

# Handling of Structural Imbalances (Deterministic Frequency Deviations)

Trondheim, 20 May 2015

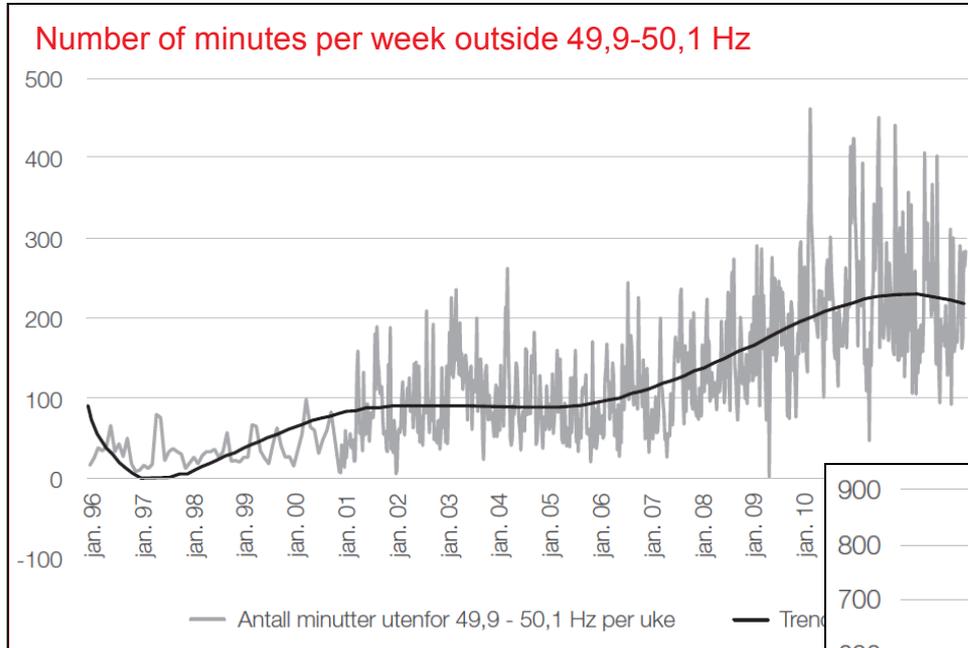
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**Statnett**

# Agenda

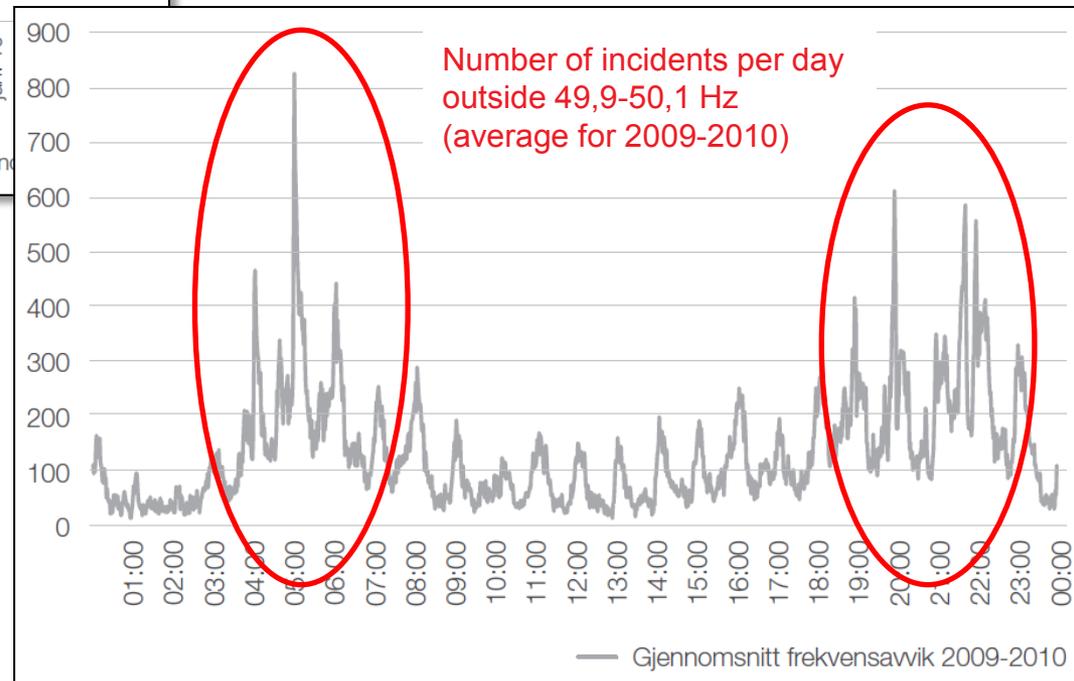
- Current trends for Nordic frequency quality
- What are *Structural Imbalances*?
- Current system operation tools
- Key premises for a future solution
- New tool: *Generation "Smoothing"*
  - Basic algorithm
  - Example
- Summary
- Extra: LARM test 2015-05-02

# The Nordic frequency quality is not satisfactory today



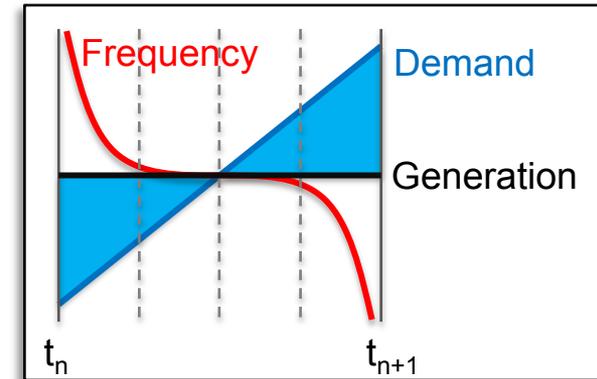
The largest frequency deviations occur morning and evening with large changes in production, demand and HVDC exchange.

The main cause is considered to be **structural imbalances**.



# What are Structural Imbalances?

(Deterministic Frequency Deviations)



- **Structural imbalances**

- Imbalances within an hour due to a repetitive and predictive mismatch between generation, demand and exchange, mainly caused by:

- Bilateral or market trade with hourly resolution
- Hourly resolution in plans for generation and exchange
- Administrative rules for HVDC exchange

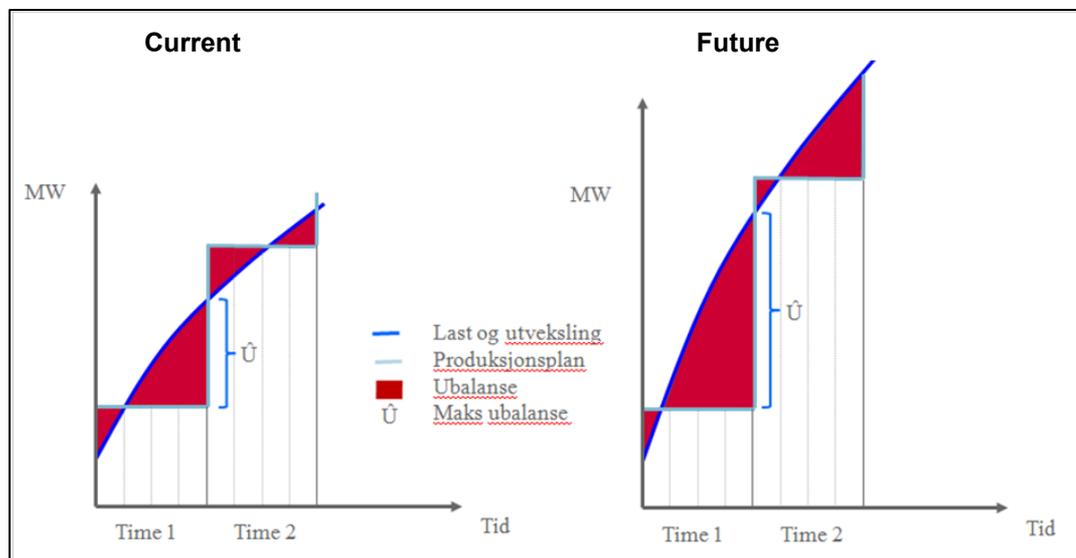
➤ *Note: Nobody can be "blamed" for the structural imbalances; nobody is doing anything wrong to cause the imbalance*

