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# ATTEST

# Advanced Tools Towards cost-efficient decarbonisation of future reliable Energy SysTems



March 16th, 2023

# Project

## Advanced Tools Towards cost-efficient decarbonisation of future reliable Energy SysTems

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|---|---|
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| Duration | 3 years (Mar2020 – Feb2023) |
| Coordinator | INESCT TEC (PT) |
| Partners | 9 |
| Countries | 6 |
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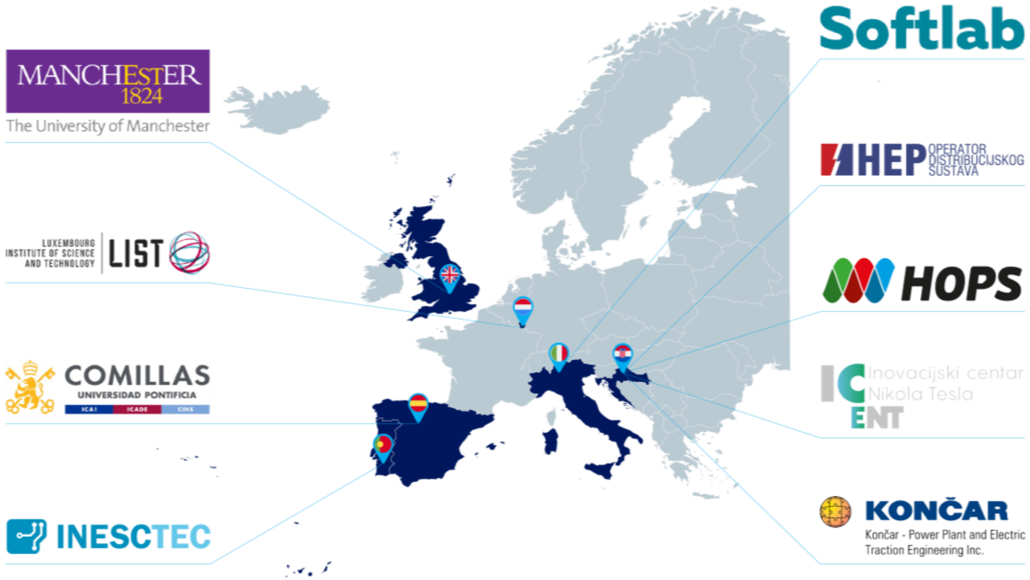


ATTEST_energy

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# Energy systems of 2030 and beyond

1. Increasing power system flexibility and generation back-up capacity
2. Increasing the share of renewable energy sources in the energy mix
3. The strong trend toward the electrification of the energy system
4. Realizing the vision of a user-centric energy system and consumer empowerment
5. Promoting digitalisation of the energy sector
6. The integration of different energy systems (multi-energy networks)
7. Ensuring the security of operation with respect to critical disturbances
8. Enhancing interactions between DSO and TSO
9. Increasing social welfare through a common, more competitive EU electricity market

