ELIA INNOVATION

Innovation incentive 2020-2023
Plan update

Project details

Update on the structure and the list of projects for the innovation incentive for the year 2022

01/07/2021

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Content

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Appendix

Project 1: SPACS 3 &4 and OSMOSE

Domain 4.3

2021 Decision: Accepted

Trends: Decarbonization, decentralized generation and new players, digital revolution

Consequences: Digital tools and data use, aging of the infrastructure, interface with new players

Challenge: 4. Optimize the development, the construction and maximize the use of new and existing infrastructure

Domain: 4.3 Advanced material and connected technology to maximize use for infrastructure.

Project-specific context

- SPACS 3 and SPACS 4 relate to the next generation of protection cubicles that will be deployed on the Elia grid in order to move from a wired substation to a digital substation using optical fiber
- SPACS 3 is the first step on the path to digital substations. It involves introducing the IEC61850 communication standard at substation level by using Edition 2 of this communication protocol in a multivendor environment, and improving the efficiency of the design and testing of PAC functions through functional integration and standardization. IEC61850 Edition 2 does not represent the majority of installations in the industry at the moment; it was officially released in 2011, but it took several years for the manufacturers to implement this release in their equipment and to obtain the appropriate certificates from the official testing bodies.
- The innovative aspect of SPACS 4 is that it introduces the Digital Substation concept, where process bus technology (exchange of information between the bay and the protection cubicles though the IEC 61850 protocol) plays a key role. The expected capacity of the solution will make it possible to test the installation of the equipment in a container. This container will be fully tested before installation on site in order to minimize the outage time during com
- In parallel with starting the testing of SPACS 3 and 4 and in order to prepare Elia for the implementation of SPACS 3 and 4, Elia has been participating since Q4 2017 in Work Package 7 of the OSMOSE project subsidized by the European Commission in the context of its H2020 tenders. The goal of the project is to test the interoperability framework (IEC 61850) in line with ENTSO-E's dedicated workgroup and by integrating real-life feedback from the demonstrations. To be noted that the project OSMOSE has been extended following some delays.

Project-specific state of the art/literature review

- Up to now, there have been only a few pilot projects performed in Europe, and no large-scale deployment has started yet. Such deployment would have also a strong impact on design, commissioning, and maintenance activities.
- The demonstration that will be performed in the context of OSMOSE, including the development of the IST tool, is also the first demonstration at European scale.
- Expected impact for Belgium
- OSMOSE will test the feasibility of interoperability in digital substations that are set to have an impact as a result of SPACS 3 and 4.
- SPACS 3 should bring about a 10% reduction of CAPEX of secondary systems in the years ahead for new projects.
- SPACS 4 should result in more flexibility in the replacement and maintenance of switching cabinets, leading to the optimization of the overall cost and increasing availability. The exact gain will be calculated in WP 2 Task 2 described below.

Starting point for Elia

- Nowadays, all substations that are installed are still equipped with copper wires. Tests performed by Elia some years ago demonstrated the lack of interoperability of Edition 1 of the protocol, and so it was decided to wait until Edition 2 before using this technology.

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Uncertainties and risks

- Uncertainty surrounding the availability of multi-vendor interoperable solutions in Edition 2 of the standard, both at equipment and at engineering level
- Uncertainty regarding tool availability for the efficient design and testing of IEC 61850-based substations
- Uncertainty surrounding the competencies needed to develop, maintain, and use such digital substations

Project description

- WP 7 of the project H2020, OSMOSE: Elia is leading task 1 from Work Package 7 with a view to improving the interoperability framework (IEC 61850) for plug & play integration and better utilization of flexibility solutions, in line with ENTSO-E's dedicated workgroup, and integrating real-life feedback from the demonstrations with development of an interface tool and a test with two suppliers. The demonstrator is hosted by R&D Nester, the lab branch of the Portuguese TSO REN, part of the OSMOSE consortium.
- The SPACS 3 and 4 innovation projects should be completed by early 2023. In light of the need to replace existing equipment, the objective is to integrate innovative solutions aimed at:
    1. reducing the cost of the switching cabinets forming part of the grid, thereby accelerating the volumes replaced while limiting the overall impact on the community;
    2. limiting the impact on resources despite the growing inherent complexity of the technology used;
    3. restricting the power cuts required for corrective maintenance and commissioning tests, notably through more flexibility;
    4. Maintaining at least the same performance level as the solutions that are currently being used.

- Approach:
    - In OSMOSE, test with two suppliers the interoperability of cabinets in a digital substation (in a demonstrator hosted by REN in Portugal) and an Interoperability Specification Tool (IST)will be worked out;
    - In SPACS 3 & 4, test the implementation of a digital substation in Aarschot as a testbed. First realizations of SPACS 3 (infrastructure project with full commissioning) will take place in *confidential*
- Work packages and timing (M = month)
    1. WP 1 & WP 4: SPACS 3

       Task 1 (WP 1)
        - Feb. 2019 – Dec. 2021: Development of applicative standards
        - Jan. 2020 – Dec. 2022: Technical description of the solution
       - Task 2 (WP 4)
        - Sep. 2020 – Dec. 2021: Training of operational team
        - From late 2021: Large-scale deployment
    2. WP 2: SPACS 4

       Task 1
        - Feb. – June 2019: Definition of pilot perimeter
        - April – Dec. 2019: Functional specification
        - Jan. – March 2020: Pilot scoping
        - Jan. – Dec. 2020: Engineering/design of pilot
        - Jan. – Dec. 2021: Construction of digital substation pilot

       Task 2
        - Jan. – Dec. 2021: Feedback
        - March – Dec. 2021: Definition of scenarios and cost-benefit analysis
    3. WP 3: OSMOSE WP 7 task 1
        - Jan. 2018 – Jan. 2019: Specification (definition of criteria, functional test specification, IST format definition, comparison between ISD (IED Specification Description) and SSD (System Specification Description)
        - Dec. 2018 – April 2019: Project design (implementation of virtual signal flow, implementation of comparison between ISD and ICD, first pre-test
        - Aug. 2018 – May 2019: Development of the IST tool

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- May 2019 – July 2021: Creation of the design for the demonstrator
- July 2021 – September 2021: Commissioning and testing with the two five suppliers
- September – End 2021: Report and conclusion of the testing
- 2022: Start of market integration

UPDATE*: the date for Osmose have been updated following some delay to build the demonstrator.*

- Deliverables and milestones

WP 1 & WP 4: SPACS 3

1. Dec. 2021: Applicative standards
2. Dec. 2021: Training procedure
3. Dec. 2022: Report on the technical description

WP 2: SPACS 4

1. Dec. 2019: Pilot specification
2. Dec. 2020: Design of pilot
3. Dec. 2021: Completion installation
4. Dec. 2021: Completion of cost-benefit analysis

WP 3: OSMOSE

- June 2018: Completion of IST specification
- Feb. 2019: Provision of SSD and ISD files
- April 2019: Provision of SCD file
- March 2020: Completion of testing
- Dec. 2020: Completion of reporting to the OSMOSE consortium

Partners

WP 1 & 4: SPACS 3

- Manufacturing of the cubicles: *confidential* (35%) and *confidential* (65%)
- Manufacturing of the control system: *confidential*
- Development of the engineering tool: *confidential*
- Development of the testing equipment and methodology: *confidential* (protection devices), *confidential* (RTUs)
- Experience-based feedback from other users/recommendations from international working groups: CIGRE Study Committee B5
- Benchmarking/exchanges of experiences and visions: other TSOs/DSOs

WP 2: SPACS 4

- Manufacturing of the cubicles: *confidential* and *confidential*
- Manufacturing of the control system: *confidential*
- Development of the engineering tool: *confidential*
- Manufacturing of the container and the integrator for the various cubicles in the container: to be determined
- Development of the testing equipment and methodology (including for interoperability tests): *confidential* (protection devices), *confidential* (RTUs)
- Experience-based feedback from other users/recommendations from international working groups: CIGRE Study Committee B5
- Benchmarking/exchanges of experiences and visions: other TSOs/DSOs

WP 3: OSMOSE

- Supply of the technology for testing interoperability: *confidential* and *confidential*
- Development of the IST tool: *confidential*

- Demonstrator and commissioning: REN (the demonstrator will be set up in REN facilities)
- Testing and conclusion: *confidential*, *confidential* , *confidential* , *confidential* are participating in the other task involved in Work Package 7 of the OSMOSE project

Summary of project efforts in person months (by work package and by year)

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Domain 3.3

Project 2: Asset Condition & Control (ACC)

2021 decision: Accepted

Trends: Decarbonization, decentralized generation, digital revolution

Consequences: Digital tools and data use, aging of the infrastructure, uncertainty of generation, intermittency of generation

Challenges: 3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping a high level of safety

Domains: 3.3 Predict and optimize the preparation of maintenance

Project-specific context

- Currently the asset maintenance strategy within Elia is strongly time-driven, whereas the need for condition-based Asset Management has been identified as a major gain within the AMEX program. The AMEX or Asset Management Excellence program was focusing on optimization of the Maintenance and Replacement Strategy of the different fleets between 2016 and 2020. The developed methods (like FMECA, Risk Model, …) are in the meantime anchored within the Business As Usual and the ACC is an enabler for a number of levers identified in the AMEX program.
- To be able to shift the focus from time-based to condition-based asset management, dynamic asset data need to be acquired, managed and analyzed in order to estimate/calculate the physical health condition of an asset (Health Index ,HI).
- Dynamic asset data typically change over time during operation of the asset and have an operational application in terms of asset management. Aside from typical measurements like voltage and load, they also cover indicators such as number of operations, switching time, pressure level, expert assessment during visual inspections and fault recordings. Aside from typical measurements like voltage and load, they also cover indicators such as number of operations, switching time, pressure level, expert assessment during visual inspections and fault recordings.
- Dynamic data can be retrieved as online data (temperature probe, DGA probe, remote reading, EMS, etc.) or as offline data (maintenance checklists, site patrols, historical analysis reports, etc.)
- Storing and using these big data was not possible in an efficient way with the current available tools which have a static referential nature.
- Therefore, Elia needed to develop an innovative data platform that would collect and sort stored data from the various sources in order to build up an HI by asset type to closely follow the maintenance requirements.

Project-specific state of the art/literature review

- During a proof of concept (2014-2016) we discovered that there were no HI algorithms available on the market for Elia's fleet of assets. Elia conducted multiple exchanges and benchmarks with various TSOs who are considered to be leaders in asset management (e.g. Fingrid, Terna, National Grid, RTE). None of these had implemented the HI concept but they are all willing to perform this type of asset management in the future. Typically this type of exchange is sensitive and in general not shared publicly amongst TSO's.
- There are multiple reasons for this:
    - The lack of such concepts (as yet) at academic level (e.g. at CIGRE consortium level); in the meantime there is a publication for AIS (Air-Insulated Substation) assets, but a large part is based on Elia's experience;
    - Black-box solutions from vendors that cannot be tweaked, cannot be made by other manufacturers or do not have the desired focus;
    - Experimental algorithms from other TSOs are only valid on their fleet with their applied maintenance policy and their asset management strategy.
    - Experiences from the process industry are rarely relevant as their asset management does not share the same goals and has much shorter asset life cycles. Also at other utility companies (like gas and water), this type of concepts are mostly to be found on roadmaps or smaller pilots.

- Therefore Elia decided to develop its own HI based on the experience of its asset managers and field staff (applying FMECA, or a Failure Mode, Effects, and Criticality Analysis) and the expertise from vendors, other TSOs and DSOs, and last but not least the academic community or CIGRE and IEEE.

Expected impact for Belgium

- Some gains can be found in other strategies (maintenance & replacement), but these are high-level assumptions. Similar projects such as their application to power transformers have already resulted in more efficient asset management and it is reasonable to expect that benefits (efficiency, quality, safety and environment) can also be achieved on other assets.
- This project will allow Elia to gain a better understanding of the condition of its grid, allowing it to be more efficient in its maintenance and replacement of assets.
- Furthermore the developments will lead to better understanding of equipment failures and will therefore also allow Elia to act before failures happen. This is an important aspect as it will lead to increased safety for the employees and the environment. (Example 2019: identification of current transformers with an increased risk of explosion when operated at summer temperatures of over 35°C.)
- By assessing the health of assets, the project will enable Elia to act before incidents happen or in other words to apply a condition-based maintenance. It is however not possible to calculate the number of avoided incidents, or their impact, in a statistical correct way because the type of fault we try to detect in an early stage are quite rare (example: 1500 transformers and 1 or 2 failures on a yearly basis : Too small number of occurrences with too different failure modes to have statistical sound proof) . The calculation of the system risk has not been performed either. The model to calculate this makes part of the "Project 4: Risk-based approach for grid development decisions".

Starting point for Elia

- In the period 2017-2019, Elia had already successfully implemented this approach on a number of asset fleets: power transformers, switchgear with a rating of ≥70 kV (disconnectors, circuit breakers, CTs, and VTs), underground cables, overhead lines, and gas-insulated Switchgear.

Uncertainties and risks

- The first uncertainty relates to the possibility of integrating the data into the current platform.
- The second uncertainty concerns the relevance of the results of the HI, as for each HI algorithm, it needs to be shown that this makes sense and is applicable.
- The third uncertainty is that data are insufficient to build up a qualitative HI that will reduce the risk of outage of the asset while lowering the maintenance cost compared to a time-based approach.
- As this methodology will need substantial development and also new capabilities (in data management), a risk for the project is the unavailability of resources.

Project description

- For the period 2020-2023, Elia envisions testing the data platform and the condition-based methodology via the HI for new fleets of assets: Air-Insulated Switchgear (AIS) with a rating of ≤70 kV, substation buildings, 48 and 110-VDC batteries, shunt reactors, capacitor banks, metering cubicles, HVDC, low-voltage equipment (automation, control, protection, measurement). On top of this, the project will aim to optimize previously implemented fleets. This includes gathering data from additional sources (IoT sensors or other databases), and also adapting existing algorithms based on our initial experiences and innovating with a view to achieving a predictive approach in asset management.

- Approach : ACC's implementation is based on the waves of the AMEX program, identifying which asset fleets benefit from condition-based asset management. ACC Wave 1 implemented power transformers, switchgear with a rating of ≥70 kV (disconnectors, circuit breakers, CTs, and VTs). ACC Wave 2 implemented underground cables and overhead lines. Each wave involves tool development (reporting, interfaces with sources, data model, data cleaning, etc.) and the

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definition and validation of the specific HI and Equivalent Age (EA) for each (sub)fleet. The operational use of the HI/EA falls outside of the project scope and forms part of the ACC team's business as usual.

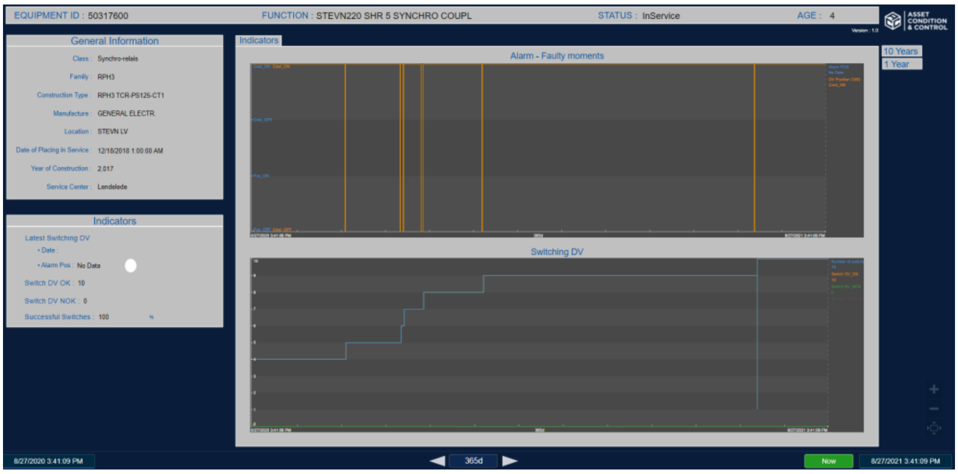
- Work packages and timing
  1. *WP 1 ACC Phase 3 (linked to AMEX waves)*
     1.1 *Task 1: Development of the Health Index with gas-insulated switchgear, 48- and 110-VDC batteries, shunt reactors, diesel generators, Point-on-Wave switching IED and Overhead Lines:*
     - Oct. 2019 – Dec.2020:
       - GIS HI: Develop Health Index for GIS in PI system, including reporting, dashboarding, notifications
       - Batteries HI: Proof of Concept Health Index for Batteries in PI system, including reporting, dashboarding, notifications
       - Diesels HI: Develop Health Index for Diesels in PI system, including reporting, dashboarding, notifications. Interface with Dieselwatch has already been integrated during Wave2
       - Shunt Reactors HI : Develop Health Index for Shunt Reactors in PI system, including reporting, dashboarding, notifications
       - OHL HI 2,0 : Additional development of OHL HI, which was out of initial wave2 scope (ie/ HI weighted + corrections)
       - PI optimisations: HMI for ACC-IR, ACC-Tran, eForms; Reports to eDoc, PI system monitoring, PI Dashboard at PUTM of Net element level.

     1.2 *Task 2: Optimization of AIS with a rating of ≥70 kV, power transformers, introduction of a new Health Index:*
     - Sep. 2020 –Dec. 2020 :
       1. OLAF interface for TI/TP data : replace the current monthly reporting from Laborelec with a real time API connection to Laborelecs cloud: OLAF
       2. Optimization AIS & TFO HI: Adapt the current reporting with the new insights of the AM, including the HI formulas.

  2. *WP 2 ACC Phase 4 (linked to AMEX waves)*
     2.1 *Task 1: Optimisation of the health index with air Insulated Switchgears (AIS) ≥70kV and power transformers, SCOF Cable Monitoring, HI Batteries Substation,*
     - Jan. 2021 –Dec. 2021 :
       - AIS ≥70 kV HI: Optimize Health Index for AIS ≥70 kV and add new types of data, including reporting, dashboarding, notifications
       - Power Transformer HI: Optimize Health Index and add new types of data, including reporting, dashboarding, notifications
       - PoW (Point On Wave): Dashboard and alarms for the follow up of the new PoW devices RPH3 (number of correct and failed switches) in support of AM APA.
       - Batteries HI: Develop Health Index for Batteries in PI system and Automated Remote Discharging, including reporting, dashboarding, notifications
       - SCOF Cable Monitoring: Develop algorithm for oil leakage detection with IoT sensors on SCOF cables including reporting, dashboarding, notifications

<u>In august 2021 we already have reached:</u>

- PoW is finalized. The dashboard is now available and enables the asset manager to follow up on his asset fleet. Below you will see an example of the view from the new developed dashboard.



- All the other tasks have started, ongoing and on track according planning.

3. *WP 3 ACC Phase 5 (linked to AMEX waves and previous WP2)*

   3.1 *Task 1: Development of the health index with air Insulated Switchgear (AIS) ≤70kV, Capacitor Banks, HVDC equipment*

   - Jan.2022 - Dec 2022 :
     - AIS ≤70 kV HI: Operational monitoring for AIS ≤70 kV (example: days not switched) including reporting, dashboarding, notifications + preparation of HI
     - Capacitor Banks HI: Develop Health Index for Capacitor Banks, including reporting, dashboarding, notifications (TBC!)
     - HVDC HI: Develop Health Index for HVDC, including reporting, dashboarding, notifications

   1.2 *Task 2: Feasibility assessment and low level development of the health index with Metering Cubicles and Low Voltage equipment*

   - Jan.2022 - Dec 2022 :
     1. LV or Secondary Systems HI: Feasibility assessment & Develop Health Index, including reporting, dashboarding, notifications
     2. Metering Cubicles HI: Feasibility assessment & Develop Health Index, including reporting, dashboarding, notifications
     3. Other (TBD)

Partners

- Compilation of a historical database for WP 1 and 2: Elia is working on a partnership with *confidential*
- The Elia Asset management team will be leading the project, working in close coordination with the Asset Department's Transformation Office, while the Asset Committee will be responsible for monitoring progress.
- Sensors for data retrieval: Various suppliers will be involved*confidential*
- Preliminary conclusions: At CIGRE level a working group has published a technical brochure called *Methodology of Asset Health Index concept* (B3.48). Elia was an active contributor to this brochure and the content is in line with ACC's work. Elia has not performed any additional publication.

Summary of project efforts in person months (by work package and by year)

confidential

Domain 3.3

Project 2bis ACC 2.0

NEW PROJECT:

Trends: Decarbonization, decentralized generation and nuclear phase-out, digital revolution

Consequences: Digital tools and data use, aging of the infrastructure, uncertainty of generation, intermittency of generation

Challenges: 3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety

Domains: 3.3 Predict and optimize preparation of the maintenance

Project Specific Context

- The ACC 2.0 program is the next step in Asset Management after ACC. With Asset Condition & Control 2.0, Elia focuses on **Remote Maintenance** activities and **Predictive Maintenance** (vs condition based maintenance @ ACC) on the short and long term with a desired end state around 2030-2035.
- Remote Maintenance allows Elia to optimize or replace OPEX activities. We combine our maintenance experience and digital technology to remotely execute or even automate manual and time consuming processes, without losing focus on safety and (cyber) security.
- Using the same types of technology we can perform Advanced Monitoring that will allow Elia to better define the condition of the assets and enable Predictive Asset Management for even better decision making (Near real-time, short term and long term).

Project specific State-of-the-art/Literature study

- Elia started this program after having multiple exchanges and benchmarks with various TSOs who are considered to be leaders in asset management (e.g. Fingrid, Terna, National Grid, RTE). None of these TSOs have a complete vision on Remote Maintenance or Predictive Maintenance but they are all in the phase of discovery and development. Typically this type of exchange is sensitive and in general not shared publicly amongst TSOs.
- There are multiple reasons for this:
    - The limited number of topics at academic level (e.g. at CIGRE consortium level);
    - Black-box solutions from vendors that cannot be tweaked, cannot be made by other manufacturers or do not have the desired focus;
    - Experimental algorithms from other TSOs are only valid on their fleet with their applied maintenance policy and their asset management strategy or are difficult to access due to IP protection;
    - Experiences from the process industry are rarely relevant as their asset management does not share the same goals and has much shorter asset life cycles. Also at other utility companies (like gas and water), this type of concepts are mostly to be found on roadmaps or smaller pilots.
- Therefore Elia developed its own program "ACC 2.0" that groups Remote Maintenance and Predictive Maintenance activities in all asset management domains of Elia (Primary Systems, Secondary Systems and Linear Assets and structures). The goals of the program are to:
    - Identify the relevant use cases
    - Build and evaluate the business case for each use case
    - Prioritize the positive business cases in a roadmap
    - Develop the use cases for implementation
    - Implement the solution

Expected impact for Belgium

- Main **drivers**:
    - Increase **efficiency** by automating manual and time consuming processes.

- Increase availability and **quality** of monitoring data for Condition Based Maintenance and Predictive Asset Management, resulting in an optimized quality of the grid (avoid ENS and create social welfare: a first high level assessment has shown a potential of 50% ENS reduction by 2030, depending on the digitalization rate of the assets and feasibility of certain use cases).
- Increase **safety** by having less physical presence in a substations and a better view on the actual condition (and potential hazard) of our assets.
  Reduce our carbon footprint on the **environment** by reducing travelling to substations and harmful leakages through leakages with through better monitoring (example: SF6 and oil leakages).

Starting point Elia

- Elia has successfully implemented Asset Condition & Control over the last years (see figure). Here the focus was mainly on Condition Based Asset Management, but it opened up the mindset to go even further, where it makes sense, towards predictive asset management using more sensors, more data and more analytics. Also the first 'Control' activities on the automated remote diesel generator testing has matured the need of further Remote Maintenance activities.

Uncertainties & risks

- The first uncertainty relates to the identification of the different use cases in order to match the desired end state of a Digital TSO that relies on predictive and remote maintenance to fulfil its missions.
- The second uncertainty concerns the relevance of the predictive models, as for each model Elia needs to make sure this makes sense and is applicable. Indeed, the marginal added value of predictive, compared to condition based, will depend on criticality of assets justifying the investment and the availability of data.
- The third uncertainty is the availability of data (on and offline), technology to access the data (industrial IoT, Data Lakes, Artificial Intelligence, Machine Learning) and competences (in house or through partnerships).
- Possibility to get sensors data or to install the required sensors.

Project description

We expect to reach maturity of Remote Maintenance & Predictive Maintenance by 2030-2035
Focus 2021-2023

- Analyze, quantify and justify the business cases for Remote Maintenance and Predictive AM
- Investigate and build detailed MVPs on RM and PAM on the selected use cases, to deploy industrialized solutions before and be ready by 2024 (ramp up).
- Implement today the no regret solutions that support our current challenges.

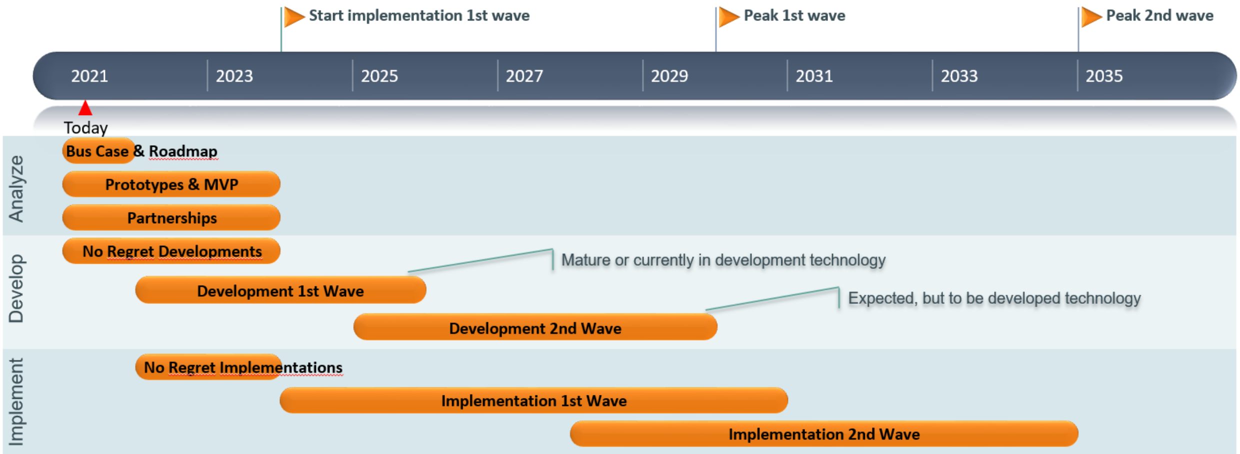


Figure 1- Planning of the ACC project

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The complete detailed description of ACC2.0 will not be available before end of the year 2021 because of the ongoing use case and business analysis, as communicated during the meeting with the CREG in Spring 2021.

Partners

The ACC2.0 program has a challenging scope and the outcome is vital for Elia's ambition to become a Digital TSO. Elia strongly believes in the value of partnerships to obtain this objective. Therefore a number of internal and external partnerships have been developed or are under discussion.

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Figure 2 – Partners of ACC 2.0

Summary of project efforts in person months: per work package and per year

At this stage, the ACC2.0 program is still under development. This means that currently over 50 use cases have been identified, which will now be further investigated and prioritized. Later in 2021 (according to the planning below), it will become clear which subprojects will need to be launched in 2022, allowing to identify the necessary resources and work packages.

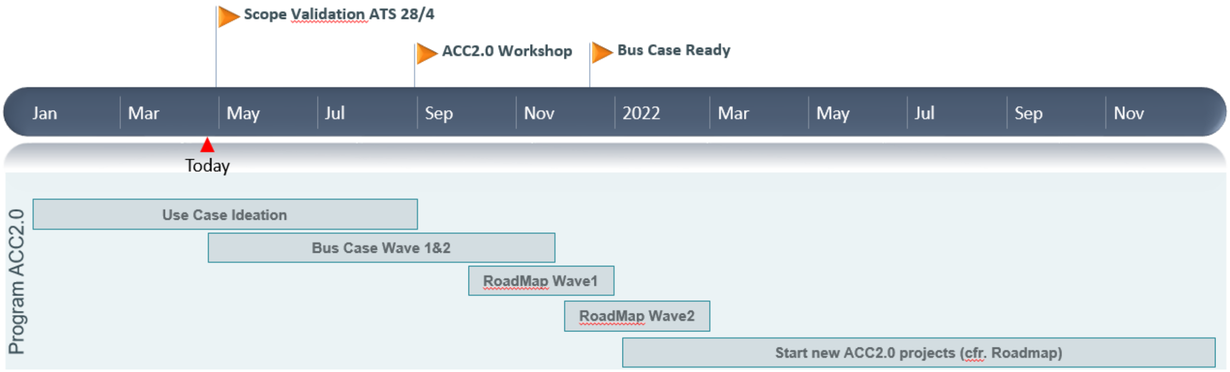

Figure 3 – Efforts summary of ACC 2.0

At this stage, we provision 2 FTE for IT, 2 FTE from the Business Unit and some material and license costs for 2022 and 2023.

Summary of project efforts in person months (by work package and by year)

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Domain 3.3

Project 3: Synapse (former Optiflex)

2021 decision: Accepted

Trends: Decarbonization, digital revolution

Consequences: Digital tools and data use, aging of the infrastructure, uncertainty of generation, intermittency of generation

Challenge: 3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping a high level of safety

Domains: 3.3 Predict and optimize preparation of the maintenance

Preliminary remark : there was neither a reassessment nor a review of the program since the initial submission to CREG. The name "OPTIFLEX" has been changed because it was leading to misunderstandings and was not correctly perceived. For this reason, it has been decided to change to Synapse (Synergy between Agile Planning and Stable Execution). Therefore the objectives and scope of the program remain the same as presented to CREG under the naming "OPTIFLEX".

Project-specific context

- We estimate that compared to 2015, the volume of renewable generations could have doubled by 2022, up to a level where the installed capacity is equal to the peak load.
- Up to 10% of the substations will have a connection with a Gflex (N or N-1) contract.
- The Belgian grid was designed for a top-down flow, with central power generation at 380-kV and 150-kV levels. The future flow will be a mix of top-down, bottom-up and international flows, with substantial installed capacity at DSO level.
- The number of outages and so the amount of MWh at risk is increasing due to the need to perform replacement projects and maintenance and because of the difficulty to find an optimal planning window due to unpredictable RES generation.
- The average time taken to restore power is rising due to the nature of the interventions requiring an outage.
- This challenge will increase in the years to come with the uptake of e-mobility, which will also affect the DSOs' outage planning.
- At the same time, the asset fleet is aging, resulting in an increased need for maintenance in the years to come.
- The number of critical outages is expected to double by 2022. The regions impacted by these outages are usually not densely populated (which has the advantage that permits can be obtained more easily) but normally do not have the infrastructure required to deal with these increased flows. However, planning is currently managed on a long-term basis and revising it generally involves repeated work. If constant planning revisions could be avoided, this could avoid extra repeated work for Elia and results in efficiency gains.

Project-specific state of the art/literature review

- The new process will apply criteria (specific flexibility and stability planning aspects in a decision-making matrix) that are not applied today by our neighboring TSOs. So far Elia has not performed an official benchmarking to compare with all existing references. In the various contacts we have had (in and outside Europe) we observe that no TSO is applying those processes and criteria like we are envisioning in this program. These criteria are specifically developed for the TSO environment, e.g. variable commitment dates for the planning depending on the criticality or flexibility of the works and outages.
- The new tool (OPSO) is currently being developed with an innovation partner to allow the integration and optimization of multiple constraints and objectives with a high frequency iteration. The underlying principles, algorithms and methodologies for this optimization are based on the scheduling optimization principles applied in other sectors like the pharmaceuticals supply chain, which are then customized to Elia's situation (outages, real-time availability, etc.). These objectives will be assessed on the basis of scenarios.

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Here below the high level description of our Macro process where the basic principles are explained

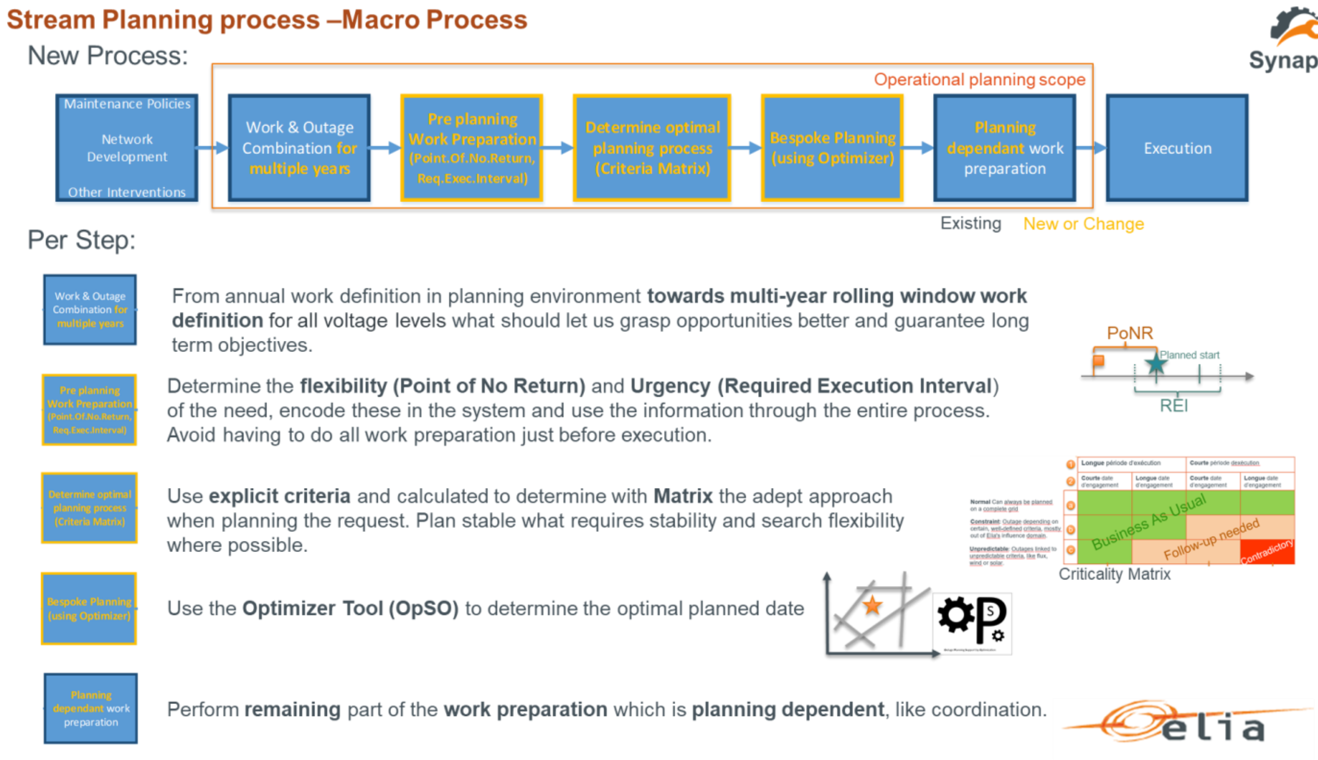

Figure 4 - Steps of the OPSO project

The Matrix implies the use of the tool we are currently developing (namely OPSO) and the criteria's and concepts we would like to apply: Flexibility (Point of no return) and Urgency (Required Execution Interval).

The underlying principles of the matrix are explained in the graph below:

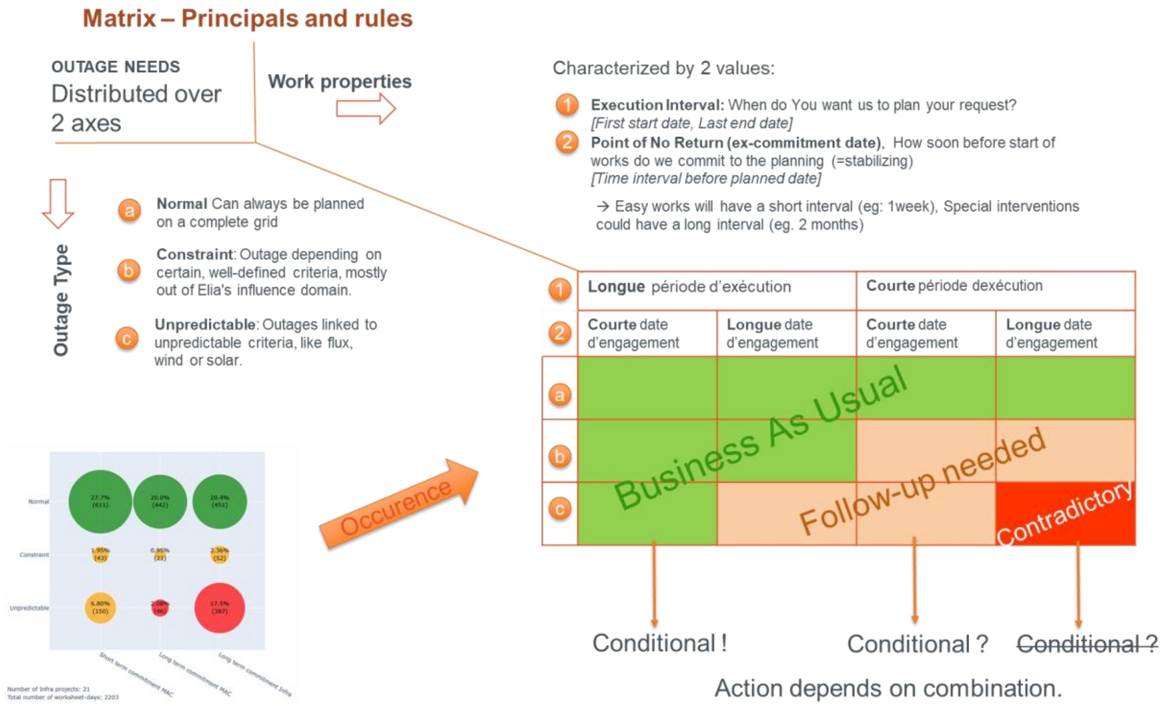

Figure 5 - Principles and rules of OSPO solution

In the example here below we illustrate the link between the process of operational planning optimization of thousands of works and outages and the Asset Life Cycle (including also ACC and health index).

