Capacity Shortage Seminary
Gardermoen, 2005-04-26

Reserve Requirements and Security of Supply

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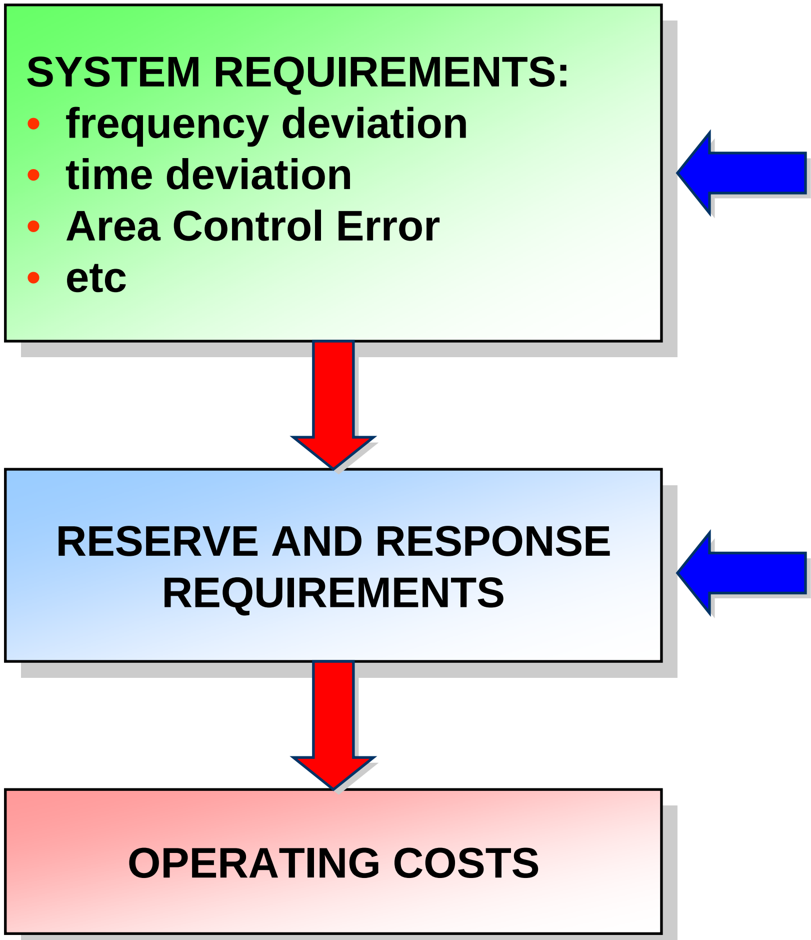
Relation between reserve requirements and reserve costs

- How can we reduce reserve costs without reducing security of supply?



1. Reduce system requirements
2. Reduce physical requirements
3. Cheaper and more efficient reserve provision

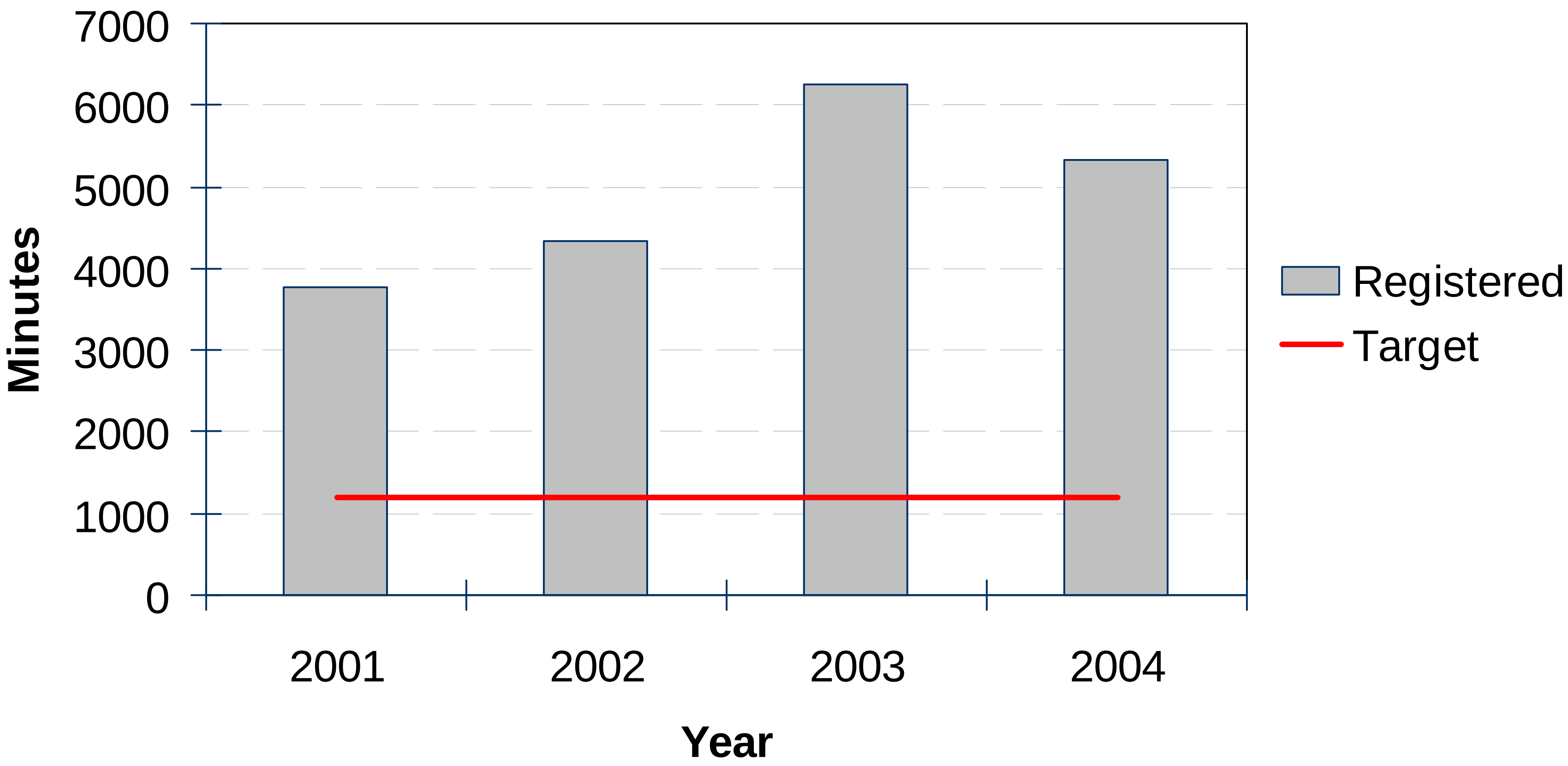
Nordel’s Recommendations

- Main structure developed in the 1970’s; very little formal documentation available
- Heuristics
  - Limits/values were chosen according to what was observed to yield satisfactory performance over time
- Test operation
  - A number of tests were made where the system was operated with increased/reduced frequency bias, frequency activated reserve etc
- Since then, the structure and limits of the recommendations have more or less been maintained without major changes
- *In a period of imminent capacity shortage, the reserve requirements must be evaluated carefully*

Approach 1: Reduce system requirements

- Frequency deviations are assumed to have the strongest impact on the following equipment:
  - Rotating machines – causing speed changes of motor drives
  - Equipment using power frequency as time reference
  - Harmonic filters – causing poorer tuning thus poorer power quality
  - Voltage measuring with reactive components and kWh-meters
- Frequency deviations of ±0.5 Hz will not cause problems for any equipment or component connected to the power system
  - Manufacturers of equipment and appliances give higher tolerances than standards and handbooks
- Time deviation requirement is now relaxed to ±30 seconds.
- Area Control Error (ACE) is now used only as a measurement of the instantaneous balance of each subsystem.

System operation outside +/- 0.1 Hz
(Minutes)



Source: Statnett tertiary reports

Approach 1: Reduce system requirements

	1. Reduce system requirements	2. Reduce physical requirements	3. Improve acquisition and perform.	Remarks
System requirements • Δf (Hz) • ΔT (s) • ACE (MW)	 + + +			 *-Already relaxed* *-Removed*
Physical requirements				
Reserve acquisition				

How to reduce reserve costs without reducing security of supply?

