards

Performance standards are usually specified with reference to the two basic System Standards of Nominal Voltage and Frequency and their permitted ranges. Three sets of ranges are specified:

- a "normal unlimited time operation" range which applies when the system is in a normal state;
- a range where indefinite operation is required, although the system is in an abnormal state;
- a range where the system is in an emergency or severely abnormal state and continued operation is required only for a limited, usually defined, period.

Many ranges may be defined as non-continuous operation is concerned, depending on the extreme values permitted and the associated duration time per event or number of events per year.

The operating ranges are usually classified by listing the admitted ranges and the associated time interval or permitted rate of occurrence [FR]. In some countries a diagram based representation is used, with the proper values adopted in the specific system [NL].

3.2.2 Operating reserve supplying

Operating reserves must be assured by power producers through their connected generating units in order to help the system facing power unbalances due to disturbances and related frequency perturbations.
Operating reserve is a means by which producers are able to modify the generated power of their units automatically in response to a decline in system frequency below a threshold. The units may be spinning or stationary prior to responding. Operating reserve is considered as an ancillary service but the TSO can give obligation if the reserves are not sufficient for a secure operation.

A distinction among primary, secondary and tertiary reserve is done in many countries, based on the type of control which is respectively associated and in accordance with the UCTE definitions.

3.2.3 Inadvertent interchange management

Inadvertent interchanges are those discrepancies between power generated and consumed due to the deviation of the actual load from the forecasted value. These errors are recovered through automatic generation control (AGC) by remotely adjusting the output of the generating units. Producers must provide a power band and a control channel to receive the centralised control signal from the TSO to adjust the power production output of their units in order to meet the AGC requirements. AGC is considered as an ancillary service.

The generating unit participating in AGC must be capable of injecting the agreed reserve power (minutes reserve) into the network within few minutes from the request (for example 5 minutes [DE]).
Inadvertent interchange management is considered a system service in the Netherlands. Power reserve capacity (either under control of AGC or manually controlled) needed for system balancing is considered an ancillary service [NL].

3.2.4 House load operation

See "operation in restoration phase".

3.2.5 Operation in disturbed conditions

The capability to withstand several types of disturbances is required by the TSO, including:

- capability to maintain stable operation in the case of faults and/or weak links to the main system;
- capability of feeding an island sub-network.

The capability of withstanding a close-up grid fault without tripping (independently of any problem of loss of synchronism) is characterised by a maximum clearing time of a three-phase fault at the connecting substation. An associated voltage profile may also be specified.
Stability requirements may be some pre and post fault impedance conditions (equivalent impedance as "seen" from the power plant), associated with some fault duration.
Operation in disturbed conditions can be considered as a type of service.

In Germany, in the event of violation of the upper or lower limit values of the main criteria:

- frequency deviations ($f \leq 47{,}5$ Hz),
- loss of stability (with a defined number of pole slipping),
- drop in system voltage on the HV side of the generator transformer ($U \leq 80$ % of the reference voltages (400/220/110 kV))

the generating unit must be disconnected automatically from the network.

In the Netherlands, depending also on the transmission voltage level the generators are connected to, disconnection due to a voltage dip with remaining voltage value below 0.7 of the nominal value is allowed no earlier than after the smallest of 300 ms and the critical short circuit time.

3.2.6 Operation in restoration phase

The producer is required to be able of operating its unit in restoration phase with more extended domain with respect to voltage and frequency ranges (e.g. 48 to 52 Hz and 0.9 U_n to 1.1 U_n). This will avoid the unit trip during the restoration phase and the risk of compromising the recovery of the system. In order to facilitate network restoration after large-scale blackouts, the unit may be occasionally called for synchronising under abnormal frequency and/or voltage values.
Black-start capability must be available from the power station operator if required and requested by the system operator for network reasons.

House load operation
Each unit of nominal power above a fixed threshold must be capable to operate, isolated from the system, using its output to power its own auxiliaries and possibly a small amount of local load. House load operation allows for a rapid resynchronisation once the disturbed condition has disappeared and allows the system operator to quickly recover to a more secure operating state or even to start network restoration rapidly after a black out. Operation in house load mode must be guaranteed for the minimum duration time requested by the TSO.

No specific requirements are given in the Netherlands in addition of those already specified in the performance standards.
In France, it is focused that this service needs that producers are involved in studies of restoration scenarios, highly specific staff training, periodical operational tests of the scenarios, dispositions aimed to ensure the effective availability of the scenarios, and so on. This is particularly important in France because it conditions the safety of the nuclear units.
In addition, each power station operator shall prepare a specific scheme for the action to be taken in the event of a large-scale failure, to be co-ordinated with the system operator as part of a higher-level large-scale failure contingency plan [D].

3.2.7 Operation in island and synchronising conditions

The capability of supplying a sub-network operating in island, for a certain period of time, may be required by the TSO from some specific units, depending on their nominal power, local network conditions, network restoration strategies after large black out, etc..
The units required to operate in island conditions must be properly equipped to prevent unsafe operation during network separations. Specific control systems will be requested to cover those functions performed on a centralised level during normal operation and missing for networks operating in island. In particular, a local (integral) frequency regulator should be provided on these units to recover the static frequency error of the primary regulation.

3.2.8 Resistance to Unbalanced Conditions, Harmonics and Voltage Fluctuations

It is essential the generating units are able to withstand a certain amount of imbalance and harmonics on the grid, caused by the connection of abnormal loads that distort the waveform, even at the highest voltages. The distortions regard waveform difference among phases (unbalance), waveform frequency (harmonics) and module (voltage fluctuations).
Maximum unbalance can be expressed in voltage or current terms, with possibly higher levels for limited periods.
Harmonics limit requirements are normally expressed as a function of the harmonic order to control, by defining the maximum total distortion and maximum individual harmonic distortions.

3.3 GENERATION CONTROL AND PERFORMANCE REQUIREMENTS

3.3.1 Operation reserves capability

This service will be contracted from generating units operating at a power level below their maximum, or which can automatically start up and provide power within a fixed interval.

Operating reserve is a means by which generating units modify the generated power automatically in response to a decline in system frequency below a threshold. The units may be spinning or stationary prior to responding.
For this ancillary service the minimum technical requirements are concerned with the generator unit capability of automatically changing the electrical power. The minimum amount of MW has to be provided within a few minutes in a direction that will increase frequency following a fall in system frequency below a fixed threshold.

3.3.2 *Primary frequency control*

Primary control is a local control responding autonomously, rapidly and automatically, to changes in frequency by raising or lowering the output of a unit in order to counteract the change in frequency.
The minimum technical requirements for this ancillary service are as follows:

1. The automatic change in the electrical output or consumption of the generating unit must be under the control of primary frequency regulator;
2. The generating unit must have remote monitoring equipment to send signals to the TSO to indicate the actual power output or consumption and energy metering to determine the amount of energy delivered to or taken from the transmission network.
3. The electrical output or consumption of the generating unit must be capable of automatically changing in proportion to frequency deviation outside the contracted dead-band.
4. The primary control band must be at least above a fixed percentage of the nominal capacity and be adjustable at the instruction of the system operator.
5. The generating unit shall be capable of automatically activating, in a predefined time, the total primary control power requested at a quasi-steady frequency deviation, and maintaining supply for at least a minimum time requested by the TSO.

All the generating units with a nominal capacity ≥ 100 MW are requested to have primary control capability. In such a case the TSO shall be entitled to waive this obligation for individual generating units [DE]. Generating unit of power < 100 MW may also be employed for assurance of primary control by agreement with the TSO. The controller droop shall be adjustable according to the specifications of the TSO [DE].
In England all generating units >50MW are required to be able to provide frequency response (“operation in frequency-sensitive mode”) [UK].
The required primary regulation response is represented as a time dependent ramp in the Netherlands.

3.3.3 *Load frequency control*

Load frequency control is a centralised control system used to remotely control the output of the generating units. Load frequency control has the main function of modifying the output of the generating units to regulate system frequency and power exchange with neighbouring areas.
The minimum technical requirements for this ancillary service are as follows:

1. the power output or consumption of the generating unit must be capable of automatically changing following a signal from the TSO within a specific time, it must be limited and it must change in a pre-defined band, proportional to its nominal power;
2. the generating unit must be capable of responding automatically for a fixed percentage of the time the generating unit is supplying electricity (as applicable) above a minimum agreed level.

3.3.4 *Primary and secondary voltage regulation*

Primary and secondary voltage regulation is a two level control system used to locally (the primary) and remotely (the secondary) control the voltage profile on the system. The local (remote) voltage control responds to local (remote) voltage deviation outside its permissible range, by lowering or raising the reactive output of the controlled units in order to counteract the change in voltage; in other countries (FR), the secondary (remote control) is also used for optimizing the reactive outputs of the generators at a regional level, following the instantaneous actions provided by the local primary control.
The minimum technical requirements for this ancillary service are as follows:

1. the reactive power output or consumption of the generating unit must be capable of automatically changing following a local (remote) signal within a specific time;
2. the generating unit must be capable of responding automatically for a fixed percentage of the time the generating unit is supplying electricity (as applicable) above a minimum agreed level;
3. the transmission service provider may allow or require a cosϕ controlling device for generators below a certain rated power, based on the local situation.

In Germany each generating unit with a nominal capacity ≥ 100 MW must meet additional requirements where required by the system operator. If necessary, the system operator can make demands on additional power stations.
In the Netherlands all the synchronous generators must be equipped with a voltage regulator, with the droop of the voltage controller adjustable between 0 and 10%. The generating unit must be able to move through the power factor design range within a matter of minutes. The entire process must be repeatable indefinitely.
In the UK all generating stations must be capable of regulating their voltage within defined limits. Generating units with a net export of 50MW or more, under their generation licence and the Master Connection and Use of System Agreement must comply with conditions outlined in the Grid Code. Generators are obliged under the Grid Code to provide certain ancillary services which contribute to voltage support. In particular, all generating units must be able to achieve a machine reactive capability of 0.85pf lag and 0.95pf lead.

3.3.5 Control and monitoring equipment requirements

The generating unit must have control and monitoring equipment, approved by the TSO and periodically tested, in order to verify compliance with TSO standard requirements.
Technical facilities must be provided for exchange of the following information in real time.
From the power station operator to the TSO:

- circuit-breaker/disconnector/earthing disconnector/step switch settings, when required for operation or for system analyses
- measured values of the current operating mode (active and reactive power)

From the TSO to the power station operator:

- where applicable reference values for control and instantaneous demand value of the secondary control
- reference value of the reactive power in the form of the schedule or as an instantaneous value
- circuit breaker/disconnector/earthing disconnector settings, when they are required for operation of the generating unit
- if applicable, actual values of the active and reactive power and of the voltage from the incoming transmission system substation

As regards primary and secondary frequency control, the generating unit must have remote monitoring equipment to notify TSO of the generated active/reactive output of each generating unit.

3.3.6 Protection co-ordination and settings

Plant-side protection systems must be properly co-ordinated and set with the network-side protection systems in order to avoid overlapping of the protection curves or delay in relieving dangerous conditions. Interface devices tripping curves and setting values must be submitted to the TSO for approval.

3.4 DATA REQUIRED BY THE SYSTEM OPERATOR TO THE APPLICANT GENERATORS

The scope, mechanism and procedure for information interchange (for example definition of terminology, forms, formats, protocols, procedure) shall be specified in the supply connection contract.

4 ANCILLARY SERVICES

4.1 ANCILLARY SERVICES (AS) DEFINITION, IDENTIFICATION AND CLASSIFICATION

4.1.1 AS definition

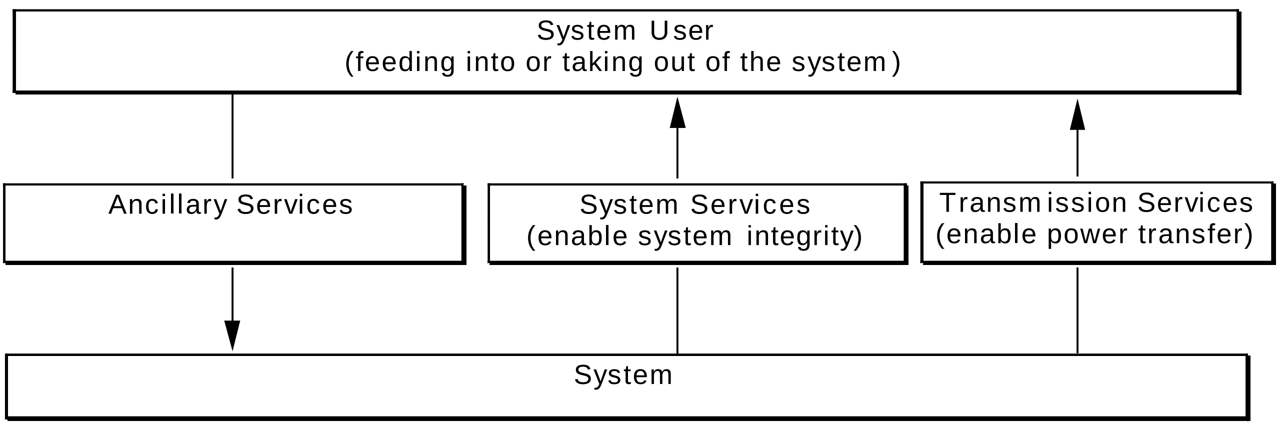
Ancillary Services are those services provided by generation, transmission and control equipment which are necessary to support the transmission of electric power from producer to purchaser. These services are required to ensure that the System Operator meets its responsibilities in relation to the safe, secure and reliable operation of the interconnected power system. The services include both mandatory services and services subject to competition.
The system operator manages the ancillary services as follows:

- obtains contributions ("elementary" ancillary services) from service producers (some of which follow from regulatory or contract obligations);
- carries out the technical management of the system, while making sure there is a suitable level of security;
- adds its own share (implementation of controls, load dispatching function) and thus elaborate the final system services;
- provides the consumers with the system services.

