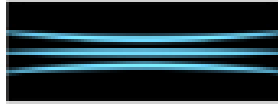


T R A N S P O W E R



Appendix A

A Collation of International Policies for Under-Frequency Load Shedding

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7 August 2009

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A Collation of International Policies for Under-Frequency Load Shedding

Introduction

The purpose of this report is to collate information on International policies and practises (50 Hz and 60 Hz systems) where possible, to be able to evaluate New Zealand's Automatic Under-frequency load shedding policy at a later date. No attempt is made in this report to evaluate the information collected.

This report looks at:

- peak demand and generation capacity
- interconnections of an operational area with outside operational areas
- interconnections within an area
- any HVDC links
- the reserves and if possible how they were obtained
- the general under-frequency response
- the automatic under-frequency load shedding schedules

Where information is unobtainable, it is marked as unknown or left blank.

Under-frequency response is generally divided up into:

- ∅ Reserves – these tend to be generation and are usually time based
 - Self regulation – includes spinning reserves, governor control and peak lopping
 - Primary control – consists of Instantaneous reserve (generation) active within 10 s
 - Secondary control – consists of Extended reserve (generation) active within 1 minute sustainable for 15 minutes
 - Tertiary control – consists of longer term reserves (generation) within 15 minutes sustainable for as long as is required, generally manually activated
 - Interruptible load – part of reserves and activated manually at any time
- ∅ Automatic under-frequency load shedding (AUFLS) – automatically activated at predetermined frequencies.

The difference between AUFLS and Interruptible Load is that Interruptible load must be dispatched as reserves and are not always available. AUFLS are not dispatched but must always be available.

Note: Countries use different terminology for their responses and where the same terminology is used it does not necessarily have the same context or meaning. Attempts were made to standardise the format for comparison purposes.

1 Pacific

1.1 New Zealand

Date of information	2009
Peak load **	6400
Generation Capacity (MW)	8804 (NI 5281, SI 3523)
Type of Generation *	Hydro 60%, Thermal 28%, geothermal 10%, Wind 2%
Highest AC voltage (kV)	220
Deadband	
Reserves (MW)	400-1000
No of Areas	2

* Energy Link LTD – Market Review

** Annual report 2009 – peak demand 2007

1.11 HVDC

The HVDC between the North Island and South Island consists of a bipole DC link. Pole 1 has two half poles with one half of the pole decommissioned and one half of the pole in operation only for special circumstances at 6 pulses 135 kV or 12 Pulse 270 kV. Pole 2 is at 350 kV (or reduced voltage at 250 kV) and maximum of 700 MW. Operation allows transfer in both directions.

From: TP.OG.48.02 HVDC: Bipole operating policy.

1.12 Interconnections

No interconnections between other countries. No importing or exporting of energy with the exception of the HVDC link between North and South Island.

1.13 Biggest risk

The risks for an AC contingency event are calculated on the largest generator unit lost. In South Island this is set at 120 MW and in North Island the largest unit of Huntly, Otahuhu B and Taranaki Combined Cycle are considered.

The DC contingency event is calculated on the transfer at the receiving end minus the DC risk subtractor. The extended contingency event for the DC is calculated on the DC transfer at the receiving end. There is no AC extended contingency event risk calculation.

New Zealand has winter peaks though that is changing particularly in North Island due to air-conditioners in summer.

1.14 Under-Frequency

Events are classified as shown in the table and diagram below:

Table 1: Under-Frequency Classification in New Zealand

	North Island	South Island	Reserve used
Normal	50 - 49.8 Hz (maintain within 5 s)	50 - 49.8 Hz (maintain within 5 s)	Frequency Regulating Reserve (spare synchronised generation) by frequency keepers.
	49.8 – 49.25 Hz restore within 1 minute	49.8 – 49.25 restore within 1 minute	Instantaneous Reserve
Contingent Event (CE)	49.8 - 48 Hz	49.8 - 48 Hz	Instantaneous Reserve , Interruptible Demand.
Extended Contingent Event (ECE)	48 - 47 Hz (47.1 Hz > 5 s or 47.3 Hz > 20 s)	48 - 45 Hz	Instantaneous Reserve, Interruptible Demand, Automatic Under Frequency Load Shedding.

From: A Market guide to RMT by M Phethean, May 2008, Reserves Dispatch

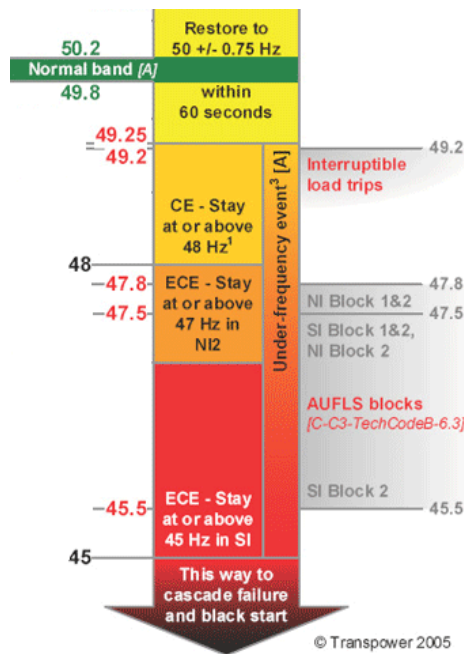


Figure 1: Frequency management diagram in New Zealand

From: Frequency Management Barometer (<http://intranet.transpower.co.nz/n10288.html>)

1.15 Reserves

The reserves consist of:

- ∅ Frequency Regulating Reserve
 - Spare synchronous generation provided by the Frequency Keepers.
- ∅ Instantaneous Reserve
 - Fast Instantaneous Reserve (FIR) – also called Six Second Reserve, activated within 6 seconds and sustained for 60 seconds.
 - w Partly Loaded Spinning Reserve (PLSR) and Tail Water Depressed Reserve (TWD) activated in 6 seconds.

- w Interruptible load (IL) occurs in one second of the frequency falling to 49.2 Hz for >200ms and is sustained for at least 60 seconds.
- Sustained Reserve (SIR) – provided during the first 60 seconds and sustained for at least 15 minutes.
 - w Partly Loaded Spinning Reserve (PLSR) and Tail Water Depressed Reserve (TWD) activated in 60 seconds and sustained for 15 minutes.
 - w Interruptible load (IL) occurs in 60 seconds of the frequency falling to 49.2 Hz and is sustained for until advised by operator.

1.16 Automatic Under-Frequency Load Shedding (AUFLS)

AUFLS are activated in two blocks for both the Islands at different frequencies as indicated in the table below.

Each block consists of 16% of peak load (NIPS minus 480 MW of exempted Industrial load in North Island and SIPS minus 610 MW for Tiwai Aluminium Smelter in South Island), giving a total of <32% of peak load.

Table 2: AUFLS activation frequencies in New Zealand

	North Island	South Island
Block 1	47.8 Hz for 400 ms	47.5 Hz for 400 ms
Block 2	47.8 Hz for 15 s	47.5 Hz 15 s
Alternative block 2	47.5 Hz for 400 ms	45.5 Hz for 400 ms

1.17 N-1 Security

For outages, N-1 security is applied to circuits only in the New Zealand transmission system.

Heavily loaded areas, like Penrose in Auckland, N-1 security is being considered for some 220 kV interconnection transformers.

There are also certain areas where some circuits are permanently on N Security due to historic and economic reasons.

1.2 Australia

Date of information	2001/3 & 2008/9
Peak load (MW)**	37207
Generation Capacity (MW) *	47400
Type of Generation *	56.7 % black coal, 24.5% brown coal, 12.2% natural gas, 6.1% hydro, and 0.6% oil and other fuels.
Highest voltage (kV)	500
Deadband	
No of Areas	5

* Figures from esaa Web site

** From Introduction to Australia's national energy market, June 2008

1.2.1 HVDC

Australia has an HVDC link from LoyYang Power Station to George Town Tasmania, 400kV, of 600 MW; The Murray link, a 220 MW interconnector between the Riverland in South Australia; and in Sunraysia in Victoria there is a 180 km underground high-voltage DC light power link.

From: Wikipedia

1.2.2 Interconnections

Australia is made up of 6 states as well as Tasmania and only has interconnections between states as detailed below.

Table 3: Interconnection capabilities in Australia

Interconnector	Year	From	To	Forward Capacity (MW)	Reverse Capacity (MW)
BassLink	Existing	TAS	VIC	600	480
NSW-QLD (MNSP1)	Existing	NSW	QLD	152	196
NSW-QLD (MNSP2)	Existing	NSW	QLD	30	234
NSW-QLD	Existing	NSW	QLD	589	1078
SNOWY-NSW	Existing	SNY	NSW	3559	1150
VIC-SA (MNSP)	Existing	VIC	SA	220	214
VIC-SA	Existing	VIC	SA	460	300
VIC-Snowy	Existing	VIC	SNY	1313	1842



Figure 2: Map of Australia showing the states

From: Comprehensive reliability Review – Design Option Analysis Appendix December 2007



Figure 3: An example of load transfer between states in Australia
 From: National Electricity Market Report Week 29 Ending Saturday 18-Jul-09

1.2.3 Biggest Risk

Unknown

1.2.4 Under-Frequency

Under-frequency response for Australia is shown in the table below

Table 4: Under-Frequency categories in Australia

	Frequency	Reserve
Normal operating frequency band	50Hz to 49.85	Governor control
Contain a generation event within 5 minutes	49.5 Hz	Industrial load trips
A single credible contingency event	49 Hz	Residential – Category 1
Non-credible multiple contingency event	48.85Hz	Commercial load – Category 2
	48.5 Hz	Industrial and large Commercial loads
	48 Hz - 47 Hz	Critical industrial load
	45 Hz	Automatic Tripping of generators.