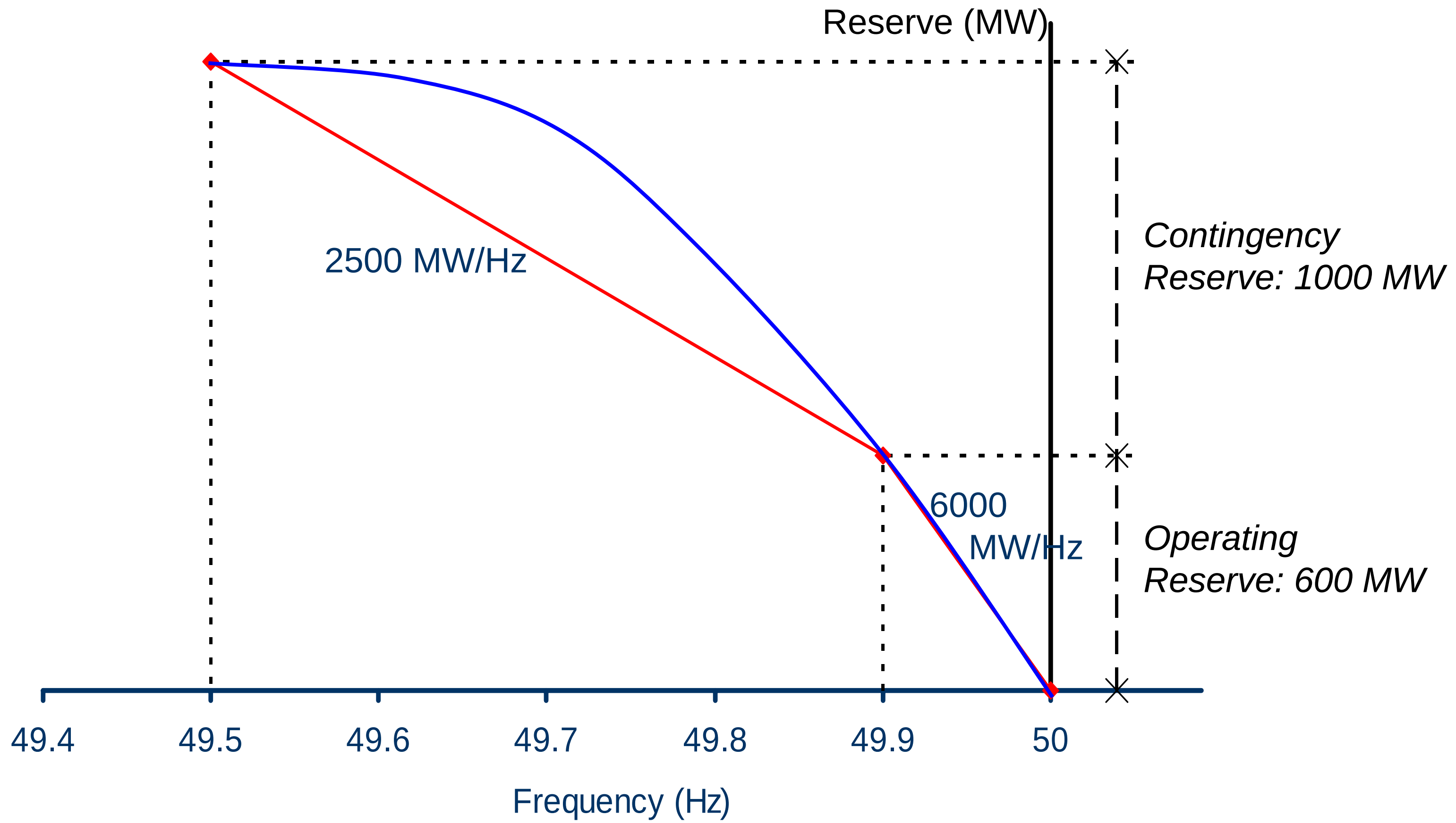
SYSTEM REQUIREMENTS:
- **frequency deviation**
- **time deviation**
- **Area Control Error**
- **etc**

