



Wind Research for North Sea Wind Energy
Secure sustainable electricity supply

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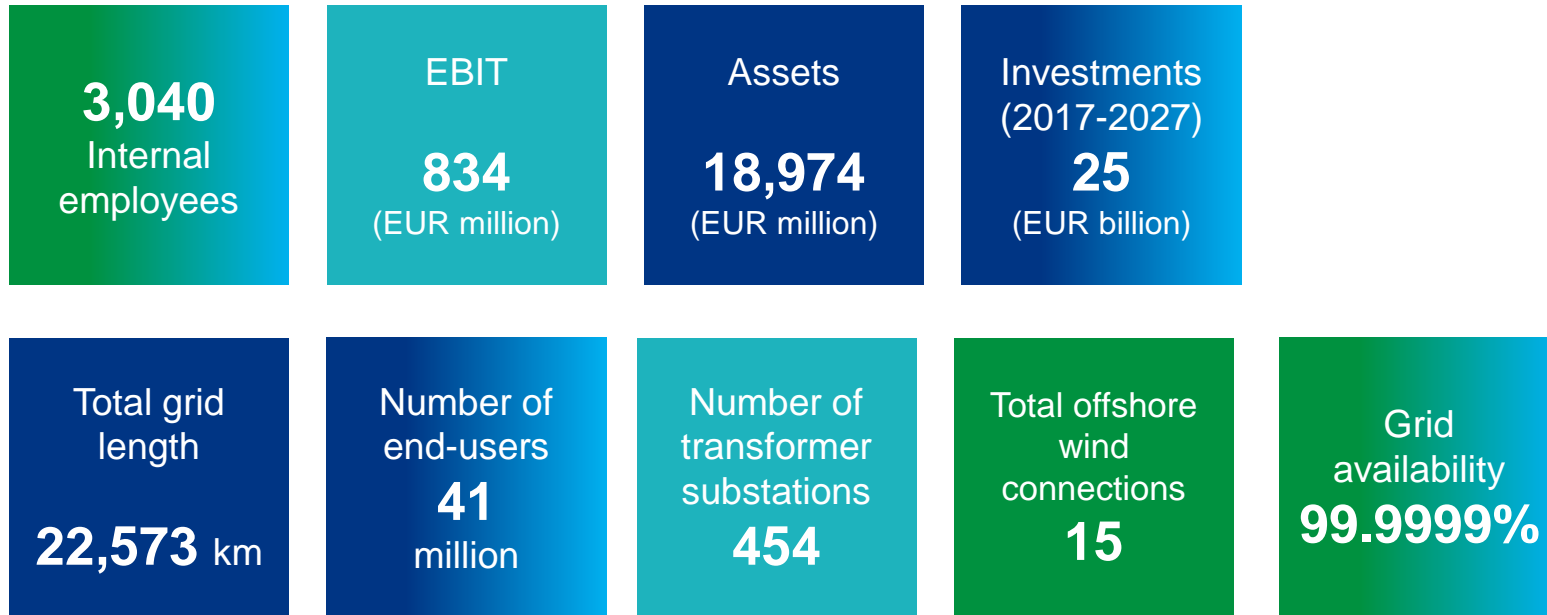
Topics overview

- TenneT short overview
- Key tasks of a TSO
- New tasks TenneT
- The Energy market is changing
- Offshore Wind program TenneT
- System Operation – More Detailed

