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Probabilistic planning of distribution networks

Consideration of users' flexibility

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Planning of distribution networks

- Starting points
  - Increasing share of ‚new‘ network users: renewables, heat pumps, electric vehicles
  - More data available: consumption and generation measurements, network data, users‘ habits...
  - ➢ Planning process: if a solution (e.g. smart grids) is not included in the planning process, it will not be used

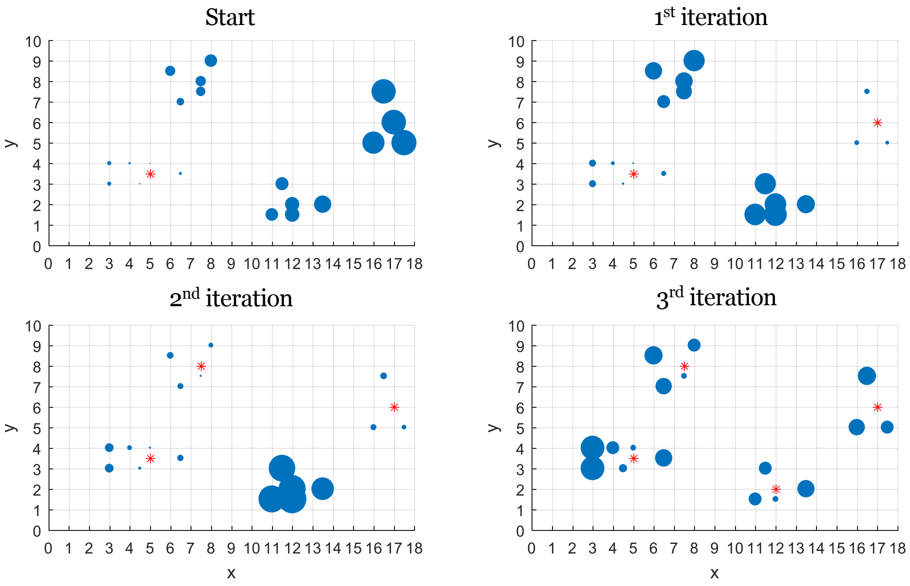
- Planning methodology - requirements
  - Take into account the high variability of consumption and generation
  - The location of future loads or generation not known
  - Integration of different methods of distribution network control (e.g. coordinated voltage control)
  - Consideration of services by users in network management (demand response)
    - The inclusion of uncertainty about user behaviour (assessment of users’ flexibility)

➢ Simulation methodology
  - Based on simulation models and statistical description of operating conditions
  - Comparison of different technical solutions and selection of the optimal solution

Planning of distribution networks – network models

- How to technically and economically evaluate solutions in distribution networks at a large scale?
  1. Reference (representative) network models are used to perform simulations
  2. Methodology for generalizing the results of reference models to the entire distribution network
  3. Economic model for cost evaluation of individual solutions

- Definition of reference network models
  - We start from a set of actual network models
  - Define the characteristic parameters
    (e.g. line cross-section, total length of cables, branching…)
  - With a clustering method, networks are classified
    into groups composed by similar networks
  - A representative network representing the whole group
    is determined in each group



