Ref. Ares(2023)7314510 - 26/10/2023

ATTEST smarter energy

The advanced toolbox for smarter energy systems

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Project Motivation and Expected Impact

ATTEST - Advanced Tools Towards cost-efficient decarbonisation of future reliable Energy SysTems is dedicated to the study and development of solutions for the planning and operation of energy transmission and distribution network infrastructures.

The project intends to address the challenges of the energy systems of 2030 and beyond, by developing a secure and open-source platform that integrates a set of optimization tools for **operating, planning and maintaining assets** of power systems.

ATTEST's mission can be summarized in support to TSO's and DSO's in improving and coordinating their systems from a technical, economic and environmental standpoint.

The results expected by the ATTEST team:

- **To enable** accelerated dissemination of the tools among a wide range of research institutions within and outside of the project consortium;
- **To help** TSO's and DSO's to better manage their networks;
- **To provide** valuable data for the scientific community and EU energy industry;
- **To attest** the relevance of the developed solutions.

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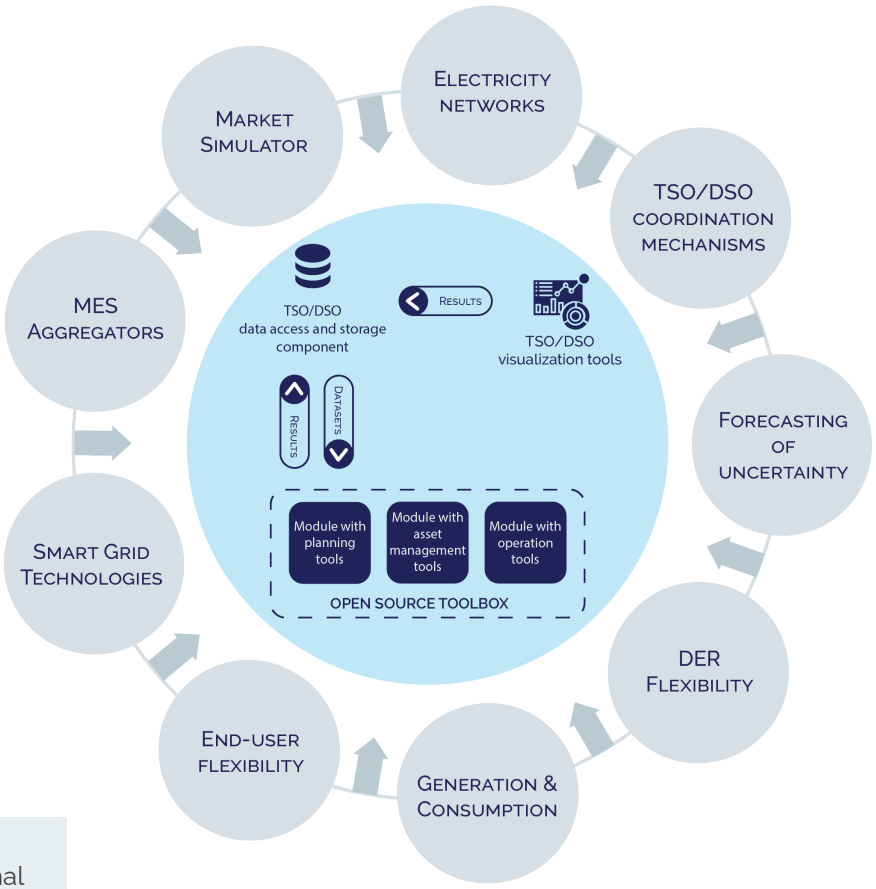
Structure