- **Stochastic imbalances**

- Imbalances caused by sudden and unpredictable events during operation
  - Outages and other contingencies
  - Forecast errors

# New tools are needed to reduce the structural imbalances

- Nordic frequency quality must be improved
- Several new HVDC connections are in planning
- More efficient use of HVDC connections requires faster change of flow direction -> Ramping throughout the hour: *Continuous Ramping*.
- Continuous ramping will increase the structural imbalances
- This challenge must be handled to avoid further reductions in frequency quality



*The current operator tools are considered to be insufficient for the increased challenges*

# Current operator tools to handle imbalances

- **Structural imbalances within an hour**

- **Planning phase:** Administrative requirement for quarterly schedules when large changes occur *over two hours*
  - Inconsistent with gate closure time in the Elbas market (T-1).
  - Large changes over one single hour not handled
  - Energy balance required, quarterly steps not adapted to system requirements
  - Many small changes may add up to large structural imbalances
- **During operation:** TSO can shift schedules with up to +/-15 min from plan
  - Efficient tool, but manual activation is demanding for operators
  - Increased risk by entering the operational hour with large imbalances

- **Stochastic imbalances (during operation)**

- Automatic reserves; FCR and FRR-A
- Manual reserves; Regulating Power Market (FRR-M and RR)
- Frequency operated system protection
- *Note: Automatic reserves are influenced by the structural imbalances*

# Key premises for future solution

- Increased **stochastic imbalances** should be solved during operation as today
  - If necessary with increased amount of reserves
  
- Increased **structural imbalances** should be solved as far as possible in the planning phase
  - The main part of the structural imbalances are known already in the planning phase
  - Reduces the risk caused by operating the system with large imbalances
  - Will reduce the need for schedule shifts during operation and thus reduce pressure on the operators
  - Allows the generation owners to include quarterly steps/adjustments in their optimal scheduling

# New tool: "Smoothing" algorithm

- Day-ahead calculation of system imbalance in 5 min steps
- Input
  - **Consumption forecast:** Linearization of quarterly values
  - **Generation schedules:** Hourly schedules adjusted around hour shift (+/- 5 min)
  - **AC exchange:** Linearization of hourly values (+/- 30 min)
  - **HVDC exchange:** Brake point values with 5 min resolution
  - (Nordic frequency response (MW/Hz))
- *Smoothing of hourly plans to quarterly steps when system imbalance exceeds chosen threshold values*
- *Planned schedule changes are shifted in time, but not size*
  - Special rule for schedule changes exceeding 400 MW
- Current rule for +/-15 minutes schedule shifts during operation is maintained

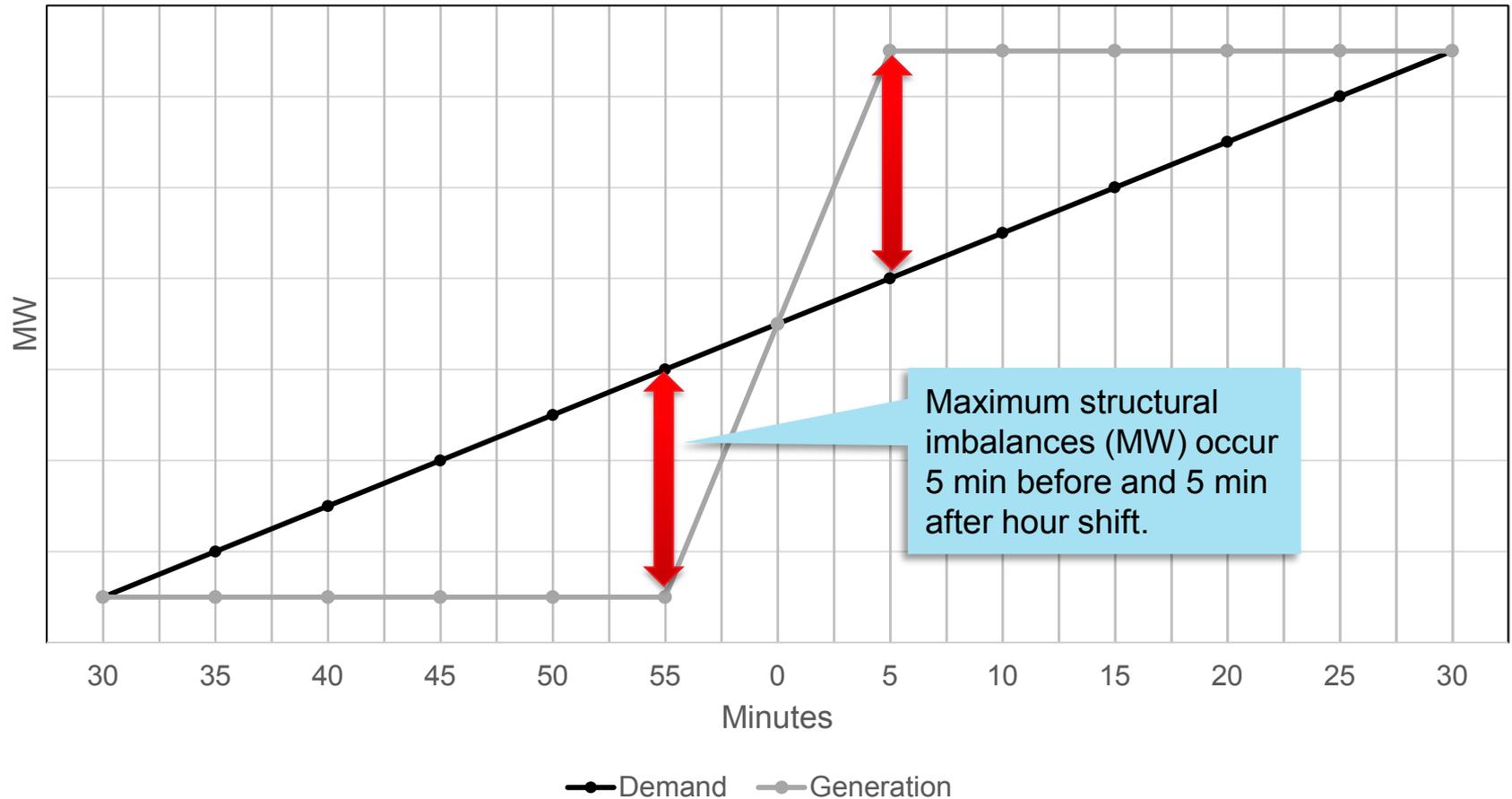
# "Smoothing" algorithm

## - basic principles

- 1. Threshold value to initiate Smoothing**
  - *WHEN* do we order Smoothing schedules?
- 2. Calculate Smoothing volume**
  - *HOW MUCH* smoothing do we order at each hour?
- 3. Selection of appropriate generators to activate**
  - Choice according to planned hourly schedule change
  - Extra large changes (>400 MW) split in two
  - Tolerance / Lower boundary of schedule change 20 MW
  - Location and risk of congestion considered
  - Generator owners can shift or decline ordered smoothing
- 4. Balance settlement and compensation**
  - Initial compensation for implementation (250,000 NOK)
  - Fixed compensation for administration (200,000 NOK/year)
  - Compensation per smoothing activation (5 NOK/MWh)
  - Compensation for energy imbalance - best of spot price and RPM price in same direction as Smoothing
  - Evaluation after one year
- 5. Verification of ordered smoothing**