# Vision & Objectives

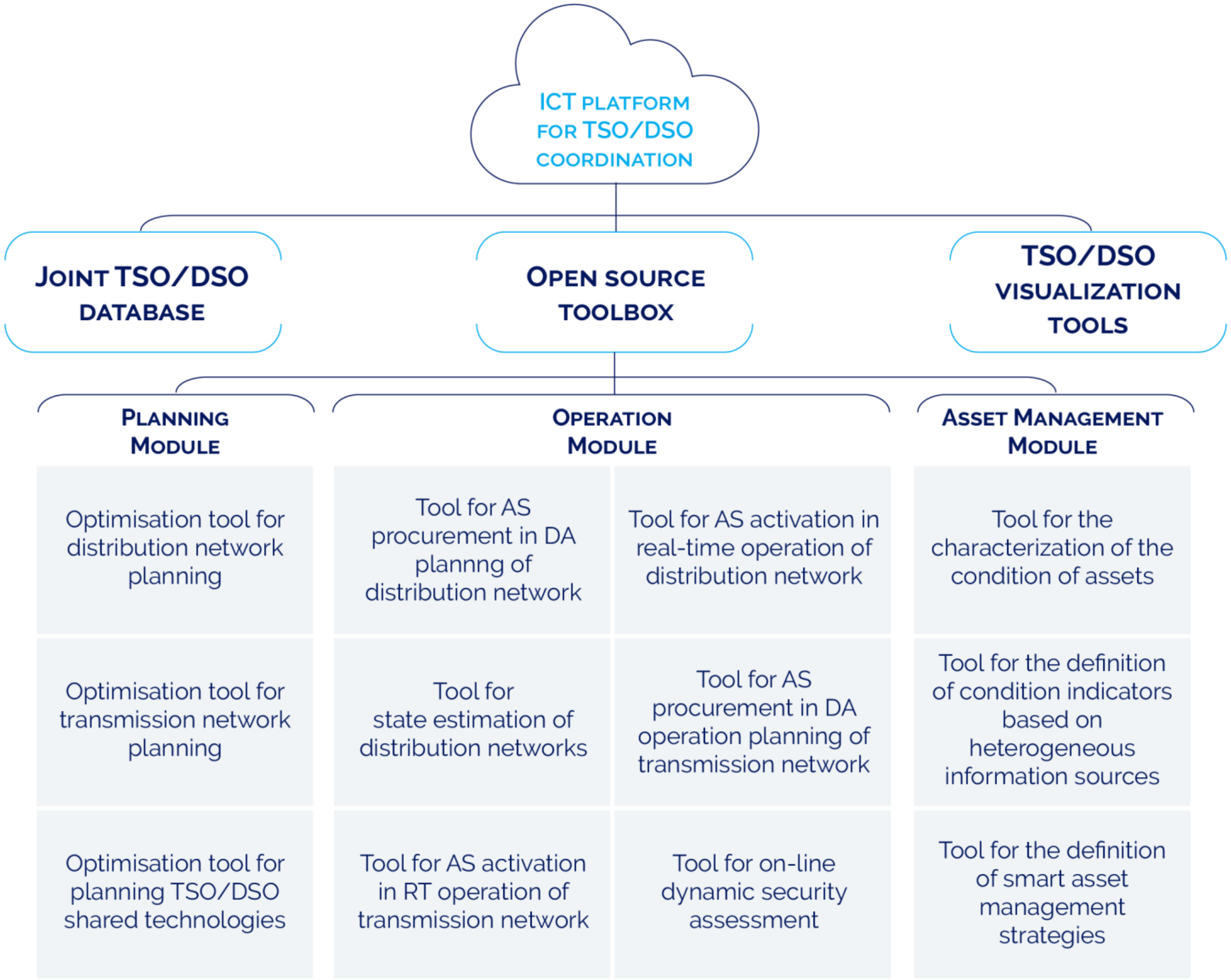
## Vision

To support the spread of knowledge and experience on a global scale, addressing the challenges of the energy systems of 2030 and beyond.

## Objectives

To develop and operationalize an innovative open-source toolbox that integrates a set of optimization tools for operating, planning and managing assets in future energy systems.
To support transmission and distribution system operators in improving and coordinating their networks from a technical, economic and environmental standpoint.

# ICT Platform



# Open-source toolbox

## Planning Module

### Optimization tool for distribution network planning

This tool will produce flexible, adaptive network investment strategies that take advantage of demand side flexibility for the provision of network support as a means to maximise network capacity, also considering environmental and economic impacts.

### Optimization tool for transmission network planning

This tool will develop optimized strategies for the transmission network to be adaptively upgraded in consideration of the new sources of uncertainty and flexibility that may emerge in different areas of the network, e.g., distributed RES, storage and MES at the demand side.

### Optimization tool for planning TSO/DSO shared technologies

This tool will assess the benefits from the installation of TSO/DSO shared technologies (e.g., storage devices) to be managed in a coordinated way to simultaneously provide flexibility to both distribution and transmission networks, thus contributing to postpone investments in assets replacement/reinforcement.