RESERVE AND RESPONSE REQUIREMENTS

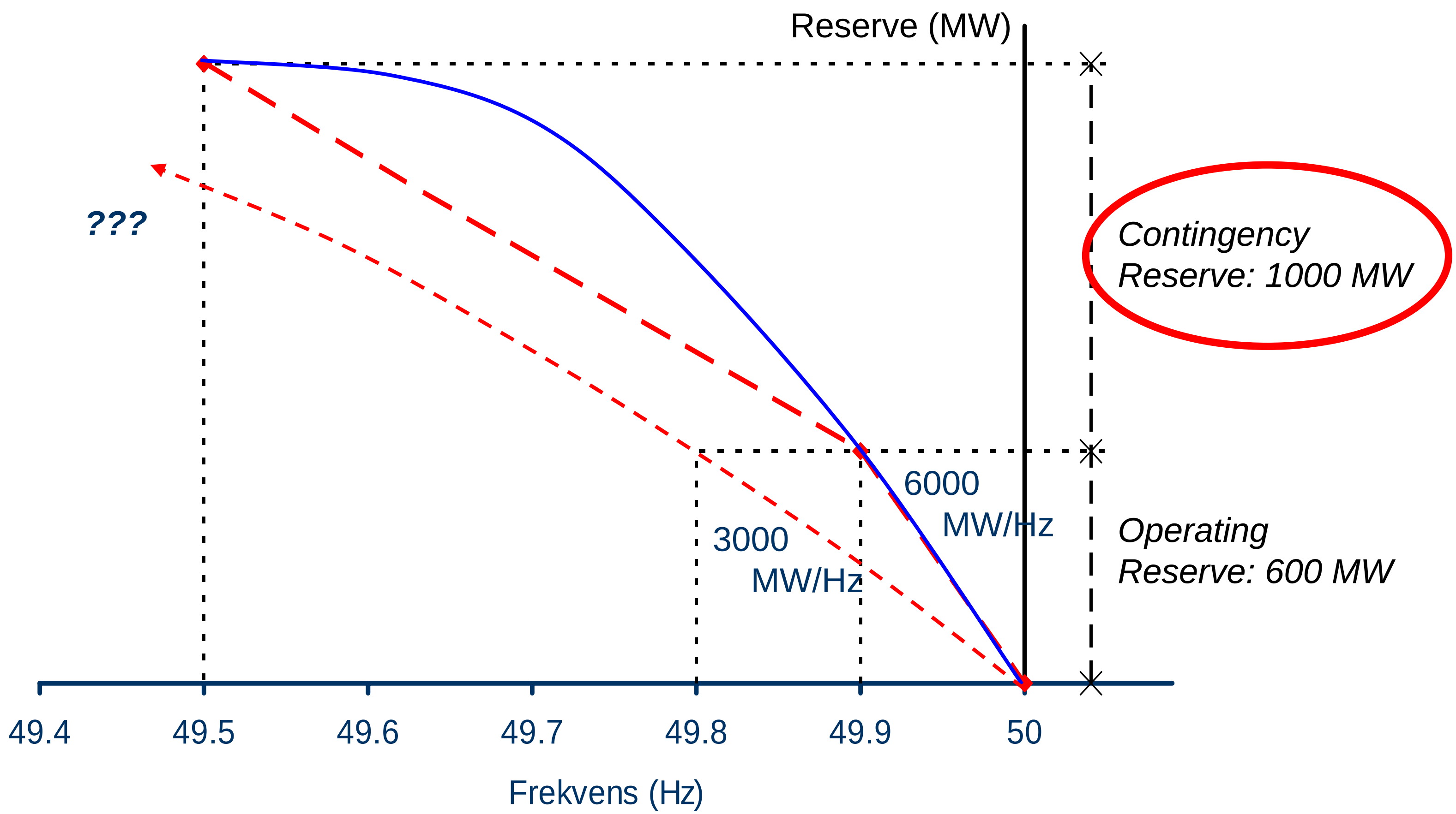
OPERATING COSTS

1. Reduce system requirements
2. **Reduce physical requirements**
3. Cheaper and more efficient reserve provision

Primary reserve requirement in Nordel

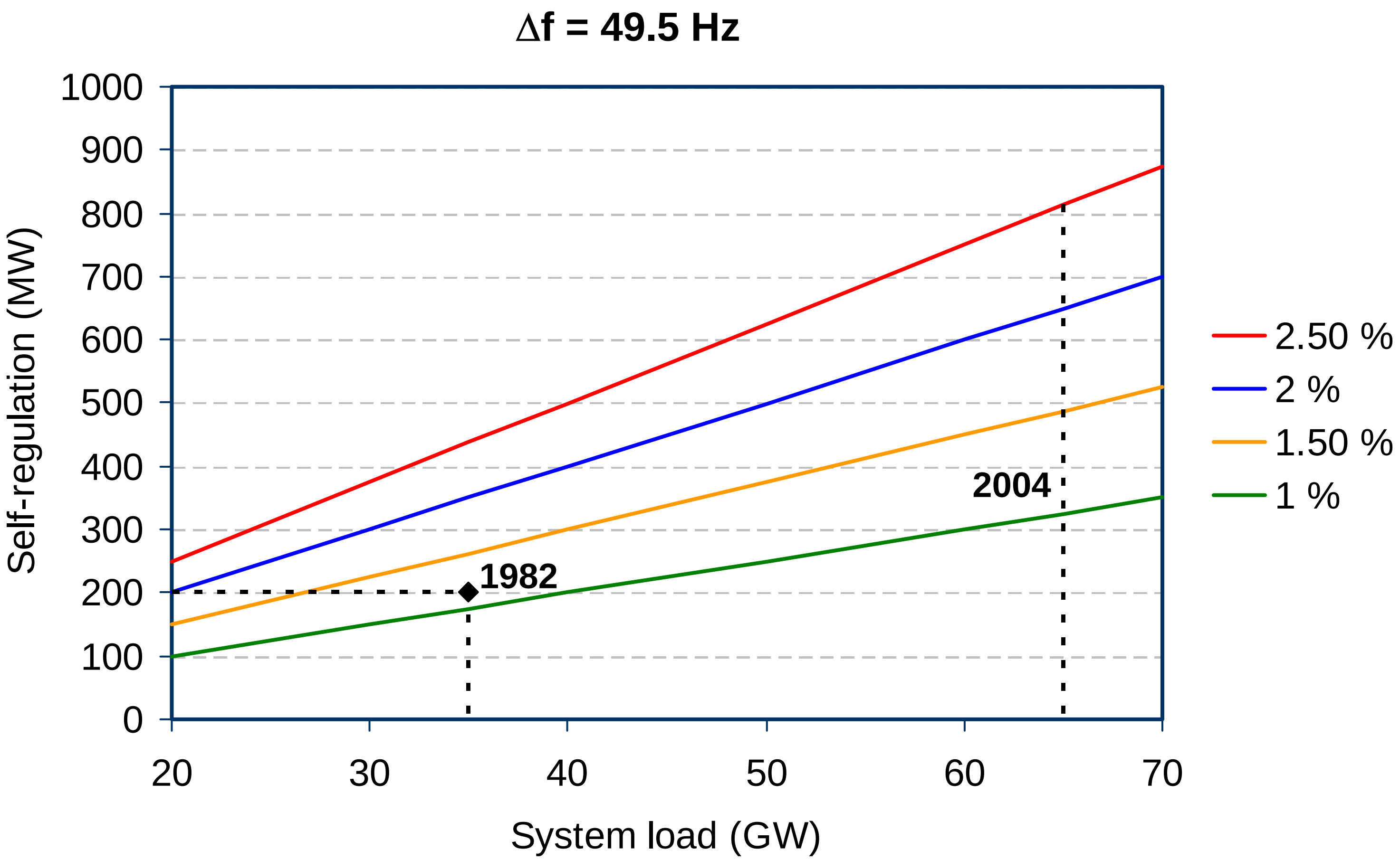


Primary reserve requirement in Nordel



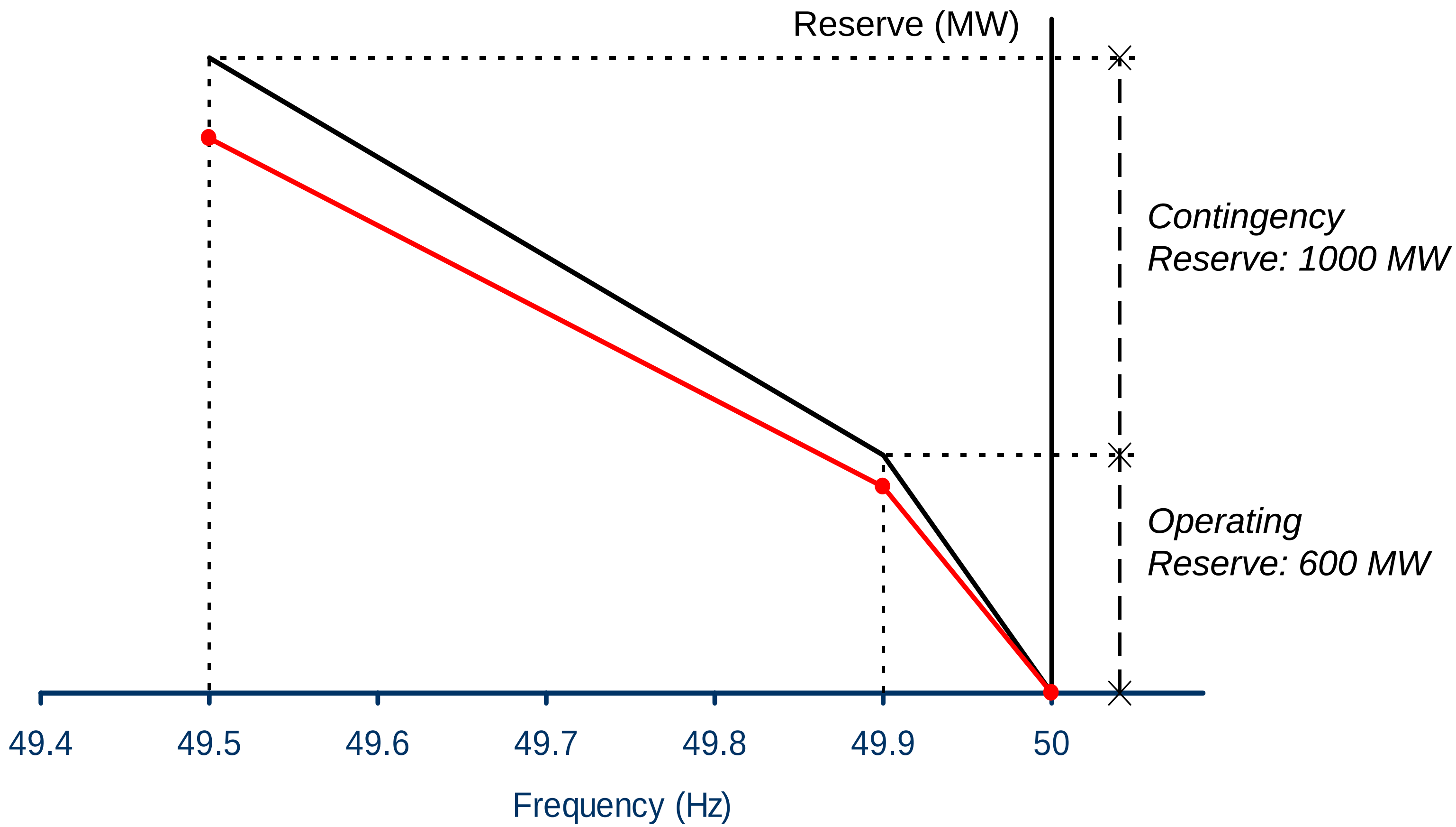
Self-regulation of load

(% / Hz)