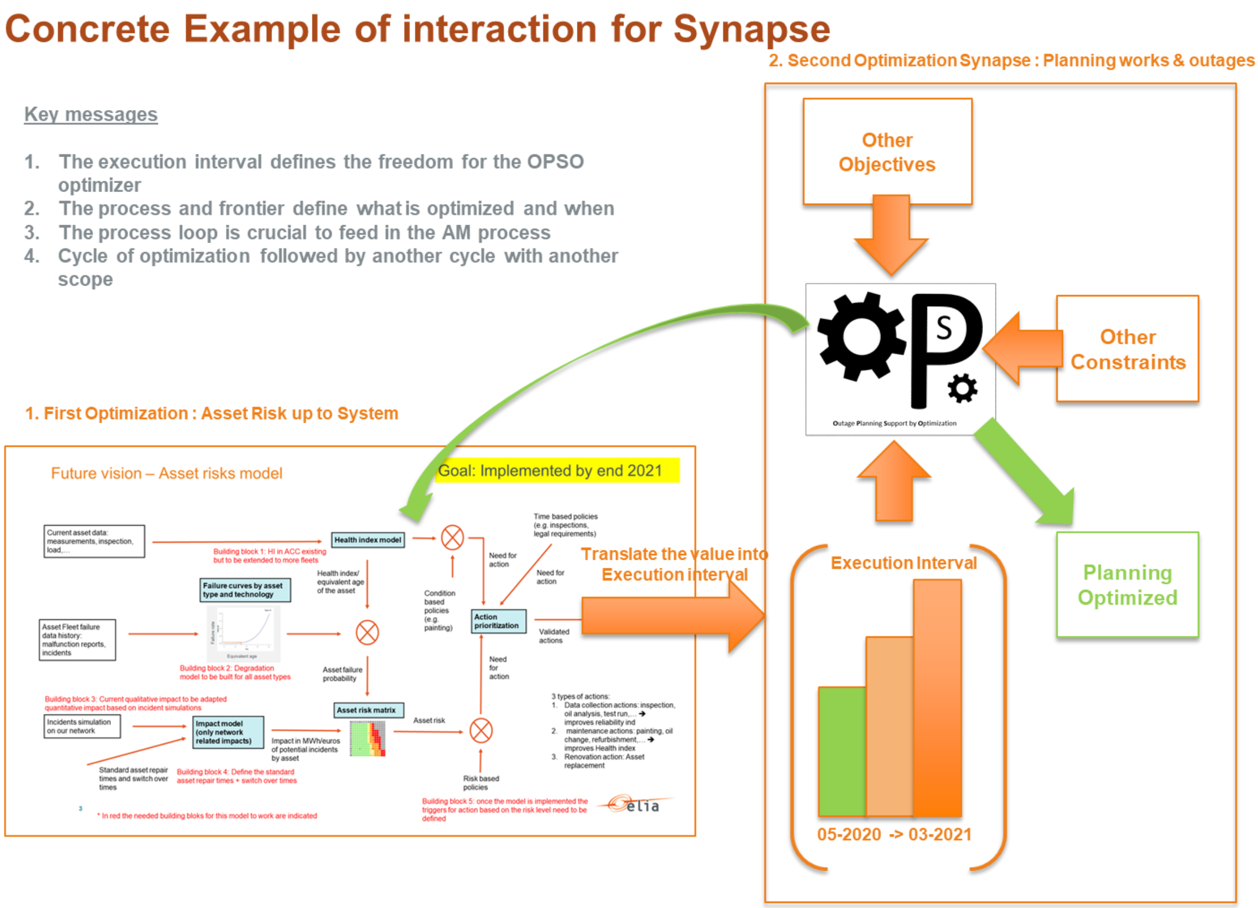

Figure 6 - OPSO solution logic and interactions

Expected impact for Belgium

- The implementation of flexible optimized planning to cope with the uncertainty of renewables generations and other components of the energy system such as e-mobility will result in the following improvements from the non-optimized situation:
    - a 10% decrease in the outage risk, or the MWh risk;
    - a 10% decrease in the number of outages and a 10% increase in works/outages;
    - in the future, limitation of the impact on the number of RES by increasing planning agility;
    - an increase in planning agility and stability for critical works and outages, allowing a higher proportion of maintenance and CAPEX plans to be implemented in the required execution time frame (70% stability).
- The improvements here above are related to the optimization related to Synapse. In the example in the previous section (interaction with Synapse) we explain the link between the Asset Risk (Asset Health Index/ACC & probability) and Synapse (the Execution Interval).
- The improvements detailed here above are compared to the non-optimized situation. Those figures have been calculated based on concrete proof of concepts realized in 2019.

- Absolute figures related to outages and works will strongly vary from one year to another and depend from external factors (RES evolution…). In other words, even with a hypothetical case with less works considering the additional upcoming constraints, the situation could be more difficult to optimize. We are currently considering the various constraints and objective that could be optimized including amongst others market capacity & RES impact. The integration of those criteria will allow us to further assess the impact of our program.
- Finally, we can say that those improvements are concrete objectives for the Synapse program and therefore will be internally closely monitored.

Starting point for Elia

- Today at Elia, operational planning is mainly managed using several planning cycles from yearly planning to weekly meetings, with printed operational documents based on various non-integrated output (operational team capacity, network availability, etc.). In the future, the increasing complexity of such planning and the higher frequency of the updates will require new integrated tools and processes.

Uncertainties and risks

- The environment evolution speed is a major uncertainty and the project implementation should adapt accordingly.
- E.g., we have foreseen a progressive implementation of various constraints (RES, impact on network, *MWh@Risk*...) in our model. If the external factors lead to new constraints we could have to change our releases and priorities;
- The program includes the development and the implementation of the solution to achieve the foreseen results foreseen. The releases will drive those implementations;
- The risks related to the program are the following
- Being able to transform large operational processes to new state of the art processes and tools impacting large population across all departments
- Software development :
    - Being able to model and integrate the various constraints and objectives;
    - Being able to integrate various types of data (large quantity, quality, reliability, availability and various protocols) and sources into a single tool and to ensuring perfect integration and optimization;
- Being ready to progressively switch to the future release of the tool including AI;
- Having the adequate resources at the right time for these specific innovative tasks and ensure adequate business continuity and development.
- The development of the solution will require to get specific competences as data scientist. As these competences are more and more in need, it could be difficult to be staffed.

Project description

- The primary objective of the Synapse project is to develop and improve, through innovative solutions (e.g. using artificial intelligence), planning and the optimization of execution in order to increase productivity (works under constraints) and decrease unavailability risk for Elia and stakeholders (consumers, generators, etc.). More specifically, the program will aim to maximize results under various constraints:
    1. safety, which remains the top priority and must not be jeopardized when carrying out our works;
    2. maximizing the planned Elia maintenance-work program and implementing the validated grid project infrastructure development program;
    3. optimizing grid availability by planning works to minimize the impact on MWh risk;
    4. minimizing downward adjustments of RES;
    5. having the adequate (skilled) personnel doing the right job, and optimizing travel costs and flexibility.

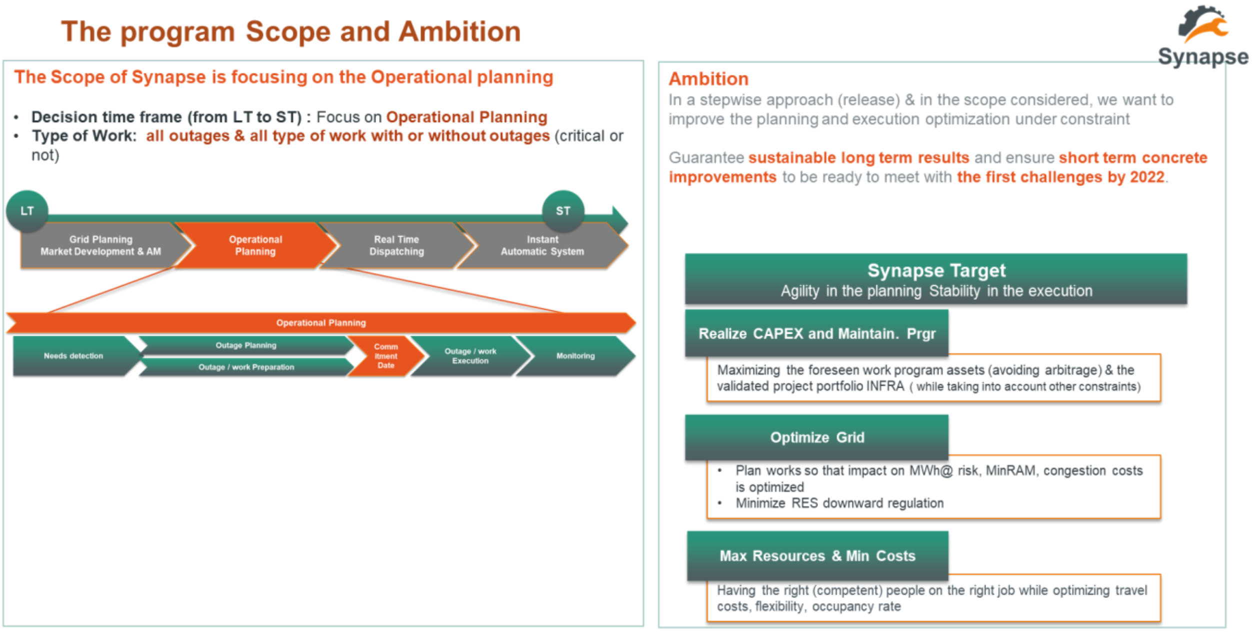

Figure 7 – Synapse scope

The high level long term planning

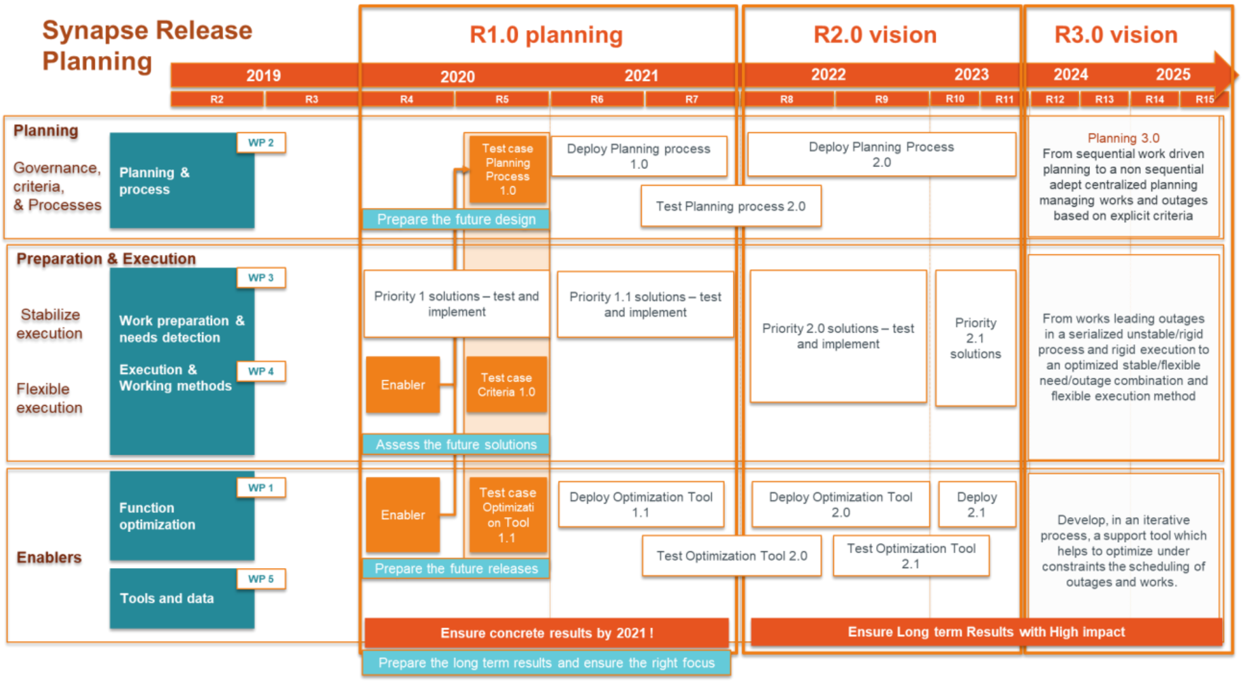

Figure 8 - Synapse release planning

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- Approach: For Synapse, Elia has decided to develop a tailored analytical model to assess the scale and urgency of critical power cuts. For this purpose, Elia is working with an experienced external partner. The goal is in particular to learn about the technology while at the same time avoiding black boxing. An Agile approach is being adopted with frequent keynotes assessing the evolution of the solution.

  The work packages are organized to provide specific results (tool, processes, governance) that will allow to achieve the global objective of the program.

- Work packages, timing (M = month) and deliverables: *Three releases are envisioned: R1 (2020-2021), R2 (2022-2023), and R3 (2024-2025).*

1. *WP 1: Tool functional optimization*

   The tool (in SaaS) should allow to increase operational (planning) **efficiency** (operators and planners) and optimization of the **prioritized works** under increasing constraints. The tool (OPSO) allows to optimize multiple constraints (Resources, Grid) taking into account **multiple objectives** (incentives, works…) on a multi-year rolling window horizon. WP1 aims to develop a tool with several releases. Each release is a concrete intensive IT and data development to ensure that reliable, available and qualitative thousands of data are processed on time to provide the adequate usable results. 2020 will also ensure the support of adequate field tests (real life test after POC 2019).
   - R1 – OPSO 1.0 (industrialized optimization tool taking resources into account: year-ahead planning with frequent intra-year updates (monthly and weekly); all voltage levels and entire Elia grid)
   - R2 – OPSO 2.0 (planning three years ahead + new constraints). We will integrate network constraints (like network element exclusion pairs for the entire Belgium, the maintainability of the network elements for the whole Belgium, the capacity of the maintenance team for the 4 maintenance zones)
   - R3 – OPSO 3.0 (integration of AI/machine learning – AATO link)

a. *WP 2: Planning and process*

   This second work package refers to the prioritization of works (decision criteria, see matrix here above, and governance) and improve agility when required by the grid. Centralization allows for better integration and cross-departmental coordination of works and resources and avoids sub-optimization. The new process and criteria will also follow the principle of releases. Those releases aim to incrementally increase the impact of the changes throughout the organization with the principles of centralization and automation.

   - R1 – Advanced maintenance planning (advanced maintenance planning – maintenance planning is steered in a centralized way, based on the results of the industrialized optimization tool and planned, including new working methods – new R&R for planners and foremen – application of new criteria)
   - R2 – Advance centralization of CAPEX and maintenance planning (to be confirmed, based on the outcome of the previous release – incremental approach). We will provide network feasibility studies to assess the feasibility of works planning (projects and maintenance) from an operational planning point of view long term and mid-term.
   - R3 – Integrated centralized planning (to be confirmed, based on the outcome of the previous release – incremental approach)

2. *WP 3 and WP 4: Work preparation and work execution*

Increase the efficiency of the process and reallocate those resources to centralized planning -> better coordination and synergies. Enable the agility to implement the works under constraints -> focus on priority works under increasing constraints

- R1 – Work preparation improvements and process streamlining (agile and efficient work preparation, remote switching, reduction in lead times, several field tests to assess the new process)
- R2 – Work preparation 2.0 and work execution improvements. We will assess the feasibility from a capacity point of view for the maintenance team.
- R3 – Work execution 2.0

3. *WP 5: Tools and data*

This WP will follow the implementation plan of other packages and ensure appropriate development of IT and tools (IT specification, data, tools, protocols). This WP is a supporting work package ensuring the development and integration of the other WP. For instance, the description of business requirements, coordination of IT developments...

In order to further explain the work packages and the program we believe that a presentation could be organized for CREG where our experts could directly answer to CREG's questions.

- Deliverables and milestones

    1. See details on figures

Partners

- Development of the optimization tool based on the input of the various Elia experts involved
- Peer review with other TSOs
- Transversally at Elia level: national and regional dispatching, Maintenance Department, project (CAPEX) and portfolio management, asset expertise management, IT and Business Analysis Departments.

Summary of project efforts in person months (by work package and by year)

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Project 4: Risk-based approach for grid development decisions

Domain 4.1

2021 decision: Accepted

Trends: Decarbonization, decentralized generation and new players, supranational coordination and digitalization

Consequences: New decentralized flexibility resources, increase in maximum usage as well as variability of the usage of grid infrastructure, need to update grid security rules and resilience rules in the interest of society

Challenge: 4. Optimize the development, the construction and maximize the use of new and existing infrastructure

Domain: 4.1 Automatic integrated system dev. risk based

Project-specific context

- Changes in the energy landscape, the energy transition, and the integration of market players at lower voltage levels are expected to result in a growing number of uncertainties for the development of the grid, mainly due to:
    1. the substantial market share of variable renewable generation;
    2. a high level of decentralization;
    3. a change in consumption profiles related to electrification;
    4. the growing frequency and magnitude of bidirectional flows between transmission and distribution systems;
    5. an increased level of imports and transit flows arising from European integration.
- These trends will drastically accelerate in the years to come due to the decarbonization target (three times more renewables by 2025) and electrification (of mobility, heating, etc.), while at the same time Elia generally invests in assets with a long lifetime (30-40 years). Therefore, it is important to accurately assess whether an investment that is needed now will still be used in 10 years from now and not become a stranded asset due to the existence of alternatives like decentralized flexibility.
- We believe that to cope with these challenges in an effective and exemplary way, there will need to be a change in decision-making processes from implicit/qualitative risk management (based for example on N-1 deterministic criteria for grid development and operation) to explicit/quantitative risk management.
- This means that in this new context, the decisions put forward by Elia can continue to be in the interest of society and be assessed from a consumers' perspective.
- Elia is therefore continuing the work launched in 2013 with the GARPUR and GRASP projects.

Project-specific state of the art/literature review (Elia and external)

- J. M. Arroyo, N. Alguacil and M. Carrión, *A Risk-Based Approach for Transmission Network Expansion Planning Under Deliberate Outages*, in IEEE Transactions on Power Systems, vol. 25(3), pp. 1759-1766, Aug. 2010, doi: 10.1109/TPWRS.2010.2042310.
- E. Karangelos and L. Wehenkel, *Probabilistic reliability management approach and criteria for power system short-term operational planning*, Bulk Power Systems Dynamics and Control X – The Power System of the Future: Global Dynamics arising from Distributed Actions (IREP), 2017 IREP Symposium, Sep. 2017.
- G. J. Correa-Henao, J. M. Yusta and R. Lacal-Arántegui, *Using interconnected risk maps to assess the threats faced by electricity infrastructures*, International Journal of Critical Infrastructure Protection, vol. 6(3-4), 2013, pp. 197-216, ISSN 1874-5482, https://doi.org/10.1016/j.ijcip.2013.10.002.
- S. Willems, P.-E. Labeau, J.-C. Maun, **A. Vergnol (Elia)** and **J. Sprooten (Elia)**, Probabilistic Power System Planning: Outcome variability and decision making, in *21st Power Systems Computation Conference (PSCC)*, June 2020.
- S. Willems, P.-E. Labeau, J.-C. Maun**, A. Vergnol (Elia)** and **J. Sprooten (Elia)**, Deterministic and Probabilistic Transmission System Expansion Evaluation Methods: Insights in the Requirements of a Probabilistic Method, in *Congrès Lambda Mu 21 « Maîtrise des risques et transformation numérique: opportunités et menaces »*, Oct. 2018.

- W. Bukhsh, K. Bell, A. Vergnol, **A. Weynants (Elia)** and **J. Sprooten (Elia)**. Enhanced, risk-based system development process: a case study from the Belgian transmission network, in *20th Power Systems Computation Conference (PSCC)*, June 2018.
- G. Dogan, P.-E. Labeau, J.-C. Maun, **J. Sprooten (Elia)**, **M. Galvez (Elia)** and **K. Sleurs (Elia)**. Discrete forecast error scenarios methodology for grid reliability assessment in short-term planning, in *Probabilistic Methods Applied to Power Systems (PMAPS*), Oct. 2016.
- G. Dogan, P.-E. Labeau, J.-C. Maun, **J. Sprooten (Elia)**, **M. Galvez (Elia)** and **K. Sleurs (Elia)**. Monte Carlo sampling and discrete forecast error scenarios in grid reliability assessment for short-term operational planning, in *IEEE International Energy Conference (ENERGYCON)*, April 2016.
- G. Dogan, P.-E. Labeau, J.-C. Maun, **J. Sprooten (Elia)**, **M. Galvez (Elia)** and **K. Sleurs (Elia)**. Grid reliability assessment for short-term planning, in *European, Safety and RELiability Conference* (ESREL), Zurich, Sep. 2015.

Expected impact for Belgium

- The idea behind developing an advanced risk model for grid development and asset management and the interaction between these two processes is to ensure that all decisions consistently meet explicitly defined reliability criteria at minimal cost for society. This will become critical for grid development in the future as the uncertainty surrounding how renewables and decentralized flexibility will evolve, might lead to sub-optimal development of the grid if they are not taken into account (oversized if we underestimate the development of decentralized flexibility as an alternative; or undersized if we incorrectly assess the development of renewables).
- First, development criteria are set out in terms of their impact on customers and society, and quantified using impacted MW, ENS, ENI, etc. In a second stage, the value of lost load is included in the objectivized risk levels to assess the impact for society.
- A methodology is developed to assess the impact of an asset (fleet) failure and backlog on the whole system. Such indicators are used to optimize asset maintenance and replacement. In a second phase, the impact on society of each asset decision will be quantified.
- A new consistent risk-based approach is developed and applied to prioritize infrastructure projects.
- Long-term studies are performed, not only to drive investment decisions but also to motivate the need to update operational tools, processes, and contracting. In a first step, the maintainability of grid components in the future and future usage of flexibility are quantified.
- Judgments on investment decisions are made explicitly based on total cost of ownership (investments and maintenance cost) for society thanks to the development of a probabilistic analysis in the context of grid development.

Starting point for Elia

- This project is the follow-up to two previous research projects in which Elia participated in the past: GRASP (a PhD project aiming to develop grid operational planning taking into account uncertainty of renewable generation) and the GARPUR project which designed, developed, assessed, and evaluated new reliability criteria to be gradually implemented in the decades ahead at pan-European level, while maximizing social welfare.
- These two projects mainly focused on operational planning and asset management where the levels of uncertainty to be managed are lower. Limited work was performed in the context of grid development and at the interface between these fields. The main challenges identified in the projects for industrial application in grid development and asset management were the need to develop an asset failure model, the need to take into account the complexity of a real system and the need to develop a pragmatic approach for probabilistic assessment to deal with inaccuracies in industrial data, the complexities of a real system, and the large size of a real system impacting the computation time.

Uncertainties and risks

- A first set of uncertainties and risk is associated with the ability to find a structural representation of each decision which is simple enough to be implemented and which is accurate enough to convince decision makers and experts looking at each decision. Indeed, this is a completely new way of developing the grid that will need to take into account a large number of parameters, including some highly probabilistic dimensions such as the evolution of installed capacity (in term of renewables, of decentralized flexibility, etc.).

- A second set of uncertainties is associated with the timing of project implementation, which will depend on the complexity of the task.
- Clarification of risks based on additional questions asked by CREG in 2020:
    - (focus on WP1) There is uncertainty whether the health index, the associated failure probabilities and estimated repair times are sufficiently accurate to obtain an adequate estimation of the system risks and impact on the grid users. To tackle this uncertainty, a feedback loop will be included to monitor the observed grid state and fine-tune the models when required. In addition, the advanced risk model was evaluated by an external academic partner and a POC is included to evaluate the usability of the model.
    - (focus on WP2) There is no certainty that the investigated probabilistic methods can be applied in all grid studies. E.g. they can be too time-consuming. This would not harm the innovative value of the project, but would seriously limit the usability of the probabilistic methods. Of course, Elia will keep the usability in mind when specifying these methods. Hybrid approaches (simplified analysis, with detailed analysis where required) could be possible as well to limit the constraints for using the methods.

Project description

- The project aims to align the risk inclination defined at company level with the risk inclination considered in operational grid-development and asset-management decisions. The main objectives will then be the identification of grid-development criteria and asset management. The project will also help Elia to develop an explicit risk mentality through ensuring consistency between planning practices and operational practices. The following results are expected:
    1. new parameters reflecting the risk taking into account the system-operations and grid-development constraints;
    2. a new approach to long-term studies and shorter-term grid planning.

  To achieve these goals, the project will start by defining the anticipated interruption time based on statistical data and will set out clearly the policies for the years ahead (e.g. what is considered to be an acceptable incident). Based on this the model, the study will adapt the risk inclination of the company and therefore also the criteria for grid development. Finally, the study will analyze the impact of the new risk-based grid-development decision on asset maintenance and grid operation.
- Approach: Following the European GARPUR project organized by SINTEF with a consortium of TSOs, Elia is now developing and re-evaluating its own risk-based criteria drawing on internal resources, in particular a PhD student hired from Université Libre de Bruxelles (ULB)/Vrije Universiteit (-VUB), who stopped work in late 2019.

- Work packages and timing (M = month)
    1. *WP 1: Alignment of the company-level risk appetite with risk management at operational levels and decision-making based on the identification of risk*
        - Jan. 2019 – Dec. 2022: Task 1.1: Set the level of the operational risk acceptable for asset maintenance, grid development and operation, in particular defining the acceptable frequency and impact in terms of ENS, ENI, and MW interrupted for industrial and non-industrial areas and based on comparisons with other TSOs' risk appetite.
        - Jan. 2019 – June 2022: Task 1.2: Improve the risk culture by disseminating initial results and establishing an understanding of the basic concepts involving asset management and system operation.
        - Sep. 2019 – Dec. 2023: Task 1.3: Set a roadmap for long-term decision-making improvements, including putting forward a plan to create a risk-matrix model, including the establishment of indicators of asset components' importance.
        - Jan. 2019 – June 2023: Task 1.4: Set up methodologies for the integration of assets (collecting and generating data/statistics) to enhance the risk matrix.
        - Sep. 2019 – June 2023: Task 1.5: Improve the portfolio management rules based on the risk-based matrix.

- Jan. 2019 – Dec. 2022: Task 1.6: Define criteria for critical grid situations requiring resilience testing and benchmarking them with other TSOs.
- **Main updates 2021**:
    - A first version of a risk matrix ENS was established. There is a delay on the risk matrix ENI. (foreseen for Q4 2021 – Q1 2022)
    - The advanced risk model was developed and reviewed by an external academic partner. A first POC with the advanced risk model was launched to test the model and uses the asset statistics developed in other tasks. After this successful POC, a new work package 4 was set up. This WP 4 will take over some of the goals of task 1.3 / 1.5.
    - After an initial POC on a resilience study, the approach on resilience was fine-tuned and the scope of this task was reduced. Due to the (very) low probabilities associated with the extreme events (cfr. CIGRE WG C4.47 definition), setting up criteria based on statistics (and excluding events below a certain probability threshold) does not seem the best approach. Additional POC for resilience evaluations will be set up to gain further experience and provide guidelines to achieve power system resilience in accordance with the CIGRE definition (i.e. the ability to limit the extent, severity and duration of the system degradation following an extreme event).
    - Formal benchmarking is left to ENTSO-E / CIGRE initiatives.

2. *WP 2: Development of consistent and risk-based grid planning and operation*
    - June 2019 – Dec. 2021: Task 2.1: Improve the consistency between planning and operational criteria. This includes coordination regarding the use of flexibility margins on the grid (for phase-shifting transformers, HVDC, thermal capacity, etc.). Moreover, enhance the feedback loop between planning and operations about the operational risks observed in the long/medium term and in real time.
    - Jan. 2019 –Dec. 2023: Task 2.2: Develop a specific approach for long-term (>Y+3) planning based on explicit and transparent formulation of the risk and including the assessment of future OPEX for operations and maintenance and a long-term model for flow-based prices.
    - Sep. 2019 – Dec. 2023: Task 2.3: Develop a specific approach for medium-term planning (Y+1 to Y+3) based on explicit and transparent formulation of the risk and including the assessment of future OPEX for operations and maintenance.
    - Jan. 2021 – Dec. 2023: Task 2.4: Develop a specific approach for short-term planning based on risk evaluation and ensuring consistency between the various time frames (Y-1, M-1, D-2, D-1).
    - **Main update 2021:**
        - Internal alignment on the use of flexibility margins is ongoing and a first proposal is under review.
        - Multi-state grid studies are operational.
        - Maintainability evaluation of the future grid and this is used as input for Project 3.
        - Task 2.4 is put on hold and will be integrated within WP 4 if appropriate. The enhanced risk model has shown potential, but requires further fine-tuning and integration in tools before it could be used (on the short-term planning horizon).

3. *WP 3: Overall project coordination and administration of the project*
    - Jan. 2019 – Dec. 2023: Coordinate and guide the project in terms of its strategic decisions and ensure project quality.

New WP, defined in 2021:

4. *WP 4: Quantified risk model*
    - Jan 2022 – Dec 2022: Task 4.1: Integration of the quantified risk model and risk assessment in various time frames and processes.

        - This task will evaluate the application of the quantified risk model in various processes and time frames. E.g. detection of needs, project portfolio managment, network risk monitoring.
        - Business requirements and implementation strategy of the model in the tools
    - Jan 2023 – Dec. 2024: Task 4.2: Development of quantified risk model in tools
        - Implementation of the quantified risk model in various tools (asset management, grid development and potentially short-term planning / close-to-real-time)
    - Jan 2024 - Dec. 2025: Task 4.3: Fine-tuning of risk criteria / TOTEX evaluations based on POC using the tools
        - Including integration of OPEX costs (cfr. Task 2.2)

- Deliverables and milestones **(update 2021 and in accordance to WP 4)**

    1. Jan. 2020: Updating grid-development and grid-operation **criteria**, ensuring **consistency** (done, updates to follow during project)
    2. Jan. 2020: Defining and **quantifying parameters (MW interrupted, ENS, ENI, etc.) to include** in the objective assessment of the risk appetite (done for ENS, ongoing for ENI)
    3. Dec. 2020: Assessing the **maintainability of grid components in the future** (done)
    4. **Dec. 2020:** Conducting **multi-state grid studies** allowing enhanced justification of CAPEX (done)
    5. Dec. 2020: Ensuring a consistent **flow-based** approach in LT/MT studies (done)
    6. Dec. 2020: Developing a high-level (and manual) **methodology to assess the impact of an asset failure** on the continuity of supply (done)
    7. Dec. 2020: **Developing a consistent risk-based approach** and applying it to prioritize infrastructure projects, and noting lessons learned (done, simplified version, further steps in WP 4)
    8. **Dec. 2021:** Developing an **objectivized understanding** for System & AM of **acceptable and unacceptable risk levels**
    9. Dec. 2021: Developing a methodology to assess the impact of an **asset (fleet) failure and backlog** on the whole system -> optimizing asset maintenance and replacement (methodology was tested in POC, further refinement in WP 4)
    10. Dec. 2021: Devising a method and process for MT planning enabling a **smooth LT-ST-RT handover**
    11. Dec. 2021: Assessing **use of flexibility**
    12. Dec. 2021: **Highlighting expected operational consequences** by grid-development studies
    13. **Dec. 2021: Conducting multi-climate annual and multi-scenario** grid studies allowing for robust decision making
    14. Dec. 2021: **Making improvements based on lessons learned** to ensure consistent application by all those with needs
    15. Dec. 2022: Including **value of loss** load in objectivized risk levels to **assess the impact for society**
    16. Dec. 2022: Establishing best practices for operational excellence thanks to a **clear view of the necessary tools**
    17. Dec. 2022 Business requirements for quantified risk model in tools and processes
    18. Dec. 2024: Performing a **probabilistic analysis** allowing decisions to be made, explicitly based on TOTEX (CAPEX + OPEX for society)
    19. **Dec. 2024: Quantifying the impact on society** of an asset decision

Partners

- Alignment of system planning and operational risk: Elia internal department for system operation (National Control Center), grid planning and asset maintenance
- Review and challenge of progress: Grid Development (acting as a sounding board) and Asset Management team
- Update May 2021: Evaluation of enhanced risk model: external academic partner (ULB)

- Development of a probabilistic grid application: Ongoing discussions with software companies to ensure that tools are available on the market to meet Elia's needs (discussion with *confidential*)

Summary of project efforts in person months (by work package and by year)

- **Main updates 2021**:
  - Rescoping of project, including reduction of scope of task 1.6 and creation of WP 4
  - More realistic workload estimation based on REX
- Budget 2021 was reduced, but due to creation of WP 4, the total budget increased with about *confidential* Note: for IT costs, an initial 80/20 division between CAPEX and OPEX costs was assumed. This estimation will be fine-tuned during the project.

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Domain 1.1

Project 5: Consumer-Centricity Program (including Internet of Energy project)

2021 decision: Accepted

Trends: Decarbonization, decentralized generation and new players, digital revolution

Consequences: New decentralized flexibility, Interface with new players, new market models, consumer centric offerings

Challenges: 1. Increase participation of flexibility sources from decentralized sources coming from electrification
Domain: 1.1 Manage market related data from and for market parties

Project-specific Context

- One of the key drivers for change in the sector is the societal ambition to put "the consumer at the center" of the energy system. As stressed by the European Commission in its communication Clean Energy for all Europeans, the EU sees consumers as active and central players on the energy markets of the future, who will be instrumental in ensuring that they themselves can fully contribute to and benefit from the energy transition.
- Consumers' current energy experience involves a lot of pinch points: complexity and non-transparency in the offering and billing, uncertainty about the final bill, limited means to align consumption with renewable production and/or energy prices, etc. The challenge for the sector is to overcome these difficulties and develop energy services addressing the needs of consumers, while at the same time seizing the opportunity to better integrate renewable energy into its offerings and take advantage of available consumer flexibility to help to meet the requirements of the grid.
- So far, consumers have been left out of the energy debate, yet they finance the sector. Technological development and the emergence of innovations such as EVs mean that consumers are gradually becoming more active players, but they still have only moderate levels of involvement, and the same goes for their contribution to system requirements.
- Enabling a substantial offering of energy services and facilitating access to them as well as creating an ecosystem of service providers are key to involving consumers in the energy debate. However, for a business, especially new entrants, to provide innovative services to end consumers, it will be necessary to get an easy access to regulated data and applications.
- The lack of access to consumers' regulated data and of the ability to exchange data in real time has been identified as a major gap in this ecosystem, and as a result, as a barrier to developing such innovative energy services. That is why Elia and all the DSOs joined forces in early 2019 to launch the Internet of Energy (IO.Energy) project, developing a real-time communication layer.
- Additionally, the IO.E initiative built an ecosystem around it as a testbed for new innovative services that has triggered significant market interest and has so far led to various inspiring use cases in 2019/2020 (e.g. Sensa, Flexity, Enleash…) and in 2021 (e.g. Citizen2Grid, Congestion, EV experience).
- Following the launch of IO.E in 2019, Elia has upgraded the project to include large-scale consumers and is also looking to go beyond the elements described in the Clean Energy Package, with an increased focus on issues related to data access management and consumer-centric market design. For that purpose, Elia has made changes to its organizational arrangements to give greater prominence to consumer-centric initiatives and move things a step forward. Therefore, alongside the development of an innovative real-time communication platform, Elia aims to study the design and operation of a consumer-centric system: one of the central principle that will be analyzed is that the end consumers have to delegate their responsibilities to their BRP(s)/suppliers as a precondition for injection or offtake of electricity and so on, resulting in passive end prosumers: consumers are not allowed to exchange electricity with other parties without the consent of their BRP(s)/suppliers.
- In the future, in line with its ambition to put consumers center stage, **Elia advocates a system based on empowered end prosumers free to exchange electricity with other parties**. This will require a new market design based on the principle of robust and flexible energy services offering between parties. This new market model will look at the new

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roles in a consumer-centric system and facilitate the development and adoption of a new Energy as a Service business model for any sector (mobility, heating…).

- Elia also advocates a system where the consumer is owner of its data and can chose for the services it wants to be provided with, as well as how and by whom its data is being used.

Project-specific State-of-the-art/Literature study

Various initiatives have now started in Europe, notably led by other TSOs that face the same challenges (see above) as Elia, and drove the move to consumer-centric program:

- **Equigy (Crowd Balancing Platform):** a platform established by TenneT, Swissgrid, and Terna to automate the involvement of small flexible assets in the balancing markets; more information can be found at equigy.com;
- **Energy Data Exchange Platform:** an interoperability platform set up by *confidential* (along with TenneT and Energinet) to provide retailers, energy service providers and other eligible market players with a single, standard access point for consumers' metering data; more information can be found at elering.ee/en/data-exchange;
- **APG (Austrian Power Grid):** a flex hub project to test and implement new elements in retail market design;
- **Energy Web Foundation:** initiative accelerating low-carbon, consumer-centric electricity systems by leveraging blockchain and decentralized flexibilities; more information can be found at energyweb.org. In parallel Grid Singularity has developed a market model and a solution called D3A.

Elia is working closely with these initiatives and participating in some of them. While the challenges tackled are similar, the basic approach differs from Elia's Consumer-Centricity program. These initiatives focus on available data (15-minute smart-meter data) and existing balancing products, while Consumer-Centricity is looking in particular at the system and market value of real-time metering data and base its reasoning on market design components can be built on top of this data layer, as well as innovative consumer capabilities and assets.

Existing research and the most recent experiences in Europe have shown that energy savings of more than 5% can be made by consumers when they have access to near real-time data. A European Commission report, produced by Expert Group 1 of the Smart Grid Task Force in 2015, showed that the majority of EU Member States already require a local real-time data interface on the meter, but no measures have been taken to make them available on the market. The recent revised Electricity Directive requires the provision of near real-time data (covering "a short time period, usually down to seconds or up to the imbalance settlement period in the national market") by the smart-metering Infrastructure, but again without specifying the access framework for market players.

However, currently, to access near real-time data, smart meters use a separate, specific hardware interface that can be drawn on by consumers, or by third parties designated by them, to connect a display or other devices that can present these data in a consumer-friendly way and/or utilize it to provide energy-related services. Making these data largely available with the consent of the consumer would greatly increase and entrench service providers' ability to set up a new offering for consumers. Testing the means to provide access to these real-time data and fostering and understanding which energy services could emerge from that and contribute to system needs are key aspects of the work performed in the Consumer-Centricity program.

As a conclusion, the Consumer-Centric program goes beyond the state of the art and explores unknown quantities in the organization of the power system of tomorrow.

Expected impact for Belgium

The Consumer-Centric program is expected to have an impact on Belgian end consumers, service providers, and Belgian system operators:

- **For end consumers:** The main ambition of the Consumer-Centric program is to initiate and facilitate energy services that have a positive impact on end consumers from a financial perspective and in terms of quality. Benefits include the ability to calculate end users' flexibility, to define a customized energy purchasing strategy, to view energy-consumption and cost data transparently in real time, to join an energy community with a single click of a mouse, and select preferred sources of energy. These services should meet consumers' need for sustainability, cheap energy, comfort, and transparency. While such offerings involve a limited number and range of players, it is expected that an initiative like Consumer-Centricity will accelerate the emergence of an ecosystem of new service providers for Belgian consumers.

- **For service providers:** The new consumer-centric model is an important enabler for enterprises to develop their business and to offer innovation to their consumers.

  The ecosystem brings together complementary players with different areas of expertise and backgrounds to test new ideas. This includes providing contractual support and helping to find an appropriate external partner or supplier. Notably, legal experts helping enterprises to ensure compliance with the EU's General Data Protection Regulation (GDPR) in their interactions with end consumers, while academic experts provide comments on and suggest improvements to their use cases, and business experts offer support when it comes to developing use cases. Then the use cases bring expertise and insights for the development of new business models.

  1. The technology platform aims to take away one of the main barriers facing enterprises, namely the access to real-time data, and provides a communication platform that can be used to build up services. Moreover, the ambition is to extend the communication layer with additional regulated/enabling services to make it even easier for market players to develop services.
  2. The new market design will offer more flexible and robust rules for the development of new energy-related services for the ecosystem.
- **For system operators:**
  1. New energy services (as forecast, data access and processing…) can provide new sources of flexibility for both residential consumers and others and could even unlock a potential 2.4 GW by 2030 (through load shedding and load shifting). Decentralized flexibility has a vital role to play in ensuring the adequacy of Belgium's power supply (as described in the *Adequacy and flexibility study for Belgium 2020-2030*).
  2. Better collaboration between TSOs and DSOs: The initiative is supported by all of Belgium's system operators, providing a unique opportunity not only to facilitate such collaboration but also to discuss and harmonize their activities based on technological resources and operational processes.
  3. The test environment provides a significant learning opportunity, testing hypotheses and analyzing trends in use cases and pinch points in an energy environment that is new to all. That is why the IO.Energy initiative at Elia has led to the creation of a consumer-centricity department that will cover the design, development, and testing of consumer-oriented initiatives and the relevant shift in the market design.
- **For regulators:**
  1. The aim of the consumer centric approach focuses on the Belgian electricity consumers and how to provide them with better and more efficient services to end consumers and society more broadly.
  2. The project also enables to understand how the consumer centric approach can be accelerated through evolutions in market mechanisms and potentially regulatory frameworks at different levels, national or regional. Regulatory barriers have also been pointed out by several participants to the IO.E as potential elements refraining the development of services for the end-consumer.

Starting point for Elia

IO.E, the journey so far

- In late 2018, Elia launched its Consumer-Centric vision paper and subsequently launched the IO.Energy initiative in early 2019 with a general 'call to participation’.
- More than 90 enterprises and organizations joined the initiatives and started to help to create consumer-centric use cases during the ideation phase, of which eight were selected for the sandboxing phase. In this phase, the concepts set out in the use cases are put into practice and assumptions are put to the test.