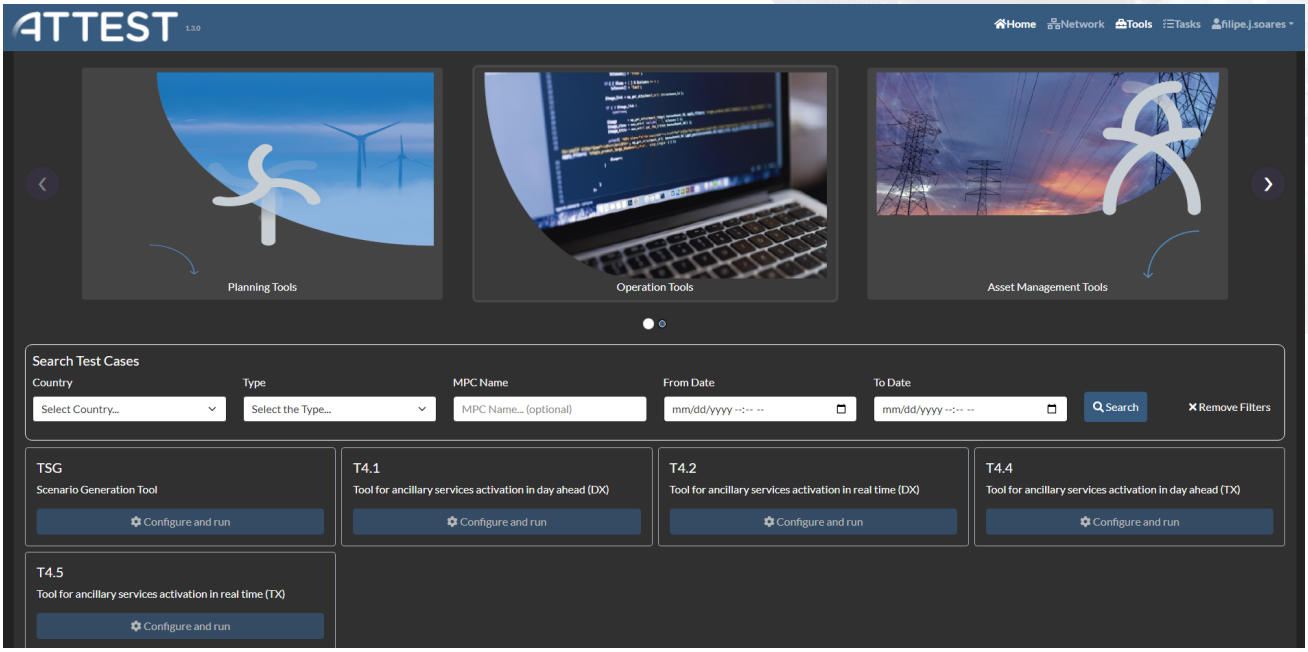
The open source toolbox that ATTEST will make available, will be embedded into an ICT platform for TSO/DSO coordination that will provide data access connectors and converters, tools' orchestration functionalities and visualization interfaces



Divided into planning, asset management and operational modules, the **12 tools** will feature algorithms that focus on "clean" or low-emission technologies. These will be highly versatile tools for collecting data directly from the SCADAs (supervisory control and data acquisition) of transmission and distribution network operators. At the same time, they will have an integrated way of operating, with the outputs of some tools serving as inputs for others, and offering a results visualization system that allows access to the outputs of the set of tools in an integrated way.

The ATTEST set of tools will be designed to make it possible to analyze energy networks from a multitude of perspectives, including ensuring analysis of multi-energy networks and optimization of interactions between transmission and distribution network operators.

The ATTEST Platform



The ATTEST ICT platform integrates the open-source toolbox, supporting TSOs and DSOs in their tasks.

The platform includes:

- a common data layer, to enable data integration and exchange through converters and connectors. It also integrates a CIM repository component and a dedicated connector for converting the CIM's node-breaker model, normally used by the operators, to the bus-branch model used by the tools.

- an infrastructure aimed at the integration of the tools from the toolbox, developed with diverse technologies and using different data formats. The integration component exploits the services provided by the data layer.

- a web-based GUI and a set of visualization components, to support the operators and the usage of the toolbox. From the GUI it is possible to manage networks and auxiliary data; prepare the inputs for a tool, start and monitor its execution; retrieve and display the results.

The main novelty and useful aspect of the ATTEST platform is that it provides an integrated study environment to TSOs and DSOs, with a single coherent access point to many tools, supporting network planning, operation, and maintenance, and targeting both transmission and distribution. The platform, providing a unified data layer, has been also designed to support data exchange among tools and operators.

The reliance on open-source development offers better interoperability, reliability, and ability to extend and customize the platform to fit specific or future needs. The platform provides a framework where new tools can be integrated, and existing ATTEST's interface components can be reused to visualise the outputs. Furthermore, the platform's support to open standards like CIM ensures that the software will continue to be relevant, for the long term.

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Planning Module

1

Optimisation tool for distribution network planning

An adaptive planning tool with path-dependent network reinforcement strategies.