TenneT at a glance 2016



Europe's first cross-border grid operator



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

TenneT at a glance



The Netherlands



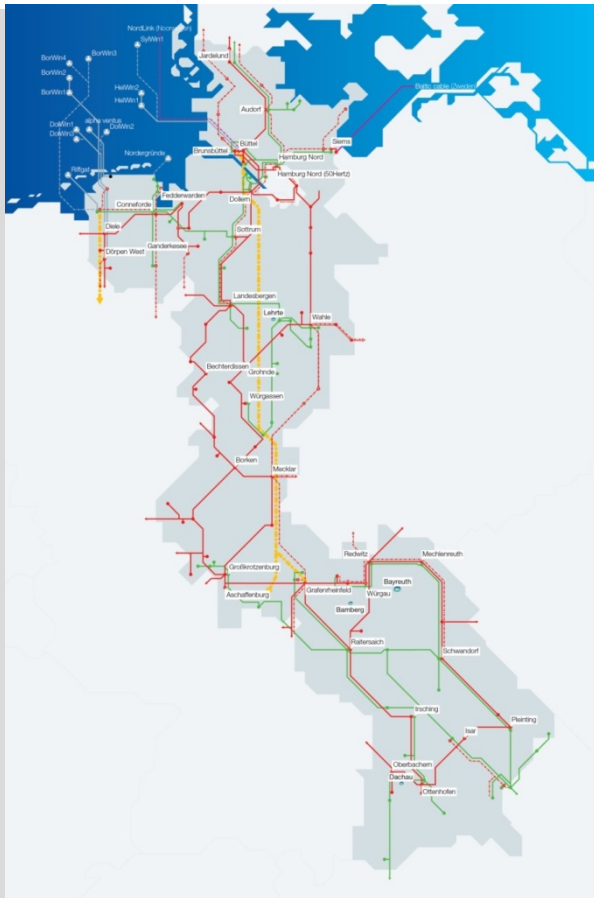
Facts & figures

| | |
|------------------------------------|-----------------|
| 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

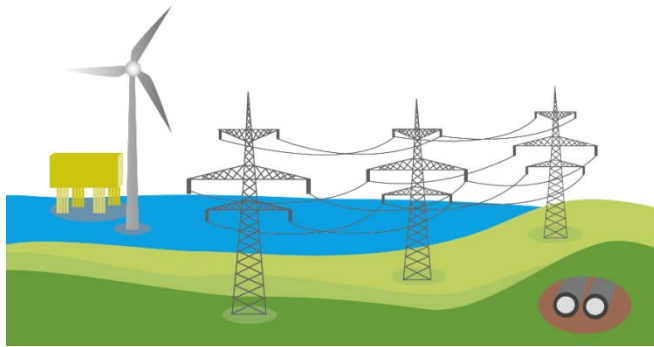


Facts & figures

| | |
|------------------------------------|------------------|
| 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

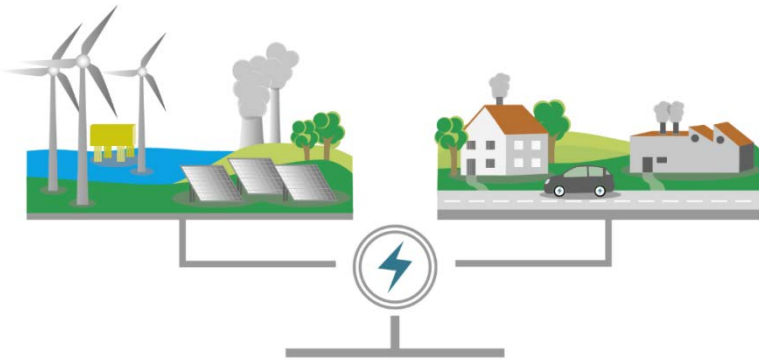
Key Tasks TenneT



1

Transmission services

planning, constructing and maintaining a robust high and extra high voltage grid



2

System services

maintaining the balance between electricity supply and demand at all times



3

Market facilitation

facilitating a smoothly functioning, efficient, liquid, and stable electricity market



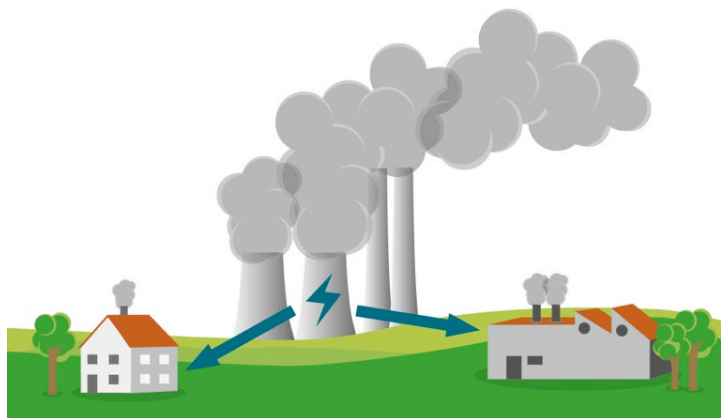
Renewables challenge the Grid

Renewables fundamentally change how power grids work

The old Electrical
Power System



The new 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.



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.