- The sandboxing phase of the first iteration of the IO.E has ended in September 2020, leaving room for preparing the second iteration. The results from the first IO.E have materialized in the success and feedback received by the participants, but also in the continuation of some use cases to scale-up (e.g. Flexity).
- The first iteration has drawn lots of attention from different sectors which has led to a call for new use cases launched in October 2020.
- Unlike the first IO.E use case launch, the ideation for new v2 use cases did not start from a blank page: during the "end of sandbox" event, early October 2021, various consumer driven, system driven and sustainable driven challenges were presented. Interested parties could register for IO.E v2 and indicate what challenge / use case triggers their interest. Based on a first round of input, the IO.E team analyzed all input, proposed a "matchmaking" by suggesting a consortium fit and use case scope. This turned out well and served as input for an ideation phase that resulting in 6 selected use cases for IO.E v2 use cases.
- The use cases were being selected by the founding fathers of the IO.E. This new edition's structure, organization and governance has been improved to ensure better and more efficient service to the ecosystem, which in the end will provide better energy services to the end-consumer.
- The IO.E v2 sandbox is set to take place from May 2021 till end of December 2021.

Consumer Centricity: from IO.E and beyond

- Fleshing out the various use cases and the obstacles that became apparent in this context have, first, revealed various pinch points/areas to make improvements in the current operational processes, the available tools, and the energy value chain in general and have, second, reinforced the consumer-centric dynamic/mindset at Elia.
- The IO.E initiative has so far shown itself to be a useful starting point and therefore was expanded at Elia side into a Consumer-Centric program, consisting of the following organizational structure with "squads":
    - **Data Access Management**: This first focus area is focusing on the data from and of consumers and how society should be organized, including the Transmission System Operator, to manage these data in compliance with EU regulation (e.g. GDPR, CEP). Finally, this stream focuses on defining the role of Elia within this framework.
    - **Consumer Centric Market Design**: Several existing design elements, related to data and flexibility are being analyzed and reshaped. This stream is focusing on defining retail market design. More specifically, the current market mechanisms and products have been pointed by different stakeholders are not fit to facilitate the contribution of decentral flexible assets to the energy transition and solving system pains related to this energy transition.
    - **Technological framework:** The real-time communication layer will be reviewed to cope with an increasing data exchange volume and will also be extended to include several enabling services, such as a consent management tool and a module for historical data access to tackle and overcome pinch points that have already been identified. The end consumers of the consumer centric program will not be limited to those connected to the distribution grid but will include major industrial players for example. Besides the technical and business implementation of enabling such real-time communication layer, there will be looked at the potential impact that these recent trends (more distributed resources, more IOT connected devices) bring. In more specific, there will be looked at the cybersecurity risks of these devices when participating to ancillary services, Energy-as-a-Service or even when no service participation is done.
    - **EPIC:** As part of its Consumer Centric approach, Elia has focused on digitalizing the services it provides to its direct clients. The platform that is being used is called EPIC. As part of this platform, the first service developed is the provision of insights into metering data. The platform is being developed using design thinking methods, where the platform is developed based on the needs of the customers being part of the pilot project. In the future, additional services will be provided to direct and indirect consumers of Elia through this platform.
    - **'Factory' use cases:** The factory has examined, upgraded and integrated the use cases of the first iteration of IO.E into (or removed from) a second sandbox initiated early 2021. Also, new use cases, specific to Elia, are developed and tested, for example relating to e-mobility and large-scale consumers, to increase the impact by iteratively dropping unsuccessful use cases and launching new ones, thereby developing insights and gradually increasing value.

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The 'Factory' is an Elia-internal stream to analyze the use cases in detail, gain insights, and identify lessons learned and pain points. This knowledge is shared within the enterprise but is also contributing to the identification of new use cases and ways in which the real-time communication platform could evolve.

  - **Ecosystem**: Interactions of Elia with business service providers and other market actors, such as DSOs, take place via the Ecosystem. On one side the Ecosystem defines the timetable, milestones, and next practical steps of the external program to maintain the IO.E's momentum, while organizing contractual, business, and organizational support for the various IO.Energy use cases. On the other side, the Ecosystem also enables Elia internal use cases to team up with the right partners to achieve its learning objectives.
- The IO.E has evolved from the initiating project towards an integer part of the project portfolio performed by the consumer-centric teams. Some of the use cases are part of the IO.E, while others are performed by Elia autonomously to test its own assumptions.

Uncertainties and risks

- The first uncertainty is related to the many questions and assumptions Elia and other market actors have about future energy services, consumer interest, and market design (format, role evolution, data needs, rules…). The goal of the Consumer-Centric program is to verify these assumptions directly with the market players and with consumers.
- The second uncertainty surrounds the interest from market players in real-time data and in open innovation in general. One of the goals is to generate interoperability between players, although these players might try to create a lock-in effect for end consumers and create their own unique, direct connection with them.
- The third uncertainty is related to the technical feasibility of the technological framework behind the Consumer-Centric program. This includes the issue of connectivity to avoid the platform being inflexible or being too complex for service providers to connect to and interface with.
- The fourth uncertainty addresses the willingness and capability of market actors to adopt new market mechanisms to enable the development of consumer services, and at once provide system operators with new means to palliate the risks related to the energy transition.
- The fifth uncertainty relates to the capability of the sector as a whole to transform sufficiently fast, to secure the access of energy services at an affordable price for the consumers, while ensuring compliance with regulation and safeguarding the security of the electric system.
- Another uncertainty revolves around the viability and (consumer) traction for the business model and tools developed around the consumer centric technology framework.
- Another uncertainty can be found in the impact that Elia or in general the government can have on the security level of software, IOT connected and hardware devices in a residential sphere.

Project description

- The project's objective is still to anticipate future required shifts in market and system processes to unlock the potential of decentralized flexibility for the consumer. The consumer being at the center of our preoccupations, this does nevertheless not mean that the end-consumer is being involved in the elaboration of the system enabling the provision of consumer services. The only interest is to assure the experience of the consumer is seamless, and focused on answering consumer pains, known or unknown.
- To achieve this objective, the IO.Energy project has evolved from a project towards a larger Consumer Centric Program.
  - This program consisted firstly of 3 streams (limited to IO.E initiative): platform, ecosystem and factory
  - This program upgraded towards 4 streams: Design (special focus on data access management, but also market design), Technology Framework (platform, including enabling services), Ecosystem and Factory.
  - In 2021, to sustain the pace of the evolutions expected by the consumers, the four initial work packages were scaled up towards 6 work packages: whereas the ecosystem (1) and Factory (2) technological framework (3) data access management (4) were complemented with a specific Consumer Centric Market Design (CCMD) (5) and the enabling services were renamed EPIC (6).
- Three of the work packages are concentrated on defining the vision of Elia with regards to Market Design, Data Access Management and enabling Technology Framework, as well as the assumptions to be tested to fulfill these visions; two

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of the work packages are developing and implementing use cases to test the visions through real-life cases with partners from the energy sector and beyond (ecosystem and factory); while EPIC is focusing on the provision of services to the directly connect users of the Belgian transmission network.

- To better apply Agile and fast learning/testing, Elia has strengthened its consumer-centric department that consists of six teams/squads with solid governance, representing the work packages. In the past year, the department has shown its adaptability and flexibility to ensure the ambitions of the consumer centric vision of Elia. Elia has, beyond becoming consumer centric also been capable to develop a culture and mindset that is required to follow the pace of the consumer, and remain relevant for society and all consumers.

- Work packages and timing (M = month)
  1. *WP 1: Design: Data access management*
     - Develop the data manager role, as defined by the Clean Energy Package
     - Develop new tools and processes for managing consent and data flows in a GDPR compliant manner (will be required to facilitate opening up of ancillary market towards residential consumers together with the upcoming energy-as-a-service market)
  2. *WP 2: Technological framework*
     - Enable data flows and providing open access to data towards service providers, when given consent
     - Elaborate lessons learned from different POCs around the technical feasibility of data gathering and study around the value of real-time data performed in 2021
     - Analyse cyber security challenges, to guarantee a safe operation of the grid of tomorrow
  3. *WP 3: Factory:*
     - Initiate, support and coordinate IO.E use case
     - Analyse IO.E use cases, gain insights and lessons learned
     - Communicate status, insights and lessons learned internally of IO.E within Elia and within the larger ecosystem
  4. *WP 4: Ecosystem*
     - Attract and manage stakeholders for all consumer centric related use cases
     - Support the initialization of use cases
     - Support the initialization of the consumer panel (representing a testbed of 100+ end consumers)
     - Organize and coordinate the IO.Energy Ecosystem in Belgium
  5. *WP 5: Consumer Centric Market Design*
     - Initiate and support use cases for innovative energy services to further develop and test the consumer centric market design
     - Fine-tune the consumer centric market design and gradually scale up
     - Enable active participation of consumers assets through new consumer centric services
  6. *WP 6: EPIC*
     - Maintain and further Develop the consumer portal released in 2021 and integrated services:
       - Ensure that the portal remains up to date from a technical point of view, and integrate the feedback received from the users about the existing features (view Metering Data, view Contracts and Invoices) (cf. remark below)
       - Provide "more information" to the client (cf. remark below). This could be as broad as general information about the services Elia is offering or more specific about the consumption of the clients and some remarkable facts on that matter.
       - Enrich the list of services available in the portal. The current services considered concern the digital signature flows, an easier access the invoices and invoicing information, and an easier access to operational documents used in the context of maintenance works, but this should still be evaluated based on the preferences of our clients, which will be assessed thanks to surveys and interviews.

  - Provide access to their own metering data in near real-time (not possible to implement in 2021 for technical reasons, but remains expected by our clients)
  - **Remark**: the contents to be handled will be defined together with the clients in 2022, using co-creation methodologies, in line with our consumer centered vision and our user-centric approach

Partners

- Orchestration of the consortium, and decision-making bodies: DSOs (Sibelga, Fluvius, ORES, RESA); facilitated by Co-Station
- Technology provider for the IoT platform: *confidential*
- Expert support:
  - Academics: Damien Ernst, Grégoire Wallenborn, Ronnie Belmans, Sven De Cleyn (imec.istart), Leonardo Meeuw, Ariana Ramos
  - Regulators
- Legal support and IP requirements: Cresco Law
- Support for development and validation of use cases: Delta-EE, EnergyVille
- Market-related regulatory issues: EnergyVille
- Participants: More than 60 participants, including enterprises from the relevant industries (*confidential*), technology firms (*confidential*), start-ups, and leading energy players (*confidential*). The full list can be found here: ioen-ergy.eu

Summary of project efforts in person months (by work package and by year)

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Project 6: Digital backbone

Domain 1.1 Domain 3.1

2021 decision: Accepted

Trends: Decentralization of generation and new players, digital revolution

Consequences: New decentralized flexibility, interface with new players, new market models

Challenges: 1. Increase participation of flexibility sources from decentralized sources coming from electrification

3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety
Domains: 1.1 Manage market related data from and for market parties
3.1 Connect and cyber secure our asset and substation

Project-specific context

- As TSO activities become more digitalized, Elia needs to prioritize data over processes. On many occasions, innovative proofs of concept (POCs) have blocked the way to creating an initial product (e.g. imbalance forecasting), as new technologies like artificial intelligence and the Internet of Things (IoT) require new innovative solutions to manage data.
- As a consequence, data management now needs to be taken forward with the introduction of a new ecosystem that complements the existing frameworks, in which data are cleaned up, enriched, connected, and tracked.
- The innovation and the associated challenges mainly have to do with interactions, platforms, connectivity, and automation.
- Elia plans to implement new features where it must innovate because no solution on the market offers this type of integration and automation, which can then also be incorporated into our IT infrastructure. This includes: using metadata (integrated into a first component) and interlinking them with a glossary (defined in a second component) to automatically create data quality rules (executed in a third component) governing the conflict resolution process in reference data management (in a fourth component):
- Building these components requires some tangible, cross-cutting applications that rely on them to allow our partners and stakeholders (internal and external) to get involved. Therefore, Elia is developing new innovative applications such as an Open Data platform and an IoT platform enabling implementation of various use cases:
    1. Open Data: e.g. asset localization for contractors, updated grid publication data for stakeholders, data stories for events (e.g. the impact of COVID-19);
    2. IoT: e.g. cable-oil leakage monitoring, detection of copper thefts, market-price incentive notification.

Project-specific state of the art/literature review

- As indicated, we identified two key elements Belgium is lacking that will play a vital role in unlocking decentralized flexibility via new innovative solutions:
    1. an IoT platform to provide access to decision support tools, automation along with the ability to exchange information and services in near real time to match the needs of consumers themselves, the market players and the power system at all voltage levels;
    2. an Open Data platform facilitating the co-development process with all relevant stakeholders from consumers themselves to market players (not only from the energy sector), system operators, and – last but not least – regulators.
- These two elements have to be created from scratch, and apart from some scientific papers and various POCs, there are currently no concrete existing POCs or even detailed designs that could be made available to all consumers.
- To that regards, a good example is Fingrid with the Elvis project aiming to revamp completely the information system based on 8 modules.

Expected impact for Belgium

- The main impact of the data architecture provided by the Digital Backbone program is easy access to internal and external data with a flexible interface to innovative applications like IoT…. The main benefit of this is that it will improve efficiency and flexibility levels when using data at Elia. By doing so, it will ensure that we can develop the innovative applications to respond to the increase in complexity of grid management (development of smart algorithms for forecasting, support for decision-making, automation, connection of infrastructure, etc.) and therefore promote the integration of renewable energy. The five main anticipated benefits are as follows:
    1. the ability to integrate and pass on to our partners more quickly more accurate, consistent, reliable data;
    2. the ability to sustainably support the increase in data volume and agility of processes resulting from the energy transition combined with the digital transformation;
    3. the ability to activate the consumer-centric energy system;
    4. the ability to mitigate the digital and technological shortcomings of our internal resources;
    5. the ability to identify among internal resources in the business side of activities use cases or better use of internal resources and the creation of added value through improved internal and external stakeholder engagement.

- Defining KPIs at such an early stage in this program is quite problematic and complex, but we might expect the following benefits:
    1. a 20% reduction in time to market for new datasets;
    2. a 50% improvement in the user experience;
    3. a 30% increase in the number of connected applications;
    4. a 15% reduction in the number of data incidents;
    5. a 10% reduction in response time to data incidents;
    6. a 5% boost to our reputation.

Starting point for Elia

- Our data infrastructure at Elia is still strongly dependent on our organization, but data using it need to be enriched during their life cycle.
- Data are often the poor relation in IT systems and usually come from the various applications supporting business processes, which evolve over time. The result is a multitude of disparate, inconsistent, corrupted, irrelevant, and duplicated data defined in an ad hoc way, meaning that there is no guarantee of their homogeneity or reliability.
- Elia is planning to attempt a paradigm shift where we prioritize data over processes. This alternative strategy has led to the implementation of a data office focusing primarily on data governance and their intrinsic quality in their respective reference framework. However, this now needs to be taken forward with the introduction of a new ecosystem that complements the existing frameworks, in which data are cleaned up, enriched, connected, and tracked: this is the new data backbone.

Uncertainties and risks

- The first risk is that the components developed as part of the Digital Backbone program cannot interface with the legacy infrastructure.
- The cybersecurity of the new innovative data lakes is of course a major risk as well.
- The first work package, namely data preparation for data scientists and the Integration Hub, must be available before the other innovative modules can be developed as open data.
- For the shared data lake component, the underlying technology should be supported by some providers. We initially expected some key progress related to this underlying technology during the period 2019-2021 but the dynamic market of data technologies only had a few tiny improvements in this area.
- The main risks are as follows:
- the continuing uncertainty surrounding the infrastructure's ability to scale up the wide range of data needed;
- data sovereignty and the EU's General Data Protection Regulation (GDPR) (risks that must be mitigated);

- partners not being sufficiently involved in terms of data and features potentially leading the data infrastructure being underused;
- the tendering process slowing down the adoption of commercial off-the-shelf packages.

  A mitigation of these risks has been added in the work package WP-05 in the form of data packages enabling the exchange of large data volumes tagged with a version and enabling cooperation between parties on a given set of data and guarantying that this collaboration is on a same set of data. This mitigation doesn't fully cover the scope (and the benefits) of a data lake but the literature and open source movement sounds to put the traction on this area more than on the shared data lake which is facing multiple roadblockers.

Project description

- Digital Backbone is a cross-cutting transformation program that aims to introduce a new IT infrastructure based on a modernized organizational framework that tackles the data-related challenges posed by the transformation program of the company's operational departments. It revolves around the following key aspects:
  - coordinating the data needs of the various activities to converge on an architecture that will be used by computer scientists, data scientists, the various operators, and external partners to create applications specifically relating to the respective activities;
  - implementing the data strategy: a set of Elia-wide processes and frameworks for managing and integrating data into new technologies and solutions;
  - creating a set of architectural components based on new technological aspects enabling integration and access to cross-cutting data flows;
  - working with human resources and external partners to co-develop the digital skills and data-driven organization of the future.
- To address these four priorities, Elia will develop eight modules, each representing a work package of the Digital Backbone project:
  1. ***Integration Hub***: The operational data integration process consists of merging and enriching two or more data items sourced from distinct systems to use them in another system. Today, this process takes many hours of development for each release. To solve this, Elia will create a pilot project to put in place the foundations and initial iterations of an Integration Hub, where we will deploy the various technical components needed for an Integration Hub and developing best practices and policies about this Integration Hub.
  2. ***Data Preparation for Data Scientists*****:** Each data science project consumes large volumes of data. It takes a lot of time to extract these data from the source system. Unavailability of the data is leading to a delay in the data science projects. Due to the size of the volumes, source systems are permanently deleting data that are never stored anywhere else. To overcome this challenge, we will set up a data lake to maintain structured and unstructured data (LIDAR, IoT, documents) data and also create pipelines to enrich these data. This data lake should be sourced from existing IT landscapes as smoothly and automatically as possible by leveraging the notion of business events generated by applications.
  3. ***Lambda Architecture*****:** Currently, historical data for publications are sourced by a single source, but data from the most recent few days are not integrated into this data store. When a publication needs both recently created and historical data, those responsible for this are on their own carrying out this complex consolidation. Lambda Architecture integrates various solutions to fill this gap. The first step is to create a 'hot track' (ideally coupled with the establishment of the Integration Hub) and then a service layer consolidating the hot track and a 'cold track' (storing historical, so pre-existing data). The hot track represents the channel for real-time data, whereas the cold track represents the channel for archived data. Both tracks are abstracted from users' point of view but must be there to support end-to-end scenarios.
  4. ***Metadata-Driven Integration*****:** Manually building and maintaining the whole set of artefacts (error management) for data integration is a daunting task. At the start, it is not necessarily a huge issue but the more artifacts one has to maintain, the less time one has to construct new artifacts. Soon, it will take so much time to maintain existing artifacts that it will be impossible to construct new artefacts. To solve this question, we will use metadata (a business glossary, technical lineage and data-quality artifacts), it is possible to partially

automate the development and maintenance of data-integration artifacts. Metadata-driven solutions reduce the cost of maintenance and development of new artifacts but also increase the quality of the development.

5. ***Open-Data APIs*:** The integration of Elia-owned real-time data with our external partners and customers is managed on a case-by-case basis and not in a uniform way. This creates gaps in our monitoring and testing systems, resulting in data-quality issues. Elia will then provide a uniform, modern layer to present the real-time data to the external providers based on an open-data API. For 2022, this work-package has been extended to also enable the exchange of large datasets tagged with a given version enabling collaboration on a same set of data of remote participants and facilitating the partial update of this set of data to onboard data recently added to this data set. This addition enables to cover a part of the scope of open-data APIs that was difficult to cover with previous technologies and ways to approach the exchange these open-data with partners.
6. ***Data Lake Shared with External Parties***: Nowadays, when two companies want to use each other's data (speaking in terms of large historical volumes), they transfer the data to their own environment, creating a lot of data traffic that consumes a lot of resources in terms of manpower, financial resources, and energy and creating many data-quality issues and some regulatory matters (GDPR, etc.). It will be possible to share data in a data lake (filled by Elia and other parties) and optionally to do their invoicing based on consumption calculations. This work item is paused for 2022, expecting additional developments on the underlying technologies and in the literature around this topic. Elia will continue to monitor the progresses on this topic and is partially mitigating this delay with the extension explained in WP-05.
7. ***Master Data Management (MDM) for Grid Components***: Many businesses within Elia across Customer and Market Services, Assets, and Infrastructure are relying on a list of grid components (assets or functions), but all of them have valid unique requirements leading to different lists of such components. To overcome this problem, we will launch an MDM project where we will have multiple source systems, each of them driven by an individual business but needing to be bundled together again so that after warning businesses in case of misalignment, data can be presented to the relevant applications. Each issue must be dealt with by the various impacted businesses with a formal process. The more you can automate the process, the easier it will be to manage it.
8. **IoT Platform**: This project aims to put in place an IoT platform considered to be the final access point to an IoT ecosystem. An IoT ecosystem is a set of integrated tools to support the huge numbers of IoT initiatives (see for example project 17)at Elia. The development of such a platform will avoid silos, facilitate the adoption of IoT solutions, and explore/understand all the IoT-related technologies, a concept that is new to Elia. This group of new technologies will help to innovate based on relevant use cases.
   This will help the business side to achieve its digital transformation through a connected infrastructure.
   The focus is on user experience in order to make sure everyone at Elia can benefit from and manage IoT initiatives.

- Work packages and timing (M = month)
  1. *WP 5: Open-Data APIs*
     - July 2020 – July 2021: Eye opener and early enablers in the form of a new open-data portal
     - September 2021 – March 2022: push mechanisms for efficient publication of near real-time information (public mode)
     - April 2022 – April 2023:
  2. *WP 6: Data Lake Shared with External Parties*
     - April. 2023 – Dec. 2024: First data available and processing power put at disposal of the market participants
  3. *WP 7: Master Data Management (MDM) for Grid Components*
     - July 2019 – May 2020: Initial enrollment to help comparisons of related sets of data on different topological layers
     - January 2021 – September 2021: Support of many-to-many relations between datasets and in the rule engines

- July 2021 – December 2021: Ease import of datasets and rules' definition, first works on a tool to ease the match of elements from different datasets based on processing rules. Exposition of the results on the Integration Hub.
- September 2021 – December 2022: Merging of distinct topological layers in order to create new compounded topological layers.

4. *WP 8: IoT Platform*
    - January 2020 – September 2021: early enablers and first PoC
    - September 2021: Link between Panoptic and Pi System (OsiSoft) to get additional IOT data
    - October 2021: 75 Devices to be deployed in the field for the SCOF monitoring Use case
    - November 2021: SCOF Monitoring Use case to be completely Operational
    - December 2021 – February 2022: Start 1st POC scope for Boston Dynamic Spot (with a Robot)
    - January 2022 – September 2022: Integration of the IoT platform with other work packages of the digital backbone
      March 2022 – December 2022: IoT MVPs Implementation

Partners

- Thanks to the open-data APIs and the shared data lake, including the Data Usage and Privacy Agreement features, the Digital Backbone will be able to handle the use of Elia data by partners such as DSOs, BRPs, BSPs, start-ups, and universities and also to collect new types of external data as part of items jointly created with these partners.
- Technology partners will be: *confidential*, *confidential*, *confidential*, *confidential*, *confidential*, I*confidential*, *confidential*, *confidential*, *confidential*, *confidential*, *confidential*, *confidential* etc.
- Digital and Data Department

Summary of project efforts in person months (by work package and by year)

confidential

Project 7: Automation of voltage control

Domain 2.4

Decision 2021: Accepted

Trends: Decarbonization, supranational coordination, digital revolution

Consequences: Uncertainty and intermittency of generation, new system dynamics, new decentralized resources

Challenge: 2. Automate system operations to be able to optimize the network in minute timeframe for frequency, voltage and congestion

Domain: 2.4 Predict and automate voltage decisions

Project-specific context

- Voltage control in the high-voltage grid is becoming more and more complex as a result of multiple factors.
  - First of all, small and intermittent distributed energy sources are emerging, which means that conventional power plants are being decommissioned. Up to now, these conventional units have been the main means to manage voltage control dynamically (up to 60%). For instance, the nuclear power plants of Doel and Tihange have a total band of [-1180;2675] Mvar (~650 Mvar band for 1 GW).
  - Secondly, more and more overhead lines are being replaced by underground cables that generate much more reactive power. These cables are then offset by switchable and variable shunts distributed throughout the grid.
  - A third development is the increase in active power exchange capacities through upgrading interconnections, causing the Belgian power system, driven by the European market, to become highly volatile. This will result in a highly volatile reactive power distribution, because of higher Mvar losses with higher load / power flows. This results in grid voltages that change continuously and need close attention from the system engineer.
- These trends together have an impact in two ways:
  - First, due to decommissioning, decisions will need to be taken for multiple small units instead of one big unit. This will mean the messages sent in connection with each decision will increase.
  - In parallel, due to the increased dynamics, more decisions will be necessary in each time step. Therefore, the complexity of voltage management will increase significantly.
- The integration of renewables and associated power electronics equipment will also change the dynamics of the system, leading to voltage issues and therefore also a risk of blackout. Voltage support is a system control task mainly performed with synchronous generators today, which will be joined by non-synchronous devices in the future.
- We see an increasing number of HTLS and PSTs in the Belgian and European grid, which are responsible for high Mvar losses at high load, in turn again changing dynamics related to grid voltage. The trends mentioned above are not fully compensated by new Mvar sources. On top, the Mvar sources are not always ideally placed in the network, for instance on an antenna instead of firmly meshed into the grid.
  - Offshore wind voltage control is not yet fully implemented, and the fact that they will provide Mvar services at zero active power is to be confirmed
  - Potential new thermal power plants on Elia grid will not be running all year long, and their availability for Mvar services will be volatile
- Simulation sessions with experienced System Engineers have shown that up to 13 voltage related actions per hour will be necessary in the future if we do not change the current approach. Given the fact that an action comes with multiple actions (aligning with stakeholders, checking N-1 security etc.) this would mean that voltage control becomes a full-time job for the System Engineer.

- A general approach by TSOs to solving voltage problems is to revert to the installation of power electronics assets such as STATCOMs, devices that can cost millions of euros. At Elia, we want to look into trying to avoid such investments by optimizing the usage of the voltage-regulating assets we have today (e.g. shunt or capacitor bank) and making their control more dynamic, for instance by making modulation possible instead of switching on and off.

- The COVID-19 crisis has had a negative impact on the situation. Due to load reduction, voltages have increased in many parts of the European grid. Several European TSOs have triggered emergency alerts via the European emergency alert system (EAS) due to extremely high voltages. Mass dispatcher interactions and coordination with neighboring TSOs and impacted DSOs have been necessary to keep the European system up and running.

Project-specific state of the art/literature review

- RTE and Swissgrid have already developed some initial solutions. Specifically, RTE is looking into improving voltage control using artificial intelligence as part of its APOGEE project. In this project, the idea is to develop an assistant for short-term operations. RTE is working on achieving this goal with various PhD students. They take four parallel approaches, namely (i) using machine learning to mimic humans; (ii) using optimization algorithms or optimizers; (iii) using expert systems, such as a remedial actions database; and (iv) capturing what operators intend to do in near to real time. Experiments with dispatchers are ongoing. Swissgrid is working in a slightly different context than Elia, in the sense that they do not have proper voltage-regulating assets and instead depend on services contracted from Swiss DSOs. They have developed a day-ahead market optimizer that works out voltage schemes for a 15-minute time scale.
- We had a call with Energinet DK, who have attempted to implement a similar scheme some years ago. Their feedback was that their OPF proposed too many actions that had a limited validity (e.g. activation of a shunt that will be deactivated in the next hour). This is a clear attention point for our project, and we will stay in contact with the relevant persons. Subsequently, via our links to the R&D committee of Entso-E (RDIC) we try to identify other relevant stakeholders in the TSO business.
- We also had contact with relevant people at AEMO (Australian market operator), who confirmed our feeling that we are pushing the state-of-the-art with this project. They indicated that they are very interested to be updated about intermediate results of the project in order to learn from us.
- Based on calls with our peers, none of them has for the moment reached a level of automation that might be required in the future after the nuclear phase out in Belgium.
- We have contacted several startups *confidential* etc.) and multinationals (*confidential* , etc.) to assess the possibility of launching a partnership. We launched an RFP via our social platforms, to identify other potential companies we might have missed. In response to this, we received about 15 proposals of a multitude of companies, who are interested to build the solution with us. Once again it became clear that our challenge has not been undertaken before, and therefore no off-the-shelf products exist.

Expected impact for Belgium

- Significant voltage deviations can lead to decoupling of many devices and ultimately to a local blackout. One of the best examples of this is the blackout in New York, Ohio, Michigan, and Ontario on August 14, 2003 mainly caused by a voltage control and stability issue and costing between USD 4 and 10 billion.
- Given that in Belgium, nuclear power plants account for around 50% of the voltage control and considering the increase in the share of renewables in the energy mix, an automated voltage control solution needs to be developed to increase the dynamic voltage capabilities of our grid. This way we can ensure the security of the grid in case of voltage instability caused for example by an abrupt change in the generation of renewables. So far, no exact quantitative impact calculation has been made available. This will be evaluated in the first part of the study.
- Due to the current trend of replacing conventional conductors with HVDC lines (reactive power depends on the square of flux) combined with higher market volatility and the fact that plants regulating voltage automatically will be replaced by solar and wind energy infrastructure, an increase in voltage-related actions in the future is expected.

Starting point for Elia

- Up to now, at Elia we have not used an optimizer or a decision support tool to control voltages. Voltage management is a specialist task performed by system engineers. Today, the system engineer has two different, complementary tools, depending on which task he needs to perform. Firstly, there is the EMS, which via our SCADA system directly controls assets we own, such as shunts or condenser batteries. By sending (de)activation signals, the voltage is managed. Secondly, if the system engineer wants to change the Mvar absorption or production of a specific power plant, he needs to use the ReVolt tool, which sends requested signals to the operators of these plants.

- In the processes, voltage management is started in at 11:00 the day before the voltage is needed. Through coordination between the National Control Center (system engineer) and the Regional Control Center, all voltages in the system are normalized. That day at 18:00, the procedure should be finished, and the actions that are still necessary are decided on and coordinated in (near) real time by the system engineer or the near real-time engineer.
- Today, this is a manual process that requires a lot of expertise, knowledge, experience, and manual interventions from the responsible parties.
- Because of the shift from big, centralized assets connected to the extra-high voltage level to small, decentralized units, coordination between different control centers will be crucial but also more complex.

Uncertainties and risks

- The first uncertainty relates to the availability of tools for such voltage management automation, as previous research has shown that there are no existing solutions on the market. Voltage management is a highly complex issue because we need to take into account interactions between loads, electrical zones, neighboring TSOs, impacted DSOs, and voltage-regulating assets, such as capacitor banks and shunts.
- The second uncertainty is about whether the decentralized voltage control resources will be sufficient to cope with the uptake of renewables and the nuclear phase out, and whether a human can control these resources.

Project description

- The goal of the project is to support dispatchers in managing the voltage schedule and Mvar distribution on the grid to prepare for an energy system with a high share of renewables. The first step is to improve the forecasting of voltage control needs, before gradually increasing the support provided to the dispatcher until there is full automation of some voltage control processes (still to be determined). This support to the dispatcher will become vital in the years to come, given that today around 50% of dynamic voltage control is managed via nuclear power and that in an energy system with a high level of penetration of renewables, dispatchers will need to activate voltage control more frequently and with a much wider pool of decentralized control resources.

Introducing an optimization algorithm in Planning and Dispatching, which will help the system planner and dispatcher or system engineer to always achieve the optimal voltage spread over the grid over a 15-minutes time span. This tool will need to take into account existing predictions for load and production and consequences in terms of the N-1 security of its decisions. On top of this, the tool will need to be able to cope with the complex reality of voltage regulations, in which many actors and influencing factors play a role, such as local load fluctuations, neighboring TSOs' voltage management, voltage-regulating assets, and transformer tap changers. In that sense, the tool will be usable as a means of communication and alignment between all stakeholders.

Eventually, the experience gathered in those projects will be used to pave the way for automated voltage regulation.

For the second project, we need to gain a clear view of the business needs of our Dispatching team. This is the most important part of the work. By aligning with these business requirements concerning what the tool should be capable of (which assets to control, which constraints to respect, which objective function to use, etc.), we will be able to describe in detail what we need to develop (potentially in a partnership) or buy. This means that currently only this first study phase of the project is being planned. This will enable us to learn from other TSOs and contact startups and multinationals to understand what is possible and what is not. Based on the identified needs, by the end of the year we would like to further flesh out the business requirements and develop potential ways of implementing the tool in Dispatching. This will give us a clear view of the road to be followed, when we want to start implementing voltage-management support and coordination at Elia.

2021 update: Throughout 2020 we have gathered all needs and business requirements for the voltage control tool. We have finalized the market scanning and peer interviews, from which we concluded that currently nothing can be bought off the shelf. Because of this, we launched a 'request for proposal' to look for a partner. We received a high number of qualitative proposals, and after three selection rounds the *confidential* consortium won the project, thanks to a high expertise combined with a competitive price.

In 2021 we are developing the PoC, aiming to get a first answer on our set of hypotheses by Dec 2021. The main hypotheses are related to the ability of the tool to read and understand all grid data, whether the optimizer can take into account time coupling aspects, and whether all defined control means and objective functions can be used and reached by the tool. It will furthermore be important to create a basic GUI by the end of the year, to make sure end users (such as system engineers and planners) can interact with the tool and start building confidence.
Assuming that the learnings and hypotheses in 2021 will be successful, in 2022 we will aim to create confidence and further understanding in the way of working of the prototype. For this, we will put in place a testing schedule and scenarios. The user tests should lead to a further fine-tuning of the prototype, and consequently a better understanding to move towards an industrialization phase by 2023.

- Deliverables and milestones
    1. Internal knowledge spreading and valorization
    2. *Potential publishing of scientific paper with insights*

Partners

- Analysis of the needs, criteria/the design: experts from the Elia Group's control centers and relevant experts from EGI.
- Exchange of expertise with other TSOs, DSOs, startups, multinationals, etc. and assessment of the best partnership for the project.
- Development of the algorithm: This will be analyzed in close liaison with Elia's Artificial Intelligence team, set up in close liaison with the analytics consultancy *confidential*
- Alignment and potential involvement with academic experts, e.g. via EnergyVille .
- Search for potential innovative partners: *via own social platforms*
- Contact with other TSO's to exchange on the voltage solution development, notably RTE, SwissGrid, AEMO and Eirgrid

Summary of project efforts in person months: by work package and by year

In 2021, about 1 FTE in total from Elia side will work on the project. Next to that, there is about *confidential* EUR budgeted for consultancy (e.g. *confidential* developments, data engineering, Power Factory handing etc.)
We did not define work packages for the project. In an agile environment, we can re-prioritize constantly based on intermediate learnings, user-feedback and potentially reviewed priorities.

HVDC
Domain 2.2

Project 8: Understanding of new grid dynamics

2021 decision: Accepted

Trends: Decarbonization, decentralized generation and new players

Consequences: New decentralized flexibility, interface with new players, new market models, low marginal price

Challenge: 2. Automate the system operations to be capable to optimize the network in minute timeframe for frequency, voltage and congestion

Domain: 2.2 Prepare for low inertia and integrate power electronics

Project-specific context

- Future power systems will face new challenges, with traditional thermal generation units being replaced by renewable energy sources with power electronics grid interfaces. In Central Europe, an increasing share of wind and PV generation in the energy mix is leading to periods when few synchronous generators are operating. Due to the physical characteristics of these resources, this leads to a grid with low rotating inertia.
- Inertia represents the capacity of units connected to the grid to store kinetic energy and inject it back into this grid during a certain period, even after an increase in the load. This inertia is necessary to ensure that the network can overcome an imbalance between generation and consumption and stabilize again. The lower the inertia level, the faster the frequency changes when there is an imbalance between generation and consumption, and if the frequency deviates from its stability range (from 48.5 to 51.5 Hz), there is a significant risk of a grid blackout. A noteworthy example of this occurred in the UK on August 9, 2019, a day with a high level of renewables in the energy mix, when two generators disconnected leading to a partial blackout[1].
- The RoCoF (rate of change of frequency) was a parameter of minor relevance in the past, but it is now becoming relevant because of low levels of system inertia. Inverter-based generation can result in synthetic inertia through control algorithms, but these need to be implemented carefully.
- We distinguish between the risk of low *overall* inertia (on the interconnected grid) and the risk of low *local* inertia (in a limited synchronous system).
- On top of the inertia risk, which will affect frequency, the integration of renewables and linked power electronics equipment will also change the voltage level of the system, leading to voltage issues and therefore also the risk of a blackout. Voltage support is a system control task that is currently mainly performed with synchronous generators. These will be joined by non-synchronous devices in the future.
- With the increased penetration of power electronics, the assessment of the risks of system stability becomes much higher and challenging. The current state of the art for the analysis of interaction between power electronics devices from multiple different vendors and of different nature (e.g. wind parks and HVDC for example) is not mature enough and there does not exist methodologies and tools that are allowing to perform this assessment in an efficient or complete way.
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  Such issues are reflected in the problems of control stability and harmonic stability, new concepts arising on the horizon of the system stability assessment. Currently these issues are mostly discovered after commissioning of the assets and this has a huge cost with very high risks.
- For new dynamics (frequency, voltage, control interaction and harmonic interaction), Elia must understand the future risk linked to the change in dynamics so that we can continue to operate our grid reliably and without any impact on

[1] https://theenergyst.com/national-grid-blackouts-lcp-analysis/

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our users. Elia has to develop internally the capabilities to assess the risks and to design be able to specify the requirements for the assets and modify the existing ones to keep the risk under control.
- Therefore, Elia is teaming up with various universities in the context of PhD research and subsidized programs to work out how to prepare for these new dynamics, resulting in three main projects (Local Inertia, HVDC Inertia, and InnoDC).

An additional internal project, called "Dynamic and Harmonic stability" has been set up to follow-up the state-of-the-art improvements both in methodologies, risk assessments, simulation, technical solution not only from an academic point of view, but also with an eye to the industrial technological development that are often complementary to the academic research. The project has defined a set of tasks and actions that will help the development of internal competence through participation to research projects, industrial innovation projects, discussions with manufacturers and transversal cross-expertise exchanges.

Project-specific state of the art/literature review

- Studies have shown the need for synthetic inertia in the future (see the ENTSO-E study from November 2017 about the "need for synthetic inertia (SI) for frequency regulation", which recommended that TSOs conduct collaborative studies.
- As for the Rate of Change of Frequency (RoCoF), ENTSO-E has requested that TSOs collaborate on determining the RoCoF withstand capability criteria.
- National Grid UK has already performed in-depth analysis, as the UK's geographic separation from continental Europe exacerbated the risk of inertia there already.
- Central Europe[2]: A task force comprised of European system operators studied the frequency behavior of the European system for decreasing system inertia. The main conclusion is that in interconnected mode the system still exhibits acceptable frequency behavior even with significantly reduced inertia. However, in the case of split operation after a disturbance, the resulting imbalance combined with low inertia could result in unstable system behavior.
- Nordic grid[3]: Given a combination of increasing renewable generation penetration and the shutdown of nuclear power plants, the operators of the Nordic grid list low inertia as one of the three main future challenges faced by their system. Proposed solutions include technical measures and also imposing operational requirements, such as a minimum available kinetic energy.
- However, none of these studies has had a closer look at Belgium, while Elia needs to prepare for the new dynamics.
- Many of the challenges related to low-inertia power systems have been highlighted in recent reviews and magazine articles.[4] While many of these issues are now widely recognized, there is still no scientific basis for the modeling, analysis, and control of low-inertia systems.

