The University of Manchester

MANCHESTER 1824

A Survey of Definitions and Specifications of Reserve Services

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Release 2
12/10/2005

Abstract

This report surveys the definitions of reserve services used in several countries and regions of Europe and the United States that have implemented competitive electricity markets. It also compares the technical specifications of these services. The systems considered are Great Britain, PJM, California, Spain, The Netherlands, Germany, France, Belgium as well as UCTE as a whole.

Revision History

Release	*Date*	*Description*
2	12/10/2005	Clarification of some points concerning France, Germany, the Netherlands, Spain and Great Britain. Correction of the fast reserve in Great Britain
1	19/09/2005	Creation of the document

Contents

Figures

Tables

Abbreviations and acronyms

AGC: Automation Generation Control
BkV: *Bilanzkreis*
BM: Balancing Mechanism
CAISO: California Independent System Operator
Genco: Generation company
I: Integral
ISO: Independent System Operator

LFC: Load-Frequency Control
MAAC: Mid-Atlantic Area Council
MLA: Inter-TSO Multilateral Agreement
NERC: North American Electric Reliability Council
NGC: National Grid Company plc
NGET: National Grid Electricity Transmission plc
PI: Proportional Integral
PJM: Pennsylvania New Jersey-Maryland interconnection
REE: *Red Eléctrica de España*
RTE: *gestionnaire du Réseau de Transport d'Electricité*
TSO: Transmission System Operator
UCTE: Union for the Co-ordination of Transmission of Electricity
VDN: *Verband der Netzbetreiber - VDN - e.V. beim VDEW*

1 Introduction

The liberalisation of the electricity supply industry and the introduction of competitive markets for electrical energy have required the definition of ancillary services. The purpose of these ancillary services is to help maintain the security and the quality of the supply of electricity. In particular, control of the frequency requires that a certain amount of active power be kept in reserve to be able to re-establish the balance between load and generation at all times. In general, reserve can thus be defined as the amount of generation capacity that can be used to produce active power over a given period of time and which has not yet been committed to the production of energy during this period. In practice, different types of reserve services are required to respond to different types of events over different time frames. Considerable differences exist between the reserve services defined in various jurisdictions. These differences are the source of some confusion because they extend not only to the specification of the services but also to the terms used to describe them.

To help reduce this confusion, this report outlines a framework that can accommodate most definitions of reserve services. For ease of comparison, the reserve services that have been defined in several countries and regions are then placed in this framework. The report then provides a more detailed comparison of the technical specifications of the reserve services.

2 Framework for comparing reserve services

This section outlines a framework that helps compare reserve services defined in various countries or regions.

To illustrate the difficulties associated with the definitions of reserve services, let us consider the widely used term "spinning reserve". Many authors use this term without defining it because they assume that its meaning is obvious and unambiguous. However, a partial survey of the literature produces very different definitions:

- ✓ Hirst and Kirby [1]: "generators online, synchronized to the grid, that can increase output immediately in response to a major outage and can reach full capacity within 10 minutes";
- ✓ Wood and Wollenberg [2]: the total synchronised capacity, minus the losses and the load;
- ✓ Zhu, Jordan and Ihara [3]: "the unloaded section of synchronized that is able to respond immediately to serve load, and is fully available within ten minutes";
- ✓ British Electricity International [4]: "the additional output which is part-loaded generating plant is able to supply and sustain within 5 minutes. This category also includes pumped-storage plant […] operating in the pumping mode, whose demand can be disconnected within 5 minutes";
- ✓ UCTE [6]: tertiary reserve available within 15 minutes "that is provided chiefly by storage stations, pumped-storage stations, gas turbines and by thermal power stations operating at less than full output (responsibility of the TSO)";
- ✓ NERC [28]: "Unloaded generation that is synchronized and ready to serve additional demand".

These definitions disagree (or remain silent) on some important issues:

- ✓ Who provides spinning reserve? Is it limited to generators or can the demand-side participate?
- ✓ What is the time frame for responding to a request? When should it start and end?
- ✓ How is this reserve activated? Does it happen automatically or is it only done at the request of the Transmission System Operator (TSO)?

Since similar ambiguities and contradictions exist for other types of reserve services, it is desirable to define a framework that makes such issues explicit. The framework that we use is based on the way frequency regulation is achieved rather than on the technical characteristics of the services.

The simplified scheme represented in Figure 2.1 illustrates the framework that is typically used for frequency regulation. This regulation usually involves three levels of controls. Using UCTE terminology [5], these levels are called Primary, Secondary and Tertiary. In large interconnected systems, all three forms of control are usually present. In smaller isolated systems secondary control may not exist as such. For the sake of simplicity, frequency regulation using demand-side action is not included in this diagram but could be considered without conceptual changes.

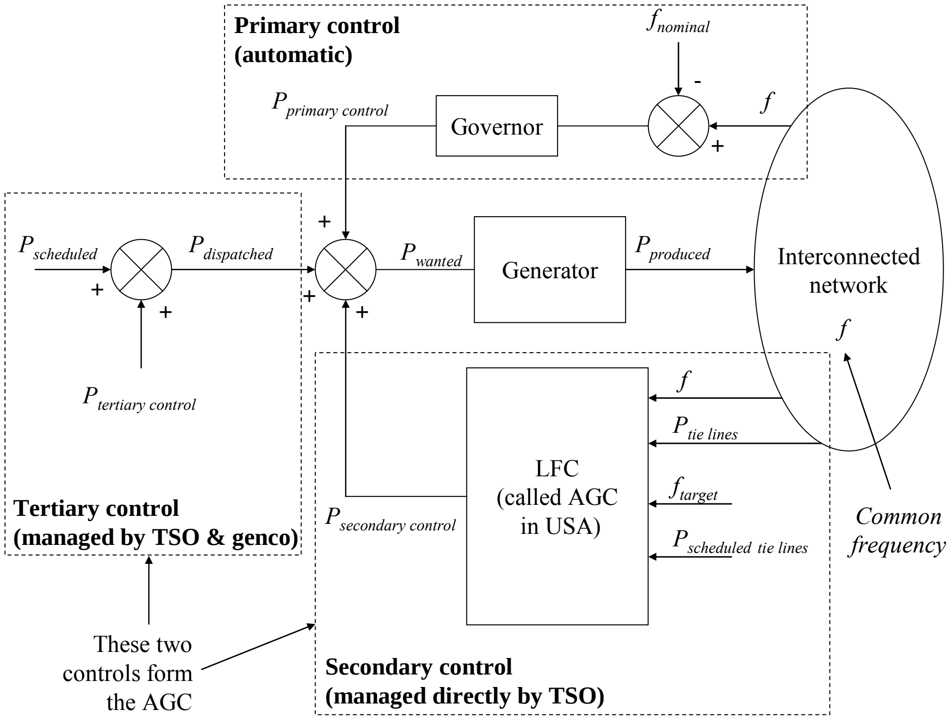

Figure 2.1: Framework for frequency regulation within the UCTE

In order to show the differences between each control, Table 2.1 summarizes the characteristics of the three frequency control levels according to six distinct questions.

Table 2.1: Comparison between the three frequency control levels

	Primary control	*Secondary control*	*Tertiary control*
***Why** is this control used?*	To stabilize the frequency in case of any imbalance.	To bring back the frequency and the interchange programs to their target	To restore the secondary control reserve, to manage eventual congestions, and to bring back the frequency and the interchange programs to their target if the secondary control reserve is not sufficient
***How** is this control achieved?*	Automatically		Manually
***Where** is this control performed?*	Locally	Centrally	
***Who** sends the control signal to the source of reserve?*	Local sensor	TSO	Genco (the TSO in the case of a pool market)
***When** is this control activated?*	Imediately	Depends on the system (See Section 3)	
***What** sources of reserves can be used?*	Depends on the system: partially loaded units, loads, fast-starting units… (See Section 3)		

Based on this table, the following definitions for each control level will be used:

- ✓ **Primary control:** local automatic control which delivers reserve power in opposition to any frequency change;
- ✓ **Secondary control:** centralised automatic control which delivers reserve power in order to bring back the frequency and the interchange programs to their target values;
- ✓ **Tertiary control:** manual change in the dispatching and unit commitment in order to restore the secondary control reserve, to manage eventual congestions, and to bring back the frequency and the interchange programs to their target if the secondary control reserve is not sufficient.