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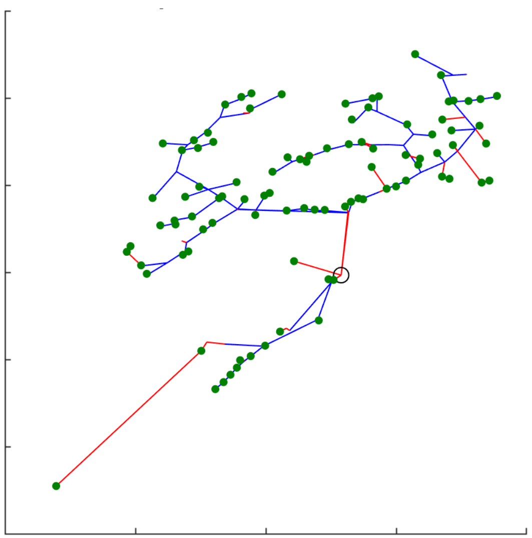
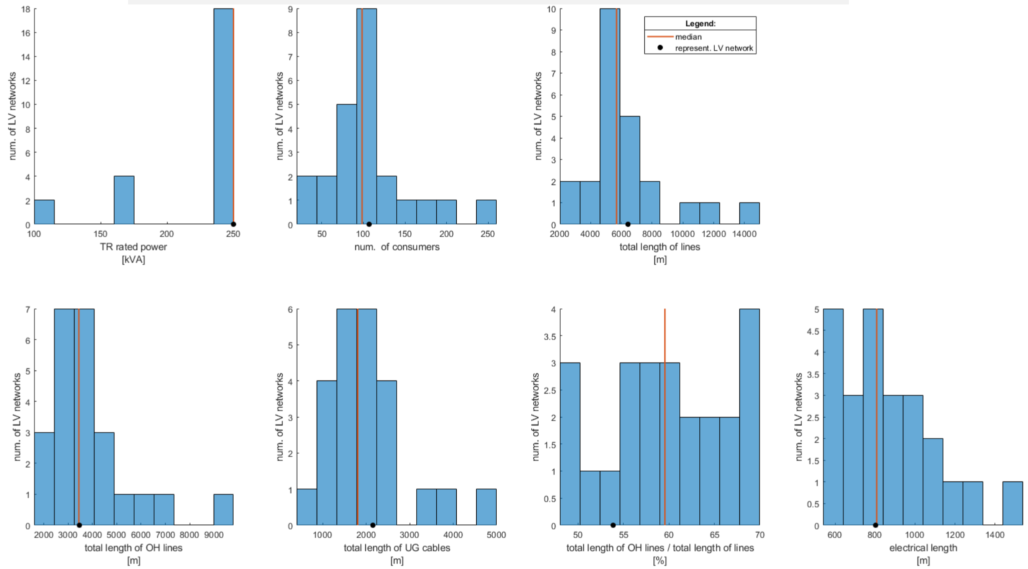
Reference network model – LV network case

- Reference models defined based on actual LV networks
- Identified clusters
  - Densely populated rural area networks
  - Sparsely populated rural area networks
  - Urban networks
  - Public institutions and companies

Densely populated rural area networks, representative network



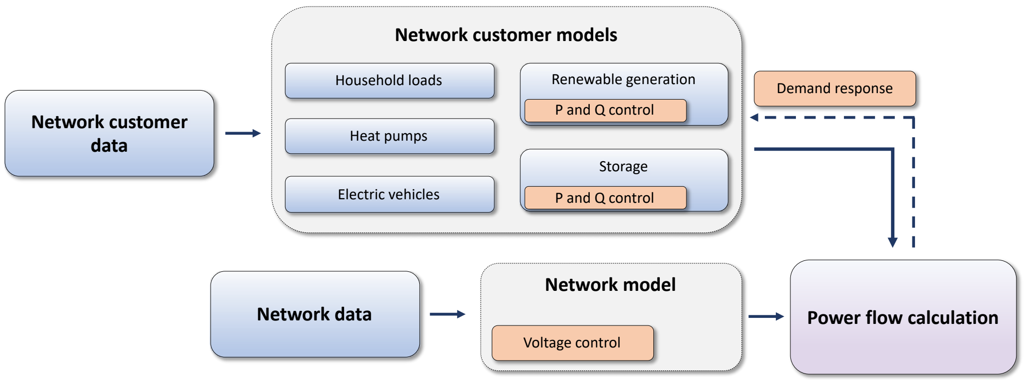
Densely populated rural area networks – cluster data



Simulations approach

- Evaluating the impact of electric vehicles, heat pumps, solar power plants and the growth of household consumption on:
  - Transformer loading, line loading, voltage profiles and voltage drops, losses

- Simulations approach
  - Simulations based on reference models of LV and MV distribution networks
  - Uncertainties assessed by Monte Carlo simulations
  - Demand response formulated as an optimisation or rule-based process

