Integration of Power-to-Gas Conversion into Dutch Electricity Ancillary Services Markets

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AGENDA

- THE POTENTIAL OF POWER-TO-GAS FOR THE NETHERLANDS
- POWER-TO-GAS CONVERSION: PEM ELECTROLYSERS
- DUTCH ANCILLARY SERVICES MARKETS
- CASE STUDY: GRONINGEN-DRENTHE-OVERIJSEEL AREA (2030)
FROM 2019: COBRAcable
FOR SURPLUS OF
DANISH WIND ENERGY

GREEN POWER
FROM GERMANY

ELECTRICITY

UNDERGROUND
GAS STORAGE

H₂

FUEL CELLS

INDUSTRY

H₂

TRANSPORTATION

H₂

HOUSEHOLDS

NATURAL GAS

CH₄

Adapted from: http://tso2020.eu/
USAGE OF NATURAL GAS IN EUROPE

- Top-6 EU Countries with Highest GDP in 2017 -
**POWER-TO-GAS CONVERSION: PEM ELECTROLYSERS**

**SPECIFICATIONS**
- Size of individual stack ≤ 3 MW
- System efficiency of 75 – 85 %
- Power setpoint change within 1 second
- Startup and shutdown within minutes

**ONGOING / PLANNED PROJECTS**
- TSO 2020 – 1 MW pilot station (NL)
- Shell / ITM – 10 MW refinery (DE)
- McPhy – 13 MW methanation (AT)
- Gasunie – 20 MW station (NL)

**CAPITAL COST (CAPEX)**
- 1000 €/kW at 1 MW scale in 2018
- 500 €/kW at 10 MW scale by mid 2020s

**LIFETIME**
- ≈ 80,000 hours for the stack
- 20 – 30 years for the rest of the plant

**POTENTIAL USES FOR POWER SYSTEMS**
- Frequency regulation
- Renewables curtailment reduction
- Congestion management
- Voltage control

*Reference data taken from different manufacturers - Electrolyzer sample image retrieved from Nel Hydrogen*
DUTCH ANCILLARY SERVICES MARKETS

- Prequalification, Market Mechanisms and Future Framework of:
  - Balancing Markets (FCR and aFRR)
  - Voltage Control
  - Congestion Management

- Assessment of the Technical Adequacy of PEM Electrolysers

- Business Model of Electrolysers as Ancillary Services Provider
FREQUENCY CONTAINMENT RESERVE (FCR)

PARTICIPANTS:
- Generators
- Loads

PREQUALIFICATION:
- Complete bid activation within 30 sec.
- Provision for 30 min. for a ± 200 mHz deviation
- Linear frequency-power characteristic

BIDDING RULES:
- Symmetric bid
- Bid ≥ 1 MW
- Bid ≤ Prequalified MW

MARKET TYPE:
- Organized capacity market
  - ± 110 MW [1]
  - Weekly auction

SETTLEMENT RULE:
- Pay-as-bid

PRODUCT RESOLUTION:
- Weekly

[1] Online trading platform at regelleistung.net / 30% Dutch exclusive and 70% auctioned together with the following TSOs:
AUTOMATIC FREQUENCY RESTORATION RESERVE (aFRR)

**BIDDING RULES:**
- Symmetric bids
- Bid ≥ 1 MW
- Bid ≤ 999 MW
- Voluntary capacity bids
- Asymmetric bids allowed

**MARKET TYPE:**
- Single-buyer bilateral market
  - ± 350 MW
  - Mandatory daily bids
- Daily bid ladder
  - Activation by merit order
  - Energy remuneration

**SETTLEMENT RULE:**
- Pay-as-bid

**PRODUCT RESOLUTION:**
- Monthly / Weekly
- Marginal price
- 15-Minute (PTU)

**PREQUALIFICATION:**
- Complete bid activation within 15 min.
- Minimum ramping of 7% of the bid per min.
- Control by Load Frequency Control (LFC)

**PARTICIPANTS:**
- Generators
- Loads

**AUTOMATIC FREQUENCY RESTORATION RESERVE (aFRR):**
- Complete bid activation within 15 min.
- Minimum ramping of 7% of the bid per min.
- Control by Load Frequency Control (LFC)