From: final year engineering project - Alida Jansen van Vuuren, Undergraduate Electrical and Mechatronic Engineering Student, University of South Australia

1.2.5 Reserves

Australia has a reserve margin of 15.9%.

Minimum Reserve Levels from SOO 2003 and SOO 2004, MW

	Queensland	New South Wales	Victoria and South Australia	Tasmania	Total
SOO 2004	610	- 290	530	144	994
SOO 2003	450	700	795	288	2 233
Change	+ 160	- 990	- 265	- 144	- 1 239

Source: "Statement of Opportunities" July 2004.

From: Australia 2005 Review, Energy Policies of IEA Countries, International Energy Agency

1.2.6 Automatic Under-Frequency Load Shedding (AUFLS)

- ∅ All loads >10 MW must provide a minimum of 60% automatic interruptible load to be used in manageable steps from 49 Hz to 47 Hz.
- ∅ Any load shedding capability of ancillary services may be counted as automatic interruptible load
From: National Electricity Code Administrator Limited, Reliability Panel, Frequency operating standards Determination, September 2001
- ∅ In the Northern Territories:
 - It is a requirement for power system security that 75% of the power system load at any time be available for disconnection:
 - under the automatic control of under frequency relays; and
 - under manual or automatic control from control centres; and/or
 - under the automatic control of undervoltage relays.

From: Northern Territories Power Networks, Network Planning Criteria 2.0, 2003

1.2.7 N-1 Security

The network is designed to operate with N-1 criterion such that the network shall be capable of withstanding the loss of any single component at any load level and for any generation schedule.

From: Northern Territories Power Networks, Network Connection Technical Codes

2 Europe

2.1 UCTE (now ENTSOE-)

From the 1 July 2009 the ENTSOE (European Network of Transmission System Operators for Electricity) has taken over all operational task from 6 existing TSO (Transmission System Operators) including the UCTE (Union for the Coordination of Transmission Electricity). The scope of the ENTSOE is shown in the map below.

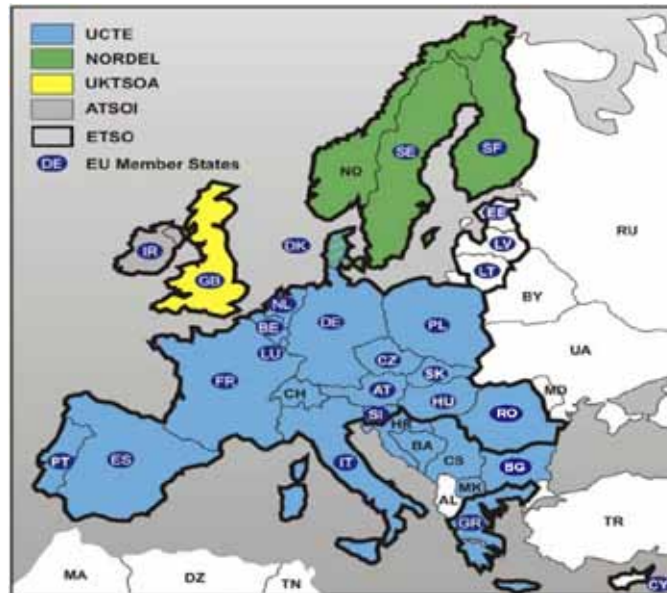


Figure 4: ENTSOE control from 1 July 2009

Country	UCTE	- France	- Spain
Date of information	2007/9	2008	2009
Peak load *	410000	92400	40000
Generation Capacity (MW) *	650000	120000	92033
Type of Generation**	Hydro (11.5%), Nuclear (29%), Thermal (54%), Wind (3.4%), Other (2.1%)		
Highest voltage (kV)	750		
Deadband	<10mHz	<10mHz	
Reserves (MW)	3000	650	450 with Portugal
No of Areas	8		

* From: ENTSOE Winter Review and Summer Outlook, Report 2009

**Statistical Yearbook UCTE 2007

2.1.1 HVDC

There are nine HVDC links in the UCTE region, five of which are to countries outside the UCTE.

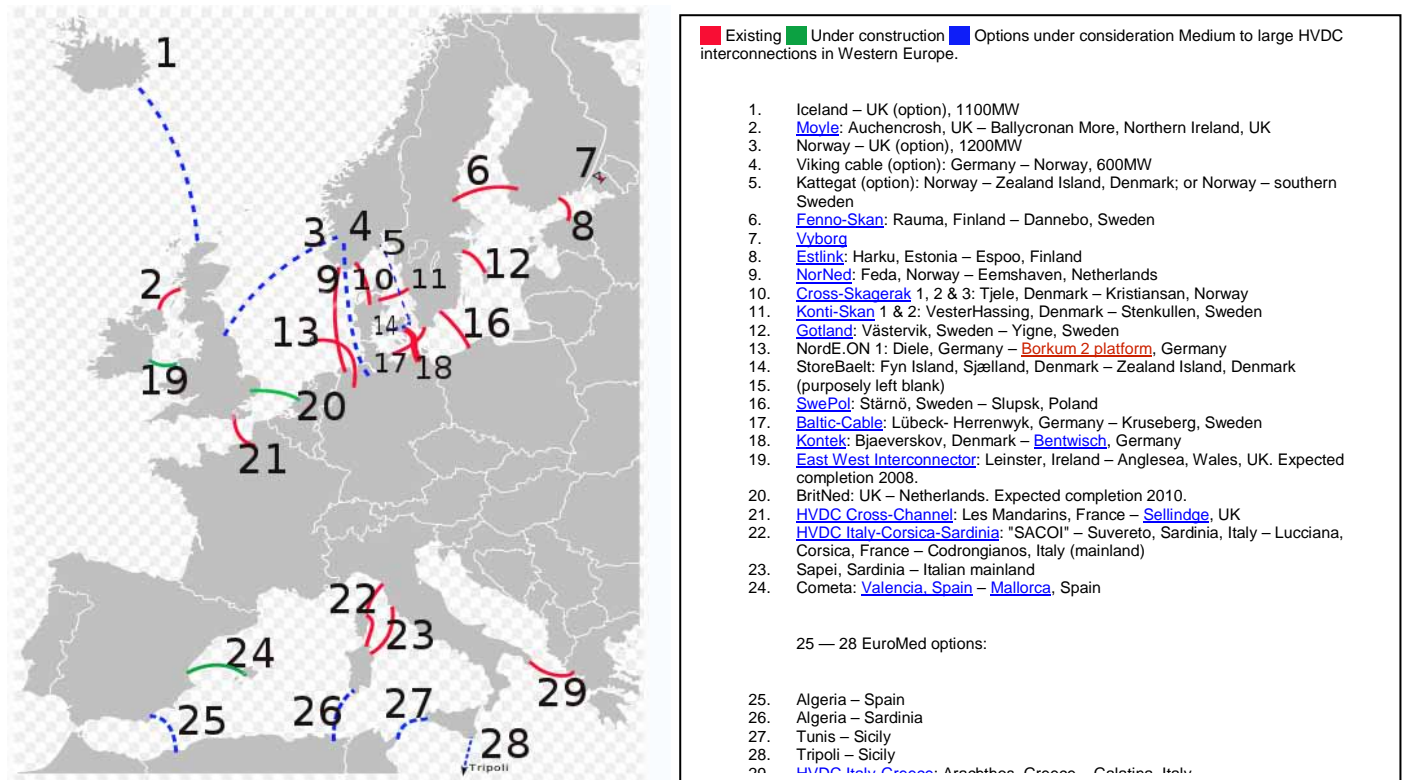


Figure 5: HVDC links in Europe
From: Wikipedia

2.1.2 Interconnections

The UCTE has synchronous areas which are made up of Control blocks, within each Control Block are Control Areas.

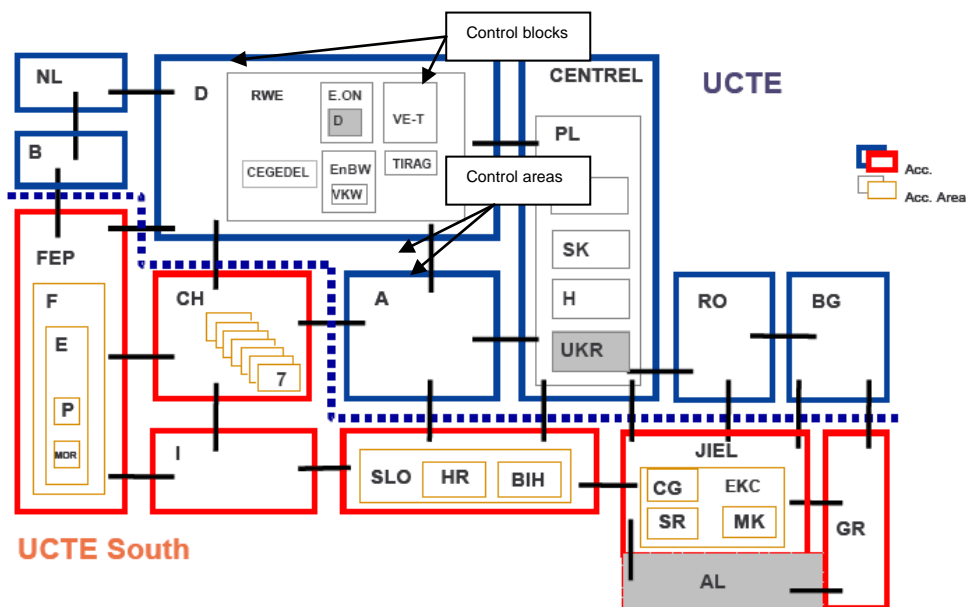


Figure 6: Synchronous areas and Control blocks that form UCTE
From: UCTE Operational handbook – Introduction Final v2.5

The UCTE also interconnects with Great Britain, Nordic countries, top of North Africa and Eastern Europe.