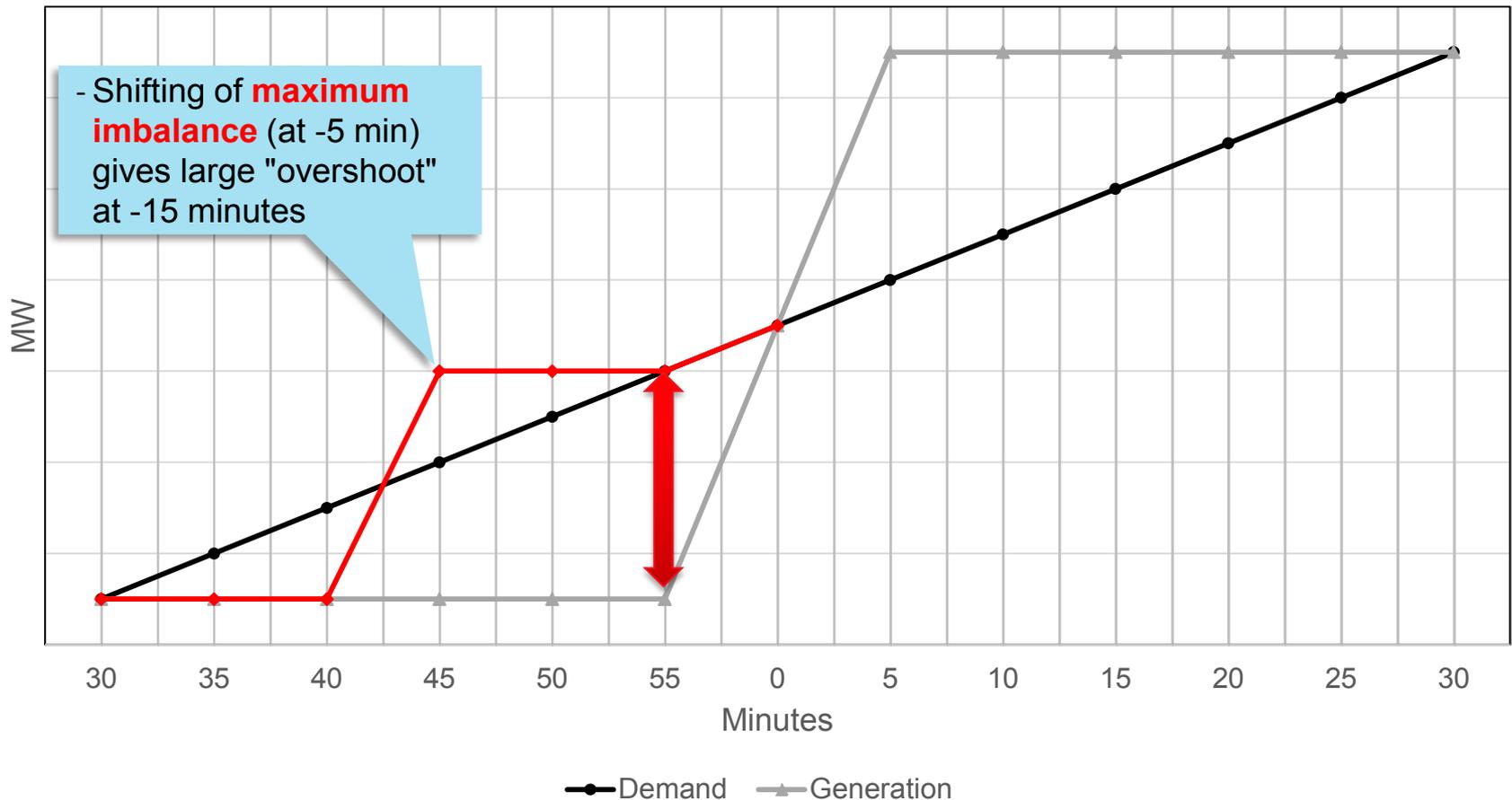
# Simplified illustration

## 1. Threshold value to initiate Smoothing



# Simplified illustration

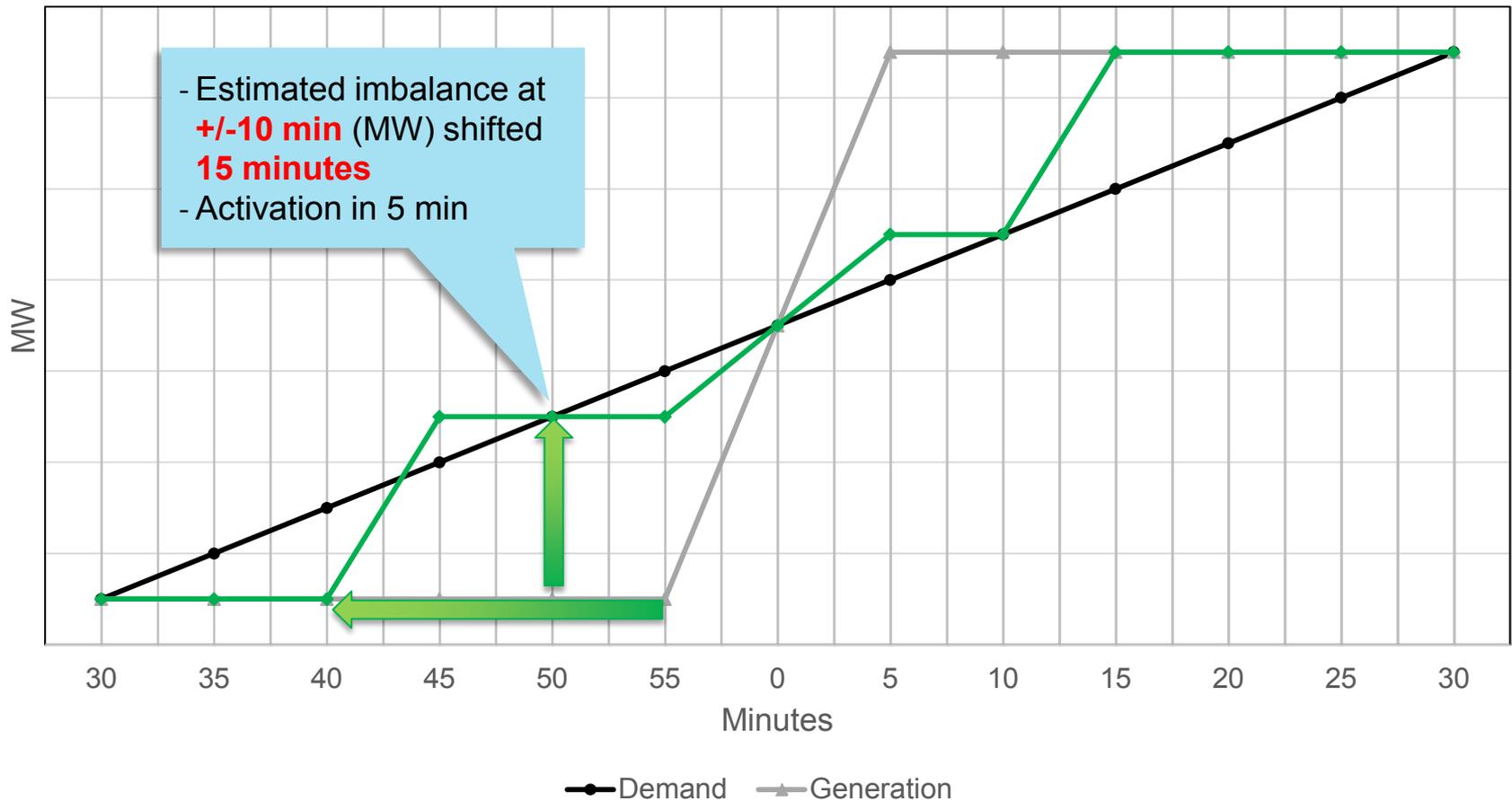
## 2. How much smoothing do we order?



