Extremes and the energy system: a short introduction

Summer school Energy, mathematics, and theoretical challenges
2 October 2024

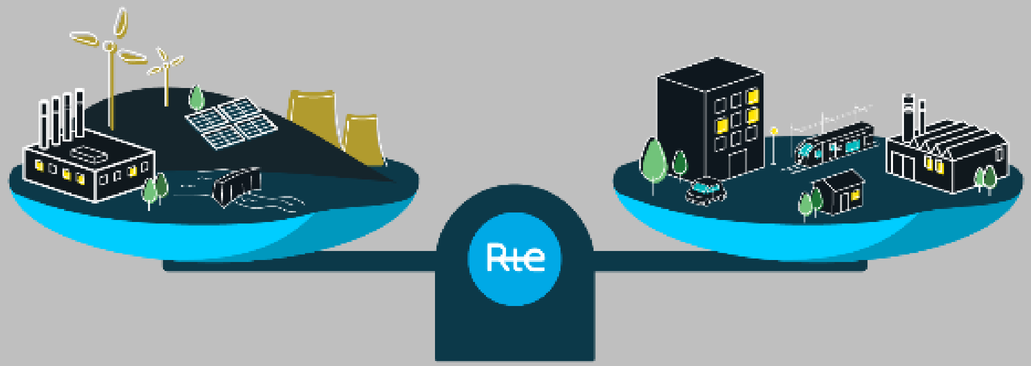
Laurent Dubus, R&D, Expert Météo & Climat

Thanks to Catherine Lelong

Weather and climate impact the transmission power network

Network Resilience

Supply/Demand Balance
Resource adequacy



The power system is sensitive to weather and climate variability, and in particular to extremes

Power systems are exposed to multiple hazards

Warm/Extreme heat

- Increase in mean temperature
- Heat waves
- Droughts
- Wild fires

Cold

- Freezing rain
- Freezing fog in plains
- Freezing cloud in the mountains
- Sticky snow
- Cold wave

Water

- River flooding (overflow)
- Runoff
- Rising water table
- Rising sea levels and coastal erosion