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[2] RG-CE System Protection & Dynamics Sub Group, *Frequency stability evaluation criteria for the synchronous zone of continental Europe*, ENTSO-E, Tech. Rep., 2016.
[3] Svenska Kraftnät, Statnett, Fingrid and Energinet.dk, *Challenges and Opportunities for the Nordic Power System*, Tech. Rep., 2016.
[4] EirGrid and Soni, *DS3: System Services Review TSO Recommendations*, EirGrid, Tech. Rep., 2012.
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B. Kroposki, B. Johnson, Y. Zhang, V. Gevorgian, P. Denholm, B.-M. Hodge and B. Hannegan, *Achieving a 100% renewable grid: Operating electric power systems with extremely high levels of variable renewable energy*, IEEE Power and Energy Magazine, vol. 5(2), pp. 61-73, 2017.

- The risks related of controller and harmonic interaction in a system with high concentration of power electronics have been looked at in several research project but an effective solution at early stage of development is still missing as also clarified within ENTSO-E RDIC working group[5].

Expected impact for Belgium

- With the implementation of Stevin and Ventilus and the de facto increase in renewable energies, we need to be cautious about the behavior of HVDC and wind farms, and have a clear definition on which ratio of power electronics to synchronous generators is manageable.
- The vision to extend the current coastal area with high density multiterminal HVDC and multivendor power electronic devices (MOG2, Ventilus, Boucle de Hainaut and Nautilus) exacerbate the need and urgency to advance the knowledge of controller and harmonic interactions at an earlier step in time.
- In Belgium, the level of overall inertia is higher than in the UK due to the higher level of interconnection; however, the uptake of renewables and the nuclear phase out could in the future bring about a similar situation to the blackout on August 19 in the UK, which cost millions of GBP (to give a rough quantification of this, RWE and Orsted agreed to pay GBP 4.5 million to close the investigation).
- The exact impact of the risk of a local inertia issue was quantified during the local inertia study. In parallel, the role of HVDC converters in supporting the low-inertia Belgian power system is currently being quantified in the HVDC inertia study.
- The InnoDC study will give a better idea of system stability modeling in the context of high-voltage power electronics.
- Finally, we want to analyse the potential of so-called 'grid-forming converters'. This is a way of controlling static generators and make them active stabilizing assets in the grid, rather than grid-following current injectors.

Starting point die Elia

- As ENTSO-E's RG-CE System Protection & Dynamics Sub Group stated, "decreased system inertia will have a significant impact if the Continental European power system faces a system split similar to the November 4th 2006 event" (referring to the blackout affecting 15 million people on November 4, 2006).
- It has been said that new equipment, and in particular, HVDC converters, could provide an opportunity to solve inertia issues. Since we have more and more of this equipment at our disposal, this is an interesting avenue of investigation that needs to be explored further.
- We have created a special Dynamics and Harmonics working group, bringing together key experts from the company and keeping its finger on the pulse when it comes to problems concerning dynamics and harmonics in operations, grid planning, incident analysis, and other domains.

Uncertainties and risks

- The first uncertainty relates to the effective risk of blackout that Belgium as an interconnected power system will face in a system with high levels of renewables and a much-decreased role of centralized power plants in the energy mix. Today we have not seen evidence in the state-of-the-art that such system can stay operational, so a risk for this project is the possibility to find a solution. This is both in terms of blackouts and voltage stability.
- The second uncertainty the study aims to tackle surrounds the fact that the HVDC converter can effectively solve issues linked to low-inertia systems.
- Considering this uncertainty, should the projects be not successful, ELIA will have to cover the risks in different ways that may increase the overall cost of the investments with a remaining risk to increase the probability of having large scale incidents with brownouts/blackout.

[5] Research, Development and Innovation Committee (entsoe.eu)

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Project description

- The project takes the form of three separate studies (PhD projects) and one concrete demonstrator:
    1. *Local Inertia*: PhD research project started with Brunel University in London and pursued with KU Leuven in order to better understand the local inertia distribution on the Belgian grid and the associated blackout risk and also potential mitigation measures;
    2. *InnoDC*: on this project, a researcher working for Elia and in close liaison with KU Leuven is trying to develop a methodology to improve modeling to better assess the risk for the stability of the grid with high penetration of power electronics.
    3. Grid Dynamics: In this project KUL&Energyville is supporting ELIA to develop the necessary skills and methodologies to be able to perform assessment of system stability in zones with very high integration of power electronics based on EMT tools.
    4. HVDC Inertia Provision: This project will develop methods for assessing the value of and the requirements for inertia emulation from HVDC transmission schemes. In order to meet the requirements, it is also important to analyse how control systems for different types of converter stations in such systems should be designed. HVDC systems can help avoid issues related to low equivalent inertia if the systems' power electronic energy converters can be regulated to provide virtual inertia. The project will examine whether this can be achieved by having the control system in the converter stations emulate the general characteristics of a synchronous generator. Accurate HVDC models, as well as real-time simulation of control algorithms, will also be used to assess system stability.
    5. Grid forming moonshot: This project initiated by the Innovation department will gather knowledge, make simulations, develop methodologies and partner up with manufacturers to assess the following statement: "By 2024, a utility scale demonstrator with renewable energies and storage stabilizes the grid in weak conditions". It aims to answer questions around integration renewable energy with less rotating machines. These questions cover two topics: the grid forming aspect, and the interaction risks.
        - 1. Grid forming: Can we use Power electronic devices to stabilize the grid in voltage, frequency, inertia etc.
        - 2. Interaction risks: What are the risks of high density of power electronics devices near each other from different manufacturers in term of interactions and harmonics?
    6. Grid dynamical and harmonic stability: continuous work group

- Approach:
    1. For each of these studies, the approach is to team up with universities (KU Leuven, *confidential*) or research consortiums to perform the analysis in close liaison with the relevant Elia departments (mainly the National Control Center and the departments responsible for protection and harmonic analysis). In that context we will notably work with PhD student.
    2. Regarding the assessment moonshot, this will be achieved though close collaboration with manufacturers and/or other TSOs.

- Work packages and timing (M = month)

    1. ***Local Inertia***
        - RoCoF screening methodology
        - RoCoF BE system impact assessment
        - Performance assessment of protection devices
        - Outlook and other challenges
    2. ***InnoDC***
        - Jan. – July 2019: Literature review relating to phasor-based models of electrical components used in transient stability programs

- July – Oct. 2019: Implementation of VSC models on MATLAB/Simulink with and without quasi-stationary phasor simplifications
- Oct. 2019 – May 2020: Analysis of the accuracy of the VSC models to represent stability issues in weak grids considering the small-signal behavior of the system
- May – July 2020: Literature review relating to control interactions between large converters embedded in the AC system
- July – Dec. 2020: Test-case implementation of two large converters and analysis of the impact of phasor-based representations
- Jan. – June 2021: Development of an aggregated (reduced-order) system model for several converters in large offshore wind farms
- June – Dec. 2021: Compilation of benchmark results

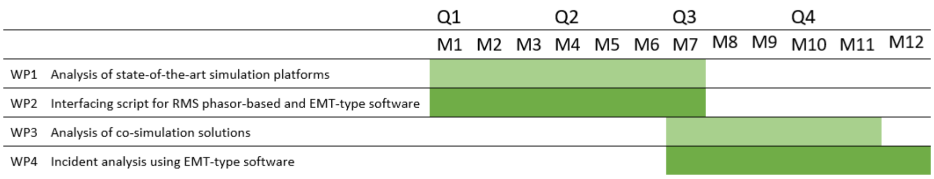
3. Grid dynamics

Work package 1 – Analysis of state-of-the-art simulation platforms
The first work package seeks to provide an in-depth assessment of current state-of-the-art simulation platforms available. The overall aim is to gain insights in the potential of various hardware/software solutions that could result in an increased performance. Furthermore, the work package seeks to analyse the current state-of-the-art for defining the required system boundaries for EMT-type simulations depending on the type of phenomenon under consideration.

Work package 2 – Interfacing script for RMS phasor-based and EMT-type software
The second work package seeks to provide a methodology and developed software script to automatically build PSCAD simulation models starting from PowerFactory models by enriching them with standard characteristics. The script will be tested on a small test network (academic example, or example from PowerFactory), and a larger system inspired by a part of the Elia system.

Work package 3 – Analysis of co-simulation solutions
The third work package investigates the possibility for co-simulation solutions (including, but not limited to, between PSCAD and PowerFactory) as a means to speed up the simulation.

1.4. Work package 4 – Incident analysis using EMT-type software
The fourth work package seeks to propose a methodology and develop a software script for automatic simulation of multiple incidents and result analysis in PSCAD. The script will be tested on a small test network (academic example, or example from PowerFactory), and a larger system inspired by a part of the Elia system.



4. **HVDC Inertia provision**

- **WP1:** Feasibility and benefits for the power system of HVDC Inertia support
  1. Task 1.1: Data collection and literature study on the quantified needs for inertial response support and the possible implementations
  2. Task 1.2: Preparation of user‐defined case studies
  3. Task 1.3: Analysis of the potential benefits and implications of operating HVDC interconnectors for inertia support from a transmission system perspective
  4. Task 1.4: Phd study at KU Leuven (Prof.van Hertem)

- **WP2:** Control design and interface to VDC controllers
  1. Task 2.1: Assess level of access for control of different HVDC converters
  2. Task 2.2: Depict possible implementations depending on level of access to the HVDC converter control system
  3. Task 2.3: Phd study on implementation and control system integration of inertia support schemes at Ecole Centrale de Lille (L2EP), (Professor Guillaud)
- **WP3:** Impact of HVDC inertia support schemes on dynamics and stability of large-scale power systems
  1. Task 3.1: System modelling and time ‐ domain simulation of different implementation schemes in a large ‐ scale power system
  2. Task 3.2: Small ‐ signal modelling and evaluation of dynamic characteristics and system stability with different implementation schemes
  3. Task 3.3: post.doc at NTNU (Prof. Fosso)
- **WP4:** Laboraty demonstration
  1. Task 4.1: Demonstration of the most relevant inertia support implementations in relevant laboratory ‐ scale grid configuration
  2. Task 4.2: Laboratory demonstration of inertia support implementations connected to a grid emulator running a power system model in real time

5. **Grid Forming moonshot**
   - 2021 : Scope: Defining the objectives of the project, the roadmap and the workstreams. Engage with internal stakeholders and align on the project's scope.
   - Q2 2021 – Q3 2021: State of the art: Identify and analyze similar activates within other TSOs or universities. (Papers, PoC, studies, products,…)
   - Q4 2021 – Q2 2022: Supplier identification & onboarding. Suppliers might coming from the "generation" or "transport" part. Goal is to find common interests and agree on processes to co-shape solutions.
   - Q4 2021 – Q3 2022: Scenarios: Defining scenarios to be tested to will allow to validate or not the hypothesis about grid forming
   - Q1 2022 – Q3 2023 – Test modelling: Modelling of the assessment scenarios by taking into account assets criteria's, zone, time, behavior and scenarios.
   - Q2 2022: Identify interaction risks between the identified assets of the scenarios. Literature review and knowledge acquisition about assets interaction will be needed to beforehand.
   - Q3 2022 – Q4 2022: Business case to identify the best scenarios and evaluate the value of the project compared to the status quo--> This could lead to stop the project
   - Q2 2023 – Q2 2024: Control loop & software development to adapt assets for grid forming assessment
   - Q3 2024 – Q4 2024: Organization & realization of the assessment
6. **Grid dynamical and harmonic stability**: continuous work group
   - Assess the needed knowledge to acquire in the topics of large-scale power electronics control and power system interaction.
   - Develop method and tools that can be used to improve the assessment and forecast the needed technical requirements to avoid issues of controller and harmonic interactions in multivendor and multiterminal HVDC environment.

- Deliverables and milestones
  1. **Local Inertia**
     i. June 2021: Report on the system impact assessment of high RoCoF values, including guidance on RoCoF settings/specifications/limits to consider in grid codes or analytical tools

ii. June 2021: Report with the results of the impact assessment specific to the Belgian (and Central-European) power system
iii. August 2021 Report on the RoCoF screening methodology and the proposed procedure that might be used in the Belgian context
iv. August 2021: Report with the results of the application of the methodology to the Belgian (and the Continental European) power system
v. December 2021: Report on the performance assessment of protection devices – evaluation and test procedures, including guidance on RoCoF limits and analytical tools
vi. December 2021: Report with the results of the application of protection devices' performance to the Belgian (& Central-European) power system
vii. June 2021: Report on the qualitative assessment of other challenges related to low levels of local system inertia, including a proposal for additional phases/an extension of the project

2. **Grid Dynamics**

Work package 1

i. D1.1 Report on the analysis of the current state of the art for simulation platform to provide insight of what hardware/software solutions can allow better performances
ii. D1.2 Report on the current state-of-the-art for definition of system boundaries for EMT simulations based on the type of phenomenon under study

Work package 2

iii. D2.1 Report on the methodology & software to automatically build PSCAD simulation models starting from PowerFactory models, by enriching it with standard characteristics, including the application to a small test network (M7)
iv. D2.2 Script to run the PowerFactory-PSCAD conversion (M7)
v. D2.3 Report on the application of the script to run the PowerFactory-PSCAD conversion to a larger system inspired in part by the Elia system

Work package 3

vi. D3.1 Report on the analysis and proof-of-concept of possible co-simulation solutions (e.g. interfacing of PSCAD and PowerFactory) to speed up power system dynamic simulation (M11)

Work package 4

vii. D4.1 Report on the methodology & software for automatic simulation of multiple incidents and analysis of results in PSCAD
viii. D4.2 Script for automatic simulation of multiple incidents and analysis of results in PSCAD (M12)
ix. D4.3 Report on the application of the script for automatic simulation of multiple incidents and result analysis to a larger system inspired in part by the Elia system

3. **Grid Dynamics**
   i. … TO be added

4. **HVDC Inertia Provision** – long term plans for deliverables and synthesis
   i. Open report or review paper on grid‐forming control, VSM implementations and grid‐following inertia emulation based on activities in WP2
   ii. Open report summarizing main findings and activities in the paper
   iii. Open workshop in 2022 with presentation of main results
5. Grid dynamics and harmonic
   i. December 2021: Roadmap for acquisition of knowledge for control interaction and harmonic interaction studies.
6. Grid forming demonstrator

i. Q4 2021: Scope & state of the art
ii. Q3 2022: Identified suppliers & defined scenarios
iii. Q3 2023: Grid forming assessment modelled and simulated
iv. Q3 2022: Business case
v. Q2 2024: Control loops and software ready
vi. Q4 2024: Grid forming assessment

Partners

- First part of WP 1 (Local Inertia): Study led by Brunel University in London in 2018 and 2019
- Second part of WP 1 (Local Inertia): Study by a postdoctoral researcher from KU Leuven (yet to be hired)
- HVDC provision: Consortium led by *confidential* , including *confidential*
- InnoDC: Elia is taking care of a researcher as part of a broader consortium with Cardiff University, Universitat Politecnica de Catalunya (UPC), *confidential* Universidade do Porto (UPorto), *confidential*, Danmarks Tekniske Universitet (DTU), Katholieke Universiteit Leuven (KU Leuven), and *confidential*
- InnoDC subsidy: The European Commission is subsidizing the project in the context of the H2020 program.
- InnoDC supervision: KU Leuven is providing the academic supervision while the expert's team from the National Control Center is providing business support
- Grid Dynamics – ELIA is collaborating with researchers from KUL and Energyvill.
- The experts from the NCC and the Grid Dynamics workgroup will support the follow-up of each project.

Summary of project efforts in person months (by work package and by year)

confidential

Domain 3.2

Project 9: BVLOS drones for automate inspection

2021 decision: Accepted

Trends: Decarbonization, decentralized generation and new players

Consequences: New decentralized flexibility, interface with new players, new market models, low marginal price

Challenge: 3. Automate asset inspection and make maintenance more flexible to cope with planning changes, keeping a high level of safety

Domain: 3.2 Automate inspection onshore and offshore

Project-specific context

- To ensure the secure transmission of electricity through the transmission assets, regular visual inspections and maintenance are of high importance.
- Today, these inspections entail regular (twice a year) foot patrols with climbing and the use of binoculars by technicians and engineers as well as Helicopter flights that cover the complete Belgian grid every 1-3 years.
- During these helicopter flights, high resolution cameras are used to take detailed photos of the towers and powerlines to detect damages such as rust. Infrared cameras are used to detect damages such as hotspots, and LIDAR laser scans are used to identify areas where vegetation is reaching the safety limit and require pruning.
- In case of an emergency, such as extreme weather conditions that cause damage to a transmission asset, a car or foot patrol is used to identify the location of the damage, its seriousness and to perform the recovery as quickly as possible from a potential outage.
- Both foot patrols and helicopter inspections are expensive, inefficient, inflexible, time consuming, unsustainable, and entail major risk for the assets and employees
  Helicopter inspections have an estimated annual cost of over 200K euro.
- Autonomous drones have the potential to substantially reduce the cost of power line inspection (lower cost than helicopter flights) while increasing the safety of assets and employees (less climbing on towers, no risk of helicopter accidents that may cause damage to the assets, people and surroundings), increasing the flexibility and frequency of inspections while reducing the negative environmental impact (less CO2 and noise emission).
- More specifically, autonomous drones together with AI can substitute conventional power line inspections of foot patrol and helicopter inspections. Autonomous and digital inspections entail drones in BVLOS mode (Beyond Visual Line of Sight) that carry high-resolution cameras for detailed inspections of damages such as rust, LIDAR laser scans and photogrammetry scans for vegetation management and the development of 3D Models, infrared cameras for detecting thermal damages such as hotspot, and an AI that is able to evaluate the data that is captured to automate the analysis of damage detection.
- Currently Elia has already tested and implemented remote control drones in VLOS mode (Visual Line of Sight) for micro view, work preparation, air inspection, and diagnosis of line incident or painting inspection.
- However, these drones require to be flown by a pilot in visual line of sight (VLOS), decreasing the potential of automation and therefore the potential improvement of cost and efficiency.
- The goal of the BVLOS project is to substitute helicopter inspections with inspections that are undertaken by autonomous drones on long distances of up to 100-200 km using embarked technologies (lidar, HD camera) for data collection used for automatic analysis (incident analysis, default detection, painting analysis…).
- The goal of the BLVOS project is extended to foresee more use cases around verification of incidents on over headlines which in turn will enable a faster and safer reaction to such incidents, with the end goal being able to re-energize the line as soon as possible.

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Project-specific state of the art/literature review

- Today, the legal framework for unmanned aerospace systems (drones) is described in Regulation (EU) 2018/1139 which regulates unmanned aerial systems below a take-off mass of 150 kilograms at EU level. From 01.01.2021, the EU Regulations 2019/947 and 2019/945 bind member states to require permission for drones' flights based on a common European risk assessment. Drones may only be flown on visual line of sight without permission and flying drones at altitudes above 100 m is generally prohibited. BVLOS operation is only allowed with specific derogations.
- From a technical point of view, drones with 100 km coverage incl. multi-Camera/sensor systems and portable data storages can be seen as state of the art but due to the legal framework described above, it is not allowed for any industry/branch to operate drones BVLOS. In many industries/branches, different applications and services are currently developed but until now no commercial services are available. In addition to the energy infrastructure industry, the following industries are marked by certain development effort :
  - Agriculture (including targeted use of plant protection products and fertilizers),
  - Medical care (e.g. transport of medicines, blood, tissues),
  - Distribution logistics (including delivery UAS),
  - Railway

- Many European TSO are testing whether drones can support the monitoring of overhead lines but mostly those flown by drone pilots and in visual line of sight. A few TSO made some first pilot projects such as:
  - RTE (France) : they have tested drones for the inspection of power lines on VLOS (Visual Line of Sigh) mode
  - CEPS (Czech Republic): will test drones VLOS mode in the end of 2021
  - Swissgrid: which is tested multiple drones
  - APG (Austria) : they are testing drone applications for incident inspections in mountainous terrain.
- At 50Hertz in Germany, Drones were already successfully tested to undertake automated 75km BVLOS inspection using high resolution cameras, infrared cameras and LIDAR laser scans and an AI to assess the images.
- However, the full automation via image recognition or test to onboard multiple technologies as HD lidar and thermography, HD cameras at the same time is still being tested.

Expected impact for Belgium

- The expected impact is a cost reduction between 20-70% (to be confirmed during the PoC) due to reduction of helicopter inspections from over few 100kEUR. The exact estimation needs to be performed based on the capabilities of the technology.
- Furthermore, there will be an increase in safety due to less need to climb on towers is also expected for the Elia employees as well as for third parties.
- A decreased environmental impact is also expected by the reduction of helicopter inspections (reduced pollution and noise).
- The 3D models resulting in the Lidar modelling can be seen as additional added value for future innovation activities.

Starting point at Elia

- Currently VLOS (Visual line of Sight) drones are implemented;
- BVLOS first flight has been performed in the context of the SAFIR project, a consortium aiming to demonstrate the feasibility of a flight in the European sky;
- At the end of 2020 and in the beginning of 2021, we undertook the first BVLOS flights for asset inspections in Germany

Uncertainties and risks

- The major uncertainty is the feasibility to obtain permission to perform drone autonomous flight in the Belgian sky (according to the European directive "Sora").
- Another important risk is the technology risk as the autonomous drone is not a technology that is yet very mature.

Project description

- The first goal of the project is to automize the data capturing process of inspecting the transmission assets by substituting helicopter inspections with inspections undertaken by autonomous drones. The second goal is to digitize the data analytics of the inspecting the transmission lines by developing an algorithm that can effectively detect the default on an overhead line and a pylon.
- For the first goal, the project aims to validate the maturity and feasibility of substituting helicopter inspections with autonomous BVLOS drones by testing:
    - Long distance flights of 75-120 km to demonstrate the potential to compete and substitute helicopter inspections
    - Detailed inspections of the assets by using drones with high resolution cameras to detect damages such as rust i
    - Vegetation management by using LIDAR Laser scans to develop 3D models to calculate the distance between assets and vegetation
    - The development of digital twin that can be used to map and assess the infrastructure by using photogrammetry as a new technology to develop 3D models
    -
    - Thermal analysis by using Infrared cameras to detect damages such as hotspots

- For the second goal, the project aims to develop, test and benchmark the analysis of the data that is captured by autonomous drones through an AI technology. To do this, the projects aims to undertake the following:
- Work together with a partner to develop an internal AI based on deep learning methods to use photos of transmission assets to automatically detect damages such as rust
- Feed the AI with existing photos of previous inspections to train the model on damage detection
- Work together with a third party to test an external AI solution to develop a benchmark for AI damage detection of transmission assets
- Use the data that is captured during the BVLOS project flights to further feed the internal and external AI solution
- Use the data of the BVLOS flights to benchmark the internal AI against the external AI and to benchmark the AI technologies against the current manual detection of inspection data on criteria such as time, detection rate, and cost data should then be sufficiently qualitative to detect default through the pre-developed algorithm

- Approach: the algorithm will be developed jointly with external suppliers. Then the test of the BVLOS drones flight will be performed via partnership with drones Operation Company (selected via tender process). In parallel, the in-house algorithm will be compared to vendor solutions Elia is currently testing with VLOS drones.

- Work packages & Timing(M=month)
    1. *WP1 Initial BVLOS drone flight*
        - vii. Feb. 19 –Sep : Consortium set-
        - viii. Sep.19 – Sep. 19: test in the port of Antwerp
        - ix. Jan.20-Mar.20: report writing
    2. *WP 2 Development of an AI solution for image recognition for overhead lines and pylon defect detection.*
        - x. Oct. 19 –Jan. 20: capture of pictures via VLOS (View Line Off Sight) drones
        - xi. Dec.19-Feb.20: development of the first version of the algorithm
        - xii. Feb.20 – May.20: Labelling of the picture
        - xiii. Apr.20-Jun.20: Training of the model
        - xiv. Apr.20 – Jul.20: Back-testing of trained model and report
    3. *WP 3 Application for permission of corridors to fly with BVLOS drones*
        - xv. Apr. 20 –Jun 20: Selection of partner
        - xvi. Feb..21 – July.21: Application for the Sora (long process due to civil aviation authority)
    4. *WP 4 Train the AI solution for image recognition with specific images obtain via preliminary drone flight*

xvii. Jul.20 - Aug. 20: Selection of drone company
xviii. Jul.20 - Aug. 20: Selection of zone to be inspected
xix. Aug. 20 - Sep : 20: New pictures taken from VLOS flight on pre-define sight
xx. Sep.20 – Oct.20: training refining based on BVLOS drones pictures

UPDATE
July.21 – Oct.21: Data capturing with BVLOS flights to training

5. *WP 5 First long distance flight including a 3D scan (Lidar and photogrammetry)*
   xxi. Jan.21 – Sep.21: preparation of the flight and obtainment of permission
   xxii. Aug.21 –Sep.21: BVLOS flights in the south of Beligum
   xxiii. Sept.21 –Oct.21: Analysis of the picture and back-testing of the model
6. *WP 6 Detailed inspection of minimum 10 towers*
   xxiv. Jan.21 – Mar.21: preparation of the flight: preparation of key assumptions, identifications of on boarded technologies
   xxv. Apr.21 –Jul.21: potential additional contracting with new partners
   xxvi. Jul.21 –Sep.21: Test flight in the identified areas including benchmark (e.g. foot patrol or helicopter images)
   xxvii. Nov.21 – Nov.21: Analysis of the results
   xxviii. Dec.21-Jan 22: Conclusion, identification of complementary tests
7. *WP 7 Exploratory POC: BVLOS flights and data capturing for Post OHL Incident Verification*
   xxix. Jan.22 – Mar.22: Scoping demonstrator including incident scenarios that can be tested
   xxx. Apr.22-Sept. 22: Preparation of the flights, permits and technology around demonstrator
   xxxi. Sept. 22 – Jan 23: Integrate demonstrator with other use cases & technologies that will be tested around incident management analysis and verifications
   xxxii. 2023 – Test and demonstrate

New WP7: In the future, we envision to use BVLOS drones beyond the automation of inspection, towards incident verification. This work package aims in general to increase grid awareness, and in specific, to develop the ability to understand and verify grid incidents once they have occurred on an OHL. In the future, extreme weather events are going to happen more frequently, which would require us to build a resilient approach on quickly reacting and preparing for such unexpected extreme events. This will have a direct impact on the energy supplied (the quicker we can react to an incident the quicker we can re-energize the line and minimize losses).

- Deliverables & milestones
  1. Nov. 19: SAFIR project finalized
  2. Aug. 20: AI solution for image recognition developed
  3. Aug. 20: BVLOS permission for 3 different corridors received (if not possible in Belgium due to delay in the change of regulation, use of German testbed where regulation is more flexible for delivering corridor authorization)
  4. Dec. 20: First technical tests are finalized
  5. Dec. 20: Conclusions of operational tests for drones flight
  6. Jul.21: Test case definition for detailed inspection (e.g. thermography, hyperspectral camera…)
  7. Jul. 21: BVLOS flight permission for the south of Belgium obtained
  8. Aug.21: BVLOS flights in south of Belgium (long distance +120km, Lidar Lascar scans for vegetation management.
  9. Oct.21: Results of inspection and business case
  10. Feb.22: Recommendations for the business and communication
  11. 2022 –2023: Conceptualize, scope & deliver WP 7 around Incident Management

Achievements 2021:

- **Permissions**: In July 2021, we have obtained the official permission from the aviation authority to perform BVLOS flights with a heavy autonomous helicopter drone in designated elia corridors in the south of Belgium
- **Flights**: in August 2021, we have performed the first official autonomous long distance BVLOS flight with a heavy helicopter drone in Belgium
- **Output**: The objective of the flights were to test the competitiveness of autonomous drones against helicopters to perform powerline inspection. To test the competitiveness, the work packages entailed long distance performance, creation of 3D models with LIDAR laser scans for vegetation management, detailed inspections with high resolution cameras forthe detection of damages, cost and efficiency
- **Results**: Currently, the results are being analyses and further tests are required to validate the security of technology as well further use-cases to test the possibility of using drones for incident management to reduce the downtime of powerlines. Prelimanary results entail a competitiveness to cover a long range of powerline inspection (achieved +120km in under 2 hours),
- **Benefits**
- We have performed the first official autonomous BVLOS flight in Belgium with a heavy helicopter drone
- The drone proved its competitiveness to helicopter inspection by flying a distance of over 120km in less than two hours, a higher resolution output for detailed inspection, and an estimated cost saving of over 600k per year which would allow more frequent visual inspections.
- **Next steps**

Partners

- Flight demonstration:, Elia has partnered several public and private organizations .
- Neural network development: For the development of the algorithm Elia has partnered with external suppliers while we plan to exchange also data with other European TSO's
- BVLOS test: The BVLOS flight will be managed with partners that were selected in the context of a tendering process in the summer of 2020
- Internally, the transformation team from the asset management department will partner with innovation to follow the test of BVLOS drones including the comparison with the currently VLOS drones solutions

Summary of project efforts in person months (by work package and by year)

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Project 10: Blockchain to facilitate investment in decentralized Flexibility

Domain 1.2

2021 decision: Accepted

Trends: Digital revolution, decentralized generation and new players, supranational coordination

Consequences: New decentralized flexibility resources, interface with new players

Challenge: 1. Increase participation of flexibility sources from decentralized sources coming from electrification

Domain: 1.2 Apply scalable process for authentication of devices and activation

Project-specific context

- The coming decades will see a huge increase in behind-the-meter installed capacities connected to the internet and investments in decentralized energy resources. With the battery prices decreasing, not only home storage installations are expected to increase, but also electric vehicles (EVs). By 2030, it is anticipated that there will be 33 millions of EVs on Europe's roads. In parallel, as energy system is starting to digitalize various services for customers using artificial intelligence and mass data analytics will be developed, meaning that easy access to such data will be required.
- As presented in section 3.1, over the next 10 years, it will be vital for Elia to draw on the potential provided by decentralized flexibility (heat-pumps, batteries, EVs, etc.) to balance the grid and ensure its security, given that such resources will need to account for at least 5 GW of balancing power by 2030. This will be largely because of the absolute increase in errors in intraday/day-ahead generation forecasts due to renewables.
- However, if we continue operating the system as we do today, this would mean that asset and customer information would be fragmented across multiple siloed systems, often remaining invisible to grid operators and therefore unable to reveal its full potential. Above all, the separated management of the data will make transparency and trust very difficult to verify.
- In parallel, the process of introducing new flexibility to the ancillary services market is not currently scalable because of the many bilateral interactions it involves (verification of the status, installation of a meter, pre-qualification tests, etc.) which will results in a highly costly process if no change is applied to the current practice.
- As we will be shifting from a portfolio of dozens of flexibility resources to one of hundreds of thousands of such resources (albeit small), Elia must provide a scalable secure way to qualify decentralized assets and to ensure/verify the activation of these assets delivery monitoring), given that introducing flexibility in a conventional way would drastically increase OPEX costs and kill any business case for decentralized flexibility.
- The aggregation will of course happen at market level but as adequacy and the grid balance are a TSO responsibility, Elia needs to guarantee that at any time the required flexibility (whether aggregated or not) will actually be available and if not, Elia needs to quantify the lack of availability so that penalties can be applied accordingly.
- Therefore, Elia is looking into how to create trusted decentralized digital identities on the basis of self-sovereign identifiers for the decentralized assets that could then be used to authenticate any resource and validate the relevant activation (delivery monitoring) and potentially even payment. The status of each identity could be shared with other system operators to optimize the use of decentralized flexibility and provide access to the devices to multiple services (if the user agrees): balancing, market arbitrage, DSO congestion, P2P trading, proof of origin and use, etc.
- The technology comes with another promising benefit, in that it gives full control of the device to its owner who can easily give any service provider his or her consent without losing control of his/her data.
- As the blockchain is, by design, decentralized and trusted/ secured, Elia is looking into how this technology could facilitate the creation of a digital identity for the ancillary services market that could interface with the TSO system and could also be used for other market purposes.
- The project will also assess the feasibility of implementation, interfacing with legacy systems and the level of trust in blockchain technology for the primary and secondary reserve market (to be confirmed).

- As, in the future, electric vehicles could become a major source of flexibility, accounting for several GW if we consider the whole fleet of connected cars (in one-way charging 2 ways, charging-discharging, i.e. V2G), Elia has decided to apply its first test to e-mobility.
- In an initial phase, the goal of the project will be to test (including hardware components), if possible, the introduction of EVs onto the ancillary services market. After that, we could also consider the rest of the value chain of flexibility management: activation, validation, settlement, and payment. As presented in project 18, this use case could also be used as a testbed for Gaia-X the European cloud. More detailed about this initiatives are presented in project 18.
- **Update 2021**: As a result of this project Elia is looking at decentralized identification in combination with secure data vaults for citizens as well (see Project 16). The project benefits from the learnings about DID and includes the concept of personal online data stores (PODS).

Project-specific state of the art/literature review

- Elia contacted the Energy Web Foundation (EWF) as a strategical partner and had discussions with various players active in the blockchain ecosystem having experience of running proofs of concept on decentralized flexibility in the past two years:
  1. Austrian Power Grid (APG) is collaborating with the Energy Web Foundation with a view to connecting 1 million decentralized energy devices to a flexibility market based on the decentralized identifier (DID) concept.
  2. EnBW, a German energy supplier, developed a white paper describing a blockchain-based authority model to introduce decentralized energy resources (DER).
  3. TenneT already runs projects with Sonnen batteries to use the devices for balancing purposes and congestion management. Moreover, together with Vandebron, they connected electric vehicles to the balancing market.
- The aforementioned TenneT initiative gave birth to Equigy, which aims to provide a cross-TSO platform to manage flexibility. It mentions the use of blockchain technology to log energy transactions, but no information has been found regarding the specific application (which data and when). Also, the concept is based on a private blockchain closed to the consortium of TSOs while the current project is targeting the use of a public/semi-public blockchain that is also open to other market players such as DSOs.
- Alongside this, all larger vehicle manufacturers are discussing and testing DID solutions for autonomous driving. Bosch and Daimler Trucks are already implementing blockchain wallets in cars and trucks and is testing the solution with a view to using it to pay for parking services, etc. Daimler Mobility set up a Mobility as a Service platform that uses trust through DID to offer a seamless mobility experience and customer-friendly payment services.
- Therefore, Elia is aiming to test the application of DID for pre-qualification as well as for delivery monitoring. This can be seen as an initial step in the process of giving the power sector access to energy IoT devices with DID.

Expected impact for Belgium

- Assuming that the use of a trusted decentralized ledger could accelerate the registration of new flexibility resources and the pre-qualification test from 2.5 days in total (registration, consent mechanism and pre-qualification test) to 0.5 days and that in the future we will have millions of decentralized flexibility means active each day, the use of a blockchain-based solution to onboard DER means, monitor the delivery (or to give a tamper proof record) could avoid an increase in back office of 20-30 additional resources internally (purely theoretical calculation).
- In the future, the use of a blockchain-based DID could facilitate the convergence of different sectors by linking the energy-market identity to other identities (mobility, consumer, industry, etc.) and vice versa that could then facilitate new optimization based on better exchanges of data and greater insights.
- The blockchain-based solution could also facilitate exchanges between the market players and create transparency regarding the cross-cutting use of flexibility.

Starting point for Elia

- In 2019, Elia concluded an initial proof of concept with *confidential* regarding the development of a flexibility exchange platform using blockchain technology. This project showed that blockchain technology could easily be used to store trusted data in a shared ledger and quickly create a common platform for the use of flexibility. The whole project was carried out in a closed environment without direct interfacing with flexibility, the related hardware, or the Elia's

legacy system. That's why these proof of concept still left many hypothesis to verify, especially when it comes to the implementation of digital identity or the physical integration.
- For this reason, the goal of the project here will be to gain more understanding of the application by integrating directly with flexibility resources and delivery monitoring and prepare the concept of pre-qualification tests.
- Several companies are showing interest in participating to the PoC which is a clear indication that the topic is of high relevance.

Uncertainties and risks

- The main risk is the interfacing between the blockchain technology, the connected hardware, and the TSO legacy system which is highly complex to handle.
- Another uncertainty relates to the performance and the cost of the transaction for each item of data stored on the blockchain. Linked to this is also the issue of the type of data stored on the blockchain as du to the immutability and cost of storage, only relevant data will be stored on the blockchain.
- Another assumption to be validated concerns the immutability of data on the blockchain.
- The highest learnings would be achieved with the participation of car manufacturers or suppliers of automotive technologies. At this point in time collaborations are discussed but no contracts signed. Alternatively, the PoC can be done software based (simulations) or with microcomputers simulating real devices.
- The most important lessons would be learned if automobile manufacturers or suppliers of automotive technologies were to participate.
- The input from car manufacturers also serves as a reality check. Since OEM are naturally trying to keep identities internally and are careful with regards to decentralized systems. The concept might need to adapt in order to test and validate a relevant solution.
- Finally, as data will be immutably stored on the blockchain, the question of GDPR compliancy needs also to be validated/ assessed.

Project description

- The project focuses on how Elia can access decentralized energy resources and verify the delivery flexibility from these new flexibility means. In this case EVs have a very important potential, for ancillary services for which digital identities will facilitate their introduction (identification, pre-qualification) and verification of delivery.
- Elia aims to answer the technical and market questions related to the use of digital identity, embedded in a blockchain, for introducing decentralized flexibility and delivery monitoring:
  On the technology side:
    - First of all, there is the compatibility of authentication options with the high security standards of market communication processes. This includes elliptical curve encryption standards and also the protection of personal data.
    - The latter is linked to the challenge of having a transparent decentralized system based on blockchain technology on the one hand and GDPR requirements under which personal data must be protected on the other hand.
    - An efficient identity management system is required to connect entities and verify information. Information such as technical skills, capabilities, and ownership information (DID document) need to be vetted to make reliable statements about the asset behind the digital identity. At the end, such a solution needs to prove its worth compared to centralized solutions in terms of availability and reliability. At the same time DID owners needs to be protected. With technologies such as zero knowledge proof, DID owners do not have to expose all private data to service providers who at the same time have sufficient trust to offer services.
    - Various technical solutions to build DID are available. The goal is to increase understanding of these options and their applicability.

- For authentication, the following options (for each option potential partners are identified) will be considered in the project:
  - Cryptographic chips (firmly integrated and with built-in wallets - *confidential*) ;
  - Cryptographic SIM cards that are integrated into cars (e.g. provided by Vodafone and being incorporated into the Energy Web Foundation network);
  - Physically unclonable functions (PUFs) or unique fingerprinting solutions provided by microchips hold out the prospect of software-based identification without the need for any hardware to be involved;
  - Authority models in which OEMs authenticate their cars by means of a hierarchical validation process based on smart contracts (developed by EnBW). This solution could be combined with PUFs.
  - **Update 2021**: Due to a lack of in-built cryptographic elements in vehicles or charging stations focus was set on the software architecture. PUFs are not considered anymore but in-built wallets from *confidential* are still under investigation.

- On the market side:
  - The project aims to validate the scalability of pre-qualification at manufacturer level with an embedded digital identity at vehicle level.
  - It also analyzes the prequalification process at Elia and assesses efficiency gains by digitizing the process. Even new ways of PQ might be discovered. Today's processes are optimized for larger power plants which does not mean that these processes should be applied 1:1 to more decentralized devices.
  - The initial proof of concept already showed that 80% of the steps involved in changing suppliers can be skipped thanks to the use of blockchain technology to forge decentralized trust via DID. What is special about electric vehicles is that their location changes and with it, the balancing responsible party (BRP). Current market processes do not provide an off-the-shelf solution for this 'roaming' issue.
  - Proof of delivery becomes crucial if small flexibility devices reach larger shares. Automated processes with verification on a blockchain promise trust and scalability.
  - This is a first step in integrating devices with DID into the power system. Use cases can be expanded to cover congestion management ('redispatching'), adequacy planning, e-roaming, wholesale market trading, etc.

- Approach: Elia will team up with the Energy Web Foundation to develop the blockchain application and aims at winning partners such as manufacturers, technology providers (crypto-chip provider, mobility service provider, etc.), or other market players (CPO, MSP, suppliers, TSOs, DSOs, etc.) to develop an end-to-end delivery monitoring and pre-qualification process using blockchain technology.