# Simplified illustration

## 2. How much smoothing do we order?

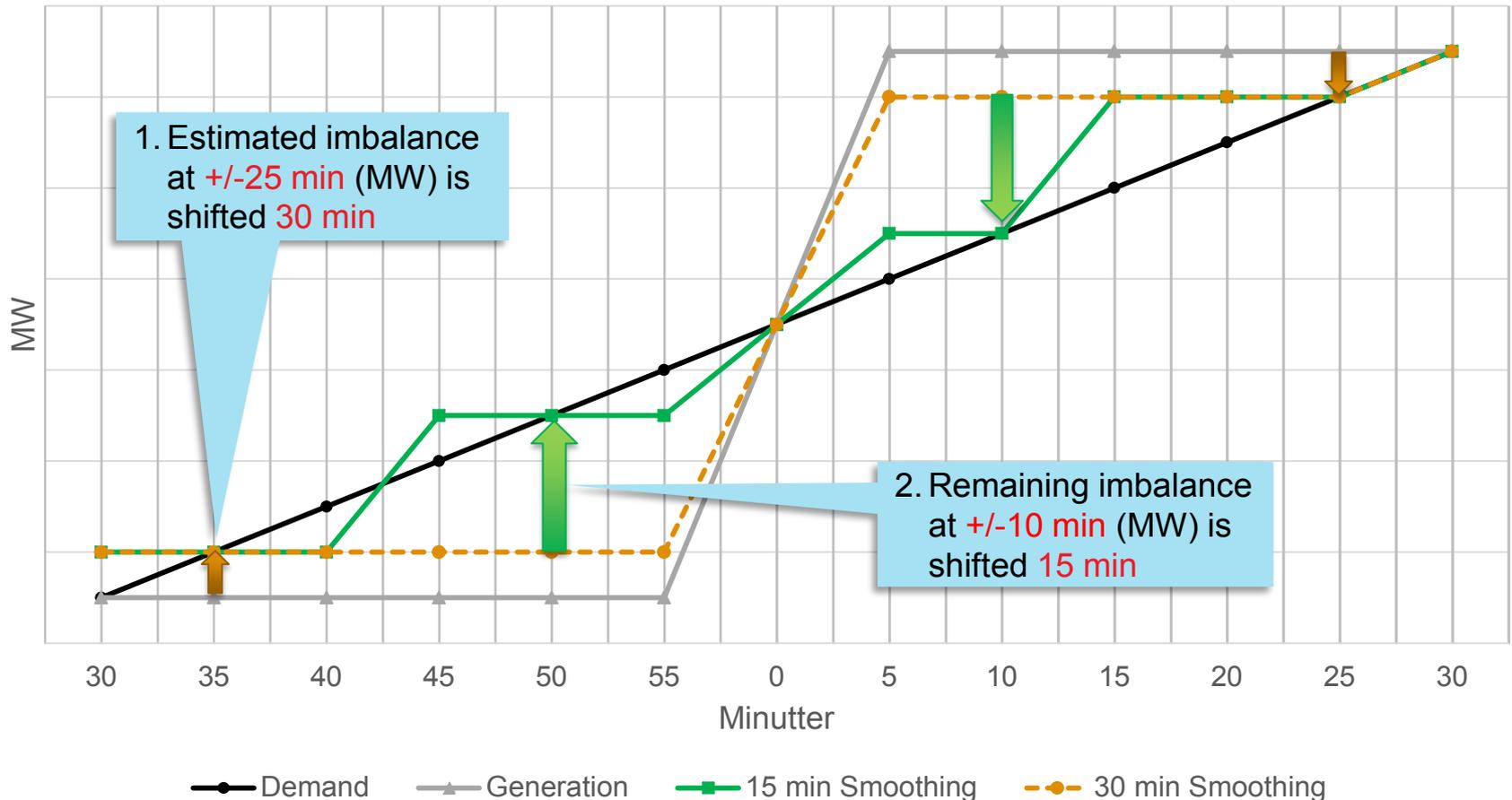
- Imbalance at **+/-10 min** is shifted **15 min**
- Trade-off between risk of overshoot at 45 min and reduced smoothing at 55 min



# Simplified illustration

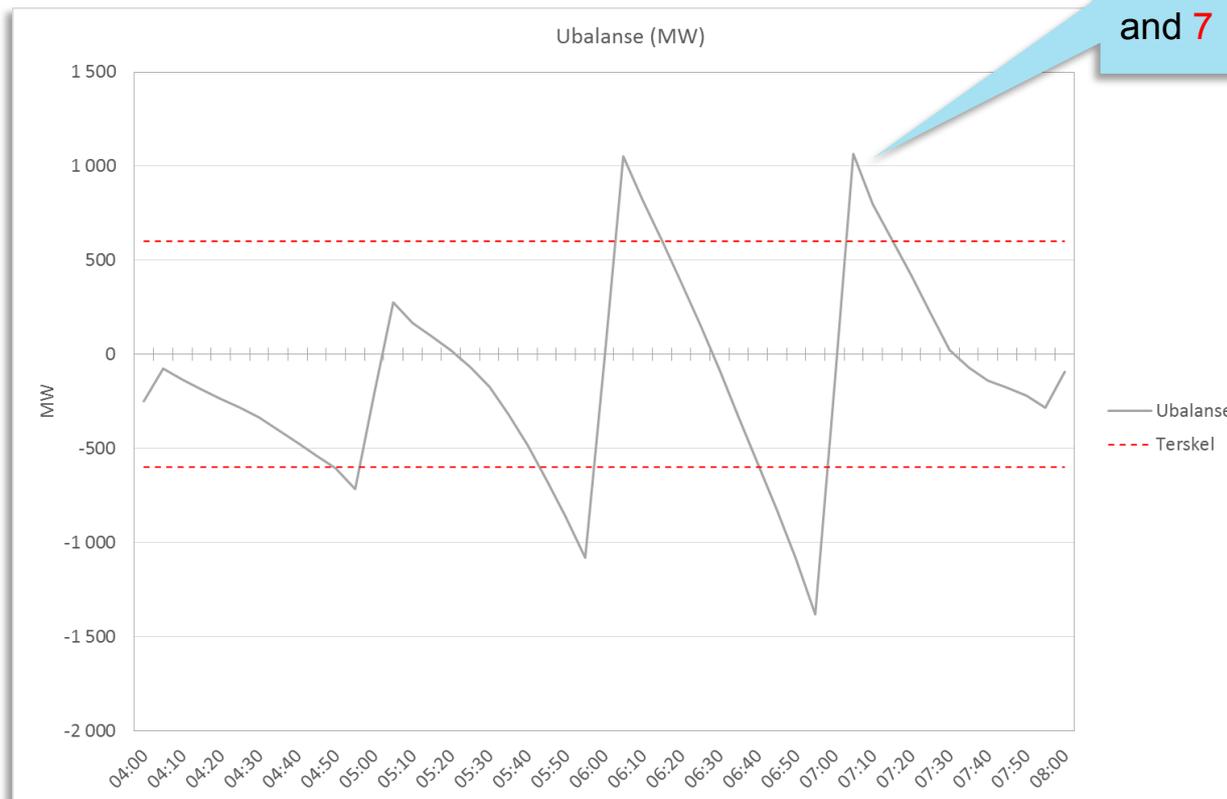
## Smoothing +/-15 min and +/-30 min

- Trade-off between risk of overshoot and reduced smoothing
- 1. Imbalance at **+/-25 min** is shifted **30 min**
- 2. Remaining imbalance at **+/-10 min** is shifted **15 min**