**Prequalification:**
- Generators
- Loads

**Bidding Rules:**
- Symmetric bids
  - Bid ≥ 1 MW
  - Bid ≤ 999 MW
- Voluntary capacity bids
  - Asymmetric bids allowed

**Market Type:**
- Single-buyer bilateral market
  - ± 350 MW
  - Mandatory daily bids
- Daily bid ladder
  - Activation by merit order
  - Energy remuneration

**Settlement Rule:**
- Pay-as-bid

**Product Resolution:**
- Monthly / Weekly
  - Marginal price
  - 15-Minute (PTU)
**FCR:**
- Daily auction frequency
- Product resolution of 4 hours
- Marginal pricing settlement rule
- Introduction of asymmetric bids

**aFRR:**
- Full activation time of 5 or 7.5 minutes
- Gate closure times closest to real-time
- Increased imbalance netting through IGCC\(^1\)
- Unified European market model
- Energy activation by a common merit order list
- Cross-border marginal pricing settlement rule

Involved TSOs:

\[^1\] International Grid Control Cooperation
**VOLTAGE CONTROL & CONGESTION MANAGEMENT**

**CONGESTION MANAGEMENT:**

- **Participants:** Generators, Loads
- **Single-buyer bilateral market**
  - At TenneT's request
- **Settlement Rule:** Fixed fee
- **Product Resolution:** No details

**LOADS**

- **Participants:** Generators, Loads
- **Single-buyer bilateral market**
  - Based on local needs
  - Yearly tender
- **Settlement Rule:** Pay-as-bid
- **Product Resolution:** Yearly

- **Mandatory provision for generators > 5 MW (Contracted service)**

**FACTS**

- **Participants:** Generators, Loads
- **Single-buyer bilateral market**
  - Activation in 15 min.
- **Settlement Rule:** Pay-as-bid
- **Product Resolution:** Yearly activation in 15 min.

- **Prequalification:**
  - 10

- **The reinforcement of the grid is the preferred action plan in TenneT to avoid future congestions**
TECHNICAL ADEQUACY OF PEM ELECTROLYSERS

FREQUENCY RESTORATION RESERVE (aFRR)
- 1 MW active power steps by LFC
- Power setpoint change within 1 second

CONGESTION MANAGEMENT
- Curtailable industrial load
- Interruptible load
- Fast ramping in both directions

FREQUENCY CONTAINMENT RESERVE (FCR)
- Power setpoint change within 1 second

VOLTAGE CONTROL
- Purely DC load
- Reduction of active power demand
- Use of converter at partial loading

Inverse droop control:

- Electrolyzer sample image retrieved from Nel Hydrogen -
The sale of H₂ (production with cheap electricity) and syngas is the main financial revenue source.

The provision of ancillary services adds extra revenue to the power-to-gas business model.

Most interest in short product horizons and capacity payments.

In the new framework, prioritization of FCR and voluntary bidding for upward regulation aFRR.
CASE STUDY: GRONINGEN-DRENTHE-OVERIJSEEL AREA

- Grid topology according to TenneT’s development plan for 2030
- High cross-border power import and low conventional generation
- Issues to be investigated:
  » Preliminary assessment on voltage control and likelihood of congestions
  » Technical impact of the participation of electrolyzers in FCR
  » Combined operation of renewables and power-to-gas
**FCR PROVISION: EFFECTS ON FREQUENCY RESPONSE**

**Frequency nadir for different allocations of FCR capacity**

- **Only P2G**
- **10 MW CCGT + P2G**
- **Only CCGT**

**Frequency response for different allocations of FCR capacity**

**EVENT:** Loss of generation due to disconnection of wind turbines or sudden decrease of COBRAcable power import
Example of the coordinated operation between the wind park and the large-scale power-to-gas facility

**INTERACTION WITH WIND ENERGY GENERATION**

- Maximum consumption during cheap electricity hours
- Shutdown during the most expensive electricity hours
- Operation at partial load output
- No grid injection for low wind power output
CONCLUSIONS

- Technically, electrolyzers could participate in frequency balancing markets, voltage control and congestion management.
- Economically, FCR is the most attractive service due to the capacity payments and short product resolution (from 2021).
- The fast dynamics of electrolyzers improve the frequency response of the power system.
- Large-scale power-to-gas can become one of the potential solutions to mitigate renewable energy variability.
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