3 Comparison of the definitions of reserve services

3.1 Introduction

In this section, we will consider the reserve services that have been defined in different countries and regions and place them within the framework defined in the previous section. We will concentrate on the definition of these services and for each power system considered, we will provide the following information:

- ✓ **Definition of reserves:** names of the main reserve services that have been defined and positioned within the framework defined in Section 2. It is important to keep in mind that the same term can have different meanings in different power systems. For instance, UCTE's primary control is not the same thing as NGET's primary response, which is again different from PJM's primary reserve;
- ✓ **Translation:** a literal translation into English of each service that has a non-English name;
- ✓ **Values:** whenever possible, we provide the formula used in each power system to calculate the amount of each reserve service required. The values given are for an increase in the generation of active power or a reduction in load. We use the following conventions:
  - → L_{max}: the maximum load of the system during a given period. We may detail more the subscript in order to define precisely which system is mentioned (e.g. $L_{max\ zone}$).
- ✓ **Timing:** Requirements related to the timing of the availability of each service. Three characteristic times are specified:
  - → **Start:** the time before which the source of reserve has to begin delivering the power it held in reserve;
  - → **Full availability:** the time, which is measured from the instant the call is received, during which the source of reserve has to deliver its full reserve. Unfortunately, recommendations are sometimes unclear. Therefore, deployment duration (i.e. from the start of the deployment to the instant when reserve is fully deployed) and full availability may be sometimes confused;
  - → **End:** the duration spanning from the call instant to the moment when the required amount of reserve does not have to be provided anymore.
- ✓ **Time line:** Visualisation of the timing requirements of each service. The origin of the time axis marks the beginning of a frequency disturbance. We assume that both primary and secondary reserves are called instantaneously by the TSO from a state where no reserve is used. Bold lines illustrate the service requirements that providers have to meet when their services are requested. Dashed lines show how a service might be deployed in order to meet these requirements. The reader should note that the time scales are not linear.

Section 0 provides more details on technical characteristics of these services such as active power gradients, symmetry of reserves, type of controller, dead-band, and cycle times.

3.2 UCTE

UCTE is the union of all the TSO of the European synchronous zone and its purpose is to coordinate their operations. On 1 July 2005, UCTE standards became mandatory through a binding agreement called the Inter-TSO Multilateral Agreement (MLA).

3.2.1 Definition of reserves

Table 3.1 will be our reference for the definition of services in the rest of this document.

Table 3.1: Reserves according to the UCTE

Primary control	***Secondary control***	***Tertiary control reserve***
Primary control reserve	Secondary control reserve	Tertiary control reserve
		Minute reserve or 15 minute reserve

The minute reserve does not have to be synchronised to the network. This capacity has just to be fully available within 15 minutes. Hence, both gas turbine and redispatching can be used for providing this reserve.

3.2.2 Values

- ✓ Primary control reserve: 3 000 MW, shared by all the different control areas;
- ✓ Secondary control reserve + minute reserve: $\sqrt{10L_{max\ zone} + 150^2} - 150$ in MW, where $L_{max\ zone}$ is the expected peak load in the zone for the considered period (e.g. one hour);
- ✓ Tertiary control reserve: no recommendation.

3.2.3 Timing

Table 3.2: Timing of reserves according to the UCTE

Reserve	***Start***	***Full availability***	***End***
Primary control reserve	Immediate	≤ 30 s	≥ 15 min
Secondary control reserve	≤ 30 s[1]	≤ 15 min	As long as required[2]
Minute reserve or 15 minute reserve	No recommendation	A short time[3]	No recommendation
Tertiary control reserve	No specific recommendation		

Actually, UCTE recommends liberating secondary control reserve as soon as possible through minute or tertiary control reserve.

3.2.4 Time line

Figure 3.1 shows the time constraints imposed on its members by the UCTE. Control power must be provided both upwards and downwards, but not necessarily in a symmetrical way.

[1] Actually, UCTE recommends that the frequency begins to return to its target value within 30 sec.
[2] This can be achived with several participants who replace each other.
[3] UCTE [5] specifies only "a short term". However, since the term "15 minute reserve" is used, we can suppose the value of 15 min is recommended.

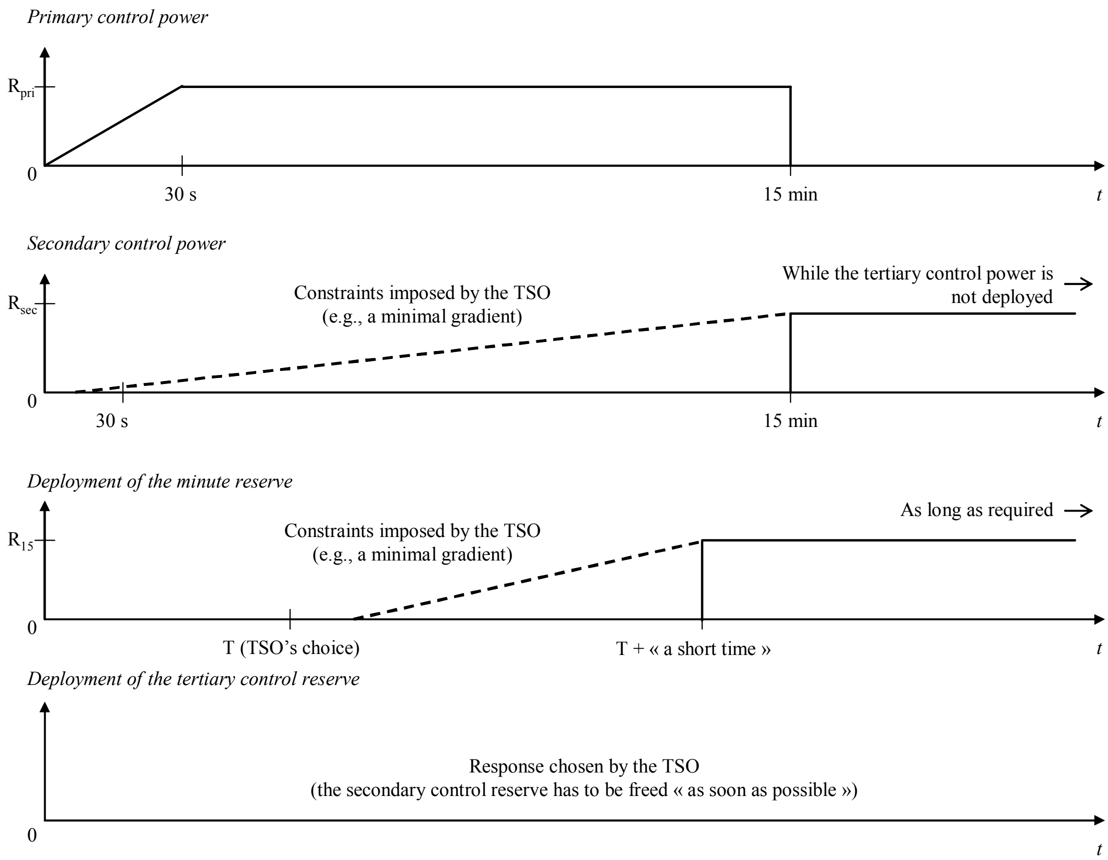

Figure 3.1: UCTE time line

3.3 Belgium

ELIA is the name of the TSO responsible for the entire transmission system of Belgium.

3.3.1 Definition of reserves

Table 3.3: Reserves according to ELIA

Primary control	***Secondary control***	***Tertiary control***
Réserve de puissance pour réglage primaire	*Réserve de puissance pour réglage secondaire*	*Réserve de puissance pour réglage tertiaire*

3.3.2 Translation

- ✓ *Réserve de puissance pour réglage primaire*: Power reserve for primary control;
- ✓ *Réserve de puissance pour réglage secondaire*: Power reserve for secondary control;
- ✓ *Réserve de puissance pour réglage tertiaire*: Power reserve for tertiary control.

3.3.3 Values

- ✓ *Réserve de puissance pour réglage primaire*: around 100 MW;
- ✓ *Réserve de puissance pour réglage secondaire*: recommendation of the UCTE;
- ✓ *Réserve de puissance pour réglage tertiaire*: 460 MW by generators + 200 MW with interruptible loads.