# Smoothing algorithm - Example

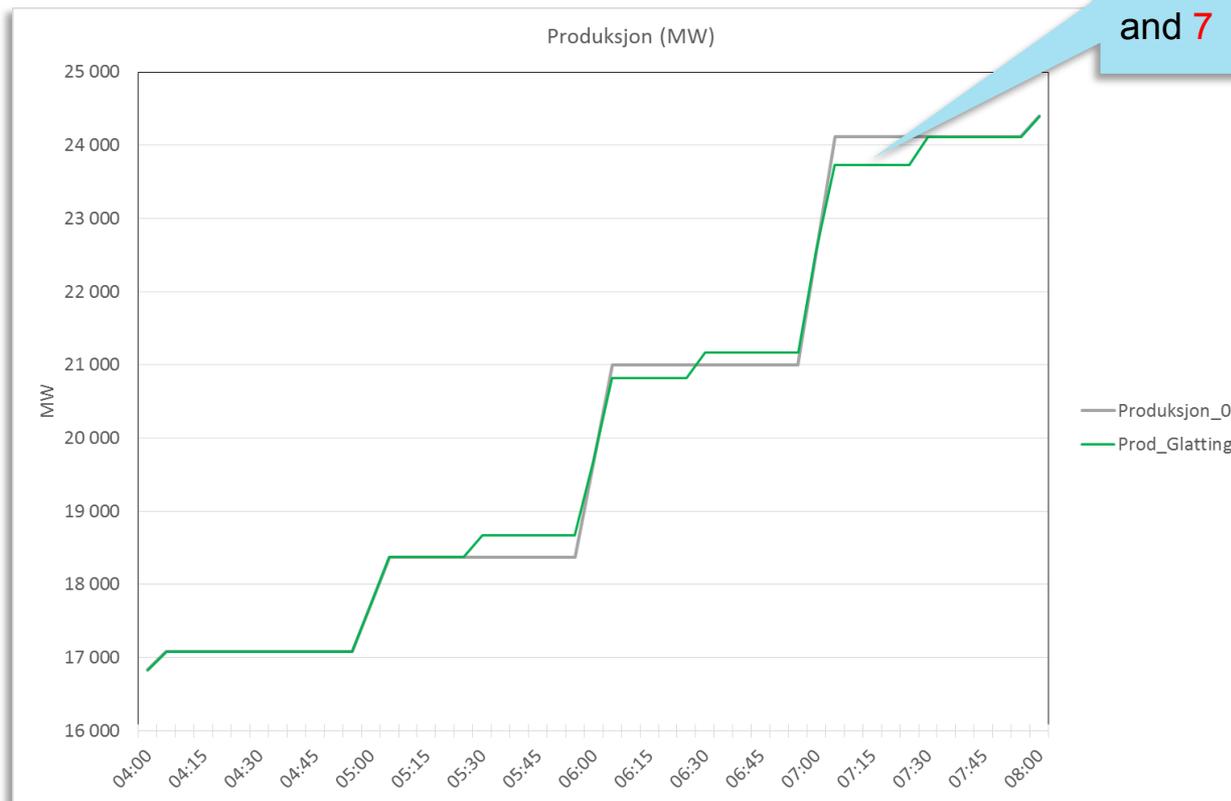
1. If maximum imbalance before or after an hour shift exceeds **600 MW**, imbalance at **+/-25 min** will be shifted **+/-30 minutes**



+/-30 min Smoothing  
needed at hours **6**  
and **7**

# Smoothing algorithm - Example

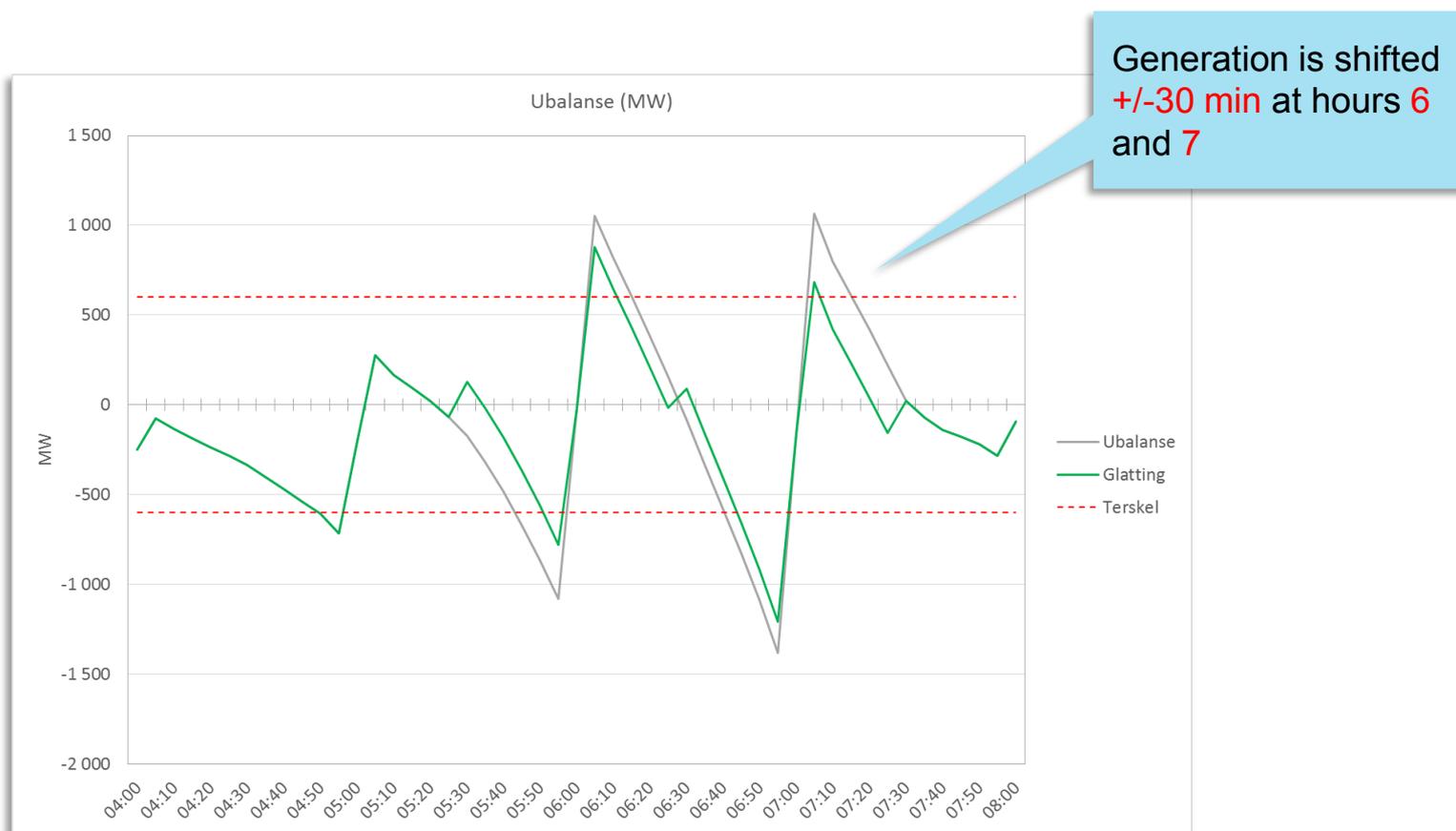
1. If maximum imbalance before or after an hour shift exceeds **600 MW**, imbalance at **+/-25 min** will be shifted **+/-30 minutes**