The planning tool finds hybrid portfolios of investments that can capture the features of both asset and non-asset based solutions (e.g., flexible resources). The planning approach combines investment clustering and a recursive function to offer feasible and cost-optimal solutions for each future scenario, with maximum use of flexible resources.

What can you expect from this tool?

THE TOOL DEPARTS from the traditional robust planning approaches towards adaptive solutions that can be readily customised to different futures.

Identified investment strategies utilise both asset based and non-asset based solutions, which facilitate the integration of flexible and distributed energy resources at lower costs.

A scalable open-access approach that enables converting large portfolios of investments into investment strategies with a limited number of future scenarios.

Andrey Churkin
The University of Manchester

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2

Optimization tool for transmission network planning

A two-stage scenario-based stochastic optimisation model that considers both long-term uncertainties and operational uncertainties. Can be applied for the whole system or for certain regions that may evolve differently from the rest.

The tool considers the use of flexibility from emerging bulk generation technologies to complement network investments.

An iterative two-stage optimisation approach verifies that investment decisions are feasible for a set of predefined contingencies. The second stage includes a full nonlinear AC power flow operational model with security constraints. The outputs of the operational model are passed to the investment model (first stage) as linear approximations.

What can you expect from this tool?

IN CONTRAST to traditional deterministic planning approaches, the tool enables optimising capital expenditures and associated operation costs for many future scenarios.

The planning tool not only meets the demand by upgrading transmission networks, but also maximises the provision of flexibility.

The combination of investment and operational models enables incorporating security constraints into the investment strategies.

Andrey Churkin
The University of Manchester

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3

Optimization tool for planning TSO/DSO shared technologies

A bi-level tool for planning of TSO-DSO shared technologies, focused on energy storage systems. It is considered that these resources can participate in the energy and secondary reserve markets. The model considers uncertainties derived from market price forecasts and operational forecasts (e.g., secondary reserve activation).

At the upper-level, investment decisions are performed for the planning period 2020-2050, considering constraints for budget, power-to-energy ratio (related to the energy storage technology), and installed capacity (related to the space available for the installation of the energy storage units). Furthermore, battery capacity degradation is also considered in the planning procedure, derived from calendric and cyclic ageing.

At the lower-level, the TSO-DSO coordinated operational planning is simulated, considering ATTEST's TSO-DSO coordination mechanism. TSO and DSOs' operational planning problems are modelled as an exact multiperiod stochastic AC optimal power flow problem, that considers flexibility from asset and non-asset based solutions.

Mathematical decomposition techniques are applied to decompose the large-scale problem into smaller subproblems, with the objective of maintaining tractability and data privacy of the several agents involved in the optimization procedure.

What can you expect from this tool?

TO THE EXTENT OF our knowledge, it is the first time that a tool for the planning of TSO-DSO shared technologies is proposed. The model also considers battery capacity degradation and operational uncertainties, which are topics that only recently have started to be considered in energy storage planning tools. Furthermore, we consider that these resources will operate in networks where a large number of non-asset based flexibility providing resources will be present.

Micael Simões
INESC TEC

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Asset Management Module

4

Tool for the characterization of the condition of assets

This tool will characterize and model the life of important network asset components, such as power transformers, exploring techniques that include the characterization of the reliability using fault history and the characterization of the mean time to repair based on the history of maintenance actions, while also taking into account patterns for component behavior and condition collected from sensors and utilization rates. Clustering of assets in groups of similar characteristics respect to the dimensions considered: life assessment, health condition, maintenance and economic and environmental impact. Reduction of the assets to groups to be attended in the most convenient way.

What can you expect from this tool?

FLEXIBLE ADAPTATION to the information available in every company. Use of machine learning techniques for automatic classification.

Miguel A. Sanz-Bobi
Comillas

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5

Tool for the definition of condition indicators based on heterogeneous information sources

This tool will incorporate an innovative approach to translate the results obtained from the previous tool into a set of harmonised, easily measurable and comparable life indicators for different types of assets, which will allow determining the remaining useful life and the underlying sensitivities against different operation conditions. Labeling each asset with indicators according to the cluster's dimensions to which it belongs. It is essential to focus on the assets that require a careful attention. The indicators are obtained by a weighted contribution of the results obtained from each dimension. These weights can be adapted according to the desired exploitation strategy of the assets.