Although the Directive 96/92/EC, concerning common rules for the internal market in electricity, uses only the term ancillary services (with the meaning of all the services necessary for the operation of a transmission or distribution system), it is useful (from a technical point of view) to distinguish between "Ancillary services" and "System services". "System services" are all services provided by some system function (like a system operator or a grid/network operator) to users connected to the system. "Ancillary services" are services procured by a system functionality (system operator or grid/network operator) from system users in order to be able to provide the system services. Within system services a further sub-classification is sometimes suggested, relating to the specific system function that is supplying the service (i. e. the system operator or the network operator). In practice these arrangements differ widely, depending on the kind of system service provided by the functions in question. As an example there are systems where network losses are provided by the system operator and some other systems where they are provided by the grid operator.

Here it is suggested to define system services as those services from the system that enable system integrity and to define transmission services as those services from the system that enable and assist economic power transfer. This does not provide an unambiguous framework and the assignment of each of the services from the system to one of those categories will depend on the specific arrangements in each system.

A scheme of this unbundling is in the following figure:



The Directive 96/92/EC uses one term for system operator, which shall be responsible for:

- operating, ensuring the maintenance and developing the grid (Article 7.1)
- managing energy flows (Article 7.3)

- ensuring a secure, reliable and efficient electricity system
- ensuring availability of all the necessary ancillary services (Article 7.3).

From this point of view the System and Grid Operator are one person, the Transmission System Operator (TSO).

The advantages of this decomposition are:

- it is possible to define clear interfaces between system operator and system user so that users are separated from difficult problems with power system control and the technical requirements can be defined;
- a fair contribution of the individual users to the system proper and safe operation can be ensured;
- a clear separation is created between the TSO and the generation, especially when they are parts of one company.

The difference between the ancillary services from on one hand the generation and on the other hand the system/network is still under debate. The non-existence of an official list of these services has to be put into evidence. CIGRE has recently issued an indicative list of ancillary services, only for information purposes and certainly not yet laid down by legislator.
There could be differences of ancillary services to be applied to the generators depending on numerous factors, with different level of commitments, the big generators having a predominant role compared to another very small one.

4.1.2 AS identification

The ancillary services may be expressed in terms of basic participation in active power reserves, load follow capacity, voltage capacity and reactive power supply, good performance in a disturbed situation and possibly a contribution to service restoration following an incident.

Therefore, in order to maintain the system in a secure operating state, the following actions must be assured.

- To control the frequency of the system
- To control the voltage of the system
- To control the stability of the system
- To control the loading of the transmission network
- To restart the system in certain circumstances

In order to have the required capabilities, the following ancillary services must be procured by the TSO.

- Automatic generation control (load/frequency control)
- Governor control (primary frequency regulation)
- Reactive power;
- Operating reserve;
- Standing reserve;
- Black start capability;
- Emergency control actions (f. e. fast-valving/automatic load shedding)
- Compensation for inadvertent tie-line interchange

These are the most commonly recognised AS, needed for providing the system services.

In some countries another applicable identification points out those ancillary services needed for transmission services, such as:

- Reactive power and energy
- Compensation for grid losses
- Power factor and voltage control
- Means to solve internal transmission constraints
- Means to solve congestion on cross border lines

4.1.3 AS classification

Ancillary services can be classified by origin of need, purchasing method, reimbursement method and supplier.
Origin of need is either system services supply or transmission services supply.
Purchasing methods can be classified into mandatory, bilateral contracting (under the counter), public tendering or dynamic market (exchange).
Within mandatory methods, sub-classification can be found by reimbursement method. These are no reimbursement and reimbursement based on costs, value or tariff.

One of the main classification is based upon system needs in terms of operating requirements. Therefore, being the need for each ancillary service determined by the TSO in accordance with system operating standards, AS are classified in the following based on their contribution to specific system requirements.

Frequency Control
Frequency control can be obtained through the following ancillary services:

- automatic generation control
- governor control
- operating reserve
- emergency control

Sufficient control range should be available at all times to control frequency within specified limits under various circumstances including unexpected load changes and unexpected generation changes.

Voltage Control
Voltage control capability will be achieved using the reactive power ancillary service.

Stability Control
If it is applied as standard criteria that the power system should remain stable after any credible contingency and oscillations should be suitably damped after any credible contingency, the following AS can help stability control:

- governor control
- operating reserve
- emergency control

System restart
Sufficient electricity sources should be available to restart the power system after a partial or complete shutdown.
This is mainly obtained through the black start capability.

4.2 AS MANAGEMENT

In order that the power system remains in a secure operating state, sufficient ancillary services must be available to respond to a single credible contingency and return the power system to a satisfactory operating state. The following sections outline how the AS are managed by the TSO depending on the source type and location.

4.2.1 AS by native generation

It is universally recognised that generation is the main source for ancillary services. In particular most generators are involved in the provision of *the following* ancillary services:

- governor control (primary frequency regulation)
- reactive power
- operating reserve
- standing reserve

To specific units or loads with particular equipment are demanded the remaining services, such as:

- automatic generation control (load/frequency control)
- black start capability
- emergency control: fast valving/automatic load shedding

Certain system services may be attributable on the provider's and/or the receiver's side. An attributable service on the provider's side means that the provider of the system service in question can be identified. On the receiver's side it means that facility exists for precise determination of which customer(s) is (are) using a particular system service, and to what extent.
Irrespective of the position on the provider side, the costs of non-attributable system services on the receiver side must be borne by all customers connected to the network.

In the context of an electric power system, system services refers to the services essential to the proper functioning of the system which system operators provide for their customers in addition to the transmission and distribution of electric energy, and which thus determine the quality of power generation.

Ancillary services are services attributable on the provider’s side which are made available by the relevant system users (e. g. power station operators) on request of the TSO who pays for their provision (technical design, operating cost) in accordance with the prices quoted by the ancillary services providers in the framework of a request for bids. These individual ancillary services are upgraded by the TSO into system services to fulfil his task concerning the assumption of responsibility for the system.

4.2.2 AS by network

For the voltage control, some devices are existing in the network. The produced services in using such facilities (f. e. SVC) could be more or less expensive than using the reactive power of the generators.
In England, the voltage profile is maintained on the transmission system and at the interface with the distribution networks, using a variety of controllable reactive sources, such as static compensation and by tap changing on grid supply transformers.

4.2.3 The role of interconnections

Interconnections are directly involved in the service of load/frequency control, and may be involved in the exchange of other services such as operating reserves. Interconnection tie lines represent, for importing areas, fixed power generation source while, for exporting areas, they are constant-power loads to serve. Thus, importing areas may be viewed as additional sources of reserve and exporting areas may be contracted for partial shedding in emergency conditions.

4.2.4 Co-ordination among the TSOs

TSOs of the interconnected systems must maintain the level of co-ordination assured by integrated utilities under monopoly, in order to perform the basic centralised service of power-frequency control all over the system.
A major co-ordination level among TSOs may be necessary as the number of services exchanged trough interconnections will increase.

4.3 AS MARKET

The dispatch of AS should be obtained in a manner that maximises the total benefits to market participants.
The services can be purchased in a competitive market but additional procedures must be used to manage those cases when AS are not sufficient to cover system requirements.
The procedure will result in imposing constraints on the energy market dispatch where units need to be constrained. It should be allowed to impose constraints where there is no alternative means of obtaining the service.

As a whole, system services are managed by the TSO through mandatory agreements or directly through the market. Ancillary services markets do exist in Nordic countries, in UK and in Spain today. In Spain the market deals with secondary and tertiary frequency control, the voltage control, the reactive power (also provided by specific devices like SVC - Static Var Compensators), and the black start function. In the UK, the mandatory services concern reactive power (with market arrangements in place since 1998) and the frequency response (with market arrangement currently under discussion). Market mechanisms have been used to procure standing reserve since 1993.

In Germany, concerning system services attributable on the provider's side, the TSO shall remunerate the service providers in accordance with their prices quoted in the framework of a request for bids for the provision of the required ancillary services. The TSO incurs costs as a result of these payments.
Based upon their service schedule, the TSO and the relevant system users (eg. power station operators) shall agree on bilateral conditions for providing ancillary services required for the provision of system services. The provision of certain services may be linked contractually to the operation of certain installations (eg. for voltage stability).
On the basis of this communication from the power station operators and communications from other system users as well as of the instantaneous demand for system services, the TSO shall utilise the requisite ancillary services from the contracted system users. They shall be selected upon the basis of minimum cost to the system operator and assurance of maintained power.

4.3.1 Suppliers and consumers

The nature of entities exchanging AS strongly depends on who will provide services (generators/loads/network) and who will buy them. Being the management of AS under the TSO responsibility, it is expected the System Operator will purchase most ancillary services too.
Occasionally, in more competitive structure, producers and consumers will be able to directly contract for certain amount of ancillary services (such as reactive power). As for the basic power of service, these contracts will be submitted to the TSO for approval.

4.3.2 Need vs. competition

This item is explained through Table 4.3.2.

Table 4.3.2: Need vs competition

SERVICE	SUPPLIER/ SERVICE SUPPLIED	TIME FRAME ω_T [rad/s] o t [min]	LOCALISATION Local/centralised	SYSTEM STATE	COMPETITIVELY PROVIDED ?
Primary regulation	Generators equipped with governor control • Power band	$\omega_T = 0.3$	Local	Perturbation of local frequency	Not yet / Yes in the next future in some systems
AGC	Generators able to receive the centralised signal: • Power band	$\omega_T = 0.01\text{-}0.02$	Centralised	Long-term perturbation of system frequency	Yes
Reactive power	Generators: • Reactive band	=	Local	Long-term perturbation of system voltage	Yes
Operating reserve	Generators	t = 5 min	Centralised	Emergency	Yes
Standing reserves	Generators	=	Centralised	Emergency	Yes
Black start	Generators	t = 10 min	Centralised	Emergency	Yes to some extent - To be defined for the future
Emergency control	Generators/loads	t=0.1 - 1 min	Centralised	Emergency	Yes to some extent - To be defined for the future

4.3.3 Price determination

The payment for *ancillary services* will be based on a structure recognising the different conditions relating to provision of facilities by service providers, delivery of the service by a facility, and different modes of use by the TSO.
Basically, three types of payments can be classified:

Availability
Availability payments will be applicable when the units are continuously able to deliver the ancillary service and the TSO has a continuous, but indeterminate, level of usage in any particular time period.
It applies for example to automatic generation control and to operating reserve.

Usage
Usage payments will apply when the use of a service due to the occurrence of a defined event may significantly increase the operating costs of the service provider during the period of use. This payment can apply to the operating reserve service or to the emergency control service.

Compensation
Compensation payments apply when the usage of a service constrains the energy production or usage of a generating unit in the primary electricity market.

In England [UK], mandatory services are formally remunerated under "cost-reflective" charging principles. Income or costs will be recovered both from the "Pool" and from AS contract payments. For example, when a generating unit is instructed to operate in a frequency sensitive mode at less than full output, it will receive two distinct payments. A variable «loss of profit» payment through the Pool, and an Ancillary Services contract payment for frequency response capability. The loss of profit payment is intended to compensate generators that are despatched to operate at an output below its intended "unconstrained" level in the Electricity Pool. The Ancillary Service payments are designed to recompense the generator for the cost of additional inefficiencies incurred when operating in frequency sensitive mode. Ancillary Service payments are made on a £/MW/hr basis.

4.3.4 Types of contracts

The types of contracts under which AS will be exchanged basically depend on the above price determination procedures and on the market structure. If all the three payments will be recognised, the service supplier must enter the market with a two-part or three-part bid where it asks for availability, usage and compensation payments. The market structure depends on which entities are allowed to purchase AS. If all the AS are purchased by the TSO, the supplier bids will be evaluated in a pool-like environment to match the single-consumer requirements. If also distributors or end users may purchase AS, the exchange may take place under bilateral contracts then submitted to the TSO for technical approval.

As regards reactive power in the UK, generating units can receive payments for providing reactive power under a «default» payment mechanism or under «market» arrangements.

4.4 AS PROVISION RESPONSIBILITY

4.4.1 AS planning

The TSO will be responsible for AS planning as the planning of the system directly affects the secure operation of the system. The same procedures adopted by integrated utilities for source planning can be extended to market operation, by properly taking into account market rules and additional constraints.
Based upon their service schedule, the TSO and the relevant system users (e.g. power station operators) shall agree on bilateral conditions for providing ancillary services required for the provision of system services. The provision of certain services may be linked contractually to the operation of certain installations (e.g. for voltage stability).

4.4.2 AS provision and management

The responsibility for procuring AS depends on the structure of the Electricity Supply System. Generally procurement of Ancillary System Services is a System Operator responsibility while procurement of Ancillary Transmission Services is a Grid Operator Responsibility. Wherever System Operator and Grid Operator functions are combined within one company (like a TSO) that company will be responsible for both.

The suppliers (either generators, consumers or adjacent grids) of ancillary services are responsible to provide the ancillary service, as prescribed in some code or by statutory law. Besides, they have to adhere to the contractual agreement with the purchaser, or to adhere to the rules for players on a dynamic market. In the end the purchaser should have some way to force suppliers to adhere to their responsibilities, either through a penalising system and/or by contract, statutory law, system code or grid code.
The dispatch of ancillary services is a sole responsibility of either the System Operator or the Grid Operator.
The settlement of ancillary services should be done under mutual agreement of purchaser and supplier. Under this condition it can be also agreed to contract settlement with a third party.
As regards the management of the ancillary services by the market, the most crucial question is to which extent the market can solve problems of safe operation.

As regards the management of the ancillary services, it seems that it existed until now enough facilities to ensure the primary and secondary controls; however, this must be checked by a better control, for example in the way UCTE performs it with its new rule " Supervision of the application of rules concerning primary and secondary control of frequency and active power in the UCTE"; furthermore, precautions must be taken so that the future generators will really be able to provide ancillary services, and the level of remuneration will be important in that way. Through the international interconnections, a market of the secondary control is by definition excluded. On the contrary, for the primary response, the reserves could be purchased on a market, with the risk of a non-suitable location of this reserve. The same possibility can see foreseen for the tertiary reserve (D-load). For example the DC links in NORDEL and that between France and England are able today to provide both of such contributions.
In Spain the tertiary reserve is managed on a voluntary basis.
Concerning the determination of the prices, one of the open problem is how to compare the price of the reactive power produced by a generator with the reactive service provided by a SVC on the network.

