Global grid

Elia grid
Impact of renewable energies
Global grid
Energy future
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Elia presentation 01/12/2017  Jean-Jacques Lambin
Le Groupe Elia

Le groupe Elia, une position unique au coeur de l’Europe

Le groupe Elia s’articule autour de 2 gestionnaires de réseau de transport haute tension (GRT),

Elia en Belgique,
50Hertz en Allemagne
The TSO is a vital link between the production and the industrial or private consumers.
Elia in some numbers

- 800 high voltage substations
- 30,000 pylons
- 5,560 km overhead lines
- 380,000 km underground cables
- 2.800
- 81.7 TWh

Elia is de Belgian Transmission System Operator (30 kV - 380 kV) managing over 8,400 km lines and underground cables.

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Short-term/Medium-term planning
Permanent monitoring of all equipment

Any component, even the largest (1,000 MW power plant, international line), can be tripped
  - Always check that the N-1 is covered. If NOK, look for a solution as quickly as possible.

The more stressed the base case (N), the more critical the N-1 case

Importance of short-term and medium-term planning
N-1 concept

Example 1

Station A

100 MVA

Line 75 MVA

Station B

Line 75 MVA

N-1 NOK
N-1 concept

Example 2

Station A

75 MVA

Line 75 MVA

Station B

Line 75 MVA

N-1 OK
Iterative planning process

- Planning Revision Generation
- Need to cut grid components in Belgium and abroad
- Belgian load (+import/export)
- Suggested unavailability 365 days Y+1
- Modification of suggested unavailability
- 365-day analysis
  - Load flow + N-1
- Process launched in Y-1 and ends on D-1
  - Plan approved
  - NOK
  - OK

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Schedule

The process is iterative and each day is analysed at least seven times.

The closer day D, the more accurate the data and hypotheses.
Day Ahead Congestion Forecast: 25 countries
Italy, black-out on 28 September 2003

The N-1 rule was not respected
Import/export capacities
Market coupling
Import/export capacities
Import/export generates Loop flows

Potential import/export capacities

**Problem of loop flows**

Controlling loop flows

Electricity follows the laws of physics:
path of least resistance
Impacts of wind power on the Elia grid

- Unscheduled flows:
  - Caused by wind farms located in neighbouring countries (north of Germany)
  - Variations between -2,000 and 2,000 MW on the Belgian grid
Flow management

Installation of Phase Shifter Transformers on the Northern border for managing increasing Loop flows
Coreso: centralised coordination between TSOs

- The first Regional Technical Coordination Service Centre
- Independent company (SA) with its own employees
- Created December 2008 in Brussels
- Operational since 16 February 7d/7 (afternoon shift)
- Round-the-clock operations since 29 June 2009
- Employs 25 engineers (18 are on shift)
Impact of import/export capacities on the markets

Market Coupling
Market Coupling
**Market Coupling (basic concept)**

- **Market A**
  - Purchase: PA
  - Sale: QA
  - Export: QA

- **Market B**
  - Purchase: PB
  - Sale: QB
  - Import: QB

- Isolated price Market A < isolated Price Market B
- Market A can export to market B (purchase- and sale curve shift)
Market Coupling (basic concept)

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**Market Coupling (basic concept)**

- Isolated price Market A < isolated Price Market B
- Market A can export to market B (purchase- and sale curve shift)
- Prices market A and B converge till price market A = price market B
Impact of renewable energies on grid management
20-20-20 targets

Resources available in Belgium

• 1) Major offshore/onshore wind farms
• 2) Decentralised generation
  • Small wind farms/individual wind turbines
  • Photovoltaics
  • Industrial/individual cogeneration units (Stirling)
  • Biomass
  • Small hydraulic units

Considerable decentralised generation potential
Germany, incident on 4 November 2006

Le Norwegian Pearl
Incident on 4 November 2006
Incident on 4 November 2006

Europe is divided into 3 electric zones
Impact of decentralised generation on Elia’s activities

- Although decentralised generation units are connected to DSOs’ grids, as the volume of these units is growing significantly, it affects the overall management of the electricity grid in Belgium.