What can you expect from this tool?

CLASSIFICATION of assets by indicators based on the asset lives. Method able to put in a common base of analysis of heterogeneous information.

Miguel A. Sanz-Bobi
Comillas

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6

Tool for the definition of smart asset management strategies

This tool will define common approaches to evaluate the assets under different perspectives (operation, maintenance, cost, impact) resulting in asset priority lists. Smart strategies for asset management based on the previous asset evaluation and common life indicators will also be developed. Finally, the outputs of this tool will be embedded in the grid planning and operation tools available in the toolbox to allow optimized decisions considering not only CAPEX but also OPEX costs.

Depending on the health indicators, a recommendation for the assets about actions to take is elaborated. Also, an algorithm can project the condition of the assets in the future based on the current condition. Different scenarios can be prepared to evaluate the possible impact in the future of the asset management actions taken now.

What can you expect from this tool?

USE A REINFORCEMENT learning algorithm for preparing the actions to take. Use of a reinforcement learning algorithm for preparing the actions suggested. Capability to evaluate future evolution of indicators of the assets.

Miguel A. Sanz-Bobi
Comillas

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Operation Module

7

Tool for ancillary services procurement in day-ahead operation planning of the distribution network

This tool will support the DSO on the procurement of ancillary services (for voltage control and congestion management) to mitigate renewables uncertainty and ensure that the network capacity is never exceeded during the real-time operation stage. The outputs of the TSO/DSO coordination mechanisms that will run in parallel with the market simulator will define constraints for this tool to avoid that TSOs and DSOs procure conflicting ancillary services in the markets.

What can you expect from this tool?

THE TOOL IS intended to support distribution system operators in procuring at least cost energy flexibility services from distributed energy resources (renewable energy sources, storage and flexible demand) to satisfy grid operating constraints in the envisioned most complex operating conditions, caused by uncertainties in distributed energy resources and the need to model their energy constraints in time

Florin Capitanescu
LIST

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8

Tool for ancillary services activation in real-time operation of the distribution network

This tool optimizes the activation of flexibility, provided by both DSO assets (e.g. stationary storage and OLTC) and procured by the DSO in the ancillary services market, using the day ahead operation planning tool. The goal is to maintain the distribution network operating in a safe mode when forecasting errors occur, while minimizing OPEX and reducing environmental impacts.

What can you expect from this tool?

THE INOVATIVE ASPECT of the tool lies in multiple aspects:

- It is developed as a model predictive control algorithm, involving predicted high and low load scenarios, and ensures feasibility of various flexibility providers over a required period of time.
- It is developed as an exact AC OPF optimization with inovative model of penalisation from DA deviations thus ensuring minimum imbalances due to RT situations
- It considers and models all types of flexibility providers: energy storage units and EV charging modelled as flexible load
- As the distribution network is typically low observable is uses a newly developed state estimator to compensate for the missing data due to lower observability

Tomislav Capuder
ICENT

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9

Tool for state estimation of distribution networks

Even in the future energy systems, where communication technologies are expected to be much more developed and communication-enabled devices prominent, communication failures may still occur, preventing an accurate definition of the network operating state due to missing data. The coverage of distribution networks is a particular challenge due to their scale. This tool will allow estimating the operating state of the network with minimal available information (by estimating the net load in each node of the grid) and thus enable the usage of all the tools developed for networks operation even when there is lack of data.

What can you expect from this tool?

Even in the electric distribution systems of 2030, when communication technologies are expected to be more prominent, it is not expected that the distribution system will reach full observability, preventing an accurate definition of the network operating state. The state estimation tool allows the development of machine learning based distribution network state estimation techniques that deduce the full operating state of the network from the available information, by estimating the net load in each grid node. It also provides the conversion from the node-breaker network model which is directly related to physical equipment into the bus-branch model required by most of the algorithms.

Hrvoje Keko
KONČAR Digital

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10

Tool for ancillary services procurement in day-ahead operation planning of transmission network

This tool is an evolution of the conventional Deterministic Security Constrained Optimal Power Flow (SCOPF), which will be enhanced to be a multi-temporal SCOPF under forecast uncertainty. The tool will enable the TSO to procure ancillary services (congestion management, voltage control and frequency control) on a 24-h ahead basis. Additionally, the TSO/DSO coordination mechanisms will be used together with this tool to avoid that TSOs and DSOs procure conflicting ancillary services in the ancillary services markets.