5 DISPERSED GENERATION

Concerning the dispersed generation, the following items are mainly related to the German and Spanish experiences.

5.1 QUESTIONS RELEVANT TO THE CONNECTION RULES

Special requirements
Some special requirements concerning operation and protection of dispersed generation units are made. according to the operation and protection scheme of the network, in which these units are integrated. In Germany medium-voltage overhead line network is present. In the case of a three phase short-circuit, dispersed generation units, feeding into a network fault, could interfere with this short circuit interruption. Therefore they have to be disconnected as fast as possible, so that the duration of the short-circuit interruption is not influenced by them.
No interference with the audio-frequency remote control system is allowed. To guarantee the operation of this control system, the impedance of the dispersed generation unit at the broadcast frequency should be high enough. This can be realised by installing filters at the generation sites. Also a harmonic distortion of maximal 0,1 % U_n is allowed for the harmonic orders in the neighbourhood of the broadcast frequency.
The supply conditions must assure that no power deficit will occur as a result of too high adjusted under-frequency limiting values. Besides should be fixed an information duty of the supplier concerning unavailability.

The so-called dispersed generation corresponds in the Spanish system to the special generation, programmed to be connected to distribution networks with a global efficiency purpose at national level (in economic, energetic and environmental terms). That is why the current regulation exclusively refers to this possibility, while the current reality is that the magnitudes considered nowadays completely exceeds the scope and possibilities of the distribution levels. In any case, current conditions for the connection refer to the infrastructure capabilities associated to the MVA magnitude of the application. Such a magnitude must be lower than 1/2 Rated Capacity of evacuation facilities at the point (rated capacity of the line if connected to it or transformation capacity if connected to a substation).

For synchronous generators the operation of connection to the network (synchronising) must observe the following conditions:

DIFFERENCE GENERATOR vs. GRID	RATED POWER OF GENERATOR	
	> 1 MVA	= 1 MVA
VOLTAGE	± 10 %	± 8 %
FREQUENCY	± 0.2 Hz	0±.1 Hz
PHASE	± 20º	± 10º

In terms of VAR compensation, a minimum value for the power factor (cos φ) is required for the plant:

- 0.85 for asynchronous generators
- 0.90 for synchronous generators

In addition of these technical requirements, there is an economic scheme by which values of cos φ greater than 0.9 (and lower than 1.1) are incentivated.
Other aspects related to the quality of supply are treated in coherence with the European Regulation EN-50160:1994.

Protective relaying

In Germany, to prevent any damage to the generation unit by influences from the network all units should trip on abnormalities in the network. For this purpose, a short-circuit protection like an over current relay has to be installed. Protection against influences of the generation unit on the network is in most cases only installed on agreement with the local utility. If demanded, over current relays or in special cases neutral voltage displacement, earth fault or reverse power detection are installed. Isolated operation is generally prohibited. To prevent from this situation, slow over and under voltage (three-phase) and over and under frequency relays (one phase) are installed. These relays should be parameterised as defined in table 5.1.1.

relay	setting			
U <	1.0	….	0,7	Ur
U >	1.0	….	1,15	Ur
f <	50	….	48	Hz
f >	50	….	52	Hz

Table 5.1.1: relay parameters

In Spain, in terms of protective relaying, the following Table summarises the current requirements for distributed generators (asynchronous plants up to 7.5 MVA and synchronous plants up to 10 MVA) connecting to the grid (protection of the interconnection and subsequent grid is presented):

REQUIRED EQUIPMENT	Regulation	Purpose
Automatic breaker	-	Plant disconnection
Undervoltage relays (3 between phases)	0.85*Um	Detection of 2-phase and 3-phase faults at the plant output and abnormal isolated behaviour
Overvoltage relay	1.10*Um	Detection of abnormal isolated behaviour
Zero-seq. Overvoltage relay	(1)	
Frequency deviation relay	49-51 Hz	
Instantaneous overcurrent relay (3, at each phase)		
Intertripping mechanism		

Um: voltage between phases.
(1): to be determined in each case.

Summary of connection criteria adopted in the German system

Table 5.1.2 provides with an overview of the main aspects of the guidelines to connect dispersed generation to the medium-voltage grid in the German system.

network interference	
voltage interference	d ≤ (2 % MV, HV: 3%)
VAR-compensation	• control, no fixed capacitors • only at operation • cos φ = 0.8 ind…0.9 cap
voltage distortion	• flicker: A < 0.1 • harmonics limited
Synchronising	• synchr. generator: ΔU < 10 %, Δf < 0.5 Hz, Δφ < 10° • asynchr. Generator: no load, speed at 95% … 105% of n_n
Protective relaying	
influence from network	short-circuit protection
influence on network	short-circuit, over current
isolated operation	ΔU (3~), Δf(1~)
Special requirements/remarks	no interference with: • short –circuit interruption • audio-frequency control

Table 5.1.2: summary of connection criteria for dispersed generation on medium voltage in Germany

5.2 HOW TO TREAT THE INTERMITTENT GENERATION (RENEWABLES) ?

In Spain additional requirements are issued for the wind power generators, whose magnitude cannot exceed 1/20 of the short circuit power (S_{cc}) published for the connection point (aimed at avoiding severe fluctuations derived from changes in the wind conditions).
In terms of voltage distortion, a maximum voltage drop at the connection stage of 5% (vs. rated voltage) is established for asynchronous generators, except for wind power generators where the level is set at 2%. In addition, frequency of connection/disconnection to the grid must not exceed 3 times per minute, while the connection operation must be carried out when generator speed has surpassed a percentage of synchronism speed:

- 90% for generators equal or lower than 1 MVA.
- 95% for generators greater than 1 MVA.

In the UK, renewables are excused from complying a number of Grid Code requirements that apply to conventional plant – including any mandatory obligation to provide ancillary services.

5.3 QUESTIONS RELEVANT TO AS

The problem of the intermittent generation, also called embedded or dispersed generation, is the impact of missing ancillary services in a large region where intermittent production without mandatory commitment for ancillary services could represent a non-negligible part of production. How to manage the voltage control and the guarantee of supply for the customer in case of unavailability of the generators due to the maintenance period, the lack of wind (for the wind-farms), etc.? How to manage the reserve for the frequency control (primary and secondary)?
This problem is occurring mainly in countries they have developed or are developing a large fleet of new renewable source's production (large hydro excluded).
For example in Spain where forecasts derived from Regional Authorities and particular petitions point to values above 10.000 MW (in fact, around 20.000 MW at the moment) of new Renewable Generation Capacity (windfarm essentially), the risk of a loss of a large magnitude of generation becomes very serious due to the cases of concentration -dispersed is an adjective which has lost its significance when an area may have more than 1.500 MW- and the fact that the current regulation obliges the instantaneous disconnection for "special" generation when voltage goes under 0.85 p.u., what could lead to the loss of a great part of the

wind power cluster. The role of the network and its reinforcement is essential, as well as the need for an adequate management and an adaptation of legislation.

6 RECOMMENDATIONS AND CONCLUSIONS

The report deals with common issues on the connection of generation plant into the network, particularly independent owned generation and plants embedded in the distribution system. Furthermore, the need for ancillary services has been investigated and an overview on how these services are managed in the different systems has been presented.

Questions relevant to the connection rules have been debated with reference to:
- advantages and drawbacks of defining an appropriate grid code,
- the appropriate extension and the detail degree of the grid code,
- how to treat the intermittent generation

Questions relevant to Ancillary Services definition and provision have been examined and in particular whether power plants connection rules, relevant to Ancillary Services provision, contribute to the quality aspects and to reliable operation.

Questions relevant to AS marketing have been considered with particular reference to the problem of how to get competition in ancillary services market and what kind of economic signals have to be provided by the Transmission System Operator (TSO) or other Customers.

A number of questions relevant to AS characteristics and their provision responsibility have been treated, pointing out the different solutions adopted in the various countries.

It has to recognise that the interconnected power system has achieved, over the last decades, a good degree of reliability and a kind of general economic optimum. Therefore, it seems be useful to look for criteria able to maintain the achieved level, even in the presence of the new institutional arrangements.
As the market advent probably causes a certain number of consequences, such as a proliferation of transactions, more volatile patterns of generation, a considerable variability of the power flows, it seems reasonable to adopt rules and specify requirements for managing for the better all the resources and the activities needed to operate the system in a secure manner.

It would be recommendable to clearly define the concepts of ancillary, system and transmission services and the functionality in charge of their procurement and management.

In conclusion, when dealing with generator connection, it is necessary to take into account the following points.
- Compliance with reliability standards
- Management of emergency response
- Management of transmission congestion
- Maintenance of the system security taking into account the interactions with the various markets
  From this point of view on the one hand the market of the primary service has a strong impact on the system security at the stage of congestion resolution, on the other hand the AS markets have impact on the various phenomena affecting the system security even taken into account the different solutions adopted in the various countries.
- Meeting co-ordination requirements in a competitive environment
- Calibration of centralisation (Authority, TSO) vs. de-centralisation (market players)
- Co-ordination, allocation and specification for AS along with rules and requirements
- Adoption of more robust control in the presence of greater system volatility.

All these points require to be very carefully dealt with by all the players and the decision makers involved in the electricity sector. Besides, stated the different stages of implementation and the various solutions adopted or foreseen in the different countries, it would be appreciated some effort in order to define common framework in the area of connection rules for generators and AS management.

7 APPENDIX

7.1 ANCILLARY SERVICES IN ENGLAND & WALES

Introduction

In England and Wales, trading of the «energy» component of electricity between Generators and Suppliers is handled through the Electricity Pool. Prices for the sale and purchase of electricity are calculated for each half-hour, and are determined by a set of rules set out in the Pooling and Settlement Agreement. Other components of electricity trading, known as Ancillary Services, are managed by the National Grid Company (NGC) as part of its regulated licence obligations.
Ancillary Services are required to maintain the quality of electricity supply through ensuring satisfactory voltage and frequency levels, as well as providing for the restoration of power supplies in the unlikely event of a system incident. These services are primarily provided by large generators, electricity users and from small-scale generation.
The purpose of this contribution is to describe the main ancillary services and the current arrangements for their procurement.

The main ancillary services are:

- *Reactive Power* - required to maintain voltage.
- *Frequency Control* - required to maintain system frequency.
- *Reserve* - required to balance the system in the event of loss or shortfall in generation or demand under-estimation.
- *Black Start* - required to facilitate restoration of the system in the event of a complete or partial shutdown.

Reactive Power

Reactive power flows must be carefully controlled across the transmission system to ensure compliance with the voltage criteria specified by the Transmission Licence and within the Grid Code. Reactive power flows can give rise to substantial voltage changes across the system, and the Grid Operator therefore attempts to maintain reactive balances between sources of reactive generation and points of reactive demand on a «zonal» basis.
The voltage profile is maintained on the transmission system and at the interface with the distribution networks, using a variety of controllable reactive sources, such as generating units, static compensation and by tap changing on grid supply transformers.
All generating stations must be capable of regulating their voltage within defined limits. Generating units with a net export of 50MW or more, under their generation licence and the connection contracts must comply with conditions outlined in the Grid Code. Generators are obliged under the Grid Code to provide certain Ancillary Services which contribute to voltage support. In particular, all generating units must be able to achieve a machine reactive capability of 0.85pf lag and 0.95pf lead.
Generating units can receive payments for providing reactive power under a «default» payment mechanism or under «market» arrangements. The potential income that generating units can receive under the default arrangement varies according to the number of generators providing the service within a particular zone and the relative need within that zone. This mechanism covers only the minimum Grid Code specified and is applied consistently to all generating units. Alternatively, generators can tender their Grid Code service into the reactive market. Under the market terms generators can structure their bids to better reflect the value of that they perceive the service is worth. Unlike the default arrangements, tenderers are able to offer specific prices which better reflect the actual cost of providing the service.

Frequency Response

The balance between demand and generation must be continually and automatically maintained such that the system frequency remains within limits. The system normally operates within the operating limits (50Hz ± 0.2Hz). Under large generation or in feed losses, the maximum frequency excursion is contained to the statutory limits (50Hz ± 0.5Hz) except in abnormal or exceptional circumstances.

Each generating unit must be capable of operating to provide automatic frequency response to changes in frequency, when instructed, in order to contribute to the containment and correction of the system frequency. The Grid Operator issues instructions to each generating unit to operate in a "frequency sensitive mode". Also, there is a "limited frequency sensitive mode" default for all uninstructed generators, so that they can take corrective actions automatically for excessive high and low frequency deviations.
When a generating unit is instructed to operate in a frequency sensitive mode at less than full output, it will receive two types of payments. A «loss of profit» payment through the Pool, and an Ancillary Services contract payment for frequency response. The loss of profit payment is intended to compensate generators that are despatched to operate at an output below its normal unconstrained level in the Electricity Pool. Payments are based on the difference (if any) between the half hourly system marginal price and the prevailing bid price of the individual generating unit. The Ancillary Service payments are designed to recompense the generator for the cost of additional inefficiencies incurred when operating in frequency sensitive mode. Ancillary Service payments are made on a £/MW/hr basis.
The Ancillary Service Agreement contains a full matrix which details the expected levels of primary and secondary response. These levels are given for different levels of plant deload, and for different changes in system frequency. Primary response is essential to minimise the initial frequency incident and is released increasingly with time, through automatic governor action, in the period 0-10 seconds and sustained for a further 20 seconds. Secondary response is the automatic positive power contribution in the subsequent frequency stabilisation phase beyond 30 seconds to 30 minutes after the incident.
NGC also contracts for frequency response from large demands that are prepared to be tripped from low frequency relays. In this case the price offered by the demand manager is accepted if use of the service would result in a reduction in total payments for frequency response.
NGC is currently considering the benefits of introducing a market for frequency response. A response market would provide for freedom of pricing and greater transparency through the introduction an open tender process.