# Open-source toolbox

## Operation Module

**Tool for AS procurement in DA operation planning of the distribution network**

To support the DSO on the procurement of ancillary services and mitigate renewables uncertainty.

**Tool for AS activation in RT operation of the distribution network**

To optimize the activation of flexibility and maintain the distribution network operating in a safe mode.

**Tool for state estimation of distribution networks**

To allow estimating the operating state of the network with minimal available information.

**Tool for AS procurement in DA operation planning of transmission network**

To enable the TSO to procure ancillary services on a 24-h ahead basis.

**Tool for AS activation in RT operation of transmission network**

To maintain the transmission network operating in a safe mode when forecasting errors occur.

**Tool for on-line dynamic security assessment**

To perform a security assessment of transmission networks considering static and dynamic constraints.

# Open-source toolbox

## Asset Management Module

| Tool for the characterization of the condition of assets | Tool for the definition of condition indicators based on heterogeneous information sources | Tool for the definition of smart asset management strategies |
|---|---|---|
| To characterize and model the life of important network asset components through fault and maintenance history, component behavior and condition collected from sensors and utilization rates. | To define a set of harmonised, easily measurable and comparable life indicators for different types of assets based on characterization of their condition. | To evaluate the assets under different perspectives, defining asset priority lists to allow optimized decisions taking into account not only CAPEX but also OPEX costs. |

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# Demos

## Zagreb

Two buildings able to provide flexibility at the MV level.

## Northwestern Croatia

Part of the Croatian transmission network to be used for testing and validating the optimization tool for transmission network planning.

## Koprivnica

The entire 35 kV, 20 kV and 10 kV distribution networks in the Distribution Area Koprivnica.

# TSO-DSO Coordination Mechanisms

- The TSO-DSO Coordination Mechanisms proposed in the literature can be broadly classified into:

  - Centralized schemes:
    - TSO, or ISO, solves a large-scale problem comprising of TN and DN

  - Decentralized schemes:
    - The large-scale problem is decomposed into smaller subproblems
    - Two main approaches:
      - Hierarchical schemes: follow a “leader-follower” organization
      - Distributed schemes: the several agents (subproblems) involved in the optimization procedure must reach a consensus regarding common (coupling) variables

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# TSO-DSO Coordination Mechanisms

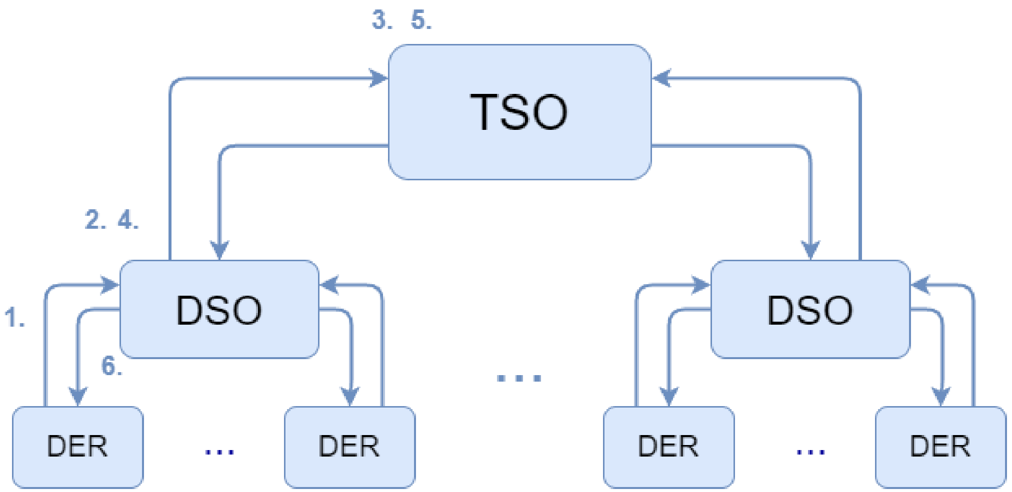
## ATTEST Approach

- The ATTEST project proposed a new coordination mechanism:
  - Decentralized scheme
  - Draws some characteristics from other coordination mechanisms proposed in the literature (e.g., SmartNet project)
  - Local markets exist for resources connected to the DN
  - Active and Reactive power bids are decoupled, and communicated to the TSO via DSO