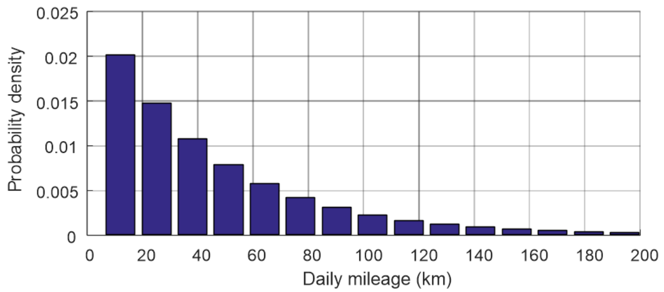


- Simulation scenarios
  - Current (existing) situation (2020)
  - Future scenario (2030) without measures: impact of increasing consumption and generation
  - Future scenario (2030): all active users participate in demand response
  - Future scenario (2030): 50 % of active users participate in demand response

Simulations approach – electric vehicles

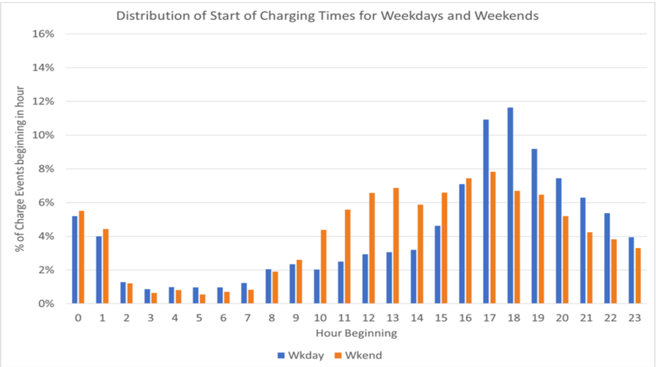
- EVs as an electrical load
  - Daily mileage statistics: definition of the duration of charging based on the daily travelled distance

Statistics of daily travelled distances



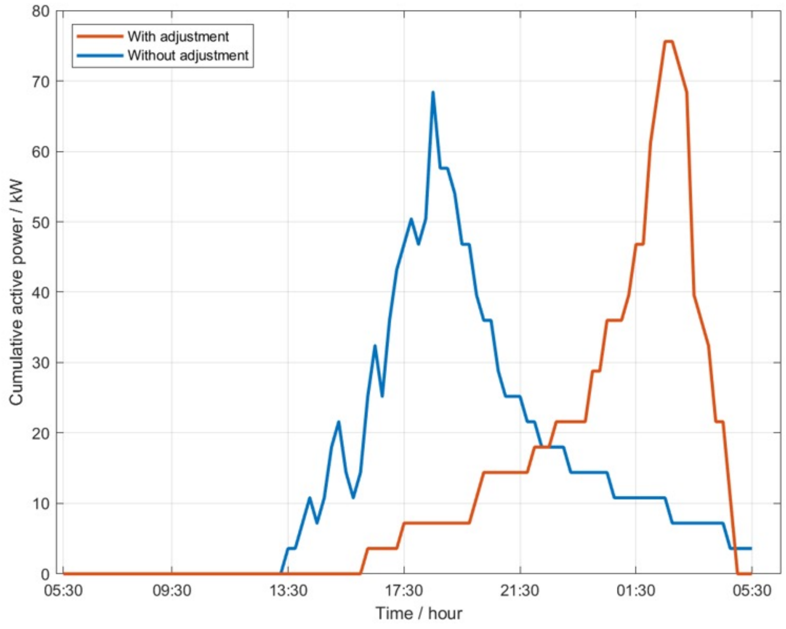
  - Beginning of charging based on a normal distribution and different charging scenarios (afternoon charging, evening charging…)