Reserve

Reserve is required to cover contingencies such as generation loss, generator shortfalls and imbalances caused by demand under-estimation. This service is required to restore the frequency response service to guard against further incidents. It is an instructed service which is available to the Grid Operator within 1-20 minutes. When reserve services are called off they may be utilised for up to 4 hours.
There are two main sources of reserve available to the Grid Operator. Synchronised reserve which is provided by generating units operating below full load. For example, a generating unit of 400MW may be operating at 350MW. It can them provide 50MW of synchronised reserve, since it could increase its generation to full load if required. The other category is standing reserve, which is provided either by unsynchronised generating units, able to start-up rapidly such as diesel generators and gas turbines, or by demand reduction.
Standing reserve tends to be utilised predominately over the peak periods of demand, whereas in the trough periods synchronised reserve is utilised. This is because there is inherent synchronised reserve available in between peak periods, because it is often cheaper to part load generating units rather than shut them down.
Most service providers are remunerated for synchronised reserve directly through the Pool. Standing reserve is contracted through an annual tender process, which results in the award of a significant number of AS contracts. Standing reserve providers receive an availability fee over the contracted periods and a utilisation fee each time the service is instructed.

Black Start

Black start is a procedure for the recovery from a total or partial shutdown of the system and is defined within the Grid Code. It is required to facilitate re-energisation of the system and to restore customers demand. It represents the Electricity Supply Industries final insurance against unforseen circumstances, such as times of severe weather when significant parts of the transmission system have been shut down causing loss of supply to both consumers and generators. It is also required to recover the system from major system disturbances such as voltage collapse.
Black start is an extremely rare situation in England and Wales since NGC's transmission system is well designed and effectively managed. The black start procedure was last called upon in 1987 when some 25%

of customer demand was disconnected, following a serious disturbance on the transmission and distribution systems, caused by bad weather.
All power stations need an electrical supply to start-up. Under normal operation this supply would come from the transmission or distribution system, under emergency conditions black start stations receive this electrical supply from small auxiliary generating plant located on-site. These auxiliary supplies are provided by small gas turbine and diesel plant.
The overall strategy following a full or partial shutdown is to restore customers' demand via the establishment of isolated power stations as separate «power islands». This would then be followed by step by step integration of these power islands into larger sub-systems and to eventually re-establish the complete Transmission System.
The costs involved in providing a black start capability predominately arise from the capital outlay on auxiliary plant. A significant proportion of these capital costs are recovered through an Ancillary Services Agreement. In addition, other opportunities exist to receive energy and capacity income (via the Electricity Pool) and the provision of standing reserve.

Further information and perspective of evolution

Broadly, there are some ancillary services that NGC explicitly pay for through contracts and other requirements, which are similar to ancillary services, that are required as part of connection requirements. These arrangements apply to generators in England and Wales.
For ancillary services, we use the concept of "System" and "Commercial" services. System ancillary services are basically provided on a cost-reflective basis, and commercial services on a value-basis. Cost-based services for reactive power and for response are gradually evolving into value-based services. That means, as a result of increased market mechanisms and competition, we buy services at the price the generator (or other service provider) wants - and do not pay for them if we do not use them.

All large users, both Generators and Suppliers, are obliged to comply with the Grid Code.
Connection rules are described generically in:
- the Grid Code (as agreed with the Regulator); and
- within the Transmission Licence (again approved by the Regulator); and
- bilaterally within individual connection agreements.

In the presence of Connection Rules, the Transmission Operator ought to have some sanction if those rules are not followed.

It is interesting to note that with NGC:
- For ancillary services where payment is due, failure to provide the service will normally led to simply withholding of any payment due (financial penalties as such are not used). This applies to all service providers.
- For services where payment is not explicitly due, and required as part of the connection arrangements, failure to provide the service will lead to restricted plant operation or disconnection from the system. This must be an obvious consequence where the safety of the system, plant or personnel is at risk.
- For services (ancillary or connection) that lead to a degraded, but not dangerous, service, the generator must put in place an agreed works programme to restore that service capability. Occasionally this may not be necessary if the Regulator agree to a derogation of the connection requirement (e.g. full restoration of MVar capability).

Also used is the concept of "emergency assistance" as a service. This solely relates to emergency dealings with Scotland and with France, where at certain times, either system is short in some way (and needs "assistance"). Each system obviously is required to meet its' own requirements in the first instance, but if it is able to provide MW, reserve, response or reactive power when needed, it shall do so and be fully reimbursed for such costs. This is to ensure that the customers of one system do not subsidise the other.

New electricity trading arrangements are expected in Autumn 2000, which will have significant repercussions in the services that are required, and how they will be contracted. The Electricity Pool will disappear, which will obviously affect services with a strong energy bias (such as reserve). The regulator is also further encouraging the development of market mechanisms for services.

7.2 CONNECTION RULES AND ANCILLARY SERVICES IN SPAIN

Connection rules for generation

The connection rules for generators in the Spanish System are under development, existing at the moment two categories, depending on the consideration of the new plant as special generator (to be dealt with in the Chapter 5) or not.
For the general case (i.e., not special) the Electricity Act establishes that the access will be free unless power supply may result at danger. Therefore, network capacity reserve is disregarded, and possible limitations derived from operation of existing or former users will not constitute a barrier for the newcomers. Being grid constraints solved by market mechanisms within the daily market, the preceding approach obliges to competitiveness not only at the system level but also at the zone level; in order to soften this aspect, complementary procedures may be established to cover financial risk. Unlike other power systems, the Spanish system operator is not given the function of deciding which agent might have preference in the usage of the network resources, but provides information about the foreseen constraints and especially analyses the possible misbehaviour derived from the new generation. This is the only argument to deny access to the system at a given point. This is a key design point by which power supply is recognised as the raison d'être for the electric system having thus the priority over the power generation, which influences all other aspects dealt with here.
In economic terms, it is assumed that the new facilities are to be paid for by the new agent in the elements necessary for connection to the existing or planned grid, while the system will globally pay for the further developments which might result necessary within the grid. A signal of the expansion network cost derived from the access is thus generated. There is a perception by the new agent of the investment cost directly derived from connection, while the reinforcement needs are perceived by the likelihood of being included in the grid expansion plans and the likelihood of their realisation.
In practical terms, this context affects the generation connecting to 220 kV and above (400 kV).

Ancillary services

Definition.- The ensemble of services necessary within a power system so as to accomplish the primary function of providing active energy, with the sufficient degree of reliability and quality of supply.

Identification.- The recognised ancillary services are the following:
Primary Regulation
Secondary Regulation
Tertiary Regulation
Voltage Control
Black start Capability

Classification and management.- In spite of their physical necessity, the provision of the preceding services may be carried out in a compulsory or voluntary basis; complementarily, the services may or not be paid for. These variables permit a classification of the services, for which purpose technical and economic reasons together with practical feasibility and convenience must be considered. The eventual economic management of these markets is carried out by the TSO).

Primary Regulation.- This ancillary service is aimed at the automatic correction of the load-generation unbalance. It is proposed as compulsory and not economically remunerated by the active (on) generators (autonomous and immediate - 0÷30 s - response of speed regulators of turbines). The current exigency is the capability of varying 1.5% of rated power for frequency deviation of 200 mHz. The obligation is subject to technical possibilities, and the assignation is proposed on an annual basis. In the case of technical impossibility the agent must contract these resources with another agent capable of providing the service (contract supervised by the TSO and subject to certain constraints: rated power of provider group must equal or exceed the sum of those for which it provides).

Secondary Regulation.- This ancillary service is aimed at the preservation and reposition of inter-area programmes (international interchanges at the moment -restoration within 20s÷15min-). It is proposed as voluntary and economically remunerated. The TSO will manage this market (daily) : as a result of offers to increase and to decrease (MW-up and MW-down proposals) given by the agents in a price basis (? /MW associated to the hours of the period), the TSO assigns the necessary resource for each hour of the period considering requirements associated with geographic regulation zones. The retribution is carried out observing two terms: available band (payable according to spot prices resulting from the market) and actual usage of the resources (payable considering the value of substituting tertiary band).

Tertiary Regulation.- It is aimed at the coverage of the secondary reserve (5 - 15 min), being quantified as the maximum expected generation programme in a 15 minute period. It is proposed compulsory (all available resources must be offered) and remunerated. In a similar way to the secondary reserve, the agents will offer the corresponding resources to increase and decrease, as well as the energy price (? /kWh). The resulting spot price will be the basis for the valuation of the service, whose retribution observes the actual usage of resources (without availability term).
Both secondary and tertiary reserves may need exceptional mechanisms of assignation when the requirements have not been met by the respective markets. Such special procedure is carried out by the TSO with a pre-established economic assignation linked to daily market prices.

Voltage Control.- It is aimed at the preservation of the voltage levels within a margin, accomplishing reliability criteria. The current proposal contemplates two time-stages in the future: at the first stage, generators, transmission companies and eligible consumers might participate, with a second stage which would incorporate distribution companies (possibly represented via regional distribution operators). In terms of participation, (due to the essentially local nature of this service and the unfeasibility of a global application) two parts are considered: there is a compulsory magnitude of resources that the agents must provide and additional resources might be offered in a particular market, by generators, eligible consumers and distributors. The retribution is associated to this declared additional capacity (and its correct utilisation).
The first stage has already been approved, concerning the potential suppliers:

- Generators over 30 MW, directly connected to the transmission grid (or generation clusters injecting a net power greater than 30 MW for the corresponding periods). The compulsory reactive requirement is associated to reaching $\cos\varphi=0.989$ inductive or capacitive (at the generator mains).
- Transmission companies, which must contribute with the available means (transformer taps, switching of lines, compensation elements, …).
- Qualified consumers (eligible) connected to the transmission whose contracted power exceeds 15 MW, which must comply with different $\cos\varphi$ margins for the established periods.
- Distribution grid operators (extension of this management is to be developed).

Beyond the preceding obligations the service suppliers may offer the extra resources which will be required by the SO in a year basis. This is carried out by the suppliers knowing the prices, which will initially be regulated and published at the end of the year to be applied for the next (the information requirements depend on the type of supplier and for generators and consumers are associated to period type and voltage level). At the end of the year the SO will carry out the reactive assignation for the next year.

Black start Capability.- It is aimed at the restoration after regional/national black-out. The mechanism is undefined at the moment.

In addition to the preceding, there are markets (which include mechanisms not recognised as ancillary services in Spain, although they constitute **system services** in the sense that they are considered necessary for the adequate performance of the power system they have different procedures. These, together with ancillary services, are integrated within the **Operation Markets**, in correspondence with their technical nature and the fact that they are managed by the System Operator -REE-.
At the moment, these additional services are the so-called "Load-Production Unbalance Management" and "Restrictions Solution", which are presented next:

Load-Production Unbalance Management.- This service is in fact an extension of the tertiary reserve, slower in terms of the required response time. It is aimed at solving the load-generation unbalance when within the intra-daily scope (there are 6 intra-daily sessions at the moment, i.e., one every 4 hours) the divergence between demand forecasted by the SO and generation assigned by the MO is greater than 300 MW. When this circumstance is noticed by the SO -after the intra-daily session closing- the agents are asked to offer during a period of 30 min. and they will offer ranges of increase and decrease with the corresponding price. The matching algorithm will minimize the hourly overcost derived from this mechanism.

Restrictions Solution.- Although it is not a market at the moment (in the sense that agents are not called for solving network constraints with the consequent price competition by the potential candidates) the process is included within the mentioned Operation Markets due to the market oriented philosophy in it. There are also some heuristic criteria associated to the share of restrictions when national and international facilities (and the corresponding power flows) are involved.

Black start Capability.- It is aimed at the restoration after regional/national black-out. The mechanism is undefined at the moment.

7.3 ANCILLARY SERVICES IN ITALY

The market of primary power and energy service is under regulation in Italy, following the European Directive 96/92/CE of 1996. In the first phase of the market, independent power producers and eligible consumers will be allowed to state bilateral contracts. In a second phase, as the number of participants grows, a pool entity will be established to manage the power market.
An independent authority for energy is responsible for establishing transmission pricing methodologies, wheeling tariffs and ancillary services payments.
As regards ancillary services, no market has been established so far, however they have been recognised as those functions necessary for a reliable and secure network operation.
The main ancillary services are:

1. Frequency regulation
2. Reserve
3. Black start capability
4. Reactive power provision

The Transmission System Operator will be responsible for the provision of a sufficient level of each ancillary service, in order to maintain system reliability and security for all operating intervals.

Frequency regulation

Two types of frequency regulation are used in the Italian electrical network: the primary frequency regulation and the power-frequency regulation.
The primary regulation of frequency is achieved through the control system available on each generating unit acting on the steam valve opening (for steam turbines) to change the power output level in response to a frequency deviation. This is a local regulation usually acting after a perturbation event.
Presently, each dispatched unit participates to primary frequency regulation in the relative dispatching interval, so the total amount of power devoted to primary regulation is sufficient to meet network requirements.
The power-frequency regulation is the large-scale frequency control obtained through a centralised system, which sets the proper level of units power output and power exchanged with neighbouring areas through interconnecting tie-lines. The goal of this centralised control action is to maintain the system frequency and the total power exchange through tie-lines equal to a set value. The total amount of power devoted to secondary frequency regulation is 1000 MW (500 MW for up-regulation and 500 MW for down regulation).
The Authority for energy stated that generating units must provide frequency regulation when called after a frequency deviation. They will be paid for the use of frequency regulation under a tariff-based mechanism.

Reserve

The power reserve is classified as follows:

Operating reserve (spinning reserve)
The spinning reserve on a specific dispatching interval is, on each dispatched unit, the difference between the maximum power output and the dispatched power level. This is the theoretical definition of spinning reserve. However, in practical operation, the reserve is defined through the units which can actually give it, that are:
- dispatched thermal units which can give more than 45 MW in 15 minutes
- gas turbines which can give power in 40 minutes

- cold (not dispatched) hydro units which can give power in 15 minutes
- cold (not dispatched) hydro units with hydro reserve which can be continuously used for 4 hours in the morning or in the afternoon

The operating reserve is sometimes defined as “vital reserve” since it includes the secondary frequency up-regulation band. The vital reserve must always be greater than 2500 MW for the Italian electrical system, calculated as the 6.5% of the system load. This value is increased to 3500 MW on Monday to take into account the major probability of loosing starting units.