Demand-side management (DSM)



Storage



Flexible supply



Energy efficiency/savings



Phased development offshore wind

Three phase (parallel) development:

- | | | |
|-----------------------|---------------|--|
| Short Term (to 2023) | NL: 3,5 GW | ➤ Currently under development (near shore) |
| Medium Term (to 2035) | NL: 7 – 10 GW | ➤ Use full potential near shore locations ➤ Prepare for large scale and international cooperation |
| Long Term (to 2050) | 70 to 100 GW | ➤ North Sea Wind Power Hub ➤ International cooperation necessary |





Processes to secure electricity supply 1/3

Scenario's of wind production and other electricity sources are used for 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 operational plan to allign new developments



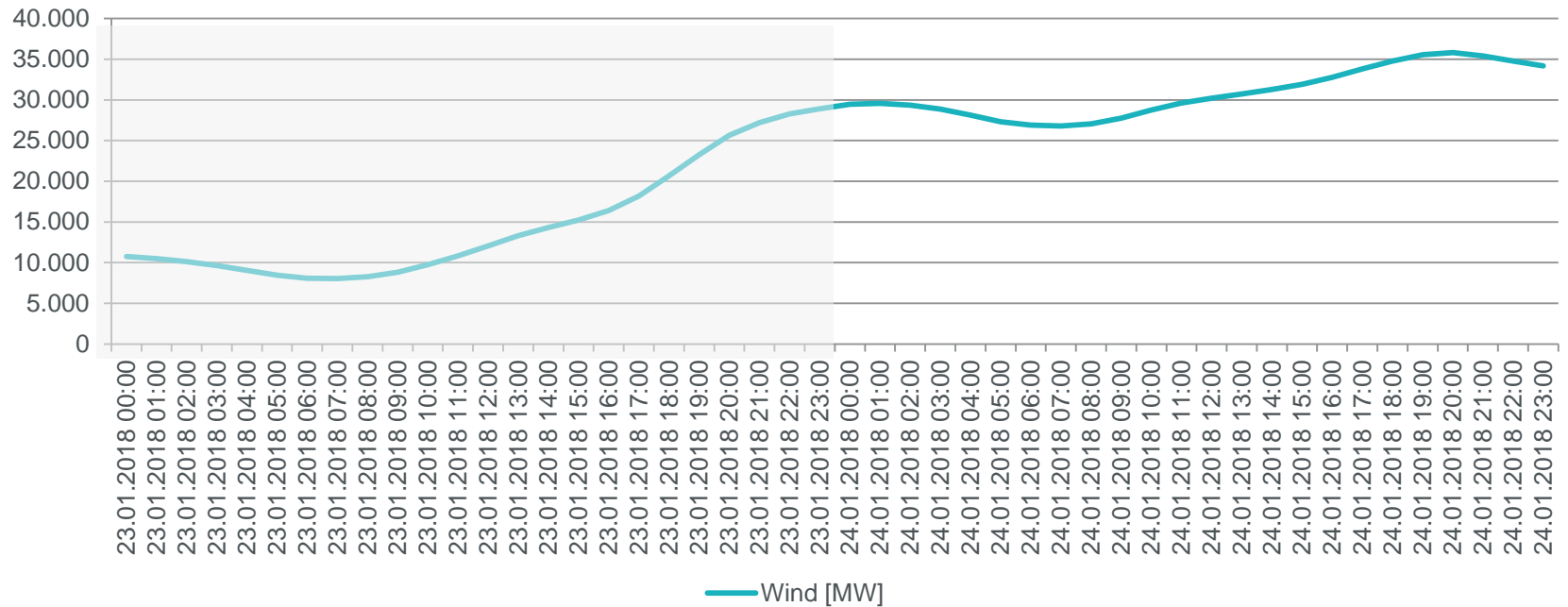
Processes to secure electricity supply 2/3

Forecasts of wind production and other electricity sources are used for Analysis of grid data in many different time frames and in different scale or geographical area:

- Week ahead “Short and medium term Adequacy plans” per TSO and for EU
- 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,
- 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.