3.3.4 Timing

Table 3.4: Timing of reserves according to ELIA

Reserve	*Start*	*Full availability*	*End*
Réserve de puissance pour réglage primaire	Immediate	≤ 30 s	≥ 15 min
Réserve de puissance pour réglage secondaire	≤ 10 s	≤ 10 min	As long as required
Réserve de puissance pour réglage tertiaire	No recommendation	≤ 15 min	As agreed

3.3.5 Time line

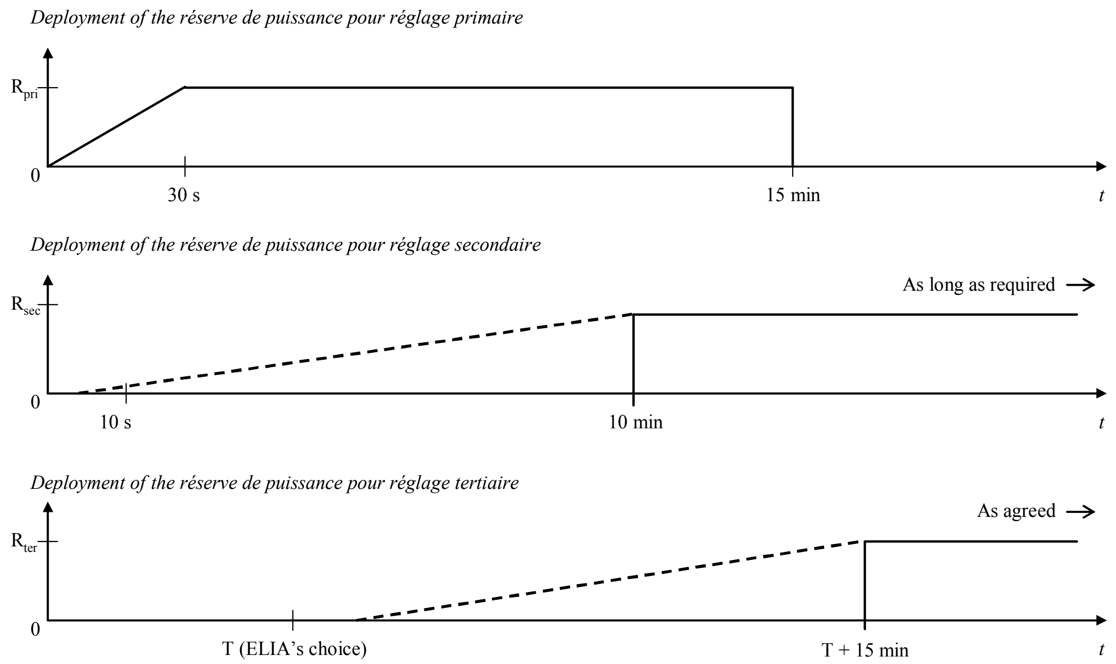

Figure 3.2: ELIA time line

3.4 France

The *gestionnaire du Réseau de Transport d'Electricité* (RTE) is the name of the TSO responsible for the entire transmission system of France.

3.4.1 Definition of reserves

Table 3.5: Reserves according to RTE

Primary control	***Secondary control***	***Tertiary control***		
Réserve primaire	*Réserve secondaire*	*Réserve tertiaire*		
		Réserve tertiaire rapide 15 minutes	*Réserve tertiaire complémentaire 30 minutes*	*Réserve à échéance ou différée*

3.4.2 Translation

- ✓ *Réserve primaire*: Primary reserve;
- ✓ *Réserve secondaire*: Secondary reserve;
- ✓ *Réserve tertiaire*: Tertiary reserve;
- ✓ *Réserve tertiaire rapide 15 minutes*: Fast tertiary reserve available within 15 minutes;
- ✓ *Réserve tertiaire complémentaire 30 minutes*: Complementary tertiary reserve available within 30 minutes;
- ✓ *Réserve à échéance ou différée*: Delayed or term reserve.

3.4.3 Values

- ✓ *Réserve primaire*: around 700 MW;
- ✓ *Réserve secondaire*: recommendation of the UCTE or more conservative during peak hours (increase of 15%), and at least 500 MW;
- ✓ *Réserve tertiaire rapide 15 minutes*: 1 500 MW (in order to compensate the loss of the French largest unit);
- ✓ *Réserve tertiaire complémentaire 30 minutes* and *Réserve à échéance ou différée*: depends on the operating margin (*marge d'exploitation*) defined by the TSO. The calculation of this margin is not well known, but based on the probability of using exceptional means (load-shedding, using the groups at their maximum output…). In addition to contracted reserves, all the generators have to bid their available reserve in the balancing mechanism (*méchanisme d'ajustement*).

3.4.4 Timing

Table 3.6: Timing of reserves according to RTE

Reserve	*Start*	*Full availability*	*End*
Réserve primaire	Immediate	≤ 30 s	≥ 15 min
Réserve secondaire	≤ 30 s	≤ 430 s or ≤ 97 s[4]	As long as required
Réserve tertiaire rapide 15 minutes	No recommendation	≤ 15 min	≥ 1 h
Réserve tertiaire complémentaire 30 minutes	No recommendation	≤ 30 min	≥ 6 h
Réserve à échéance ou différée	As agreed		

3.4.5 Time line

The RTE time line is given in Figure 3.3. Negative deployments are symmetric to positive ones, except for the primary control.

[4] In case of emergency, the *réserve secondaire* has to be fully available in ≤ 97 s (the device is said to be able to respond to a signal with a *pente rapide*, i.e. a fast slope).

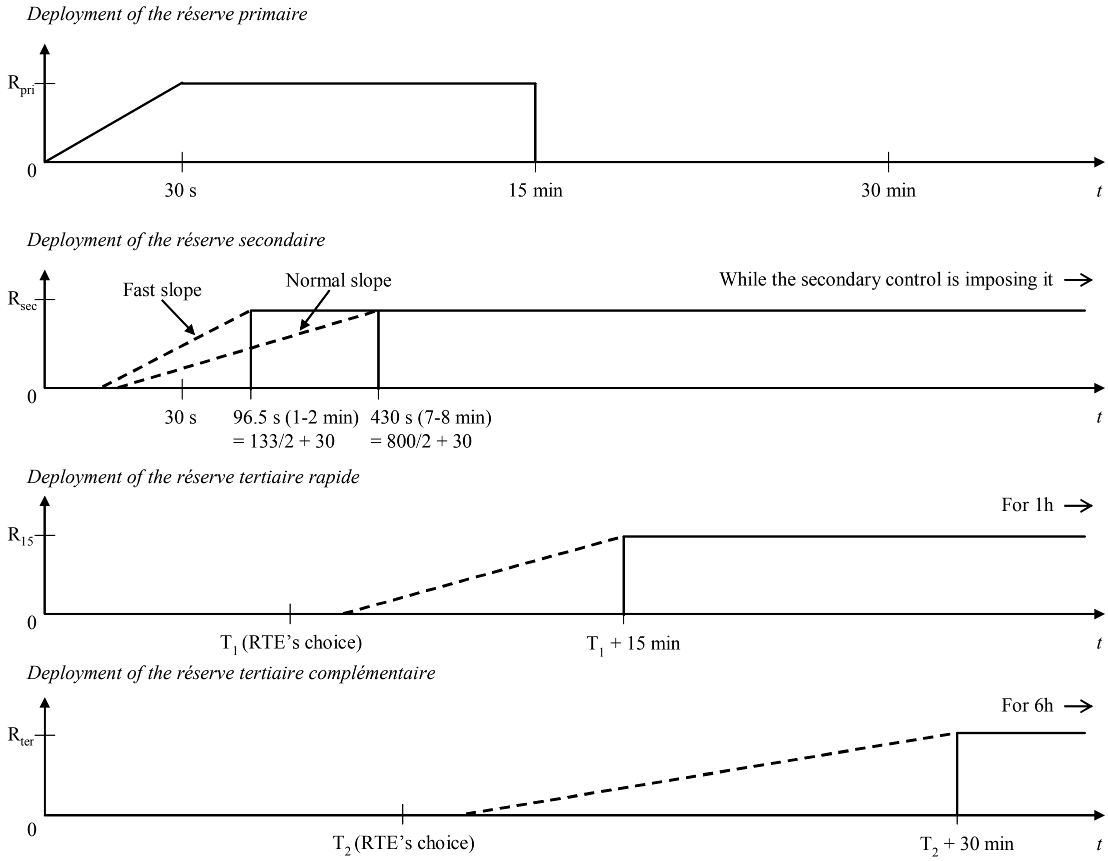

Figure 3.3: RTE time line

3.5 Germany

Germany has four different TSOs (*EnBW Transportnetze*, *E.ON Netz*, *RWE Transportnetz Strom*, and *Vattenfall Europe Transmission*). *Verband der Netzbetreiber - VDN - e.V. beim VDEW* (VDN) is the union of German TSOs and it is responsible for the coordination of their actions.

3.5.1 Definition of reserves

Table 3.7: Reserves according to VDN

Primary control	***Secondary control***	***Tertiary control***		
Primärregelreserve	*Sekundärregelreserve*	*Minutenreserve*	*Stundenreserve*	*Notreserve*

3.5.2 Translation

- ✓ *Primärregelreserve*: Primary control reserve;
- ✓ *Sekundärregelreserve*: Secondary control reserve;
- ✓ *Minutenreserve*: Minutes reserve;
- ✓ *Stundenreserve*: Hours reserve;
- ✓ *Notreserve*: Emergency reserve.