Table 5: An example of some of the imports and exports

EXPORTS	March 2009 (GWh)	Trend compared with the same period in 2008	
		March	Since 1 st January
Belgium	420	⬇️ -68%	⬇️ -66%
Germany	795	↔️ n.s.*	↔️ 150%
Switzerland	2 336	↔️ 12%	↔️ 11%
Italy	1 932	↔️ 15%	↔️ 4%
Spain	530	↔️ 23%	⬇️ -34%
Great Britain	620	⬇️ -27%	⬇️ -41%
Total	6 633	↔️ 1%	⬇️ -10%

IMPORTS	March 2009 (GWh)	Trend compared with the same period in 2008	
		March	Since 1 st January
Belgium	403	↔️ n.s.*	↔️ n.s.*
Germany	1 149	⬇️ -58%	⬇️ -45%
Switzerland	145	⬇️ -53%	↔️ 11%
Italy	10	⬇️ -92%	⬇️ -71%
Spain	272	⬇️ -2%	↔️ 95%
Great Britain	278	↔️ 151%	↔️ 196%
Total	2 257	⬇️ -38%	⬇️ -11%

From: ENTSOEWinter Review and Summer Outlook, Report 2009

2.1.3 Biggest Risk

Some parts of Europe have a summer peak and some have winter peak.

The biggest risk is the largest generation unit or set, HVDC links, power infeed on single busbars in an Area.

The reserve is calculated on the maximum value of an incident that causes a deviation of -180 mHz and has been set at 3000 MW.

2.1.4 Under-Frequency

The ENTSOE has Primary, Secondary and Tertiary Control to operate the generators in an under-frequency event as shown in the figures below.

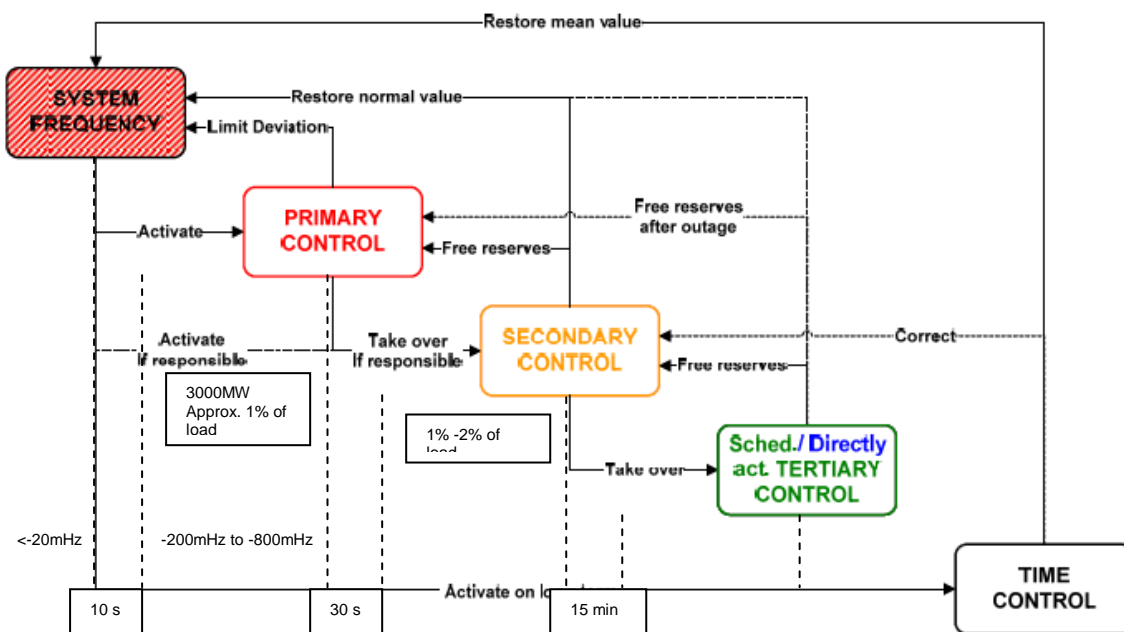


Figure 7: Control scheme and actions starting with the system frequency within UCTE

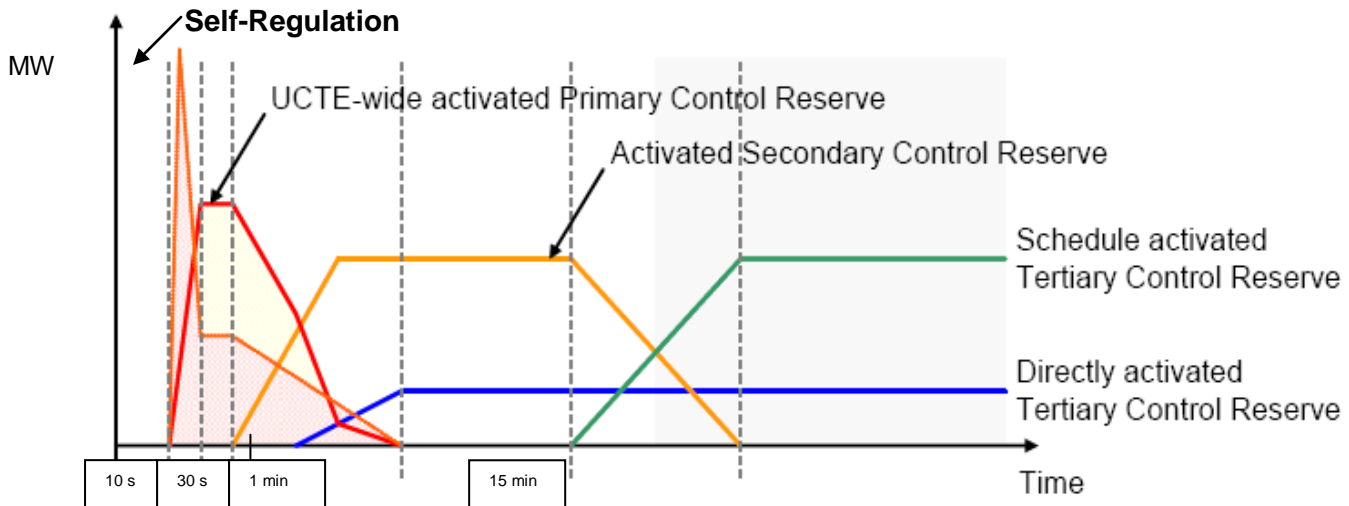


Figure 8: Principle frequency deviation and subsequent activation of reserves
 Diagrams from UCTE OH – Policy 1: Load-Frequency Control - Final Version (approved by SC on 19 March 2009)

Under-frequency actions include:

- Ø Manual load shedding of interruptible customers.
- Ø Shedding of storage pumps
- Ø Switching on of shunt reactors
- Ø Blocking of OLTC
- Ø Deliberate tripping of Tie-lines
- Ø Automatic Load shedding for under frequency events

2.1.5 Reserves

UCTE incidents are defined as follows:

- Reference Incident: The maximum value of an incident (3000 MW) that causes a deviation of -180 mHz
- Observation Incident: Loss of generation > 600 MW.



Figure 9: Approximate present distribution of Primary Control Reserves

From: Geographical Distribution of Reserves – (2005-08-29 UCTE-GDR - Final Report 3 - Primary Reserve - Version 1)

Ø Primary Control Reserve

- The Reserve of 3000 MW is divided up between all UCTE member countries as shown in the map in Figure 9.
- The Primary control reserve is activated within 10 seconds
- Require 50% of reserves within 15 s and 100% of reserves in 30 s
- If a generator that provides Primary Reserve trips, the subsequent loss of that Primary Reserve must be limited to 90 MW or 3% of Reference incident.

Ø Secondary reserve

- The figure below shows how Secondary Reserve is obtained.

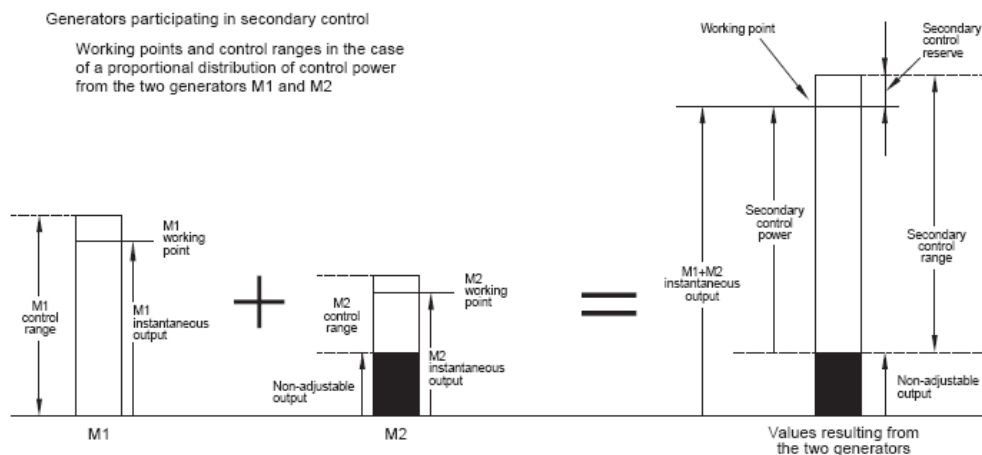


Figure 10: Demonstration of how Secondary Reserve is obtained

- The recommended Secondary Reserve values are between 1 and 2% of peak load as shown in the figure below.