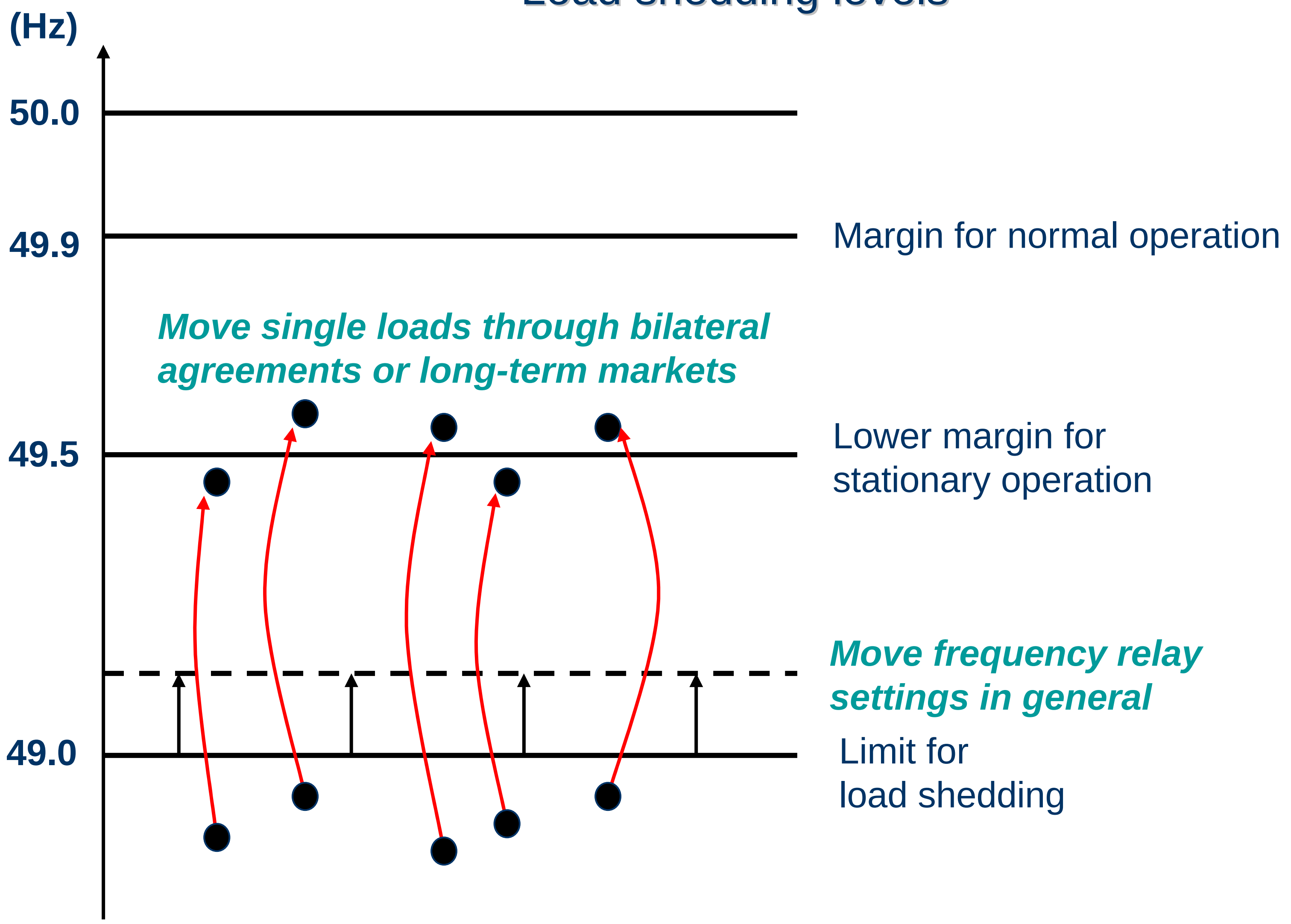
Primary reserve requirement in Nordel

1.25% / Hz self-regulation, P_L = 65 GW



Operational margins

Load shedding levels



Current active reserve requirements
2003

	Consumption 2003 (TWh)	FAOR (MW)	FACR (MW)	FCR (approx.) (MW)	Freq. Bias (MW/Hz)
East Denmark	14	24	90	600	240
West Denmark	-	-	75	620	
Finland	85	141	205	1 000	1 410
Norway	115	192	313	1 600	1 920
Sweden	145	243	303	1 200	2 430
TOTAL	**358**	**600**	**1 000**	**5 020**	**6 000**

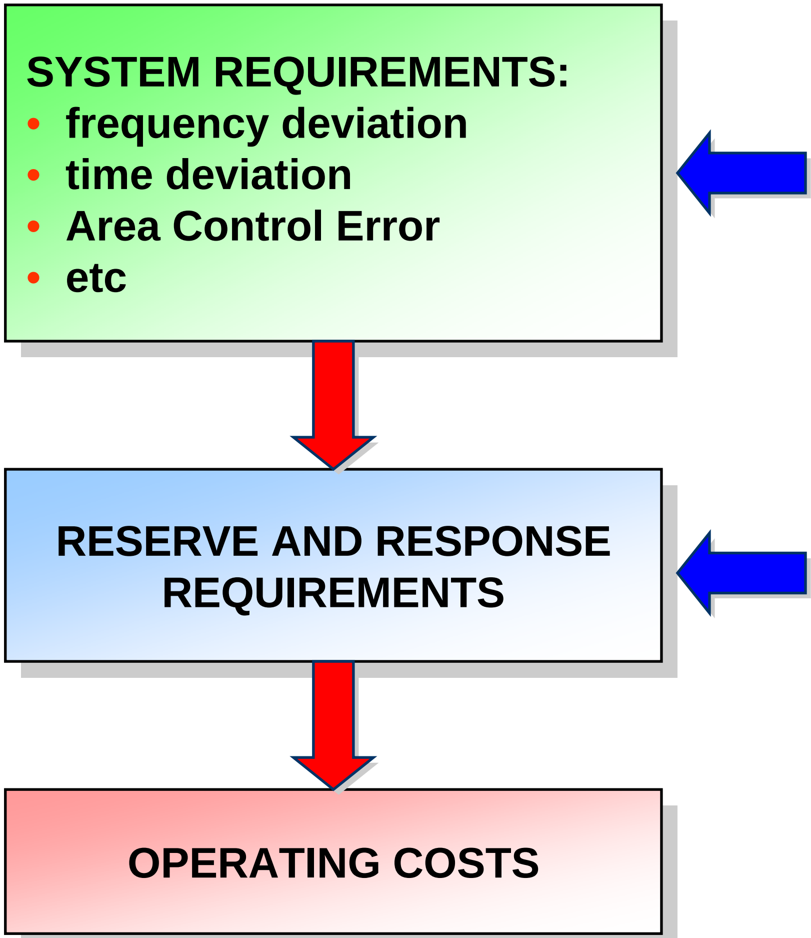
Approach 2: Reduce physical reserves

- It is not possible to reduce frequency bias without relaxing also the frequency deviation requirement
  - The frequency will have to decrease more to activate necessary reserves
- The same conclusion applies to Frequency Activated Operating Reserve (FAOR)
- It is possible to reduce the requirement for Frequency Activated Contingency Reserve (FACR) from generating units
  - update the value for self-regulation of loads
  - contracted load shedding more actively
- The amount of Fast Contingency Reserve (FCR) can be reduced by totally removing any requirement of national balance (ACE)
  - operate the system by frequency and congestion handling alone
  - mutual Nordic BM

Approach 2: Reduce physical reserves

	1. Reduce system requirements	2. Reduce physical requirements	3. Improve acquisition and perform.	Remarks
System requirements				
• Δf (Hz)	+	0		*-Must cover Dim. Fault*
• ΔT (s)	+	?		
• ACE (MW)	+	+		
Physical requirements				
• Bias (MW/Hz)	÷	÷		
• FAOR (MW)	÷	÷		*-Must cover Dim. Fault*
• FACR (MW)	0	+		*-Self-reg.+LdShedding*
• FCR (MW)	0	+		*-Nordic BM*
Reserve acquisition				

How to reduce reserve costs without reducing security of supply?



1. Reduce system requirements
2. Reduce physical requirements
3. **<u>Cheaper and more efficient reserve provision</u>**

Approach 3:
Improve reserve acquisition and performance

- The *Balancing Market* ensures an efficient acquisition of reserves on an hourly base, but does not in itself reduce the required *amount* of reserves
- The *ROM* seems to be an efficient way of ensuring reserves from *existing* capacity during peak load periods
- Too early and too small volume to give a conclusion about cost-effectiveness of long-term contracts of *Balancing Power from new capacity*
- Offer for *extra frequency bias* during low-load periods is similar to the BM design, but too early to give a conclusion about the cost-effectiveness of the "market"
- Through a combination of technology, market design and incentives consumption can contribute to nearly all reserve requirements

Possible contribution from consumption

Reserve category	Contribution from demand	Remarks / Market solution
FAOR / Freq. bias markets	÷	Generally not capable of continuous droop response
FACR (MW)	+	Tender/contracts for frequency activated load shedding
FCR (MW) / BM / ROM Long-term BM	+	Necessary technological and organizational arrangements to fulfill BM requirements must be in place for smaller consumers to participate
Energy Reserve / Disconnectable consumption	+	Might be used in a Slow Reserve Market together with non-spinning (thermal) units

How to reduce reserve costs without reducing security of supply?