# TSO-DSO Coordination Mechanisms

## ATTEST Approach

- Procedure:
  1. DERs communicate their bids to their respective DSOs
  2. DSOs compute the **active power flexibility band** they can provide at the TN-DN interface, considering the available DERs, and communicate them to the TSO
  3. TSO computes the **active power profile required** at the TN-DN interface, and communicates it to the DSOs
  4. DSOs compute the **reactive power flexibility band** they can provide at the TN-DN interface, considering the active power profile requested by TSO, and communicate them to the TSO
  5. TSO determines the **reactive power profile** at the TN-DN interface and communicates it to the DSOs
  6. DSOs dispatch the DERs

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# Shared Resources Planning

- Role of ESSs in Future Power Systems:

  - For high levels of renewable energy and consumer participation in power system operation, the balancing task becomes more complicated:
    - Effectively dealing with the uncertainty derived from these types of resources requires more flexibility

  - Energy storage increases the flexibility of power systems and therefore their ability to deal with uncertainty is recognized as a valuable means to provide:
    - Additional system security, reliability and capacity to respond to changes that are difficult to accurately forecast

  - The increasing uncertainty associated with network operation creates new opportunities for ESS integration at different levels of the electric power systems:
    - Although ESS technology is maturing and continuously reducing in cost, these still require a relatively high initial investment cost
    - Due to unbundling regulation, it is likely that many of these ESSs will be deployed by private investors

# Shared Resources Planning

- ESS Planning tools:
  - Most of the published work is mainly focused on the optimal investment in ESSs either from an independent investor, DSO, or TSO perspective
  - Only recently the models adopted for ESS planning have started to consider complex topics:
    - Energy capacity degradation
    - Full AC model of the power flow equations
    - Uncertainty associated with the operation of the network (market prices, operational forecasts)
  - Little to no research has been published on the joint-planning of ESSs or planning of ESSs in the presence of TSO-DSO coordination schemes

- In the presence of a TSO-DSO coordination mechanism, shared ESSs can:
  - Provide additional ASs (e.g., frequency regulation)
  - Reduce investment costs
  - Improve asset utilization
  - Additional flexibility to deal with uncertainty (RES, load) in real-time operation

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# Shared Resources Planning

- Shared Energy Storage System Planning:
  - Investment performed by a third-party, private investor (Energy Storage System Owner, ESSO)
  - The shared ESSs can be simultaneously used by TSO and DSOs for the operation of their networks
  - It is considered that the ESSs can be installed at the TN-DN interface (with ADNs participating in the coordination scheme)
  - Battery capacity degradation considered in the planning procedure (calendric and cyclic ageing)
  - The shared ESS can participate in energy and secondary reserve markets

- Stochastic bi-level planning tool:
  - Upper-level: Investment decisions (sizing of the ESS units to be installed)
  - Lower-level: Operational planning (simulation of TSO-DSO coordination, considering market and operation scenarios)

- Decomposition techniques used at the planning and operational planning stages:
  - Tractability
  - Data privacy preservation