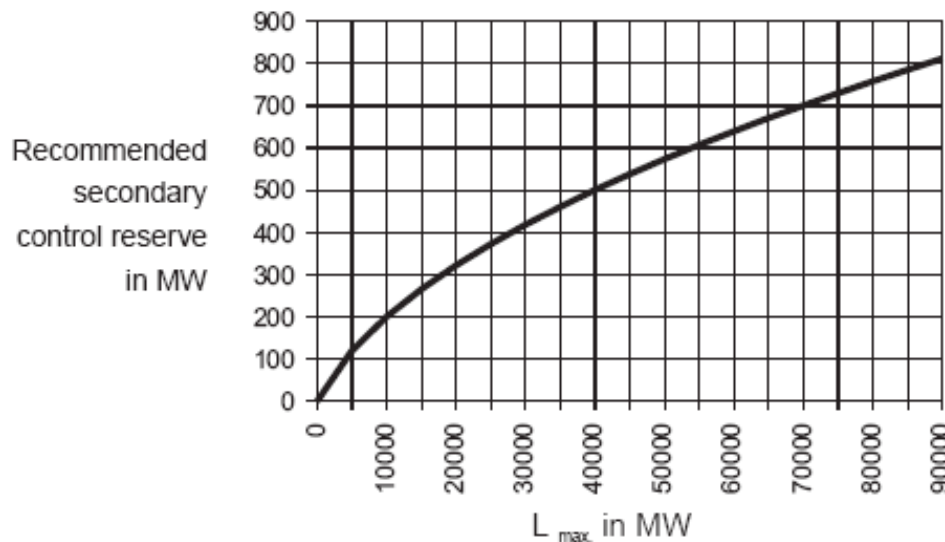


Figure 11: graph of recommended Secondary Control Reserve

- The Secondary Reserve must be sustainable for at least 15 minutes and is activated within 20 to 30 seconds.
- 50% of the total Secondary and Tertiary reserve must be within the Control Area.

Ø Tertiary Reserves

- Tertiary reserves consist of:
 - w Directly activated Tertiary control Reserves – can be activated manually at any time. In a reference incident it is activated within 1 minute.
 - w Schedule activated Tertiary Control Reserves – activated to a pre-defined time-frame such as 15 minutes.
- Tertiary reserves support the secondary reserves as shown in the figure below.

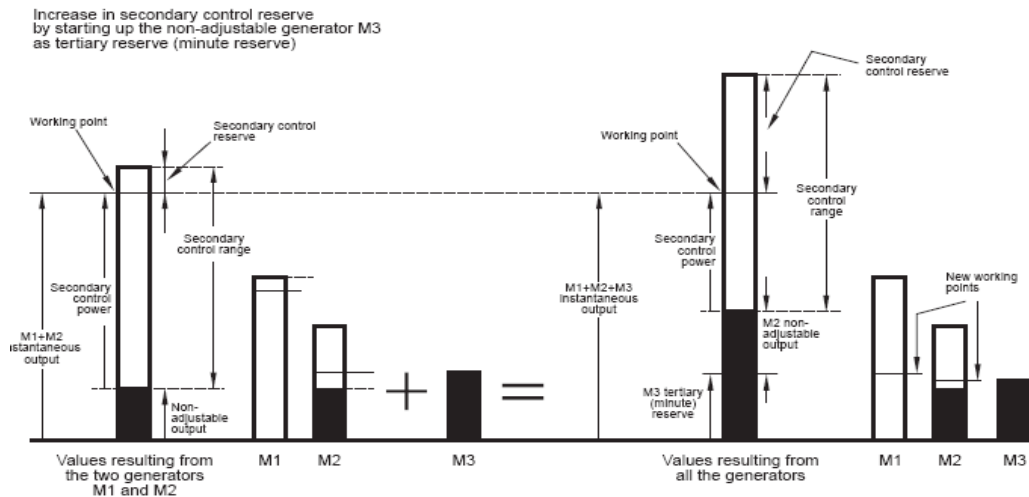


Figure 12: Demonstration of how Tertiary Reserve is obtained

- Tertiary reserves remain activated until no longer required.

Table 6: UCTE reserve

	Frequency	Reserves
Normal	To -20 mHz	Self regulation Frequency characteristic assumed to be a minimum of 1% of load decrease = 1 Hz drop in frequency
	-20 mHz to -180 mHz	Quick start generation activated
Primary	-200 mHz to -800 mHz (49.2 Hz)	3000 MW Reserve Frequency Characteristic 30% higher i.e. 19500 MW/Hz. Require 50% of reserves in 15 s and 100% of reserves in 30 s (Required to be checked on a regular basis). If a generator trips the loss Primary reserve must be limited to 90 MW or 3% of Reference incident.
Secondary (to balance control area)		Size of reserve is calculated by deterministic / probalistic means. (i.e. largest generation unit or set, HVDC links, power infeed on single busbars). Uses automatic generation control, sustainable for 15 minutes. 50% of the total Secondary and Tertiary reserve must be within the Control Area.
Tertiary (minute reserve)		Extra Generation sufficient to support Secondary Reserve. Activated within 1 minute to 15 minutes until no longer required.

From: UCTE Operation Handbook, Policy1 and Appendix 1, final versions

2.1.6 Automatic Under-Frequency Load Shedding (AUFLS)

The actual Automatic under-frequency load shedding percentages differ for each Control Area. Each Control Area is to ensure that the disturbance stays within their boundaries.

Table 7: UCTE requirements for AUFLS

	Frequency	AUFLS
Stage 1	49 Hz	Minimum 10 -20% of load
Stage 2	48.7 Hz and 48.4 Hz (France: 48.5 Hz and 48.0 Hz)	10-15% of load each triggered in steps of 0.3 and 0.5 Hz.
	47.5 Hz	Power stations automatically disconnect.

From: UCTE Operation Handbook, Policy1 and Appendix 1, final versions

Total load shedding is approximately 50% of peak load.

2.1.7 N-1 Security

The UCTE has defined the following types of contingencies:

- ∅ Normal contingency
 - A single line
 - A single generating unit
 - A single transformer or 2 transformers connected to the same bay, a phase shifter transformer
 - A large voltage compensation installation
 - A DC link considered as a large generating unit or a large consumer
- ∅ Exceptional contingency
 - A double line (two circuits on the same tower over a long distance)
 - A single busbar where deemed a higher than normal risk
 - A common mode failure with the loss of more than one generating unit, including large wind farms and common mode failure of DC links
- ∅ Out-of-range contingency – has very low probability of failure and constitutes an emergency event
 - The independent and simultaneous loss of two lines
 - The loss of a whole substation with more than one busbar
 - The total loss of power station with more than two generating units
 - The loss of a tower containing more than two circuits
 - Severe power swing or oscillations

All networks in the UCTE must ensure that with the proposed outages N-1 security is maintained.

N-1 security encompasses the normal and exceptional contingencies.

From: UCTE Operation Handbook – Policy 3: Operational Security – Final Version 19 March 2009

Examples from Countries within the UCTE

Spain:

Reserve margin:	20%
Reserve allocation: (together with Portugal)	400 MW

Table 8: Table of AUFLS for Spain

Instantaneous Automatic Disconnection (no elapsed time)	
49.5 Hz:	50% synchronized pumping groups
49.3 Hz:	50% synchronized pumping groups
49.0 Hz:	15% load
48.7 Hz:	15% load
48.4 Hz:	10% load
48.0 Hz:	10% load
Distribution companies are responsible for automatic load shedding from the demand side.	
Minimum frequency protection of generation units are only allowed to trigger after frequency fall and remain below 48 Hz for 3 seconds.	

From: John Campbell's Questionnaire - Sanchiz Garrote, Jaime [<mailto:jsanchiz@ree.es>]

France:

Reserve allocation: 650 MW

Any unit with rated power > 40 MW must contribute to primary frequency control.

Any unit with rated power > 120 MW must contribute to secondary frequency control.

From: C2 -201 Contribution Of Generating Units To Load Frequency And Voltage Control In France: Contractual Agreements And Performance Monitoring By Rte By P.Bertolini, S.Pescarou, P.Juston Rte (French Transmission System), Cigre 2008

2.2 Great Britain

Date of information	2009
Peak load *	59151
Generation Capacity (MW) *	74000
Type of Generation *	Nuclear 20%, Gas 45%, Coal 34%
Deadband/ accuracy	0.01 Hz
No of Areas	3

* From: ENTSOE Winter Review and Summer Outlook, Report 2009

2.2.1 HVDC

Great Britain has two HVDC links. One 270 kV link to France with a capacity of 2000MW. The other, called Moyle link from Scotland to Northern Ireland, consisting of two monopole 250 kV DC cables with a transmission capacity of 250 MW.

From: Wikipedia

2.2.2 Interconnections

Interconnections to France with an average peak of 1500 MW and to Northern Ireland via the Moyle Link.

2.2.3 Biggest Risk

Unknown.

2.2.4 Under-Frequency

All generators > 50 MW are obliged to provide Frequency Control by means of frequency sensitivity.

Table 9: Table showing under-frequency response Great Britain

	Frequency	Response
Normal conditions	50.0 - 49.5 Hz	Frequency sensitive generators
Under-frequency	50.0 - 47.5Hz Hz	Continuous operation required by generators Primary and Secondary Response Automatic load shedding
	47.5 - 47 Hz	Generators required to remain in operation for a period of at least 20 seconds is required each time the Frequency is below 47.5Hz.

2.2.5 Reserves

The reserve margin for Great Britain is 23%.