What can you expect from this tool?

THE TOOL IS intended to support distribution system operators in procuring at least cost energy flexibility services from distributed energy resources (renewable energy sources, storage and flexible demand) to satisfy grid operating constraints in the envisioned most complex operating conditions, caused by uncertainties in distributed energy resources and the need to model their energy constraints in time.

Florin Capitanescu
LIST

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11

Tool for ancillary services activation in real-time operation of transmission network

This tool will be used to optimize the activation of flexibility, provided by both TSO assets (e.g. stationary storage and capacitors banks) and procured by the TSO in the ancillary services market, using the day-ahead operation planning tool. The goal is to maintain the transmission network operating in a safe mode when forecasting errors occur, while minimizing OPEX and reducing environmental impacts.

The tool is developed as an exact formulation of the AC OPF problem in the transmission network and it activates the not only flexibility from the conventional units connected to the transmission grid but also defines activation point at the interface with the DSO, within the interval defined as a feasible one at the DA stage. This then is coordinated with the Tool for ancillary services activation in real-time operation of the distribution network enabling activation of flexibility resources in the distribution network. The out of the tool are the amounts of flexibility activated and assignes them to the providers depending on their locations both in the trasmission grid and at the interface with the distribution grid, all by minimising the cost of providing these services.

What can you expect from this tool?

"The innovative/ disruptive part of the tool is mutiple:

• The tool uses inputs from an dynamic security assessment eveloped as a neural network to keep the ROCOF and nadir in the allowed limits.

• It is developed as a model predictive control algorithm, involving predicted high and low load scenarios, and ensures feasibility of various flexibility providers over a required period of time.

• It enables coordination of both system operators and ensures there are no activations of couteracting services from DERs and conventional units

Tomislav Capuder
ICENT

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12

Tool for on-line dynamic security assessment

This tool will perform a security assessment of transmission networks considering both static (i.e. voltages and currents) and dynamic constraints (i.e. stability) violations caused by N-1 contingency analysis. The tool implements a machine learning approach based on an Artificial Neural Networks (ANNs) to perform on-line dynamic security assessment with respect to frequency stability in future power systems characterized by large shares of converter interfaced generation, namely RES such as wind and solar. The ANNs are trained off-line using functional knowledge obtained through off-line dynamic simulations for a set of critical contingencies and for all the foreseen operating scenarios. The tool outputs are the frequency indicators RoCoF and nadir, as well as a classification regarding system security (secure/ insecure state) which is performed considering the regulated limits established for these indicators. In addition, it also provides information to the decision-maker about the proper measures to be taken whenever an unsecure state occurs, namely about the synchronous condensers units that need to be turned on to bring the system to a secure state. The tool is developed considering a standalone version that might be run either on-line or off-line (e.g., for day-ahead operational planning purposes), but also in integration with other two ATTEST tools: T4.4 – Tool for ancillary services procurement in day-ahead operation planning of the transmission network and T4.5 – Tool for ancillary services activation in real-time operation of the transmission network.

What can you expect from this tool?

The tool integrates unit commitment/dispatch algorithms that were specific developed for the context of this tool whenever there is a lack of real historical data that is needed for the training process of the tool. These algorithms ensure the creation of robust functional database with enough diversity for a wide range of operating conditions that are likely to be expected in present and future scenarios, namely for high-RES integration scenarios.

• Selection of input explicative/ variables for the training processes based on enhanced F-measure based algorithm that enables a more efficient way to perform feature selection to choose the most proper variables, thus improving tool's accuracy regarding the estimation process of system security indexes.

• Suitable for both day-ahead and real-time operational planning purposes for several/multiple contingencies at same time due to a parallel processing implementation.

• Allows a preventive control mode during real-time operation by proposing the best measures to be taken based on the dispatch of synchronous condensers units to ensure gird security whenever an unsecure state is verified at the dynamic point of view.

Pedro Barbeiro
INESCTEC

Support tools

13

Day-ahead and real-time optimisation tool to support MES aggregators

This tool incorporates two modules, one for day-ahead and another for real-time operation. The day-ahead module defines optimal bidding strategies for eligible clients and aggregators which participate in energy and ancillary services markets by intelligently using flexibility from multi-energy systems, including electricity, gas and heating/cooling networks and also electricity/thermal storage, RES, CHPs, etc.. The bids are optimally defined to maximise the aggregator's profit, always without violating networks' technical limits.