Cold reserve

The cold reserve is a long term standing reserve: it is provided by cold units whose starting time ranges from 12 to 36 hours.
The Authority for energy stated that generating units are obliged to reserve power to face potential perturbations. They will be paid for the use of reserve when called up after a perturbation under a tariff-based mechanism.

Reserve allocation

The reserve allocation is particularly important in the Italian network, as the structure of its transmission system is radial from north to south for geographical reasons. If all the reserves were allocated in the North or in the South, it would be difficult to transfer that power when called up after a contingency in the opposite part of the system.
For this reason, the system is divided into 5 main areas and an amount of reserve proportional to the area load must be located inside the area itself.
Another allocation rule regards the amount of power reserved on thermal and hydro units.
The reserve allocated on the overall thermal system must be equal to the power of the greatest dispatched unit (usually equal to 800-900 MW). This value is increased on Saturday and Sunday.
The rules of reserve allocation should be respected also in the presence of a market for reserve, because they are vital for a reliable and secure network operation.

Black start capability

It is provided to ensure the system is able to restore from a blackout condition.
It is given by few specific units on the system, of two basic types:

- hydro units (the system is restored by building a radial system until a thermal unit is reached and powered)
- combined cycles with gas-turbines (the system is restored by building a small load system surrounding the combined cycle)

The black start capability is a vital service for the system security but the associated probability of use is very low. For this reason payments to black start producers take mainly into account the costs for the equipment employed in their units and the cost of periodical tests.

Reactive power

The energy service must be assured with a proper voltage profile on the whole transmission system. The voltage profile is controlled by managing the reactive service resources on the network.
Reactive power is mostly provided by generating units in Italy, but also the transmission system can give a contribution as it is equipped with reactive sources such as capacitor banks.
The reactive power given by generating units can be manually set by unit operators or automatically and continuously controlled through voltage regulation systems.
As for frequency regulation system, the voltage regulation is done on a two-level basis, that is both local and global action assure the voltage recovery due to sudden (local) or system perturbations.
The Italian Authority for energy includes the payments for reactive service provision in the wheeling transaction. The reason is that reactive service is strictly coupled with active power service and always involved when a power transaction takes place.

7.4 THE STATE OF THE ART IN GERMANY

7.4.1 Unbundling

Consistent implementation of unbundling also requires a separation of information systems and channels to ensure the necessary confidentiality of sensitive commercial data relevant to the market. In this respect, a balance certainly has still to be established between the requirements of system operation and the interests of system users. On the one hand, the system operator needs detailed knowledge of commercial transactions between his customers, except their price agreements. On the other hand, system customers are hardly inclined to comprehensively satisfy this information demand.

The market as well as the experience gained by market participants with regard to their relations will help to develop mechanisms which should be favoured over bureaucratic regulations for the development and control of so-called “Chinese Walls” between the transmission system operator and the remaining fields of activity of the same company.

7.4.2 The DVG

Since 1st July 1999, the DVG Deutsche Verbundgesellschaft e. V. has been the association of German Transmission System Operators (TSOs) with responsibility for the system. Its members will concentrate on the tasks of transmission system operation. This means in particular treatment of all questions relating to the access and utilisation of the German transmission systems. This requires co-ordination of the eight German TSOs among themselves and with European TSOs with a view to assuming responsibility for the whole system.

7.4.3 The Grid Code

The Grid Code [1] applies exclusively to the transmission level. Its counterpart referring to the distribution level is the Distribution Code that was drawn up by the VDEW (Association of German electric utilities).

In view of the question of how precisely the market for the ancillary services ought to be organised, the German GridCode provides the flexibility on details that is much needed by the market participants. The procurement of ancillary service components is left open with regard to tendering procedure, contract duration and structure.

System services have to be provided by the Transmission System Operator. This task is part of the system responsibility. This is best implemented by the TSO striving to serve as the centrepiece of the ancillary services markets with full responsibility for its functioning, for the system security and reliability that the market supports and for a non-discriminatory market organisation. These individual ancillary services are upgraded by the TSO into system services. The supply of ancillary services is organised in competitive markets wherever possible. In many cases it will not be feasible, however, to charge individual users of the transmission grid according to individual load characteristics. Yet the overall effect is still that the TSO provides a marketplace where anonymous transactions between the suppliers and either individual or collective users of system services are made possible while establishing a market-clearing price and guaranteeing the quality of the product traded.

The Grid Code published by the eight German Transmission System Operators within their association Deutsche Verbundgesellschaft (DVG) adheres to these principles. It demonstrates in an examplary fashion how competition can be incorporated into the supply of ancillary services without endangering the exercise of system responsibility. Furthermore, it encourages subsidiary and flexible solutions and is thus part of the German implementation of the EU directive on the IEM which relies on the concepts of subsidiarity and federalism.

To date, positive experience has been gained in Germany with the technical supply conditions in the framework of the DVG Grid Code.

The Grid Code must follow the market development and needs to be adjusted in accordance with the experience acquired. In this respect, the DVG can provide a forum for TSOs and system users. To this end , a consultation group was constituted that has already convened several times. This committee comprising about 30 persons is composed of representatives from the various sectors, such as generation, distribution, trade, major customers and renewable energies as well as TSOs. The Federal Ministry of Economics has a guest status in this committee. The members will co-operatively develop the Grid Code 2000 on the basis of the new Associations’ Agreement that is to be implemented at the beginning of this year.

In accordance with the new Associations’ Agreement, the costs of system services required for the system utilisation are included in the utilisation payment. Frequency stability costs are allocated to the EHV level, whereas the costs of the remaining system services are allocated to the network level where they arise. Furthermore, international developments within UCTE and ETSO must be taken into consideration.

The GridCode 2000 on "Network and System Rules of the German Transmission System Operators" is in preparation [3] and will probably be published in Summer 2000.

7.4.4 Associations’ Agreement

The Associations’ Agreement on criteria for electric energy transmission pricing implemented at the beginning of this year, provides a basis for

- agreements concluded between system operators and system users about the utilisation of the system on a contractual basis (NTPA);
- corresponding pricing pursuant to the Energy Industry Act which implements the Electricity Directive 96/92/EU into German legislation.

This Associations’ Agreement has no immediate impact on the technical supply conditions defined in the DVG Grid Code. Only an adjustment has to be made in terms of the wording.

7.4.5 Specific contributions to all the general items

Ref. To3. Connection rules for generation

- Common basic requirements shall be placed upon individual generating units.
- Some of the generating units must meet additional requirements to provide ancillary services.

Ref. to 3.1 Reliability standards

- All technical facilities servicing connection of the generating unit must correspond to established good practice as embodied in the TSO's network.
- Synchronizers shall be installed.

Ref. to 3.2.2 Operation reserves supplying

- Continuous load changes of at least 2% P_N /min (where P_N = nominal capacity) must be possible across the entire spectrum between the minimum stable generation power and the continuous output power.
- Each generating unit must be capable of operation at reduced power output. The level of minimum stable generation must be agreed bilaterally between the power station operator and the TSO.
- The generating unit shall not reduce its active power supply at frequency characteristics above a fixed characteristic, even when operated at nominal capacity.

Ref. to 4.2.3 Inadvertent interchange management

The generating unit must be capable of injecting the agreed reserve power (minutes reserve) into the network within 5 minutes of the request.

Ref. to 3.2. 4 House load operation

Following tripping onto auxiliary supplies, the generating unit must be capable of being operated for at least 3 h with the generating unit auxiliary supply only.

Ref. to 3.2.5 Operation in disturbed conditions

Characteristics of the turbine-generator set relevant to the stability, i. e. the resulting effect of turbine and generator control, shall be coordinated between the power station and system operator.

Ref. to 3.2.6 Operation in restoration phase

- Each power station operator shall prepare a specific scheme for the action to be taken in the event of a large-scale failure, to be coordinated with the system operator as part of a higher-level large-scale failure contingency plan.
- Black-start capability must be available from the power station operator if required and requested by the system operator for network reasons.

Ref. to 3.2.7 Operation in island and synchronizing conditions

- The ancillary service "capability of isolated operation" must be available from the power station operator if required and requested by the system operator for network reasons.
- The control mechanism for the generating units must be designed such that synchronization to any given partial load above an auxiliary supply requirement to be specified is controlled as reliably as synchronization to generating unit auxiliary supply. A time limit must be avoided if possible. Isolated operation of this kind must be sustainable for several hours.
- Where the generating unit is operated with the loading of the generating unit auxiliary supply or a partial load, the generating unit must be capable of withstanding sudden load connections of up to 10 % of the nominal capacity.
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Ref. to 3.2.8 Resistance to unbalanced conditions (see the general part)

Ref. to 3.3 Generation control and performance requirements (see the general part)

Ref. to 3.3.3 Primary and secondary frequency control

Primary control
Additional requirements with respect to those already presented in the general part.
- The primary control band must be at least ± 2 % of the nominal capacity and be adjustable at the instruction of the system operator.
- The controller droop shall be adjustable according to the specifications of the TSO.
- The generating unit shall be capable of activating, within 30 s, the total primary control power requested at a quasi-steady frequency deviation of ± 200 mHz, and maintaining supply for at least 15 minutes.
- The primary control power must be available again 15 minutes after activation, assuming that the reference frequency has been attained again.
- In the case of minor frequency deviations, the same rate of power change shall apply until the required power is reached.
- The neutral zone shall be below ± 10 mHz.

Secondary control:
- Specifications shall be drawn up between the power station operators and the TSOs regarding the secondary control reserve/secondary control band, the rate of change and rate of occurrence of power changes, the stand-by duration, and the technical availability.

Ref. to 3.3.4 Primary and secondary voltage regulation

- Each generating unit with a nominal capacity ≥ 100 MW must meet fixed additional requirements where required by the system operator.
- If necessary the system operator can make demands on additional power stations.
- The generating unit must be able to move through the power factor design range within a matter of minutes. The entire process must be repeatable indefinitely.

Ref. to 3.3.5 Control and monitoring equipment requirements

Technical facilities must be provided for exchange of the following information in real time:
From the power station operator to the TSO:
- Circuit-breaker/disconnector/earthing disconnector/step switch settings. insofar as they are required for operation or for system analyses.

- Measured values of the current operating mode (active and reactive power).

From the TSO to the power station operator:

- Where applicable. reference values for control and instantaneous demand value of the secondary control.
- Reference value of the reactive power in the form of the schedule or as an instantaneous value.
- Circuit breaker/disconnector/earthing disconnector settings, insofar as they are required for operation of the generating unit.
- If applicable. actual values of the active and reactive power and of the voltage from the incoming transmission system substation.

Ref. to 3.3.6 Protection co-ordination and settings

The settings for the electrical protective equipment must be agreed between the TSOs and the power station operators.

Ref. to 3.4. Data required by the System Operator to the applicant generators

The scope, mechanism and procedure for information interchange (for example definition of terminology, forms, formats, protocols, procedure) shall be specified in the supply connection contract.

Ref. to 4.1.2 AS identification

In the context of an electric power system, system services refers to the services essential to the proper functioning of the system which system operators provide for their customers in addition to the transmission and distribution of electric energy, and which thus determine the quality of power generation:

- Frequency stability;
- Voltage stability;
- Restoration of supply;
- System management.

Ref. to 4.2 A/s management

- Irrespective of the position on the provider side, the costs of non-attributable system services on the receiver side must be borne by all customers connected to the network.

Table 7.4.1 shows an overview of system services, provision of ancillary services and attributability of system services in Germany.

System services	Ancillary services provided by	Attributable services on the supplier side/attributable ancillary services	Attributable services on the receiver side/attributable services
Frequency stability	Power Stations [1)] (Transport over the network)	Yes/primary control secondary control and minutes reserve power	No[2)]
Voltage stability	Power stations and network	Partly/reactive power	Partly/loads for which $\cos \varphi \neq 1$
Restoration of supply	Power stations and network	Partly/capability of isolated operation, black start capability, tripping onto auxiliary supply	No
System management	Network	No	No

Table 7.4.1: System services provision of ancillary services and attribution possibility of system services

[1)] The minutes reserve may also be provided by the disconnection of customer loads

[2)] Secondary control and minutes reserve energy shall generally be charged to the parties responsible

- In the operational planning phase, i.e. up to noon each day for the following day, the contracted power station operators shall inform the TSO of the generating units from which they shall be supplying the contracted services.
- On the basis of this communication from the power station operators and communications from other system users as well as of the instantaneous demand for system services, the TSO shall utilise the requisite ancillary services from the contracted system users. They shall be selected upon the basis of minimum cost to the system operator and assurance of maintained power.
- The primary control power to be maintained in the respective UCTE control areas is specified each year in accordance with the coefficients of participation.

Ref. to 4.3 A/S market

The TSO shall remunerate the service provides in accordance with their prices quoted in the framework of a request for bids for the provision of the required ancillary services. The TSO incurs costs as a result of these payments.
Based upon their service schedule, the TSO and the relevant system users (e. g. power station operators) shall agree on bilateral conditions for providing ancillary services required for the provision of system services. The provision of certain services may be linked contractually to the operation of certain installations (e. g. for voltage stability).

Frequency stability
- The TSO shall remunerate the power station which is obliged to maintain primary control capability for the commissioning and running maintenance of these technical facilities (including metrological requirements
- On the basis of this communication from the power station operators and the instantaneous demand for system services, the TSO shall utilise the requisite power from the contracted power station operators. The power station operators shall be selected on the basis of minimum cost to the system operator and secure maintenance of power availability.
- Should the TSO establish during daily operational planning that insufficient primary control power is available, he shall instruct a power station operator to make primary control power available.

Voltage stability
- The network concerned, the consumers, the power stations, and in an interconnected system, the boundary areas of the adjacent networks, shall be involved in maintenance of voltage stability under the coordination of the system operator.
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Restoration of supply
- The TSO shall procure contractually from other TSOs and system users the right to resort to the capability of isolated operation and black-start capability of the respective installations for provision of the "restoration of supply" system service.