Table 10: Response time for Reserves in Great Britain

	Time
Primary Response	10 to 30 Seconds for 0.5 Hz drop
Secondary Response	30 Seconds to 30 Minutes

2.2.6 Automatic Under-Frequency Load Shedding (AUFLS)

Table 11: AUFLS allocation in Great Britain

Frequency Hz	%Demand disconnection for each Network Operator in Transmission Area*		
	NGET	SPT	SHETL
48.8	5		
48.75	5		
48.7	10		
48.6	7.5		10
48.5	7.5	10	
48.4	7.5	10	10
48.3			
48.2	7.5	10	10
48	5	10	10
47.8	5		
Total % Demand	60%	40%	40%

*Percentage of load shedding is based on Peak demand.

From: UK Grid Code: Appendix 5 - Technical Requirements Low Frequency Relays for the Automatic Disconnection of Supplies at Low Frequency - CC.A.5.5

Great Britain's electricity transmission companies are:

- National Grid Electricity Transmission (NGET)
- SP Transmission Ltd (SPT)
- Scottish Hydro Electric Transmission Ltd (SHETL)

2.3 Ireland

Country	Republic of Ireland	Northern Ireland
Date of information	2009	2009
Peak load (MW)	5084 MW*	1800****
Generation Capacity (MW)	6317**	≈2800*
Type of Generation ***	Hydro (7%), thermal, pumped storage, wind	Thermal
Highest voltage (kV) ***	400 kV	275 kV
Deadband	<15mHz	<15mHz

* From: ENTSOEWinter Review and Summer Outlook, Report 2009

** EirGrid Monthly Availability Report – May 2009

*** Eirgrid / Soni Map of Transmission system October 2007

****Forecasting Peak Demand & Annual Energy Consumption in the Economic Downturn, June 2009

The Irish power system is made of two, synchronised, operating areas. SONI (System Operator for Northern Ireland) operate the system in the North, EirGrid operate the system in the South. The System Operators share operating reserve in line with the levels set out in the Operating Reserve Requirements paper on the EirGrid website¹. This operating reserve is partially dynamic (spinning) and partially static.

2.3.1 HVDC

There is one HVDC link from Scotland to Northern Ireland, called the Moyle link which consists of two monopole 250 kV DC cables with a transmission capacity of 250 MW.

From: Wikipedia

2.3.2 Interconnections

There are interconnections through the HVDC link with Scotland to Northern Ireland. There is a tie-line between the Republic of Ireland and Northern Ireland.

2.3.3 Biggest Risk

The largest single infeed is the HVDC link.

2.3.4 Reserves

Table 12: Reserve requirements and categories in Ireland

Operating Reserve Requirements			
Category	All Island Requirement % Largest Single In-feed	EirGrid Minimum ¹ (MW)	SONI Minimum (MW)
POR ²	81%	100 / 75	50
SOR	81%	100 / 75	50
TOR 1	100%	100 / 75	50
TOR 2	100%	100 / 75	50

¹ EirGrid lower values apply from 22:30-08:00 inclusive

² Minimum values of POR in each jurisdiction must be supplied by dynamic sources

¹ <http://www.eirgrid.com/media/Operating%20Reserve%20Requirements.pdf>

Operating Reserve Definitions

	Delivered in	Maintained for
Primary (POR)	5 seconds	15 seconds
Secondary (SOR)	15 seconds	90 seconds
Tertiary 1 (TOR1)	90 seconds	5 minutes
Tertiary 2 (TOR2)	5 minutes	20 minutes

Sources of Operating Reserve

	EirGrid	SONI
Dynamic Reserve	Synchronised Generating Units	
Static Reserve	Turlough Hill units when in pumping mode Interruptible Load (45MW 07:00-00:00)	Moyle Interconnector (75 MW)

From: Eirgrid / System Operator for Northern Ireland, Operating Reserve Requirements Valid from 1st October 2008

Dynamic reserve:

- Each conventional generator on the system regulates with a typical governor droop of 4%. If a frequency event occurs, the initial dynamic response is from the automatic governor initiated response of the generating units. The system operators then dispatch generators to higher levels to rebalance generation and demand.
- There is also a pumped storage station (4 x 73 MW units), which is typically generating or spinning in air to provide dynamic reserve during the day and pumping at night (thereby providing static reserve – see below). When system frequency falls, the pumped storage units, at predefined trigger frequencies, automatically begin ramping up their output. The trigger frequencies range from 49.8 to 49.35 Hz and vary by unit and mode of operation – generating, spinning in air, or standstill (de-synchronised).

Static reserve:

- The Moyle Interconnector (a HVDC link between Northern Ireland and Scotland) generally provides 75 MW of static reserve, 24 hours a day. This static reserve is triggered at 49.6 Hz.
- STAR (Short Term Active Response) is a scheme whereby demand customers are paid for making their load available for short term interruptions. STAR provides up to 45 MW of static reserve between the hours of 07:00 and 24:00. This static reserve is triggered automatically, and without notice, (via an under frequency relay at each customer site) when the system frequency falls to 49.3 Hz.
- If the pumped storage units are pumping, they operate at a fixed load and do not provide normal governor response. However, they will trip from pumping almost instantaneously at predefined frequencies. Once tripped, the unit will synchronise and begin generating as quickly as possible. The predefined frequencies for the four pumped storage units range from 49.65 Hz to 49.2 Hz. In general operation, the pump with the highest frequency setting is the first to be loaded & last to be unloaded and so on. Typically 2 to 3 turbines would be pumping overnight.

2.3.5 Automatic Under-Frequency Load Shedding (AUFLS)

Automatic Under frequency load shedding:

- As highlighted above, STAR customers (who are paid in return for providing static reserve) are automatically interrupted at 49.3 Hz. This corresponds to approximately 1% of system load, the interruption of which is considered 'normal' for single generation contingencies.
- Under 'abnormal' conditions, such as the coincident loss of multiple generating units, automatic shedding of regular tariff customers may occur. This load shedding is stepped and commences if the frequency falls to 48.85 Hz and continues down as far as 48.5 Hz. Up to 60% of system load may be disconnected in this manner.

Table 13: AUFLS Schedule for Ireland

U/F Setting	% of SYD
48.85	5.9%
48.80	6.4%
48.75	5.0%
48.70	7.4%
48.65	6.8%
48.60	5.6%
48.55	9.8%
48.50	10.3%
Total	57.1% of SYD

SYD SYstem Demand

Information in Table 13 obtained during visit to Ireland in April 2010.

2.4 Nordic Countries

Country	Nordel	Denmark East	Denmark West	Norway	Sweden	Finland	Iceland
Date of information	2008/9						
Peak load*	64310	2640	3670	21890	24900	13010	1700
Generation Capacity (MW)**	97199	12618		30789	34181	17036	2575
Type of Generation	Hydro 58%, nuclear 20%, CHP 19%, Wind 3%						
Highest voltage (kV)	750						
Deadband							
Reserves (MW)	600MW						
No of Areas	5						

* From Entsoe Winter Studies.

** From Nordel Annual Report 2009

2.4.1 HVDC

There are ten HVDC Links in the Nordel region, five of which are to other countries outside of the Nordic group.

From: Wikipedia

2.4.2 Interconnections

Interconnections with Netherlands, Germany, Poland, Russia and Estonia.

Note: Western Denmark also belongs to UCTE.



Figure 13: Interconnections of Nordel countries

Table 14: Table of interconnections for Nordel

Countries/Stations	Rated voltage kV	Transmission capacity MW		Total length of line km	Of which cable km
		From Nordel	To Nordel		
Denmark - Germany					
Kassø - Audorf	2 x 400~	1500	950	107	-
Kassø - Flensburg	220~	150	150	40	-
Ensted - Flensburg	220~	600	600	34	-
Ensted - Flensburg	150~			26	5
Bjæverskov - Rostock	400=			166	166
Finland - Russia					
		From Nordel	To Nordel		
Imatra - GES 10	110~	-	100	20	-
Yllikkälä - Viborg **	2 x 400~			2 x 67	-
Kymi - Viborg **	400~	-	1400	132	-
Nellimö - Kaitakoski	110~	-	60	50	-
Finland - Estonia					
		From Nordel	To Nordel		
Espoo - Harku	150=	350	350	105	105
Norway - Russia					
		From Nordel	To Nordel		
Kirkenes - Boris Gleb	154~	50	50	10	-
Norway - Netherlands					
		From Nordel	To Nordel		
	450=	700	700	580	580
Sweden - Germany					
		From Nordel	To Nordel		
Västra Kärrstorp - Herrenwyk	450=	600*	600*	269	257
Sweden - Poland					
		From Nordel	To Nordel		
Stärnö - Slupsk	450=	600	600	256	256

*The transmission capacity is currently limited to 460 MW from Nordel and 390 MW to Nordel due to limitation in the German network.

