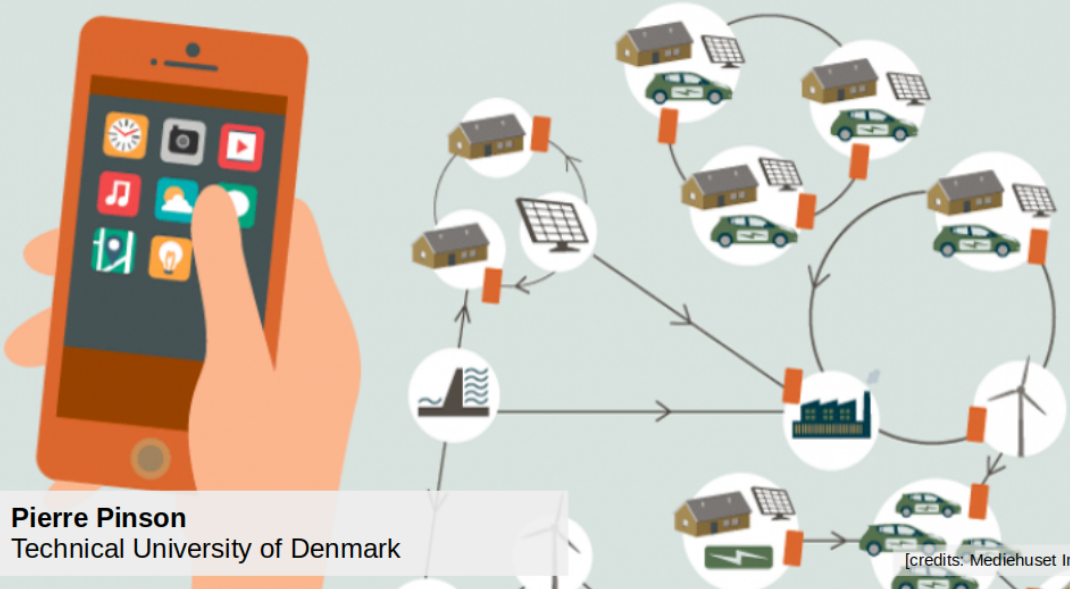
Module 4 – Ancillary Services

4.3 Ancillary services and payments



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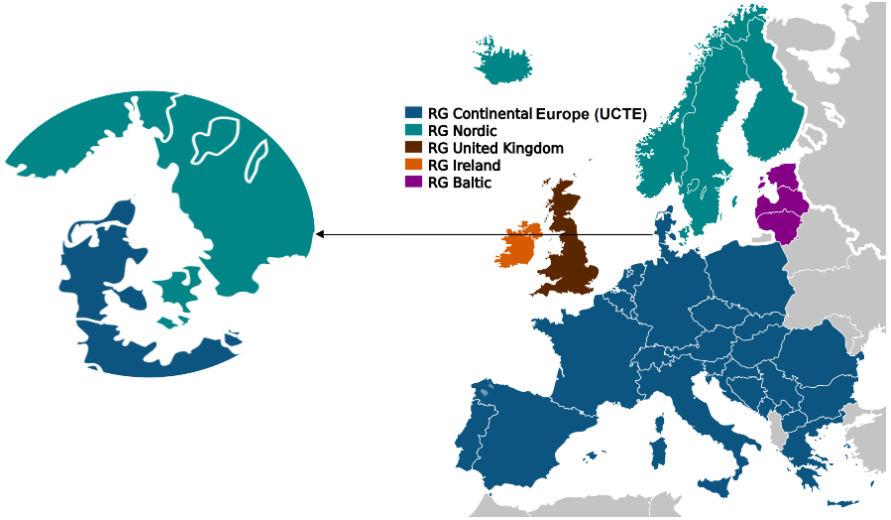
[credits: Mediehuset Ingeniøren]

Ancillary services in Denmark

Denmark is originally connected to two different power systems with different operational practice



Ancillary services are then different in DK1 and DK2...

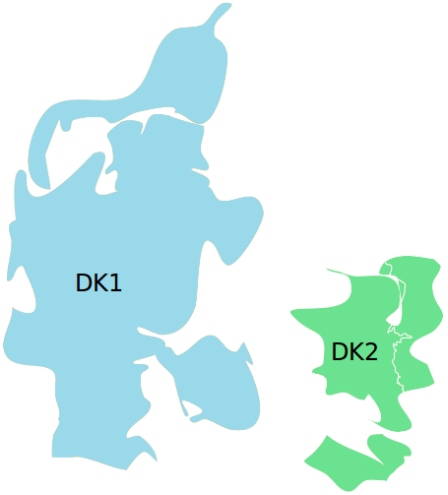
Energinet, "Ancillary services to be delivered in Denmark – Tender conditions", October 2012 (link).