3.5.3 Values

- ✓ *Primärregelreserve*: Calculation unknown, probably based on the UCTE criteria, and constant for six months, after a tendering process. *E.ON Netz* asks 166 MW for the end of 2005 [19];
- ✓ *Sekundärregelreserve*: Calculation unknown, and constant for six months, after a tendering process. *RWE-Netz* asks roughly 1 300 MW for *Primärregelreserve* + *Sekundärregelreserve*. *E.ON Netz* asks 800 MW for the end of 2005 [19];
- ✓ *Minutenreserve*: Calculation unknown. *RWE-Netz* asks roughly 780 MW. *E.ON Netz* asks roughly 1100 MW [19]

3.5.4 Timing

Table 3.8: Timing of reserves according to VDN

Reserve	***Start***	***Full availability***	***End***
Primärregelreserve	Immediate	≤ 30 s	≥ 15 min
Sekundärregelreserve	Immediate or ≤ 5 min[5]	≤ 5 min	As long as required
Minutenreserve	No recommendation	≤ 15 min	As agreed
Stundenreserve	No recommendation	≤ 1 h	As agreed

Note that the *Stundenreserve* is obtained by the *Bilanzkreiz* (the "scheduling coordinator"), and not directly by the TSO. The function of the *Stundenreserve* is to insure that the *Bilanzkreiz* (BkV) has enough reserve for balancing its scheduling in case of an unplanned imbalance.

[5] The start time depends on the type of the unit.

3.5.5 Time line

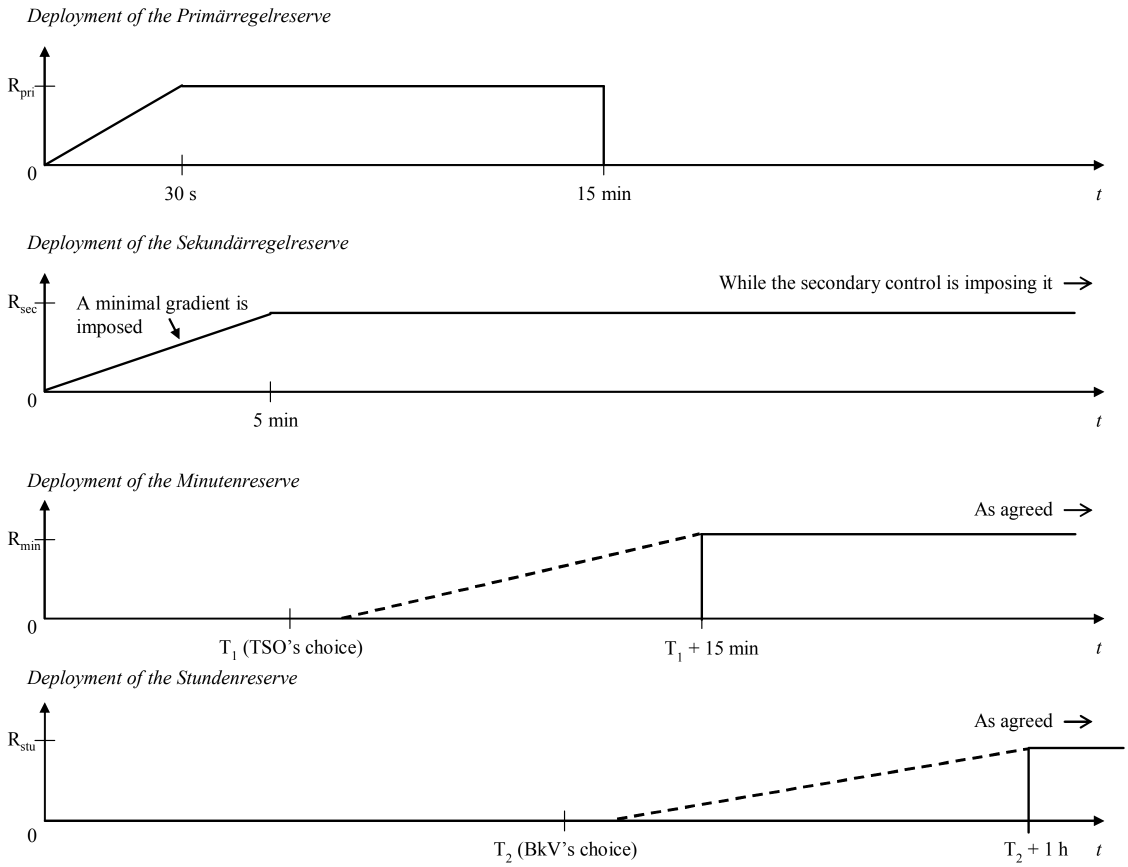

Figure 3.4: VDN time line

3.6 The Netherlands

TenneT is the TSO responsible for the transmission network of the Netherlands.

3.6.1 Definition of reserves

Table 3.9: Reserves according to TenneT

Primary control	***Secondary control***	***Tertiary control***
Primaire reserve	*Secundaire reserve*	*Tertiare reserve*

3.6.2 Translation

- ✓ *Primaire reserve*: Primary reserve;
- ✓ *Secundaire reserve*: Secondary reserve;
- ✓ *Tertiare reserve*: Tertiary reserve.

3.6.3 Values

- ✓ *Primaire reserve*: roughly 100 MW;
- ✓ *Secundaire reserve*: recommendation of the UCTE. In addition to contracted reserves, all connection including more than 60 MW generation are obliged to offer available reserve. Four different amounts of *Secundaire reserve* per day are secured by TenneT. Values asked during a week are the same during six months. Details can be found on TenneT website [22]. Note that this system is scheduled to be simplified before 2006;

✓ *Tertiare reserve*: more than 300 MW available between 15 and 30 min (to match with a period). 300 MW contracted (e.g. large consumers) and all connections superior to 60 MW have to offer all the available reserve.

3.6.4 Timing

Table 3.10: Timing of reserves according to TenneT

Reserve	*Start*	*Full availability*	*End*
Primaire reserve	Immediate	≤ 30 s	≥ 15 min
Secundaire reserve	from 30 s to 1 min[6]	≤ 15 min	≥ 15 min and as agreed
Tertiare reserve	No specified	As agreed	from 15 min to 4 h, as agreed

Dutch reserves are always contracted for a period which is a multiple of 15 min, except the *Primaire reserve*, which is compulsory.

3.6.5 Time line

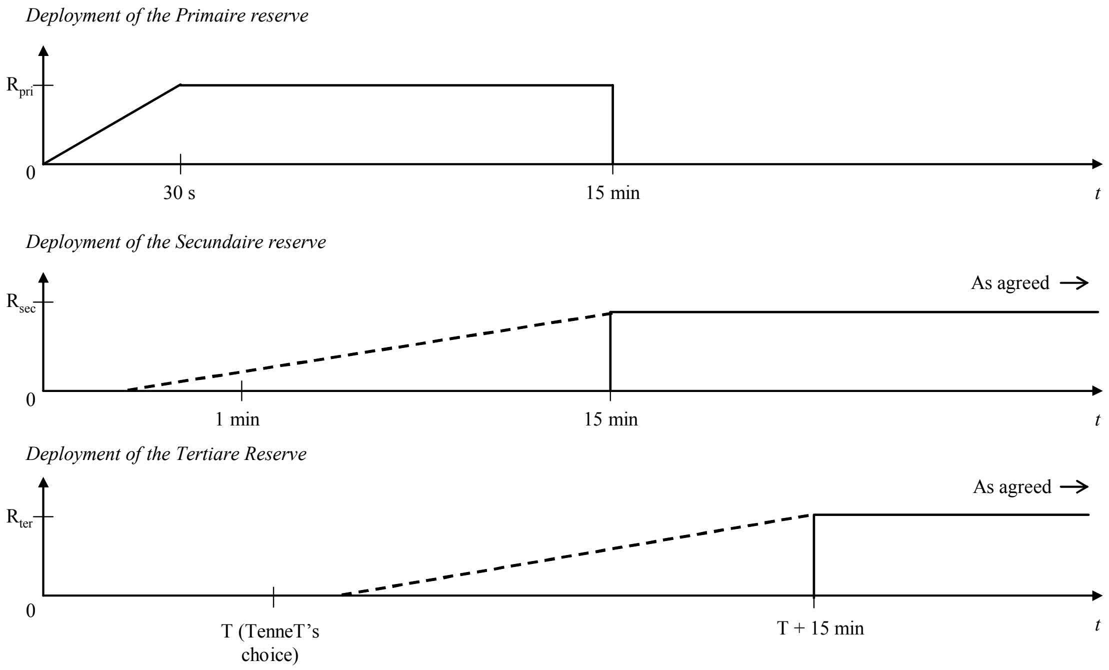

Figure 3.5: TenneT time line

3.7 Spain

Red Eléctrica de España (REE) is the Spanish TSO.