** Back to Back HVDC (+85 kV =) in Viborg and synchronous operation of NWPP power plant.

From: Nordel Annual Statistics 2008

2.4.3 Generation breakdown

Table 15: Breakdown of electricity generation

		Nordel	Denmark	Finland	Iceland	Norway	Sweden
Hydropower	%	58	0	23	75	98	47
Nuclear power	%	20	-	30	-	-	42
Other thermal power	%	19	80	47	0	1	10
Wind power	%	3	20	0	-	1	1
Geothermal power	%	-	-	-	25	-	-

From: Nordel Annual Statistics 2008

2.4.4 Under-Frequency

Table 16: Overview of Under-frequency actions for Nordel

50 Hz to 49.9 Hz		Normal state - Self-Regulation Frequency controlled normal operation reserve.	
Automatic Frequency controlled start-up of production		Frequency Disturbance Reserve -	
49.8 Hz	25 MW Gas Turbine – Western Denmark	49.9 Hz to 49.5 Hz	50% reserve in 5 s, 100% reserve in 30 s. load shedding, e.g. industrial, district heating and electric boiler consumption as frequency controlled disturbance reserve. Increase use of frequency controlled regulation of DC.
49.7 Hz	520 MW Gas Turbine in 3 Stages (for Sweden), 180 MW Gas Turbine in 15 s (Finland)		
49.6 Hz 49.5 Hz			
49.5 Hz to 47.0 Hz		Automatic load-shedding	

From: Appendix 2 of System Operation Agreement 5 (8) 2008-06-13

In Denmark East, the Swedish link is disconnected when the frequency < 47.0 Hz for 0.5 s or <47.5 for 9 s.

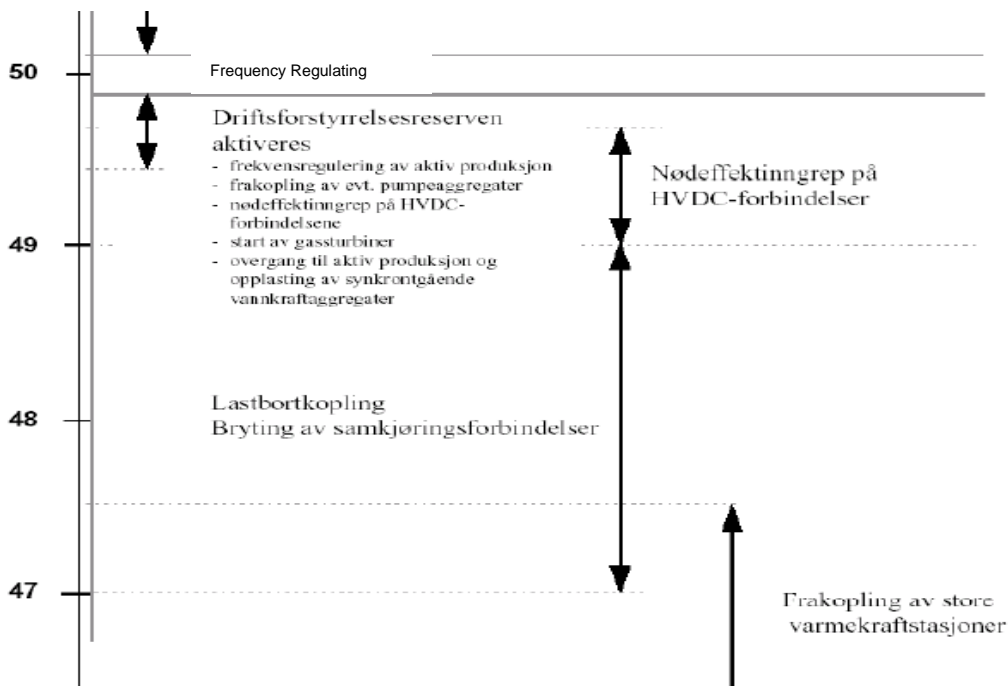


Figure 1

Figure 14: Nordel frequency response

From: Ole Gjerde [mailto:ole.gjerde@statnett.no], Appendix 5 of System Operation Agreement 1 (14) 2008-08-27
<http://www.nordel.org/content/default.asp?pagenam=openfile&DocID=6009>

2.4.5 Biggest Risk

Unknown.
 Nordic countries have a winter peak.

2.4.6 Reserves

Table 17: Reserves for the Nordel region

Countries	Frequency controlled normal operation reserve (MW)	Frequency controlled disturbance (MW)	Fast Active disturbance reserve (MW)
Eastern Denmark	23	78	600 (300 MW of which is slow active disturbance reserve)
Western Denmark		75	680
Finland	143	251	1000
Norway	202	348	1200
Sweden	231	394	1200
Synchronous System	600	1160	4680

From: System Operational Agreement 1(13) 2009

Automatic active reserve:

∅ Frequency Normal Reserve:

- Normal reserve at least 600MW – Each subsystem must have 2/3 of operational reserve in own system. This will be activated between 50 Hz to 49.9 Hz.

∅ Frequency Disturbance Reserve:

- In the event of a frequency drop between 49.9 to 49.5 Hz:
 - w 50 % of the frequency controlled disturbance reserve in each subsystem shall be regulated upwards within 5 seconds.
 - w 100 % of the frequency controlled disturbance reserve shall be regulated upwards within 30 seconds.
 - w This is activated automatically.
 - w Load shedding can be used as frequency controlled disturbance reserve provided it meets the same technical requirements as for generators.

Manual active reserve:

∅ Fast active forecast reserve

- Restores the Normal Operation Reserve, activation with in 10 – 15 minutes.

∅ Fast active disturbance reserve

- Restores Disturbance Reserves and must be available in 15 minutes. It consists of gas turbines, thermal power, hydropower and load-shedding

∅ Slow active disturbance reserve must be available after 15 minutes (long term).

From: Appendix 1 & 2 of System Operation Agreement 5 (8) 2008-06-13

2.4.7 Automatic Under-Frequency Load Shedding (AUFLS)

Table 18: AUFLS Schedule for Nordel Region

Denmark	East	10 % of consump. f<48.5 Hz momentary, f<48.7 Hz 20 sec. 10 % of consump. f<48.3 Hz momentary, f<48.5 Hz 20 sec. 10 % of consump. f<48.1 Hz momentary, f<48.3 Hz 20 sec. 10 % of consump. f<47.9 Hz momentary, f<48.1 Hz 20 sec. 10 % of consump. f<47.7 Hz momentary, f<47.9 Hz 20 sec.	Total: 50%
	West	15 % of consump. f<48.7 25 % of consump. f<47.7	
Norway		7,000 MW* in stages from 49.0 Hz to 47.0 Hz	Total: 32%
Sweden	South of constraint 2	electrical boilers and heat pumps P ≥ 35 MW. f< 49.4 for 0.15 sec 35>P ≥ 25 MW. f< 49.3 for 0.15 sec 25>P ≥ 15 MW. f< 49.2 for 0.15 sec	
		15>P ≥ 5 MW. f< 49.1 for 0.15 sec 30 % of consump in 5 stages stage 1. f< 48.8 for 0.15 sec stage 2. f< 48.6 for 0.15 sec stage 3. f< 48.4 for 0.15 sec stage 4. f< 48.2 for 0.15 sec. f<48.6 for 15 sec stage 5. f< 48.0 for 0.15 sec. f>48.4 for 20 sec	Total: 30%
Finland		10 % of consump. f<48.5 Hz 0.15 sec. f<48.7 Hz 20 sec 10 % of consump. f<48.3 Hz 0.15 sec. f<48.5 Hz 20 sec	Total: 20%

From: Nordel, Appendix 5 of System Operation Agreement 3 (14), 2008-08-27

2.4.8 N-1 security

The Nordel region uses N-1 security for outages.

N-1 security is defined as: A power system that can withstand the loss of an individual principal component (production unit, line, transformer, bus bar, consumption etc.) complies with N-1 criteria.

Correspondingly, N-2 entails two individual principal components being lost.

3 Africa

3.1 South Africa

Date of information	2009
Peak load	38000-39000
Generation Capacity (MW) *	39176
Type of Generation *	Coal 86%, gas 4%, nuclear 5%, hydro 5%
Highest voltage (kV)	765
Deadband	<15mHz
Reserves (MW)	1000
No of Areas	1

From: Eskom web site www.eskom.co.za

3.1.1 HVDC

South Africa has one HVDC line from Cahora Bassa in Mozambique to Apollo in South Africa, bipolar (2 x monopoles 1 km apart), ±533 kV and a capability of 1920 MW.

From: Wikipedia

3.1.2 Interconnections

South Africa is part of the Southern African Power Pool and is interconnected directly and indirectly with countries in Southern Africa as indicated on the map below.



Figure 15: Map of Southern African Power Pool
 Table 19: Table of Interconnection and South Africa 2007/2008

Country	Utility	Installed Capacity MW	Net Capacity MW	Maximum Demand MW	Generation Sent Out GWh	Net Imports GWh	Net Exports GWh
Angola	ENE	1155	870	535	3,293	21	0
Botswana	BPC	132	120	493	657	2,572	0
DRC	SNEL	2,442	1,170	1050	7,581	78	1,014.00
Lesotho	LEC	72	70	109	486	49	7.4
Malawi	ESCOM	302	246	240	1,447	-	0
Mozambique	EDM	248.5	174	365	222	1,352	309
Namibia	NamPower	393	360	449	1,576	2,045	0
South Africa	ESKOM	43,061**	38,384	36,513	239,108	10,998	11,368
Swaziland	SEB	51	50	196	125.8	993	0
Tanzania	TANESCO	1186	680	653	4141	57	0
Zambia	ZESCO	1,737	1,630	1,468	9,677	-	199
Zimbabwe	ZESA	2,045	1,825	1,758	7,781	2,367	30
TOTAL SAPP		52824.5	45579	43829			
Total Interconnected SAPP		52327	44698	42429			

From: Southern African Power Pool STATISTICS 2007
 ** Includes mothballed power stations

3.1.3 Biggest Risk

The biggest risk to the power system is approximately 900 MW as the largest generating unit or DC link. Most of the power stations are situated in the North of the country, this requires long transmission lines. South Africa has a winter peak.