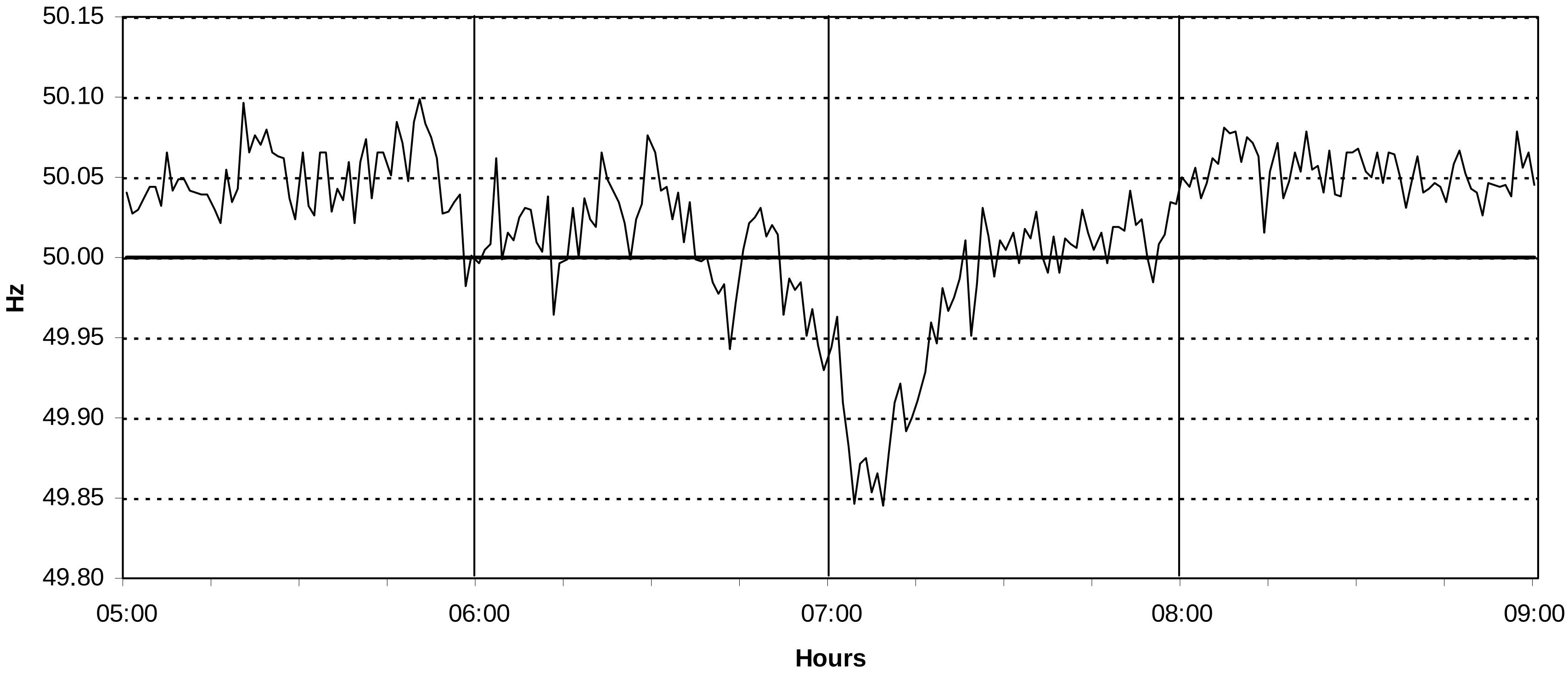
Summary

	1. Reduce system requirements	2. Reduce physical requirements	3. Improve acquisition and perform.	Remarks
System requirements				
• Δf (Hz)	+	0		*-Must cover Dim. Fault*
• ΔT (s)	+	?		*-Already relaxed*
• ACE (MW)	+	+		*-Removed*
Physical requirements				
• Bias (MW/Hz)	÷	÷		
• FAOR (MW)	÷	÷		*-Must cover Dim. Fault*
• FACR (MW)	0	+		*-Self-reg + Ld.shedding*
• FCR (MW)	0	+		-Nordic BM
Reserve acquisition				
• BM		0	+	
• ROM		+	+	
• Long-term BP		+	?	*-Ensures new capacity*
• Freq. bias markets		+	?	*-Ensures freq. bias*
• Demand reserves		+	+	

The Stepwise Powerflow algorithm (SPF)

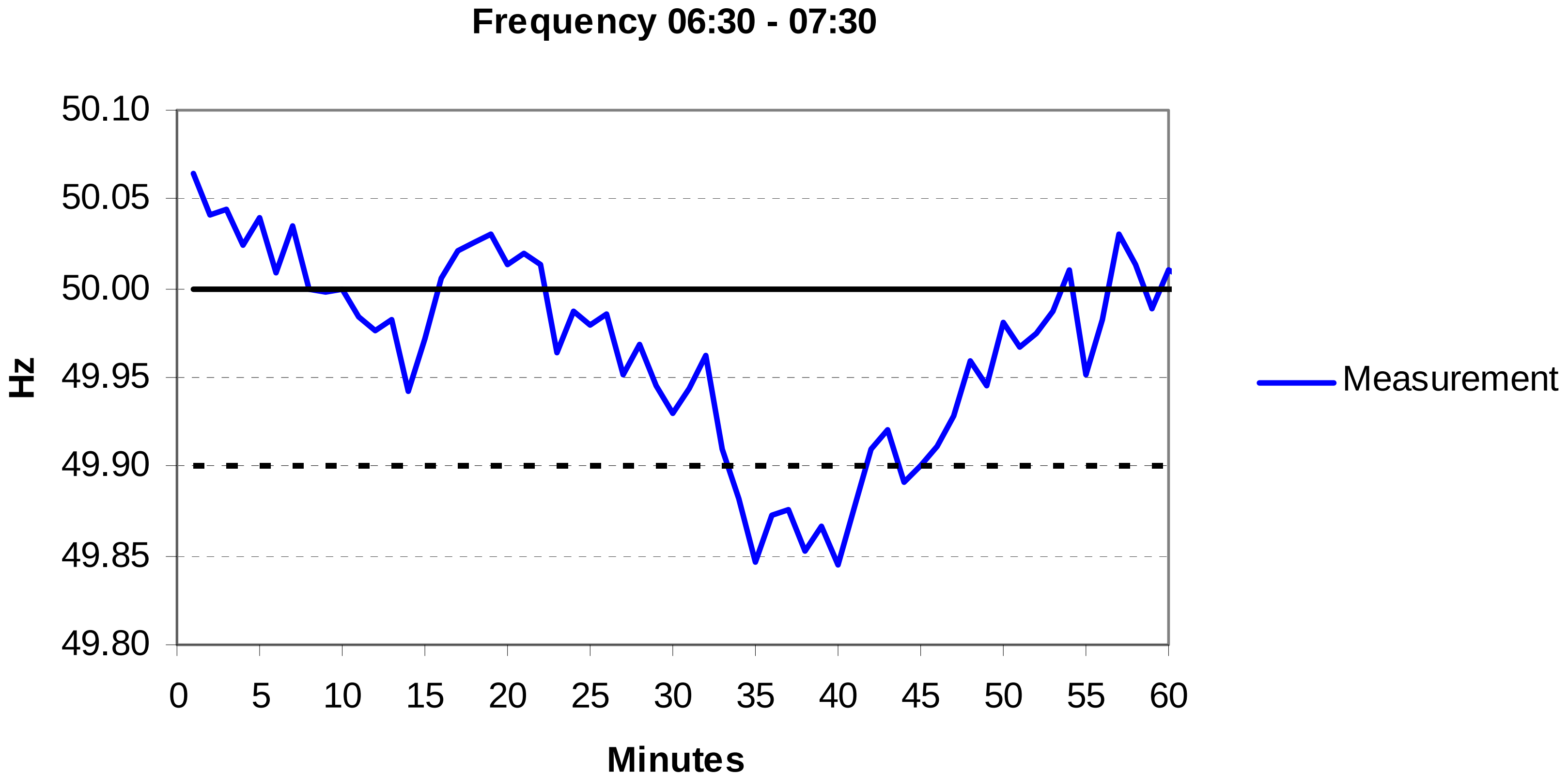
- Frequency and active power controls work over a time range from seconds (inertia, primary frequency control) to minutes (AGC, secondary control) and longer (load following, unit scheduling, tertiary control)
- Few standard computer tools are available to analyse slow power system dynamics in the minutes to hours range
- **Stepwise Power Flow (SPF)** is developed to analyse slow system dynamics with quasi-steady-state power flow calculations

Measured system frequency
13 October 2003, hours 06-09
(1 min. average)