The real-time module dispatches the operation of multi-energy resources and ensures the reliable delivery of the energy and ancillary services traded by the aggregators in the day-ahead markets.

What can you expect from this tool?

"This tool enables the optimal utilisation of multi-energy flexible resources in favour of distribution and transmission networks. It emulates flexible clients and aggregators' behaviour in the market, so DSOs and TSOs can estimate where and when flexibility will be available to aid networks operation."

Filipe Joel Soares
INESC TEC

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Market simulator

The market simulator purpose is to emulate future energy and ancillary services markets, so that the ATTEST open-source toolbox operates in a realistic manner that takes into account the economic influence of the market on the networks' operation and assets utilization. Furthermore, the market simulator allows defining network operating states for future scenarios of grid development, which enable a more effective network planning taking into account the foreseen existence of DER flexibility and its optimal utilization.

What can you expect from this tool?

"Since future energy systems operation and assets utilization will be highly influenced by electricity markets functioning, a market simulator was developed in ATTEST. The consideration of the market outputs in the network management tools developed assures that they can be easily integrated in TSOs/DSOs everyday tasks and seamlessly applicable to future networks."

Leonel Carvalho
INESCTEC

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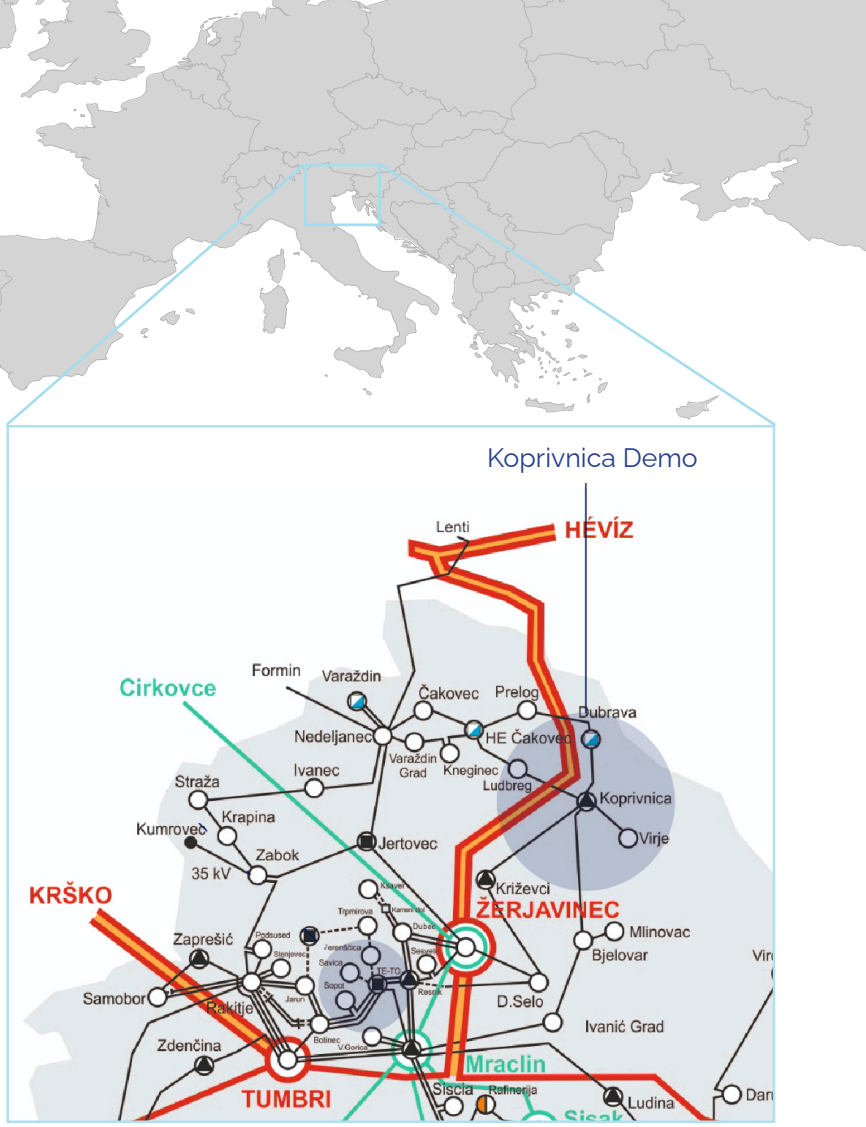
Demonstrators