Distribution of the starts of charging between working days and weekends



Based on 94,519 events

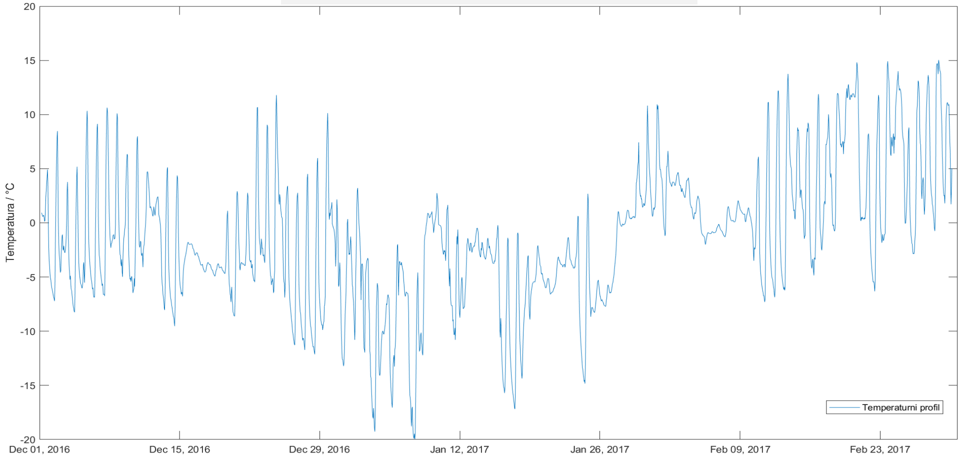
Cumulative consumption of 30 electric vehicles with and without smart charging



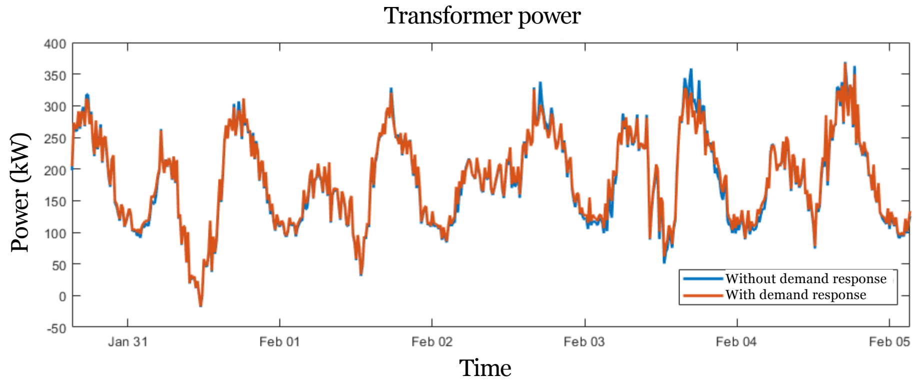
Simulations approach – heat pumps

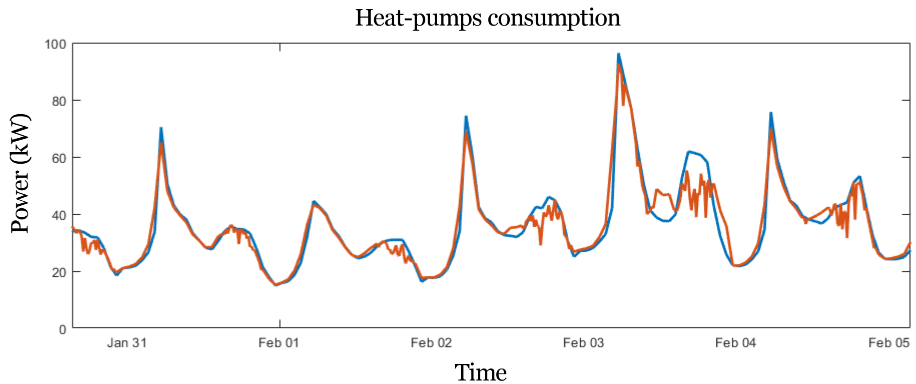
- Heat pump
  - Electric power of a HP depends on: outside temperature, building type and isolation, inside temp…
    - Use of a database of typical buildings
  - Demand response: shifting of demand from peak hours to a time before and after the event