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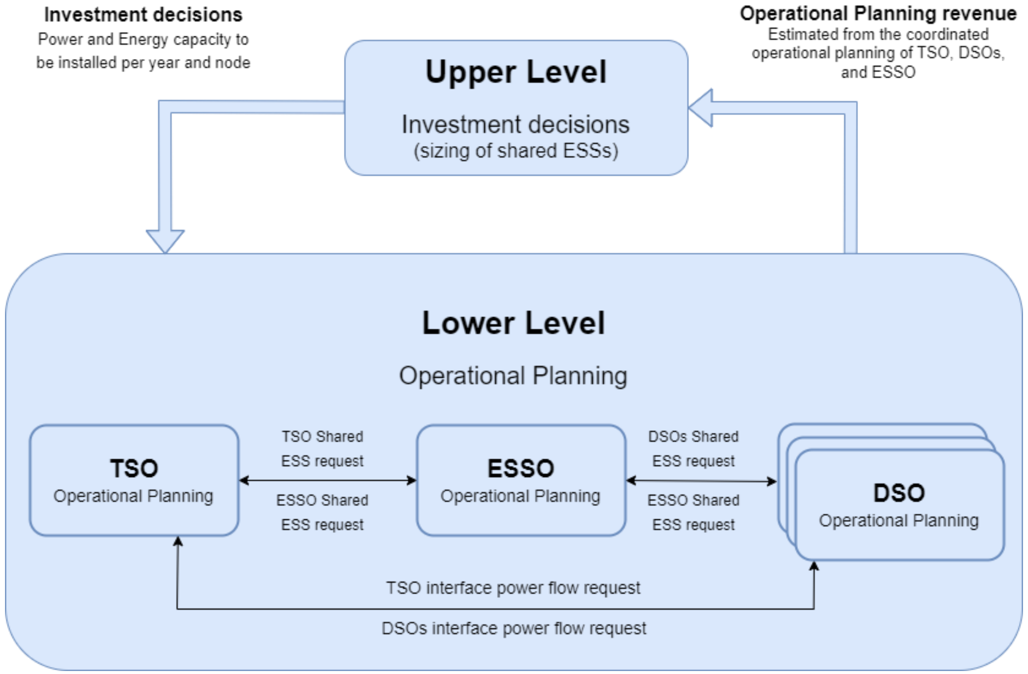
# Shared Resources Planning

## Proposed Framework

- Upper-level (investment decisions)
  - Power and Energy capacity to be installed per year and node, subject to budget, energy capacity (space available at the substation), and power/energy capacity ratio constraints

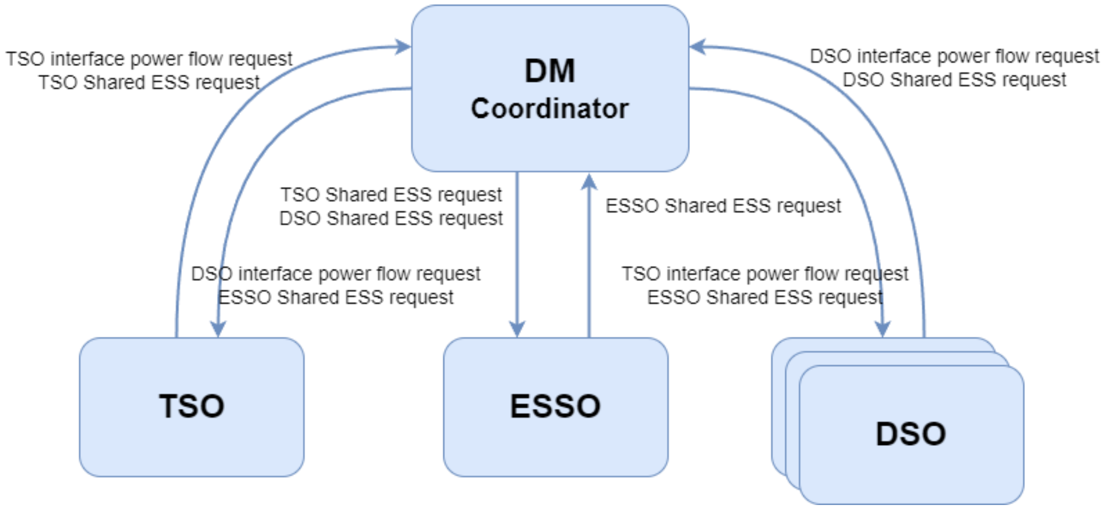
- Lower-Level (coordinated operational planning):
  - Estimation of the operational revenue
  - TSO, DSOs, and ESSO coordinate their operation to determine the shared ESS power profiles, and active and reactive power floes at the TN-DN interface