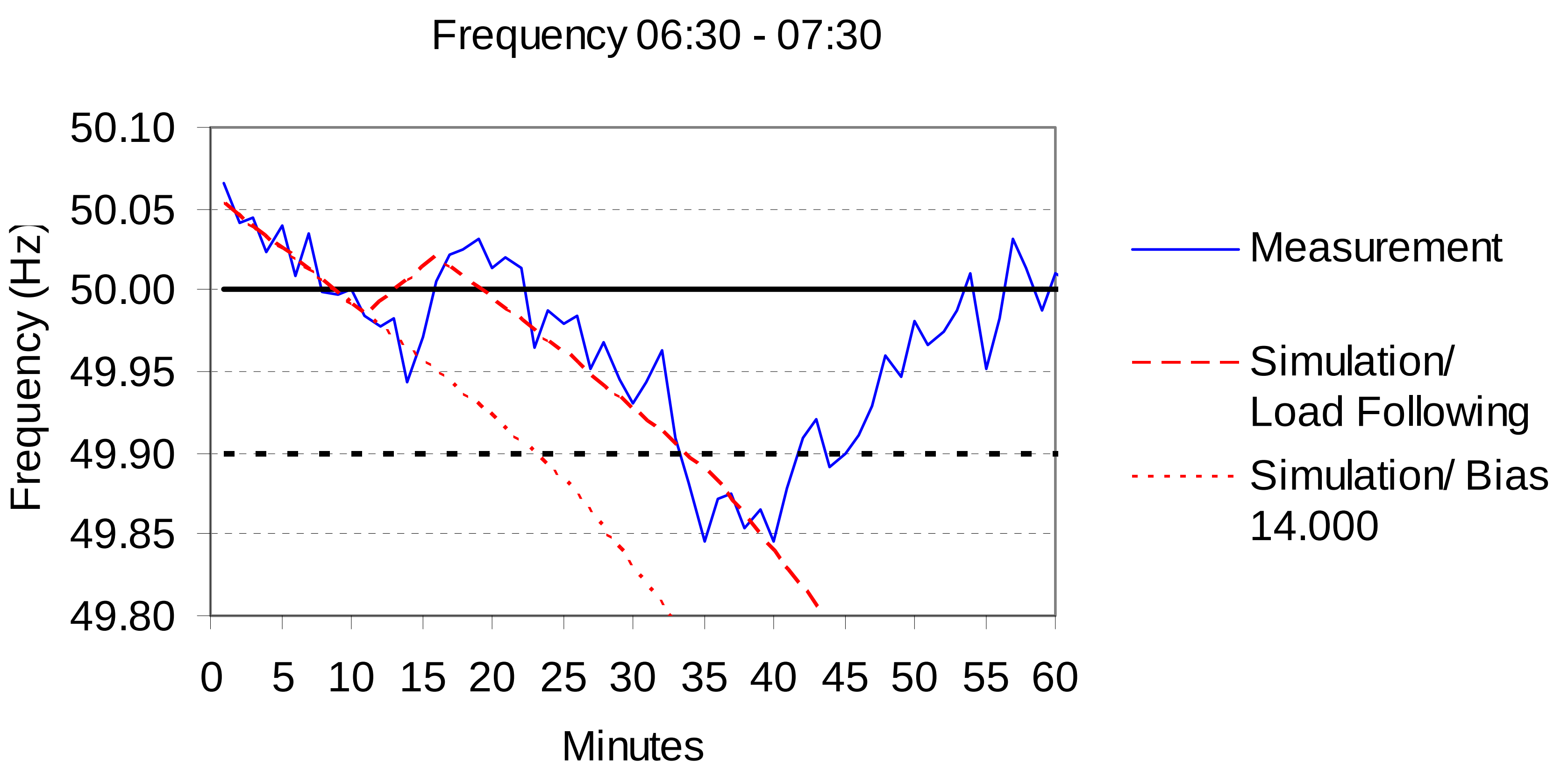


Comparison of measurement and full-scale SPF simulation

13 October 2003



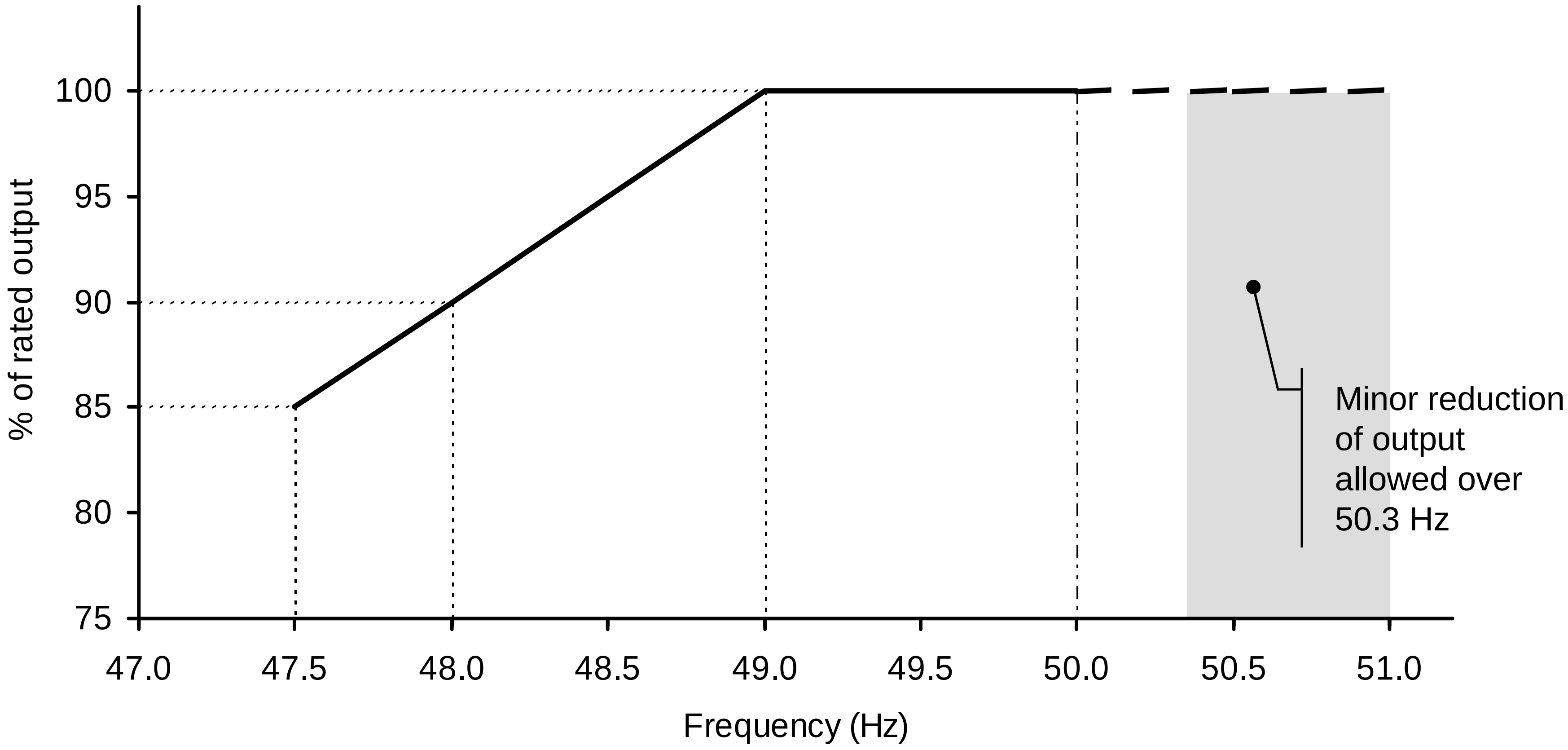
Comparison of measurement and full-scale SPF simulation