[6] These values correspond to the instant when TenneT actually receives data. Therefore, it takes in account transmission and processing delays.

3.7.1 Definition of reserves

Table 3.11: Reserves according to REE

Primary control	*Secondary control*	*Tertiary control*
Reserva primaria	*Reserva secundaria*	*Reserva terciara*

3.7.2 Translation

- ✓ *Reserva primaria*: Primary reserve;
- ✓ *Reserva secundaria*: Secondary reserve;
- ✓ *Reserva terciara*: Tertiary reserve.

3.7.3 Values

- ✓ *Reserva primaria*: 1.5% of the nominal capacity of any generator;
- ✓ *Reserva secundaria*: $6\sqrt{L_{max}}$ when the load variation is fast, otherwise $3\sqrt{L_{max}}$. This reserve is calculated for each hour every day;
- ✓ *Reserva terciara*: capacity of the biggest unit + 2% of the expected load on the considered period.

3.7.4 Timing

Table 3.12: Timing of reserves according to REE

Reserve	*Start*	*Full availability*	*End*
Reserva primaria	Immediate	≤ 30 s	As long as required
Reserva secundaria	No recommendation	≤ 300-500 s[7]	≥ 15 min
Reserva terciara	Immediate	≤ 15 min	≥ 2 h15

[7] The equivalent system should have a time constant of 100 s [24]. Therefore, if we considerer a step change in the power balance, the full control power should be delivered within 3 to 5 times the time constant.

3.7.5 Time line

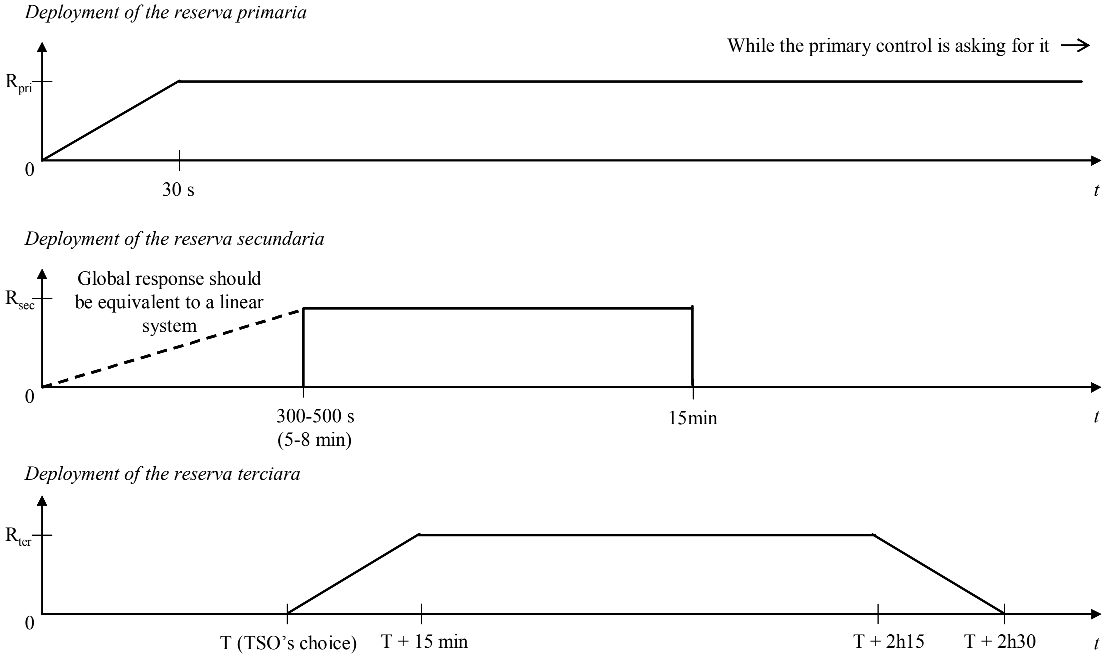

Figure 3.6: REE time line

3.8 PJM

PJM ISO, simplified to PJM in this document, is the operator of the Pennsylvania New Jersey-Maryland interconnection in the United States.

3.8.1 Definition of reserves

Table 3.13: Reserves according to PJM

<table>
<tr><th>Primary control</th><th>Secondary control</th><th colspan="4">Tertiary control</th></tr>
<tr><td>Dynamic reserve</td><td>Regulating reserve</td><td colspan="3">Operating reserve</td><td>Reserve beyond 30 min</td></tr>
<tr><td></td><td></td><td colspan="2">Primary reserve</td><td>Secondary reserve</td><td></td></tr>
<tr><td></td><td></td><td>Spinning reserve</td><td>Quick start reserve</td><td></td><td></td></tr>
</table>

The operating reserve is the power which is produced by changing the unit commitment or the dispatching. Therefore, the spinning reserve is the generating capacity that is synchronised, fully available within 10 minutes, and activated by redispatching. The regulation and the dynamic reserves are thus not considered to be part of the spinning reserve in the PJM system.

3.8.2 Values

- ✓ Dynamic reserve: so far, no specific dynamic reserve has been set by NERC or PJM. This problem has been identified, and NERC is working on the development of new standards [31];
- ✓ Regulating reserve: 1.1% of the expected peak load during the off- or on-peak period (for the Mid-Atlantic regulation zone);

✓ Operating reserve: calculated probabilistically for a given period [33]. PJM produces a table every a few months that gives the amount of operating reserve as a function of the day of the week, the hour and the level of load. However, the amount of primary reserve is fixed. Lastly, spinning reserve should represent more than 75% of the primary reserve (in the MAAC zone). Therefore, the spinning reserve is quasi-fixed: only 25% of the primary reserve can be provided either by quick-start or by spinning, depending on the unit commitment.

3.8.3 Timing

Table 3.14: Timing of reserves according to PJM

Reserve	*Start*	*Full availability*	*End*
Dynamic reserve	Immediate	No recommendation	
Regulating reserve	No recommendation	≤ 5 min	As agreed
Primary reserve	No recommendation	≤ 10 min	As agreed
Secondary reserve	No recommendation	≤ 30 min	As contracted
Reserve beyond 30 min	As agreed		