# Shared Resources Planning

## TSO-DSO Coordination Mechanism in the Presence of Shared ESSs

- To mathematically formulate the TSO-DSO coordination mechanism in the presence of shared ESSs, the proposed mechanism was upgraded and implemented using the Alternating Direction Method of Multipliers (ADMM):
  - The lower-level is decomposed by the several actors that participate in the coordination mechanism (TSO, DSOs, ESSO)
  - A consensus must be reached regarding the coupling variables of the operational planning problem (active and reactive power flows at the TN-DN interface, and power profiles of the shared ESSs)

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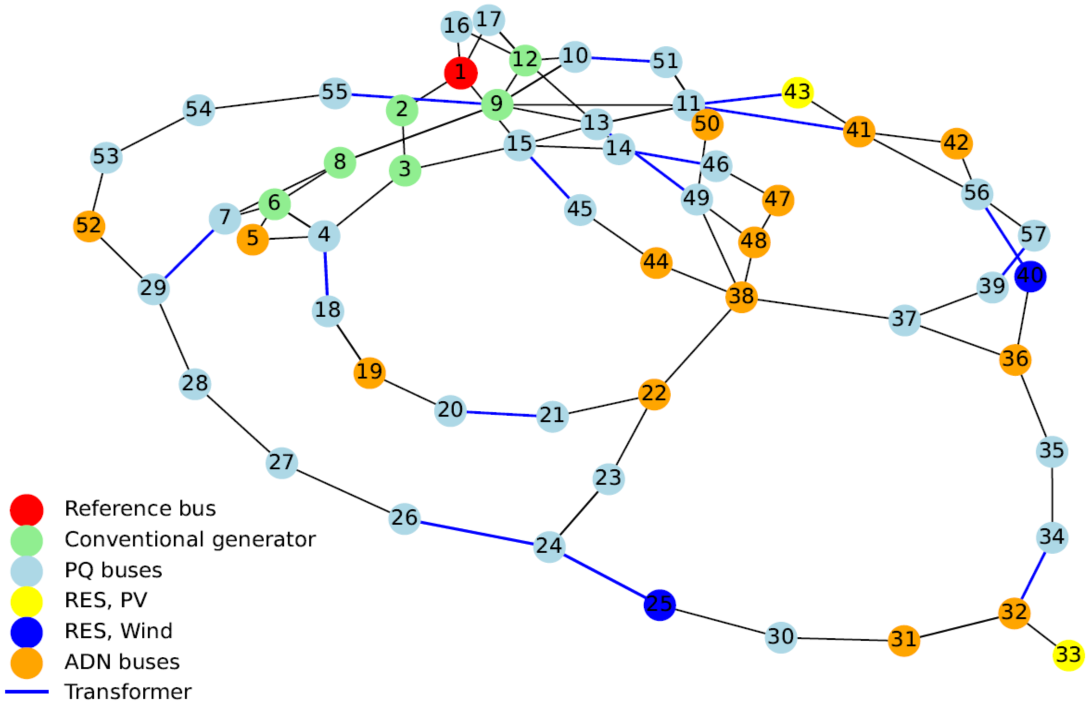
# Shared Resources Planning

## Case Study – Coordinated Operational Planning

- Case Study (operational planning):
  - Transmission Network (IEEE 57-bus):
    - 2 wind generators added
    - 2 solar PV generators added
    - Flexibility bands corresponding to 5% of the active power consumption
  - Distribution Networks (18-bus radial DNs):
    - EVs and PVs added, ranging between 30% and 40% of the peak active power consumption
    - Flexibility bands corresponding to 5% of active power consumption
  - 3 market price scenarios
  - 5 operational scenarios (TN and DNs)
  - 2 shared ESSs (1 MW, 2 MWh) installed at nodes 31 and 32