Update 2021: *Since the start of the project many new possibilities to use this technology have popped up. The potential of decentralized identification is still enormous and will be applied in what we call a "Consumer Centricity Moonshot". In this moonshot Elia Group wants to demonstrate the technical capability to electric vehicle charging at any location in Belgium and Germany with home-generated roof-top-PV electricity. This moonshot combines different ongoing initiatives within the Elia Group:*

1. ***Peer-to-peer trading of excess PV energy between customers (see here)***
2. ***Supplier switching processes at public charging stations ("bring your own supplier")***
3. ***Cross-country, granular certificates of origin (green charging)***
4. ***Decentralized Identification of assets***

In order to charge a car at any public charging station with self-generated electricity, specific user information are required. These information contain:

a. ***The responsible supplier (respectively the service provider that settles with own PV generation)***
b. ***Consent to participate in a supplier switching process***

Both information are ideal use-cases to test the functionality of decentralized identifier. The solution is powerful since it would allow the supplier to directly interact with the vehicle's identity. It can assert a claim to the DID so that third parties can independently verify that the vehicle is covered by this specific supplier. The same is true for the user's consent to participate in that system.

The use-case is reflected in the below described working packages. For all use-cases (balancing power, green charging, supplier switching, smart charging) it is required to allocate the charging process to the portfolio of the BSP/BRP/supplier. Our activities will focus on extracting a charging process which is the basis for all flexibility use-cases. Hence, the scope and goal are still very similar to the initial idea but instead of focusing on balancing power, we pivot towards green charging.

- Work packages and timing (M = month)
  1. *WP 1: Project scoping and selection of partners*
     - i. Feb. – Mar. 2020: Project scoping and strategic alignment; market research, interviews, and exchanges with industrial partners (*confidential*, etc.)
     - ii. Apr. – May 2020: Tendering and selection of a strategic partner
     - iii. Jun. 2020: Mapping of the pre-qualification process (FCR, aFRR, mFRR) and stakeholders
     - iv. Jun. 2020: Project scoping with the strategic partner in the form of a 'kick-off' workshop with the marketing and communication departments
     - v. Jul. 2020: Final project scoping and selection of an industrial partner
  2. *WP 2: Designing of a blockchain-based pre-qualification/delivery monitoring process and development of the blockchain framework*
     - *vi.* Jul. 2020: Designing and modeling of the existing PQ process*/delivery monitoring* (FCR, aFRR/mFRR) to be applied on a blockchain basis. *Update 2021: PQ process successfully implemented and tested, delivery monitoring under development (see WP3)*
     - vii. Jul. 2020: Development of a concept for the blockchain framework by assessing the applicability of existing open source solutions and protocols (i.e. Open Charge network, communication and DID standards, etc.). *Update 2021: all done*
     - viii. Aug. – Oct. 2020: Development of the blockchain framework and definition of DID specifications. Update 2021: all done.
     - ***ix.*** ***Summary 2021:***
       1. *We selected the OpenChargeNetwork as the interface to the mobility sector.*
       2. *We developed a client software that enables the creation of DID for mobility service provider active in the OCN.*
     - x.
  3. *WP 3: Creation of DID and connection of the hardware*
     - xi. Oct. – Dec. 2020: Establishment and testing of the connection of DID embedded in selected hardware solutions. Ideally use cars fitted with wallets to create, adapt, and communicate DID. This will go hand in hand with the testing and selection of communication options (Wi-Fi, 4G, charging pole infrastructure).
     - *xii.* ***Update 2021:*** *Before the integration of hardware wallets, the DID has been implemented as a cloud solution. A decentralized registry has been built based on the open charge network. Moreover, a software has been developed that allows the creation of decentralized identifier for electric vehicles. The registry allows the interaction with the vehicles and charging stations DID. It allows OEMs to add trusted and verifiable technical information to the vehicle DID. These information is used for a pre-qualification claim.*
       1. **July 21:** Implement DID client in vehicle and display DID in EVMI Registry
       2. **August 21:** Onboard charging station with DID into EVMI Registry. Register charging point operator as CPO in Open Charge Network
  4. *WP 4: Test pre-qualification and delivery monitoring*

xiii. Jan. – March 2021: Implementation of a simplified flex activation and a delivery monitoring on blockchain

xiv. Jan. –Mar. 21: Automated registration of devices and PQ tests. On-chain validation of PQ by Elia Group and integration of PQ certificate in the DID document of the device.

xv. ***Update 2021:*** *A simplified PQ process has been implemented. The process covers the request for PQ by OEM as well as the attestation of a PQ into the DID document.*

1. ***June 21:*** *PQ process has been successfully tested on the EVMI Dashboard. Our partner OEM requested a PQ Claim which we can cryptographically sign.*
2. ***September 21:*** *Field test with DID equipped EV and charging station for delivery monitoring. The charging session will be transmitted to the EVMI Dashboard and is available to Elia Group or other authorized players.*

5. WP 5.1: Roadmap towards activation (TBD)

xvi. Mar. – Oct. 2021: Definition of technical requirements of a balancing power activation process in real environment, or more specifically, how devices with DID can bid automatically on the balancing market. Assessment of opportunities for the tokenization of balancing energy and transfer of tokens to the fiat currency. Planning of the roadmap for the first car to autonomously bid and provide balancing power.

xvii. ***Update 2021:***

1. *Balancing power activation and automated bidding has been discarded. The activation itself is not necessarily linked to DID and rather a communication challenge. Instead focus has been set on tracking the origin of electricity for green charging and a supplier switching process as well as settlement options. With a mobility as Service Partner we analyze how a vehicle identity concept and a decentralized contractual framework (based on DID and verifiable credential) can enable an end-to-end transaction process.*
2. *But for all flexibility use-cases (balancing power, green charging, and supplier switching, smart charging) an allocation of the charging process to the portfolio of the BSP/BRP is required. This means that, even though the product changed, the results can be used for balancing power in a later step as well!*

Our activities shifted towards the following milestones:

3. ***December 21:*** *Renewable energy production to proof token-based green charging*
4. ***December 21:*** *First demonstrator of a supplier switching process. The DID is used to provide a proof of the contract between EV driver and supplier. This happens in in form of a verifiable credential. The DID of the charging station contains the metering ID. Both information are today not available to the TSO.*
5. ***December 21:*** *Demonstrate how protocol based mirco-transaction can be used for ex-post financial settlement.*

6. WP 5.2: Settlement (TBD) -> Rename to ***WP 5.2 Demonstrator***

xviii. Aug. 2021 – Jun. 2022: Development and implementation of the roadmap to automate the full balancing power value chain from DID creation until settlement. Assessment of the possible ways to link the cryptocurrency layer to the Elia Group's accounting system.

xix. ***Update 2021:*** *As described above a pivot happened away from balancing power towards the very practical supplier switching use case as part of the moonshot. We will use the elements developed in the WP 1-5.1 and integrate them into full demonstrator. Decentralized technology will be used to reach the following milestones:*

1. ***June – October 22:*** *Integrate the delivery proof as well as the concept of verifiable credentials into a virtual balancing area system required for supplier switching.*

2. ***October – December 22:*** *Enable active steering of a charging session (=flexibility) through Open Charge Network*
3. ***June – December 22****: Allow cross-border trading of tokens that proof green charging and the retirement of tokens against the charging session.*
4. ***June – December 22:*** *Integration of token-based settlement between all involved parties (CPO, eMSP, supplier, trader, etc.)*

Partners

- Two German car manufacturers
- *confidential* .
- 50Hertz (for the test bed and the support), other TSO's as APG, Tennet to share experience
- Development of the blockchain application and Open Charge: EWF
- Development of the hardware: TBD (*confidential*)
- E-mobility specialists: *confidential*
- E-mobility market players: Charging Pole Operators, Mobility Service Providers
- Energy suppliers: TBD depending on the opportunity and the test-bed.
- Elia Customer Relations Department

Summary of project efforts in person months (by work package and by year)

confidential

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Project 11: Robotics for inspection in remote, difficult, or dangerous locations

Domain 3.2

2021 decision: Accepted

Trend: Digital revolution

Consequences: Digital tools and data use, aging of the infrastructure

Challenge: 3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety

Domain: 3.2 Automate inspection onshore and offshore

Project-specific context

The initial need for the use robots at Elia is based on two main challenges related to asset monitoring: inspection automation, and operation in dangerous or remote situation – aspects that are becoming more and more important due to new and more complex systems:

1. Some assets are difficult to physically access assets because of their location in dangerous environments (as HVDC converter station) or involve long and costly trips (offshore).
    a. This applies to remote locations such as an offshore platform, which takes at least 24 hours to reach (including planning), and even longer in bad weather conditions. Moreover, it is very difficult to deal with emergencies in such places because of this **time factor and the cost** of the helicopter. In these situations, robots can be a useful tool to perform a quick assessment and carry out low-level activities.
    b. It also applies to places where it is difficult to move and that are **hostile for humans**. A good example is the ALEGrO cable tunnel where an outage is required for any inspection to be performed due to a lack of oxygen, the absence of lighting, and high voltages. Moreover, installing sensors along the tunnel would be far too expensive.
    c. This is also the case for **places that are dangerous for both humans and equipment**, such as the converter hall of the Nemo interconnector, where nobody can enter when it is in operation due to the strong magnetic field and where conventional cameras do not allow a failure to be detected. Thermo-cameras could perform such detection but would be too expensive to be fitted out throughout the converter hall (around €1 million).
2. We see that on top of hostile environments, the deployment of fixed sensors has its limitations in terms of access to digitalized/connected infrastructure. Here, robots would be an innovative way to transport sensors, responding to these two main issues:
    a. **Lack of flexibility** for remote sensors: In remote locations such as offshore platforms, fixed cameras cannot cover every angle of the whole area and therefore cannot detect every problem. An example is a water leak-age that requires a moving camera to be detected on the ground. Flexibility can also be seen in the possibility of changing the sensor on the robot or upgrading to the most up-to-date technology instead of undertaking a major operation to change all fixed sensors.
    b. High **deployment costs** to cover particular areas: As mentioned before, the number of cameras required to cover a complex environment such as the Nemo Link converter hall (with many large converter modules) is huge and costs about €1 million while a robot costs about €80,000 (cost of the robot only).

Project-specific state of the art/literature review

- Robots on wheels or caterpillars have been in use since 2013, with a first deployment by State Grid of China to automate the inspection round in an onshore substation. Today, in total, more than 20 substations are currently covered and the robots are controlled by a central control room for infrared and visual inspections, replacing foot patrols. They have enabled a 75% decrease in the time required for infrared inspection and a 50% decrease in the operator's workload.

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- TenneT also has also tested an 'animal-shaped' robot in an offshore substation. However, tests are still ongoing and there is still no clear conclusion regarding the potential of such technology. TenneT is now starting a five-year R&D program with a university and a supplier to assess the potential of such technology.
- In other business segments such as offshore oil rigs, use of a robot is becoming more and more common for multiple inspections. For example, Total is currently using its brand-new version of a robot on one of its sites in Scotland.
- Among the different sectors, such as the military sector, have been developing robots since years but focusing largely on hardware. These robots are able to do a lot in harsh environments but are mainly tele operated and not benefiting from autonomous algorithm for industrial environment.
- Research has been conducted mainly into hardware, such as in army applications, and remote control.
- As of 2021 more TSOs are expressing interest in the use or robots, a recent example is the National Grid collaboration with Boston Dynamics and the use of their robot 'spot' in a substation.

Expected impact for Belgium

Robot technology, by addressing the issues mentioned above, can impact the efficiency and quality of maintenance and therefore avoid risks of outages thanks to a more precise and systematic inspection, thereby improving monitoring and operation, but also can affect safety by limiting human exposure to danger.

- Based on a rough estimate, in the context of the ALEGrO project a robot being used to inspect the tunnel could halve the need for a planned outage.
- In the case of Nemo Link, the use of a robot for an inspection in the converter hall could enable early detection of a fault in a power module, reducing the risk of an outage and therefore an imbalance for the grid and the related impact on the short-term market. Based on an assumed risk of default Elia could then in average avoid €20,000-50,000/year.
- The estimate of the impact for inspections in substations could be close to the State Grid of China case (a 75% reduction for thermography) and we could avoid up to 20 trips to the offshore platform per year. However, we first need to better understand what the capability of robots in the Elia onshore and offshore substations would be.

Starting point for Elia

- Elia has no experience with robots.

Uncertainties and risks

- The main uncertainty surrounds not the robot itself since, as we mentioned before, the hardware is already developed and tested in the military sector for example, but rather the ability to perform tasks specific to Elia's core business. The main risk is then related to the robots' adaptation to our environment (e.g. substations onshore and offshore, air or gas insulated…).
- In the case of robots in substations, the primary uncertainty is that the robot can actually perform normal tasks required for inspections, ranging from opening 30-kg doors to climbing stairs in a substation or reading the various meters required. This relates to both hardware and software development capabilities.
- The software aspect is shrouded in great uncertainty because it requires specific development for our core business, while the hardware is challenged by many other sectors.
- In the case of the use of robots in the Nemo converter hall, a major risk is that robots will also operate in an environment with a strong magnetic field. Another resulting risk of this use case is that the manufacturer does not accept the presence of robots in such an environment without affecting the terms of its guarantees. Finally, another risk could be that robots can also damage equipment by triggering electrical arcs or in case of lack of control and damaging the infrastructure
- Finally, in all these cases an additional uncertainty is that in every situation, high-quality and stable communication must be maintained between robots and the control room, as must the battery range for the various robots.

Project description

- The project covers the three use cases mentioned above:
    - ALEGrO tunnel: tailoring the development of robots on wheels to perform remote inspections of corrosion and water leakage and check cable fixtures after a short-circuit;

- Nemo converter hall: testing robots so that they can perform inspections regarding heat and leakages alongside general continuous inspections;
- Onshore/offshore substations: testing of robots on wheels / caterpillar for basic inspection work and thermography.

For the first two cases, the goal is to select a supplier and develop solutions tailored to the situation and then perform testing in real-life conditions to validate the capacity of the robots.
For the last case, the initial goal is to understand the capabilities of the robots in a substation environment that might be followed by specific use cases.

- Approach: For each of these use cases, we will team up with an external provider to test existing robots and in some cases develop specific features. In the case of the Nemo converter hall, we have envisioned to partner with a laboratory for resistance to the strong magnetic field.

- Work packages and timing (M = month)
  1. *WP 1: Exploratory work*
     - xx. Feb. 2018 – Feb. 2019: Research study and contact with market players
     - xxi. Feb. – Mar. 2019: Identification of use cases
     - xxii. Jun. – Sep. 2019: RFP for the most challenging use cases in order to select suppliers with the most appropriate capabilities
  2. *WP 2: Robots for tunnel inspection*
     - xxiii. Oct. 2019: Roundtable with the TSOs owning the ALEGrO tunnel and shortlisted suppliers with an off-site demonstration
     - xxiv. Nov. 2019: Selection of final suppliers
     - xxv. Jul.– Sep. 2020: On-site demonstration
     - xxvi. Jul. – Oct. 2020: Performance of EMC laboratory tests
     - xxvii. Nov. 2020: Final selection
     - xxviii. Jan. – Feb. 2021: Robot development and adaptation through iterative steps

Update 2021: Following the tests in late 2020, no further decision has been taken to progress with the tunnel inspection use case in 2021 because the efficiency gain is finally limited and the use cases are very different from each other needing a lot or tailoring which makes the business case difficult.

  3. *WP 3: Robots for converter hall inspection*
     - xxix. Sep. – Nov. 2019: Study of the problem
     - xxx. Nov. 2019 – Feb. 2020: Supplier identification
     - xxxi. Jun. – Nov. 2020: EMC study and laboratory tests
     - xxxii. Nov. 2020 – Feb. 2021: Robot R&D
     - xxxiii. Mar. – Apr. 2021: Similar environment tests
     - xxxiv. May 2021: Decision on implementation

Update 2021: *The use case around the Robot for Converter Hall inspection has been developed in detailed as per identified steps in WP 3. The supplier identification, selection & testing (laboratory and HVDC Conv Hall visit) have been completed between Q4 2020 – Q1 2021 in different stages with different suppliers. Additional external partners have been onboarded into this research project which share the same interest to use the robot in the HVDC Conv Hall. In May 2021 the green light was given by Elia Steering Committee to enter in the R&D development of the Robot which upon successful contractual signing will be kicked off in beginning of Q3 2021 and has the following delivery plan:*

- Stage 1: Project Kick Off - July – August 21
- R&D 1: Base platfrom build & test cycles - Sept 21 – Feb 22
- R&D 2: Sensor build & test cycles - March 22 – June 22
- Build Implementation - Production build&test cycles – July 22 – Dec 22

- 'Deploy' - Deploy & UAT (1x platform) - Jan 23
- Scale up - Supply & deploy - Feb – Jul 23

WP 4: Robots for substation inspection

xxxv. Nov. 2019: Identification of scenarios
xxxvi. Mar. 2020: Roundtable with other TSOs that worked with unmanned ground vehicles (UGVs)
xxxvii. Jun. 2020: Online assessment of remote capabilities
xxxviii. Jul. 2020: Scenario filtering 1
xxxix. Sep. 2020: Off-site visit and first high-level use cases involving testing on current supplier work sites (Total)
xl. Oct. 2020: Scenario filtering 2
xli. Nov. 2020: On-site test: AIS/GIS training
xlii. Dec. 2020: Scenario filtering 3: Selection of use and offshore adaptation study
xliii. Jan. 2021: Same procedure for offshore

Update 2021: Review of scenarios for onshore/offshore substation is being done again in 2021 as new features are being installed into robot technologies which will make this specific use case more attractive, if successful. An on-site demo planned for August 2021 with Boston Dynamic is going to establish whether this work package can be progressed further.

Partners

- Supplier for the Nemo converter hall: *confidential* (TBD)

Update 2021: *The use case around the converter hall (Nemolink + ALEGrO) partnership has extended to further external & internal Elia Group companies which are joining us in the development of the robot:* *confidential* *, NemoLink, 50Hertz. The supplier chosen is* *confidential*. *(*confidential* *were the three ones which were identified & analyzed)*

Summary of project efforts in person months (by work package and by year)

confidential

Project 12: New Steel

Domain 4.3

NEW PROJECT:

Trend: Decarbonization

Consequences: Develop infrastructure to flow important RES infeed

Challenge: 4. Optimize the development, the construction and maximize the use of new and existing infrastructure

Domain: 4.3 Advanced material and connected technology to maximize use for infrastructure

Project Specific Context

By 2030, the transmission capacity of the Belgian high voltage grid is set to double due to the massive introduction of renewable energies on the network. Faced with this transmission capacity, the current network is obsolete and must therefore be significantly reinforced. To address this issue, and thanks to the combination of analytical, numerical and experimental approaches, the present project aims to demonstrate the interest of S460 steel for the rapid and agile reinforcement of existing tower structures and thus guarantee the reliability of the network.

1) Position of the project in the context of the energy transition
   a) Europe has committed to a decarbonization of society to 55% by 2030 and to more than 80% by 2050 through the massive integration of renewable energy sources. These climate objectives require a profound transformation of the European energy system focusing on improving energy efficiency, electrifying key sectors (transport and heating) and decarbonizing the electricity system as much as possible.
   b) On the one hand, the increased electricity production combined with the increase in electricity consumption and the bi-directional nature of electricity requires more electricity transmission capacity; on the other hand, the decrease in conventional energy sources (nuclear, fossil) in favor of renewable energies is leading to the decentralization of the energy system, relocating electricity production from the major consumption centers to regions that were previously marginally connected to the networks. This decentralization results in electricity being delivered to consumers over longer distances within the country, but also in an increase in international electricity flows (incoming and outgoing) requiring additional interconnections to ensure greater availability of the renewable part of the electricity mix.
   c) The reinforcement and restructuring of the Belgian electricity network are two key elements to meet the electricity transmission capacities of the future, to ensure network connections with new production sites and to develop new interconnections with neighboring networks. The development of a robust grid, allowing continuous access to sustainable, reliable and affordable electricity for everyone, is an essential condition for the success of the Belgian energy transition.

2) Underlying problem and objective of the research
   a) Built between 1969 and 1982, the backbone of the Belgian high-voltage network (380 kV) has undergone very little changes because of a very efficient use of existing installations. The replacement of conductors with higher capacity conductors or high performance conductors and the pulling of additional circuits have so far made it possible to increase the transmission capacity of the network sufficiently by structurally reinforcing existing towers, as far as the structural stability of these towers allows.
   b) In order to meet the challenges of the energy transition, the transmission capacity of high voltage lines must be doubled in the next ten years. To achieve this, the traditional doubled 621 mm² conductors on the backbone grid must be replaced by four 707 mm² conventional conductors or two 1000 mm² high performance (HTLS). These changes in the number and/or cross-section of conductors have a direct impact on the structural stability of towers. Designed to support a maximum weighted load of 100 T (OM34 type tower) in 1970, the towers must now be able to support loads of at least 180 T for an identical tower and up to 1200 or even 1400 T for exceptional towers, this due an accumulation of the following load increasing requests:

(1) The applied load by the connected conductors is raising with the increase of the conductor sections, being from 2 x 621 = 1242 mm² towards 4 x 707 = 2.828 mm² or 2 x 1000 = 2000 mm²
(2) The climate change has resulted in a normalization that prescribes > 20% higher wind loads then in 1970.
(3) The normalization is requesting on top of point (2) that the wind condition that needs to be used for design is changed from 50years in 1970 to 500 years presently for 380 kV lines
(4) Due to the very high density of buildings in Belgium, new lines or new towers need to be designed up to 20 m higher than in 1970 in order to realize sufficient safety clearance.

c) . These loads significantly exceed the acceptable load limit for existing towers and therefore impact their structural stability.
d) Currently, all high voltage lattice towers make use of S355 steel. S355 steel was introduced in towers in the early 1960s and is still used in new towers today; this means that the design of the majority of towers is based on a steel quality that is more than 40 years old, a quality that is no longer sufficient to meet the new structural performance requirements in the tangible context of the energy transition.
e) Although new and better performing steels have been developed, the lack of evolution concerning their use in electrical pylons is due to the slow evolution of the extremely strict normative context to which the dimensioning, fabrication and production of steel structures (Eurocode 3) and in particular steel structures for overhead electrical lines (EN50341) are subject. This slow evolution of the standards does not follow the rapid evolution of the means of production of high performance steels in the steel industry and therefore does not allow them to be up to date and to cover the dimensioning of structures made with these new high performance steels.
f) Among the high-performance steel grades, S460 stands out with a yield strength up to 30% higher than S355. Due to its higher yield strength and for exactly the same structure and tower geometry, an S460 tower could support loads 20 to 30% higher than those supported by an S355 tower. Moreover, for an equivalent supported load, the weight of an S460 tower could be reduced by 20% compared to its S355 counterpart by optimizing the section of the profiles, leading to lighter structures.
g) Developing new grid infrastructure takes an average of 10 years, while building a renewable energy generation facility takes between 3 and 5 years. By simply substituting S460 angles for S355 angles, the load-bearing capacity of existing structures could be increased quickly without extensive studies for new tower design (± 6 months). The tower could by this means be upgraded with a perfectly identical structure without any visual impact, which has a major positive impact on the environmental and public impact studies.
h) Therefore, the S460 appears to be a promising candidate for the sustainable strengthening of existing towers and for the design of new structures that will contribute to the successful energy transition of the grid.

Project specific State-of-the-art/Literature study

Elia already possesses a large in-house experience in the design of lattice towers. This project continues onward from the European ANGELHY project where in this case a development of the design rules is in the scope of the S460 project. The European ANGELHY project has proven the potential of steel angles is S460 for lattices structures. The potential being demonstrated and documented for some specifically tower design, this new steel is presently still missing design rules in order that this steel could be applied in other more general lattice towers

The implication of Elia experts is requested in order guided the design rules to be developed in to compliance with the existing norms EN50341 for lower grade steels.

Expected impact for Belgium

As mentioned above, this project was launched in order to address the issue of the increasing introduction of renewable energies on the Belgian high voltage grid. The completion of this project will ensure that the further decarbonization and electrification of society and the reinforcement of the obsolete backbone grid can be met in an agile way. The project has several specific economic, social and environmental effects for Belgium:

- New alternative solution for tower upgrades where assemblies become limiting design factors
- A significant time saving in the design of the pylons (up to 200 resource hours per standard tower type), which results in a definite economic benefit and agility, on the one hand, and which has a positive impact on society, on the other.

The actual benefit is the avoidance of delay in infrastructure implementation, that would in turn cause delay in connecting new RES and a delay in reaching national and EU climate goals.

- Positive impact on the speed of reinforcement of the electricity grid and the interconnections required for the massive integration of electricity from renewable energy sources by 2030, due in particular to the gradual withdrawal of nuclear power.
- Technology to realize the request of Port of Antwerp on time (-2 years) and with less study cost (-500 hours study cost).
- Slimmer towers compared to S355J2 steel towers, which results in an improved acceptability for local communities.
- Simpler designing details which allow for simpler (more classic) production methods and hence less production costs The **ANGELHY** project has proven there will be an economic benefit but the present study is needed to evaluate the gain.

Starting point Elia

The knowledge from the existing design and the results from the European ANGELHY project form the base of the starting point for Elia. The ANGELHY project was led by ULiège, which acts as a technical partner in this project. From this information, Elia, ULiège *confidential* will continue to study and test the effects of higher grade steel (S460) within lattice structures.

Uncertainties & risks

Within the project there are some inherent risks, which will need to be further mitigated:

- COVID-related timing extensions: open issue.
- Unexpected failure modes: unlikely, as manufacturer within the workgroup can adapt specifications if needed.
- Quality issue on bolt deliveries: mitigated by use of standardized DIN7990 bolts.
- Normalization and ratification issue: mitigated by the presence of ULiège, the Belgian representative in the Eurocodes normalization, in this project.

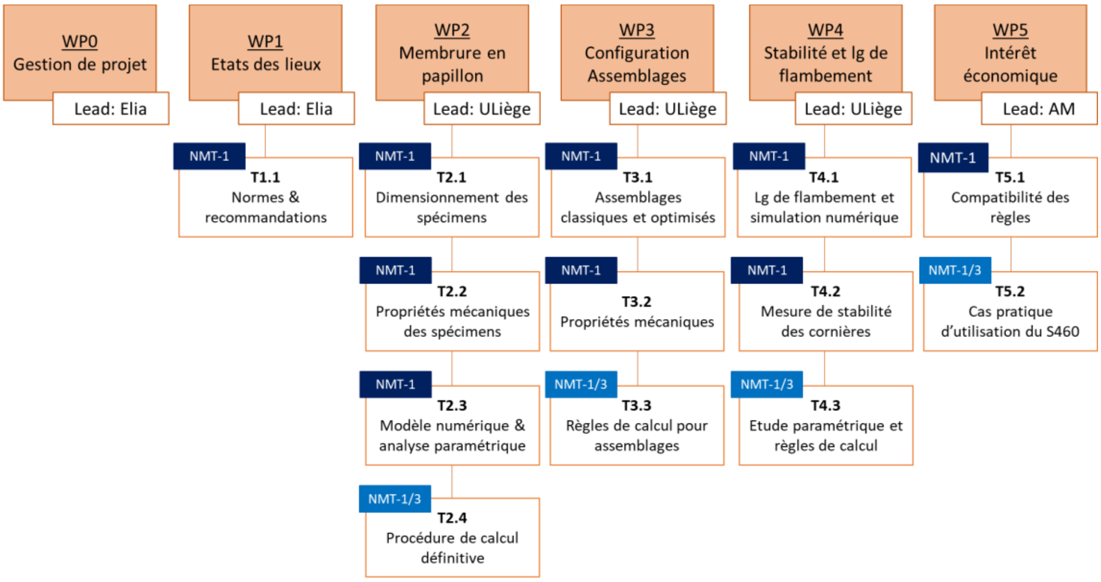
Project description

In the context of the reinforcement and restructuring of the grid for the ongoing energy transition, it is becoming urgent (i) to investigate in depth the mechanical properties of S460 steel profiles and their connections as structural elements of electrical pylons, (ii) to derive calculation rules for S460 profiles and their connections and (iii) to establish the manufacturing tolerances and the relative product standards. To achieve this, the present project brings together the steel industry ***confidential***), the university (ULiège), the tower designers and the network operator (Elia), all players in the chain, with a common objective: to complement and broaden the normative framework regulating overhead power lines in order to integrate S460 steel as a structural material in the most rigorous and precise way possible, thus allowing the rapid and proactive development of a robust power network, achieved in time for the benefit of the community.
The normalisation and ratification should not be an issue because the project partners (Arcelor Mittal and Uliège) are members of the normalization committee issuing the new normalization. Therefore, we estimate the risk of non-normalization non existing.

Updating the normative framework to include the use of S460 steel in high voltage electrical towers requires the completion of several intermediate technical and scientific objectives:

- WP 1 – Current state from a technical perspective
    - T 1.1 – Existing norms and recommendations
- WP 2 – Butterfly frames with 2 angles L250x250x29 mm in S460
    - T 2.1 – Dimensioning of test specimens based on ANGELHY calculation rules
    - T 2.2 – Measurement of mechanical properties of specimens
    - T 2.3 – Numerical model, parametric analysis and comparison with standards
    - T 2.4 – Final calculation procedure for butterfly frames
- WP 3 – Study of lattice assemblies in S460
    - T 3.1 – Classis assemblies and optimized assemblies
    - T 3.2 – Measurement of mechanical properties of assemblies

  - T 3.3 – Development of calculation rules for angle assemblies
- WP 4 – Stability of angles and buckling lengths
  - T 4.1 – Buckling length: Critical analysis of EN-50341 & numerical simulation
  - T 4.2 – Stability measurement of S460 angles at assemblies on extremities
  - T 4.3 – Parametric study, calculation rules, and buckling lengths of S460 angles at assemblies on extremities
- WP 5 – Economic interest of S460 in the industrial context
  - T 5.1 – Compatibility of use of the rules in the European normative context
  - T 5.2 – Use of the S460 in real life situations, economic interest & recommendations



Partners

- Elia (Technical lead: ir. *confidential*)
- ULiège (Technical lead: prof. dr. ir. *confidential* & prof. dr. ir. *confidential*)
- *confidential* l (Technical lead: dr. ir. *confidential*)

Summary of project efforts in person months: per work package and per year

The estimates below may change following the reception of the final offer from the external partners in early Q4 2021.

confidential

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Project 13: Training and collaboration in virtual and mixed reality

Domain 3.4

2021 decision: Accepted

Trend: Digital revolution

Consequences: Digital tools and data use

Challenge: 3. Automate asset inspection and make maintenance more flexible to cope with planning changes, keeping high level of safety

Domain: 3.4 Secure and connected Workforce

Project-specific context

- The user experience offered by mixed reality (where a virtual element can be visualized and interact with the existing environment) and virtual reality (when the user is immersed in a completely virtual environment) is improving at breakneck speed. In recent years, multiple breakthroughs have made these technologies viable and useful in business environments. In many cases, they can help our workforce to improve workflows, operate more safely, and collaborate more effectively.
- For a few years now, at Elia we have been investigating the use of virtual and mixed reality in multiple aspects of our day-to-day tasks. However, previous iterations of the technology were not user friendly and involved a complex configuration procedure, cumbersome hardware, and low image quality. The quality of the hardware and software available at the time meant they could not be used in a production environment.
- With the recent development and the affordability of the technology with new hardware solutions like the Hololens 2 and the Oculus Quest, all these issues disappeared. They are now portable and much easier to use and do not require a specific room or separate computer to be set up for them to work. They can work anywhere and anytime, and they can be set up in less than a minute. These new headsets are also much lighter and more comfortable to wear. All these improvements make them the perfect tool to achieve what the previous generation of hardware could not.
- Therefore, the mixed reality can be used for better collaboration and understanding of the existing environment (i.e. to communicate more efficiently in real time with experts in remote locations during an inspection), and virtual reality could be notably used to immerse Elia operators in dangerous conditions for training purposes (e.g. a strong magnetic field in the converter hall of an HVDC interconnector, offshore platforms, etc.).

Project-specific state of the art/literature review

- Some companies in various industries are already testing the technologies for manufacturing purposes, e.g. Sidel, Tetra Pak, PSA/VW/Renault.

- In late 2018, RTE tested virtual reality as a training tool, but no information is available regarding its use for offshore activities or climbing transmission towers.

Expected impact for Belgium

- Limitation of the number of FTEs needed in organizing training (estimated reduction impact at *confidential*)
- Reduction in maintenance costs:
  - reduction in experts' trips offshore (cost: a single trip for an expert to the offshore station cost at minimum 4.5k€ for one day and produce about one ton of CO_2, with the help of this project we reduce the cost to 70€/h and less than 0.5 kg of CO_2 produced on previous maintenance);
  - reduction in team numbers and increase in efficiency onshore (quantification to be confirmed at a later stage of the project)

- Decrease in commuting costs with helicopter and boat which Elia evaluate at 45K EUR/year in human resource cost (opportunity cost) + cost of the transport mode.

Starting point for Elia

- Elia already has prior experience of this technology. Two years ago, the SARQA VR project replicated a substation in virtual reality to enable visualization of hazardous high-voltage areas and interactions with various items (a construction truck, a ladder, etc.). This project taught us that the technology was not yet ready for day-to-day use at Elia and should be re-evaluated at a later date.
- We also held various workshop sessions involving external companies and various Elia departments to brainstorm on potential use cases and assess the level of interest and among end users. The result is the use case described in this document: collaboration and training
- The available technology, hardware and software are currently being evaluated.

Uncertainties and risks

- The technology is fairly new and changing rapidly; we are confident that it is now mature enough to form the basis for this project, but it has not been widely tested in a production environment.
- As the technology is new, end users' reaction to it and their take-up may vary. Recent breakthroughs have made the technology much easier and more comfortable to use but end users' perception of it may be affected by a previous impression that it was chunky and cumbersome to use. It will be a challenge to get end users to adopt the use cases without trying the technology themselves. Therefore, promoting and communicating about it will be major priorities.
- We will have to emphasize the quality of our 3D visualization and user experience to optimize user take-up.
- The Pandemic of 2020 has had a huge impact, both positive and negative, on this project. On one hand: many face to face tests and meetings were impossible but on the other, it highlighted the importance of remote collaboration.

Project description

We have identified three areas where virtual and mixed reality could really bring a value. However, all of these share an initial technological exploration phase.

- Work packages and timing (M = month)

- WP 1: Technological exploration
  - Mar. – Jun. 2020: During this first phase we will meet existing suppliers and obtain test hardware and software licenses and evaluate them for the next phase.
  - May – Jul 2021: After one year of test of one specific proof of concept solution for collaboration in augmented reality, we will create a tech report analysis comparing different leading solution providers based on a number of KPIs identified by our business.

- WP 2: Training: Improving our workforce's hard and soft skills with the aid of virtual and mixed reality
  - Jun 2020. – Nov. 2021: Climbing Transmission Towers use case (hard skills): Working in a high-voltage environment is dangerous, leaving no margin for error. As a result, it is problematic to train our personnel in real conditions. Providing staff with a simulation and immersion tool so that they can experience these situations in a learning environment where they can make mistakes is a major step forward in terms of the quality of our training courses. Virtual-reality e-learning is an immersive process that is mature enough to be used in the initial projects that are under construction.
  - Sep. 2020 –Sep. 2021: Edison use case (soft skills, centered on Edison, Elia's training substation): Being able to react to a dangerous error made by a co-worker is an important skill within a team. Providing staff with a simulation of work colleagues' actions in a dangerous situation and asking them how to react will help them to prepare for a real-life work situation.

Both use cases offer the same series of advantages. For example, they enhance training, enable repetitive training without the need for a trainer, reduce training time and costs, accelerate changes in behavior, etc.

We are still working actively on both use case and have a dedicated team of developers and 3D designers currently creating the applications. The first test should be available around July 2020 and the Edison use case will be ready for large testing around September.

- WP 3: Sharing in remote location to increase efficiency. This WP consists in improving sharing and collaboration between teams in remote locations. This work package is even more important now following the COVID-19 lockdown. Elia was able to keep all its non-field operations going during lockdown because we have the modern tools to share and communicate information. Improving these tools through more immersion, easier sharing and collaboration between personnel working together remotely is key for the future. Moreover, enabling more remote collaboration will help to reduce our carbon footprint by avoiding unnecessary travelling for meetings. It will also mean that remote support can be provided for both field work and offshore operations.

    - Sep. 2020 – Dec. 2021: Connected Screens in Substations use case: Up to now, most of the information and plans drawn up during work planning in the field are provided on paper. These documents are not always the latest version and cannot be shared for collaborative purposes with members of a team working elsewhere. Installing touchscreens in substations would be a big step in the right direction in this regard.

    - Aug. – Nov. 20210: Virtual Meetings between Sites use case: Elia personnel dedicate a share of their working time traveling to meetings across Belgium as remote meetings are currently not always as efficient as physical meetings. Allowing more interactive and immersive meetings between sites with virtual telepresence and collaborative tools will help reduce the time spent on journeys to and from meetings.

    - Jan. – Dec. 2021: Virtual NCC Control Room use case: Currently, control rooms use a big wall to display a large amount of information. It is impossible for operators to see all of this information remotely as no screen available to the general public is large enough to display all of it. Replicating this information in a virtual control room accessible in virtual or mixed reality would allow control-room operators to take action remotely in case of an emergency on the grid.

- WP 4 Improving maintenance, support, and work planning for our substations and sites:
    - Jun. – Nov. 2021: AR-impetrant use case: During construction work, knowing where to dig to avoid damaging existing infrastructure is vital. For instance, cutting a water or gas pipe could cause catastrophic damage. Most infrastructure can be found on maps but it is sometimes complicated to interpret these in situ. This use case aims to make underground infrastructure visible in workers' field of view because it is much easier to avoid digging up a pipeline if you can see it. (November)
    - Sep. 2020 – Mar. 2021: Remote Support use case: Getting experts from the industry to resolve an issue at remote locations like the offshore platforms in the North Sea is sometimes complicated and takes a lot of organization ahead of time. Experts sometimes need to travel from another country and to have certification to enter a site. Mixed-reality technologies allow a normal field worker at the relevant location to share their ideas and collaborate remotely with an expert in order to carry out required maintenance and repairs on an asset without the need for the expert to be present in person. The use case will involve onshore testing before offshore testing.
    - Feb. – Jun. 2021 (TBD): Closed-Off Planning use case: Elia often has to plan work for restricted areas. Some buildings or tunnels cannot be accessed easily as doing so would involve having to cut off part of the grid or

conducting a lot of preliminary security/safety checks. By replicating the location in a 3D environment and allowing it to be explored and work there to be planned virtually, we aim to greatly facilitate the work of our field operators.

- Approach: Elia will test the sets of hardware and software required for each use case and will work with external suppliers and experts in the industry. It will be supported by a full-time expert consultant, who will help manage and organize the projects.

- Deliverables and milestones
    1. Jul. 2021: Comparative report of various technologies for remote assistance
    2. May 2020: Obtain and set up hardware for mixed reality and connected screens(done)
    3. Nov. 2020: working demo/proof of concept for the Remote Support use case (done)
    4. Nov. 2021: working demo/proof of concept for the Climbing Transmission Towers use case
    5. Jun. 2021: working demo/proof of concept for the Closed-Off Planning use case
    6. Nov. 2020: working demo/proof of concept for the Virtual Meetings between Sites use case (first POC completed, more POC planned in 2021)
    7. Sept. 2021: Have a working demo/proof of concept for the Edison use case
    8. Dec. 2021: Have a working demo/proof of concept for the Connected Screens in Substations use case (the use case is ongoing since a few months already, we will compile our findings in a comprehensive document at the end of the proof of concept)
    9. Dec 2021: Have a working demo/proof of concept for the Virtual NCC Control Room use case and an impact assessment
    10. Dec. 2021: Have a working demo/proof of concept for the AR-impetrant use case (A first use case was completed in Dec 2020 but we decided to start a second POC using augmented reality glasses instead of augmented reality on a smartphone to improve security)

Partners

- Multiple hardware suppliers for the augmented-reality and virtual-reality headsets, connected screens, capture tools, cameras, LIDAR technology, and other necessary accessories
- Multiple software providers for tools for collaboration, operation, capture, etc.
- Experts from the industry to organize workshops and brainstorming sessions and help with planning proofs of concept
- Elia departments and teams, e.g. Assets management, infrastructure, offshore
- *confidential* for the support of development of tailor made applications.

