Impact of System Resilience on TSO processes and hardware
Topics overview

- TenneT short overview
- Key tasks of a TSO
- Resilience
  - Mechanisms used
  - Defined Policies
  - Processes used
  - Data and Communication
  - New Developments
- The Energy market is changing
- Towards a reliable grid
- Questions
TenneT at a glance 2016

Europe's first cross-border grid operator

- **3,040** Internal employees
- **834** (EUR million) EBIT
- **18,974** (EUR million) Assets
- **25** (EUR billion) Investments (2017-2027)

- **22,573** km Total grid length
- **41** million Number of end-users
- **454** Number of transformer substations
- **15** Total offshore wind connections
- **99.9999%** Grid availability

Investments account for 16.7% of 150 billion in the EU. Number of end-users account for 7.7% of a total of 532 million in the EU.

*Figures for the year ended 31 December 2016 based on underlying financial information*

May-15-2017  Impact of System Resilience on TSO processes and hardware
TenneT at a glance 2015

Europe's first cross-border grid operator

- **2,974** Internal employees
- **1,075** (EUR million) EBIT
- **15,424** (EUR million) Assets
- **22** (EUR billion) Investments (2016-26)
- **22,245 km** Total grid length
- **41** million Number of end-users
- **454** Number of transformer substations
- **11** Total offshore wind connections
- **99.9975%** Grid availability

Investments account for 14.7% of 150 billion in the EU. Number of end-users account for 7.7% of a total of 532 million in the EU.

*Figures for the year ended 31 December 2015 based on underlying financial information*
TenneT at a glance

The Netherlands

Facts & figures

- Employees (internal): Approx. 1,320
- Assets: EUR 4.3 billion
- Imports: 30,759 GWh
- Exports: 22,013 GWh
- Total grid length: 10,118 km
- Number of transformer substations: 325
- Number of end-users: 17 million
TenneT at a glance

Germany

Facts & figures

Employees (internal): Approx. 1,650
Assets: EUR 13.2 billion
Imports: 52,289 GWh
Exports: 54,255 GWh
Total grid length: 12,127 km
Number of transformer substations: 129
Number of end-users: 24.3 million

NB: TenneT is one of the four German TSOs
Key tasks of a TSO

Our three key tasks

1. **Transmission services**
   Constructing and maintaining a robust and efficient high-voltage grid for the required transports.

2. **System services**
   Maintaining the balance between electricity supply and demand 24/7.

3. **Market facilitation**
   Facilitating a smooth functioning, liquid and stable electricity market.
Resilience

Wikipedia: resilience is the ability to provide and maintain an acceptable level of service in the face of faults and challenges to normal operation.

Resilience construct: Prevention, response, and recovery

- Which mechanisms are used within the European TSO's to achieve resilience during normal and extreme situations?
- How will this impact the normal processes of the TSO?
- What will be the impact of the increase of RES on these processes and which new processes have to be developed?
- Which Control center applications to support resilience are then needed?
Resilience - Which mechanisms are used

In Continental Europe a comprehensive set of Operational Handbooks has been developed. It ensures a framework for the Interconnected operation of the electricity grids.

https://www.entsoe.eu/publications/system-operations-reports/operation-handbook/Pages/default.aspx

Resilience requires a wide range of measures to ensure both “transport” and “system” services.

The N-1 Principle is a key principle:

Policy 3 A1-S1. N-1 principle. Any event of the contingency list (normal and exceptional types of contingencies considered in the contingency list) must not endanger the security of interconnected operation. After any of these contingencies the operational condition within the TSO’s responsibility area must not lead to the triggering of an uncontrollable cascading outage propagating across the borders or having an impact outside the borders: “no cascading with impact outside my border”.