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System management
- The most important functions of system management of the transmission system include network monitoring, the assurance of network security, the requesting and performance of switching operations, the performance of voltage/reactive power and power/frequency control operations, and the commissioning and maintenance of the requisite facilities for metering and pricing between TSOs (customers individual)

Ref. to 4.4 AS provision responsibility

- In order to ensure secure operation, the TSO must have control over all system services, i.e. the TSO shall specify what ancillary services are to be provided when and by whom.
- Based upon their service schedule, the TSO and the relevant system users (e.g. power station operators) shall agree on bilateral conditions for providing ancillary services required for the provision of system services. The provision of certain services may be linked contractually to the operation of certain installations (e.g. for voltage stability).

Ref. to 5 Dispersed generation

Protective relaying

To prevent any damage to the generation unit by influences from the network all units should trip on abnormalities in the network. For this purpose. a short-circuit protection like an over current relay has to be installed. Protection against influences of the generation unit on the network is in most cases only installed on agreement with the local utility. If demanded, over current relays or - in special cases - neutral voltage displacement, earth fault or reverse power detection are installed. Isolated operation is generally prohibited. To prevent from this situation. slow over and under voltage (three phase) and over and under frequency relays (one phase) are installed. These relays should be parameterised as defined in table 2 (see the general part).

Special requirements

- Some special requirements concerning operation and protection of dispersed generation units are made. according to the operation and protection scheme of the network, in which these units are integrated. In German medium-voltage overhead line networks a three phase short-circuit interruption is present, Dispersed generation units feeding into a network fault could interfere with this short circuit interruption and therefore have to trip that fast, that the duration of the short-circuit interruption is not influenced by them.

- No interference with the audio-frequency remote control system is allowed. To guarantee the operation of this control system, the impedance of the dispersed generation unit at the broadcast frequency should be high enough. This can be realised by installing filters at the generation sites. Also a harmonic distortion of maximal 0,1 % U_n is allowed for the harmonic orders in the neighborhood of the broadcast frequency.

Summary of connection criteria

Table 7.4.2 provides with an overview of the main aspects of the guidelines to connect dispersed generation to the medium-voltage grid (see also [2]).

network interference	
voltage interference	d ≤ 2 % (MW, HV, 3%)
var-compensation	• control, no fixed capacitors • only at operation • cos φ = 0,8 ind…0,9 cap
voltage distortion	• flicker: A_t < 0.1 • harmonics limited
synchronising	• synchr. generator: ΔU < 10 % Δf < 0,5 Hz, Δφ < 10° • asynchr. Generator: no load, speed at 95% … 105% of n_n
Protective relaying	
influence from network	short-circuit protection
influence on network	short-circuit over current
isolated operation	ΔU (3~), Δf(1~)
Special requirement remarks	no interference with: • short –circuit interruption • audio-frequency control

Table 7.4.2: summary of connection criteria for dispersed generation on medium voltage in Germany

- The supply conditions must assure that no power deficit will occur as a result of too high adjusted under frequency limiting values. Besides should be fixed an information duty of the supplier concerning unavailability.

References

[1] DVG: The GridCode
Network and System Rules of the German Transmission System Operators, July 1998

[2] CIGRE: Impact of increasing contribution of dispersed power generation on the power system (WG 37.23), 1998

[3] DVG: GridCode 2000
Network and System Rules of the German Transmission System Operators, 2000 (in preparation)

7.5 PERSPECTIVES IN FRANCE

Introduction: present situation in France

The French law has been definitively voted at the beginning of the year 2000 (law dated 10.02.2000).

The official discussion about the future French grid code is not yet engaged (but the future French ISO – GRT in French[1] – has already largely completed an internal draft for its own preparation).

Officially, France has a recent public document (dated 30.12.99) related to the connection of the power units to the "public transmission grid"[2]; it addresses generation units with Pn ≤ 120 MW connected to the main grid at voltage ≥ 45 kV (excluding the 400 kV grid); this was considered to be the priority in France. There are also specific documents for combined heat & power generation.

A similar document is in progress for generation units above 120 MW (as the previous one, this document is prepared by a working group including system users, managed under the responsibility of the French minister of industry).

3 Connection rules for generators

3.1 Reliability standards

As far as ancillary services are concerned, the generation units must meet specific requirements.

Design (constructive) requirements must first be met before allowing the first connection of a unit to the grid. This is a counterpart for the right to be connected to the network. According to the terms of the European Directive, the System Operator is responsible for ensuring a secure, reliable and efficient electricity system, and, in that context, for ensuring the availability of all necessary ancillary services. As written in /1/, the contributions to the ancillary services to be consequently provided by the producers at a given time depend to a great extent on the power system operating conditions (expected development of consumption in particular). The System Operator (GRT) must therefore be able to make use of a volume of available contributions to the ancillary services. This implies that the System Operator assumes the responsibility of defining, under the Regulator's Control, the list and the characteristics of the design performances of the units and of the basic services that any producer must be capable of providing so as to be integrated into a power system meeting the desired safety conditions. The basic principle is the obligation that any generation unit (except specific derogations granted by the Regulator), whether it contributes to the supply of eligible customers of that of non-eligible customers, must be capable of providing minimum contributions to the ancillary services.

The performances of a unit are part of the contract between the producer and the GRT. The producer has to prove that the performances of the unit meet the requirements. The GRT has the right to

[1] GRT: Gestionnaire du Réseau de Transport

[2] the "public transmission grid" is the grid at voltage ≥ 45kV which the ISO (GRT) is responsible for

proceed to control of the performances (or to ask it to an independent body approved by the Regulator). The control include three types:

- initial control of performance, as a prerequisite for the first connection agreement,
- continuous control in operation,
- non continuous control.

3.2 Operation requirements

3.2.0 Operational conditions liable to be met by the units connected to the power system

Frequency conditions expressed as liable to be met by the units on the French power system:

- [49,5 – 50,5 Hz]: continuous operation
- [49,0 – 49,5 Hz]: maximum duration per event 5 h, cumulated duration 100 h during lifetime
- [50,5 – 51,0 Hz]: maximum duration per event 1 h, cumulated duration 15 h during lifetime
  [47,0 – 49,0 Hz]: maximum duration per event 3 min, exceptionally
- [51,0 – 52,0 Hz]: maximum duration per event 15 min, 1 to 5 times per year
- [52,0 – 55,0 Hz]: maximum duration per event 1 min, exceptionally

Voltage conditions liable to be met by the units on the French 225kV power system:

- [200 – 245kV]: continuously (normal operation)
- [245 – 247,5kV]: during 20 min, a few times per year
- [247,5 – 250kV]: during 5 min, exceptionally
- [180 – 190kV]: during 1 h, exceptionally once per year
- [190 – 200kV]: during 1 h 30 min, exceptionally a few times per year

Voltage conditions liable to be met by the units on the French 63kV and 90kVpower system:

- voltage fields are determined for each instance, with mention of continuous fields and of limited duration fields

Voltage conditions liable to be met by the units on the French 400kV power system:

- [380 – 420kV]: continuously (normal operation)
- [360 – 380kV]: during 5 h, 10 times per year
- [340 – 360kV]: during 1 h 30 min, a few times per year
- [320 – 340kV]: during 1 h, exceptionally
- [420 – 424kV]: during 20 min, several times per year
- [424 – 428kV]: during 5 min, a few times per year
- [428 – 440kV]: during 5 min, once every 10 years

3.2.1 Performance standards (voltage/frequency domain)

Continuous and limited duration times required from the units (voltage and frequency):

- units ≤ 120 MW connected to the main grid at voltage ≥ 45 kV (excluding the 400 kV grid)(for commodity, we will call these units "units of type A" in the following text): as expressed above, with a specific mention regarding the behaviour in case of voltage disturbances.; a [U,Q] diagram is defined which includes a "normal" field and four "exceptional" fields (high voltage / low voltage / slow voltage collapse / exceptional behaviour between 0,7 Un and 0,8 Un); duration prescriptions are given according to the situations expressed in 4.2.0 and the position in the [U,Q] diagram.
- units > 120 MW and other units connected to the 400kV network (we will call these units "units of type B" in the following text): should probably be identical to what is expressed above, but under discussion on some points. Owing to the peculiar importance of the behaviour of the main units, some performances could (or should) be different in the exceptional situations; it must be noticed that the present EDF main units meet higher standards than those which have been decided in December 1999 for units of type A; if this were to be reproduced in the future text for units of type B, this would lead to a decreased system security.

3.2.2 Operating reserves supplying

As is the UCTE Ground Rule /2/ entered into force in 1998, there is a distinction between primary reserve, secondary reserve and tertiary reserve.

The tertiary reserve is the power which can be connected automatically or manually under tertiary control, in order to provide an adequate secondary control power reserve. This reserve must be used in such a way that it will contribute to the restoration of the secondary control range when required.

Tertiary control is any automatic or manual change in the working points of generators participating in secondary control, in order to:

- guarantee the provision of an adequate secondary control reserve at the right time,
- distribute the secondary control power to the various generators in the best possible way, in terms of economic considerations.

Just as primary control and secondary control, contribution to tertiary reserve is a specific ancillary service.

3.2.3 Inadvertent interchange management

This is proceeded through secondary f/P control. Contribution to secondary control is a specific ancillary service.

This service is not required from units of type A; so no design (constructive) requirement is asked to such units.

3.2.4 House load operation

Every thermal unit > 20 MW must be designed so as to be able to proceed to house load operation (except if the GRT specifically does not want it).

3.2.5 Operation in disturbed conditions

The requirements precise the conditions to be fulfilled:

- behaviour in the voltage and frequency fields,
- capability to withstand close up faults,
- condition of stable operation without loss of synchronism (steady state and transient stability),
- conditions of separation from the network,
- behaviour in separated network,
- behaviour in house load operation,
- preparation of network restoration.

3.2.6 Operation in restoration phase

For units of type A, the ISO (GRT) may negotiate the possible contribution for units with Pn ≥ 40 MW, case by case and for well-founded cases.

For units of type B: under discussion.

It must be stressed that the design (constructive) ability of an unit is not enough to allow the producer to provide a service of contribution to restoration; this service needs from the producer involvement in studies of restoration scenarios, highly specific staff training, periodical operational tests of the scenarios, dispositions so as to ensure the effective availability of the scenarios, and so on. This is peculiarly important in France because it conditions the nuclear safety of the nuclear units.

3.2.7 Operation in island and synchronising conditions

The ability to perform operation in island is required from units of type B, and of units of type A for Pn ≥ 20 MW (this includes provision of regulators able to perform this function).

3.2.8 Resistance to unbalanced conditions and 4.2.9 harmonic and voltage conditions

For units of type A, the document specifies that the perturbations that the network may present are those already defined in France in terms of quality of supply through the official "Contrat Emeraude".

The document also specifies the maximum disturbances that the generation unit is allowed to produce on the network.

Similar requirements will be specified in the document related to units of type B, which is under discussion.

3.3 Generation control and performance requirements (Hardware requirements)

3.3.1 –3.3.3 – 3.3.4 Frequency reserves capability

Primary reserve:

Every producer operating units of type A with Pn ≥ 40 MW must be have a design (constructive) ability to provide a primary reserve equal to 2,5% of the total amount of the power of these units; the 2,5% ability is not required from each unit but may be mutualized between the units of the producer.

For units of type B, the 2,5% constructive ability is required individually from each unit.

The UCTE rules concerning the regulators (insensitivity, dead band ...) must of course be followed.

Secondary reserve

For units of type B, each unit must have a design (constructive) ability to provide a secondary reserve equal to 4,5% of its nominal power Pn.

The generating unit must be equipped with the automatic equipment and communication links with the system control centre.

The specifications precise the time to be able to stand for the full crossing of the secondary band at normal and at urgent speed.

Tertiary reserve

Not yet discussed for units of type B.

4 Ancillary services

The ancillary services are those services which are necessary to transmit the energy from the generation units to the loads while ensuring system security.

The ancillary services (in French: services système) are elaborated and provided by the System Operator (GRT) /1/.

The GRT:

- obtains contributions to the ancillary services or ("elementary" ancillary services) from service producers,
- carries out the technical management of the system, while making sure there is a suitable level of security,
- adds its own share (implementation of controls, load dispatching function) and thus elaborate the final ancillary services,
- provides the consumers with the ancillary services.

The producers provide *contributions to the ancillary services*, or "*elementary system services*", which may be expressed in terms of basic participation in active power reserves, load follow capacity, voltage capacity and reactive power supply, good performance in a disturbed situation and possibly a contribution to service restoration following an incident.

Because he is connected to the power system, each consumer is also a consumer of ancillary services, even if he has never known it until now. The other users of the transmission system (producers, distributors) are in fact also consumers of ancillary systems (though they generally do not know it).

As far as contributions of producers to ancillary services are concerned, one must distinguish:

- the design (constructive) ability of the units to provide contributions to ancillary services, which is – as said before – a counterpart for the right to be connected to the network; in every country, this is governed by <u>prescriptions</u> which are found in the grid code or in equivalent documents; in France, the trend is that this design (constructive) ability must not be remunerated because it is the counterpart of the right to be connected;
- the effective contribution of the producer to the services (in real time) is ensured differently according to the countries; it may be governed by prescriptions or by market (tenders, pools ...) or by combination of both, and the partition between prescription and market may be different according to the ancillary service which is considered (primary f reserve, secondary f reserve, tertiary f reserve, U/Q control, black start, restoration ...). These differences come from the countries and their peculiarities (philosophy, history of the power system, arrangement of the electricity field between actors of the system, characteristics of the network and of the generation, characteristics of the generation mix in the country, and so on); this may also explain that some of the services are remunerated or not.