Generation shifted  
+/-30 min at hours 6  
and 7

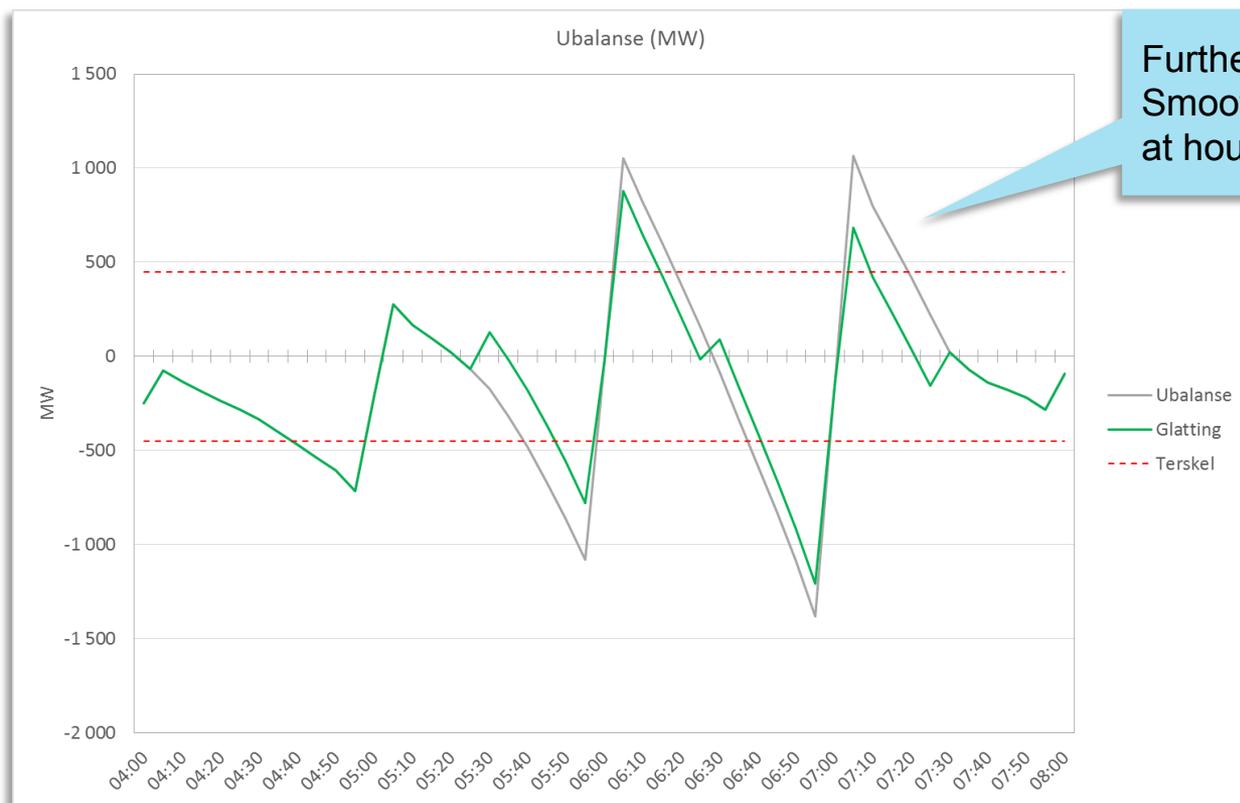
# Smoothing algorithm - Example

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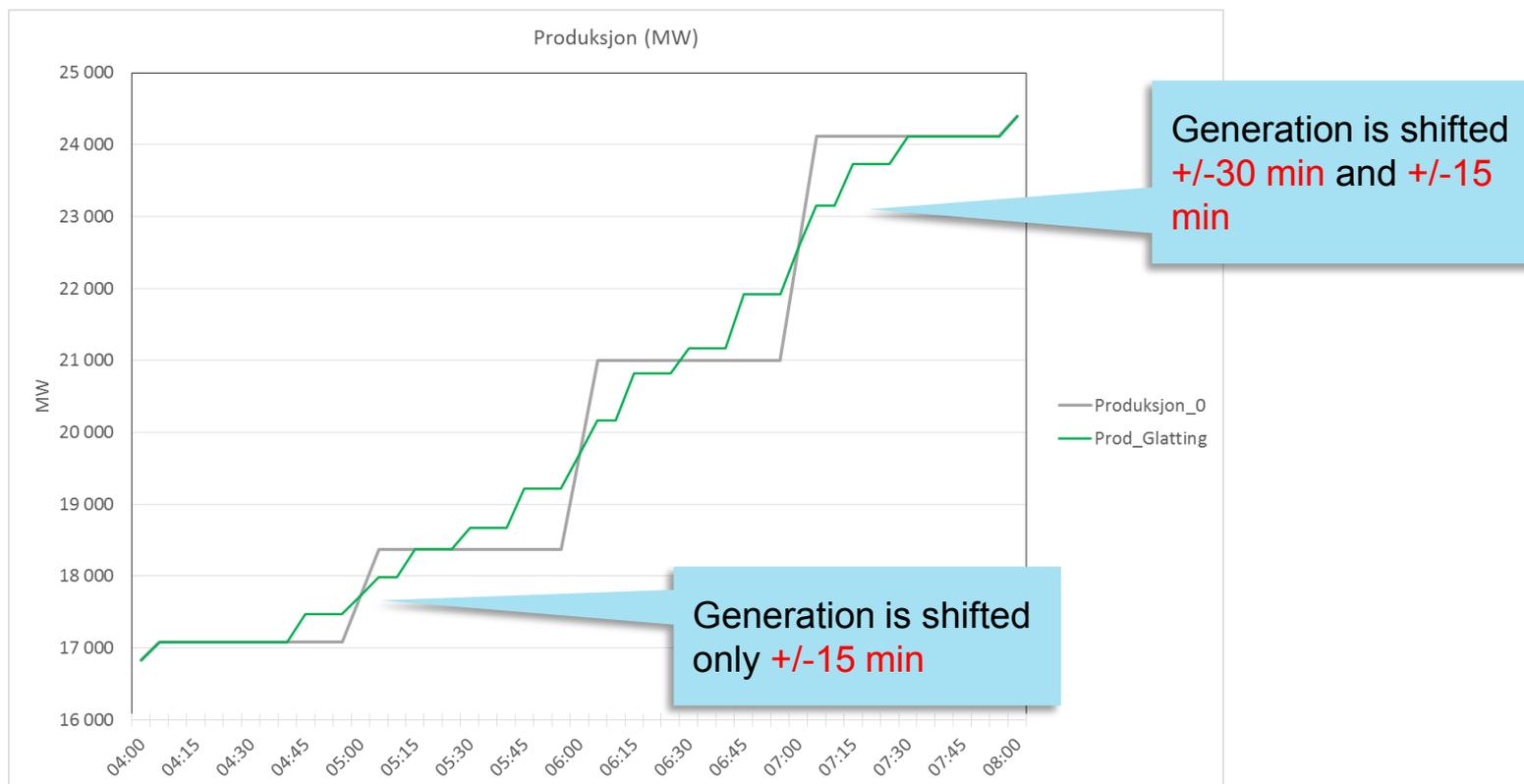
# Smoothing algorithm - Example

1. If maximum imbalance before or after an hour shift exceeds **600 MW**, imbalance at **+/-25 min** will be shifted **+/-30 minutes**
2. If remaining imbalance before or after an hour shift exceeds **450 MW**, imbalance at **+/-10 min** will be shifted **+/-15 minutes**



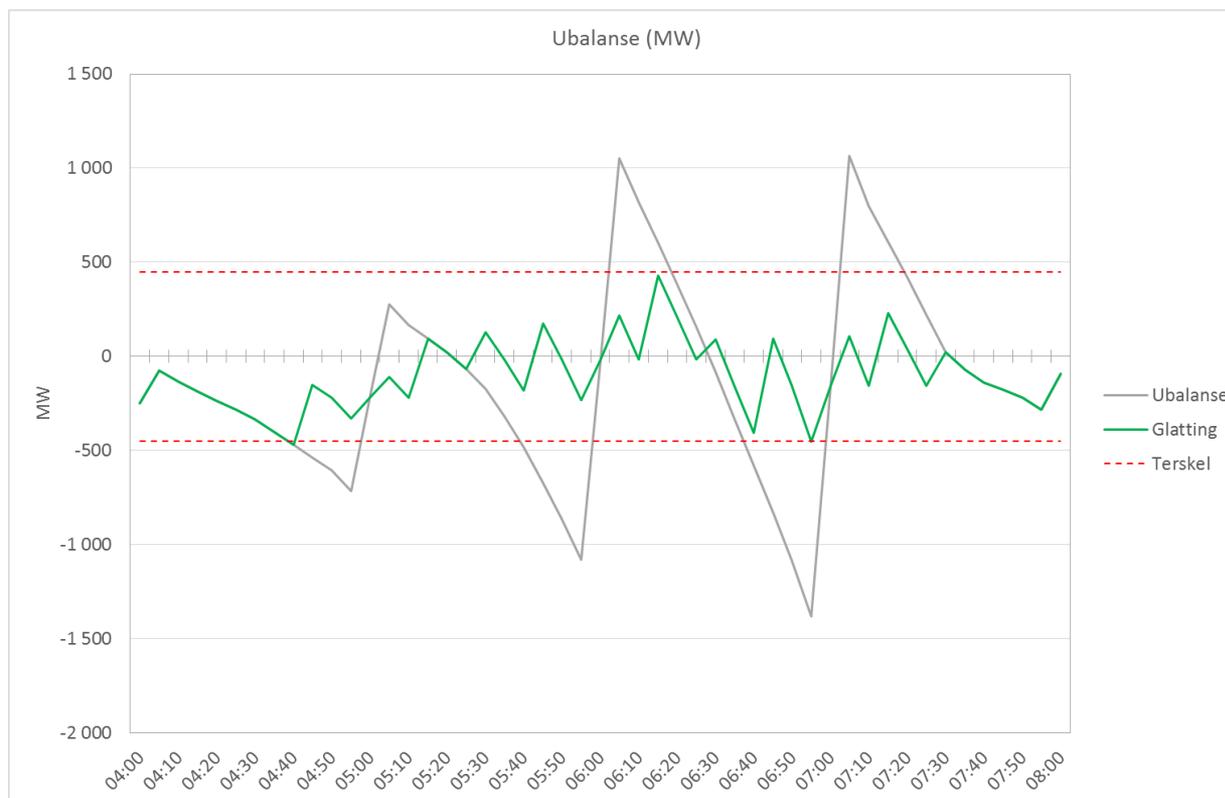
# Smoothing algorithm - Example

1. If maximum imbalance before or after an hour shift exceeds **600 MW**, imbalance at **+/-25 min** will be shifted **+/-30 minutes**
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# Smoothing algorithm - Example