May-15-2017

Impact of System Resilience on TSO processes and hardware
Resilience - Which Policies are defined

P1 Load-Frequency-Control and Performance
A. Primary Control
B. Secondary Control
C. Tertiary Control
D. Time Control
E. Measures for Emergency Conditions

P2 Scheduling and Accounting

P3 Operational Security
A. N-1 Security (operational planning and real-time operation)
B. Voltage control and reactive power management
C. Network faults clearing and short circuit currents
D. Stability
E. Outages scheduling
F. Information exchanges between TSOs for security of system operation

P4 Co-ordinated Operational Planning
A. Outage Scheduling
B. Capacity Assessment
C. Capacity Allocation
D. Day Ahead Congestion Forecast
E. Congestion Management

P5 Emergency Procedures

P6 Communication Infrastructure
A. The EH Network, Architecture and Operation
B. Real Time Data Collection and Exchange, File Transfer data Exchange, ...

P7 Data Exchanges
A. Code of conduct and generic rules to handle the data

P8 Operational Training
Which processes are used to ensure Resilience

Analysis of grid data in many different time frames and in different scale or geographical area

- Starting Ten year ahead with a “Capacity and quality plan” for our own TSO area and on EU scale “Ten Year Network Development Plan” (TYNDP) to link all the national plans
- Yearly outlook for summer and winter worst case scenario’s per TSO and for EU
- Regional coordinated outage plans for generation and grid to secure safe transport yearly and / or quarterly
- Week ahead “Short and medium term Adequacy plans” per TSO and for EU
- Week ahead operational plan to align new developments
- Two days ahead Market coupling capacity calculations Based on forecasted load and based on the generation shift between renewables and conventional generation and between the countries, which results in the transport needs which need to be safely available.
- Day ahead congestion forecast calculations per TSO and merged results per region and for EU with local measures to reach a safe transport forecast per TSO and regional coordination of these measures and merging of all these results including feedback loops of the interdependencies.
Which processes are used to ensure Resilience

- During the day, hourly updates of the congestion forecast
- Local intra day measures to reach a safe transport forecast per TSO and regional coordination of these measures and merging of all these results including feedback loops of the interdependencies
- Real time load flow calculations based on TSO wide measurements (every few seconds) of all the relevant parameters.
- Grid safety calculations (at least every few minutes) for the contingencies in the TSO’s grid and the neighboring “Observability area” where outages would have significant influence
- Real time measurements of the frequency and activation of corrective fast reserves to stabilize the frequency with Real time calculation of the imbalance of the TSO area and Real time signal for correction of the imbalance towards production (or load) to regulate up or down.
- Real time analysis of the potential for exchanging the imbalance with a foreign TSO which has an opposite imbalance
- Realtime measurements are needed faster (milliseconds) to detect fast dynamic instability based on Phasor Measurement
Resilience - data and communication

How do TSO's reach a resilient data and communication infrastructure?

Two levels:

• Within the TSO’s Area
  • Private glasfiber Network in the overhead lines

• Between the TSO’s. The Electronic Highway (EH)
  • The EH is a private network dedicated to data exchange between electricity sector TSOs and operates under the responsibility of the TSOs with two ENTSO-E RG CE Network Operation Centres (NOCs).
  • The primary scope of the EH is the real-time data exchange, in support of TSO operational processes, aimed at enhancing the security of electricity supply in Europe.
  • ENTSO-E is developing a separate Operational Planning Data Environment

All communication has redundancy and backup power supply.
Are there new infrastructure requirements that need to be implemented?

- Electronic Highway capacity increase needed
- Other Synchronous Areas in EU also connected to EH
- More frequent data exchange
- Interaction of data with market parties much more relevant
- Implementation of CIM based data exchange
- More IP based communication standards
- Cyber security, ISO 27000 implementation, NERC
Which strategies can be applied, are new strategies under development, can we use new infrastructure design as a strategy for increase of resilience?

- Well developed Operational Planning and Real Time processes
- Next generation SCADA-EMS infrastructure and software
- New functions in Protection Devices and software
- Better protection of Substations and grid
- Prepare for Climate change effects like extreme weather and flooding
- More intensive Crisis training in wider organizational context
- Better ENTSO-E wide crisis communication tooling
The energy market is changing
Increase in renewable energy and local generation

- **Share of renewable energy**
  - 2013: Realization
  - 2020: Objective

- **Share of renewables in electricity mix**
  - 2013: Realization
  - 2020: Forecast

Netherlands needs to catch up. Netherlands might outperform Germany.