Ancillary services in DK1 and DK2

(with focus on frequency-related services)

DK1

- Primary reserves
- Secondary reserves (Load Frequency Control)
- Manual reserves



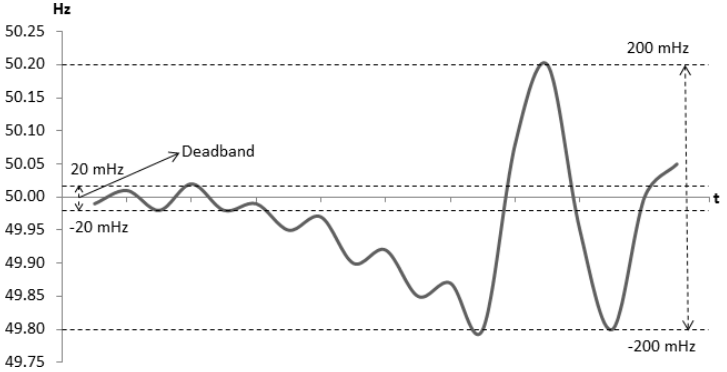
DK2

- Frequency-controlled normal operation reserves (FNR)
- Frequency-controlled disturbance reserves (FDR)
- Manual reserves

Primary reserves (DK1)

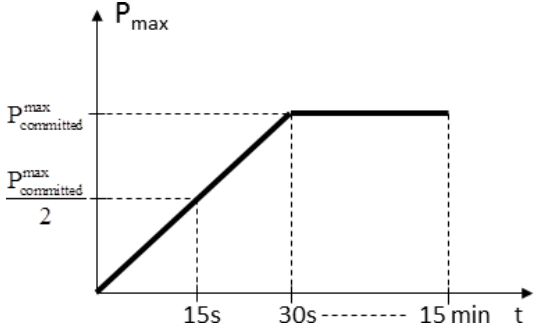
- There is an overall need for $+/-3.000$MW of primary-type reserves over continental Europe (following ENTSO-E assessment and recommendation)
- This amount (capacity) is shared among all system operators
- For DK1, this share is of $+/-27$MW

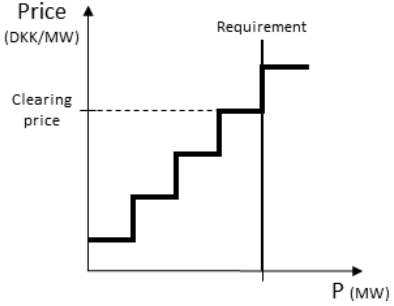
Response to frequency deviation



Primary reserve activation and market (DK1)

Required characteristics of reserve response (prior certification)





- daily day-ahead auctions
- inflexible demand (27MW)
- need for upward and downward capacity
- merit order on capacity offers
- energy is not considered (**Energy-neutral service**)

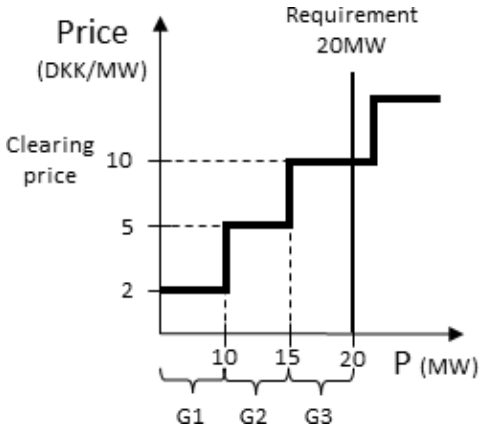
Primary reserve payment (DK1)

For market participant i:

$$\text{Revenue}_{G_i} = P_i^G \lambda_c$$

where

- P_i: accepted capacity
- λ_c: clearing price



In this example:

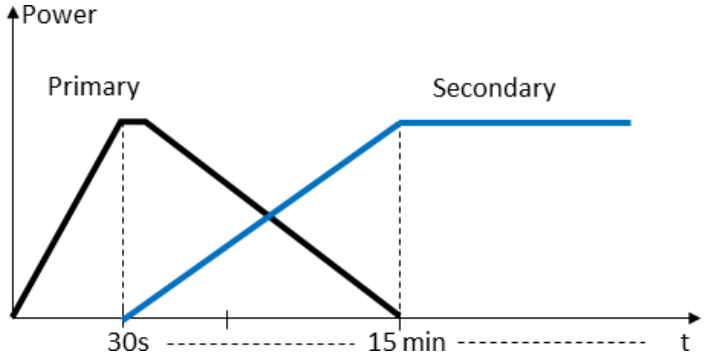
- G_1: 10MW $\times$ 10DKK/MW $=$ 100DKK
- G_2: 5MW $\times$ 10DKK/MW $=$ 50DKK
- G_3: 5MW $\times$ 10DKK/MW $=$ 50DKK (out of the 6MW originally offered)
- others: 0DKK

Here, only generators are considered... Though demand could also provide such services (e.g., batteries, electric boilers)

Secondary reserves (DK1)

Two distinct goals:

- Relieve the primary reserve which has been activated
- Restore any imbalance on the interconnections



The capacity requirement for DK1 is of $+/-90$MW (following ENTSO-E assessment and recommendation)

Secondary reserve market (DK1) (1)

Payment for capacity AND for energy (This is not an energy-neutral service!)

Capacity

- purchased on a *monthly basis*
- *combined and symmetrical* upward and downward products
- based on *bilateral contracts* (negotiated, non-public)

$\rightarrow$ **Result** for Generator G_i: P_i^G (MW) and λ_i^G (DKK/MW)

Secondary reserve market (DK1) (2)

Energy

- All energy ΔE_i generated/consumed is to be paid for (for given generator G_i)
- Two *reference prices* are to be considered: day-ahead price λ^S for that time, as well as balancing price λ^B (from balancing market)
- Minimum revenues are ensured by always having a spread of at least 100 between day-ahead and balancing prices
- In practice, in the upward regulation case:

$$\text{Energy revenue}(G_i) = \begin{cases} (\lambda^S + 100)\Delta E_i & \text{if } \lambda^B < \lambda^S + 100, \\ \lambda^B \Delta E_i & \text{otherwise} \end{cases}$$

- And, in the downward regulation case:

$$\text{Energy revenue}(G_i) = -\begin{cases} (\lambda^S - 100)\Delta E_i & \text{if } \lambda^B > \lambda^S - 100, \\ \lambda^B \Delta E_i & \text{otherwise} \end{cases}$$

The (negative) revenue in the downward regulation case consists in buying back energy that was already sold through the day-ahead market!

Secondary reserve payments (DK1)

Example (for a given time unit, upward regulation cases):

- $\mathrm{RT}^{®}$ is to generate 50MWh through the day-ahead market ($\lambda^S = 200$DKK/MWh)
- $\mathrm{RT}^{®}$ has a contract for secondary reserve provision, with $P^G_{\mathrm{RT}} = 10$MW, λ^G_{RT}=20DKK/MW

2 illustrative cases:

- Need for **upward** regulation, energy fully delivered, balancing price $\lambda^B = 250$DKK/MWh,

$$\text{Revenue}(\mathrm{RT}^{®}) = 10 \times 20 + 10 \times (200 + 100) = 3200\text{DKK}$$

- Need for **upward** regulation, energy half delivered, balancing price $\lambda^B = 320$DKK/MWh,

$$\text{Revenue}(\mathrm{RT}^{®}) = 10 \times 20 + 5 \times 320 = 1800\text{DKK}$$

Secondary reserve payments (DK1)

Example (for a given time unit, downward regulation cases):

- $\mathrm{RT}^{®}$ is to generate 50MWh through the day-ahead market ($\lambda^S = 200$DKK/MWh)
- $\mathrm{RT}^{®}$ has a contract for secondary reserve provision, with $P^G_{\mathrm{RT}} = 10$MW, λ^G_{RT}=20DKK/MW

2 illustrative cases:

- Need for **downward** regulation, energy fully "consumed" (/reduced), balancing price $\lambda^B =$ 150DKK/MWh,

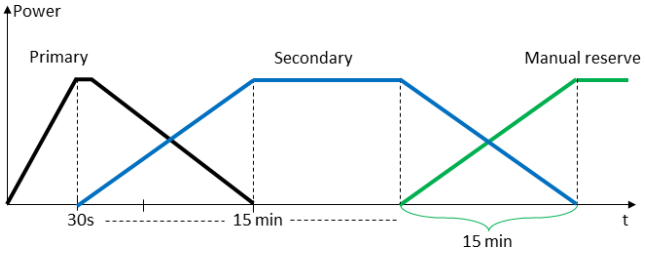
$$\text{Revenue}(\mathrm{RT}^{®}) = 10 \times 20 - 10 \times (200 - 100) = -800\text{DKK}$$