In France, as far as this effective contribution of the producers in real time is concerned, the grid code is not yet established, so it is difficult to state what the future will be without risk; but these future conditions have a fairly high probability to be as following:

- the priority is to organize the ancillary services for frequency / power (f/P) control and voltage / reactive power (U/Q) control; this is where are the major stakes in terms of economic value, system security, interest of the new producers; the other services (contribution to restoration, black start, ...) will probably dealt in a second stage for the following reasons:
  - . there are not high economic interests in those fields;
  - . the new units which are going to be connected to the network are generally small units and / or combined heat and power units, and such ancillary services are not easy to provide by such units;
  - . if a producer wants to provide such services, he will not need only design (constructive) ability but also strong involvement in staff training, preparation of scenarios and so on, in a situation which will need high responsibilities (possible negative effect in terms of nuclear safety of nuclear units) (see §4.2.6 above).
  - considering contribution to U/Q control, it should be remunerated, and this remuneration will be based on the amount of reactive reserve provided (and not on the VARS which are really produced and absorbed, because such VAR are not really representative of the U/Q service, which is to be able to stand not only actual but credible contingencies; an other reason is that the VAR deviation in case of contingency is very short and difficult to measure precisely, which could bring disputes in the evaluation of the actual service); a market solution is difficult to provide in the U/Q field because of the local / regional nature of U/Q control;
  - considering contribution to tertiary f/P control, this is a good place for a market-based solution (market extended to interconnected countries); the arrangement has a fair chance to be based on offers provided to the GRT by the producers one day before (with proposition of quantities, with a price on the rise and a price on falling evolution of power);
  - considering contribution to primary and secondary f/P control, the conditions do not exist presently in France for a market, because there is not a high ability to provide such services, so the arrangement has a fair chance to be based on a global prescription given to each producer, combined with a remuneration; if we take the example of the primary contribution, each producer would have to meet a prescription being an extension of the UCTE principle: this producer would have to provide a volume

of reserve equal to the volume that the GRT must constitute (roughly 700 MW in France) multiplied by its contribution coefficient (this coefficient being equal to the generation provided by the producer divided by the total amount of generation in France); the producer would have the following degrees of liberty:

- possibility to distribute this volume as he wants between its generation units provided that some other requirements are met (regulating energy, geographical repartition of the reserve);
- possibility to contract with other producers if he is not able to provide his required contribution only with his own units.

The principle would roughly be the same for the secondary control.

The role of interconnections

If we except the case of the contribution to the tertiary U/Q control, the other services seem to offer very few possibilities:

- the U/Q control is by nature local and regional;
- the secondary f/P control is by UCTE rule a responsibility of the control zone, and so the service cannot come from other control zones;
- the primary f/P control may be a field of interest, but it will be difficult to arrange something till there are no really feasible means to be sure that a contribution bought in a different system is really available and produced;

A/S market

As the main aspects have been presented above, we will present only the price determination.

A basic principle is that all the costs of the producer (including investment and operation) should be covered.

- contribution to U/Q control:

  a cost is difficult to identify and to quantify both in investment and in operation; however a remuneration is necessary as an incentive for the producers to contribute to U/Q control; the price – rather arbitrary – will probably be a regulated tariff ratified by the Regulator; for establishing this tariff, a comparison will certainly be used with other substitution means (more or less equivalent, going from the capacitors – which are not at all equivalent – to static VAR compensators); the regulated tariff will be in fact an indication of the value of U/Q security seen from the system users!
- contribution to tertiary f/P control:

  the price will come from the confrontation of the market offers one day before;
- contribution to primary and secondary f/P control:

  the price will probably be – at a first stage – a regulated tariff ratified by the Regulator; it should be based on long term costs including both development (investment) and operation costs.

References:

/1/ J.M. Tesseron, B. Heilbronn, A. La Rocca, A. Queffelec, P. Sandrin, C. Trzpit
"Independent power producers and system services provided to the power system"
CIGRE Symposium "Impact of the Open Trading on Power Systems", Tours (France), June 8-10, 1997

/2/ UCTE
Ground Rule concerning primary and secondary control of frequency and active power within the UCPTE
(Ground Rule adopted by the Assembly on 16.04.1998, entered into force on 01.06.1998)

7.6 THE GRID CODE AND THE ANCILLARY SERVICES IN THE NETHERLANDS

In the Dutch system TenneT serves as a System Operator as well as Grid Operator of the 380 and 220 kV transmission system, including all cross border connections. Currently all non mandatory Ancillary Services are contracted with one supplier, the Dutch Electricity Generating Board (Sep). Per 1-1-2001 this contract will end. By the end of this year TenneT will have specified the need and requirements for regulating and reserve power and black start provisions. Purchasing will start next year.

Specific contribution to the general items are shown below.

Ref. to 3 Connection conditions for generation

The Dutch system is, in addition to and prescribed from the Dutch Electricity Law of 1998, ruled by a series of Technical Codes. The System Code concerns rules regarding system services. The Grid Code concerns rules regarding the connection to the Grid and the transmission of electrical energy. The Metering Code concerns rules regarding metering and exchange of metering data. The Tariff Code concerns the structure of the tariff system in the Netherlands. Finally there is an Agreement of Co-operation between all the grid operators. Connection conditions for generation are specified in System Code (concerning security and efficiency of electricity transmission) and Grid Code , depending on the specific service supported (system service or transmission service).

Ref. to 3.1 Reliability standards

Reliability criteria for generators are not specified. Reliability standards concerning the transmission service are specified in the Grid Code as a result of the grid planning criteria prescribed. Reliability standards concerning system services are not specified.

Ref. to 3.2 Operation requirements
Ref. to 3.2.1 Performance standards (voltage/frequency domain)

Four operating domains are defined in this respect:
Capability of nominal power output during unlimited time period
Capability of nominal power output during 15 minutes, followed by unlimited parallel operation
Unless parallel operation in operating domain II is applicable, capability of 90% of nominal power output during 10 seconds, followed by unlimited parallel operation
The applicable voltage/frequency limits for each operating domain differ per voltage level and are displayed in the general fig. a.

Ref. to 3.2.2 Operating reserves supplying

See inadvertent interchange management

Ref. to 3.2.3 Inadvertent interchange management

Inadvertent interchange management (or system balancing) is the responsibility of the national grid operator (TSO). Inadvertent interchange management is done mainly by AGC and partly by manual control (mainly load reduction through load management contracts). Inadvertent interchange management is considered a system service. Power reserve capacity (either under control of AGC or manually controlled) needed for system balancing is considered an Ancillary Service.

Ref. to 3.2.4 House load operation

There are no requirements specified regarding house load operation in the Technical Codes. House load operation is considered own responsibility of the generator in fulfilling the requirements regarding operation under disturbed conditions.

Ref. to 3.2.5 Operation in disturbed conditions

The capability requirements of withstanding near-by grid faults (short circuit conditions) are specified in the System Code and are considered a mandatory Ancillary Service without reimbursement.
The following requirements are specified:
For generators connected at a voltage lower than 110 kV disconnection due to a voltage dip with remaining voltage between 0.8 and 0.7 of the nominal value is allowed no earlier than after 300 ms. If the remaining voltage is lower than 0.7 of the nominal value, disconnection is allowed no earlier than after the smallest of 300 ms and 90% of the critical short circuit time
For generators connected at 110 kV and higher, disconnection due to a voltage dip with remaining voltage value below 0.7 of the nominal value is allowed no earlier than after the smallest of 300 ms and the critical short circuit time
All generators must be capable of stable synchronous operation within 30 minutes after relieving of the short circuit. This does not apply if the grid voltage does not return within one hour.

Adherence to these requirements is considered a mandatory Ancillary Service.

Ref. to 3.2.6 Operation in restoration phase

There are no specific requirements other than under section 3.2.1 (voltage/frequency domain) specified.

Ref. to 3.2.7 Operation in island and synchronising conditions

Main difference in Ancillary Services requirements between interconnected and island operation concern the primary reaction. A maximum primary reserve capacity of between 3 and 5% of the maximum power output is generally required. Depending on the specific operating conditions, the TSO will specify the amount applicable. For connected operation the TSO will adhere to UCTE requirements (currently 1%). For island operation the 3%/5% requirement will be applied up to the maximum value.

The voltage/frequency domain requirements as specified earlier remain applicable also.

Ref. to 3.2.8 Resistance to unbalanced conditions and Harmonics and voltage fluctuations

No general requirements. Necessary requirements will be negotiated between the grid service provider and the generator to be connected.
Regarding harmonics generators have to adhere to NEN 3173 (year 1991).
All connected apparatus with a capacity of 11kVA and more has to adhere to specific requirements issued by EnergieNed in 1996.
Also for single phase traction feedings connected to high voltage grids specific requirements are issued by EnergieNed.

Ref. to 3.3 Generation control and performance requirements (Hardware requirements)

Ref. to 3.3.1 Operating reserves capability

Operating reserves are necessary for system balancing to provide for differences between momentary supply and demand due to random deviations and differences due to generator outages. Operating reserve necessary for the first category of system unbalance is called regulating power. Operating reserve to provide for generator outages is called reserve power.

In the Netherlands a system of program responsibility is in operation from 25 May 1999. Under this system each connected customer has the responsibility to provide (or let provide by a third party) energy programmes to the grid companies. A penalty system is used regarding unbalance between programmed and actual values to provide balancing incentives to the program responsible parties. Relieve of resulting system unbalance remains the responsibility of the system operator.
A system of contracting for regulating and reserve power will be active starting from 1-1-2001 which marks the end of the current long term contracts in the Dutch ESI. Not all of the required reserve capacity may be

contracted. Additionally market opportunities on a spot market will also be considered. A nomination and dispatch procedures for reserve capacity (long term contracts and spot market) are under development.

Regulating and reserve power must be dispatchable within 15 minutes.

Ref. to 3.3.2 AGC

See secondary frequency control.

Ref. to 3.3.3 Primary and secondary frequency control

A percentage of the nominal power output of each generating plant larger than 5 MW has to be reserved for primary reaction. This percentage is between 1 and 3-5% and will be specified by the system operator. Primary reaction must be given under automatic control (primary control). Additional power output under primary control up to the maximum reserved capacity will have to be released depending on the primary reaction demand according to figure 7.6.1:

- If primary reaction demand is equal to the maximum value the reaction must be completed within 30 seconds after the frequency disturbance
- If demanded primary reaction is between 50% and 100% of the maximum value, this reaction must be completed within an equivalent percentage of 30 seconds after the frequency disturbance
- If the primary reaction demand is lower than 50% of the maximum value, this reaction must be completed within 15 seconds after the frequency disturbance
- Primary reaction must be sustained during 15 minutes
- Non-reaction due to dead bands are allowed if this is compensated by other generators of the same connected party

Supply of primary reserve is considered a mandatory Ancillary Service without reimbursement.

Specifications for power reserve under secondary frequency control are currently under development by TenneT. Contracting has to allow for individual contributions of generators as well as for contributions of groups of generators. Specification covers issues as location of reserve capacity, maximum reserve capacity, dead band, regulating speed, control cycle period and operational metering data. Secondary reserve will be paid a market oriented price. Reserve capacity under secondary frequency control is considered an Ancillary Service to be contracted and paid for by the system operator. Contracting is done by a public tendering procedure.

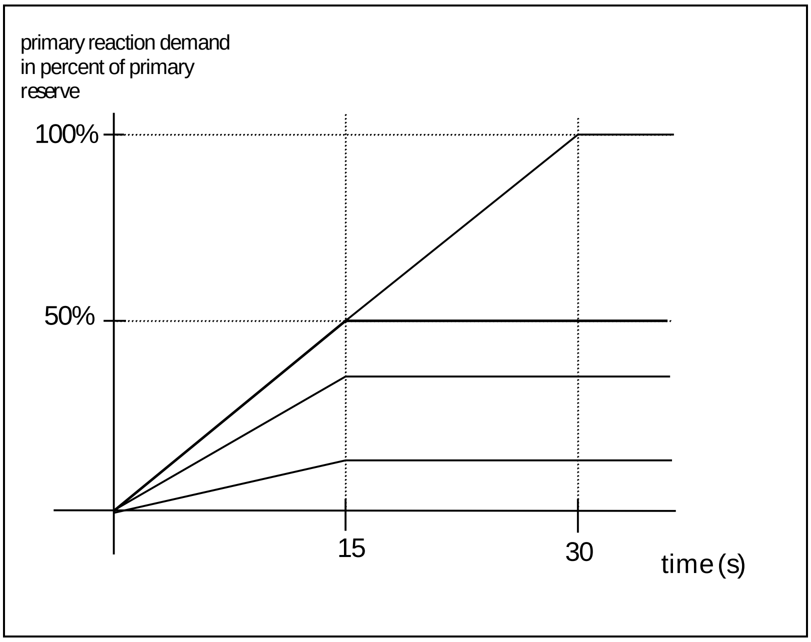

Figure 7.6.1 : Required completion time of primary reaction

Ref. to 3.3.4 Primary and secondary voltage regulation

The following requirements are specified in the Grid Code:
- All synchronous generators have to be equipped with a voltage control that is active or can be activated automatically under a voltage change. The transmission service provider may allow or require a cosφ controlling device for generators below a certain value, based on the local situation
- Generating units connected at 50 kV or higher which have been assigned a role in the voltage/reactive power household, under mutual agreement between the generation asset manager and the transmission service provider, must be able to operate with a power factor between 1.0 and 0.8 lagging
- Generating units connected below 50 kV which have been assigned a role in the voltage/reactive power household, under mutual agreement between the generation asset manager and the transmission service provider, must be able to operate with a power factor between 1.0 and 0.85 lagging
- Available reactive power capacity (leading and lagging) at the connection point will be determined once
- Droop of the voltage control must be adjustable between 0 and 10%

The exact requirements and reimbursement of these Ancillary Services are thus subsidiary to bilateral agreements between transmission service providers and connected generation asset managers.

Ref. to 3.3.5 Control and monitoring equipment requirements

All connecting points will be equipped with computable metering devices that adhere to requirements specified in the Metering Code. The site of the metering device will be determined by the transmission service provider after communication with the connected party. Variables to be metered are specified in the connection agreement.
All generators connected at 110 kV or higher have to be equipped with an operational metering device of class 2, unless agreed otherwise with the transmission services provider concerned.

Ref. to 3.3.6 Protection co-ordination and settings

Protection on generators must be selective towards transmission system protection. Generators are responsible for correct protection against system faults and extreme voltage and frequency conditions.