3.8.4 Time line

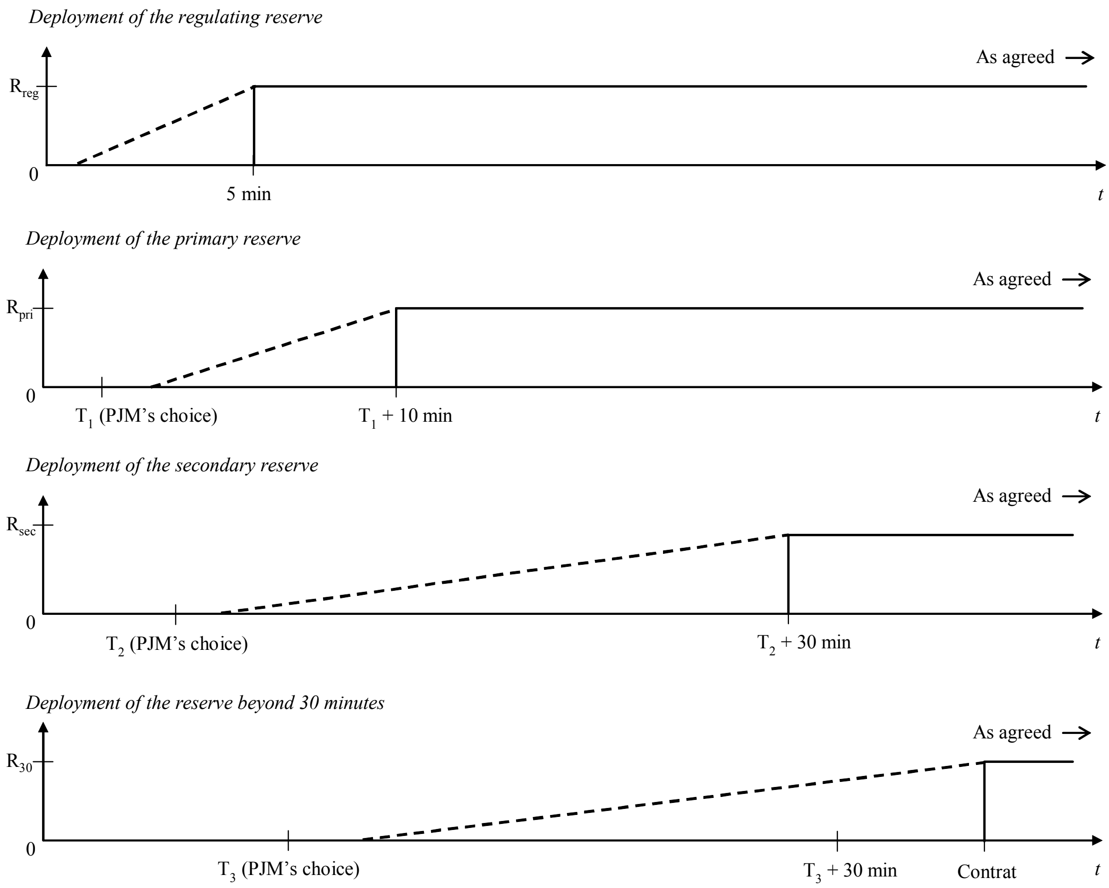

Figure 3.7: PJM time line

3.9 California

CAISO is the TSO responsible for the transmission system in the state of California. Because CAISO is in the process of restructuring its market, the description given here is likely to change in the near future.

3.9.1 Definition of reserves

Table 3.15: Reserves according to CAISO

<table>
<tr><th>Primary control</th><th>Secondary control</th><th colspan="4">Tertiary control</th></tr>
<tr><td>(no name)</td><td colspan="3">Operating reserve</td><td>Replacement reserve</td><td>Supplemental energy</td></tr>
<tr><td></td><td>Regulating reserve</td><td colspan="2">Contingency reserve</td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Spinning reserve</td><td>Non-Spinning reserve</td><td></td><td></td></tr>
</table>

In California, the spinning reserve thus consists of the reserve capacity used by the AGC (the regulating reserve) and of a part of the contingency reserve (capacity used for redispatching).

3.9.2 Values

- ✓ (Primary control reserve): same problem as in PJM (See Section 3.8.2);
- ✓ Operating reserve: computed each hour. It is equal to $\max(5\% \times P_{hydro} + 7\% \times P_{other\ generation}; P_{largest\ contingency}) + P_{non-firm\ import}$ [38], where:
  - → P_{hydro}: scheduled generation from hydroelectric resources;
  - → $P_{other\ generation}$: scheduled generation from resources other than hydroelectric;
  - → $P_{largest\ contingency}$: value of the power imbalance due to the most severe contingency;
  - → $P_{non\text{-}firm\ import}$: total of all the interruptible imports.
- ✓ Spinning reserve: 50% of the operating reserve.

3.9.3 Timing

Table 3.16: Timing of reserves according to CAISO

Reserve	*Start*	*Full availability*	*End*
(Primary control reserve)	Immediate	No recommendation	
Regulating reserve	Immediate	≤ 10 min	≥ 2 h
Contingency reserve	No recommendation	≤ 10 min	≥ 2 h
Replacement reserve	No recommendation	≤ 1 h	As agreed
Supplemental energy	No recommendation	≥ 45 min and as agreed[8]	As agreed

[8] The supplemental energy comprises bids accepted up to 45 min before the beginning of the operating hour.

3.9.4 Time line

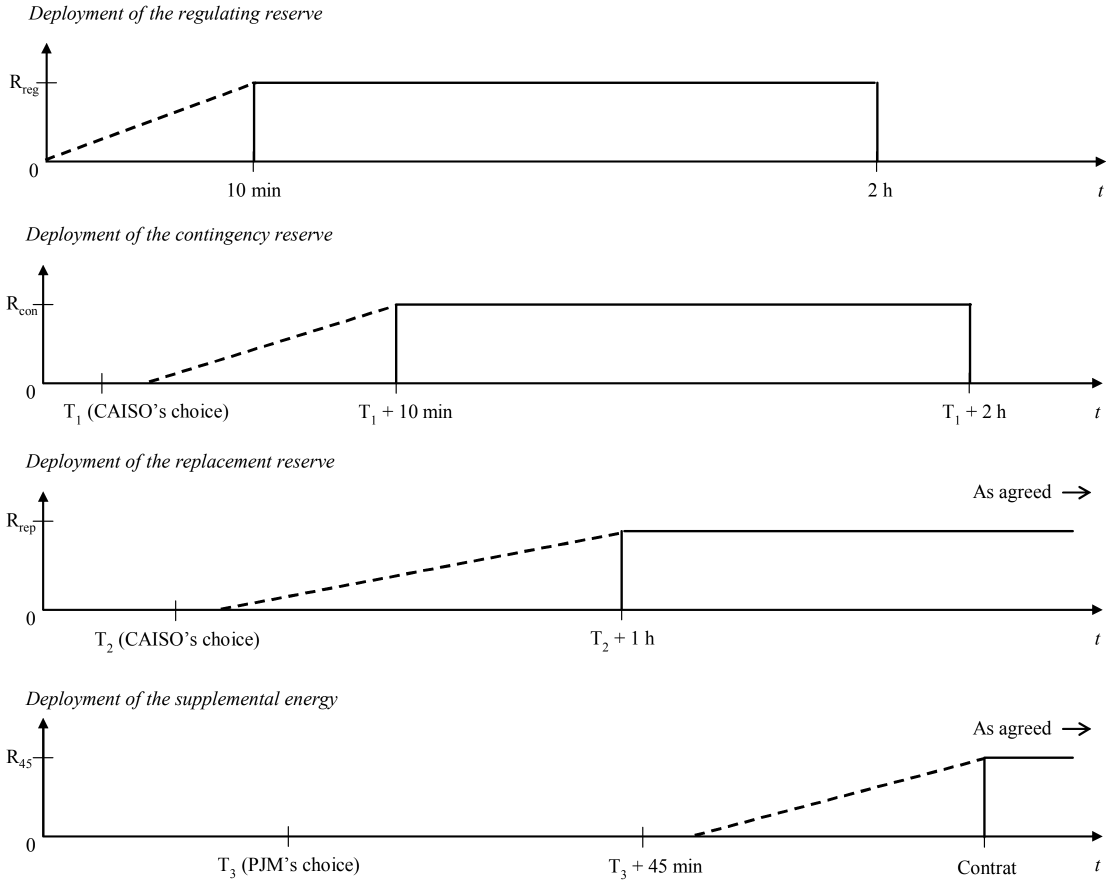

Figure 3.8: CAISO time line

3.10 Great Britain

National Grid Electricity Transmission plc (NGET, former National Grid Company plc or NGC) was responsible for the transmission system of England and Wales and is now the TSO responsible for the entire British transmission system, including Scotland. Since NGET does not use LFC, it controls the frequency using only governor response (divided into three subsets: primary, secondary and high frequency responses), and by changing the dispatching and unit commitment (by activating respectively regulating and standing reserve) through the balancing mechanism (BM) and bilateral contracts.

3.10.1 Definition of reserves

Table 3.17: Reserves according to NGET

<table>
<tr><th colspan="2">Primary control</th><th>Secondary control</th><th colspan="4">Tertiary control</th></tr>
<tr><td colspan="2">Operating reserve[9]</td><td rowspan="3"></td><td colspan="2">Operating reserve[9]</td><td colspan="2">Contingency reserve</td></tr>
<tr><td colspan="2">Response</td><td>Regulating reserve</td><td>Standing reserve</td><td>Fast start</td><td>Warming and hot standby</td></tr>
<tr><td>Primary response</td><td>Secondary response</td><td colspan="4"></td></tr>
</table>

The high frequency response is not represented in this table, since it is used for reducing the frequency. The regulating reserve is provided by part-loaded units and is also known as fast reserve. Warming and hot standby contracts are agreed by NGET in order to secure enough offers in the BM.

3.10.2 Values

- ✓ Response: curves are used by NGET, giving the necessary response in function of the largest connected unit and the demand. Since October 2005, this reserve is calculated for each half-hour of the day (working and non-working days are distinguished) every month [42];
- ✓ Operating reserve: the NGET's calculation is unknown. The asked reserve for each day can be found on NGET's website [45]. Particularly:
  - → Regulating reserve (or fast reserve): same principle as response with 48 half-hourly periods per day. In average, roughly 450 MW are asked by NGET [43];
  - → Standing reserve: 2,255 MW contracted from April 2005 to March 2006 [44];
  - → Fast start: amount unknown.