Figure 16: Map of generating stations in South Africa
 From: Overview of Electricity Demand and Supply Situation – 29 November 2004

3.1.4 Under-Frequency

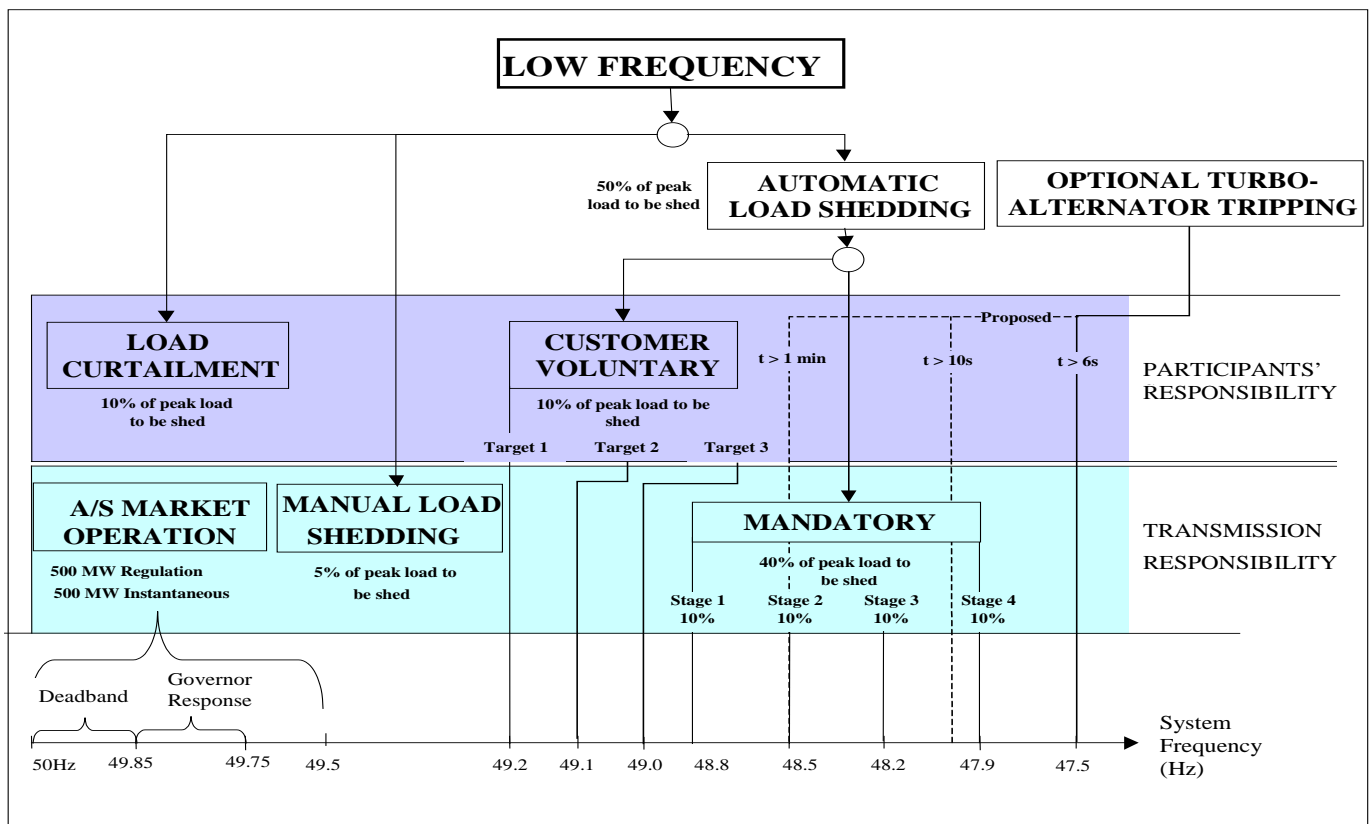


Figure 17: Graph of under-frequency actions in South Africa
From: John Campbell's Questionnaire –Eskom

3.1.5 Reserves

South Africa has a reserve margin of 10% - 12%.

Table 20: Reserves in South Africa

Frequency	Reserves		
50 to 49.85 Hz	Deadband	Load curtailment: 10% peak load	500 MW Regulation reserves 500 MW Instantaneous reserves
49.85 to 49.75 Hz	Governor Response		
49.75 to 49.5 Hz			
49.5 to 49.2 Hz	Manual load shedding: 5% of peak load		

3.1.6 Automatic Under-Frequency Load Shedding (AUFLS)

Total Automatic Load Shedding is 50% of peak load.

Table 21: AULFS program in South Africa

Frequency	AULFS
49.2 Hz	Customer voluntary Load (automatic) 10% of peak load in 3 stages.
49.1 Hz	
49.0 Hz	
48.8 Hz	Mandatory – total 40% 10%
48.5 Hz	10%
48.2 Hz	10%
47.9 Hz	10%
47.5 Hz	Optional Turbo-Alternator Tripping

From: John Campbell's Questionnaire – Eskom

3.2 Libya

Date of information	2007
Peak load	4420
Generation Capacity (MW)	6284
Type of Generation	Oil (59%), gas (41%)
Highest voltage (kV)	400
Deadband	
No of Areas	7

* General Electricity Company of Libya Statistic figures 2007, www.gecol.ly

** International Energy agency, Libya statistics 2006

3.2.1 HVDC

None

3.2.2 Interconnections

Libya has interconnections with Egypt of 120MW as well as with Tunisia (150 MW). There is also a West-East transfer of 63 MW.

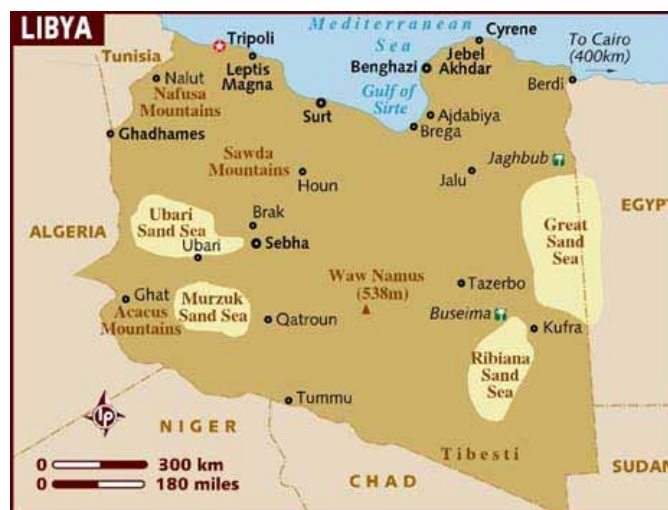


Figure 18: Map of Libya

3.2.3 Biggest Risk

Libya has a population of 6 million people.

The North has heavy loads and most of the generation. The South has light loads located far from any generation.

Egyptian interconnection with peak load of 120MW and 64 MW transfer from the West to the East. Busbar faults are considered in assessing security.

3.2.4 Under-Frequency

Libya splits in to 6 islands if the frequency drops below the last the automatic load shedding frequency.

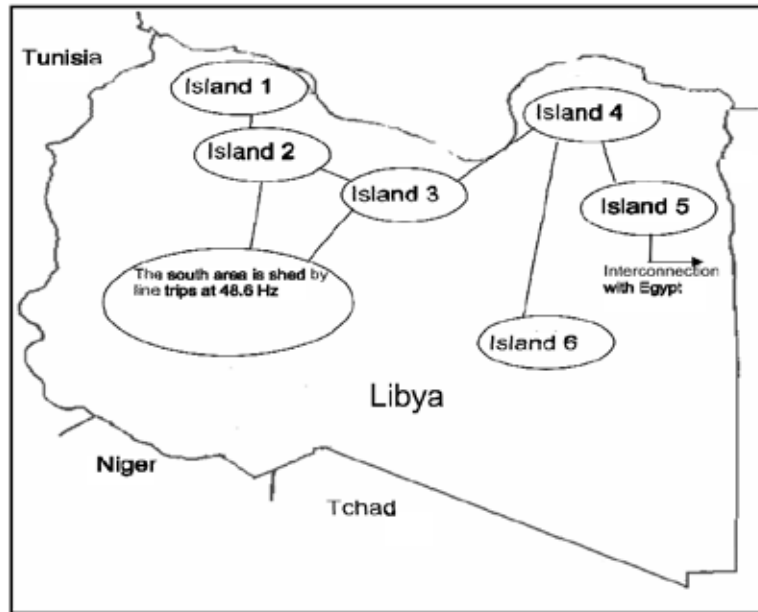


Figure 19: Libya's islanding scheme for under-frequency

3.2.5 Reserves

Unknown

3.2.6 Automatic Under-Frequency Load Shedding (AUFLS)

Table 22: AUFLS schedule in Libya

AREA	LOAD SHEDDING FOR EACH THRESHOLD					Total
	49.4 Hz	49.2 Hz	49.0 Hz	48.8 Hz	48.6 Hz	
Area 1	3.30%	3.3%	0.00%	0.4%	0.0%	6.9%
Area 2	2.4%	1.8%	4.7%	3.9%	1.3%	14.1%
Area 3	1.60%	1.20%	1.2%	2.30%	1.9%	8.2%
Area 4	0.4%	0.0%	2.8%	1.7%	6.60%	11.6%
Area 5	2.9%	1.5%	2.4%	0.5%	2.1%	9.4%
Area 6	0.00%	0.9%	0.00%	1.6%	1.30%	3.8%
Area 7	0.00%	0.00%	0.00%	0.20%	0%	0.20%
Total	10.6%	8.7	11.1%	10.7%	13.2%	54.3%

From: Design of an optimised defence plan for a power system, C2-209, Cigre 2008

4 60Hz Systems

4.1 Brazil

Date of information	2007
Peak load	Consumption: 410 TWh *
Generation Capacity (MW)	96294
Type of Generation	Hydro (76%), nuclear (2%), thermal (22%)
Highest voltage (kV)	765
Deadband	
No of Areas	4 main regions

* Electricity_sector_in_Brazil -Wikipedia

Table 23: Generation capacity of Brazil

Source	Number of plants	Installed capacity (MW)	% Total
Hydroelectricity	633	73,678	72.1%
Gas	101	10,798	10.6%
Oil	568	4,446	4.4%
Biomass	269	3,693	3.6%
Nuclear	2	2,007	2%
Coal	7	1,415	1.4%
Wind	15	237	0.2%
Total installed capacity	1,595	96,294	94.3%
Contracted imports		5,850	5.7%
Available power		102,144	100

From: Ministry of Energy and Mines, 2007

4.1.1 HVDC

Itaipu Power station in Paraguay has two bipolar lines at ±600 kV with total rated power of 6300 MW from 50 Hz system to the Brazilian system of 60Hz.