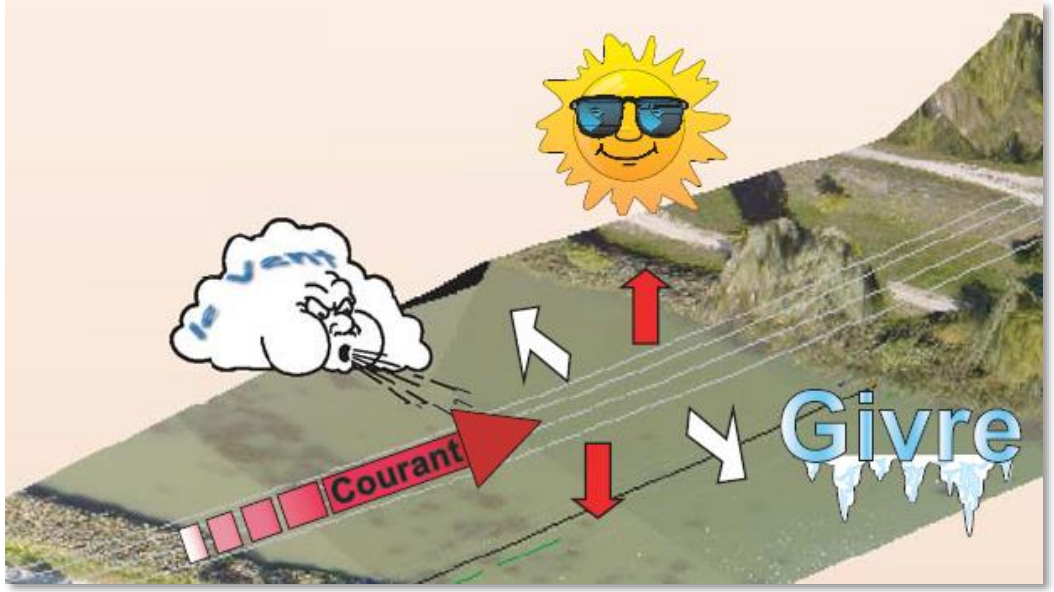
Wind and thunderstorms

- Winter storms
- Tornadoes
- Thunderstorms

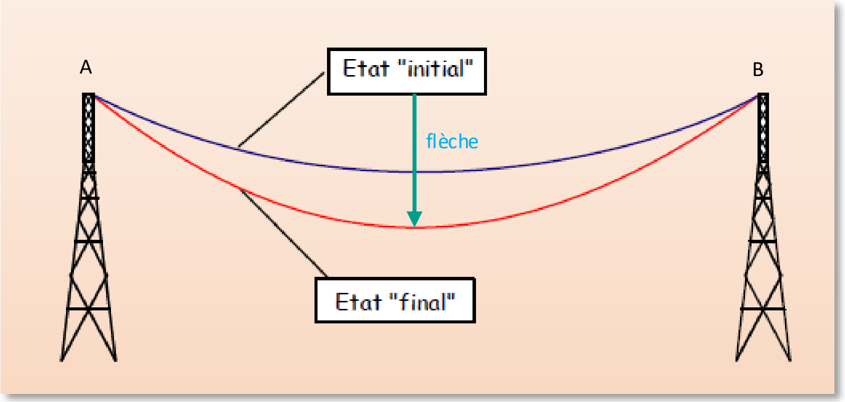
Wind storms

Flooding

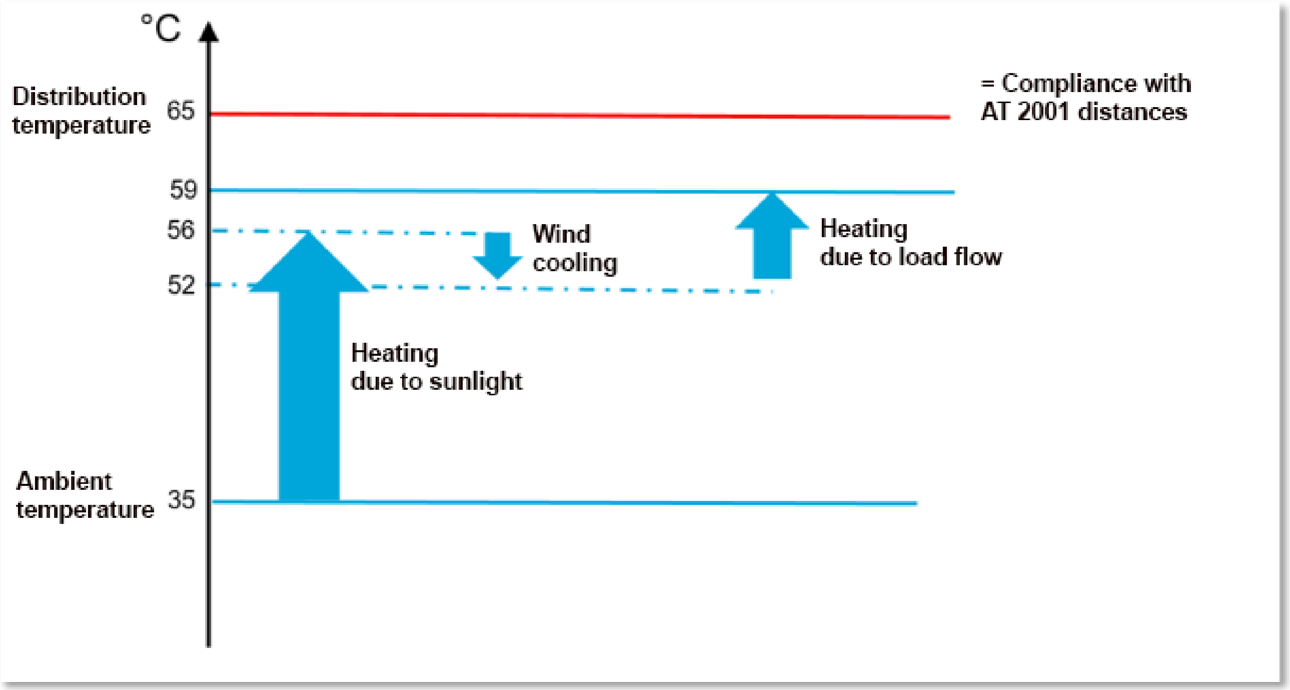
Snow and frost accretion on overhead power lines