3.10.3 Timing

Table 3.18: Timing of reserves according to NGET

Reserve	*Start*	*Full availability*	*End*
Primary response	Immediate	≤ 10 s	≥ 30 s
Secondary response	Immediate	≤ 30 s	≥ 30 min
Fast reserve	≤ 2 min	As agreed	≥ 15 min
Fast start	No recommendation	≤ 5 or 7 min[10]	≥ 4 h
Standing reserve	No recommendation	≤ 20 min	≥ 2 h

[9] Note that the operating reserve is separated here only to represent the absence of secondary control in Great Britain.

[10] Full availability has to be reached within 5 min in case of an automatic delivery, and within 7 min in case of a manual delivery.

3.10.4 Time line

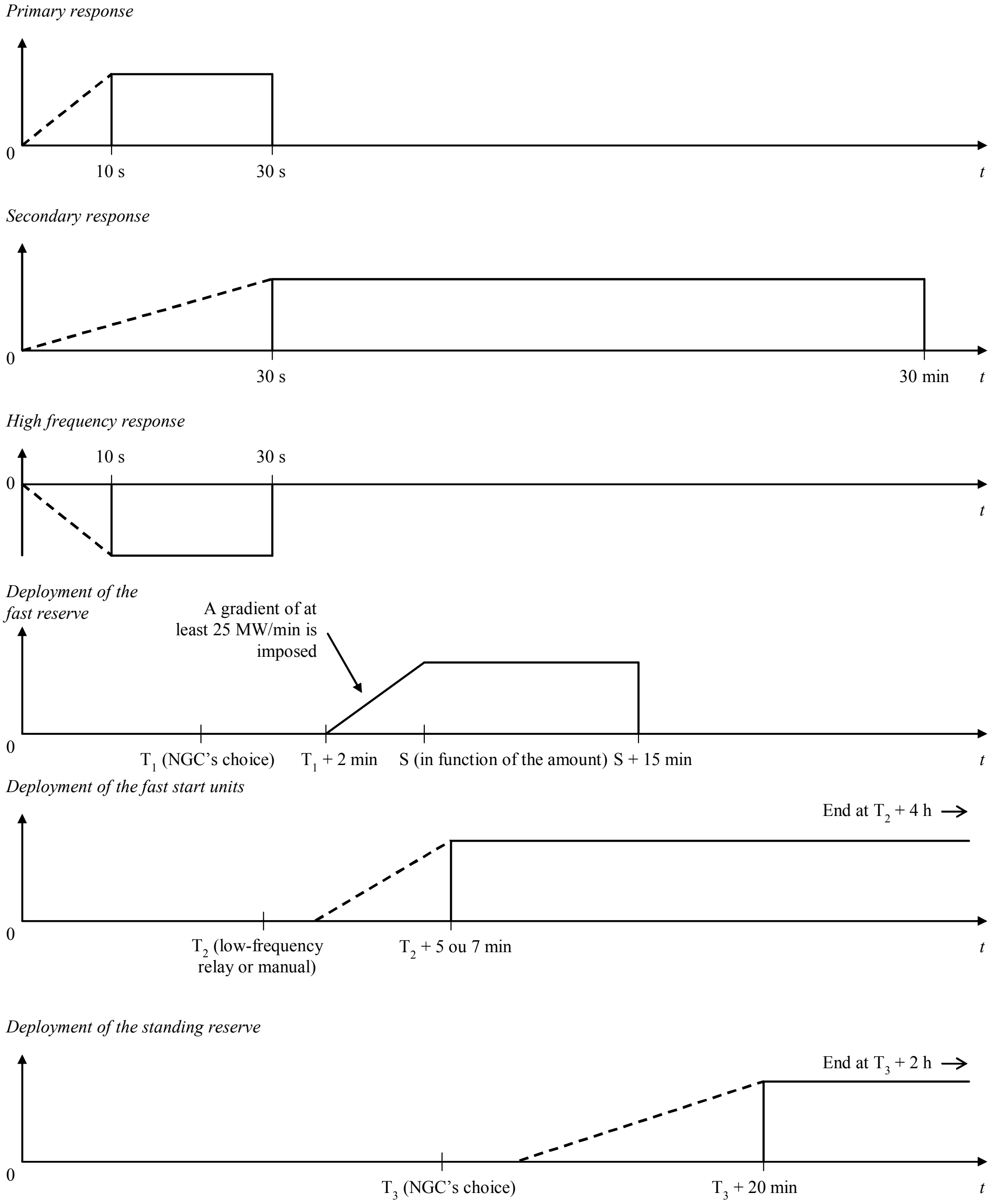

Figure 3.9: NGET time line

3.11 Summary

Based on the information contained in the previous sections, this section compares the services provided in each system.

3.11.1 Primary control reserves

Table 3.19: Comparative of primary control reserves

System	*Reserve*	*Start*	*Full availability*	*End*
UCTE	Primary control reserve	Immediate	≤ 30 s	≥ 15 min
Belgium	*Réserve de puissance pour réglage primaire*	Immediate	≤ 30 s	≥ 15 min
France	*Réserve primaire*	Immediate	≤ 30 s	≥ 15 min
Germany	*Primärregelreserve*	Immediate	≤ 30 s	≥ 15 min
The Netherlands	*Primaire reserve*	Immediate	≤ 30 s	≥ 15 min
Spain	*Reserva primaria*	Immediate	≤ 30 s	As long as required
PJM	Dynamic reserve	Immediate	No recommendation	
California	(no name)	Immediate	No recommendation	
Great Britain	Primary response	Immediate	≤ 10 s	≥ 30 s
	Secondary response	Immediate	≤ 30 s	≥ 30 min

3.11.2 Secondary control reserves

Table 3.20: Comparative of secondary control reserves

System	*Reserve*	*Start*	*Full availability*	*End*
UCTE	Secondary control reserve	≤ 30 s	≤ 15 min	As long as required (See note 2 p. 12)
Belgium	*Réserve de puissance pour réglage secondaire*	≤ 10 s	≤ 10 min	As long as required
France	*Réserve secondaire*	≤ 30 s	≤ 430 s or ≤ 97 s	As long as required
Germany	*Sekundärregelreserve*	Immediate or ≤ 5 min	≤ 5 min	As long as required
The Netherlands	*Secundaire reserve*	from 30 s to 1 min	≤ 15 min	≥ 15 min and as agreed
Spain	*Reserva secundaria*	No recommendation	≤ 300-500 s	≥ 15 min
PJM	Regulating reserve	No recommendation	≤ 5 min	As agreed
California	Regulating reserve	Immediate	≤ 10 min	≥ 2 h15
Great Britain	(none)			

3.11.3 Tertiary control reserves

Tertiary control reserves are often divided into several subsets by TSOs, depending mainly on their deployment time. Therefore, in order to compare tertiary control reserves, we split them into two arbitrary categories:

- ✓ "Fast" tertiary control reserve: tertiary control reserve which is deployed within 15 minutes or less;
- ✓ "Slow" tertiary control reserve: tertiary control reserve which is deployed within more than 15 minutes.

3.11.3.1 "Fast" tertiary control reserves

Table 3.21: Comparative of "fast" tertiary control reserves

System	***Reserve***	***Start***	***Full availability***	***End***
UCTE	Minute reserve or 15 minute reserve	No recommendation	A short time	No recommendation
Belgium	*Réserve de puissance pour réglage tertiaire*	No recommendation	≤ 15 min	As agreed
France	*Réserve tertiaire rapide 15 minutes*	No recommendation	≤ 15 min	≥ 1 h
Germany	*Minutenreserve*	No recommendation	≤ 15 min	As agreed
Spain	*Reserva terciara*	Immediate	≤ 15 min	≥ 2 h
PJM	Primary reserve	No recommendation	≤ 10 min	As agreed
California	Contingency reserve	No recommendation	≤ 10 min	≥ 2 h
Great Britain	Fast reserve	≤ 2 min	As agreed	≥ 15 min
	Fast start	No recommendation	≤ 5 or 7 min	≥ 4 h

3.11.3.2 "Slow" tertiary control reserves

Table 3.22: Comparative of "slow" tertiary control reserves

System	*Reserve*	*Start*	*Full availability*	*End*
UCTE	Tertiary control reserve	No specific recommendation		
France	*Réserve tertiaire complémentaire 30 minutes*	No recommendation	≤ 30 min	≥ 6 h
	Réserve à échéance ou différée	As agreed		
Germany	*Stundenreserve*	No recommendation	≤ 1 h	As agreed
The Netherlands	*Tertiare reserve*	No specified	As agreed	from 15 min to 4 h, as agreed
PJM	Secondary reserve	No recommendation	≤ 30 min	As agreed
	Reserve beyond 30 min	As agreed		
California	Replacement reserve	No recommendation	≤ 1 h	As agreed
	Supplemental energy	No recommendation	≥ 45 min and as agreed	As agreed
Great Britain	Standing reserve	No recommendation	≤ 20 min	≥ 2 h

4 Technical survey

This section provides more technical details on the definitions of the reserve services presented in the previous section. This information takes the form of tables that are unfortunately not exhaustive but are as complete as we could make them given the information to which we had access.