Summary of project efforts in person months (by work package and by year)
confidential

Domain 2.3 Domain 2.5

Project 14: Decision support for the dispatching

2021 decision: Accepted

Trends: Decarbonization, supranational coordination, decentralized generation and new players, digital revolution

Consequences: Uncertainty of generation, intermittency of generation, new decentralized flexibility means, digital tools and data use

Challenge: 2. Automate the system operations to be capable to optimize the network in minute timeframe for frequency, voltage and congestion

Domain: 2.3 Predict and automate imbalance dispatching decision

2.5 Automate maintenance planning, the congestion and the outages

Project-specific context

- The uptake of renewables (50% by 2030 following the ambition of the Green Deal) will increase the complexity of dispatchers' work, e.g.:
  - an increased residual load;
  - a risk of frequency instability due to low inertia;
  - the need to replace 48% of voltage control from nuclear power plants with decentralized alternatives;
  - a shift from dozens to hundreds of thousands of flexibility resources;
  - an increase in forecast errors to 2 GW on an hourly basis for offshore activities, and an overall increase of 50% in flexibility resources.
  - A ramp of up to 4GW/h in exceptional situations (considering 4.4 GW of offshore installed capacity)
- On top of this, decisions made by dispatchers are always collaborative, which means that many counterparts and interdependencies need to be considered. Dispatchers need to be aware of all grid constraints, especially as the grid is operated closer to the limit than before, while the role of voltage regulation must also be taken into account.
- In the future, the need for multi-dimensional optimization (voltage, imbalance, congestion) along with the volatility of the system will increase and result in many more uncertainties: for example, a deviation of wind production from a short-term forecast might mean that a planned outage will now create dangerous congestions that could trigger some re-dispatching and therefore have some impact on energy prices.
- Considering that the system will be operating closer to the limit, and with the emergence of a decentralized system, the number of decisions that need to be made in the NCC will dramatically increase (only for balancing, we could move from 50 to more than 1,000 activation messages), soon expanding beyond what can be handled by the human brain alone.
- With all this information in mind, Elia is looking into creating a smart dispatching system which can initially help grid operators with their day-to-day decisions and operation process and ultimately automate these processes as much as possible. This will have as a result that many topologies or options can be analyzed in parallel by an optimizer, increasing the chance of reaching a global rather than a local optimum.
- The smart Dispatching system could take on multiple forms, first by automating laborious tasks, and second by supporting Dispatchers in their decision-making process:
  - it would initially be used for accurate forecasting, shifting into support for Dispatchers' decisions and eventually full supervised automation;
  - it would also be deployed for various dispatching decisions: frequency regulation, voltage regulation, congestion and outage management, incident management, etc.
- In this context, the project is aiming to test artificial intelligence's ability to reduce the burden on the Dispatcher so that the latter can make better decisions and not miss dangerous situations. The following tasks were identified:
  - Automation of switching notes at regional control centers to reduce errors in planned outage management at regional level;

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- Automatic alarm filtering in case of an incident, making the response to any incident safer and more systematic;
- Application of reinforcement learning to optimize topological decisions like re-dispatch or tapping of phase-shift-transformers for the upcoming 24 hours;
- Subsequent identification of other use cases.

Project-specific state of the art/literature review

- Today, the state of the art is not very well documented. We see European TSOs working in this direction, but practical implementation will depend largely on the TSO-specific context. Research projects are still crucial to grasp the full potential.
- AI is not an unknown quantity. We see it in digital applications such as *confidential*, and applications such as the autopilot in commercial aircraft have also adopted it.
- ENTSO-E developed a roadmap targeting a fully automated control center as part of *ENTSO-E RDI Flagship 6*. Indeed, one of the work packages for after 2020 is called *Virtual control centers and AI-based decision support systems*.
- The Electric Power Research Institute (EPRI) notes that "ML [machine learning] methods can provide significant value to future grid operations".[6] However, this value still has to be harvested.

Expected impact for Belgium

- As set out in the context section for this project, the system complexity will increase. For instance, by 2030 the residual load error will rise, half of voltage control will need to be sourced among new resources (after the nuclear phase out) and the number of flexibility resources will move from dozens to hundreds of thousands.
- Automation will limit the risk for the operator:
    1. Among the notes prepared for the outage operation, currently, 60% of switching notes need to be revised, and the goal is to achieve 90% correct switching note in an initial phase, using artificial intelligence or implemented business rules. This will ensure that the same number of dispatchers can handle the increased workload, because high intensity tasks can be taken over by AI.
    2. Alarm filtering will reduce the time required to identify the root cause and provide a solution to an incident, thereby reducing their impact (and associated costs) and indirectly support the adequacy of the grid. This will result in a containment of grid tariffs and high security of supply for the end user.
    3. Topology optimizations with the help of AI will ensure faster and more optimal solutions to reduce overloading in time even more efficiently. Therefore reduce workload of the dispatchers, allow more efficient use of the grid asset and efficient counter measures reducing costly redispatching.

Starting point for Elia

- A first initiative was performed at Elia in 2017 to test the use of artificial intelligence in forecasting imbalance. The results were encouraging, but it took a long time to train the model (3 months). We are now aiming in the first WP of the project to achieve more efficient training of the forecast algorithm.
- Elia is gaining maturity in the field of artificial intelligence. We know that the field is already quite advanced externally, with many new applications making use of AI, but none have been implemented at Elia. We are integrating knowledge via partnerships and thereby building up our expertise.

[6] EPRI – Control Center of the Future. EPRI European Virtual Workshop Week 2020, April 20, 2020

Uncertainties and risks

- The first uncertainty, of course, surrounds whether in each case artificial intelligence can provide the quality of data we need (e.g. error levels in imbalance forecasts, correctness of switching notes, correctness in filtering alarms).
- The second uncertainty relates to whether the algorithm can be trained for continuous learning when the situation is changing all the time.
- Another unknown is how long such computation could take.
- We need to make a clear decision on how we deal with black-box models, or whether we only accept 'explainable AI'.
- We need to ensure that, where relevant, human supervisors will be able to overrule decisions made by AI.
- Data quality and availability is always a big issue, following the 'garbage in = garbage out' principle.

Project description

- The main aim of the project is to integrate automation and decision support b into the system's management tools.
    1. Switching Notes automation: We want to develop a tool to automate the creation of switching notes. If switching notes could be created automatically, the dispatcher would be able to spend the time freed up by this on other, high-value work. We want the tool to create switching notes for 'standard' situations automatically (e.g. 80% of all notes), with only exceptional situations probably still being handled by a human.

    Update 2021*: Half a year into the development of the tool, we can now create some types of switching notes. We have clustered the process into different operations, such as isolating and connecting to earth, and different grid topologies such as lines with multiple extremities, transformers, and bus bars. We aim to put in place a pragmatic mix between applying business rules and enhancing the results with AI. We are incorporating feedback from actual Dispatchers to assess and improve the performance of the tool. We are also thinking about various subsidiary items, such as visualization of the steps suggested by the tool, indicating a confidence level for the notes created, and further digitalizing the whole switching process (from paper to digital devices, etc.).*

    2. Switching execution:
    3. AATO: Advanced analytics for topology optimization develops a prototype for decision support system for the system operation. The use of Artificial Intelligence is researched and tested. The primary goal is to reduce load violations through topological actions, and this way avoid costly re-dispatch actions. For that data from the system operation process needs be read, preprocessed and analyzed to find non-costly remedial actions that can be suggested to the system operation engineers in the short time windows available during the daily processes.

- Approach: For the first project we want to team up with a vendor of innovative artificial intelligence algorithms (*confidential*). The other two projects (automation of switching notes and filtering of alarms) will be developed internally in partnership with an external expert on artificial intelligence (*confidential*).

- Work packages and timing (M = month)
    1. *Automation of the switching notes in the regional control center*
        - i. Jul. – Nov. 2019: Analysis and modeling
        - ii. Nov. 2019 – Feb. 2020: Data gathering and initial model building
        - iii. Mar. – May 2020: Testing of and feedback on easy use cases
        - iv. Jun. – Sep. 2020: Integration of feedback, increase of complexity
        - v. By the end of 2020: Closure of the POC phase
        - vi. Jan-Jun 2021: user interviews, UX

vii. Jun-Aug 2021: Wireframes, testing UX
viii. Oct 2021: User testing
ix. Nov-Dec 2021: Operational testing, user trainings

The switching note creation will be finished by the end of the year. We're currently in our 4th stream that started on the 27th of September and will be finished by the 15th of October (going to 3 weeks sprint to increase velocity after 4 weeks sprint in the last 3 sprints)

It is planned to have 3 other sprints before we wrap up with a Go Live by the end of the 7th sprint.

The budget that is estimated until now is equivalent only for this stream to +/- 470k euros taking into account that we started around the 28th of June our 1st sprint.

The Goal for this year is to:

- Implement the automation for the creation of the PUTM actions linked to Lines, Bays, Transformers and Rails as NetOp Elements
- Generate automatically the Pre and Post Manœuvres based on the sub-station
- Generate automatically the Standard Actions
- Ability to create a switching note from scratch (Business Continuity in case of no Availability of *confidential* Engine)
- Ability to Edit the switching Note
- Ability to save and consult the switching notes
- Ability to digitally validate the switching note from with the CM
- Implementation of a dashboard to access the switching note by date of validation and execution
- Implementation of a color code to differentiate validated, in progress, to be executed and executed switching notes

As for next Year:

The plan is to:

- roll out the new tool to replace the current one in a stable mode
- Integrate the remaining NetOp elements
- Integrate the tool with E-Lock and Optimus (+ any relevant data source depending on further analysis)
- Implement a decisional computed process to detect errors based on historical data
- study the implementation of Artificial intelligence
- study and implement the integration with the replacement (or completion) of SARQA

2. *AATO*
    i. Investigate remedial actions recommended today by system operators
    ii. Research the mathematical complexity of the topological optimization of power system models
    iii. Research most recent advanced algorithms and methods for the optimization of topological actions
    iv. Create Proof of concept for the optimization approach for generic grid model
    v. Interview key users
    vi. Adapt POC and develop first Prototype for more realistic power system model

- Deliverables and milestones for 2020
    1. Feb. 2020: Presentation of imbalance forecast results (WP1)
    2. Q1 2021: Decision on imbalance forecasting for a discretionary incentive, implementation
    3. Mar. 2020: Switching notes keynote 1: First implementation (WP2)
    4. May 2020: Switching notes keynote 2: Increased complexity
    5. Sep. 2020: Switching notes keynote 3: View on integration into business
    6. Nov. 2020: Final switching notes tool ready, roadmap for integration into business available
    7. Q3 2021: New opportunities for automated dispatching identified

Partners

- Solution provider for the artificial intelligence algorithm: *confidential*
- External expert for the partnership regarding internal artificial intelligence development: *confidential* via the Elia Group's Center of Excellence on Artificial Intelligence (CoE AI)
- Elia's national and regional control centers
- 50Hertz's transmission control center

Summary of project efforts in person months (by work package and by year)

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Domain 3.3

Project 15: Analyzing vibration sensors for our infrastructure monitoring

2021 decision: Accepted

Trend: Digital revolution

Consequences: Aging of the infrastructure, digital tools and data use

Challenges: 3. Automate the inspection of the asset and make maintenance more flexible to cope with planning changes, keeping high level of safety

Domain: 3.3 Predict and optimize preparation of the maintenance

Project-specific context

- Elia operates about 18,000 lattice high-voltage transmission towers across Belgium interconnected by power lines. Some of these towers are quite old considering that 20% of the grid are more than 80 years old, and 80% of towers are more than 40 years old which very high compared to the European average. Nowadays, targeted audits are performed, providing periodic non-continuous data about structures while visual inspections are costly, time consuming and difficult to objectively quantify. Moreover, detailed drawings are often missing, and records of repairs carried out a long time ago are incomplete.
- At the same time the IoT technological breakthrough and the spreading of technology offer new opportunities. Therefore, a low-cost monitoring strategy, based on an IoT solution and advanced data processing algorithms, should be developed to track in continuous mode the physical parameters of a tower which can be linked to its in-situ structural behavior.
- These data-driven reduced digital twins should make it be possible to detect changes overtime, compare the behavior of comparable structures within the fleet, and objectively and quantitatively assess the structural reliability of each asset.
- Finally, all the towers need to be painted regularly to prevent corrosion. Therefore some damages cannot be invisible to human eyes or camera during an inspection. This is why as an alternative solution, inspecting the internal and global behavior can complete a traditional analysis.
- The project will also result in safer working environments as structural integrity can be determined before workers access structures and so put themselves potentially at risk. Climbing work on towers in a normal state is covered by working methods and intrinsic safety devices. However, all these precautions are only valid if the structure is in an acceptable condition, and that is what we would like to evaluate with this new technology.

Project-specific state of the art/literature review

- Ambient vibration test of Rainbow Bridge, in Tokyo, performed by the University of Exeter (UK) and the University of Tokyo
- Research collaboration on asset management of bridges between the University of Exeter's Vibration Engineering Section and the University of Cape Town (contact: Prof. *confidential* (University of Cape Town))
- Test of *confidential* monitoring of offshore wind turbines
- Smart Structures, Italian research on tower monitoring with sensors for concrete degradation
- Flod AI, collaborate with RTE to monitor the flexibilty of towers

Expected impact for Belgium

- For Elia, this is an opportunity to make headway on its digitalization projects for its infrastructure in the years to come and integrate the initiative in a wider IoT perspective (see project 17).
- The tracking of the infrastructure health will also benefit to consumers in the form of capex reduction and the decrease of outage risk This goal could be reach with a better anticipation of the end of life of a line and give therefore the time for Elia to construct a better, stronger and more integrated project to treat this end of life
- The project also results in safer working environments as the structural integrity can be determined before workers potentially run a risk by accessing structures. Indeed the precautions from standard methods used currently are only valid if the structure is in an acceptable condition, and that is what we would like to evaluate with this new technology.

Starting point for Elia

- For one and a half years, Elia has been looking at the state of the art for vibration analysis. The initial approach was to find objective data to determine towers' aging and reduce the impact of human advice. During this research, we have started to work with *confidential* solutions and have already installed a prototype on two new towers. The idea was to validate the design of these new towers, but we decided to also take this opportunity to collect vibration data. The initial results look promising for further research and the launch of this project.

Uncertainties and risks

As this technology does not currently exist, multiple technical aspects could result in failures, such as:

- Climate effects (wind, temperature, etc.) that can affect the results, leading to uninterpretable results;
- The impact of the natural vibrations of conductors;
- The level of details that needs to be available for a vibration analysis.

Project description

- A twofold strategy is proposed based on the fleet-leader concept. Under this concept, various assets will have an extensive measurement set-up that should make it possible to develop a better understanding of the envisioned structures. Alongside these, a fleet-leader low-cost monitoring solution will be developed that could be rolled out across the entire fleet. Combining the knowledge of the fleet leaders with data coming from the entire fleet, a fleet-wide comparison and assessment can be made using advanced machine-learning algorithms. This should make it possible to significantly improve current Operations and Maintenance (O&M) decision support, reduce visual inspections, cut maintenance and repair callouts, and – most importantly – lower the risk of (catastrophic) failures and potentially extend the operational lifetime of the monitored structures by taking the appropriate corrective actions.
- <u>Approach</u>: Vibration analysis has already been shown in various specific domains that it can be used for predictive maintenance by detecting damage before critical problems occur and before there are visible to the eye. This technology is already well known for operating engines but not for static structures subjected to climate factors. A small-scale partnership between *confidential*, and Vrije Universiteit Brussel (VUB) has already been studying this technology for wind turbines, resulting in an initial monitoring solution for these in an offshore environment. After discussions with all of them, we decided to work further together on identifying what could be done for HV towers. The approach involves each specific partner handling its field of competence:
    1. Elia: Knowledge of the grid and towers
    2. VUB: Theoretical research and in-depth knowledge of vibration analysis

- Work packages and timing (in total 32M)

    Part 1 (8M): Development of a monitoring approach for the fleet leaders, focusing on the assessment of strain and vibration measurements

    i. Strain measurements to work out load and fatigue parameters
    ii. Vibration measurements to work out vibration levels and dynamic parameters (frequencies, damping values) of both the tower and the lines

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Part 2 (16M): Development of a low-cost monitoring solution for the entire fleet

iii. Optical accelerometer/strain (IoT solution)
iv. MEMS accelerometer (IoT solution)
v. Work on the requirement for a mobile solution

Part 3 (16M): Development of a fleet-wide data analysis approach

vi. Fleet-wide model training tools translating monitoring data into condition/health parameters
vii. Fleet-wide comparison tools translating monitoring data into condition/health parameters

Part 4 (12M): Creation of an automated data pipeline in the cloud for data collection, storage, analysis & visualization

viii. Data collection and storage
ix. Data analysis
x. Data visualization

Part 5: Development of O&M decision support tools

xi. Predictive maintenance rollout

- Deliverables and milestones:
  1. Sept. 2021: Production of a instrumented fleet leaders (1)
  2. Dec. 2021: Launch of research with VUB and first reporting
  3. Dec. 2022: Report on loads and dynamics to improve the general understanding of these structures under different operating conditions with comprehensible decision support
  4. Dec. 2022: Low-cost monitoring solution for a number of structures (5-10)
  5. Jun. 2023: Python toolbox for fleet-wide data-driven models and anomaly detection
  6. Jun. 2023: Python toolbox for fleet-wide comparison and anomaly detection
  7. Dec. 2023: Policy on predictive maintenance or end of life based on results

Partners

- Academic Research: VUB
- Supplier of the accelerometer: to be defined with VUB (market analysis by VUB first)

Elia's infrastructure and innovation department Summary of project efforts in person months (by work package and by year)

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Project 16: Decentralized identifier & Solid Pods for user registration and higher data availability

Domain 1.2

NEW PROJECT:

Trend: Decentralized generation and new players, Digital Revolution, secure data vaults, decentralized identifier

Consequences: New decentralized flexibility means, digital tools & data use, interface of with new players

Challenge: Give access to decentralized flexibility

Domain: 1.2 Authentication of devices and activation

Project Specific Context

The energy ecosystem is changing quickly. In order to solve the energy trilemma (sustainability, affordability and reliability) a paradigm shift to a more complex energy system is necessary. While the old world was centered and monopolistic, the new world's epicenter is decentralized and prosumer centric. With more decentralized renewables, the electrification of other sectors such as the transportation and the heating sector and more interconnected markets, we can see the following consequences and challenges:

- More stakeholders and market participants
- More dynamic, uncertain, close to real-time markets
- More complex and granular needs.

In order to deal with those challenges Elia has to take action as a market facilitator. This includes building a decentralized platform ecosystem and ensuring the customer's data sovereignty by using new technologies such as decentralized identification (DID) or personal online data storage (Pods). There are different use cases for this technology, which can be broken down to:

- Authentication,
- Proof of Identity,
- Generic proofs,
- Consent management.

We want to foster innovation and lower the entry barriers for new services. Data transfer between energy players is a suboptimal process requiring a lot of coordination. By defining a single point of truth on user side, we access the data directly from the end user storage and it allows us to be compliant for the next iterations of GDPR with less burden. Also, removing the current silos around the data will simplify the creation of new services and innovation for the consumer. So, the advantages will be highlighted when multiple new services will use the same data storage on the user space. Cyber security is a hot topic and by introducing a technology that would offer more effective authentication and proofs, we shield us from some future attacks.

We think this technology is of high importance because:

- Solid can be an enabler for realizing the consumer centric vision and enabling competition behind the meter as stated in the consumer centric market design paper.
- Elia group keeps its innovative image across Europe and will be seen as one of the first movers if this eventually gets worldwide adopted
- Data will become even more important in the future, Solid could open new value streams for non-regulated activities

In comparison to Project 10 we focus on the use of Pods and combine them with the concept of decentralized identifier, verifiable credentials.

Verifiable credentials

This technology allows to make any sort of claims that a trusted authority agrees to sign. These signed claims can be considered as a proof because the verifier can read the content of the claim and be sure it has not been tampered. If he trusts the authority

that signs it, he can be confident that it is the truth. For example, the claims can be an identity signed by an eIDAS identity provider, a car specification signed by a manufacturer, the homologation certificate of a smart meter issued by a DSO, etc.
Verifiable credentials (VC) can also be used to authenticate on web portals. This authentication mechanism is password less and offer by multiple order of magnitude more security for the user and the portal. It allows also to sign documents like contracts, consents linked to the real identity of the user.

DID
Decentralized identity, mostly written on blockchain, enables the user to create an identity that he owns. He can create new ones or reuse previous ones to sign contracts or authenticate to web portals, etc.
Combined with Verifiable Credentials, DID offer the ability to prove ownership of any type of asset, like a car or a smart meter.

Personal Online Data Stores (Pods):
It can be considered as a decentralized storage because the end user would own the storage and be able to switch from storage provider or even host it himself. The user has the ability to authorize a third party to read or write inside its private storage.
If multiple parties need to share data about a user, it can be easier to store the data at the user space enabling a de facto single truth and ease the compliance with the GDPR.

Project specific State-of-the-art/Literature study

A significant number of companies is currently implementing projects using DIDs, which underlines the importance and the high expectations for this technology. Some examples can be found here:

- In Utah, USA, the government is currently implementing a digital driver license using a DID.
- *confidential* is creating a *confidential* connected to their "*confidential* ".
- Multiple startups are working on the topic, like *confidential* (and many others).
- W3C (The World Wide Web Consortium (W3C) is an international community where Member organizations, a full-time staff, and the public work together to develop Web standards) have released multiple normative documents about DID and VC.

While DIDs are already well known and implemented by a broader number of companies, PODS are a newer technology. Nevertheless, the potential is tremendous since they enable the self-sovereignty of the costumer when it comes to storing and sharing their personal data. Instead of giving the data to a company and trusting this company not to sell the data to a third party, users can just provide (temporarily) access to their data, which is still stored in their PODS. Additionally, they can update the information easily for all parties that have access to the data and even revoke the access as soon as a company no longer needs to be able to ready the data. Provides of this technology are:
- Inrupt: Solid Pods: Solid | Inrupt
- PolyPoly: polypoly | Home

Expected impact for Belgium

The cost of personal data management and the onboarding of new clients will increase for all companies in Belgium and Europe. Hence, we need a way to scale the processes and limit the costs of implementation. Few reasons why DID will be an enabler to manage these constrains:
- DID allows to put the data in the hand of the end user, leaving our applications stateless, they become GDPR compliant by design
- Pods serve as a secure data vault and will store sensitive data. Instead of putting them in the hands of companies, users remain in full control.
- DID allows physical devices to prove their identity and operate according to a defined policy
- DID allows users and devices to authenticate on our applications without the need of interactive password prompts (with increased security)

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- DID allows users and devices to prove claims that we will be able to trust (based on the issuer authority), like identity, flexibility capabilities, give consent, etc.

A direct impact of such an implementation are the reduction of know-your-customer processes in B2B as well as B2C business. Moreover, data that is required for new service providers will be available to anyone (if the consumer agrees) and trustable due to cryptographic signatures of the issuer of the data. Last but not least, it will change the way consent management is handled. With DID, Pods and smart contracts, consent management becomes transparent for all participants. This cold then offer an efficient solution to bring security and the GDPR compliancy for the handling of consumer energy data.

Starting point Elia
As part of the blockchain initiatives at Elia we already gained knowledge and experience with decentralized identifier for IoT devices (see Project 10), e.g. for electric vehicle integration. As a result of these initiatives and through interaction with stakeholders, Elia realized that self-sovereign identity management for citizens as well as secure date management is a key trend and technology in the coming years with significant consequences and potential. To better understand the technology, we already conducted workshops with technology provider (***confidential***), the ***confidential*** and ***confidential*** to assess the potential and identify project partner

.Uncertainties & risks
We have identified the following three main uncertainties and risks:

1. Handling of data: It is unclear how different kind of data types (meta data vs. metering data) can be stored, saved and accessed through API and protocols.
2. Connection of DID and data vaults: It has to be tested, how a DID based identification system can handle data vaults and vice versa.
3. Consent management: Since the user will be in control of its data, consent management processes are required. It is still unclear where this consent is given and which IT system will be responsible.

DID:

- DID are indeed well known and technical evaluations are very mature. Nevertheless the application of DID and (decentralized) verifiable credentials are not applied in any processes in the energy sector (as far as we are concerned). The technology still requires a lot of evangelization, training and demonstrators to be fully understood. An application of the technology only works if a broad number of companies understand the potential and agree on a standard. So the risk in technological capabilities are rather low compared to PODs but the challenge is to get the technology applied.

PODS:

- Solid technology promises to be an enabler for many future use cases such as Exchange of Energy Block or NEO. Our first analysis showed that the technology is currently not ready for production use in its decentralized format. Solid is a specification of standards, not a specific implementation. But the current state of Solid specification is DRAFT. This implies that the technology implemented today does not have stable constraints and the communities are looking for the best constraints and features to introduce in the technology. The fact that the specification is still in draft form alone demonstrates that the technology and its ecosystem are in their infancy and that there is a long way to go before we can use this technology in production (out-of-the-box).
- In the long term, it has the potential to facilitate interoperability and data exchange between energy players, which will increase innovation and competition in the sector. Moreover, the user will play a central part in such a technology. Important benefits are expected, such as the ease of migrating from one service to another thanks to the possibility of changing data access authorizations. The user will also have greater transparency as to how their data is exchanged between energy players. The potential of this technology will not be realized without strong cooperation between the different actors to agree on common definitions, formats and structures for the storage of energy data.

- **Success criteria:**
  - Demonstrate the interoperability of data between PODS be developing interoperability specifications
  - Authorization of PODs in the energy ecosystem and for specific applications

- Demonstrate that sensitive data (e.g. metering data) can be stored in the POD and that Elia can set up queries to retrieve this data.
- Demonstrate that client-side queries are efficient with the data interoperability specification in place.
- Demonstrate that we can guarantee the authenticity and integrity of the data

- Fort the last point on data integrity, verifiable credentials are required. Ideally in a decentralized system based on DID. But this is not necessarily required since verifiable credentials can use centralized structures as well. Hence, the project would still be a success also without the application of DID/blockchain.

The link between this project and project 10 (blockchain)

- In project 10 we focus on DID and the new moonshot exercise and want to combine different technology in a complex use-case (Charging a beligum EV at a public charging station in Berlin with the roof-top PV plant installed in Belgium).
- For this moonshot we will use the results of the Solar2You project, where we also see large potential for Solid PODs (to store the metering data, give consent, provide the responsible supplier)
- If the Solid POD can provide the above mentioned criteria we want to use it also for the moonshot of project 10 as a secure data storage and for consent management purposes.

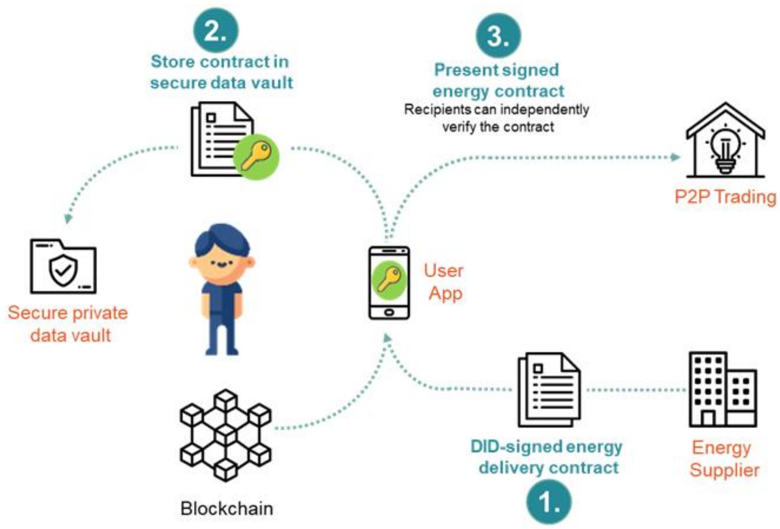
Project description

Elia aims to demonstrate the feasibility and the advantages of those two technologies, DID and PODs, in the energy sector in a proof of concept (PoC) that uses Solar2You respectively the moonshot described in Project 10 as a practical use-case. Solar2You is an initiative of Elia to enable consumers with a PV panel and a smart meter to exchange energy with their peers across balancing responsible parties and suppliers (link). The project is based on the consumer centric market designed (link).

The goals of this PoC are to integrate the following points in Solar2You respectively in the moonshot presented in Project 10:

- Demonstrate a decentralized registration process combining user DID and data vault
- Implement a DID-based consent management process for participants to accept data sharing
- Implement an on-chain user registration process eventually with an identity validator
- Store data in PODs
- Create a query to receive data from PODs

Work Packages:



WP1: Infrastructure

- January 2022:
  - Set-up of PODs either at Elia's premise
  - Understand how to write and read information from the PODS

WP2: Generic Proofs

- January-March 2022:
  - Develop a set and an applicable logic of verifiable credentials (VC) to create Linked Data. See step 1, 2 and 3 in above figure.
  - Linked Data are the key develop cross-sectoral interchange i.e. to enable interoperability
  - Verifiable credentials can work with or without blockchain. In case complexity is manageable VC are signed with DIDs of the entities. Energy Web Foundation offers an open-source tool (EW Switchboard) to support the creation
  - The data vault will be used to store the credentials (see step 2 in above figure)

WP3: Use-case

- March – August 2022
  - Embed the infrastructure and VC in Solar2You and/or the moonshot (see Project 10).
  - Following information are provided through PODS:
    - Metering data
    - EAN code of the head meter
    - Energy Supplier
  - Test a decentralized consent management for Solar2You/Moonshot

Partners

- ***confidential*** t:
  - Provide a personal data vault
  - Adapt data vault to Solar2You use-case
  - Create the interface to blockchain / DID
- ***confidential***:
  - Development of DID logic
  - Development and implementation of verifiable credential process
  - Development and implementation of a consent management process
  - Development of a user application
- I***confidential***:
  - User identification
  - Development of a verifiable claim on blockchain

Development of an interface to ***confidential*** / DID

Summary of project efforts in person months (by work package and by year)

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Project 17: SOS - Smart Offshore Surveying with USVs (Unmanned Surface Vehicles) and ROVs (Remote Operated Vehicles)

NEW PROJECT:

Trends: Digitalization, remote inspection

Consequences: Digital tools and data use

Challenge: 1. Increase safety, efficiency and flexibility of offshore asset surveying and inspection to prevent damages and outages

Domain: Offshore

Project Specific Context

- To ensure the secure transmission of offshore power into the onshore grid, regular visual inspections and surveying missions of the offshore assets (subsea cables, platform) are of high importance
- However, these surveying and inspection missions are related to substantial costs and risks regarding safety, security and sustainability
- In general, transmitting the offshore power to the onshore grid is accomplished through the installation of a network of underground cables buried beneath the seafloor
- In Belgium, offshore wind generation assets in the north sea are connected to the world's first Modular Offshore Grid (MOG) at the Offshore Switchyard Platform (OSY) 40km from the port of Ostende
- In the future, the Belgium offshore transmission assets will gain major importance due;
    - To Further developments of offshore electricity assets in line with the Belgium and European strategy to increase offshore generation from 12GW to 60GW by 2030
    - To provide a stable, secure and decarbonized supply of energy to cover the national demand
    - To serve hub for interconnections between Belgium at the center of European and its neighboring countries
- The planning, installation, and assessment of subsea offshore wind energy cables present various planning and procedural challenges that are addressed by surveying missions that include in-depth integrated hydrographic, geophysical, and geotechnical data by vessels with geophysical tools such as Multibeam Echosoundsystem, sonar, sub-bottom profilers, and magnetometers to provide a comprehensive set of data which was charted and incorporated into our cable routing GIS software
- These vessels and their surveying capabilities are heavily dependent on weather conditions (Estimated WOW cost),
- In the future, Unmanned Surface Vehicle will be able to remotely and potentially autonomously undertake regular, flexible and more efficient surveying and inspection mission with substantial reduction of cost and a substantial increase in safety of employees, security of the assets and their transmission capacities, and the overall sustainability due to a reduction of environmental footprint into the ecosystem and climate

Project-specific state of the art/literature review

Regulation

- EU OPERATIONAL GUIDELINES FOR SAFE, SECURE AND SUSTAINABLE TRIALS OF MARITIME AUTONOMOUS SURFACE SHIPS (MASS) (2020) Available here

Research

- SMART OCEAN TECHNOLOGIES SOLUTIONS FOR RESPONSIBLE OCEAN USE Available here

Industry

- USV remote survey in Australia Available here

Project description

The objective of the SOS Project- Smart Offshore Surveying with Unmanned Surface Vehicles and Remote Operated Vehicles is twofold.

First, to test the maturity, feasibility and desirability to support current offshore asset surveying and inspection missions with remotely operated USVs and ROVs.

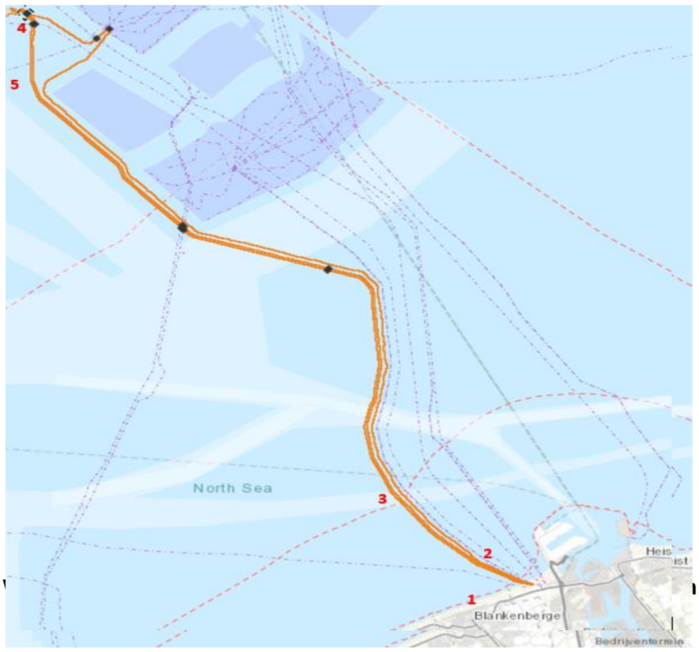
Second, to create market access and support for highly innovative developments to facilitate offshore grid integration

To test this, the project has two aims:

First, to undertake two separate full cycle cable surveying mission and platform inspections. One of the inspections will be undertaken by above water USV and the other by an underwater ROV. Both inspection criteria will be aligned with quantitative benchmarks of currents inspections that include:

a) Cable tracking
b) Multbeam Echosoundsystem
c) Crossing and Platform surveying
d) 3D underwater image and sonar Sidescan
e) Lidar Scans

Depending on the success of both individual surveying missions in 2022, the aim will be to test a combined surveying and inspection mission with ROV that is loaded onto a USV in 2023.



USV

1: Departure from the Port of Blankenberge with assistance from CTV vessel
2: Go to the 220 kV cable route and start MBES survey (cable route length +/- 40 km)
3: crossing of lane
4: Arrival at OSY platform location and start Lidar (above waterline) and 3D imaging (under waterline)
5: Return to Blankenberge via a cable route with sidescan sonar

- August to November 2021 :Scoping of technical work packages and organization of consortium between Elia, USV provider, and support vessels that currently undertakes surveying mission to execute a full cycle surveying and inspection from Blankenberge to the OSY Platform
- November 21 to February 2022: definition of quantitative KPI, organization of logistics and re-validation of scope
- February to May 2022: Logistical organization
- May 2022 Project execution of the surveying mission North Sea
- June 2022 Wrap-up and evaluation of project

Work Package 2: Cable surveying and platform surveying mission with ROV

- August to November 2022 :Scoping of technical work packages and organization of consortium between Elia, ROV provider, and support vessels that currently undertakes surveying mission to execute a full cycle cable surveying and inspection (location TBD)
- November 22 to February 2023: Definition of quantitative KPI, organization of logistics and re-validation of scope
- February to May 2023: Logistical organization
- May 2023 Project execution of the surveying mission
- June 2023 Wrap-up and evaluation of project
-

Work Package 3: Combined cable surveying and platform surveying mission with ROV on boarded on USV

- August to November 2022 :Scoping of technical work packages and organization of consortium between Elia, USV and ROV provider, and support vessels that currently undertakes surveying mission to execute a full cycle cable surveying and inspection (location TBD)
- November 2022 to February 2023: definition of quantitative KPI, organization of logistics and re-validation of scope
- February to May 2023: Logistical organization
- May 2023 Project execution of the surveying mission
- June 2023 Wrap-up and evaluation of project

Partners

- *confidential*
- *confidential*
- Potentially other industry actors
- Potentially research institutions

Summary of project efforts in person months (by work package and by year)

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Project 18: GAIAX and Energy Data-Space

Domain 1.4

NEW PROJECT:

Trends: Digitalization

Consequences: Digital tools and data use

Challenge: 1. Increase participation of flexibility sources from decentralized sources coming from electrification

Domain: 1.4 Manage market related data from and for market parties

Project Specific Context

Digitalization is accelerating these last year's notably under the impulse of the recent pandemic which forces many companies to rethink their approach to digital solutions. This implies notably an acceleration of the migration to the cloud. That is also the case for the energy business which will rely more and more on data from smart meters but also from OEM's as electrical cars, heat pumps etc… Therefore the use of cloud services for the organization of the energy system will become more and more necessary, notably in operations. More broadly, there will be a continuous increase of the IT technology stack over the business technology stack in the years to come as presented in figure 9

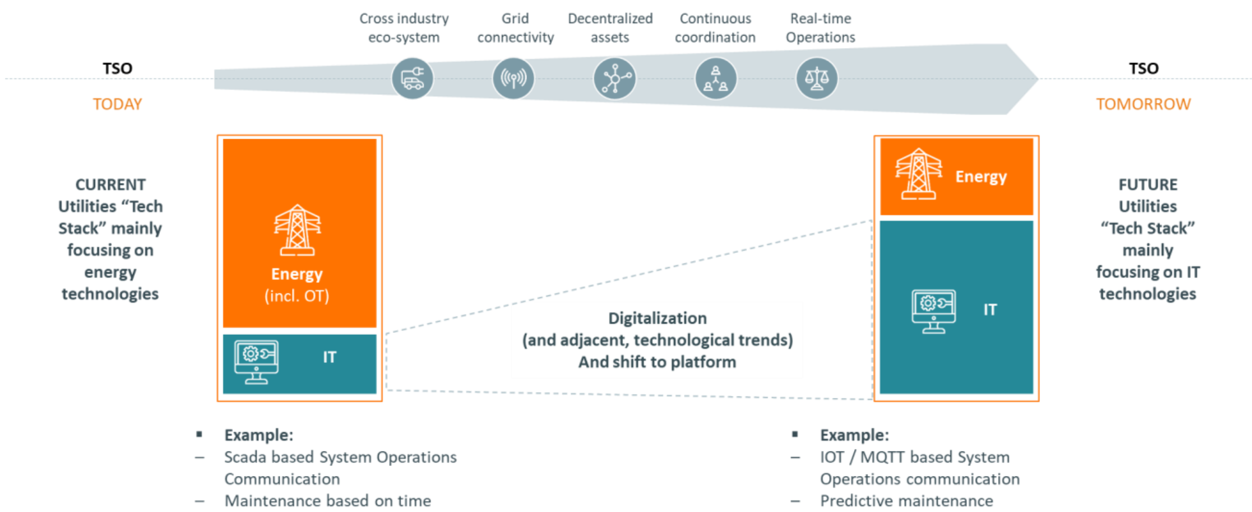

Figure 9 – Evolution of the technology stack of TSO's in the years to come

In parallel the market of cloud services is currently highly dominated by hyperscalers (e.g. ***confidential*** …) and this dominance brings questions of sovereignty of data in Europe which is affecting many crucial domains as mobility, industry 4.0, agriculture… That is why under the impulse of Germany and France the initiative Gaia-X has been launched in November 2020 to provide a structural European answer to the aforementioned dominance of US and China in the cloud space.