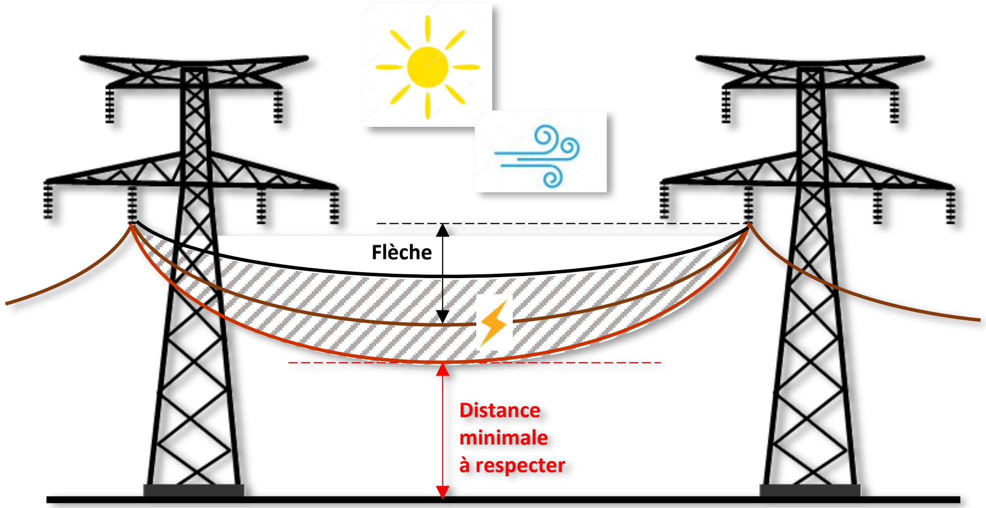


- Frosted and wet snow accumulation can increase the lines' length



The main problem with very hot weather is the operating temperature and load flow capacity of overhead power lines