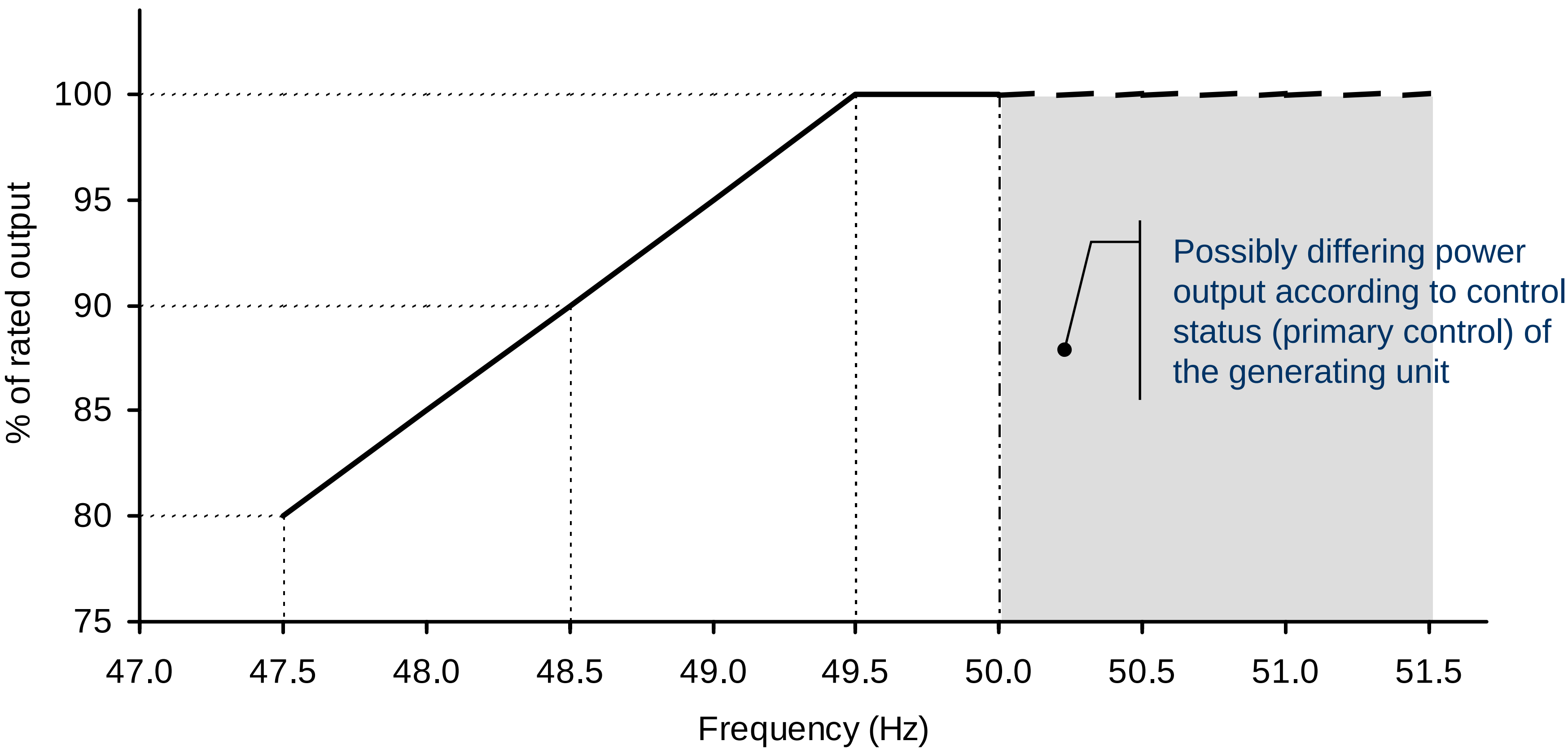
The Stepwise Powerflow algorithm (SPF)

- **Stepwise Power Flow (SPF)** is developed to analyse slow system dynamics with quasi-steady-state power flow calculations
- Prototype developed in Matlab based on an aggregated Nordel model with 18 generators
- Tested on a full-scale Nordel model
- The Matlab format is not feasible for regular use by the system operator
- The algorithm should be converted to PSS/E script for regular use
- The aggregated Matlab model is useful for more principal studies

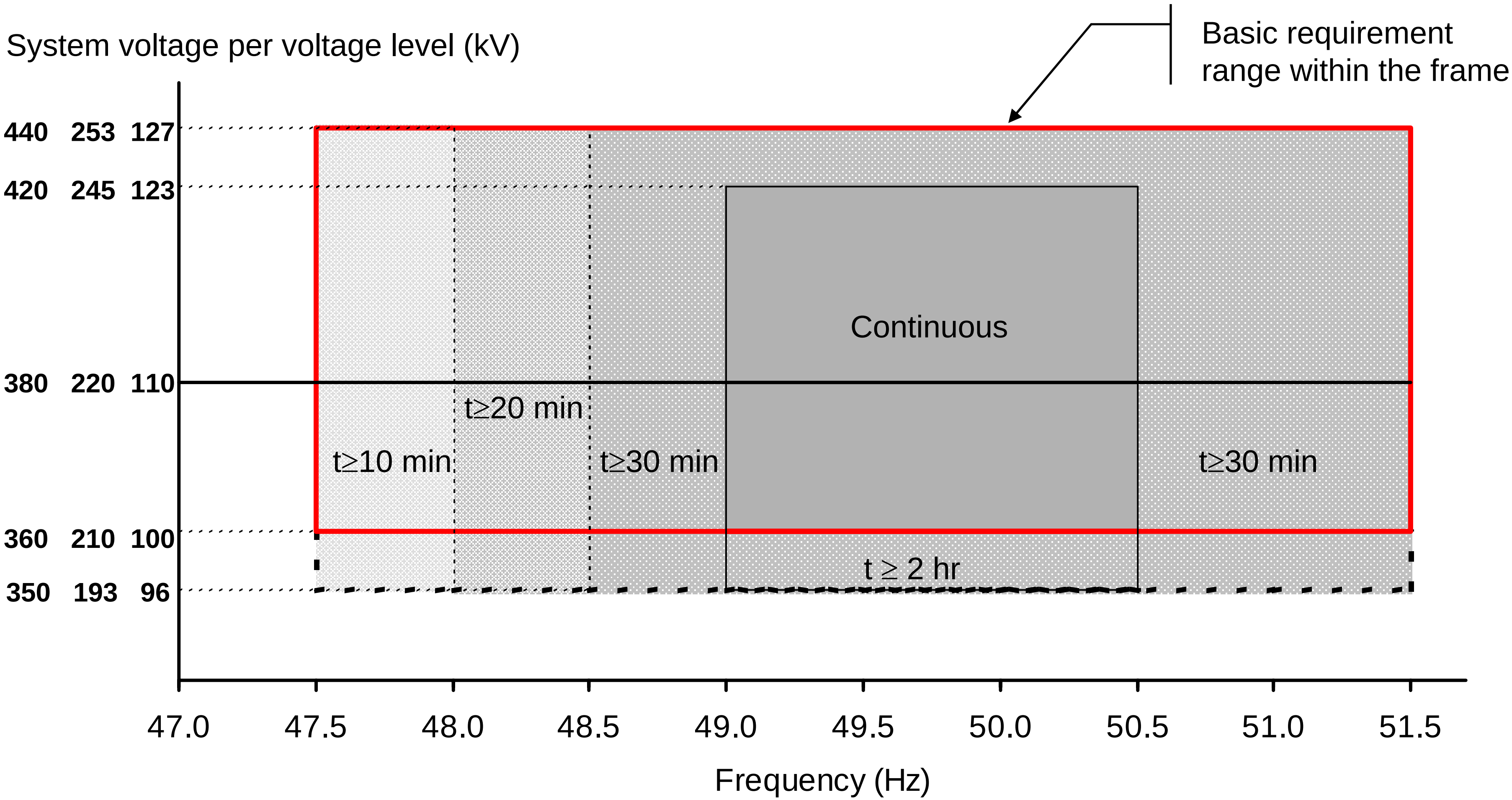
Nordel requirements for output from generating units



