Europe is strong in software and using HPC systems
Europe is struggling on leading HPC infrastructure
Europe has weaknesses in supplying HPC technology
Speakers today

- HPC as an example of a digital tool used in the energy sector
  
  Presentation by F. Häberlein (TenneT)

- Extreme weather conditions identified as a risk factor for electricity crisis, c.f. Regulation (EU) 2019/941 on risk-preparedness

  Presentations by H. Elberrn (EoCoE project) and Peter Bauer (ECMWF)
HPC at TenneT
Application to Grid Planning Processes
Successful cooperation on HPC knowledge transfer

- In the context of future grid planning and operation a wide variety of simulation tools is used by the responsible TSOs.
- Time to solution as well as the number of possible parametrisations are the limiting factors.
- Starting in 2015 TenneT TSO GmbH, together with the Jülich Supercomputing Centre of Forschungszentrum Jülich GmbH, adapted HPC capabilities to the TSO demands.
- All aspects of a HPC environment were targeted: hardware, software (performance and adaptation), data flow, reliability, usability.

Industry relations team at JSC:
http://www.fz-juelich.de/ias/jsc/EN/Expertise/IndustryRelations/_node.html

Smart Computer for the Energy Transition
Bayreuth/Jülich, 31 July 2018 – The expansion of renewable energies is increasingly pushing the German electricity grid to its limits. In Northern Germany in particular, large quantities of wind power are fed in: at peak times, this is often more than can be transported via power lines to the south and west of the country, where many large consumers are located. Together with the transmission system operator TenneT TSO GmbH, experts from the Jülich Supercomputing Centre (JSC) have now developed a special computer system. It aims at helping to adapt the electricity grid, which has grown over decades, to the requirements of the energy transition. The grid operator uses computer simulations of the power flows in the grid for the expansion. With the new system, these flows can be accelerated more than 30 times.

Power grid related simulations

- Grid planning, market simulation
- Grid failure simulation
- Load flow calculation, redispachment

HPC by higher throughput
HPC by parallel algorithms

Short time-to-solution necessary
Simulation of different scenarios required
Impact of HPC on grid simulation

Load flow calculation
- 8760 cases in parallel
- 5 scenarios towards 2030
- ~300 grid projects

Time to solution single case

<table>
<thead>
<tr>
<th>Year (Infrastructure)</th>
<th>Time to Solution</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014 (Notebook)</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>2015 (48-core standard server)</td>
<td>19%</td>
<td>up to 14 times faster</td>
</tr>
<tr>
<td>2017 (SPC)</td>
<td>7%</td>
<td></td>
</tr>
</tbody>
</table>
A custom-tailored HPC

- Design and implementation of a heterogeneous HPC environment covering all models/algorithms of grid planning processes
- Expertise of JSC in designing and running HPC systems used for realise system with standard industrial infrastructure provider

portable applications
high clock rate

non-portable applications
high scalability

Central SPC manager and user interface

Linux Cluster system

Single partition runs or combined workflows

Windows Cluster system
Lessons learned

• The demand for HPC capabilities in the context of TSO simulation demands gets more and more relevant.

• TSOs leverage the capabilities of software packages by various vendors. Realisation of HPC capabilities are only possible in close contact with the corresponding software companies.

• Many algorithms and solvers, especially for optimization problems, are currently not designed to be directly adaptable to HPC demands.

• To be useable as an production-ready environment, the HPC system must be able to fulfil higher demands in context of availability, reliability and security in contrast to more research oriented HPC systems.
Outcome

• Together with Jülich Supercomputing Centre a complete change of the full power grid simulation environment could be designed and implemented.

• All aspects of the system: Hardware, software environment, application adaptation and support mechanics could be established to allow TenneT and the IT service provider to use the system in all day production work.

• The system is actively used, is extended in size and further development is ongoing to support new functionality.

• So far the system allows up to 30 times faster production runs for certain applications as well as an overall higher throughput even for non scalable applications, due to the ability to run multiple parametrisations in parallel.
Further project @ TSO

Project Gridcast  http://gridcast.iee.fraunhofer.de/

Cooperation between Fraunhofer IEE, Deutscher Wetterdienst and 4 German TSOs (TenneT, Amprion, TransnetBW, 50Hertz)

Increase day-ahead/intraday weather forecast/nowcast by means of HPC:
- higher model quality
- more detailed feed-in prediction by solar/wind power
- to be used in system operations
Disclaimer

Liability and copyright of TenneT

This PowerPoint presentation is offered to you by TenneT TSO B.V. ('TenneT'). The content of the presentation - including all texts, images and audio fragments - is protected by copyright laws. No part of the content of the PowerPoint presentation may be copied, unless TenneT has expressly offered possibilities to do so, and no changes whatsoever may be made to the content. TenneT endeavours to ensure the provision of correct and up-to-date information, but makes no representations regarding correctness, accuracy or completeness.