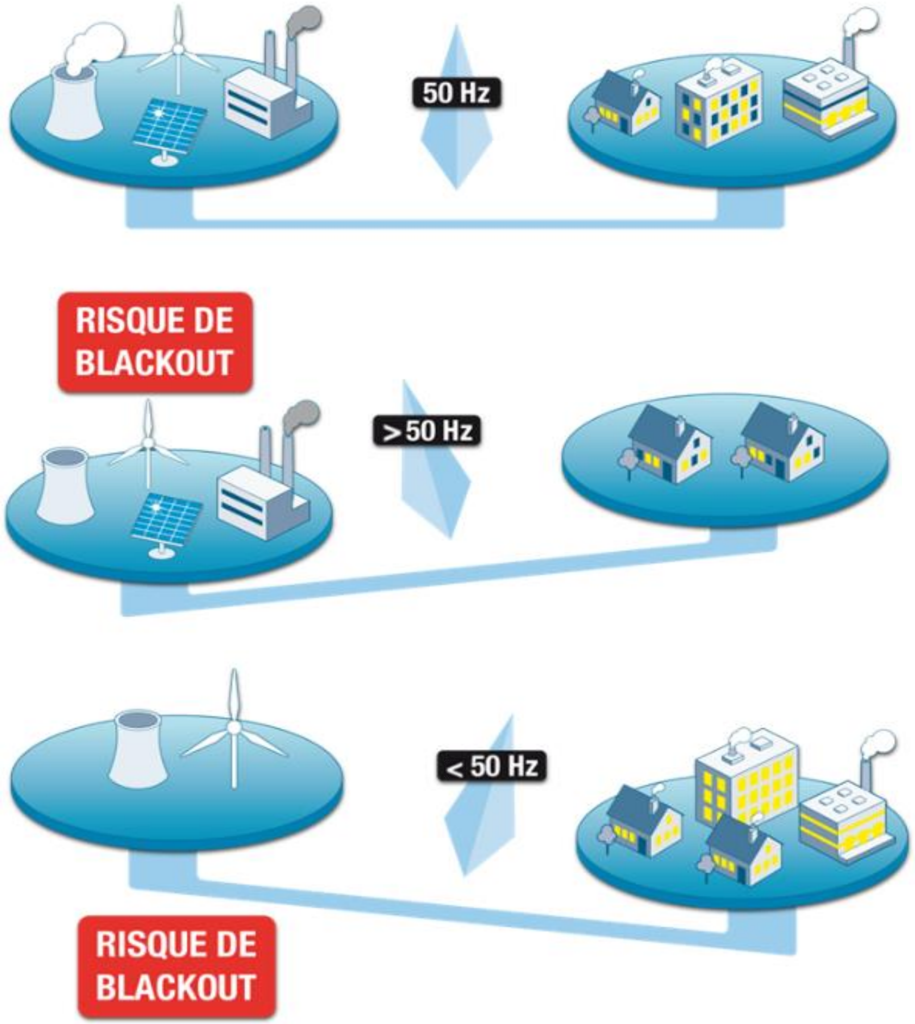


Above a certain ambient temperature, a cable heats up and expands under the effect of the sun and the current flowing through it (load flow). It is cooled by the wind.

There is a risk that distances will be compromised if the load flow on the line is high AND if the weather is unfavourable (high ambient temperature, low wind, strong sun).

Historically, some older structures were designed for a maximum temperature of 45 °C.

Power network management



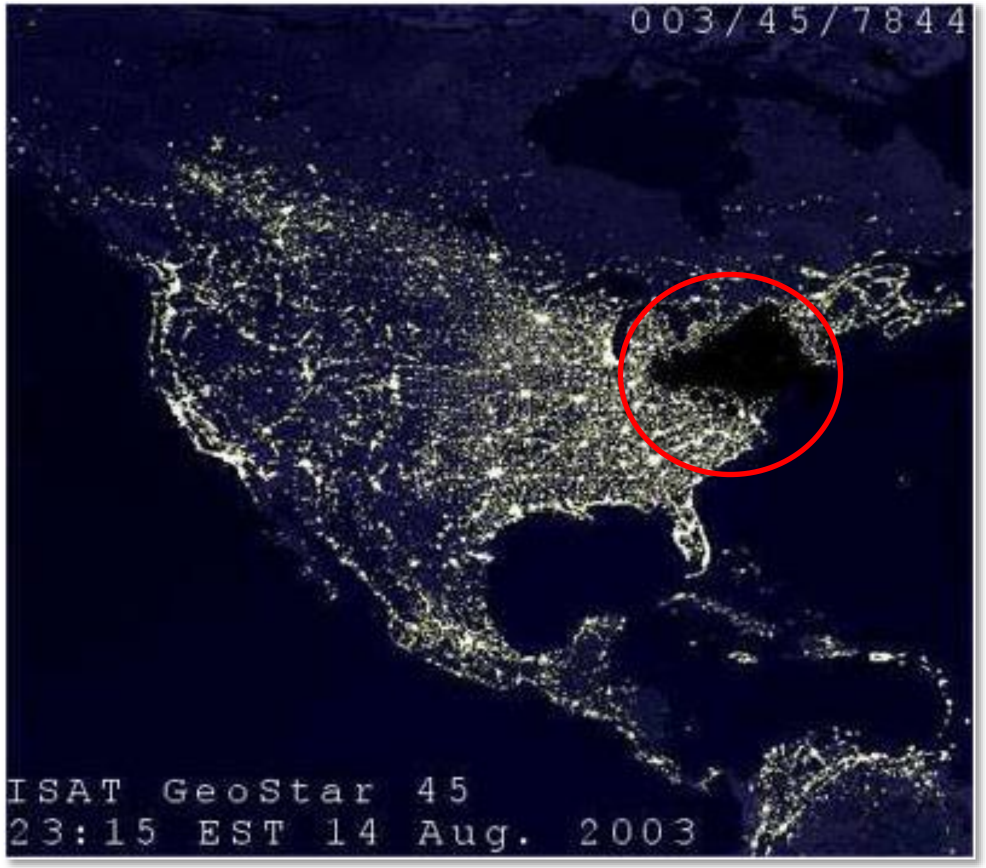
The balance has to be ensured at each time step