- **Share of wind and solar in electricity mix**
  - 2013: Realization
  - 2020: Forecast

Share of electricity from renewables will have increased fivefold by 2020.

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<th>2020</th>
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Consequences and challenges

Connecting renewables to the grid and integrating them into the system

Connecting offshore wind farms

- High investments
- Shorter lifespan for infrastructure (offshore)
- Shorter lifespan for generation capacity (wind turbines; solar panels)

Integration of solar energy

- Peak in generation when demand is low
- Issues with voltage level
- Investments in the grid for large surfaces with solar panels, often at remote locations
Integration of renewables

Consequences for conventional power plants

- Conventional plants will sell lower volume against (on average) lower prices
- Prices will rise at times without wind or sun
- Power plants will keep delivering system-supporting services

**Situation in 2012**
Sunny, windy day; daytime load

**Situation in 2020**
Sunny, windy day; daytime load
Radically changing role and tasks of TSOs

From

• Stable, predictable (price-driven) energy generation
• Maintenance and (limited) replacement
• Focus on technology
• Local markets, separate price zones
• National focus and regulation

To

• Fluctuating (sun/wind) energy generation
• Large-scale new construction
• Technology and market
• North-Western European market, price convergence
• Grid planning and regulation at European level

New roles and tasks of TSOs
At the European level, arrangements have been laid down in codes governing connections, operational management, and market cooperation.
Onshore – Netherlands

Approx. EUR 4 billion over the next ten years

Largest projects:
• Randstad 380 kV North Ring
• North-West 380 kV
• South-West 380 kV
• Doetinchem – Wesel 380 kV
• Zwolle-Diemen-Geertruidenberg-Maasbracht (2 x 380 km)
• Noordoostpolder (NOP) 110 kV
Onshore – Germany

EUR 9 to 10 billion over the next ten years

• Some 2,000 km of new connections planned: 15 large-scale onshore projects and hundreds of smaller projects
• Wind energy to be transported from the north of Germany to the south
• SuedLink: With 800 km and 2 x 2 GW the largest DC connection in Germany
• Linking up new power plants to the grid
Offshore – Netherlands

Approx. EUR 2 billion over the next ten years

- Offshore maintenance team to be established in Groningen
- Cable storage at Eemshaven
- Special team for Offshore Grid NL
- Partnership with Stichting Natuur & Milieu
- Route design and permit procedure for Borssele project

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<th>Start</th>
<th>Operational</th>
<th>Capacity</th>
<th>Area</th>
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<td>2019</td>
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<td>Borssele I</td>
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<tr>
<td>2016</td>
<td>2020</td>
<td>700 MW</td>
<td>Borssele II</td>
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<tr>
<td>2019</td>
<td>2023</td>
<td>700 MW</td>
<td>Dutch coast: North Holland</td>
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Offshore – Germany

EUR 6 to 7 billion over the next ten years

- Available in 2015: 5,221 MW
- German objective for 2020: 6,500 MW

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<tr>
<th>Projects</th>
<th>Capacity (MW)</th>
<th>Operational</th>
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<tr>
<td>BorWin2</td>
<td>800 (DC)</td>
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<td>DolWin1</td>
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<td>DolWin2</td>
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<td>DolWin3</td>
<td>900 (DC)</td>
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<td>SylWin1</td>
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<td>BorWin3</td>
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<td>Nordergründe</td>
<td>111 (AC)</td>
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<td>Alpha Ventus</td>
<td>62 (AC)</td>
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<td>Riffgat</td>
<td>113 (AC)</td>
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<td><strong>Total</strong></td>
<td><strong>7,132</strong></td>
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Questions?
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www.tennet.eu

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