Adaptation of the French Transmission Network to Climate Change
Underground Lines Resilience

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Outline

The RESILIANCE project

Climate Data

Impacts of heat on underground lines

Summary
The power network is dependent on weather and climate ...

Supply / Demand Balance
Resource Adequacy Assessment

... at all time scales

Network Resilience

Climate Change & REs Development will increase the dependance ➔ Weather & Climate Services are a critical ingredient of the energy transition
First step: identification and classification of risks

- Freezing Rain
- Freezing clouds in the mountains and plains
- Sticky Snow
- Tornadoes & Wind Gusts
- Flooding
- Sea Level Rise
- Wild Fires
- Heat Waves
- Cold Waves
- Winter Storms

Priorisation of most critical risks
Addressing most critical risks

- Soil Wetness / Droughts
- Heat waves
- Flooding (sea level rise & marine submersion)
- Flooding (rivers)
- Overhead Lines & Pylons
  - Underground Lines
  - Power stations

RESILIENCE Project
Climate data under consideration: 1- Current climate

ERA5-land

- 2001-2022
- 0.2° resolution, daily average
- T2m + average Soil temperature in Layer 1 [0.3-1m] and Layer 2 [1-2.9m]

HIRLAM

- 2001-2014
- 0.2° resolution, daily average
- Computation of mean temperature in the same layers
Climate data under consideration: 2-Reference Projections

Simulated data: (Météo-France)

Adjusted against HIRLAM 1985-2014

3 simulations sets with « constant climate » (constant CO₂ levels)

- 200 years « climate 2000 »
- 200 years « climate 2050 » RCP4.5
- 200 years « climate 2050 » RCP8.5

Available data

- Temperature T2m and -1m
- Cloud Cover
- Wind Speed
- Solaire Irradiance
- Precipitation & river flow

200 years, hourly time resolution 37,000 points over Europe

Data on more than 37,000 grid points over Europe

Black dots represent the actual observations over the last 33 years
Bias correction with Hirlam Reanalysis
Extrapolation of extreme temperature values
**Our network (63 kV to 400 kV)**

- >106,000 km of power lines and 2,783 substations currently in operation
- 22,750 km of optical fibres

Of which underground lines (mainly 63-90 kV) represent:

- > 7,000 km (2022), likely to increase significantly in the next decades

Mainly in urban and protected areas and for offshore wind farms connections landing

The dimensioning requires the max temperature in the ground
The starting point

Current heat transfer model

\[ \theta(y, t) = \theta_0 + \theta_1 \times e^{-y/\delta} \times \cos\left(\omega t + \varphi - \frac{y}{\delta}\right) \]

\[ \delta = \sqrt{\frac{2\lambda}{\mu c \omega}} = \sqrt{\frac{2a}{\omega}} \quad a = \frac{\lambda}{\mu c} \]

\( \lambda \) : soil thermal conductivity (in W/m/K)
\( \mu \) : soil density (in kg/m3)
\( c \) : soil specific heat capacity (in J/kg/°C)
\( a \) : soil thermal diffusivity (in m²/s)

NUTS2 resolution, 2 values per zone (1 for winter, 1 for summer) max of the NUTS2 grid points daily average temperature (rounded to the upper integer value)
Current heat transfer model - Maps

Summer

Depth = 3m

Winter

What will be the impact of climate change?

**Summer**
- $T^\circ_{min}$: 16°C
- $T^\circ_{max}$: 24°C

**Winter**
- $T^\circ_{min}$: 12°C
- $T^\circ_{max}$: 21°C
Comparison of the soil temperature obtained with 2 different approaches:

ERA5-Land: direct model output
HIRLAM: T2m + diffusion model

*Temperature from both reanalysis are very close at the surface*
Temperature diffusion model into the ground

ERA5-Land: direct model output
HIRLAM: T2m + diffusion model
Results

Soil temperature uncertainties

HIRLAM ~ERA5-land at the surface but significantly cooler with increasing depth

ERA5-Land: direct model output
HIRLAM: T2m + diffusion model
Differences increase with depth

HIRLAM ~ERA5-land at the surface but significantly cooler with increasing depth

(200 points chosen randomly)
Impact of soil thermal resistivity?

T2m from ERA5-land + ground thermal diffusion model, with different soil thermal resistivity values

T2m from ERA5-land + ground thermal diffusion model, with default value = $5 \times 10^{-6}$ m$^2$.K/W

ERA5-land soil temperature
What about projected values?

+1°C corresponds to a transit loss of 1-2%

200 randomly chosen points over France, depth = 1m
Take away messages

- Significant **uncertainties** depending on data source
- The current cables’ design model has **comfortable margins**...
- ... but it doesn’t take **soil wetness** and **soil’s nature properly** into account...
- With **Climate Change**, **soil humidity** may become critical and the model needs to be improved
- **Observations** of soil temperature and humidity are scarce!
- No assimilation of such data in reanalysis products? ... and what about the **quality in climate projections**?

▶ Some research & work is needed here!
Thank you

Contact: laurent.dubus@rte-france.com
RTE operates and maintains >106,000 km of power lines

RTE enlightens the public and decision makers

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RTE maintains a constant balance between power supply and demand 24/7

In compliance with its legal obligations (Generation Adequacy Report) and at the request of the French government, in 2019, RTE launched a wide-ranging study on the evolution of the power system called “Energy Pathways to 2050”.