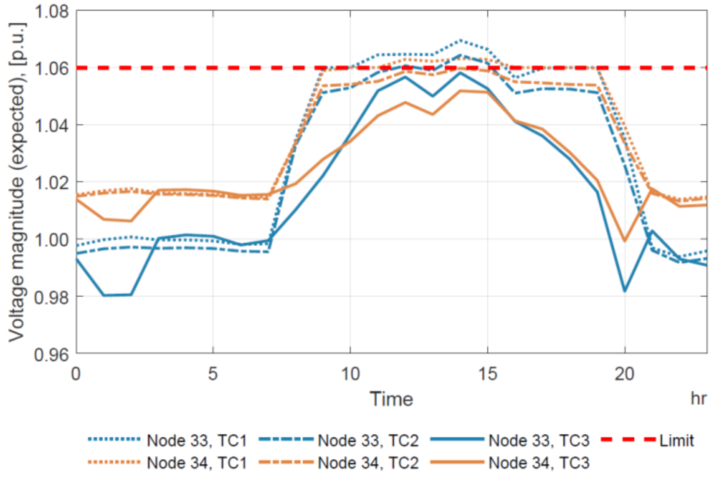

- Three test cases considered:
  - Test Case 1 (TC1): No TSO-DSO coordination
  - Test Case 2 (TC2): TSO-DSO coordination, no shared ESSs
  - Test Case 3 (TC3): TSO-DSO coordination, with shared ESSs

# Shared Resources Planning

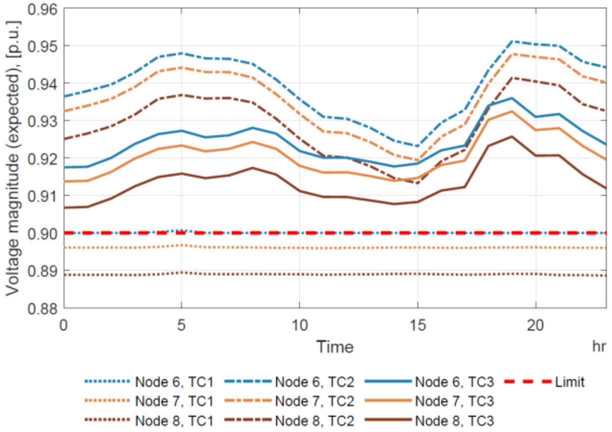
## Case Study – Results

- Without coordination (TC1):
  - TN: overvoltages in nodes 33 and 34
  - ADN node 5: undervoltages in nodes 6, 7, and 8
  - ADN node 22: undervoltages in nodes 7, and 8
- Considering TSO-DSO coordination, without shared ESSs (TC2):
  - TN: overvoltage node 34 solved; overvoltage in node 33 significantly decreased
  - ADN node 5: undervoltages solved
  - ADN node 6 undervoltages solved
- Considering TSO-DSO coordination, without shared resources (TC3):
  - All problems solved

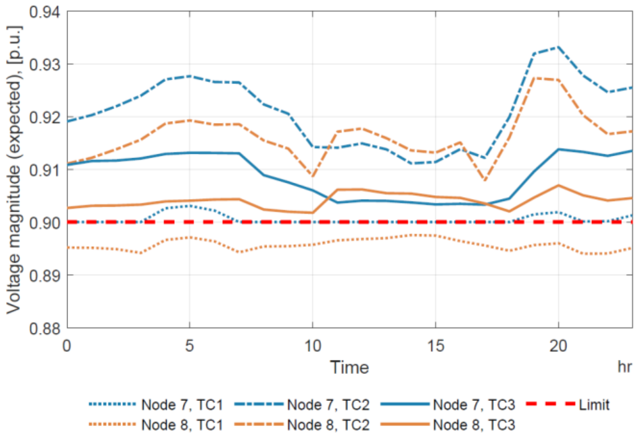
### Transmission Network




### ADN Node 5




### ADN Node 22

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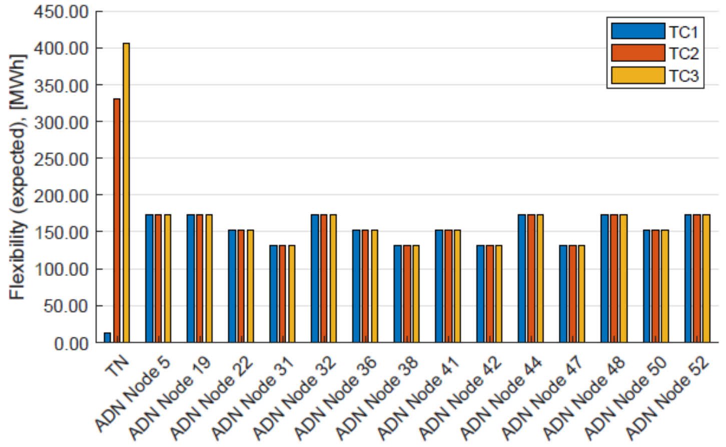
# Shared Resources Planning