Winter temperature profile



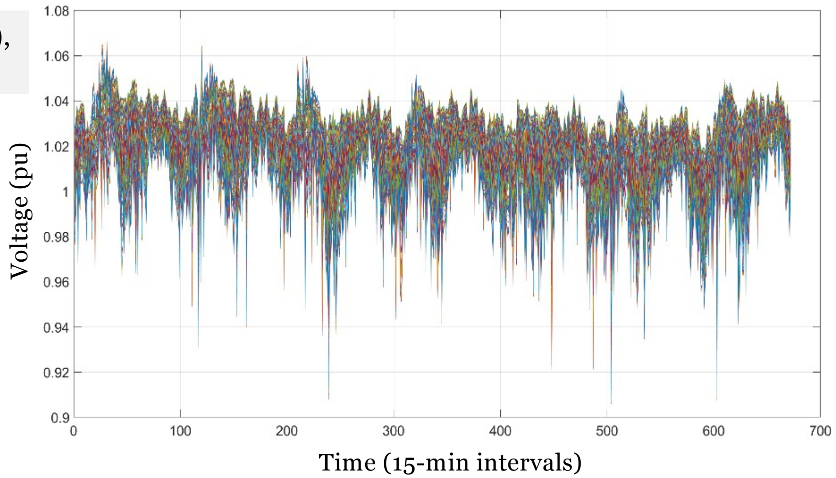
Example of a weekly consumption diagram of 22 heat pumps with and without demand response