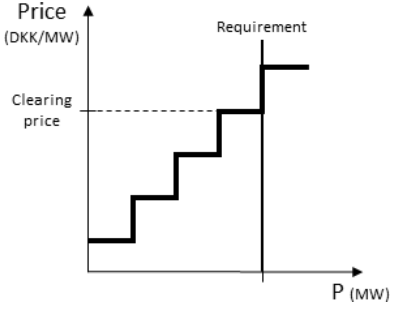
- Need for **downward** regulation, energy half "consumed", balancing price $\lambda^B = 50$DKK/MWh,

$$\text{Revenue}(\mathrm{RT}^{®}) = 10 \times 20 - 5 \times 50 = -50\text{DKK}$$

Manual (/tertiary) reserves (DK1)

The full timeline for reserve products





- daily day-ahead auctions
- **varying** demand
- need for upward and downward capacity
- merit order on capacity offers
- energy is paid for at the balancing price λ^B

Tertiary reserve payments (DK1)

Example (for a given time unit, upward regulation cases):

- $\mathrm{RT}^{®}$ is to generate 50MWh through the day-ahead market ($\lambda^S = 200$DKK/MWh)
- $\mathrm{RT}^{®}$ gets cleared to provide tertiary reserves, with $P^G_{\mathrm{RT}} = 20$MW, λ^G_{RT}=2DKK/MW

2 illustrative cases:

- Need for **upward** regulation, energy fully delivered, balancing price $\lambda^B = 250$DKK/MWh,

$$\text{Revenue}(\mathrm{RT}^{®}) = 20 \times 2 + 20 \times 250 = 5040\text{DKK}$$

- Need for **upward** regulation, energy half delivered, balancing price $\lambda^B = 320$DKK/MWh,

$$\text{Revenue}(\mathrm{RT}^{®}) = 20 \times 2 + 10 \times 320 = 3240\text{DKK}$$

Tertiary reserve payments (DK1)

Example (for a given time unit, downward regulation cases):

- $\mathrm{RT}^{®}$ is to generate 50MWh through the day-ahead market ($\lambda^S = 200$DKK/MWh)
- $\mathrm{RT}^{®}$ gets cleared to provide tertiary reserves, with $P^G_{\mathrm{RT}} = 20$MW, λ^G_{RT}=2DKK/MW

2 illustrative cases:

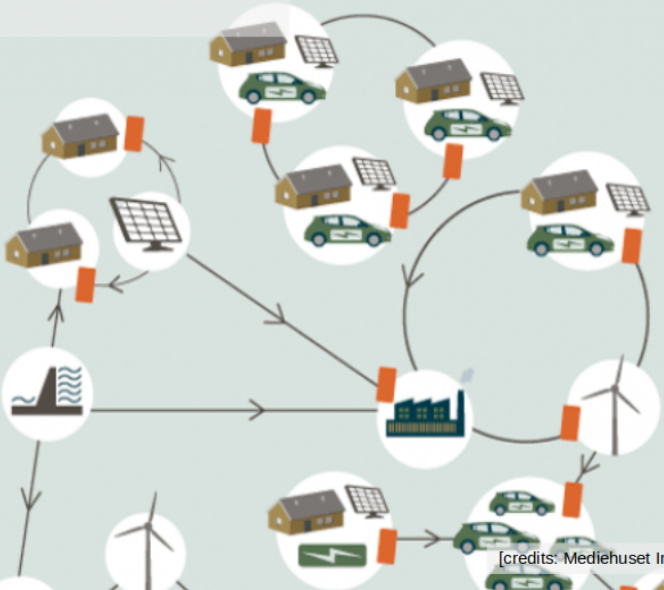
- Need for **downward** regulation, energy fully "consumed" (/reduced), balancing price $\lambda^B =$ 150DKK/MWh,

$$\text{Revenue}(\mathrm{RT}^{®}) = 20 \times 2 - 20 \times 150 = -2960\text{DKK}$$

- Need for **downward** regulation, energy half "consumed", balancing price $\lambda^B = 50$DKK/MWh,

$$\text{Revenue}(\mathrm{RT}^{®}) = 20 \times 2 - 10 \times 50 = -460\text{DKK}$$

Use the self-assessment quizz to check your understanding!



[credits: Mediehuset Ingeniøren]