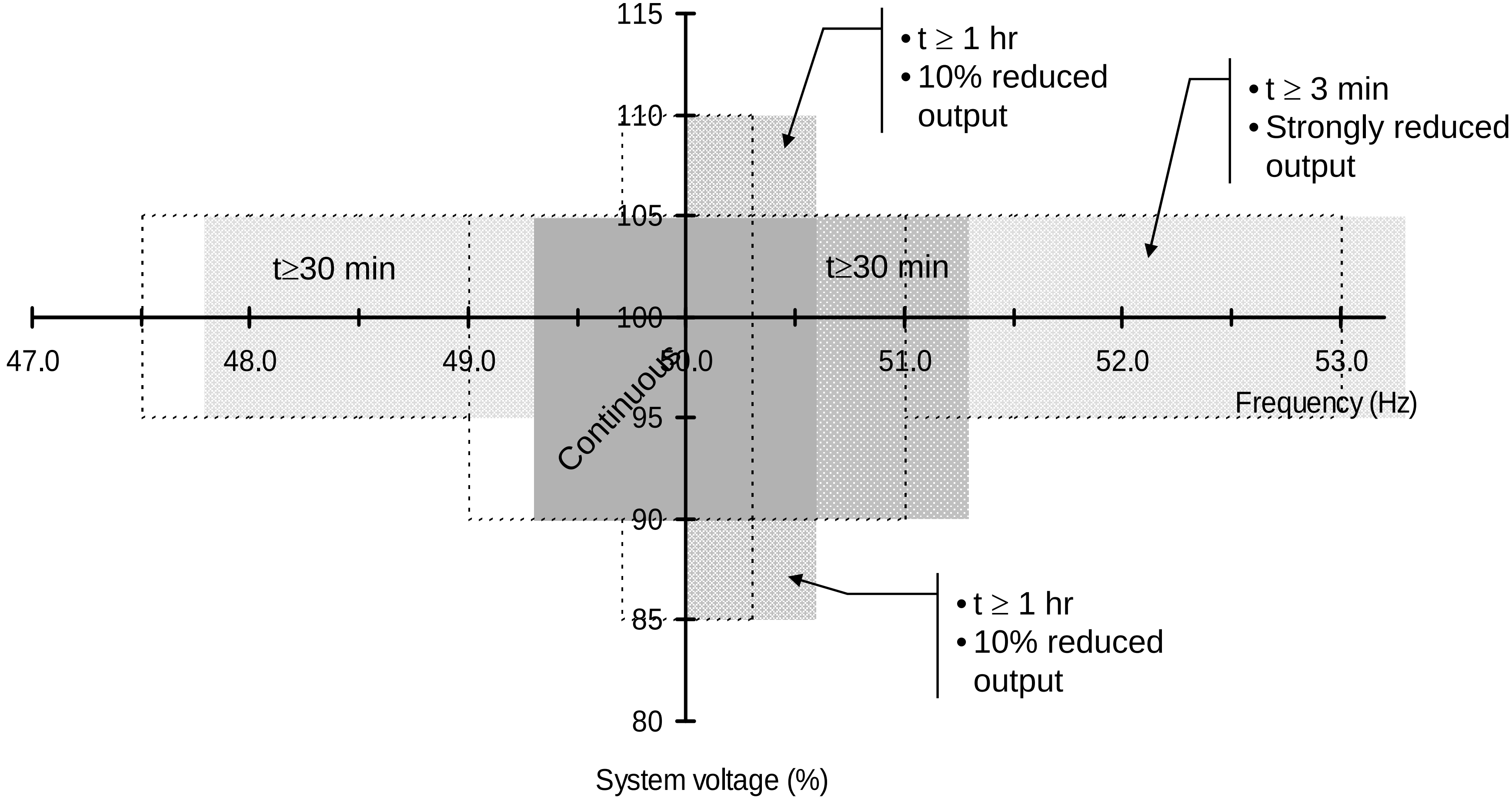
UCTE requirements for output from generating units



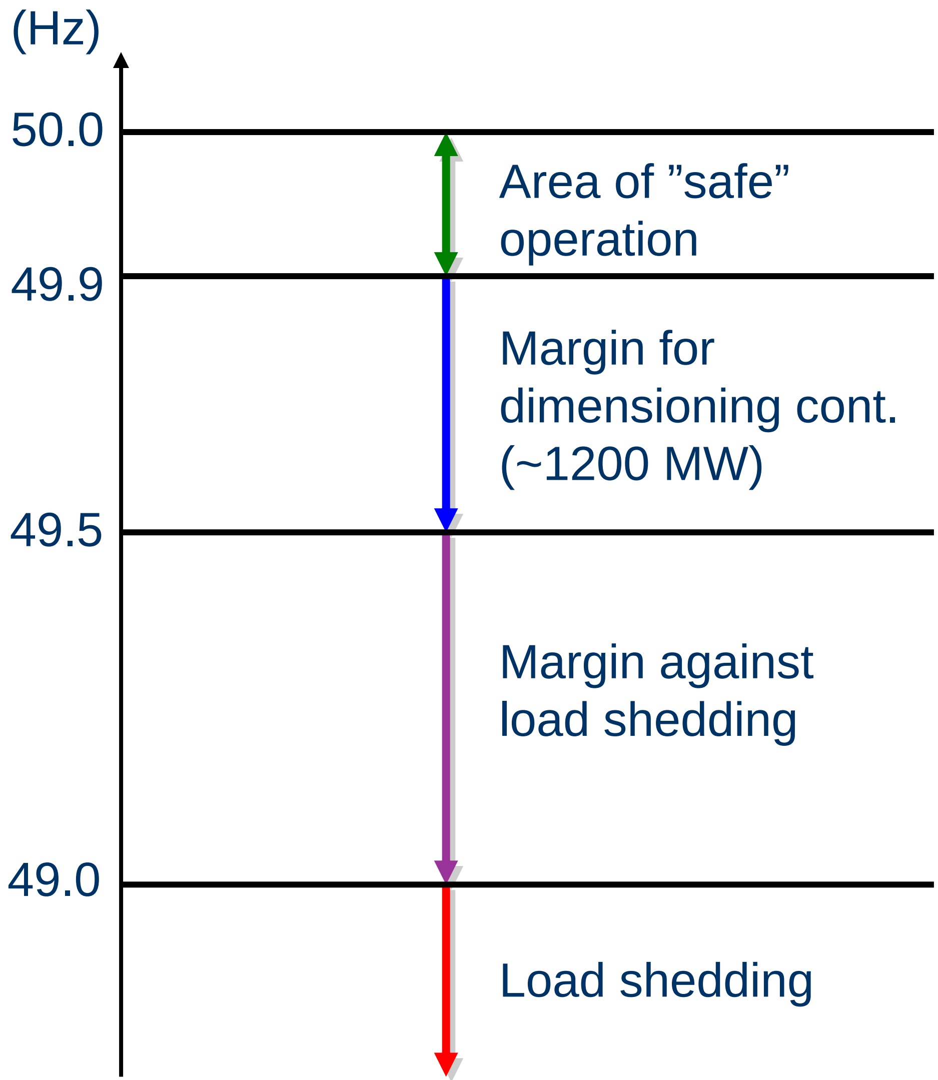
UCTE requirements for output from generating units



Nordel requirements for output from generating units



Operational margins

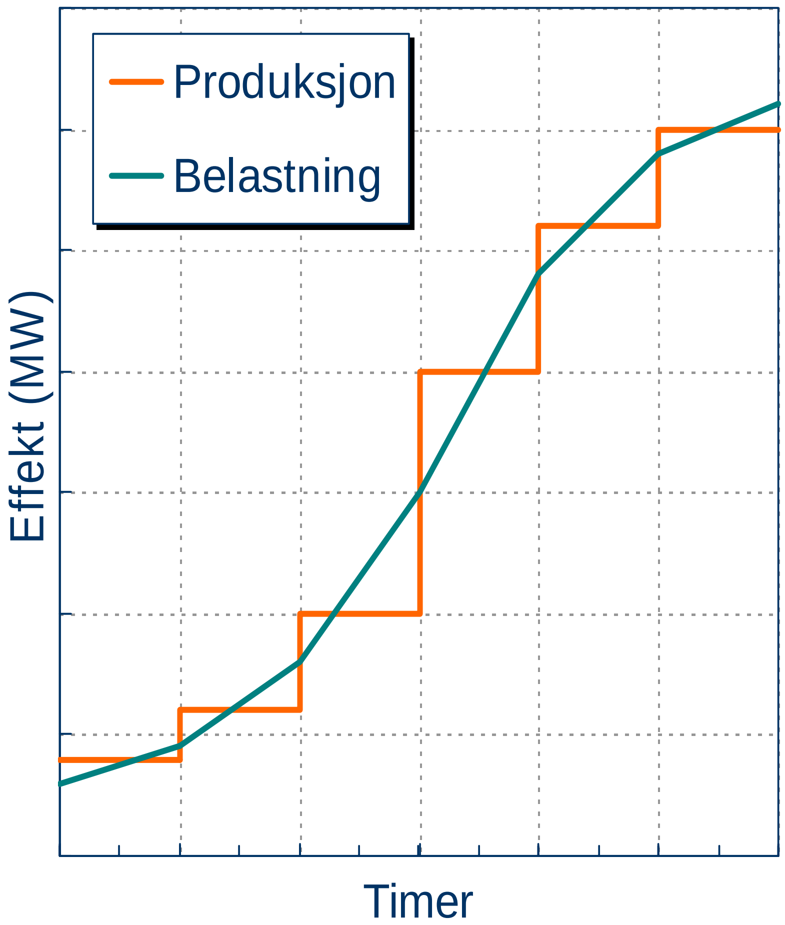


FRR = 600 MW, DFR = 1000 MW
R ≥ 6000 MW/Hz

FRR = 0 MW, DFR = 1000 MW
R = ??? MW/Hz

Lower margin
for stationary operation

Døgnregulering



- ✓ Produksjonsenheter blir normalt oppregulert/innfaset ved hvert *timeskift* i henhold til anmelding på Døgnmarkedet (MWh/h)
- ✓ Belastningen i systemet forandres *kontinuerlig*
- ⇨ Systemets frekvens er et mål på ubalansen mellom produksjon og forbruk

  Denne ubalansen må håndteres av systemoperatør