4.1.2 Interconnections



Figure 20: Map of Brazil

From: www.wordtravels.com/images/map

Power is exported/imported to and from Argentina and Uruguay. Brazil also obtains power (12000 MW) from Itaipu Power station in Paraguay via HVDC lines and a 765 kV line.

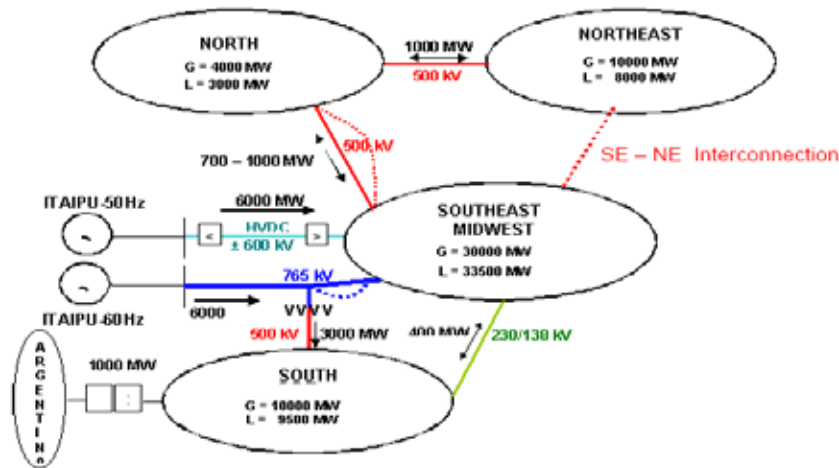


Figure 21: Interconnection with in Brazil

From: Harmonization of Frequency requirements considering the new competitive environment in the Brazilian power system, By Paulo Gomes & Sergio Luiz de A. Sardinha, 39-208 Cigre Session 2002.

4.1.3 Biggest Risk

Brazil has large hydroelectric plants located far from load centres, long transmission lines and large hydro powered generators (700 MW). Large transfers of energy occur back and forth depending on hydrological conditions.

The biggest risk is the loss of Itaipu Plant (the DC link of 6000 MW and the 765 kV transmission line of 6000 MW).

4.1.4 Reserves

Unknown

4.1.5 Automatic Under-Frequency Load Shedding (AUFLS)

The Brazilian load shedding scheme takes into consideration of automatic disconnection of capacitor banks, manual opening of multiple circuits and special protection systems to control voltage profiles.

Table 24: AUFLS Schedule in Brazil

Stage	Southeast / MW		South		North / Northeast		Load Rejected (%)
	Set (Hz)	Load Rejected (%)	Set (Hz)	Load Rejected (%)	Set (Hz)	Set (Hz/s)	
1 st	58,5	7	58,5	7,5	57,8	0,7	6
2 nd	58,2	7	58,2	7,5	57,1	1,1	7
3 rd	57,9	7	57,9	10	56,5	1,6	11
4 th	57,7	7	57,6	15	55,5	2,2	8
5 th	57,5	7	57,3	15	55,2	3,2	8
Total		35%		55%			40%

From: Harmonization of Frequency requirements considering the new competitive environment in the Brazilian power system, By Paulo Gomes & Sergio Luiz de A. Sardinha, 39-208 Cigre Session 2002.

4.2 Guam

Date of information	2009
Peak load	281.5
Generation Capacity (MW)	552.2
Type of Generation	Thermal
Highest voltage (kV)	115 kV
Deadband	
No of Areas	1

From: The Guam Power Authority - www.guampowerauthority.com

4.2.1 HVDC

None

4.2.2 Interconnections

Guam has no interconnections with other countries.



Figure 22: Map of Guam
From: www.picresorts.com/en/Guam

4.2.3 Biggest Risk

Unknown

4.2.4 Reserves

Unknown

4.2.5 Automatic Under-Frequency Load Shedding (AUFLS)

Table 25: Table of AUFLS in Guam

	Frequency	Load Shedding	Percentage Load
Stage 1	59.1 Hz	26.52 MW	9.4 %
Stage 2	58.81Hz	25.36 MW	9 %
Stage 3	58.5 Hz	25.15 MW	9%
Stage 4	58.3 Hz	26.69 MW	9.5%
Total			36.9 %

With a time delay of 0.1seconds (six cycles)

Figure 23: (a) Map of PJM area, (b) Map of interconnections between PJM with neighbouring States

4.3.3 Biggest Risk

Unknown

4.3.4 Under-Frequency

Table 27: Under-frequency response in PJM region

Frequency	Time delay			
	Mid-Atlantic Zone	PJM West Control Zone	ComEd Control Zone	South Zone
60 to 59.5 Hz		Unlimited	Automatic tripping not permitted	No standard requirements
59.5 to 59.2 Hz		30.0 minutes to trip	2700 seconds to trip	
59.2 to 58.5 Hz		7.0 minutes to trip	120 seconds to trip	
58.5 to 58.2 Hz			15 seconds to trip	
58.2 to 58.0Hz		Unit isolation without time delay can be expected		Generators start disconnecting
<58.0 Hz	>30 seconds generation and load on same bus sequestered		Owner's discretion	
57.5 Hz	>5 Seconds generators disconnect			

From: PJM manual 36 – System restoration rev 10, 30 June 2009

4.3.5 Reserves

PJM operations are required to conform to the NERC reliability standards. The North American Electric Reliability Corporation (NERC) is a self-regulatory organization, subject to oversight by the U.S. Federal Energy Regulatory Commission and governmental authorities in Canada.

Table 28: PJM Reserves

Regulating Reserve	Not less than 1% of forecast peak load
Contingency (Primary)	150% of Largest unit (1700 MW Mid-Atlantic)
Synchronised Reserve	100% of Largest unit but not less than 900 MW

4.3.6 Automatic Under-Frequency Load Shedding (AUFLS)

Table 29: AUFLS for PJM area

Frequency	Mid-Atlantic Zone	PJM West Control Zone	ComEd Control Zone	South Zone
60 to 59.75 Hz	Generators act independently to increase generation and restore frequency.			
59.75 to 59.5 Hz	Synchronous reserve and/or manual load shedding of 6% to increase frequency by 1 Hz.			
59.5 Hz		5%		
59.3 Hz	10%	5%	10%	10%
59.1 Hz		5%		
59.0 Hz			10%	10%
58.9 Hz	10%	5%		
58.7 Hz		5%	10%	
58.5 Hz	10%			10%
57.5 Hz		Generation disconnected		
Total	30%	25%	30%	30%

The unit Volts/Hz may not exceed 1.18 > 2 seconds and 1.10 for > 45 seconds cumulatively.
 From: PJM manual 36 – System restoration rev 10, 30 June 2009

Note: The Overshoot from UFLS may not exceed 61.0 Hz or 60.5 Hz for > 30 seconds.

Transmission shunt capacitor banks are removed from service until sufficient load (approximately 40% of system load) has been re-energized to prevent high voltage.

Summary

50 Hz

Primary Secondary Tertiary AUFLS



60 Hz

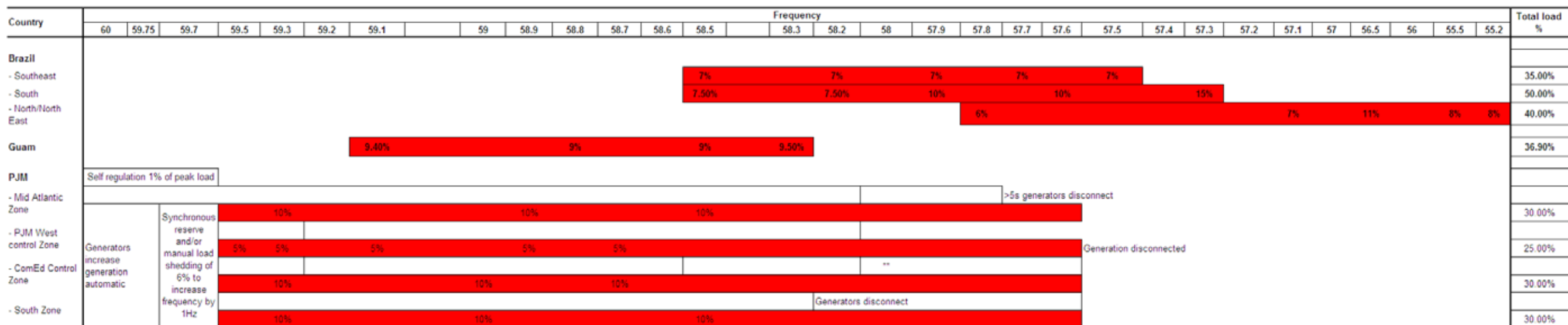


Figure 24: Summary of under-frequency response