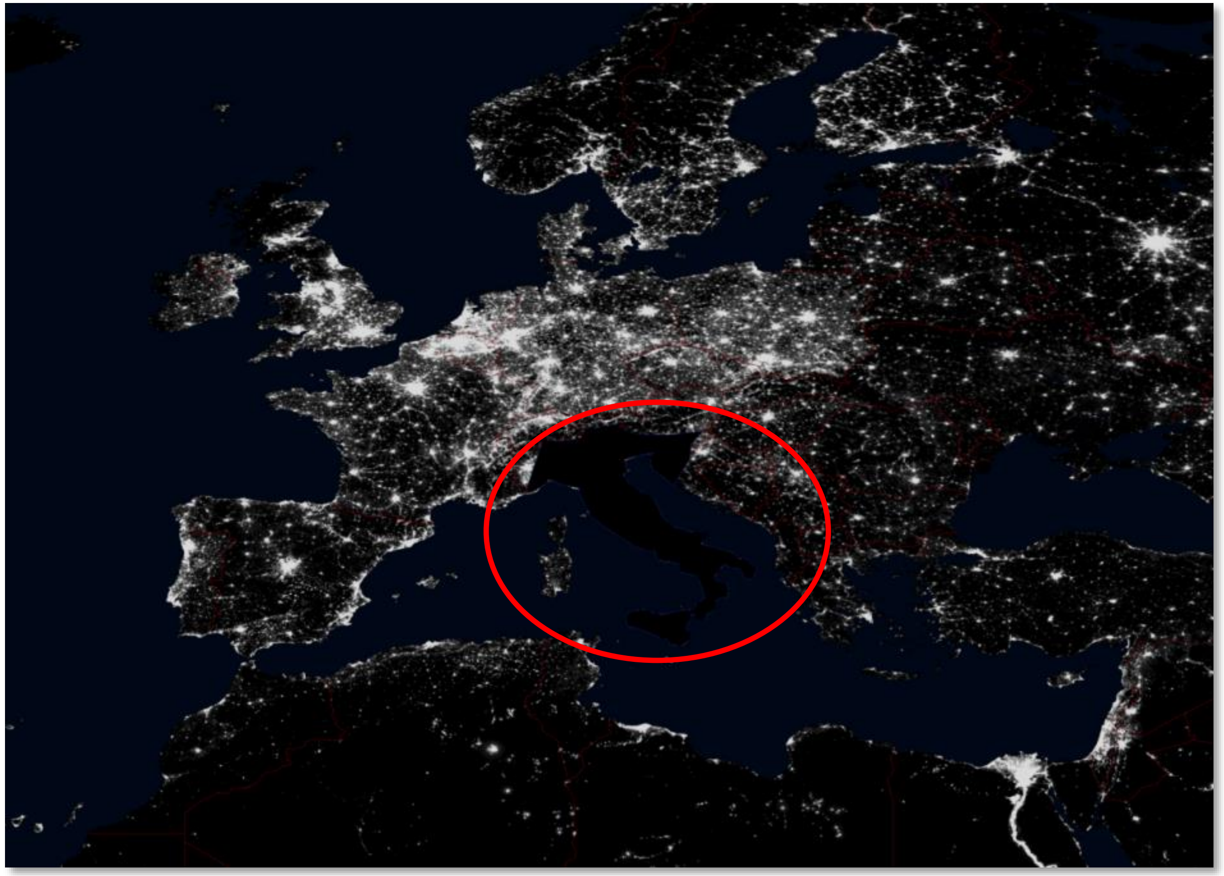
- Demand
- Production
- Unexpected stop of production units