TenneT declines any and all liability for any (alleged) damage arising from this PowerPoint presentation and for any consequences of activities undertaken on the strength of data or information contained therein.
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
Weather extremes use cases with poor predictability for energy meteorology
Results from EoCoEMeteorology for Energy
to overcome central algorithmic and computational problems in the realm of energy meteorology, each one substantially reducing or even removing bottlenecks.

Expressed user needs:

1. sound bidding at power stock exchange (rest of the day Æ week)
2. resilient electricity grid management (hours Æ day)
3. local optimized control for photovoltaics and CSP sites (up to days)
2014 statistics of extremely poor predictability

Main demand for
• Grid stability
• Power unit commitment
• Market bidding

Forecast systems show on average satisfactory accuracy

Rarely but costly occasionally forecast systems fail dramatically in the day-ahead horizon

Exemplary: Heuristics of imbalance prices

A recent example: 29. June 2019 1-216 CEST 37.856 €/MWh

Source: Mathias Stark, GEWIESELNER, Kassel, Germany, 2015
Ultra large ensemble case study: wind 09 August 20

Notes
Ensemble captures real feed-in by single outliers (>99.5% percentile)
Distribution differs from Gaussianity by extreme tails
Outliers are triggered into the direction of forecast error
Some other typical forecast failure weather situations: High fog and solar power prediction

Predictability problems in terms of occurrence, extension, dissolution time due to high sensitivities to poorly predictable parameters like humidity.
Some typical forecast failure weather situations

Misspredicted cloud cover

28 November 2014

5 GW forecast error

95% percentiles of subsamples of different sizes for

Conclusions

- Ensemble almost captures real field by single outlier
- Results are analogue to wind power case study
- Higher order moments 1024 members needed
Some typical forecast failure weather situations

Missing aerosol modules and solar power prediction

Investigation of dust assimilation

Increased cloud development

„aerosol-aware“ (e.g. nucleation)

estimation of „washout“ needed

Solar power
day-ahead forecast and
observation
03-06.04.2014

https://eathobservatory.nasa.gov/
Ensemble extension of the WRF model

Nearly perfect parallelization proven with up to 4096 ensemble members on 262,144 cores

Particle Filter assimilation cycle within a single executable
Ultra-large ensemble as automated probabilistic into real time compatible stochastic power grid optimisation

Power grid optimization under uncertainty:

the optimal operation of electricity generation facilities to produce energy at the lowest cost reliably,

recognizing any operational limits of the generation and transmission facilities.

feasibility see e.g. Petra, Schenk, anAdnitescu: Real-Time Stochastic Optimization of Complex Energy Systems on High-Performance Computers, IEEE, 2014

solve 24-hour horizon power grid problems with up to ~2 billion decision variables and ~2 billion constraints within several minutes
Weather extremes forecast and HPC (and BD)
Reliable prediction of extremes 2 weeks ahead

Ensemble-based Extreme Forecast Index (EFI) forecast where the ensemble forecast distribution differs substantially from the model climatological distribution for 2-metre temperature, 10-metre wind gusts and precipitation.
Reliable prediction of extremes 4 weeks ahead

Summer heatwave over Europe:
2m Temperature,
7 May–12 August 2018
Reliable prediction of extremes decades ahead?

850hPawind speed response to RCP8.5 forcing by 2100
World leadership in Europe

New cycle implemented on 11 June 2019
Example: Energy extremes

The grand forecasting challenge:
Predict renewable power generation, dynamic uncertainties, and space-time dependencies at onc e for Europe

... at regional scale

... with sufficient reliability

... with a changing climate
Copernicus Climate Change Service: Energy

http://ecem.wemcouncil.org

http://c4e-visu.ipsl.upmc.fr/
How does high resolution compute?

SUMMIT: DOE/SC/OAK RIDGE NATIONAL LABORATORY
No. 1 since June 2018

Summit, an IBM-built supercomputer now running at the Department of Energy’s (DOE) Oak Ridge National Laboratory (ORNL), captured the number one spot with a performance of 122.3 petaflops on High Performance Linpack (HPL), the benchmark used to rank the TOP500 list. Summit has 4,356 nodes, each one equipped with two 22-core Power9 CPUs, and six NVIDIA Tesla V100 GPUs. The nodes are linked together with a Mellanox dual-rail EDR InfiniBand network.

- O(3-5) shortfall
- x10+ Coupled Earth system
- x50+ Ensembles
- O(1000) shortfall
New Science enabled by New Technology
(www.extremeeearth.eu)
Weather extremes forecast and High Performance Computing (HPC)