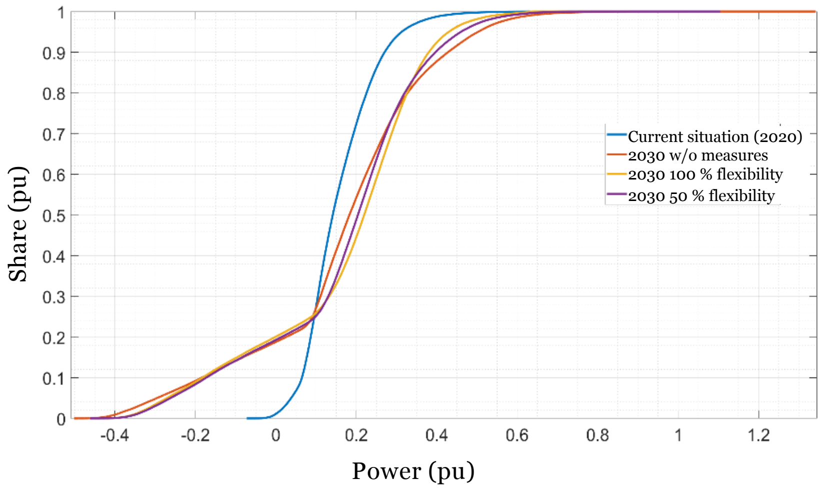


Simulation results: densely populated rural area network

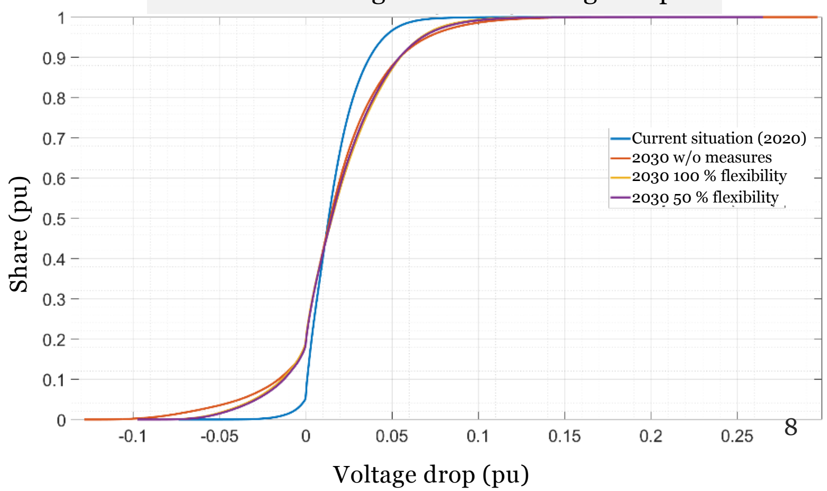
Phase voltages (L1), winter 2020



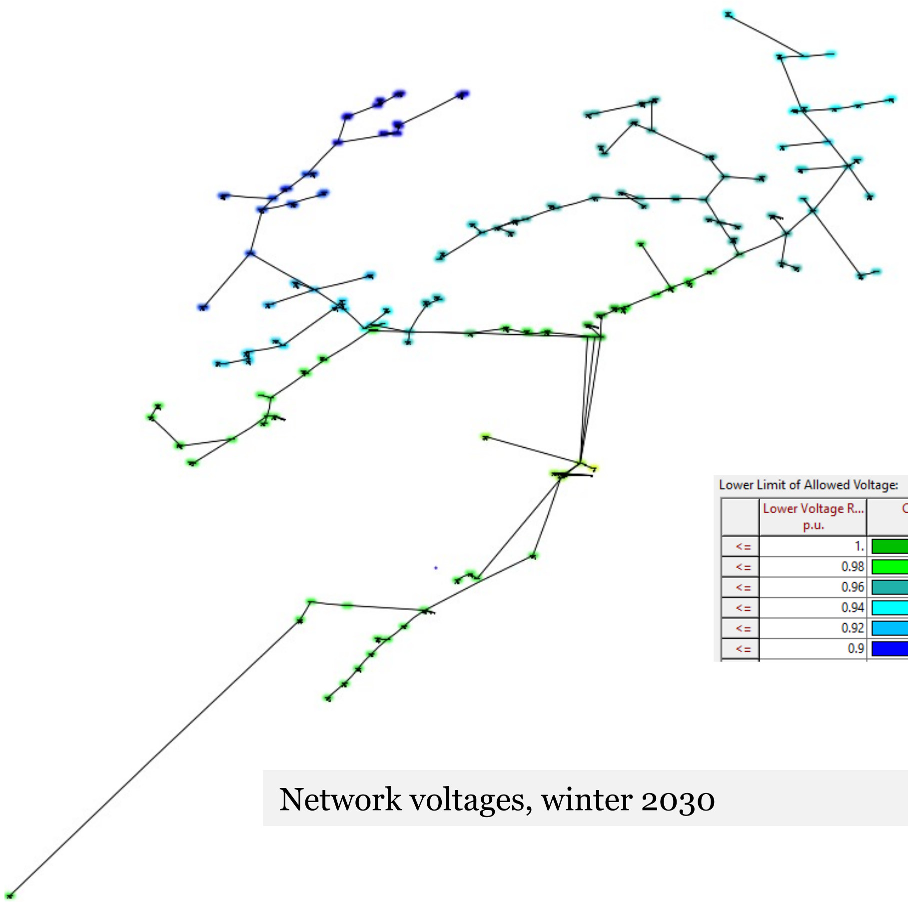
Cummulative diagram of TR power



Cummulative diagram of line voltage drops



Simulation results: densely populated rural area network



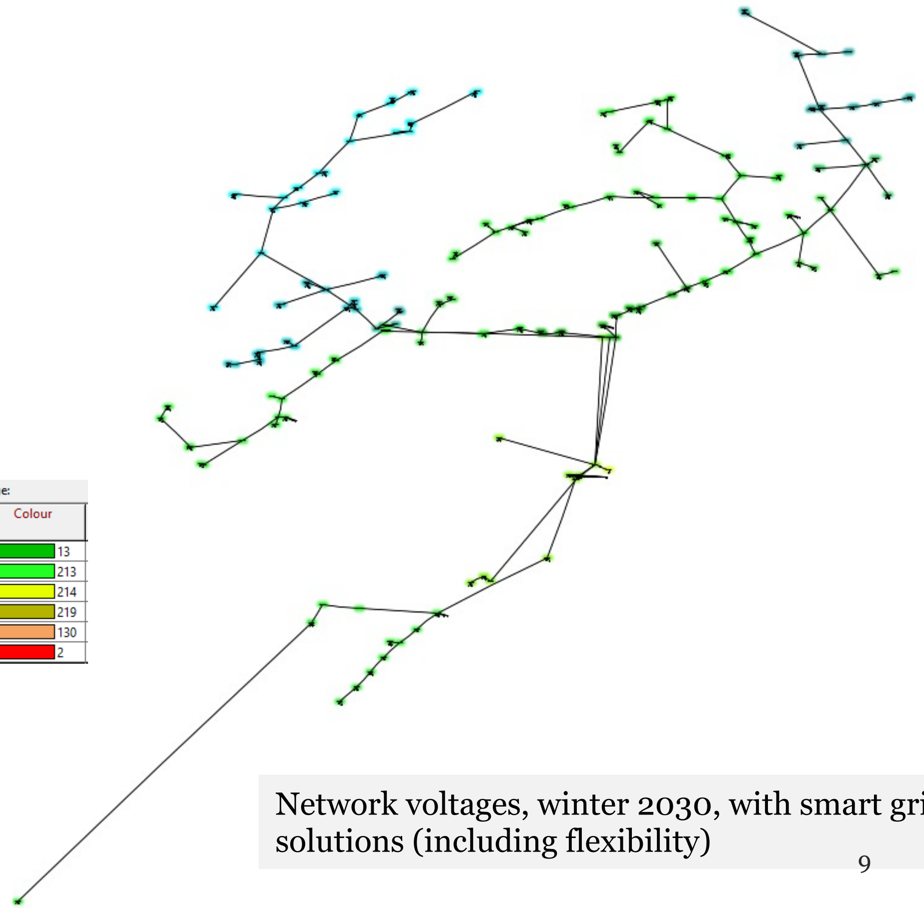
Lower Limit of Allowed Voltage:

	Lower Voltage R... p.u.	Colour
<=	1.	13
<=	0.98	104
<=	0.96	100
<=	0.94	6
<=	0.92	79
<=	0.9	4

Upper Limit of Allowed Voltage:

	Upper Voltage R... p.u.	Colour
>=	1.	13
>=	1.02	213
>=	1.04	214
>=	1.06	219
>=	1.08	130
>=	1.1	2

Network voltages, winter 2030

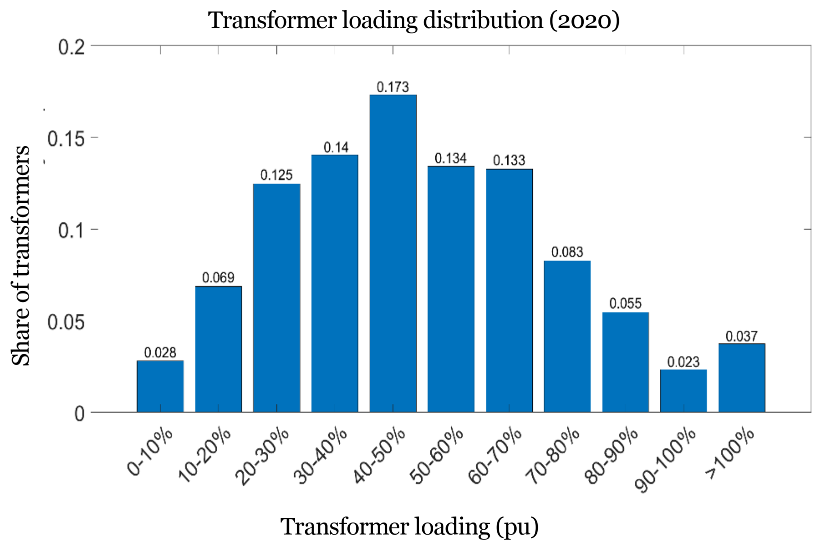


Network voltages, winter 2030, with smart grid solutions (including flexibility)

Scalability of the results

- Network reinforcement – transformer overload
  - Transformer replacement: when the power exceeds the rated power
  - Loading statistics of MV/LV transformers taken into account

- Network reinforcement – voltage levels
  - Voltage drop: when voltage drops exceed 7.5 %
  - Voltage levels: when voltages below 0.9 pu (EN 50160)



- Overall results - customer contributions to peak power and their flexibility
  - Household customers: 1 - 2 kW per customer
  - Electric vehicles: 1.8 kW per EV
  - Heat pumps, cold day (-15° C): 4 kW per heat pump
  - Average peak consumption flexibility: 0.4 - 0.7 kW per LV customer

Conclusions

- Major changes in the power systems
  - Renewable sources and electrification of heating and transport
  - ➢ Significant impact on the operation of the distribution networks

- Distribution network planning methodology
  - Simulations based on reference network models
  - Procedure for evaluating the future operational condition of the network including the uncertainties (Monte Carlo simulations)
  - Inclusion of user flexibility as a part of the solution
  - Generalisation of results to the entire distribution at MV and LV level
  - Technical and economic evaluation of the effectiveness of various solutions

Thank you for your attention!

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