It consists in the development of new cloud services rules that will follow specific security, privacy or architecture rules that will be compliant with European data management principles and guarantee sovereignity as GDPR

This will be materialized on 3 level, as described in figure 10:

1. A sovereign data exchange that will be based on data space definition in different domains including energy. These dataspace will set characteristics as data semantic in order to enable specific use cases as AI, IoT data exchange etc… The ambition of the Energy international data space will therefore be to establish new standard answering the needs of flexibility, interoperability, security and availability of data. This will pass through the set-up of a trusted exchange place for data between organization. This will notably lower down the cost of getting access to data and improve therefore the quality of data – based solutions as forecasting.

2. The set-up of federation services (for compute, storage and network) defining the technical requirements and services necessary to operate the federated Gaia-X ecosystem. They ensure the highest possible security requirements and privacy protection but also innovative applications.
3. A sovereign infrastructure that will be materialized by the construction of data center in Europe. Following the trends of the data center market guided by low latency, due to new applications as virtual reality or IoT. This will notably be supported by the EU through a specific IPCEI[7] to incentivize the development of digital infrastructure in Europe and to which a specific call has been launched by Belgium.

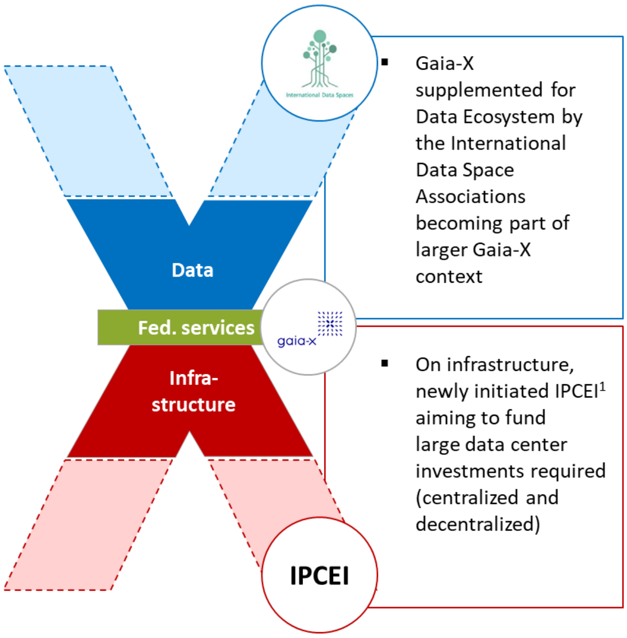

Figure 10 – Gaia-X 3 dimensions: Data, Infrastructure and federated services

For a TSO, the role of data and its related infrastructure will also become more and more important, notably due to the uptake of the role of decentralized flexibility as EV, heat pumps or decentralized storage. As an example 10.000 fast chargers could represent the power of one nuclear reactor. The hacking of the back-end of a major EV manufacturer could therefore have an major impact on the management of the network. On top, TSO's will need to rely on secure and performant cloud services in parallel of the physical communication network.
Therefore the opportunity of having a sovereign data infrastructure and service is of major importance for Elia and other European TSOs. The opportunity of Gaia-X needs therefore to be analyzed seriously into details to address the risk of lock-in from the dominant hyperscalers.
That is why Elia is actively following the Gaia-X initiative :

A. Elia participates in the energy domain discussion. More specifically, Elia is active participant to the European group of the International Data Space on Energy with the aim to shape the data space according to the need of the TSO, specifically with regards to the identity and the interoperability;
B. In that context, Elia is also participating to call for project at EU level that will aim at testing the Gaia-X tech stack and the data space results. The test will most likely be integrated into a European project aggregating many different stakeholders (***confidential***...)

[7] Important Project of Common European interest

C. Elia is also leading the effort in Belgium with Agoria in order to mobilize the energy Belgian eco-system and create transparency about the evolution of Gaia-X in Energy at EU level;

D.

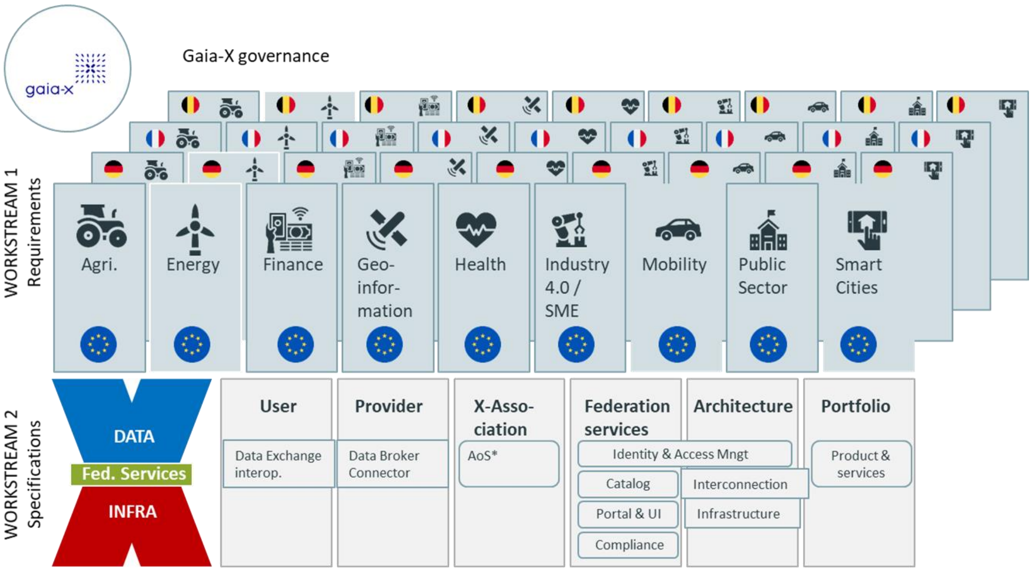

Figure 11 – Organization of the Gaia-X working groups

At the moment, the exact scope of the use case is not defined yet but it could be related to:

- The exchange of data for participation of EVs to the energy market;
- The use of data for interface between DSO and TSO for congestion management while using decentralized flexibility.

When it comes to the sovereignty infrastructure, another opportunity for TSOs could be to co-locate some data centers close to substations. Indeed, one of the critical element for any new digital infrastructure is the power connection which is de-facto present in the substation. Another major challenge is to find sufficient land for building the infrastructure which is also generally available close to the substation.

Therefore a second part of the project could be to test the development of sovereign clouds based on the very close vicinity from substations. These cloud services could be used for hosting specific and critical energy activities.

Project specific State-of-the-art/Literature study

- Gaia-X policy rules edited in April 2021[8]
- Gaia-X Architecture edited in March 2021[9]

Expected impact for Belgium

- The impact for Belgium will be first the sovereignty of data related to the cloud services for the management of the system. This will ease the set-up of new use cases requiring data exchange. The establishment of an

[8] Gaia-X_Policy_Rules_Document_2104.pdf
[9] Gaia-X_Architecture_Document_2103.pdf

energy dataspace will decrease the cost of accessing to data drastically enriching the amount of data available. This will certainly unlock new applications and improve existing one. For example, faster access to OeM's data will improve the quality of forecasting of the load or the flexibility and therefore decrease the cost of sub-optimal flexibility activation that could impact the final bill of the consumer. Another example could be a better understanding for the consumer of its energy use thanks to new and less costly analytics solution that would be enabled through a cheap and flexible access to data. Knowing that optimized consumption of energy could lead to a decrease of the bill by 30%, the implicit impact of an efficient energy data space is more obvious. If Elia is at the forefront of the development of the dataspace, it could push forward the roll-out of it in Belgium and derive quickly some benefit for its direct consumer as well as any end-consumer.

- The second implicit impact is that Elia will not be dependent on the hyperscalers for critical applications anymore. This will bring more control of the cost and the way the data is handled. At least, Elia will have the opportunity to use cloud services that are compliant to the Gaia-X framework and therefore respect higher standards of transparency and security. It will also improve the independancy from these classical cloud providers and increase the power of negociation while guaranteeing a better security and sovergnity of data.

Starting point Elia

- Elia is currently using cloud services for, mainly public cloud based application. Among these, there is for the moment no sovereign cloud services and we are using Azure Cloud notably for IoT.
- However many applications are still based on local servers for security reasons and the needs to be black-out proof. For that reason, the use of a soverign cloud would enable the shift of these critical applications to the cloud and therefore benefit from more flexibility and scalability in the development.
-

Uncertainties & risks

- The first uncertainty is whether the technology stack of Gaia-X will ultimately deliver a service that can compete with the current cloud services;
- The second is whether Elia will be able to run a sovereign cloud to secure its own services like flexibility data management.
- Another uncertainty is of course the development of the project itself. Indeed, Gaia-X, and the related energy data space, is a massive EU project involving hundreds of companies that makes it very complex to navigate. Therefore the speed of the initiative in itself will remain a challenge.

Project description

The project will consist in 3 work packages:

- **Work Package 1: Work group participation in Energy Data Space: - from November 2020 to December 2022 (minimum)**:
    - first the participation to the workgroup Energy at Belgian and European level in order to understand and influence the evolution of Gaia-X for energy in order to make sure that it meets the needs of Elia in term of cloud services. This will be materialized by the contribution to the discussions by an Innovation team member and the review of the technology evolution.

- **Work Package 2: Sovereign Cloud Test - from December 2021 to December 2022 (minimum):**
    - Eventually the potential test of sovereign cloud linked to the infrastructure of Elia. The technology is not decided yet (an option could be open stack). This will enable set the infrastructure foundation for a secured provate cloud which could host critical applications.
- **Work Package 3: - from September 2021 to December 2022:**
    - The last workpackage consists in testing the Gaia-X tech stack and the energy data space in the context of a European project called omega X. The test will most likely based on EV data interoperability for better onboard them as flexibility.
        - WP 3.1: The first part will be to establish a consortium around the use case including most likely suppliers, flexibility providers...

- WP 3.2: The second step will be to implement a solution based on the energy data space standard and the Gaia-X tech stack for EV data exchange including notably (Identity, data access...). To be noted that this is part of a wider project of testing the DiD and Solid Pod technology which could be running on the Gaia-X cloud. This Workpackage focus then only in making our development Gaia-X compliant. Therefore we consider only the cost related to this activity.
- WP 3.3: The third step will be to derive conclusions from the test for the data space

Partners

- Gaia-X eco-system: the Gaia-X eco-system includes Cloud services developers as ***confidential***
- Energy Data Space companies (***confidential***...)

Summary of project efforts in person months: per work package and per year

confidential

Project 19: Assessing the impact of local generation and prosumption strategies on the grid infrastructure

Domain 1.4

2021 decision: Accepted

Trends: Decarbonization, decentralized generation and new players and new players

Consequences: New decentralized flexibility resources, increase in maximum use as well as variability of the use of grid infrastructure, need to update grid security rules and resilience rules in the interest of society, interface with new players

Challenge: 1. Increase participation of flexibility sources from decentralized sources coming from electrification

Domain: 1.4 Predict and incentivize DER's

Project-specific context

- Overall, due to the uptake of wind and solar power, technologies of an intermittent nature that have various uncertainties surrounding them, there is growing interest in further incentivizing coordination between grid prosumers, e.g. through renewable-energy communities or other market arrangements.
- The challenge for Elia is that the strategy chosen by the parties with whom flexibility will actually be achieved in the future has a significant impact on upstream transmission costs (through grid upgrading decisions that may change due to local strategies), and therefore on general social welfare. For instance, if we consider a scenario in which each prosumer aims to minimize its electricity bill through an optimal response to wholesale prices, prosumers' local batteries will be discharged in periods of high prices (and charged in periods of low prices). In this way, if a grid contingency occurs at the end of the day (when there is no PV generation), the battery is likely to be empty since the energy was sold at peak prices during the evening. In this case, security of supply of end users may be jeopardized if no grid upgrading decisions have been made. By contrast, when prosumers are driven by a policy that maximizes their own consumption, the same contingency may not lead to significant problems since the batteries will have energy reserves (from the PV generation during the day), thereby ensuring continuity of supply.
- Interestingly, the optimal long-term transmission grid upgrading policy that needs to be applied in these two cases is completely different, meaning that it is vital that new tools be developed that properly quantify the impact of new load behaviors on the continuity of electricity supply in normal and contingency conditions.
- As the role of these decentralized flexibility resources will substantially impact the optimization of the grid investment, it is important to gain a better understanding of the real impact they could have and the opportunity they could provide depending on the type (heating, EVs, batteries) and consumers' behavior.
- Therefore, this project aims to evaluate how local economic interests and behaviors, which are becoming key in an increasingly decentralized context, affect general social welfare in Belgium.
- The project has been submitted to the energy transition fund, and a response from the federal government is pending.

Project-specific state of the art/literature review

- A look at the literature and the electricity sector clearly shows there is a lack of a grid upgrading tools combining both features: local economic interest and consumer behaviors. However, the state of the art at least points us in the right direction for scenario-based stochastic programming [1], chance-constraint programming [2], robust optimization [3], and distributional robust optimization [4].

- [1] A. Shapiro and D. Dentcheva, *Lectures on Stochastic Programming: modelling and theory*, SIAM, 2nd edition, 2014.
- [2] A. Nemirovski, *On safe tractable approximations of chance constraints*, in European Journal of Operational Research, vol. 219(3), pp. 707-718, 2012.
- [3] D. Bertsimas, D. B. Brown and C. Caramanis, *Theory and applications of robust optimization*, in SIAM Review, vol. 53(3), pp. 464-501, 2011.
- [4] H. Rahimian and S. Mehrotra, *Distributionally robust optimization: A review*, 2019. [Online]. Available: https://arxiv.org/abs/1908.05659

Expected impact for Belgium

- The main application of the project can be found in coming up with a structure for the power system and prosumption strategies to achieve the planned shift in Belgium's energy mix on time and in a cost-efficient way. By providing tools for optimal decision-making for grid investment as well as instruments to calibrate prosumer strategies taking into account societal impact at national level, the project will support the energy transition in Belgium.
- Furthermore, the expertise developed in the context of the project is of national and international interest and will be anchored in Belgium, which is where all the enterprises that are partners in the project are based. As such, it will directly benefit the Belgian economy and competitiveness.
- To illustrate the impact of decentralized flexibility on grid development, in 2018, the Norwegian DSO Agder Energi claimed it had achieved a grid deferral of €4.3 million by setting up a local marketplace with their partner NODES in order to steer decentralized flexibility appropriately.

Starting point for Elia

- Today, when grid development is proposed, it is based on an assumption of predictable customer behavior or on customers reacting to global market signals and not on them responding to local strategies and local signals.
- Models for charging EVs are based on a uniform share of domestic charging and workplace charging and of fleet EVs in all regions.

Uncertainties and risks

- As the project only looked at fundamental research, there is complete uncertainty about the output, based on which a clear pattern could be identified to create a robust model for forecasting the availability of flexibility associated with a quantification of social welfare.

Project description

- The project aims to enhance grid planning, focusing on two specific objectives that are key to a successful and cost-effective energy transition:
    1. Objective 1: Improving the time series (for a typical year) of hourly consumption profiles at the interface between the High-Voltage (HV) and Medium-Voltage (MV) levels. These time series are informed by the local strategies used to harness the available flexibility (e.g. maximizing local self-consumption using battery scheduling, etc.). This procedure makes it possible to quantify the amount of flexibility that may be leveraged at the local level to mitigate the unexpected loss of a major transmission-grid component. To that end, we will rely on macro-scenarios of the future national share of conventional and local renewable generation (associated with new economic incentives for renewable sources), on market functioning rules and on new prosumption habits (electric mobility and local storage via the new mechanism for fully harnessing the distributed flexibility).
    2. Objective 2: Adapting the methodologies and tools that drive decisions regarding grid upgrading to accommodate the growing share and importance of prosumers and demand-side response (including storage and decentralized generation). More precisely, we will develop a decision-making tool to support grid upgrading decisions, taking into account uncertainties associated with, in particular, the development and use of various decentralized technologies. To achieve this objective, recent advances in risk-conscious approaches will be leveraged to better accommodate uncertainties, while integrating the notion of risk. In this respect, a promising approach is based on the regret theory approach (such as the 'minimax regret' [14]), which focuses on making decisions with the tightest possible optimality guarantees when dealing with uncertainties.

- Approach: A four-year academic project with tasks divided between Elia and the industrial and academic partners. The University of Mons will provide researchers, who will focus mainly on time-series generation and grid upgrading methods, while the industrial partner will concentrate on supporting data extraction.

- Work packages and timing (M = month)
    - *WP1: Coherent global and local trajectories of the energy mix component* Jan. 2021 –Dec. 2024: Data collection *WP1.1 Methodologies for coherent energy mix trajectories creation*

- *Update 2021: This part of the project has been delayed by 1 year*
- *WP1.2: Data Preparation and methodology application to the Belgian test case*
  - *Update 2021:*
    1. *As first test case (benchmark), Elia has started preparing an initial dataset representing the future geographical repartition of macroscopic quantities among Belgian regions and ultimately substations. This concerns repartition of future PV, Wind and cogen decentralized generation based on potential of the area.*
    2. *Elia has started working on datamining techniques to visualize, interpret and correct historical measurements which inherently include maintenance of DSO substation (and associated load shifting), measurement errors in both active and reactive power. Finally, datamining techniques are used to identify the temperature effect on the consumption.*
    3. *It has been proposed to work with an external consultant (**confidential** in 2021) in support of internal Elia resource to improve the efficiency of the task and acquire expertise in datamining.*
    4. *The objective of these actions is to prepare an initial dataset which is of high quality for research activities.*

i.

1. *WP 2: Time-series generation*

   2.1 Definition and modeling of flexibility-management strategies

   ii. Jan. 2021 – June 2023: 2.1.1 Traditional strategies based on the current market framework
      1. Update 2021

         In order to enable the creation of local time-series which are coherent at national level, Elia and UMons have worked on methods for building local wind and PV generation profiles (time-series) based on zonal time-series of wind and PV portfolio based on the statistical analysis of correlation and spatial-temporal effects.

   iii. July 2022–Dec. 2025: 2.1.2 Disruptive flexibility-management strategies

   iv. Jan. – Dec. 2022: 2.2 Modeling of mobility patterns and their impact on available flexibility

   v. Jan. – Dec. 2022: 2.3 Multi-scenario generation for the application of flexibility-management strategies

2. *WP 3: Grid upgrading methodologies and tools*

   3.1 Methods and prototype for an academic test case

   vi. Oct. 2021– Dec. 2022: 3.1.1 Multi-scenario decision-making approaches to grid upgrading

   vii. Oct. 2022 – Dec. 2023: 3.1.2 Approaches to modeling the impact of prosumer flexibility on grid design

   viii. Jan. – Dec. 2023: 3.1.3 Implementation and application to an academic test case

   3.2 Extension of grid upgrading methodologies and tools to a real-life grid

   ix. Jan. – Dec. 2024: 3.2.1 Upscaling of methodologies and updating of the prototype

   x. July 2024 – June 2025: 3.2.2 Implementation of methods in preparation for real-life use case

3. *WP 4: Case studies and social welfare*

   xi. Jan. 2022 – Dec. 2023: 4.1 Definition of Key Performance Indicators (KPIs) for a social welfare evaluation

   xii. Jan. 2024 – Dec. 2025: 4.2 Combination of new time series and scenarios in grid upgrading tools

4. *WP 5: Coordination, Communication, and Dissemination*

   xiii. Jan. 2021 – Dec. 2024: Coordination, communication, and Dissemination

- Deliverables and milestones
  1. Jan. 2021 – Dec. 2025: Test and use cases and long-term trajectories
  2. Dec. 2022: Tool for better quantifying consumption profiles at the transmission/distribution interfaces

3. Dec. 2022: Models for mobility patterns
4. Dec. 2022: Multi-scenario generation
5. Dec. 2023: Prototype of a multi-scenario (grid reinforcement) decision-making tool
6. June 2025: Extension of the prototype to become a tool compatible with real-life issues
7. Dec. 2023: Definition of KPIs for social welfare assessment
8. Dec. 2025: Report assessing the impact on Belgian social welfare

Partners

- Elia's partners for this project will be the University of Mons and *confidential*.

Elia's Grid Development Department will participate in the various work packages.

Summary of project efforts in person months (by work package and by year)

confidential

Project 20: Congestion Management

Domain 2.4

NEW PROJECT:

Trend: Decarbonization, decentralized generation, digital revolution, more Electrical vehicles on low voltage Grid

Consequences: Grid will be more under pressure due to increasing Electrical vehicles and PV installation connected on the low voltage grid. Increasing pressure on LV grid will create increasing congestion situations on HV grid.

Challenge: 2. Automate system operations to be able to optimize the network in minute timeframe for frequency, voltage and congestion

Domain: 2.4 Predict and automate voltage decisions

Project Specific Context

- The uptake of EV in Belgium is now an evidence and forecast are foreseeing an amount of 1.5 million EV in the country by 2030[10].Among others, initiatives supporting the development of electric vehicle, such as the federal law to adapt company car rules to impose electric vehicle as of 2026, will certainly accelerate the roll-out from petrol-fueled to EV. This transition story is in first place applicable to EV, but will not be limited to it as more flexible decentral assets (heat pumps, boilers, batteries) make their appearance on the local electricity grid.
- This will lead to opportunities and challenges for the management of the overall system:
  - On the one hand, because of the increase of renewables coupled with the reduced role of classical plants, there will be increasing needs to mobilize decentralized flexibility to balance the grid. This is especially true for fast flexibility needs which needs will only be covered for 50 to 60% by 2030, as presented in Elia' study on flexibility needs (see Adequacy and Flexibility study for Belgium 2020-2030 issued in 2019). Knowing that the EV will be connected to the grid 90% of the time, getting possibility to integrate electric vehicle to the frequency control market would be of great interest for grid management by 2030.
  - On the other hand, charging of electrical vehicles will bring challenges at lower voltage level. Indeed, the network has not been necessarily sized and designed to integrate heavy EV charging power, which can cause some congestion problem at peak hours if everybody charges at the same time. When speaking about significant number of assets this will not be limited to distribution grid, but could also have an impact on the (lower level) Elia grid.
- To overcome grid congestions might require investments in the grid or reinforcement of the connection to the grid. Other (more extreme) options are the local cut off, generation curtailment or direct steering of local assets. Alternatively, consumption driven measures, such as the need of incentivizing the delay of charging in the evening has been notably been identified as a needed measure by the Synergrid study published in November 2019.
- To enable such consumer incentivization and desired behavioral change, the shaping of a time of use tariff (including both the energy and the grid components), could offer a suitable opportunity. Such a time of use tariff can serve as input for smart charging tool or behavioral triggering tools (informative or gamification based).
- The aim of the presented project is to engage with end consumers, to overcome congestions constraints in DSO and/or TSO grid, by making the grid tariff component in the electricity price for end consumer's ultra-dynamic. Related purpose of the project is also to improve the congestion forecasting tool at TSO level (in collaboration with DSO) and to see if and how a behavioral reaction can be triggered and what best practices are in that field. Another big milestone of the project is the collaboration between the DSO and the TSO to create a congestion model. During this project, the first steps will be taken.

[10] IAE

- It is not the purpose to change the model of the grid fee but to propose the customer different possibilities where he can choose for the one that fits better to his behavior: classical grid fee vs ultra-dynamic grid fee vs ...

Project specific State-of-the-art/Literature study

- We will see a high increase in EVs in the future. Please refer to the Vision paper published by Elia at the end of 2020.
  - https://www.elia.be/-/media/project/elia/shared/documents/elia-group/publications/studies-and-reports/20201120_accelerating-to-net-zero-redefining-energy-and-mobility.pdf
- A congestion model exists on the TSO grid that does not consider the real load forecasting of the DSO Grid. The project would also consider taking a look into how this will improve the TSO Grid forecasting.

Expected impact for Belgium

- **Increased security and grid performance**: through reduction of grid congestions
- **Enhanced TSO-DSO alignment**: advanced collaboration between TSO and DSO to overcome congestion challenges.
- **Promotion of local production and consumption**: Congestions are not a stand-alone phenomenon but related to local production of renewable and asynchronous consumption of energy. It is expected that the project will result in local production and consumption of energy at the same timeframe.
- **Alternative for grid investments**: less HV infrastructure/investment needed as the project can bring an alternative for transporting energy over long distances.
- **Reduction in electricity costs (conditional)**: for price sensitive, engaged consumer this will result in lower energy costs. Impact for passive consumers (with e.g. no access to smart tools or flexible devices) also to be considered.
- **Active involvement of end consumer in energy transition**: end consumers are given opportunity, on a voluntary basis, to be part of energy transition.

Starting point Elia

- Elia has currently a forecasting model of the grid for congestion. In this model, conditions on the LV grid are deducted by Elia does not receive data for all locations. The model makes a forecasting model of the HV grid for congestion.
- Project in IO.E 2.0 kicked off: Elia has launched an IoE project "Congestion" together with *confidential*. (More info about the IO.E v2 project can be found here: https://www.ioenergy.eu/use-cases-ioe-2/
  - The described CREG Inno Incentive project here concerns this IO.E project, but is also extended with the enhancement of the grid congestion forecasting tool at Elia. See more info below under 'project description'.

Uncertainties & risks

- **Effectiveness of the solutions:** can grid congestions be reduced as aimed for through this project?
- **Engagement of consumers:** are consumers interested to adjust their behavior, Is the dynamic tariff a sufficient trigger? Can grid constraints, as a result, be reduced via this method?
- **Engagement of partners:** given the more long-term timeframe and potential roll-out for the use case, are partnering companies interested to develop and test the solutions?
- **Price impact:** Is there bottom line a positive impact on the energy prices for end consumers? Is it applicable to all end consumers (also the passive or vulnerable end consumers)?

Project description

- The project can be divided into different parts (please see illustration below):
  1. **Enhancement of grid congestion forecasting model on HV grid:** Elia will look into how the Congestion forecasting model on HV grid will be affected if more accurate load forecast is received from DSO.
     - This is broader than the IO.E project
  2. **DSO-TSO congestion forecasting model:** Ores and Elia will separately create a congestion model, those will be taken together to create a common congestion model in specific area. A first try towards a common congestion model.
  3. **Definition of ultra-dynamic price signal (tariff model):** Price signal in function of the status of the grid, weather forecasts, expected renewables production, TSO predictions, DSO predictions, etc. The price signal will be tested on its effectiveness in IoE project.

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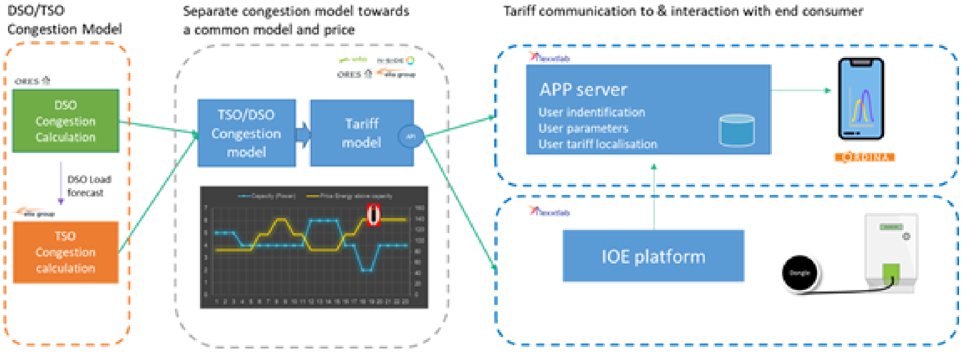
4. **On-the-field testing of ultra-dynamic price signal: i**n this project, we will make the experiment with an ultra-dynamic price signal. The common congestion model will be translated towards a price signal and a threshold capacity. At early stage, this will be limited to a specific site in Wallonia.
    - The customer will receive the profile in day ahead. If the customer stays below the threshold capacity, he will pay less grid fee. If he/she passes the capacity threshold, depending on the grid situation, he will pay a different amount of grid fee which will be the delta of the capacity multiplied with the grid fee at that specific hour (proposal at this moment).



- The project will be partnered with *confidential*. The funding for the project will be divided between Ores and Elia (50/50). The external Budget requested by Elia is the budget need estimated for 2022 for Elia *confidential*)
.

- **How does it work for Elia / grid operator?**
    - Dynamic tariff is defined based on forecasted grid status (read: forecasted grid congestions), weather conditions, renewables production, and other.
    - Dynamic tariff for end consumers is pushed 1 day ahead.

- **How does it work for the consumer?**
    - The customer will receive the profile in day ahead, via an application (fed by an API with the relevant tariff)
    - If the customer stays below the threshold capacity on a given timeslot, he will pay less grid fee. If he/she passes the capacity threshold, depending on the grid situation, he will pay a surplus grid fee (in function of the excess).
- What is the link between IoE project and congestion?
    - IoE project can be seen as an accelerator to enable collaboration with DSO and quick advancement on the future congestion model.
    - IoE project will enable Elia & co. to test this innovative solution with consumers. The purpose is to have a real use case in Belgium and asses some different tariff structures. In the same time, test in which extent this could help to reduce grid investments for the DSO and the TSO.
    - The external costs will be mainly used for the testing of this use case.

- Deliverables and milestones
    - June 2022: validation of POC: Can a time of use tariff for Grid fee shift the flexibility ?
    - Nov. 2022: verification on amount of flexibility that can be shifted. Having a first answer if it is possible to reduce congestion or not. Is it possible to reduce at least one generation curtailment if this tariff structure will be used ?

Partners

- Energyville,Ores and Elia will work together to take a look on common TSO/DSO congestion model
- *confidential* and Elia will work together in an IoE 2.0 project to have a first insight (see illustration above).

Summary of project efforts in person months: per work package and per year

confidential

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Project 21: Internal innovative idea incubator

Domain 6.1

2021 decision: Accepted

Trend: digital revolution

Consequences: Digital tools & data use

Challenge: 6. Maximize efficiency in our operations via digital solutions and embed digital technologies and skills in our organization

Domain: 6.1 Embed digital capabilities and training

Project Specific Context

- The accelerating pace of technological change coupled with the energy transition is leading to the redefinition of many industries, forcing businesses to make innovation their priority.
- This innovative potential will not be unlocked by itself and requires a set of tools to be made available to employees and will need the creation of an entrepreneurial mindset, what we call Innovation as a Service. In this light, Elia has established a new corporate digital idea incubator in 2020 which it will carry on in the year 2022. The incubator offers Elia's employees a risk-free environment where promising new innovative ideas that can improve the efficiency, quality/flexibility, or security of Elia activities can be prototyped very quickly in agile fashion.
- In the incubator, employees learn about the agile methodology and digital technologies with a view on leveraging the lessons learned in their normal business after the experience, on top of developing an effective idea.
- This incubator therefore dramatically increases the innovative potential of the company that will be much required in an energy system that is changing at an ever more breakneck speed, given the energy transition and the evolution of the relevant technologies.
- The incubator is characterized by two project rooms where agile project teams work on new ideas in a time frame of typically 14 weeks.
- The ideas are selected by an Elia panel based on pre-defined criteria (in terms of provability, impact, etc.) and are developed by a cross-functional team, including digital profiles like data scientists, UX/UI designers (from the Digital and Data department), experts (from business departments), and an Agile coach.
- By developing the capabilities of the Elia employees in entrepreneurship, developing innovative ideas, and digital skills, the innovation will transition to a bottom-up/decentralized model that will make it possible to scale up much more dramatically than a straightforward top-down/centralized approach where innovation department is pushing project to the business.

Operational details

- The incubator is responsible for identifying ideas that could have a strategic impact on Elia. Therefore three project managers regularly speak to business stakeholders to identify these ideas. Business units such as Infrastructure, System Operations and other are being invited to come up with innovative ideas that are not per se on a specific roadmap yet but could have major impact for Elia. The three project managers support the business units with ideation sessions called design thinking to unleash the potential of coming up with innovative ideas.
- Once ideas are identified, the idea owner is asked to fill out a template in order to measure whether the idea can fulfil the six criteria needed for the idea to enter the incubator. The six criteria identified are digital technology character, low maturity requiring exploration, provability, strategic alignment, desirability and cultural change.
- Once the idea is proven to fulfill the criteria, the idea owner is asked to present his/her idea in front of a Panel consisting of senior management (CDIO, CHRO, Head of Strategy) who then vote whether the idea can be accepted to enter a 14 week prototyping project.

- Once accepted by the Panel, the project team of the incubator is tasked with building a product team which will work on the specific idea. When building the team, the incubator relies on internal and external resources in order to form a product team.
- The team usually consists of an agile coach, product owner, scrum master, software developer, UX designer and IT architect. The team is self-managed according to the agile project management method and is building its own backlog to deliver a high fidelity prototype within 14 weeks.
- When delivering the prototype, the team is strongly focusing on the user needs and in 2-week intervals speaking to users to make sure that the right solution is being build, de-risking the project and making sure that the solution meets the needs of the user.
- After 14 weeks, once the project is completed, the team is asked to present their solution to the Panel. The team has 3 options in order to bring the project to the next stage. The first option is that the project could be stopped because there is no real value identified with the project. The second option is that the project could re-enter the incubator for another 14 weeks in order to further develop certain aspects of the solution. The third option is that the project and solution is handed over to the line business, which is then entering the standard project approval governance of Elia.
- The incubator accepts approx. a dozen projects per year. Each project is going through the same process from identifying the idea to presenting in front of a Panel to starting the 14-week journey of building a solution.

Expected impact for Belgium

- Directly, the incubator is enabling the validation of a dozen innovative ideas that could be implemented at Elia.
- Indirectly, via learning of the agile methodology and the digital capabilities, additional ideas can be developed even outside of the incubator, as in the normal day to day business
- In any case, both of these effects will support the same goal as the other innovative projects presented in this report: bring efficiency, quality, and security through innovation in Elia business.

Project description

- The goal of the project is to still drive forward:
  - Ideation & incubation: insourcing and developing a dozen ideas that have an impact on Elia in the short and long run in terms of efficiency, flexibility and security
  - Methodology: encouraging creativity-fostering ways of working in the incubator and strong collaboration across departments, internal/external ecosystems and experts to have the right capabilities available at the right time;
  - Cultural change: driving cultural change, fostering an innovation mindset (with a key focus on early and transparent communication) and defining the HR support framework to make participation in the incubator possible and attractive for all employees;

Uncertainties & risks

- The uncertainty exists that not enough ideas can be insourced and that the incubator becomes obsolete. However the team has been so far very successful insourcing a dozen ideas. In addition, the methodology aspect of the incubator is very much demanded within the company.
- Another uncertainty is the adoption of new methodologies by Elia employees. Not every department can or will be willing to adopt agile methodologies in their day to day work.

Partners

- The IT support (data scientists, developer…) will be provided by the Digital, IT and Innovation department with the participation of some external providers as *confidential* and other suppliers.

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- The methodology support (design thinking training) will be provided by the Innovation department with some extended support from external suppliers such as *confidential* .

Summary of project efforts in person-months: by cost allocation and by year

confidential

Project 22: Forecasting Development Platform

Domain 2.3

NEW PROJECT:

Trends: Decarbonization,

Consequences: Uncertainty and intermittency of generation, new system dynamics, new decentralized resources

Challenge: 2. Automate the system operations to be capable to optimize the network in minute timeframe for frequency,

Domain: 2.3 Predict and automate imbalance dispatching decision

Project Specific Context

- Forecasting remains an area prime for improvement and more collaboration: many business users need similar forecasts for their work. Example of forecasts are: grid losses, imbalance prices, renewable generation (solar, wind), predictive maintenance, weather conditions, grid load, etc.
- Currently, a restricted number of environments are available for cooperation between multiple parties, and even between multiple teams inside Elia. This is caused by issues such as siloed data, a lack of dataset versioning, and isolated development environments across different teams (in the same company) and different energy system players (across different companies).
- This project aims to solve this problem of lack of collaboration in developing forecasts, and this by providing code, data and trained model sharing for forecasting developers. To our knowledge, it would be the first platform of its kind to enable collaboration across multiple energy players.
- The goal of the forecast development platform is a shared data and development ecosystem aimed at fostering collaboration in advanced analytics, AI and forecasting between internal and external experts to solve forecasting challenges of future energy systems

Project specific State-of-the-art/Literature study

- NationalgridESO has introduced a platform for energy forecasting (PEF) to share historical and forecasted data. More information: **link** . However, this platform does not support collaborative forecast development, and is rather focused on sharing forecasts after they are developed.
- Open-source development platforms (*confidential* etc) exist but these do not enable collaboration. Other open-source tools for code sharing *confidential* exist but are not focused on energy. In the case of *confidential*, it is also not possible to host code in a way that is not entirely public to all.
- Several ML platforms exist but none them is focused on the energy sector and collaboration in particular:
  - Low-Code or No-Code solutions*confidential*
  - Code-based solutions: *confidential*
  - Internal Tools at corporates: *confidential* , Elia
- Elia Internal Tools
  - *confidential*: coding environment only available for the R-language. Does not allow sharing or versioning.
  - *confidential*: Notebook development on browser-based cluster. Code sharing possible via integration with Azure DevOps. Data sharing and versioning is not possible.

Expected impact for Belgium

- Direct advantages for Elia: improved forecasts quality due to synergies potential (in terms of efficiency, costs): more accurate forecasts and shorter time to develop forecasts. The forecast development platform advances the digital transformation of Elia by building the capabilities to set up a community platform and collaborate with partners in an agile environment and open innovation way. Through better forecast we could notably reduce the error of load forecasting or the reserve of ancillary services needed to be activated and then the cost of imbalance paid by BRP's.

- Indirect advantages for the end consumer: better forecasts (of renewables, of grid status, etc.) delivered more efficiently, lower system operation costs and improved renewables integration, ultimately leading to a higher security, sustainability and affordability for the end consumer

Starting point Elia

- Currently available tools at Elia limit the ability to collaborate across teams and departments for forecasting purposes
  - Too many tools: different internal tools (E.g***confidential***, etc.), different external tools;
  - Difficult to collaborate: data stored internally for one team can be difficult to access by other teams, different tools available to employees at Elia, currently not possible or very difficult to collaborate with anyone outside the Elia ecosystem.
  - Difficult to search & find synergies: no way to easily see what other groups are working on and find synergies, no centralized repository/list of projects, even within one's own department, difficult to find and share past work;
  - There is though not structural exchange between TSO's about the exchange of forecast best practice.

Uncertainties & risks

- Risk is that the tool does not sufficiently address the needs of the forecast expert's community, that it is not practical or user experience is not as good as expected. Therefore, the forecasting development platform is in competition with other platforms or alternatives available, or other internal tools developed by other TSOs.
- Players in the industry might be interested, however a higher number of participants could lead to suspicion and might lead to less sharing. There might also be a risk of limited incentive at external players' to share data.
- Access to (live) data might be limited due to security restrictions. Need to develop dedicated security protocols for agile and shared software development with a clear separation from the secure, live environment (live data also not necessarily needed for forecast development), and with respect of privacy.

Project description

- The goal of the forecast development platform is a shared data and development ecosystem to foster collaboration in advanced analytics, AI and forecasting between internal and external experts to solve forecasting challenges of future energy systems
  - enable partnerships to share and collaborate on forecast development
  - Applicable to any energy-related forecasting type
  - Exposure through Open Source access of the platform and/or forecasts: open source and sharing module to universities, other system operators, and eventually other third parties
  - Elia as Plattform facilitator
- Concept
  - Input: data and forecasting modules (open source time series and machine learning algorithms, open source programming languages and packages). The forecasting development platform can ingest data from different data sources. E.g. CGMAs[11] could be one of the input sources in the case of grid-related forecasts.
  - Platform
    - Backbone: Dataset access and versioning, code sharing and search, model versioning and sharing
    - Smart tools: Advanced functionalities (e.g., operational cloud computing, real-time data access, …) could be offered
  - Outputs: improved forecasts, sharing of data and forecast models

[11] CGMES = Common Grid Model European Standards, defines the software interface between TSOs, building on the Common information model, CIM.