Ref. to 3.4 Data required by the System operator to the applicant generators

To determine daily unbalance per program responsible party each transmission system provider collects 5 minute comptable metering of summed kWh exchange values for each program responsible party at all connection points for which the PRP is responsible in his grid.
Data required for ancillary services operation will be agreed by contract. If an OTC market mechanism will be used for the purchasing of AS, rules for members of such a market will have to prescribe data exchange requirements.
Performance test data is required in the System Code to check primary control and generator robustness requirements.
Required stability data is specified in the Grid Code.

Ref. to 4 Ancillary Services

Ref. to 4.1 AS definition, identification & classification

Ref. to 4.1.1 Definition

Ancillary Services are all services needed to provide System Services or Transmission Services.
System Services are (to be supplied by the National Grid Administrator/TSO):
- Safeguard a secure and appropriate transmission of electricity on all grids
- maintain balance of generation and consumption, including exchanges with neighbouring systems
- prepare plans (together with other grid operators) and co-ordinate actions to prevent and restore large scale disturbances

Transmission Services are (to be supplied by each of the 23 Grid Operators, including TenneT)
- provide electricity transmission without constraints (except on international tie lines) up to contracted connection capacity

Transmission Services are a Grid Service together with the Connection Service and the Metering Service

Ref. to 4.1.2 AS identification

Ancillary Services needed for System Services are:

- Primary reaction
- Generator robustness (short circuit protection and operation requirements under abnormal conditions)
- Black start
- Regulating and reserve power
- Compensation for inadvertent tie-line exchange

Ancillary Services needed for Transmission Services are:

- Reactive power and energy
- Compensation for grid losses
- Power factor and voltage control
- Means to solve internal transmission constraints
- Means to solve congestion on cross border lines (management of cross border congestion is currently under development within ETSO Task Force "International Exchange of Electricity")

Ref. to 4.1.3 AS classification

Ancillary Services can be classified by origin of need, purchasing method, reimbursement method and supplier.
Origin of need is either System Services supply or Transmission Services supply.
Purchasing methods can be classified into mandatory, bilateral contracting (under the counter), public tendering or dynamic market (exchange).
Within mandatory methods sub-classification can be found by reimbursement method. These are no reimbursement and reimbursement based on costs, value or tariff.
Suppliers can be generators, consumers and connected grids.

Ref. to 4.2 AS management

The management of AS concerns contracting, nomination or bidding and offering, dispatch and settlement.

Ref. to 4.2.1 AS by native generation

All ancillary system services, except regulating and reserve power can only be supplied by native sources. Primary reaction, generator robustness and black start are typical generator ancillary services. Compensation for inadvertent energy exchange can also be supplied by consumers.

Ref. to 4.2.2 AS by network

Adjacent grids can supply most of the ancillary transmission services, except power factor and voltage control services, provided enough transmission capacity is available.

Ref. to 4.2.3 The role of interconnections

Wherever systems are synchronously interconnected rules have to be generally agreed about frequency support and area control. Within UCTE ground rules have been established for these. Other items can be left to bilateral agreement between connected systems, like voltage set points and reactive power exchange.

Ref. to 4.2.4 Co-ordination among TSOs

International transmission capacity is a limited resource. The management if this limited resource has been long under discussion within UCTE. An ETSO task force currently deals with this item and will come with a proposal by the end of 1999. A liberalised market will prosper best with some non transactions based method. The European regulators are in favour of such a method. However many legal, statutory and technical hurdles have to be taken to implement such a method. Also harmonisation of access rules and tariff structures are a concern.

Ref. to 4.3 AS market

Ref. to 4.3.1 Suppliers and consumers

Generators and consumers can both be candidate suppliers of non mandatory Ancillary Services. Provided they can supply the service equally according to functional and technical requirements set by the purchaser they should be treated equally.

Ref. to 4.3.2 Need vs. competition

Generally ancillary services concerning security and stability of the grid are treated as mandatory services. These are: primary reaction, generator robustness, black start and power factor and voltage control.
Reactive power requirements can be mandatory up to some basic level within the same grid. Additional need often is due to local circumstances and should be contracted bilaterally with some reimbursement. Competitive procurement is often meaningless because of specific local needs and the monopsony position of local suppliers.
True and practical candidates for competitive procurement either with a tendering mechanism or through a dynamic market are all other ancillary services: regulating and reserve power, inadvertent tie-line exchange compensation, compensation of grid losses, means to solve internal transmission constraints as well as means to solve cross border transmission constraints.

Ref. to 4.3.3 Price determination

Prices can be determined based on some cost of supply, value for procurer, a tariff system or by bids and offers. See CIGRE Technical Brochure 138 for information on ancillary services generation costs.

Ref. to 4.3.4 Types of contracts

Contracts can be categorised by time horizon and way of contracting (private or public).

Ref. to 4.4 AS provision responsibility
Ref. to 4.4.1 AS planning

It is the purchasers responsibility to plan for Ancillary Services in time and provide the market with information on time so that they can prepare offers and bids. Total size and functional and technical requirements should be specified in time.

Ref. to 4.4.2 AS provision and management

The responsibility for procuring Ancillary Services depends on the structure of the Electricity Supply System. Generally procurement of Ancillary System Services is a System Operator responsibility while procurement of Ancillary Transmission Services is a Grid Operator Responsibility. Wherever System Operator and Grid Operator functions are combined within one company (like a TSO) that company will be responsible for both.
Suppliers (either generators, consumers or adjacent grids) of Ancillary Services are responsible to provide the Ancillary Service as prescribed in some Code or by statutory law, to adhere to the contractual agreement with the purchaser or to adhere to the rules for players on a dynamic market. In the end the purchaser should have some way to force suppliers to adhere to these responsibilities, either through a penalising system and/or by contract, statutory law, system code or grid code.

Dispatch of Ancillary Services is a sole responsibility of either System Operator or grid Operator.

Settlement if Ancillary Services should be done under mutual agreement of purchaser and supplier. Under this condition it can be also agreed to contract settlement with a third party.

Ref. to 5 Dispersed generation

In the Dutch system dispersed generation is all generation smaller than 5 MW or connected at voltages lower than 1 kV. Dispersed generation does not have to adhere to primary reaction and generator robustness requirements in the System Code. Mandatory ancillary transmission services, also for dispersed generation, are prescribed in the Grid Code.

7.7 CONTRIBUTION FROM CZECH REPUBLIC

The Grid Code and the Ancillary Services in the Czech republic

The Czech transmission system operator (ÈEPS) worked out a Grid Code - public document which is approved by Regulator. This Grid Code has a part B - Basic connection conditions for the transmission grid users. In this document the connection rules, system and ancillary services are defined.
The new Energy Act is prepared and ready to go to the Parliament this year. This Energy Act defines the so called transmission system operator, which:

- ensures reliable operation and development of transmission grid,
- controls power flows in the power system,
- provides the electricity transmission based on contracts with system users,
- is responsible for system services ensuring (it buys ancillary services from system users),
- can not be involved in energy trading, electricity distribution and generation.

Connection rules for generators

The Grid Code part B specifies the following sections dealing with the generators.

- Frequency and active power control
- Voltage and reactive power control
- Island operation ability
- Black start operation ability
- Operation in disturbed conditions
- Protection requirements
- Measurement and signalling
- Transmission stability ensuring

System Services and Ancillary services

There are two terms in the Czech Grid Code and in the new Energy Act: System Services and Ancillary Services. The system services are necessary activities for reliable power system operation. They are provided by the System Operator. Ancillary Services are activities contributing on System Services. They are provided by system users. The advantages of this decomposition are:

- it is possible to define clear interface between system operator and system user so that users are separated from difficult problems with power system control and the technical requirements can be defined;
- a fair contribution of the individual users to the system function can be ensured;
- it creates so called Chinese wall between the System Operator and generation, especially when they are parts of one company

There are 5 categories of transmission system user in the Czech Grid Code:
1. Generators
2. Distributors
3. Large consumers

4. Interconnected power systems.
5. Electricity traders

The list of the basic system and ancillary services are in the following table:

System services	Ancillary services from Generators	Ancillary services from Distributors and Large consumers	Ancillary services from Interconnection and Traders
Primary f control reserve ensuring	Primary f control		Contracted reserve import (under consideration)
Load frequency control	Secondary P/f Control		
Tertiary P control reserve	Tertiary Control Fast unit start-up	Emergency** load shedding	Contracted fast import
Operating reserve*** ensuring	Cold and warm reserves Slow spinning reserve	Contracted load shedding	Contracted reserve import
Pilot node voltage control	Secondary U/Q Control		
Reactive power reserve ensuring	Compensating operation	Compensation providing	
Power system restoration	Black start Island operation		Voltage providing

** In case of sudden power insufficiency due to unit outages or due to weather conditions

*** It is a surplus of the operating reserve unused for primary, secondary and tertiary control (see the following figure).

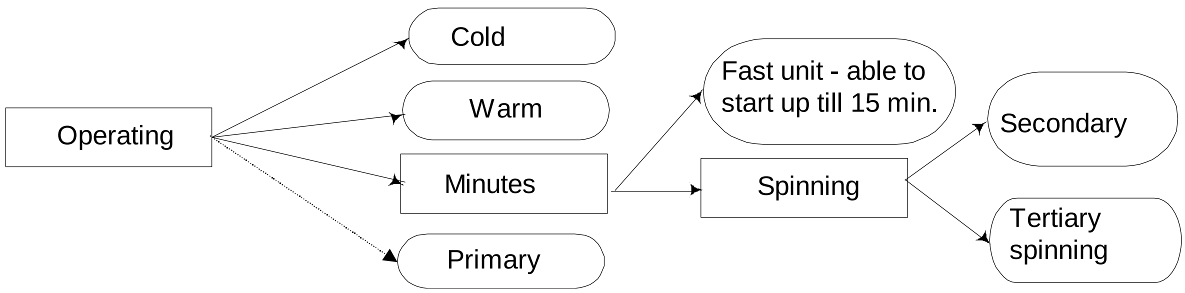

Figure 7.7. Scheme of operating reserve structure

The underlined services are mandatory to bid due to their influence on power system security. The black start capability may be obligatory for same places in the grid. The others may be on market (agreement) base.

7.8 CONTRIBUTION FROM FINLAND

For understanding of the Nordic approach to power reserves and system services, a few principles on how the frequency and national balances are maintained in the Nordic system both under fluctuating load / generation and in disturbance conditions needs are presented below.

Instantaneous reserve of rotating units shall be available within each part system or via the HVDC-connections. In the Nordic system this reserve is primarily on hydro based generation that typically runs at its best efficiency point being 80% of the rated power. Thus, the difference falls into instantaneous reserve.

In the Nordic system 600 MW is allocated for frequency control yielding to overall regulation capacity of 6000 MW / Hz in the entire system. The said reserve is fully activated at the frequency 49,9 Hz.

Responsibility on both the capacity and reserves is distributed over the countries in proportion of the national electricity consumption of the previous year.

Instantaneous disturbance reserve is defined such that while the frequency reserve being fully activated, the system shall be able to accommodate a trip of the largest single block of production, presently being 1200 MW. A portion of this reserve, fully activated within the band from 49,9 to 49,5 Hz, is provided for by self-regulating power of the system while primary share is taken from hydro plants but also to an extent from thermal plants. Within the same frequency bands, the HVDC -connections are triggered into emergency mode and assigned loads may automatically trip. Distribution of instantaneous disturbance reserve over the part systems is biased to the values of respective national rating outages. In Finland, this is an 850 MW nuclear power plant and yields to 225 MW as instantaneous disturbance reserve.

For restoration of instantaneous reserves, there shall be fast active reserve available that can be activated for elimination of generation / load unbalance within 15 min from the loss of production. In turn for the fast active reserve, there shall be slow active reserve available that can be activated within a response time whose length is dependent on economical factors. The system frequency may fluctuate between 49,9 and 50,1 Hz always so that the cumulated time deviation vs. astronomical time does not exceed +/- 10 seconds.

Frequency and national balance controls in the interchanges are scheduled on hourly basis. Commercial contracts shall be fixed prior to operation hour, processed, and iterated against available transmission facilities. As a result of the process each system operator defines its own national transmission and agrees bilaterally with neighbouring operators the flows on the interconnections. In Finland for fast active reserves Fingrid poses own or leased gas turbine capacity for 650 MW.

Each national system operator in the Nordic system is responsible for own reactive reserves needed to support the network voltage and stability in case of disturbances.

In Finland in order to access to grid service and market, a customer may have to enter one or more of the following contracts.

- connection contract (with all connectees)
- reactive power contract (with all connectees
- main grid contract (with all connectees)
- reserve power contract (with resource owners)
- balance power contract (with resource owners)

The connection contract is normally of drawn for a long duration and it defines connection options and technical requirements, title to plant and equipment, obligation to provide technical data, quality and applicable standards for approval of connection, operation and maintenance of voltage limits, minimum set of outage and disturbance procedures, protection arrangements, connection costs and finally liabilities.

The scope of reactive power contract is presently under review. The new model targets at supply of reactive power from the grid to the customers at the rate very close to the overall optimum when considering investments in compensation devices either on the main grid or distribution side. Another important feature of the new model is the compensation for reactive power reserves either in monetary terms or in additional supply of reactive power. The agreement covers the definition of the necessary supply limits and penalties in case of gross limit violation. The main source of revenue is the services contracted through the grid service contract. Apart from tariff, liabilities and other conventional contractual terms, the contract caters for all general service terms. For further detail of the grid service contract readers are kindly advised to visit in Services -section at www.fingrid.fi (http://www.fingrid.fi). In Finland for instantaneous as well as for instantaneous disturbance reserves, Fingrid acquires reserves through commercial process based on the reserve power contracts drawn competitively among the reserve owners. Payments are made per availability and actual utilisation of as well as per technical capabilities of the reserve in question. Reserves may be assigned from both generators and loads under continuous or stepwise control. In the related balance power contracts, Fingrid agrees with resource owners, presently some 20 in number in Finland, upon utilisation and pricing of balance power, rules of the regulation power market, balance settlement procedures, pricing as well as upon reporting.

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