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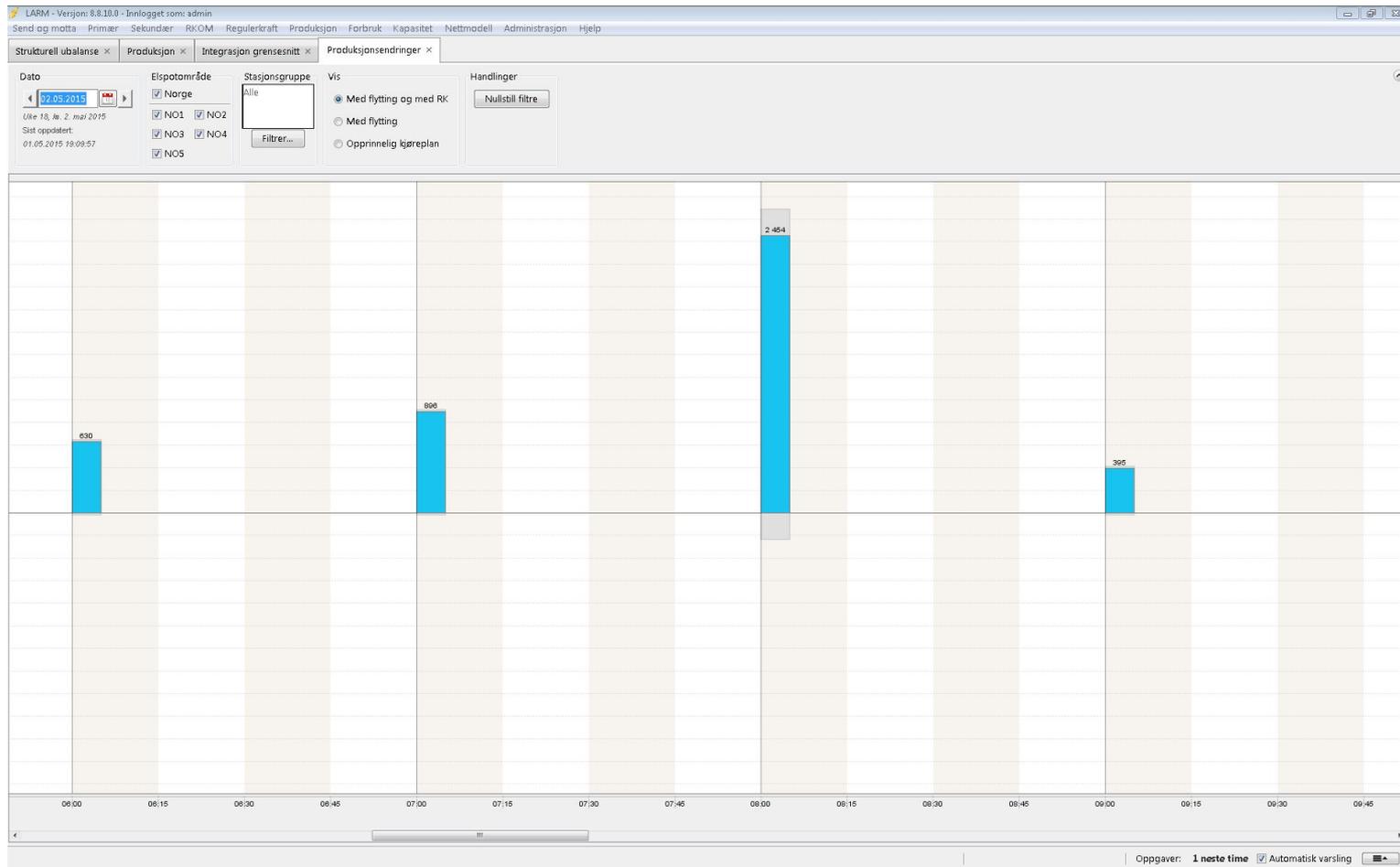
- The suggested Smoothing algorithm is better suited to meet actual system needs than current tools
  - Ordering of Smoothing based on estimated system imbalance rather than a deterministic requirement to submit 15 minute schedules
  - Actual production schedules on generator level is a good basis to calculate smoothing volumes
- Avoids instructions that may affect generator efficiency adversely
  - Only generation already scheduled for up or down regulation is considered
  - Planned generation changes are shifted in time, but not size
  - The generator owners are given flexibility to shift the required schedules within the Elspot area, or to reduce or declined the ordered smoothing
- Includes also smaller schedule steps per unit
  - Current threshold 20 MW (compared to previous 200 MW)
- In operation medio June 2015
- Conditions  
<http://www.statnett.no/Drift-og-marked/Systemansvaret/Systemtjenester/Produksjonsglatting/>

Extra

LARM test 02.05.2015

# LARM Test

## Production schedules before Smoothing



# LARM Test

## Imbalance before Smoothing



# LARM Test

## Ordered shifts

LARM - Versjon: 8.8.10.0 - Innlogget som: admin

Send og motta Primær Sekundær RKOM Regulerkraft Produksjon Forbruk Kapasitet Nettmodell Administrasjon Hjelp

Strukturell ubalanse x Produksjon x Integrasjon grensesnitt x Produksjonsendringer x

Dato: 02.05.2015  
Uke 18, år 2, mai 2015  
Sist oppdatert: 01.05.2015 19:11:22

Vis:  Graf ubalanse  Klargjør bestilling  Bestillingsstatus

Handlinger:

Stasjonsgruppe	Aktør	Område	Start kl.	Stopp kl.	Beregnet effekt	Unnta fra beregning
		NO2	00:30	00:45	-27,000	<input checked="" type="checkbox"/>
		NOS	00:30	00:45	-70,000	<input type="checkbox"/>
		NO2	00:45	01:00	-290,000	<input type="checkbox"/>
		NO2	00:45	01:00	-54,000	<input type="checkbox"/>
		NOS	00:45	01:00	-70,000	<input type="checkbox"/>
		NOS	00:45	01:00	-44,000	<input type="checkbox"/>
		NO2	01:00	01:15	290,000	<input type="checkbox"/>
		NOS	01:00	01:15	150,000	<input type="checkbox"/>
		NOS	01:15	01:30	150,000	<input type="checkbox"/>
		NOS	07:30	07:45	60,000	<input type="checkbox"/>
		NOS	07:30	07:45	149,500	<input type="checkbox"/>
		NO2	07:45	08:00	225,000	<input type="checkbox"/>
		NO2	07:45	08:00	488,250	<input type="checkbox"/>
		NOS	07:45	08:00	60,000	<input type="checkbox"/>
		NOS	07:45	08:00	149,500	<input type="checkbox"/>
		NO2	08:00	08:15	-30,000	<input type="checkbox"/>
		NO2	08:00	08:15	-225,000	<input type="checkbox"/>
		NO2	08:00	08:15	-488,250	<input type="checkbox"/>
		NOS	08:00	08:15	-140,000	<input type="checkbox"/>
		NO2	08:15	08:30	-30,000	<input type="checkbox"/>
		NOS	08:15	08:30	-140,000	<input type="checkbox"/>
		NO2	16:45	17:00	375,375	<input type="checkbox"/>
		NOS	16:45	17:00	58,000	<input type="checkbox"/>
		NO2	17:00	17:15	-50,000	<input type="checkbox"/>
		NO2	17:00	17:15	-375,375	<input type="checkbox"/>