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  - Integration into production: environment to demonstrate / industrialize developed forecasts by integrating into production environment

- Approach
  - Kick-off development through participation in Elia's "NEST" incubator: access to staffing and support, quick start date, opportunity to refine and test out in an agile and focused way
  - External users (universities, other) consulted from the start to make sure these users are considered
  - Development of platform backbone as starting point, gradual scale-up through addition of smart tools, additional data, parties and forecasts.

- Work packages and timing
  - WP 0: Design (NEST incubator) - 2021
    - Setting up of open source platform backbone, defining key features using design-thinking process
    - User interviews of both internal and external stakeholders and potential future platform users
    - Data access & sharing module
    - Applied to a one forecast (predictive maintenance or grid load). We selected a 'ready-to-use' example to apply the features of the platform. Next to predictive maintenance, grid load was also identified as one of the potential examples, given the needs of NCC.
  - WP 1: MVP Joint development - 2022
    - The platform will support collaborative forecast development with the MVP focused on shared data management for a forecast development project.
    - Additionally, a first outside forecasting partnership with an independent partner (TSO) will be targeted after the initial design, limited first to one or a restricted set of forecasts.
    - Once the platform has been established it can be opened for other TSOs, universities and players of the energy sector to participate in Elia's initiated forecast development. At the same time TSOs, and other parties should be encouraged to partner on the platform to develop forecasts independently from Elia
  - WP 2: scale up and expansion - 2022
    - The further development will then be guided by a collaboration with an external TSO on different forecast development projects
    - Universities and think tanks would be able to access data and work on improving current tools. The approach needs to ensure that forecasting development still focuses on practical applicability rather than research only
- Deliverables and milestones:
  - October 2021: Key features of the platform identified, architecture outlined. Technical roadmap created. Mock-up of key features and user interface created.
  - March 2022: Backbone features built. Platform becomes standard to use when creating new forecasts within Elia. Target partner TSO or other energy system party identified for collaboration.
  - November 2022: Additional features like access to real-time streaming data included. Number of users increases.

Partners

- Academic researcher / universities
- Other grid operators (TSO/DSO)
- Coach and other support from the Nest (cost not taken into account in this project)

Summary of project efforts in person months: by cost allocation and by year

confidential

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Project 23: Hyperspectral camera as inspection method for the condition evaluation of painted metallic towers of overhead lines

Domain 4.3

NEW PROJECT:

Trend: digital revolution, digital inspection, new technologies
Consequences: Optimize the operation of our existing assets, improve the quality
Challenge: 4. Optimize the development, the construction and maximize the use of new and existing infrastructure
Domain: 4.3 Advanced material and connected technology to maximize use for infrastructure

Project Specific Context

The goal of the project is to explore the possibility of using a new innovative technology (the hyperspectral camera) to properly detect the damages of the painted metallic towers in terms of corrosion; classify these damages according to their severity with a non-invasive method (invasive method = climbing in the tower & scratching the surface).
This technology is being explored to meet a very real need for the inspection of lattice metallic towers. The metallic towers are overhead lines assets and are necessary to transport electricity between substations. The oldest ones are from the year 1923 and they are still active. Most of them are reaching their end of life and it is very important to have a decent inspection method in order to properly assess their remaining lifetime and their repair needs. The current inspection method (the climbing inspection) is very good at assessing the state of the tower but requires a lot of resources, present a risk for the persons climbing and the outage required to inspect the tower is very hard to obtain. For these reasons, a new innovative technology is explored.

The project will be delivered in three main parts:

1. **Technical feasibility** to detect and evaluate corrosion on metallic towers and evaluate the correlation with current climbing inspections. In addition, a first alignment about the reporting of the results of the inspection technique is done.
2. **Practical utilization and methodology** of the inspection techniques on-site (e.g. with drones, during inspections on foot,…). In addition, the reporting of the results of the inspection technique is finished.
3. **Implementation of new inspection methodology** aligned with (future) inspection strategy to evaluate the condition of metallic towers of overhead lines. In this part stage, also the sourcing strategy has to be evaluated and defined.

Project specific State-of-the-art/Literature study

- No known similar study or project in the current application that we are exploring
- Literature exists for the technical assessment of the hyperspectral camera (in general)

Expected impact for Belgium

Metallic towers are old assets and as such, there are many inspection activities around them to detect deteriorations of the structure (for example the degree of corrosion behind the paint). With this new technology, we expect to improve the way we inspect these old towers & identify new ways of maintaining them better.

- Increase in safety -> less climbing in towers because we would be able to do a detailed corrosion inspection from the hyperspectral camera mounted on a drone
- Avoid outage during inspection-> we would be able to do detailed corrosion inspection from this new camera mounted on the drone (non-invasive).
- Improved quality and efficiency of the corrosion inspection. We expect to be able to do the detailed inspection better and faster. We expect the hyperspectral camera inspection to be much more flexible then climbing inspection as it'is not limited to the outage availability of the inspected line.

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- Reducing cost : Actual climbing inspection budget range from *confidential* and we expect the hyperspectrale camera activity to replace a part of it (depending on its effectiveness).

Starting point Elia

- Testing of the feasibility of the Hyperspectral camera technology
- Upon successful testing, explore the feasibility and business case around the practical utilization of the technique for the specific inspection activity

Uncertainties & risks

- Hyperspectral camera is a new technology which has not yet been fully commercialized for industrial use
- The technology is in testing phase, maturity assessment, and exploration is ongoing on how it can be applied to specific uses in the industry
- The risk of this project is related to the uncertainty whether the hyperspectral camera will deliver qualitative images that with the help of AI will be able to identify accurately the rust under the paining in our metallic towers

Project description

Work packages & Timing (M=month)

- WP-1 Technical feasibility study in the lab conditions (1-3 months)
- WP-2 Technical validation study in the field (3-4 months)
- WP-3 Implementation of new inspection methodology (5-6 months)

Deliverables & milestones

WP-1 Technical feasibility study in the lab conditions

- Deliverable 1: Technical report (2 suppliers, comparison, decision whether to proceed or not)

WP-2 Technical validation study in the field

- Deliverable 2: Algorithms for image preprocessing (software)
- Deliverable 3: Algorithms for image defect classification (software)
- Deliverable 4: Evaluation of the camera components (report)
- Deliverable 5: Reporting of the results (software)

WP-3 Implementation of new inspection methodology

- Deliverable 6: Prototype drone integration and validation (report/software)
- Deliverable 7: Protocol of the inspection on-site (report)
- Deliverable 8: Sourcing strategy evaluation (report)

Partners

confidential

Answers to questions raised by the CREG in July 2021:
The difference between this project and project 9 (BVLOS drones for automate inspection) is the focus of the project. Project 9 focuses on the use of drones that can be flown without any kind of monitoring whereas this project focuses on the inspection medium and the interpretation of the images. This project includes an implementation of the camera on a drone (smaller than the BVLOS one) to better understand the requirements linked to the use of the hyperspectral cameras (stability, lighting condition, distance of inspection, etc.).

Summary of project efforts in person months: by work package and by year

confidential

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Project 24: No new project

Domain 4.3

Project 25: Smart Wires

2021 decision: Accepted

Trends: Decarbonization**,** digital revolution

Consequences: Ageing of the infrastructure, Develop infrastructure to flow important RES infeed

Challenge: 4. Optimize the development, the construction and maximize the use of new and existing infrastructure

Domain: 4.3 Advanced material and connected technology to maximize use for infrastructure

Project Specific Context

- The purpose of this project is to test, through a proof of concept (POC) to be rolled out on our grid, a new technology called 'SmartValve' developed by the company Smart Wires.
- This new technology allows the impedance of connections (overhead lines) to be dynamically increased or reduced by injecting a voltage in quadrature with the current. In a similar way to a phase-shifting transformer (PST), this technology makes it possible to control power flows running through overhead lines.
- This technology has already been deployed on a fairly massive scale in the United States but tends to be only at the testing stage in Europe (Ireland, France).
- It should be noted, however, that this technology is not intended to replace PSTs on cross-border 380-kV lines, as the necessary surface to reach the same effect would be unreasonable . While it is true that the higher the level of current, the greater the impact of a Smart Wire module, it can be also be very useful for connections carrying a lower current.
- Elia has already identified parts of its grid where this technology could potentially be tested and be highly beneficial, namely the 150-kV Koksijde-Slijkens cable, as this would avoid redispatching at Herdersbrug (costs estimated in the future at ***confidential*** per year). Moreover, once the Ventilus project is completed, the cable would no longer face overloads. Unlike a PST, the Smart Wires module could then be disassembled and reused elsewhere.
- However, before deploying this technology on a very critical line in our grid, we propose initially performing a POC on the 70-kV meshed network in which overload limitations are also identified. This POC would allow us to test whether the device operates properly, identify any limitations, and check whether the device behaves appropriately in the event of a fault, to ensure that faults are dealt with appropriately.
- To do this, we propose installing this module in series on the 70-kV Cierreux-Houffalize line. The installation of this module in the eastern loop would reduce the need to call on the flexibility of connected renewable production units or make it possible to consider connecting more production units, in particular at the Cierreux substation. Therefore, in the event of the loss of the 70-kV Cierreux-Brume cable, this module would mean that the relevant flows could be forced north of the loop, preferentially onto the Cierreux-St. Vith line rather than the Cierreux-Houffalize line.

Project specific State-of-the-art/Literature study

- Based in the San Francisco Bay area and with offices in the United States, the United Kingdom, Ireland, and Australia, Smart Wires is the leader in grid-optimization solutions that leverage its patented modular power flow control technology. Smart Wires solutions can be deployed quickly, enabling utilities to react fast and address pressing problems.
- Smart Wires' technology was developed by utilities for utilities, led by a consortium of large US utilities at the National Electric Energy Testing Research and Applications Center (NEETRAC). This core group of utilities, which included Southern Company and the Tennessee Valley Authority (TVA), defined the vision for the original modular power flow control solution. PG&E, EirGrid (Ireland), Minnesota Power, Central Hudson, and Western Power (Australia) are just some of the other utilities leveraging Smart Wires' solutions in this domain.
- Smart Wires teamed up with EnerNex to study the implications of the SmartValve and SmartBypass for sub-synchronous resonance (SSR). EnerNex found that active voltage injection from the SmartValve provides reactive compensation at line frequency like conventional series capacitors, but its actions do not extend to other frequencies. For more information, please refer to the study *Comparative Performance of Smart Wires SmartValve with EHV Series Capacitor: Implications for Sub-Synchronous Resonance*, available on the Smart Wires website.

Expected impact for Belgium

- The targeted solution is a flexible AC transmission system that is similar to PSTs, but that has the following advantages:
  - lower costs;
  - quick installation (around one year);
  - modular technology (modules to be connected in series depending on the required flow control);
  - ease of redeployment: when the strain on the network is eliminated, the module can be easily disassembled and redeployed elsewhere, even for a different voltage level;
  - no need for transportation as an abnormal load (unlike PSTs).
- It could be an alternative solution for PSTs in the sub-150-kV grid or be combined with them. We could notably in the POC demonstrate or not the economic advantage of the smart wires in opposition to the PST. A PST is worth between ***confidential*** while the cost for smart wires is estimated at ***confidential*** . But the main gain is in the re-usability of the smart wire solution, as it can be easily transported.
- It enables renewables' penetration to increase in some regional networks/an increase in the time frame for upgrading the grid from 70 through 110 kV.
- It could ease brief periods of congestion (e.g. in case of works).
- It could be an alternative solution to overly short time frames for conventional solutions (e.g. PSTs).

Starting point Elia

As explained above, this project is new and a proof of concept. It is the first time that Elia has used such technology and therefore the idea is to learn a lot about it.

Uncertainties & risks

- There is a risk of involuntary bypass activation, requiring a quick modification of power fluxes in the lines.
- Risk mitigation:
  - For the POC: In planning and operational criteria, take into account 'n-1' smart wires (= involuntary bypass activation) to ensure that the grid can cope.
  - Take an in-depth look at the documentation produced by Smart Wires (explanations of bypass mode activation and advice regarding settings).
  - Check whether protective devices are working and/or malfunctioning.
  - Examine the possibility of historical data for I0 and I2(?).
  - To be discussed with Smart Wires: Possibly combine of the two detection functions (VDC supervision and I0/I2).
  - Contact other users for feedback about communication and bypass activation.

Project description

The purpose of this project is manifold:

- to carry out a feasibility study for installing such a module at the Houffalize substation, doing so in series on the Cierreux-Houffalize line; this feasibility study means establishing a multi-departmental working group: AM (HV, Powerlinks, LV, and the telecommunications and communications aspects with the Dispatching), Infrastructure, GD, Safety, MAC, Netop
- to purchase the Smart Wires module (3 Ω) and install it;
- to make the appropriate adjustments to the 70-kV Cierreux-Houffalize line (descent and installation of an insulator to allow the module to be installed in series on the line);
- to analyze and implement the control of flows on the grid from Elia Dispatching (remote management);
- if necessary, to move the 70-kV cable of the Houffalize 220/70-kV transformer if it is in the module's installation area.

- Work packages and timing (M = month)

<u>July 2020 – April 2021</u>

1. Preliminary study
2. Permit application
3. RFP preparation

- Deliverables and milestones
    1. Feb. 2021:
        i. Detailed project specifications
        ii. RFP selection
        iii. Issue of the permit
    2. May 2021: Implementation.

Partners

- Smart Wires

Summary of project efforts in person months: by work package and by year

confidential

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Project 26: Universal Cable joint

Domain 4.3

2021 decision: Accepted

Trend: Decarbonization, digital revolution

Consequences: Develop infrastructure to flow important RES infeed

Challenge: 4. Optimize the development, the construction and maximize the use of new and existing infrastructure

Domain: 4.3 Advanced material and connected technology to maximize use for infrastructure

Project Specific Context

- Underground cable systems are widely installed on the Belgian network. Specific test programs are performed to qualify these cable systems, for the different voltage levels and cable suppliers. This aims to have a reliable system on the long term. Up till now, no qualification has been performed of cables from different suppliers due to the differences in design, materials used, etc.
- In order to have more flexibility for projects building further on existing cable links, the idea has risen to qualify transition joints between different qualified cable suppliers in order to connect cable systems from two different suppliers with a qualified universal cable joint. This universal cable joint can also be used to perform repairs on an existing cable system with another cable supplier than the installed system. The starting point for the universal cable joint is the 150kV cable system on the Belgian grid.

Project specific State-of-the-art/Literature study

- No known similar study or project except an initiative launched by Tennet a few months ago

Expected impact for Belgium

- To have more flexibility for new projects which are building further on existing underground cable links and have the possibility to connect cables from another cable supplier to this existing underground cable link. This would bring more competition in the selection of cable providers and therefore decrease the total cost of the infrastructure. This could then decrease by few percent minimum the cost for 1 or 2 projects per year.

  The flexibility of using multi-suppliers will also allow to make repairs of existing underground cable links independent from the cable supplier who has installed the initial underground cable link. This will therefore enable more competition between companies repairing the cables and also shorten the time for a repair (then decreasing the risk of an extended outage of a critical infrastructure and support the adequacy). Currently, after the warranty period, Elia depends the goodwill of cable suppliers. Intervention times are not contractual guaranteed. The aim is to obtain contractual intervention times with the selected supplier for cables out of warrantee. Our objective (subject to negotiation) is to have a team and material on site *confidential* after the incident occurs. The *confidential* are based upon the time needed for fault localization, work permits and civil works that needs to be done upfront.

Starting point Elia

- This universal cable joints should be able to connect not only cables from different cable suppliers, but also cables with different design, conductor materials (copper and aluminum), conductor cross-sections and different types of metallic screens. The combination of all these things in one universal cable joint makes it quite complex.

Uncertainties & risks

- As the solution will bring more competition, a first uncertainty is whether Elia will benefit from full cooperation of all involved parties, since exchanges of material of different suppliers is needed
- Another risk is of course the technological possibilities to develop a design of cable junction that is able to combine the different requested parameters as described above

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- Finally, as any innovation, the test in real conditions might show operational challenges. Qualification tests of this universal cable joint could then possibly lead to the identification of unforeseen issues.

Project description

- Design and qualification of a universal cable joint for 150kV.
- Given the changing environment with different stakeholders and the expansion of the underground cable network, Elia needs to find innovative solutions and the universal cable junction is one of these.

- Work packages & Timing(M=month)
  1. MOU with involved parties
  2. Start negotiations for FA for the RTJ
  3. Determine final types of accessories and test loop setup
  4. Material acquisition for test loop
  5. Selection of test facility for type test
  6. Qualification test

- Work packages 1 and 2 have changed to a European Tender Procedure for a Frame Agreement for the manufacturing, testing, delivery and installation of an universal transition joint
  - Contract Notice has been launched in Q1-2021
  - Preparation ongoing for tender documents in Q1-2021
  - External consultant to assits with tender specifications (*confidential*)
- Updated planning for WP 3 to 6 (due to EU tender procedure instead of negotiation procedure)

  1. Q1-Q2: Technical specifications for EU tender procedure universal Transition joint
  2. Q1-Q4: EU tender procedure for FA universal Transition Joint
  3. Q4-2021 Determine final types of accessories and test loop setup
  4. Q1 – 2022 Material acquisition for test loop
  5. Q1 -2022 Selection of test facility for type test
  6. Q2-Q3 2022 Qualification test

Partners

- Cable supplier and test facility to be selected. For complete info, EU tender has been launched, three candidates have been pre-selected. Final selection will be done at the end of the EU tender procedure which will take till end of 2021

Summary of project efforts in person months: by work package and by year

confidential

Project 27: Trilate

Domain 5.2

NEW PROJECT

Trend: Decarbonization, digital revolution

Consequences: Sustainability in our business

Challenge: 5. Make the TSO business (market facilitation, system operations and asset management) more sustainable

Domain: 5.2 Sustainable system operations

Project Specific Context

In Belgium, the energy demand is very high, especially in the energy-intensive industrial clusters, while the potential for renewable energy is limited. This project will be investigating the energy system requirements for renewable energy carriers, such as electricity and gaseous molecules, including an assessment for the required energy infrastructure. The proposal contains a research component, focusing on the development of scientific models at various levels of scale and a feasibility component, performing an integrated energy infrastructure assessment for industrial clusters.

Fundamental modelling of various aspects of the industrial system, at process, site, cluster and (inter)region level is within the scope of the project. Interactions between these different modelling levels will be a special focus of this project, addressing a key research question: *"How can multi-level models starting from detailed processes up to regional industrial clusters identify optimal technologies and energy system needs for a secure, profitable and sustainable transition?"*

Furthermore, a fundamental research part, in the form of a technology study on the future power grid, and a feasibility part on the energy infrastructure needs for different industrial clusters and regions is performed. The necessary transport infrastructure will be assessed in a concrete feasibility study on renewable power and hydrogen for different industrial clusters. For the second work package, the key research question is: *"Which investments are needed in energy transport infrastructure to facilitate a cost-effective and reliable transformation towards a future climate neutral energy-intensive industry?"*

Project specific State-of-the-art/Literature study

Currently ENTSO-E and ENTSOG perform common investigations on the interlinkage between gas and electricity scenarios and infrastructure projects assessment. This work has thus a Pan-European scope.

The TRILATE project also focuses on energy system requirements for renewable energy carriers, such as electricity and gaseous molecules but with a regional focus on the Belgian system and on Belgian industrial clusters.

The TRILATE project will therefore improve the Pan-European assessment by introducing local considerations related to technology, economic interest and industrial and end-usage consumer behaviors and expectations.

Expected impact for Belgium

The TRILATE project will provide a specific assessment of energy system requirements for renewable energy carriers for Belgium, including an assessment for the required energy infrastructure.

Starting point Elia

The starting point for Elia is the latest European ENTSO-E & ENTSOG scenarios from the latest available TYNDP (eg the latest "National Trend" scenario of ENTSOG/ENTSO-E) considering relevant horizons of the study, ie 2050 or 2040 (if available) scenarios

National specificities for Belgium within the Belgian National Energy and Climate Plan (NECP) and defined within the quantitative industrial decarbonization scenarios and demand developments as part of WP1 of the TRILATE project will be used in WP2 for the "feasibility study on the identification of interconnection needs (WP2.1.2)" work

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Uncertainties & risks

The project faces the following uncertainties & risks:

- Intrinsic **uncertainty** of a research project: The project aims to answer the research question:

    - *"How can multi-level models starting from detailed processes up to regional industrial clusters identify optimal technologies and energy system needs for a secure, profitable and sustainable transition?"*

  This first question aims to identify, via a bottom up process, optimal technologies and energy system needs from the global perspective of the Belgium energy system, which is in turn part of the European energy system. The risk will be for the project to miss the right balance between a fully detailed assessment of individual sites and processes, and a regional view on the different energy carriers and needs. The project should avoid the risk of "*not seeing the forest for the trees"*

- **Risk** that a Pan-European assessment of the energy system requirements will miss or not fully capture national specificities and local needs and constraints: The project aims to answer the research question:

    - *"Which investments are needed in energy transport infrastructure to facilitate a cost-effective and reliable transformation towards a future climate neutral energy-intensive industry?"*

  The project wants to mitigate possible shortcomings of a Pan-European assessment with respect to national specificities and local needs considerations. The idea is to perform a "stress test" analysis of the Pan-European needs identified, to define non-regret robust investment strategies which include those local specificities. Also, the project could further refine the definition of any such Pan-European investment need, by translating those into more local plans also with a focus on the needs as defined by the quantitative industrial decarbonization scenarios and demand developments foreseen in the project and hence beyond the Pan-European scenarios.

Project description

WP1: Fundamental models in industrial sectors

Task 1.1 Numerical models based on thermodynamic first principles (ULiège)

Task 1.2 Industrial system integration, blueprint processes and algorithms

Task 1.3 Energy and feedstock flows synergy modeling

WP2: Energy System infrastructure needs

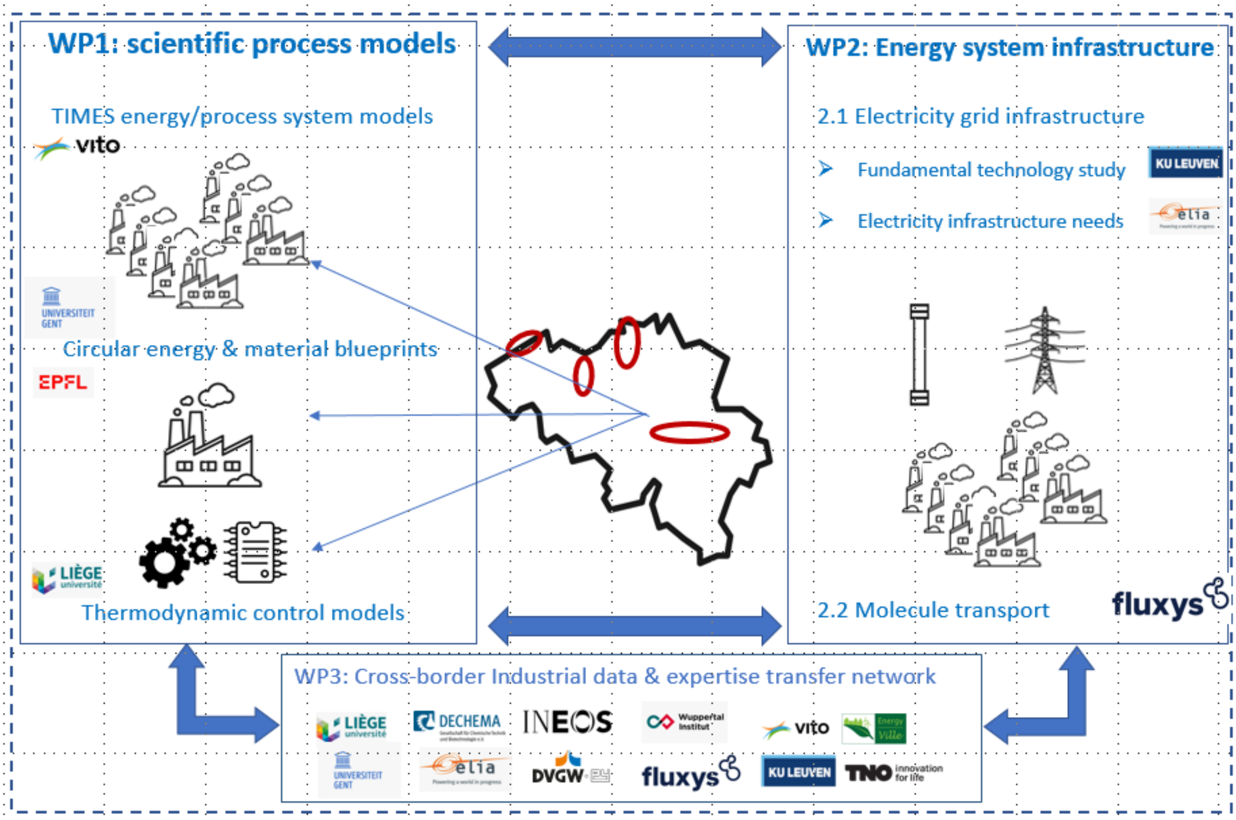
Task 2.1 Electricity grid infrastructure

-Subtask 2.1.1 Fundamental study on the needs of the power system

-Subtask 2.1.2 Feasibility study on the identification of interconnection needs (Elia lead)

Task 2.2 Molecule transport infrastructure

WP3: Industrial data and expertise exchange network



Partners

VITO/EnergyVille (coordinator)

Fluxys

Universiteit Gent

Université de Liège

Katholieke Universiteit Leuven

Summary of project efforts in person months: per work package and per year
confidential

CREG feedback Project 27 - Trilate

Regarding Quantitative estimates of the expected benefits incl benefits for the final consumers.

- Task 2.1 work to be performed by Elia will investigate the interconnection 'borders' between small zones in the model, much smaller than the bidding zones of the current market design, with focus on the Belgium area. The main delivery will be a set of identified 'solutions' in terms of infrastructure needs to enable electricity exchanges needed to reach decarbonisation targets while and keep security and costs under control.
- The modelling will consider the benefits of a fit-for-purpose network with the right investments in the right places – in terms of electricity prices, continued access to electricity and completion of climate objectives – and propose them if these outweigh the necessary efforts – investments which will need to be mobilised in the next decades for its construction.
- The different grid reinforcement & investments will be assessed by use of a CBA analysis, based on the European ENTSO-E methodology.

- The TRILATE project will

  - Provide a more in-depth analysis with respect the Pan-EU Identification of Systems Needs (IoSN) focusing on national specificities for Belgium, and by use of detailed bottom – up information provided by the industrial partners in the project, in relation to the electricity demand and future electrification of large industrial customers in Belgium, Netherlands and Germany.

  - Perform relevant sensitivities as 'stress tests' analysis for the region, to e.g. test for different industrial demand scenarios defined in the project and identify their investment needs and how those compare with the ones identified within the TYNDP plans.

Further detailed information on the project description as well as a clear roadmap for 2022, with a description of the deliverables and milestones.

- At this moment it is not possible to provide such a detailed 2022 roadmap including exact dates for deliverables and milestones. Such roadmap will be developed within the consortium upon the start of the project. Concretely regarding the work to be performed by Elia in WP2 such detailed planning will be dependent on the delivery of the electricity demand and future electrification of large industrial customers scenarios by the partners of WP1, which at the moment is not yet defined in detail.
- The kick off of the project will take place at the beginning of October.

Develop success criteria in order to allow for an efficient ex-post evaluation.

- KPIs will be the different grid reinforcements & investments needed to accommodate the newly defined industrial demand scenarios within the project.

Justification for the budget plan.

- At the moment, the budget was prepared assuming that the work will be performed by internal resources of Elia, hence no outsourcing to consultants or other external cost have been provided explicitly in the budget estimate,. However it is not excluded that external resources might actually be required during the actual work by Elia. Also note that Elia will provide 50% of the total cost as 'in-kind' contribution.

- [Trilate specific] CREG invites Elia to further explain the innovative aspect of this project
  - The innovative part of the project is provided by the combination of

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        - i) on one side a bottom-up multi-level modeling of detailed industrial processes for the different assets, located within each the different industrial clusters. These analysis will provide input for the definition and/or revision of the scenarios and sensitivities to be considered

        - ii) on the other side these 'new/updated' scenarios will be analyzed to identify optimal energy system needs and investment opportunities towards a secure, profitable and sustainable energy transition of energy-intensive industrial clusters in Belgium

    - This project is thus innovative because such scenarios have never been assessed at Elia and both the fact that i) the focus is on and ii) input is provided by, industrial partners needs, has not been assessed in this level of detail before.

    - Elia within the its core activities, is committed to ensuring a high level of quality and innovation in the market and grid assessments which are readily performed to fulfill both legally mandated tasks at national and European level.

    - While complying with the methodology frameworks prescribed in national and European legislations, Elia aims, to the extent possible, to take advantage of latest innovations and improvements, in order to keep a state-of-the-art approach. Elia is therefore committed to keep awareness on innovations in Belgium and Europe, especially though interactions with universities, research institutions and industry experts. The TRILATE project is a perfect opportunity for Elia to take advantage as well as to contribute to latest innovations and improvements

- [Trilate specific] Link between this project and the Task Force Scenario.
    - One of the project's objective is to mitigate possible shortcomings of a Pan-European assessment with respect to national specificities and local needs considerations. The idea is to perform a "stress test" analysis of the Pan-European needs identified, to define non-regret robust investment strategies which include those local specificities. These specificities will be defined by "quantitative industrial decarbonization scenarios and demand developments" foreseen in the project and hence beyond the Pan-European scenarios.
    - Elia considers that the work within the Task Force Scenario, is rather complementary as it e.g. focuses on co-creation of scenarios, especially regarding the definition of scenarios including national specificities and local needs considerations beyond the Pan-European scenarios. It should be noted that the timing of the TRILATE project might not fit one-to-one with the TF Scenario process, as these are, in principle, independent processes.
    - Elia will facilitate & monitor, to the extent possible, overlaps and interactions between these two initiatives. These interactions & overlaps could be in both directions
        - Elia could bring elements defined in TRILATE to the TF Scenario for feedback and consideration

          and/or

        - Elia might be able to add input from TF Scenario into the work to be performed in TRILATE, should there be relevant elements defined in TF Scenario which are neither captured by the Pan-EU scenarios nor by the TRILATE "industrial decarbonization scenarios and demand developments" or in case a clear synergy is identified.
        -
        - In TRILATE the focus is in defining scenarios for industry only. Inputs from TRILATE could be further used in the definition of scenarios for other Elia studies.

Project 28: Offshore grid optimizer

Domain 2.3

NEW PROJECT:

Trend: Decarbonization

Consequences: New system dynamics, Intermittency of generation, Uncertainty of generation, Digital tools & data use

Challenge: 2. Automate the system operations to be capable to optimize the network in minute timeframe for frequency, voltage and congestion

Domain: 2.3 Predict and automate imbalance dispatching decision

Project Specific Context

- Belgium will not be able to produce enough onshore renewable energy on its own to decarbonize its society while meeting its future energy demand at the same time
- Untapped offshore power and its integration to the grid is essential to bridge this gap of demand and decarbonized supply. The importance of offshore is also reflected at European level in the European Commission's strategy to increase offshore wind capacity from 15 GW to at least 60 GW by 2030
- While windfarms have already reached a very high level of maturity to in terms of their construction and operation, the integration to the grid requires innovation and progress to facilitate the transport of this clean energy from the windfarms at sea to the demand centers on land at the most cost efficient and flexible way
- Specifically, this grid integration will require further innovation to move from a conventional interconnector to a hybrid offshore interconnector that can link the transmission grids of Belgium to other countries such as Denmark via national offshore wind farm grid connections. The primary innovation of such interconnectors is the double use of wind parks that are connected to onshore grids as an interconnector that allows to use the assets to make use of the remaining capacity in times of low wind as an interconnector via a cable to the onshore grid

To successfully operate these hybrid offshore interconnectors a master controller is required to optimize the entire optimal power flow (OPF) cycle. This entails real-time data processing and evaluating P/Q references to control active and reactive power flows through the interconnector, to set the optimal power flow calculation (OPF) based on the specific grid model to undertake predictive and forecast functions to complete the interface between hardware and software for the optimizer

- The objective of the offshore grid optimizer project is to build this s master controller software to optimize hybrid interconnectors based on different topologies such as potentials interconnectors between Belgium and Denmark
- The task of the optimizer is primarily to calculate the capacity for the market (based on the designated topology, the dynamic line ratings and wind forecasts), to avoid the overload of the equipment, and to control the voltage limits.
- This will enable higher integration of renewable energy into the Belgium grid and enable complex offshore meshed grid flow optimization, reduce congestion and enhance security of supply and indirectly support public acceptance for renewable energy infrastructure.

Project specific State-of-the-art/Literature study

- Nemo Link was the first HVDC interconnector to connect onto the Belgian system. The trend clearly points towards further HVDC interconnectors, either to offshore renewable platforms or to direct interconnectors to foreign countries.
- Current projects include the Direct Non-Neighbor Interconnector and the BE Access Northern Sea Interconnector.
- The Direct Non-Neighbour is a Belgium – Danish cable that will facilitate the first connection of Belgium to an electricity market that is further away than Belgium's direct neighbors. It will make Belgium electricity system more sustainable

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- The BE Access Northern Sea is hybrid project that will allow Belgium to access large wind farms in the northern part of the North Sea where the meteorological conditions are different from those off the coast of Belgium. This will provide greater security of supply and will help energy-intensive Belgian industries to continue decarbonizing their processes and achieve the climate targets.
- All of these interconnectors require an optimizer to ensure the most efficient and cost-effective operation by providing an interface of real time data to capacity calculations, market schedules, equipment limits, system limits and the optimization of renewable energy production
- These tasks can be performed by the dispatcher but in order to reach an optimal operation of the offshore grid, it is crucial that an optimizer is at disposal which can support the dispatchers, or eventually take over the tasks in normal operation
- As of today, Elia's daughter company 50Hertz, is the first TSO in the world that has installed a hybrid interconnector (*confidential*) that is optimized by a master controller, the so-called "MIO" which is able to control the entire optimal power flow.
- However, the 50Hertz MIO is specifically tailored to the topology of the CGS and is therefore not able to be operated in different topologies
- Therefore, Elia has the ambition to develop the first modular master controller. The modularity of this master controller would be innovative by design and would allow the software to serve as plug and play product that can be operated in different topologies.
- For Elia and the Belgium consumers specifically, this master controller can be used in the context of a Belgium Energy Island in the North Sea and the interconnection between Belgium and Denmark

Expected impact for Belgium

- Thanks to an optimizer of HVDC equipment, we can ensure that the optimal working point will always be reached during normal operation. This means a maximized social welfare as we will maximize the use of the offshore infrastructure and therefore the use of green energy produced from the offshore wind park in Belgium.
- The business case of the optimizer entails the efficient integration of offshore wind by making double use of existing windfarms in operations, instead of building new assets, to serve as an interconnector via AC cables connected to the Belgium onshore grid. The optimizer itself will avoid equipment overloading and thus reduce the required maintenance. Building and operating the optimizer in-house will reduce vendor lock in of external supplier and reduce the cost of development.
- For the consumer, hybrid interconnectors enhance general public acceptance for renewable energy and their integration into the grid since the untapped offshore potential does not need to interfere with the grid expansion on densely populated areas. Furthermore, it allows to make use of the maximum reactive power exchange which will reduce congestion, minimizing tapping and control interference and transmission losses and thus enhance the security of supply. This will improve operations for the future Bornholm Energy Island and Belgium Energy Island.

Starting point Elia

- Currently, at Elia, no expertise in this domain exists.
- A first step of the project is to organize a workshop to gather relevant experts and stakeholder.
- Align with potential partners such as Belgium research institutions and offshore developers.
- Objective of this workshop is to build on existing expertise, namely from the Combined Grid Solution project and its Master Controller for Interconnector Operation, to identify the minimum viable product based on the necessary input variables and output variables.

Uncertainties & risks

- Risk on controller / make it modular;
- Risk on performance and results of such optimizer taking into account the very dynamic behavior of the renewables energy;

- Data availability in near real-time for operations will be crucial in order to feed the optimization algorithm;
- Interoperability of the different data sources.

Project description

- We will first define the input and output requirements of optimizer for hybrid offshore interconnectors controller
- Then we will work on the architecture of the software
- Finally, the objective of the project is to develop a software that is able to undertake capacity calculations (with and without DLR) dependent on wind feed-in forecast to optimize the capacity given to the market, to optimize the input for automatic counter trade processes, to take physical control of market schedules, to avoid equipment overload, and to control voltage and reactive power

Visualistation of input and output parameters of offshore grid optimizer

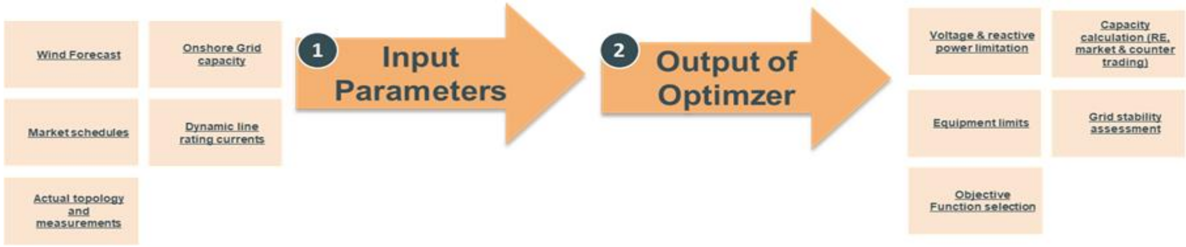

Figure 12 – Offshore optimization logic

Deliverables and milestones:

WP1: Scoping of hybrid offshore master optimizer by organizing a workshop with the objective to clearly define the input and output requirements to develop an optimizer for a hybrid offshore interconnector (October 2021 to February 2022)

- Organize workshops with different business units to define the scope and requirements of the optimizer. Based on the description above, we expected the following four modules:
  - Module 1: Interconnector capacity calculator
  - Module 2: Energy market interface to compare market schedule with available capacity
  - Module 3: Equipment overload module to prevent damage of connected assets
  - Module 4: Voltage and reactive power controlled
- For each module, the goal is to develop a modular system that can be applied as an optimizer in different interconnector set-ups.
- Therefore, the workshops aim to analyze and identify the specific characteristics of each module. During the assessment the business requirements of asset management, system operations. Market development, customer relation and wind park operators are collected and considered. With particular focus on required input parameters such as wind forecast, market schedules, grid models and equipment limits.
- This serves as an input to develop the functionalities and an architecture diagram for the modular optimizer to describe and visualize different software elements to understand required data sources and optimization module
- Based on the functionalities and architecture diagram, the objective is to develop a sequence diagram to outline the functionalities, needs and characteristics in preparation of the software development

WP2- Build software (February 2022 to October 2022)

- Set up an agile software development team with respective Product Owner, Scrum Master, Developer
- Development of a first functioning prototype based on the system architecture and sequence diagram developed in work package 1

WP3 – Test of the of prototype (September 2022 to February 2023)

- With simulated data in first step before testing in parallel system
- Based on the needs defined in WP2, identify the best testbed

WP4 – Further investigations on the development and operations of for future HVDC Grids

- Developing a consistent set of necessary tools to operate a hybrid AC/DC grid, and in particular to develop a scheduling and control environment for the HVDC grid operator perspective from several days ahead to real-time.
- Assess different decision taking processes: from capacity allocation, reserves allocation and provision, preventive and corrective control actions into a single tool, and will do this from TSO perspective

Partners

- 50Hertz will collaborate in the elaboration of the solution
- Manufacturer as *confidential* will be involved in order to guarantee inter-operability of the solution
- We will involve other TSO, including certainly *confidential* as partner in the existing projects
- Finally, academic support might be needed to develop the solution: KU Leuven would certainly be a good partner to that regards taking into account their competences on Offshore and HVDC.

Summary of project efforts in person months: per work package and per year

confidential