Unlocking grid flexibility:

November-7-2018
Jan Vorrink
TenneT at a glance 2017

Europe's first cross-border grid operator

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employees</td>
<td>4,068</td>
</tr>
<tr>
<td>EBIT</td>
<td>897 EUR million</td>
</tr>
<tr>
<td>Assets</td>
<td>20.4 EUR billion</td>
</tr>
<tr>
<td>Investments (2018-2028)</td>
<td>28 EUR billion</td>
</tr>
<tr>
<td>Connected offshore wind farms</td>
<td>17</td>
</tr>
<tr>
<td>Total grid length</td>
<td>23,000 km</td>
</tr>
<tr>
<td>Number of end-users</td>
<td>41 million</td>
</tr>
<tr>
<td>Number of transformer substations</td>
<td>462</td>
</tr>
<tr>
<td>Total HVDC stations</td>
<td>15</td>
</tr>
<tr>
<td>Grid availability</td>
<td>99.99%</td>
</tr>
</tbody>
</table>
Renewables challenge the Grid

Renewables fundamentally change how power grids work

The old Electrical Power System

Big fossil or nuclear power plants close to the industrial centers feed electricity into the transmission grid. The connected distribution grid supplies consumers.

The new Electrical Power System

Renewable energy, produced locally, sometimes far away from industrial centers and storage facilities provide electricity at all grid levels depending on the weather.
Distributed Flexibility

With an increasing amount of volatile renewable energy in the system, an **optimal dispatch of flexibility options is needed** to guarantee security of supply and affordability.
Innovation drives the Energy System of the Future

Decarbonisation and the resulting decentralization of power supply raise demand for digital innovations.
An economic layer the web never had

Transactions without blockchain

Transactions with blockchain

<table>
<thead>
<tr>
<th>Distributed system of records shared across a public or business network</th>
<th>Shared Ledger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crypto-graphy</td>
<td>Secure, authenticated &amp; verifiable transactions</td>
</tr>
<tr>
<td>All parties agree to verified transaction on the same network</td>
<td>Consensus</td>
</tr>
<tr>
<td>Smart Contract</td>
<td>Business terms embedded in ledger &amp; automatically executed with transactions</td>
</tr>
</tbody>
</table>

Note: **Bitcoin** operates on the basis of Blockchain technology, but a **Blockchain can be used for many more applications** than just Bitcoin.

November-7-2018  **Unlocking grid flexibility:**
There is a lot of potential

Blockchain is here to stay: foundational technology

Learn fast, fail often (business use cases)

Why blockchain?

The leading blockchain platform is not invented yet

Only store relevant data on-chain

Certify decentral sustainable energy production

→ Blockchain captures the end-to-end process in one ledger. All parties work on the same data.

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Unlocking grid flexibility: foundational technology

Gaining practical experience with blockchain technology and interfacing with existing TenneT systems and processes.

- Only store relevant data on-chain
- Learn fast, fail often (business use cases)
- Why blockchain?
- The leading blockchain platform is not invented yet

Aquarii: redispacth with home batteries

RepubliQ: aFRR with electric vehicles
Unlocking grid flexibility:

Aggregator Vandebron

Stop and postpone charging process: regulating up

Pilot description
- Voluntary aFRR bids (1 MW)
- Realtime data communication:
  - TenneT setpoint & verification
  - Aggregated power signals
  - Data on asset level
Unlocking grid flexibility:

automatic Frequency Restoration

- aFRR bids
- activation & measurements
- BSP
- tenneT

Taking power further
Unlocking grid flexibility:

**RepubliQ implementation**

- **Timeline**
  - 2017: first BC implementation
  - 2018: evaluation phase
  - 2019: to be determined

**Graphical Representation**

- TSO agents
- BSP agents
- Blockchain
- Bid agent
- aFRR bids (voluntary, 1 MW)
- Stop and postpone charging process: regulating up

**Notes**

- BSP (Blockchain Service Provider)
- TSO (Transmission System Operator)
- aFRR (Automatic Frequency Restoration Reserve)
Unlocking grid flexibility:

Evaluating activated bids

Power response of EV pool

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Unlocking grid flexibility:

Evaluating activated bids
Outlook

Continuation of pilots!

- Evaluation / operation with Vandebron: more cars, more bids
- Startup of aFRR pilots in Q3 2018
- Further development of blockchain pilot following European tender procedure
Thank you for your attention!

Questions?
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www.tennet.eu

Taking power further