Endret av aktør  For høy effekt/timeout

# LARM Test Ordered shifts

=> Confirmed shifts

LARM - Versjon: 8.8.10.0 - Innlogget som: admin

Send og motta Primær Sekundær RKOM Regulerkraft Produksjon Forbruk Kapasitet Nettmodell Administrasjon Hjelp

Strukturell ubalanse x Produksjon x Integrasjon grensesnitt x Produksjonsendringer x

Dato: 02.05.2015  
Uke 18, år 2, mai 2015  
Sist oppdatert: 01.05.2015 19:11:22

Vis: Graf ubalanse, Klargjør bestilling, Bestillingsstatus

Handlinger: Start glatting, Send bestilling, Eksporter underlag

Stasjonsgruppe	Aktør	Område	Start kl.	Stopp kl.	Beregnet effekt	Urinnta fra beregning
		NO2	00:30	00:45	-27,000	
		NOS	00:30	00:45	-70,000	
		NO2	00:45	01:00	-290,000	
		NO2	00:45	01:00	-54,000	
		NOS	00:45	01:00	-70,000	
		NOS	00:45	01:00	-44,000	
		NO2	01:00	01:15	290,000	
		NOS	01:00	01:15	150,000	
		NOS	01:15	01:30	150,000	
		NOS	07:30	07:45	60,000	
		NOS	07:30	07:45	149,500	
		NO2	07:45	08:00	225,000	
		NO2	07:45	08:00	488,250	
		NOS	07:45	08:00	60,000	
		NOS	07:45	08:00	149,500	
		NO2	08:00	08:15	-30,000	
		NO2	08:00	08:15	-225,000	
		NO2	08:00	08:15	-488,250	
		NOS	08:00	08:15	-140,000	
		NO2	08:15	08:30	-30,000	
		NOS	08:15	08:30	-140,000	
		NO2	16:45	17:00	375,375	
		NOS	16:45	17:00	58,000	
		NO2	17:00	17:15	-50,000	
		NO2	17:00	17:15	-375,375	

Endret av aktør For høy effekt/timeout

LARM - Versjon: 8.8.10.0 - Innlogget som: admin

Send og motta Primær Sekundær RKOM Regulerkraft Produksjon Forbruk Kapasitet Nettmodell Administrasjon Hjelp

Strukturell ubalanse x Produksjon x Integrasjon grensesnitt x Produksjonsendringer x Aktøregenskaper x

Dato: 02.05.2015  
Uke 18, år 2, mai 2015  
Sist oppdatert: 01.05.2015 19:18:42

Vis: Graf ubalanse, Klargjør bestilling, Bestillingsstatus

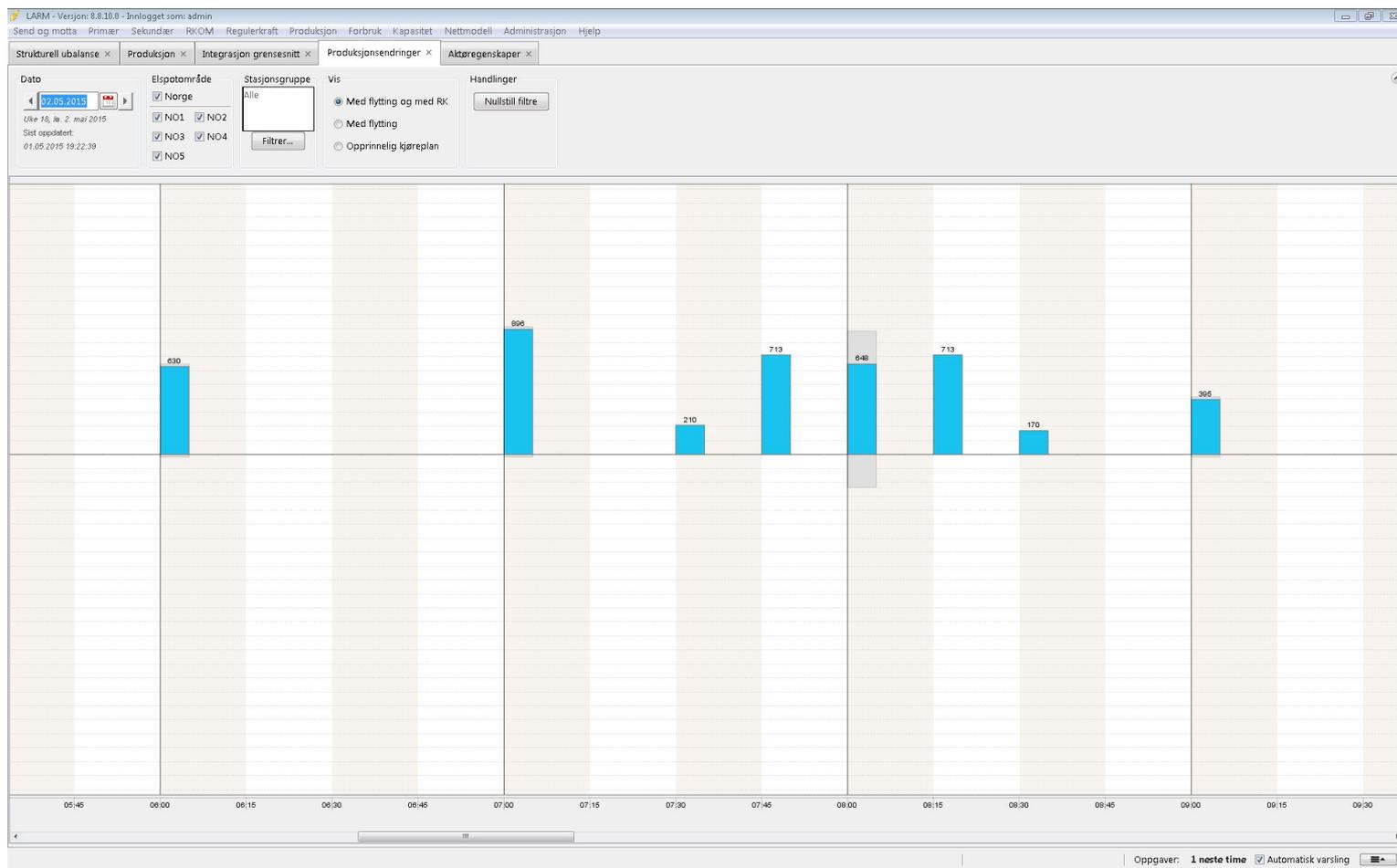
Handlinger: Start glatting, Send bestilling, Eksporter underlag

Aktør	Område	Start kl.	Stopp kl.	Bestilt effekt	Bekreftet effekt	Status
	NO2	00:30	00:45	-27,000	-27,000	OK
	NOS	00:30	00:45	-70,000	-70,000	OK
	NO2	00:45	01:00	-290,000	-290,000	OK
	NO2	00:45	01:00	-54,000	-54,000	OK
	NOS	00:45	01:00	-70,000	-70,000	OK
	NOS	00:45	01:00	-114,000	-114,000	OK
	NO2	01:00	01:15	290,000	290,000	OK
	NOS	01:00	01:15	150,000	150,000	OK
	NOS	01:15	01:30	150,000	150,000	OK
	NOS	07:30	07:45	209,500	209,500	OK
	NO2	07:45	08:00	225,000	225,000	OK
	NO2	07:45	08:00	488,250	488,250	OK
	NOS	07:45	08:00	209,500	209,500	OK
	NO2	08:00	08:15	-30,000	-30,000	OK
	NO2	08:00	08:15	-225,000	-225,000	OK
	NO2	08:00	08:15	-488,250	-488,250	OK
	NOS	08:00	08:15	-140,000	-140,000	OK
	NO2	08:15	08:30	-30,000	-30,000	OK
	NOS	08:15	08:30	-140,000	-140,000	OK
	NO2	16:45	17:00	375,375	375,375	OK
	NOS	16:45	17:00	58,000	58,000	OK
	NO2	17:00	17:15	-50,000	-50,000	OK
	NO2	17:00	17:15	-375,375	-375,375	OK

Endret av aktør For høy effekt/timeout

# LARM Test

## Production schedules after Smoothing



# LARM Test

## Imbalance after Smoothing





# Handling of Structural Imbalances (Deterministic Frequency Deviations)

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