4.1.1 Primary control

Table 4.1: Detailed technical comparison of primary control parameters in various systems

	UCTE	***ELIA (Belgium)***	***VDN (Germany)***	***RTE (France)***	***TenneT (Netherlands)***	***REE (Spain)***	***PJM (USA)***	***NGET (Great Britain)***
Droop of generators	No specification	As agreed (the frequency characteristic is bided)	No specification	from 3 to 6 %	from 5 to 60 MW: 10 % asked > 60 MW: from 4 to 20 %, practically: 10 %	≤7.5 %	5 %	From 3 to 5 %
Does the droop have to be adjustable by producers?	No specification	Unknown	Yes	Yes	For units > 60 MW	Unknown	No	Yes
Frequency characteristic of the control area	18,000 MW/Hz for the first synchronous zone (this value will be revised)	676 MW/Hz asked by the UCTE in 2003 2005: roughly 600 MW/Hz [11]	5,009 MW/Hz asked by the UCTE in 2003	4,632 MW/Hz asked by the UCTE in 2003	from 750 to 1,500 MW/Hz 736 MW/Hz asked by the UCTE in 2005	2,360 MW/Hz asked by the UCTE in 2003	Unknown	Unknown
Total controller insensitivity	± 10 mHz	± 10 mHz	± 10 mHz	± 10 mHz	from 5 to 60 MW: 150 mHz > 60 MW: 10 mHz	± 10 mHz	± 30 mHz[11]	± 15 mHz
Non intentional controller insensitivity	± 10 mHz	± 10 mHz	No specification	± 10 mHz	from 5 to 60 MW: No recommendation > 60 MW: 10 mHz	± 10 mHz	No recommendation	Unknown
Intentional controller insensitivity	If it exists, it should be compensated within the control area	Unknown	None	None	from 5 to 60 MW: No recommendation > 60 MW: None	None	No recommendation	Unknown
100% of the primary reserve is deployed for a deviation of:	± 200 mHz	± 167 mHz	± 200 mHz	± 200 mHz	from 5 to 60 MW: 30 % from 150 to 200 mHz > 60 MW: 70 % from 50 to 100 mHz	± 200 mHz	Unknown	Unknown

[11] As the American network runs at a frequency of 60 Hz, a coefficient of 5/6 have been applied to this value in order to compare it to the European system.

Technical terms employed in Table 4.1 are defined as follow:

- ✓ **Droop:** for a steady-state frequency deviation Δf from the nominal frequency, a generator participating to the primary control will change its generation by $-\Delta P_G$. The droop s_G of this generator is then defined as $s_G = -\frac{\frac{\Delta f}{f_n}}{\frac{\Delta P_G}{P_{Gn}}}$, where f_n and P_{Gn} are respectively the nominal network frequency and the nominal generator output power.
- ✓ **Frequency characteristic:** the frequency characteristic λ_{zone} of a control area is defined as $\lambda_{zone} = -\frac{\Delta P_{interconnection}}{\Delta f}$, where $\Delta P_{interconnection}$ is the variation of the exchanges of the control area following a steady-state frequency deviation Δf from the nominal frequency. Therefore, the frequency characteristic represents the combined actions of the primary control and the self-regulating effect of charges;
- ✓ **Insensitivity:** the insensitivity of a primary controller is the frequency band within which the controller does not change the generator consign.

4.1.2 Secondary control

Table 4.2: Detailed technical comparison of secondary control parameters in various systems

	UCTE	VDN (Allemagne)	ELIA (Belgium)	RTE (France)	TenneT (Netherlands)	REE (Spain)	PJM (USA)
Control organisation	No recommendation	Pluralistic	Centralised	Centralised	Centralised	Hierarchical	Centralised
Measurement accuracy of the controller	from 1.0 to 1.5 mHz	from 1.0 to 1.5 mHz	Unknown	RTE internal value	Frequency: 1 mHz Interconnections: 0.5 %	Unknown	≤ 0,83 mHz (See note 11 p. 31)
Cycle time	from 1 to 5 s	from 1 to 2 s	< 5 s	Frequency: 1 s Interconnection: 5 s Secondary control signal: 10 s	Measurement: 4 s Secondary control signal: 4 s	Unknown	< 6 s
Controller type	I or PI	PI	PI	I	PI, with additional heuristics	P or PI, depending on the regulation zone	PI
K-factor for measuring the ACE	19,801 MW/Hz	Unknown	Roughly 660 MW/Hz	Unknown from 8,000 to 9,000 MW/Hz (in the 90s, including Spain and Portugal)	900 MW/Hz	Unknown from 8,000 to 9,000 MW/Hz (in the 90s, including Spain and Portugal)	Variable in real time
Value of the proportional term (β)	from 0 to 0.5	Unknown	from 0 to 0.5	0	0.5	Unknown	Unknown
Value of the integral term (T)	from 50 to 200 s	Unknown	from 50 to 200 s	from 115 to 180 s (estimate with 90s data)	from 100 to 160 s	100 s	Unknown
Activation of the controller	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous
Beginning of the effective correction of the frequency	≤ 30 s	Unknown	Unknown	Unknown	From 20 to 120 s, in function of the error size	Unknown	Unknown
Allowed overshoot	None	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Return of the frequency to its target value	< 15 min	Unknown	Unknown	Unknown	Error correction within 15 min	Unknown	Unknown

Technical terms employed in Table 4.2 are defined as follow:

- ✓ **Control organisation:** the secondary control can be organized in three manners [5]:
  - → **Centralised:** "secondary control for the control block is performed centrally by a single controller (as one control area); the operator of the block has the same responsibilities as the operator of a control area";
  - → **Pluralistic:** "secondary control is performed in a decentralised way with more than one control area; a single TSO, the block co-ordinator, regulates the whole block towards its neighbours with its own controller and regulating capacity, while all the other TSOs of the block regulate their own control areas in a decentralised way on their own";

→ **Hierarchical:** "secondary control is performed in a decentralised way with more than one control area; a single TSO, the block coordinator, operates the superposed block controller which directly influences the subordinate controllers of all control areas of the control block; the block co-ordinator may or may not have regulating capacity on its own".

✓ **ACE** and **K-factor**: the Area Control Error (ACE) of a zone is calculated as follow: $ACE = P_{measured\ exchanges} - P_{programmed\ exchanges} + K\left(f_{measured} - f_{target}\right)$ (this formula is applied within the UCTE. In the USA, some coefficients can be added), where:

→ K is the K-factor of the zone. It is an over-estimation of the frequency characteristic of the zone;

→ $P_{measured\ exchanges}$ is the measured value of the total power exchanged by the zone with other zones (a positive value represents an overall export);

→ $P_{programmed\ exchanges}$ is the scheduled value of the total power exchanged by the zone with other zones (a positive value represents exports);

→ $f_{measured}$ is the measured network frequency;

→ f_{target} is the target frequency, which can differ from the nominal frequency when controlling the synchronous time.

✓ **Proportional** and **integral terms**: the secondary control power ΔP_{sec} deployed in a zone is calculated according to $\Delta P_{sec} = -\beta \times ACE - \frac{1}{T}\int ACE dt$, where β is the proportional term and T the integral term.

4.1.3 Tertiary control

As the tertiary control is performed manually it is not possible to compare the technical feature regarding of this control.

5 Summary

This document proposes a framework for comparing reserve services across different jurisdictions. This framework is based on the usual organisation of frequency regulation as applied within the UCTE. Frequency regulation is divided into three control levels: primary (automatic and local), secondary (automatic and central), and tertiary (manual and central).

The definitions of reserve services used in nine jurisdictions (UCTE, Belgium, France, Germany, the Netherlands, Spain, California, PJM and Great Britain) have been discussed and analysed according to this framework. For each of them, the terminology, the amounts of services required by the TSO and the time lines have been discussed. Tables providing a more detailed comparison of the technical parameters of these services are also provided.

Acknowledgement

This report has been possible only by the kind support of **Electricité de France**, which provided both a financial backing and an irreplaceable knowledge.

We would also like to warmly thank all our other contacts for their kind answers to our numerous questions, especially Noel Janssens and Ton Kokkelink.

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