1. Management of the electricity grid in Belgium

1. Balance between generation ↔ load
2. Management of system services: Prim R, Sec R, Tert R, voltage control
3. Management of flows, import/export, Must Run
4. System security, safeguard plan
Management of the electricity grid

- **Balance between generation ↔ consumption**
- **AC electricity is not stored, generation and consumption must always be balanced**

* Source: Elia Communication
Management of the electricity grid

• **Available resources: system services**

  ➢ **Primary reserve (R1):** 3000 MW in ENTSO-E. Enough for facing the loss of 2 of the biggest nuclear plants within 15’
  Frequency deviations and involuntary power exchanges on borders occur

  ➢ **Secondary reserve (automatic):** Used in order to restore the initial balance between generation and consumption and thus restore frequency and cross border power exchanges.

  ➢ **Tertiary reserve (manuel):** In case of larger imbalances in the control area.
Impact of forecasting errors

Delta $P = 1211\text{W}$
($=43\%$ of $P_{\text{installed}}$)

Delta $P = 729\text{W}$
($=41\%$ of $P_{\text{installed}}$)
Impact on CWE merit order

- Min load (summer night)
- Max load (winter day)

Marginal cost €/MWh

- Nuclear
- Biomass and/or Cogeneration unit (priority - must run)
- P.V. (priority)
- Wind (priority)
- CCGT
- OCGT
- Hydro storage
- Peak generation unit (reserve, incident)

PV: photovoltaic
CCGT: combined cycle gas turbine
OCGT: open cycle gas turbine

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CWE Prices 20/11/2016
New needs to be taken into account

- **Balance between generation ↔ load**
  - Good overview of decentralised generation units per domain of activity and substation
  - Wind/solar/temperature forecasting tools
  - System service management: takes into account the intermittent nature of renewable energies as regards the volume of reserves
    ✔ Prim R, Sec R, Tert R
Wind Forecasting

Weekly Belgian Wind–Power Forecasting

- Measured & Upscaled
- Most recent forecast

Most recent forecast P10
Most recent forecast P90
Solar Forecasting

Solar–PV Power Forecasting for Belgium

- Measured & Upscaled
- Intraday forecast
- Day-ahead Forecast

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Wind power
Available theoretical power

The available wind power \( P_{\text{vent}} \) is equal to:

\[
P_{\text{vent}} = \frac{1}{2} \rho A v_{\text{vent}}^3 \quad [W]
\]

- \( \rho \) = Air density
- \( A \) = Area swept by the blades
- \( v_{\text{vent}} \) = Wind speed [m/s]

Example:
Wind speed: 10 m/s, Rotor diameter: 82 m

Wind power: \( 1/2 \times 1,225 \times 5,281 \times 10^3 = 3.235 \text{ kW} \)
Captured power by the wind turbine = Wind power \( \times \) \( cp \)
\( Cp \) : performance coefficient, theoretical maximum = 0.59
Power curve = f(wind speed)
Restrictive areas in wind turbine operation
Onshore farms

Monthly generation of a farm

UNIT = KW
MAX: 7920L TUE 12 08:15
MIN: 0L FRI 1 00:15
ENERGY= 1208972 KWH
Onshore farm

Monthly monotonic curve for the same farm

PMAX (100% PREF) OF 2976 QUARTERS = 7920 KW THE TUE 12-MAY-09 08:15
2. **Underfrequency:**

   Optional active power boost, using the inertia of the rotor.
   - $P_{\text{boost}} = 10\% P_{\text{rated}}$
   - Available as soon as $P_{\text{actual}} \geq 4\% P_{\text{rated}}$
   - $P_{\text{boost}}$ fully available within 800ms
   - Boost for max. 10 seconds
   - Recovery time after boost = $2 \times T_{\text{boost}}$

- Performance achieved by changing excitation, using rotor inertia.
- Activated based on local frequency measurement.
- Additional investment in WF necessary.
- Cost relevant => Economical value for the power system?
- Impact to the max. installable wind power?
Photovoltaics
Potential in Europe