Koprivnica Pilot site



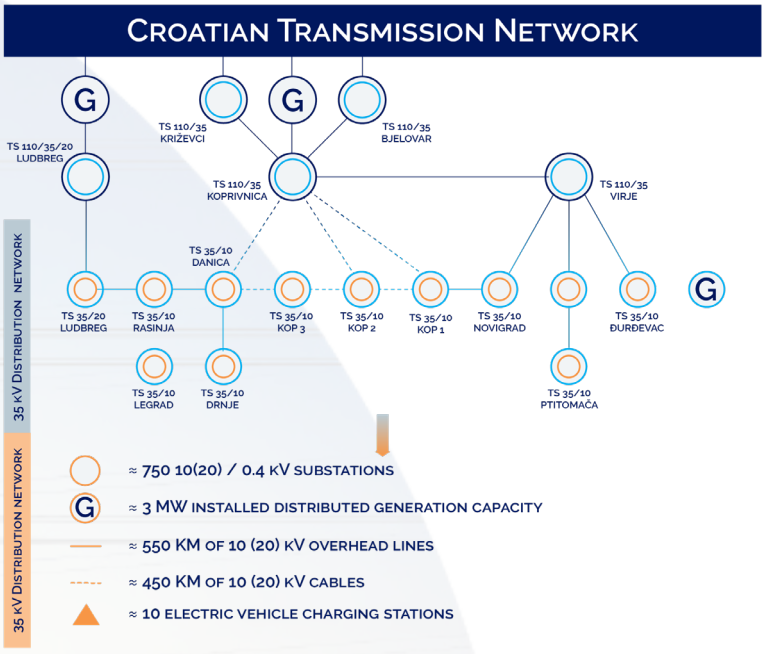
The Distribution Area Koprivnica has a higher-than-average degree of DSO asset observability when compared to the Croatia's distribution network. It also has a good mix of different customer classes (households, industry, mixed) which is needed for analyzing possible side effects of DSO operation to customers, and a relatively small number of voltage issues, which opens additional space for ancillary services provision.

In the ATTEST demonstrator, the Koprivnica MV DSO network has been used along with the corresponding section of the Croatian TSO HV network.

ATTEST tools have been demonstrated in a staged fashion, in three stages.

In the simulation stage, the tools have been run in simulation mode and executed on the Portuguese, Spanish, United Kingdom and Croatian networks, for the horizons up to 2050.

In the second stage, a virtual deployment of the operational tools has been implemented on INESC TEC premises, and the tools have been tested on a subset of the Croatian TSO and DSO networks. The utilized network model closely corresponds to the actual network model in the CGMES (Common Grid Model Exchange System) format.



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Tools tested on live data

In the full deployment stage of the ATTEST pilot, the suite of ATTEST operational tools has been installed in the Croatian DSO and TSO.

ATTEST platform has been integrated with the data coming from the TSO's energy management system software and the DSO's operational systems including the SCADA system.

A section of Croatian transmission system network and the Koprivnica region medium voltage distribution network has been synthesised into a pilot case exposed to the ATTEST operational tools.

The piloted ATTEST tools have been adapted so the TSO and DSO live data flows and the current system data models have been used.

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Project Information

BUDGET
EU Grant 4.0M€ (RIA)

DURATION
3 years and a half (Mar2020 – Aug2023)

COORDINATOR
INESC TEC (Portugal)

PARTNERS
9

COUNTRIES
6

LC-SC3-ES-6-2019

PROJECT WEBSITE
https://attest-project.eu/

OFFICIAL REPOSITORIES

INESC TEC REPOSITORY https://rdm.inesctec.pt/

ZENODO https://zenodo.org/communities/attest-eu/?q=&l=list&p=1&s=10&sort=newest

GITHUB https://github.com/ATTEST-project

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Softlab

HEP OPERATOR DISTRIBUCIJSKOG SUSTAVA

HOPS

KONČAR
Končar - Power Plant and Electric Traction Engineering Inc.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 864298

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