Prognosis Wind DE





Processes to secure electricity supply 3/3

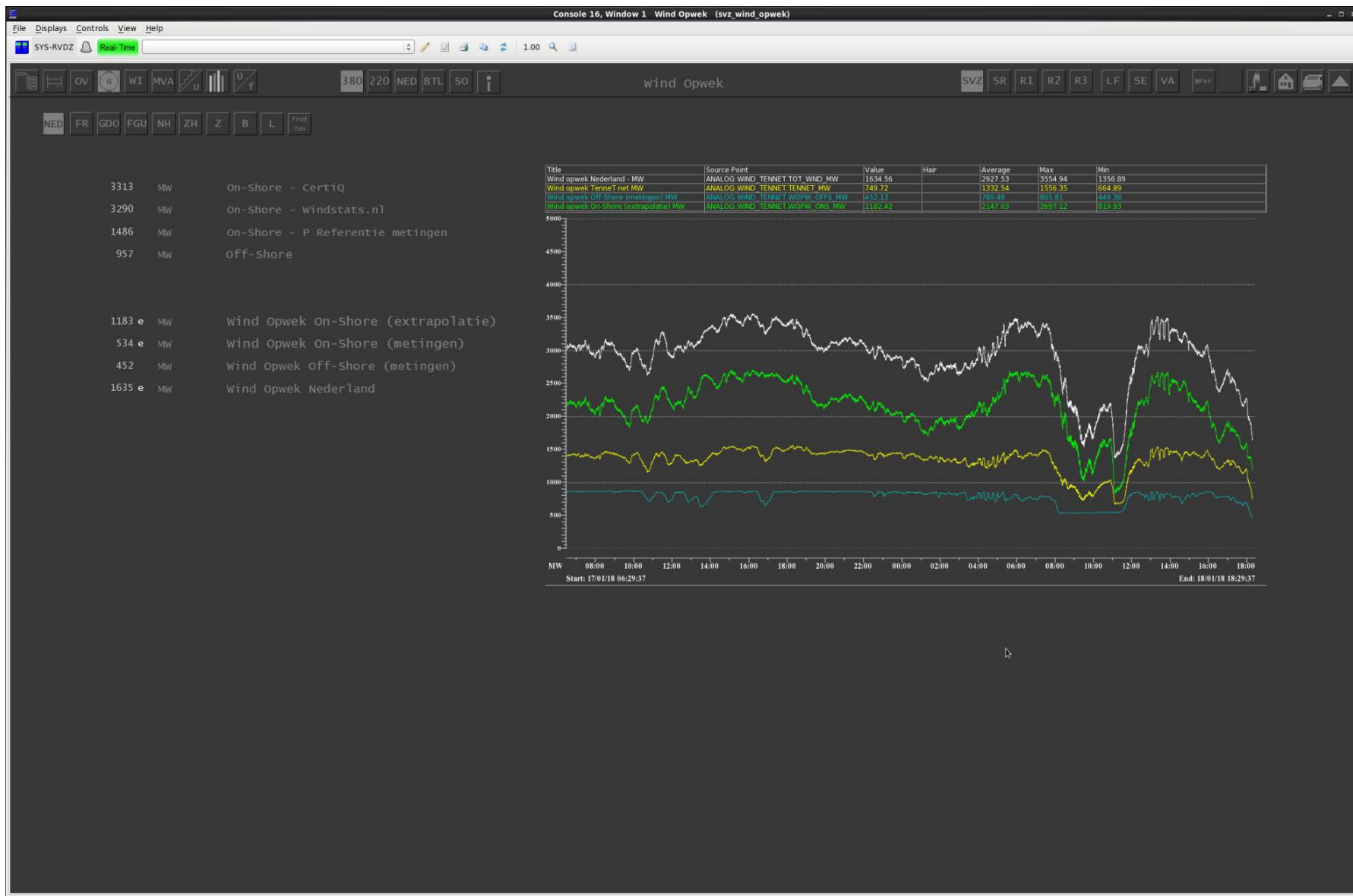
Forecasts of wind production and other electricity sources are also used for:

- During the day, hourly updates of the congestion forecast and Local intra day measures to reach a safe transport forecast per TSO and regional coordination of these measures and merging of all these results

Real time measurements of wind production and other electricity sources are used for:

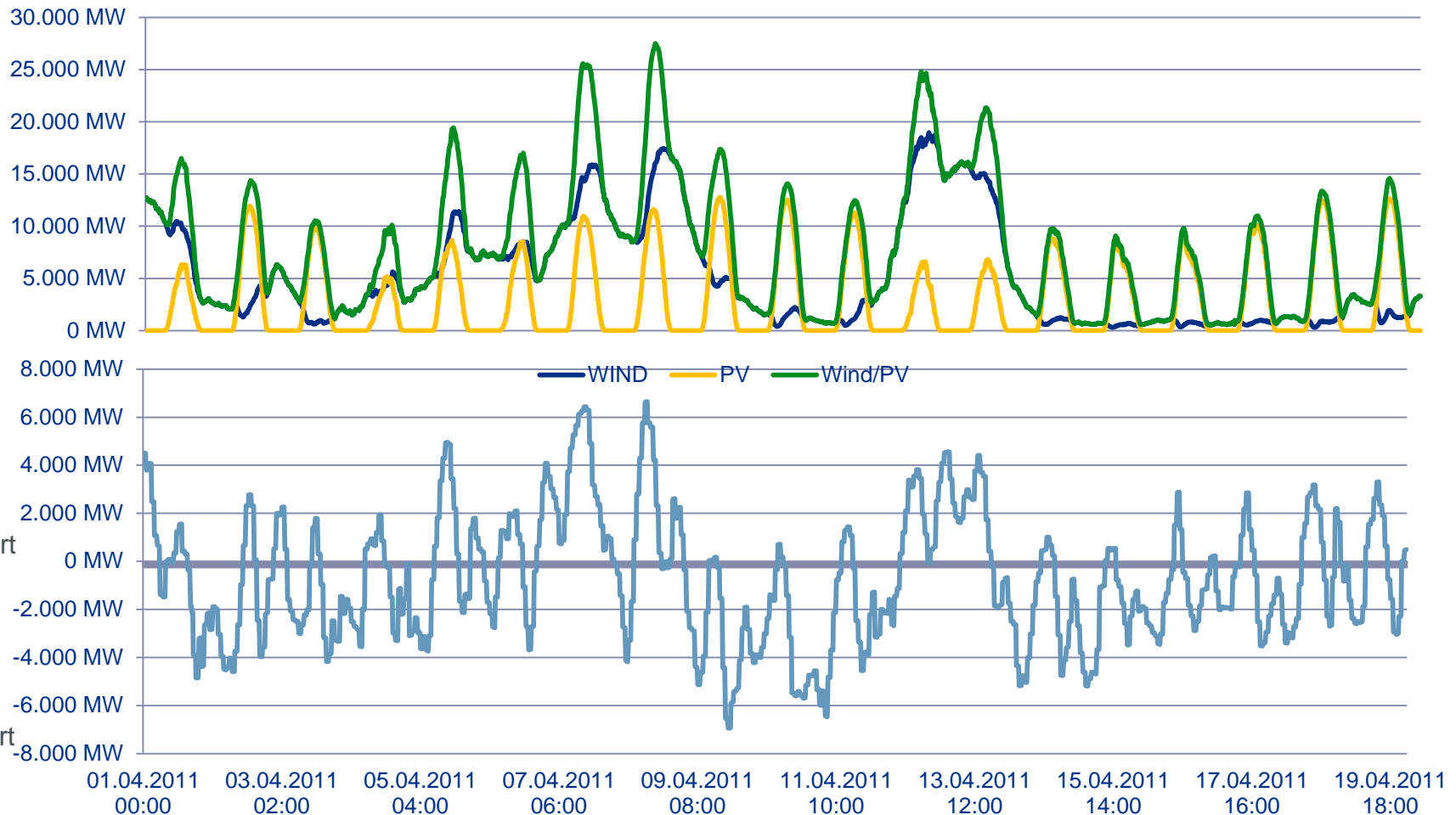
- Real time load flow calculations based on TSO wide measurements (every few seconds)
- Grid safety calculations (at least every few minutes) for the contingencies in the TSO's grid and the neighboring "Observability area" where outages would have significant influence
- Real time measurements of the frequency and activation of corrective fast reserves to stabilize the frequency with Real time calculation of the imbalance of the TSO area.

Realtime measurements of wind production And switching off during Storm on 18th January 2018





Increased volatility of Renewables infeed



Questions?



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www.tennet.eu

TenneT is Europe's first cross-border grid operator for electricity. With about 21,000 kilometres of (extra) high-voltage lines and 36 million end-users in the Netherlands and Germany, we rank among the top five grid operators in Europe. Our focus is to develop a North-west European energy market and to integrate renewable energy.

Taking power further