... including

- Variable (renewables) generation

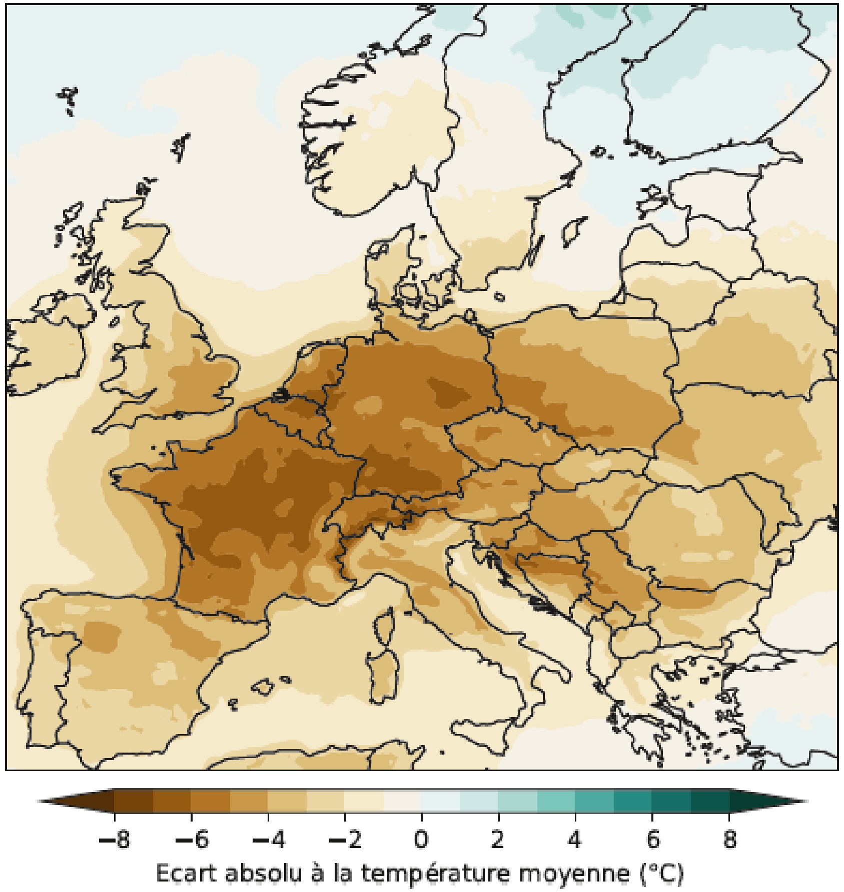
The big scary threat: the black out



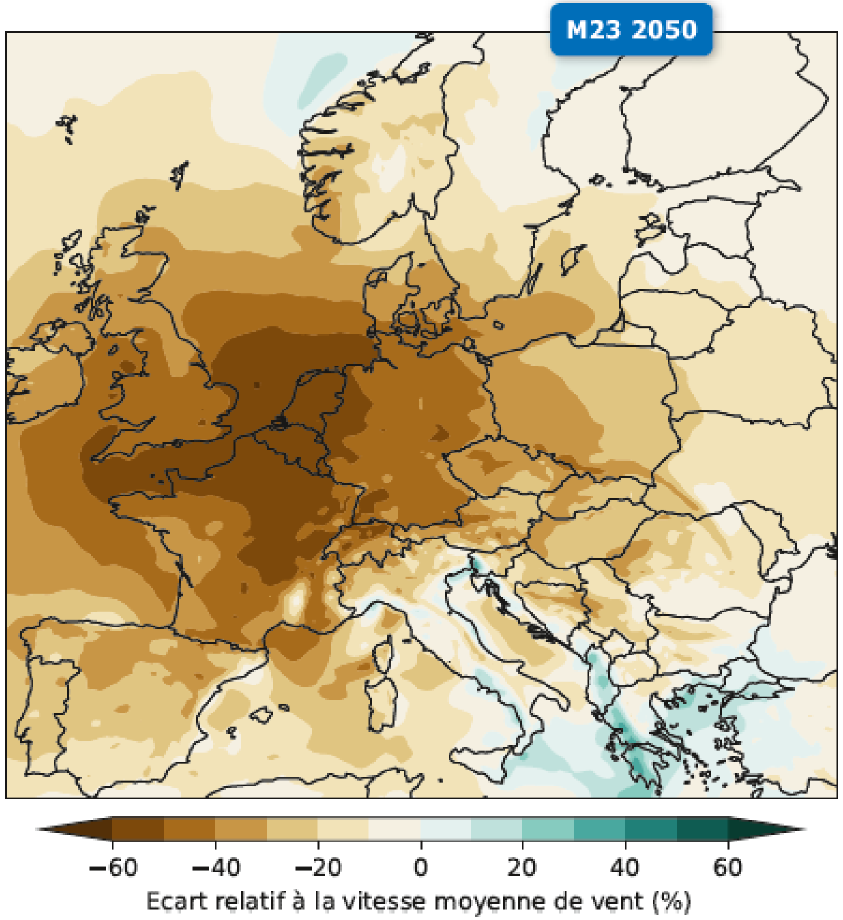


e.g. 2006 in Europe, 2008 in the USA, 2011 in Japan, 2012 in India …

The rising nightmare … cold temperature / low wind & solar generation … aka Kalte Dunkelflauten



Temperature anomaly composite



Relative wind speed anomaly composite

Anomaly = inadequacy days vs all winter days

What needs to be looked at?

Power system operation (supply/demand balance):

- Excess demand and/or low generation:
  - Cold waves in winter & heat waves in summer
  - Low wind/low solar power generation
  - Water availability for hydropower generation
  - Reduction in water cooling capacities from rivers (nuclear power plants)
  - Reduction in Carnot cycles efficiency with increasing temperature…

- Extremes are important, but also some specific return period (1 in 10 years, 1% or 3% most extreme situations…) depending on the type of study

- The new ghost: « Kalte Dunkelflauten »

What needs to be looked at?

Dimensioning of assets

- Examples of assets' life time:
  - Overhead lines : 60-90 years
  - Control-command (power electronics equipment in power stations): 10-20 years ➔ easier to replace

- Really dependent on the assets, their physical characteristics, life time, ease of maintenance/replacement, cost…

- Materials have thresholds over which (letal) damage can happen, or thresholds over which their operation is sub-optimal / compromised

What needs to be looked at?

What kind of events / variables

- Overhead lines ➔ maximum air temperature in case of max solar irradiance and low wind
- Power stations / control command: temperature inside buildings, flooding
- Painting of pylons: availability of water (for cleaning purposes)
- Offshore power transformation stations: temperature and humidity inside the building… Corrosion by sea water, extreme waves... Cables' landing: coastal erosion...
- Not only a matter of single extreme events, but accumulation of materials'fatigue or adversial conditions due to repeated « strong » events

Summary

Some final messages

Image Freeimages.com

Many types of hazards can inpact the power system

Not only extremes are important, as some materials and processes are defined/dimensioned based on specific return periods or parameter thresholds

Image @warszawianka

In addition to extreme weather events, we need to look at high impact events (might be a compound of moderate weather events that cumulate to create problems) and recurrent stressing events that create fatigue on assets

Image @Freepic

Methodologies for calculation of tailored indicators need to be transparent & authoritative

Research needs

For sub-seasonal to seasonal and prospective studies: are extremes simulated by climate models, really extreme?

Could it be worse → important for dimensioning of assets and operation of the system in the future

Are the return periods and return levels of simulated events realistic ?

Extremes theory under climate change (non stationary data) is very important.

Multivariate aspects

IA/DL and extreme event algorithms are promising → see talks by Corentin, Bastien and Amaury

Le réseau
de transport
d'électricité

Thank you