Yearly total of global irradiation on horizontal surface

200 500 800 1100 1400 1700 2000 [kWh/m²]
Risk of disconnection at 50.2 Hz

- For low frequency: average 5000 MW/Hz
- 14700 MW disconnection
- Around 50 Hz: 26600 MW/Hz
- PV trips

Outage plan

DE, BE, FR, AT = 15,000 MWp
VDE 0126 standard
Tripping at 50.2 Hz

Risk of increasing uncontrolled frequency fluctuations
taking into account the f-sensitivity of generation (primary reserve + self-regulation) and load
Modification of the standard: gradual reduction of generation

- New units (from 2012 onwards)
  - Gradual reduction of generation
- Existing units
  - Coordinated retrofitting

![Graph showing active power in relation to frequency]

Droop analog to conventional power plants
Droop by stochastic distribution of over frequency tripping settings
Voltage problems
Standard DIN VDE 0126-1-1

- Maximum instantaneous voltage: 264.5 V (115%)
- Maximum average voltage over 10 minutes: 253.0 V (110%)
- Former instantaneous limit: 243.8 V (106%)
- Reconnection after 30 seconds
Consequences at low voltage

- U: 245 V
- 264 V (contractual) Max PV (sunny)
- 250 V Low load
- 253 V (contractual) Max PV (sunny)
- 207 V (contractual) 0 PV (not sunny) Maximum load

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Fig. 4: Among others, the reactive power may be regulated as a function of the supplied active power.
Global Grid
Renewable Energy in Germany

- WIND

- SOLAR
European Objectives 2040-2050

- Energy efficiency
- Electrification
- Share of RES

The total energy consumed will be reduced with additional energy efficiency measures.
The electricity share in the final energy consumption will increase with additional electrification.
The increase of renewables in the energy mix and particularly in the electricity sector will increase.
Types of storage and limitations

- Hydraulic: pumped storage
- Lithium ion batteries
- Biomass
- Power to Gas: H2 or CH4
- CAES (compressed air energy storage)
- Kinetic energy
- Sensitive or latent heat
- Etc.
2040, need storage and flexible demand during periods of no wind and no sun

* 18 GW of PV
11 GW of wind

** if connected permanently to the grid and batteries of EV only used to store energy to balance the system
Global Grid
Technical characteristics of the global grid

Need:
Transport of very large power over long distances

Adapted technology:
Direct current links
- Low losses
- Easy flow modulation
- Participation in system services
Nemo Link: new electricity interconnector between UK and the continent
# The ALEGRO interconnector

| Converter station technology | HVDC VSC multilevel Symmetrical Monopole |
| Bi-directional capacity      | ~ 1000 MW |
| Cable technology             | HVDC XLPE |
| Applied DC voltage           | 320 kV |
| New interconnection          | Belgium Germany |
| TSO                          | Elia Amprion |
| Region                       | Liège Aachen |
| Converter station location   | Visé Oberziger |
| Route length                 | 49 km 45 km |

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**Diagram:**

- **Réseau AC**
- **Travée de raccordement AC**
- **Conversion AC/DC**
- **Câble DC**
- **Conversion AC/DC**
- **Travée de raccordement AC**

**Countries:**

- **BELGIQUE**
- **ALLEMAGNE**
Energy future
Energy future
Energy future

**Technical problem**
- Intermittence of renewable energies
- Variability of renewable energies
Problems to be solved locally, at European level and with global grid

**Political issue**
- Nuclear shutdown
- Réduction of CO2 emissions
Global problem to solve at planet level
Energy future

![Graph showing CO2 emissions from 1960 to 2020, with a significant increase in the last decade. The graph includes data from US, EU, Belgium, World, India, and China.]

![Pie chart showing the distribution of CO2 emissions by country in 2016: China 28%, USA 17%, EU 10%, Others 45%.]

Samuele Furfari  Data: BP 2016
Many thanks for your attention!

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