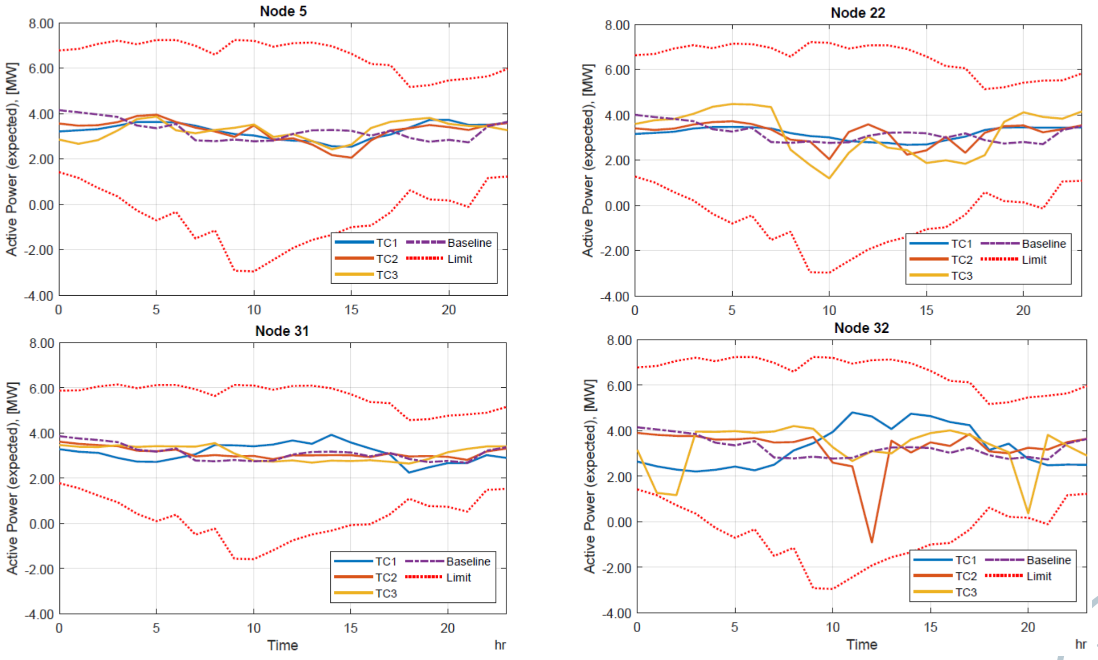
## Case Study – Results




- Total flexibility usage:
  - TN: increases significantly from TC1, to TC2 and TC3
  - ADNs: remains approximately the same, for all test cases
  - The highest amount of flexibility is required from the ADN located at node 32 of the TN, the ADN electrically closer to the nodes where the overvoltage occur

- When TSO and DSOs coordinate their operation, the flexibility available at the DN-level can be used in a more efficient manner, without necessarily increasing the total amount of flexibility required

### Interface Active Power Flows

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# Conclusions

- The project proposes a set of innovative tools for the planning and operation of future power systems, that will be made publicly available
- A new TSO-DSO coordination mechanism was proposed
- TSO-DSO Shared Resources Planning:
    - We have shown that TSO and DSOs are able to coordinate their operation by sharing a relatively small volume of information, and this coordinated operation brings several benefits to the operation of the overall power system
    - It was shown that the total amount of flexibility required from the DN does not necessarily increase
    - Investments in traditional network assets, such as OLTC transformers, could potentially be deferred
- The ATTEST project's toolbox will be shared soon, as well as the results of the demonstration

# Questions

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